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Blue-Chip or Sub-Standard?

A data interrogation approach to identify safety characteristics of shipping organisations

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A data interrogation approach for identification of safety characteristics determining whether a shipping organisation is

Blue-Chip or Sub-Standard

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Trondheim, September 2004

PREFACE

This doctorate work started in January 2000. A grant was given by the Norwegian University of Science and Technology in Trondheim at the Institute of Marine Design (Today the department of marine technology). The main supervisor is Prof. Svein Kristiansen. During the first two years the research and the compulsory studies and work was completed in Trondheim. The following six months was spent at Risø National Laboratory in Denmark and the final one and a half year of the study was completed at Det Norske Veritas (DNV) in Oslo.

During a four-year study there are numerous people to thank for support, advices, guidance and motivation. First of all, I would like to recognise my supervisor, Prof. Svein Kristiansen. He has taken an ideal supervisory role that balances the role of being a mentor, guider, motivator, and a critical discuss partner. I would like to thank Henning Boye Andersen and his colleagues at Risø for welcoming and supporting me. The Norwegian Shipowner Association gave considerable and critical economical support for this visit, which I am very thankful for. I would also like to thank DNV Research for covering my travel expenses related to this stay.

I have been hosting at Det Norske Veritas, Management Solutions, for one and a half year. This has made my workplace proximate to a range of professionals within the maritime domain, which have been important to my work and me. I have several times been impressed by the instant responses taken by Lasse Kristoffersen and his colleagues when I have asked for advices and support. There are also ranges of additional organizations that have provided me with useful information. Some data have been provided from individual shipping companies, which of some want to be anonymous. CEFOR have provided me with data on hull and machinery insurance claims.

During my study I have put most of my efforts towards obtaining insight. This has made the study of special interest to me, but has been on the expense of the presentation of the results. Therefore the help I have obtained to improve my English and the texts in general have been very important. My supervisors Dr. Svein Kristiansen and Dr. Geir Langli (Marintek AS) and Isabella Hald have taken the major effort of this support. Also Dr. Per Olaf Brett (DNV), Dr. Rune Torhaug (DNV) and Helge Soma (Safetek AS) have been of support with my written material. I am very grateful for this work. At last, but not the least, I would thank Lill Therese Grorud and our daughter Maja Grorud Soma for the amenable attitude they have showed during these years.

Trondheim, 11. September 2004

Torkel Soma

ABSTRACT

The objective of this thesis describes the characteristics that distinguish shipping companies that have a superior safety standard, called blue-chip, from those being sub-standard. The different characteristics of the companies having different safety standard are important to be aware of, as they indicate how safety may be improved in ship transportation. The scope of the study is limited to focus on recurrent high-risk accident scenarios arising in ship organisations and systems that are assumed to be of a complex nature. In order to establish this insight safety is considered in a broad context, ranging from what happens at the operational scene, back to the strategies and tactics adopted by the shipping companies. The analytical approach emphasise on data interrogation. According to Fragola (2003) *"Data "interrogation" is the process of data collection and investigation from a variety of perspectives, alternatively dissecting it into its underlying (yet often unknown) patterns"*.

This approach has made it possible to consider the safety level, and the safety culture of organisations, in relation to the economical conjectures of the business. It was found that the safest companies had a more mature safety culture. This maturity measurement focused on the organisations underlying pattern of safety attitudes, beliefs and values. Another section of the thesis found that the accident risk of shipping companies follows an inverse relationship to the economical performance of the company. When the economical performance in shipping decline, the accident risk increase and vice versa. Both the strength of the relationship and its instant effect are important to be aware of. While changes in safety culture are assumed to take years, the relationship to economical performance is instant and also seems to occur within mature safety cultures. It seems as if the organisations switch between different modes of interest, while the underlying pattern of values, beliefs and attitudes may remain unchanged. Because this relationship can be supported with quantitative evidence, this study has contributed to the causal understanding of ship accidents and safety in general. A question is raised whether it is correct to use terms like organisational accidents or system accidents, as these seem to be rooted in economical parameters. Therefore the term Commercial Accidents is proposed. The thesis is structured in a series of ten papers.

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DEFINITIONS AND ABBREVIATIONS

ADAC	Allgemeiner Deutscher Automobil Club
ANN	Artificial Neural Network
Asset Play	Asset play means to speculate with buying and selling ships i.e. to buy a ship when its market value is believed to be below its future value, and sell it off when the market value is believed to be over its value in a future market
Blue-Chip company	A company that owns or operates ships of high safety standard
Commercial Risk	Risks related to the uncertainties in economical profit making (including market risk, strategic risk and financial risk) opposed to Operational Risk
DAMA	DAtabank til sikring av MArine operasjoner (DAtabank for the safety of MArine operations)
Data interrogation	Data "interrogation" is the process of data collection and investigation from a variety of perspectives, alternatively dissecting it into its underlying (yet often unknown) patterns. (Fragola, 2003)
FOC	Flags of Convenience. Flags of registry that due to low labour costs attract foreign ship owners to convert to this flag. These flags are also attended with minimal governmental involvement in the shipping conduction.
H&M	Hull and Machinery Underwriter
ILO	International Labour Organisation
IMO	International Maritime Organisation
ISM-code	International Safety Management Code (in short)
Loss Ratio	Portion of vessels at risk that is lost due to accidents within a specified period of time
NN	See ANN
Operational Risk	Risks related to operational hazards such as grounding, collisions, fires and structural failures.
P&I club	Protection and Indemnity club
Safety standard	The real (often unknown) ability to avoid accidents related to aspects of the hull, crew, machinery, or equipment; such as for lifesaving, fire fighting, and pollution prevention
Serious Accidents	Serious accidents are breakdowns resulting in the ship being towed or requiring assistance from ashore; flooding of any compartments; or structural, mechanical or electrical damage requiring repairs before the ship can continue trading.
SMAQ	Ship Management Attitude Questionnaire
SOLAS	Safety Of Life At Sea
Sub-Standard Company	A company that owns or operates sub-standard ships
Sub-Standard Ship	A ship of low safety standard. Substantially below the standards by laws or international conventions
Total Loss	Total loss are accidents where the ship ceases to exist after a casualty, either due to it being irrecoverable (actual total loss) or due to being subsequently broken up (constructive total loss).

INTRODUCTION

STAKEHOLDERS IN SEA BORN TRANSPORT

There is a range of stakeholder in the maritime domain. In order to understand the dynamics in shipping it is necessary to familiarise with these stakeholders. The involvement of stakeholder can be illustrated by the Independent's (1996) description of an accidental vessel called Sea Empress "*Built in Spain; owned by a Norwegian registered in Cyprus; managed from Glasgow; chartered by French; crewed by Russians, flying a Liberian flag; carrying an American cargo, and pouring oil onto the Welch coast*". In reality the involved regulatory regimes, insurance clubs and companies, classification societies and salvage teams could also be added to the list of stakeholders. Each stakeholder has certain ways to influence the shipping activities and safety (Anderson, 1998). In the subsequent text some of the most important stakeholders (Figure 1) are briefly described.

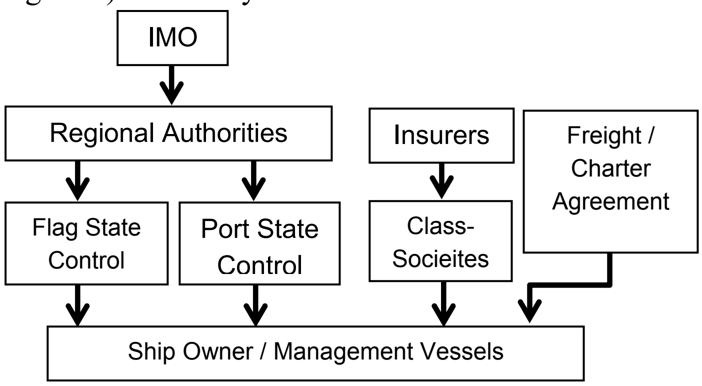

Figure 1: Mechanism between maritime stakeholders (Langli, 1998)

The International Maritime Organisation (IMO) entered the regulative scene in 1948. IMO is the United Nations specialised agency responsible for controlling maritime safety and preventing pollution from ships. IMO adopts new regulations through conventions and resolutions and then the flag states ratify and enforce the regulations. The most known conventions are the SOLAS (Safety Of Life At Sea) and the MARPOL (MARitime POLlution) conventions. The International Safety Management (ISM) code is a part of SOLAS that specifically address functional requirements and responsibilities of safety management. Other relevant conventions are the STCW (Standards of Training, Certification and Watchkeeping for seafarers) and a series of conventions related to limitation in amount of liability in compensation of damages. The STCW convention has also links to another UN body called the International Labour Organisation (ILO). While IMO has a focus towards the ship and the operation of the ship, the International Labour Organisation (ILO) has a focus on the crew's social justice and human and labour rights.

Even tough the flag states ratifies IMO's conventions, the motivation and enforcement of the regulations varies. During the 1960s (Beer, 1968) focus was aimed at certain flags of registry that were labelled Flags of Convenience (FOC). The FOC have a weak enforcement, low taxes and cheap crews (Bergantion & Marlow, 1998; Xianshu, 2000). From the accident statistics it could easily be read that the ships flying FOC carries a higher risk (Ponce, 1990). This fact has resulted in a role conflict, as there are different stakeholders who imposes the risk, are exposed to risk and regulates the risks (Brooks, 1996). Therefore, the stakeholder that is exposed to the risk started to enhance their involvement in the 1980s. The Port States started to inspect the visiting ships with reference to IMO and ILO conventions. Non-compliances, or deficiencies, typically have to be corrected before next port visit. Major deficiencies may result in lasting detentions.

Ship insurance is a formal agreement that limits the economical risk of damaging the vessel, cargo, or any third parties. Today it is also becoming regular to be insured against the loss of hire related to an accident. In principle the costs of losses are distributed on several ships. Ship insurance has roots back to the 13th century (Thorsen, 1926). During the 18th century insurance became more regular and in the mid 1800s the international competition for ship insurance grew. At the early 18th century the Protection and Indemnity (P&I) clubs emerged. This insurance was to cover liabilities for third parties. The P&I clubs have no profit making motives as the dividends are paid back to the clubs' members i.e. those being insured (Bennett, 2001). The Group of P&I clubs emerged at the turn of the 20th century pools the risk of extremely large claims. In this way the risks are in reality pooled among the majority of ship owners and is characterised by the world's cheapest insurance. While the P&I clubs have characterises of an ideal organisation, the Hull Underwriters insuring the ship itself are mostly private enterprises.

Earlier the business idea of the Classification Societies was to provide the service of classifying the ships' technical standard. Both design rules and periodical inspections should assure that the ships were seaworthy and also indicate the standard of the ships. This knowledge was valuable for the insurance companies for estimation of correct premiums. At some tome the insurance companies stopped using the classifications as a direct input for assessment of premiums, the classification societies instead assured that their subscribed ships satisfied their minimal rules. Hence today, the insurers require the subscription to a classification society, but do not take any further use of the knowledge held by the societies. Today the nine members of International Association of Classification Societies (IACS) classify 98% of the world tonnage.

The most important business stakeholder is probably the cargo owner who is the consumer of the transportation service. This stakeholder has direct influence of the decision within a shipping company. To ensure that the shipping companies have a satisfactory standard they applies a vetting practice. A vetting is an audit where potential ships and shipping companies are assessed in meeting their stated requirements. The Erika accident illustrates however that the vetting regime not is able to filter out all substandard vessels. Within the passenger transportation several consumer associations have started to assess the safety standard of various ships. One example is the "Greek Island Hoppers" warning of *Express Samina* prior to her fatal accident. This far only the stakeholders in the transportation shipping market are mentioned. In reality the shipping market also included the new building market and the scraping markets with their own stakeholders.

COMMERCIALISATION OF MARITIME SAFETY

Shipping is a mature market where the existing practice of the stakeholders is rooted in traditions and decades of experience. While shipping is considered as a market governed by free competition, also the stakeholder act in a competitive environment. Several cargo owners do however consider the shipping transportations as a homogenous service. Because the service is considered to be homogenous, the cargo owners have no interest in paying for safety and quality (Tamvakis & Thanopoulou, 2000). Even the stakeholders that directly are involved in control of risk, like the flags of registry, P&I clubs, Hull and Machinery underwriters and classification societies act in an environment where they compete with roughly identical services. The individual insurance companies have similar policies, the individual classification societies have about the same sets of rules and the flags of registry all follow IMO's conventions. In such a mature markets the importance of market shares tends to increase. Therefore the stakeholders tend to be more interested in being large than to critically evaluate the risk of accidents. Substandard ships and shipping companies can easily provide their service, under any flag, any class society and for a cheap insurance premium.

KNOWLEDGE ABOUT SAFETY

In a historical context concern about safety can most distinctly be read out of laws. While there exist laws regulating safety that are about 4000 years old, it seems as if safety first became a scientific area during the 1930s. Cramer (1930) stated, "*as a matter of fact, we find that practical insurance business has hitherto made little or no application of the results offered by mathematical theory of risk*". Simultaneously Heinrich (1931), who also worked for insurance, developed his theories of how industrial accidents could be prevented. From the late 1960s through the 1980s the experience and knowledge of safety advanced within many industrial domains. A range of new technologies were commercialised during the 1960s and 1970s. Examples are nuclear power, offshore oil production and space shuttling. These technologies introduced high risks, which had to be analysed with new modelling approaches such as Fault Tree Analysis and Failure Mode and Effect Analysis. At the late 1970s and the 1980s extensive investigations were accomplished into accidents like Felixborough, Bravo, Piper Alpha, Three Mile Island, Chernobyl, King's Cross, Herald of Free Enterprise and Challenger. The insight obtained from these investigations seems to increase the intensity of research into safety, which in turn has resulted in an extensive knowledge base.

Reasoning about safety

Before going into more details of this knowledge, it is necessary to describe what the knowledge about safety is and how it is used. Knowledge about safety involves both which Conditions (circumstances, situation, evidence, etc.) that are hazardous and Rules (certain compounds of Conditions) determining how these conditions may turn into an unwanted Performance (failure, accident, loss etc.). There are in general three types of logical reasoning about the Conditions and Rules that may cause a Failure. The three types of reasoning are deduction, induction and abduction (Coyne et.al., 1990).

Deduction:	condition + rule	→ performance
Induction:	condition + performance	→ rule
Abduction:	rule + performance	→ condition

Figure 2: The three types of reasoning about safety

Logical deduction is the mode of reasoning that is the most objective as it only applies knowledge of the actual conditions and accepted rules. For example, given the Condition that *this ship has lost its stability* and the Rule that *all unstable ships will capsize* it is given that the Performance is that *this ship will capsize*. On the other hand, given the fact that a ship has capsized together with the same rule it can be reasoned by abduction that the ship was unstable. Within science, induction is regarded as the development of theories (rules) from observations of certain phenomena. Induction involves more uncertainties as the rules are generated from individual observations, which may not represent the general or real situation. The regulators of maritime safety have historically been too uncritical towards induction of rules from individual accidents (Bird, 1969; Ayeko, 1999; Pidgeon & O'Leary, 2000). The latest decade, however, attempts are made to become more proactive (Neumann, 1995). The dominating maritime safety regulations can be traced back to the conditions of single accidents (figure 3).

Poor emergency preparedness	+ Titanic (1912)	→ SOLAS convention
Weak liability for spill cleanup	+ Torrey Canyon (1967)	→ Civil Liability Conv. (IMO)
Poor barriers against pollution	+ Torrey Canyon (1967)	→ MARPOL (IMO)
Weak liability for spill cleanup	+ Exxon Valdez (1989)	→ OPA90 regulation (USA)
Poor RoRo standards	+ Herald of Free Enterprise (1989)	→ SOLAS amendments
Poor safety management	+ Scandinavian Star (1990)	
	+ Aegan Sea (1992) + HFE(1989)	→ ISM code (IMO)
Poor RoRo standards	+ Estonia (1994)	→ SOLAS amendments
Weak enforcement by stakeholders	+ Erika (1999)	→ Post Erika

Figure 3: Examples of inductive reasoning behind regulation of maritime safety
Source: compiled from different sources like (IMO, 1998; Anderson, 1998; Fields & Rostant, 2000)

PERSPECTIVES ON SAFETY

The three types of reasoning are presented to better understand how our present knowledge about safety has been obtained. The knowledge about safety is can be obtained through three types of perspectives. The perspective of an accident investigator (Perspective 1, figure 4) is limited to the understanding of why individual accidents occurred. Therefore the investigator applies abductive reasoning to determine what conditions that caused the accident. According to Kristiansen (2000) "*It is often more easy to identify failures in the last stages of an accident than in the initiating stage. Decision makers therefore tend to look for measures that limit the damage rather than avoiding the accident*". Consequently, the reactive regulations in figure 3, does not seem to address the basic causes of the accidents (lower actual causes in figure 4) (Ayeko, 1999). In a statistical perspective it is possible to prove that accidents in general involves certain conditions (Perspective 2). For instance, the statistical evidence reveals that accidents are more frequent onboard old ships compared to the newer vessels. This perspective is helpful because it may be a guide to identify important hazardous conditions. Even though it can be proved that old ships carry a higher accident risk, the casual explanation behind this finding remains unknowns. It might be that older ships are operated differently or that old equipment has a higher failure rate. In order to understand why, knowledge of cause-effect chains (Rules) has to be applied. Therefore, through a management perspective (Perspective 3, figure 4) certain conditions or hazard can be pinpointed because their perceived dangers and actual hazards (Causes) can be identified. This perspective applies deductive reasoning (figure 2). It can for instance be concluded that all corroded hulls has less strength, and therefore corroded technical condition of a ship is hazardous. Even though this perspective may explain the cause-effect chains behind statistical relationships, it does not indicate any priority of the risk. It might be that corroded hulls in fact are weaker, but that the higher risk related to old ships are caused by other factors (figure 4). In order to prevent accidents efficiently it is important to address the basic causes of the accidents, represented as the lower black actual causes in figure 4.

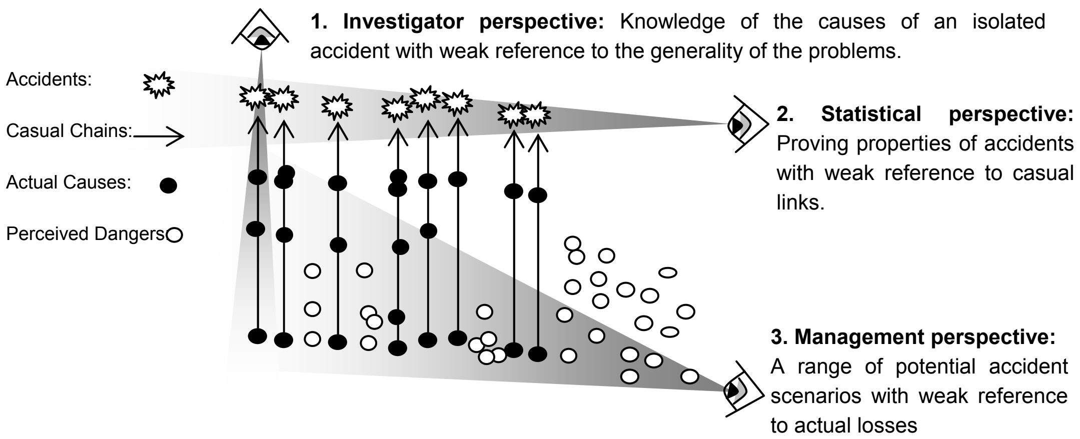

Figure 4: Variations of perspectives on safety and accident prevention

KNOWLEDGE ABOUT ACCIDENT CAUSES (CONDITIONS)

None of the three perspectives precisely address the basic causes of the accidents in figure 4. Wagenaar (1987) accomplished a pioneer study of the hazardous conditions that were relevant in the maritime domain. He investigated in detail the causes of 100 ship accidents. He found that 97% of the accidents were caused by operator (or human) error, and that there was typically more than one operator error. The typical ship accident has more than 20 causes, whereof several have an independent nature. This complexity justifies that the typical ship accident is a result of a complex scenario. Consequently the scenarios are not of a series structure as indicated in figure 4, but rather consisting of a complex pattern of causes as illustrated in figure 7. Rasmussen (1983) and Reason (1990) classifies an operator error as a Slip, Lapse, Knowledge-based or Rule-based mistake. According to Goossens & Glansdorp (1998) who investigated more than 300 navigational incidents "*…in two-thirds of the cases, incidents began with a tactical event, meaning relatively close to the point-of-no-return. … Errors involving decision-making and implementing a new course and speed seems to be minor (substantially less than 10 percent)*". Fragola (2000) describes this as an Error of Commission "*the actions was intended, the consequences were not.*" Consequently the typical navigational ship accidents (collision, grounding, contact, etc.) are a result of intended tactical actions that were decided on false premises. This indicates that the errors are not a result of difficulties in the navigational task themselves, but rather the understanding of the situation or the context of the task (Williams, 1996; Rasmussen, 1997; Hollnagel, 1998; Fragola, 2000; Wilde, 2001).

Based on this understanding of operator errors, one should then expect that navigational equipment that facilitates survey of the situation would result in improved safety.

However, the installation of radars during the 1960s did not result in any improved safety records (Gardenier, 1976). The gained information seemed to be used to sail more proximate to shore and other ships (Gardenier, 1976; Perrow, 1984,1999). Wagenaar (1987) stated that the basic causes of operator errors are dependent of the activity's work environment, rather than personal and situational related factors. The major types of operator errors contributing to the occurrence of accidents are wrong habits, wrong diagnoses, lack of attention, lacking training and unsuitable personality. The findings of investigations into ship accidents (Karlsen & Kristiansen, 1980; Waagneaar, 1987; Spouge, 1985; Sheen, 1987, Cahill, 1990; NOU, 1991; Crainer, 1993) roughly corresponded to the findings of investigations into accidents in other industrial domains (NOU, 1977; Kemeny, 1979; Kletz, 1985; IAEA, 1986; Fennel, 1988; Hidden, 1989; Cullen, 1990; Pat'e-Cornell, 1993; Vaughan, 1996). Some of these findings are listed in table 1.

Table 1: Conditions found to describe safety level

Explicit hierarchal levels, poor communication, conflicting understanding of safety, poor management commitment, poor status of safety managers, poor work morale, safe practice was not rewarded, poor procedures, no or extreme reactions on deviation from procedures, poor cooperation, low information turnover and monitoring of safety performance, poor training, low perceived importance of safety training programs, poor cleaning and formal order, weak physical barriers against hazards, poor ergonomically conditions, poor physical work environment, high mental and physical stress, little resources to tackle responsibilities, insufficient manning, weak ability to adapt responsibilities to the situation, weak job satisfaction.

The findings in table 1 have also been revealed in research into both shipping organisations (Itoh & Anderson, 1999; Parker, 1998; Sanquist, 1995) and non-maritime organisations (Zohar, 1980; LaPorte & Consolini, 1991; Paulsen, 1999) that have not experienced disasters.

KNOWLEDGE ABOUT ACCIDENT DEVELOPMENT (RULES)

These findings from accident investigations (table 1) satisfy both the Conditions and the Performances in figure 2. It is therefore possible to induce a range of Rules that describes why accidents occur. One example is to induce the rule (Rule 1, figure 5) that accidents are caused by human failures (Carver, 1992; Reason, 1990; Rasmussen, 1982, 1983). Recent studies by SIRC and MAIB (2004) demonstrate the important impact crew fatigue has on the accident frequency (Rule 2). It is also possible be more precise and address those factors that cause humans to make errors. Williams (1986) have developed one comprehensible error assessment technique that both includes and assessment of the task and the context of the task (Rule 3). Because both the difficulty of the tasks and the quality of the context are determined by the organisation, Hollnagel

(1998) and Reason (1997) have developed theories that focus on organisational weaknesses (Rule 4). A refinement of rule 4 is to focus on the safety culture (Rule 5).

All these rules are generalisations of the content of table 1. An alternative and more comprehensible reasoning approach to induce Rules is to ask why the Conditions in table 1 occur. One example is to state that poor safety management (Deming, 1991; Alteren, 1996; Reason, 1997) may result in these conditions (Rule 6). Perrow has a more sophisticated theory. He states that the system designs in are too complex and tight-coupled when disasters are being triggered by these factors (Rule 7). His idea is therefore to simplify the systems in order to make hazards more explicit, which is supported by both Wilde (2001) and Rasmussen (1997). Rasmussen has however induced an even more comprehensible theory. He states that characteristics of our modern dynamic society both produce accidents and reduce our ability to learn from accidents (Rule 8). Hovden (1996) have a stronger focus on organisational changes (Rule 9).

Rule 1. Conditions in table 1 → Human failures cause accidents
Rule 2. Conditions in table 1 → Crew fatigue cause accidents
Rule 3. Conditions in table 1 → Task and task context cause accidents
Rule 4. Conditions in table 1 → Organisational weaknesses cause accidents
Rule 5. Conditions in table 1 → Poor safety culture cause accidents
Rule 6. Conditions in table 1 → Poor safety management cause accidents
Rule 7. Conditions in table 1 → Complex and tight-coupled system designs cause accidents
Rule 8. Conditions in table 1 → Our modern dynamic society cause accidents
Rule 9. Conditions in table 1 → Organisational changes cause accidents
Rule 10. …

Figure 5: Examples of rules generated (induced) from the conditions of table 1.

THE IMPERFECTIONS IN SAFETY KNOWLEDGE

There are several imperfections or insufficiencies in our present knowledge of safety. These insufficiencies may form barriers for a further knowledge expansion. The first insufficiency is that knowledge obtained from accident investigations is dependent of what that investigation perceives and how he interprets these perceptions (Pedrali et.al, 2002). There may be important factors that are not identified (Johnson, 2000c). Investigations often tend to search for blame and not for objective causes (Wagenaar, 1997; Pidgeon & Leary, 2000). Therefore one may suspect that only the more perceptible actual causes presented at the bottom in Figure 4 are described. When the rules in figure 5 are induced, however, it is necessary to assume that no other knowledge exists other than that stated (closed world assumption). As a result some rules have been induced that are in explicit conflict. The rules presented in figure 6 are one simple example of conflict resolution (A,B,C). It is known that older ships are more frequently involved in accidents. This indicates that technical degradation determines the accident rate. However, when investigating the accidents it is seen that they are caused by human failures and not technical failures alone. This conflict intuitively indicates that some knowledge is missing. It might be that older ships are operated or managed differently or that the crew of the older vessels are in some way different. Anyhow, this knowledge is not yet obtained even though the conflict has been discussed for a century (Kysten, 1907).

A: **If** a ship is old **Then** the risk of accidents rise
B: **If** a ship is old **Then** the its equipment is old
  If the equipment is old **Then** its failure rate tend to rise
  If the failure rate rise **Then** the risk of accidents rise
C: **If** a ship accident has occurred **Then** it is unlikely that it is a result of technical failures

Figure 6: Example of conflicts resolution originated from the closed world assumption

There are other and newer insufficiencies in the safety knowledge. Although some of the rules in figure 5 have similarities the originators tend to stress importance and the uniqueness of their own theories. According to Wilde (2001) accidents are a result of failures in the risk perception of individuals. Perrow (1984, 1999) stress that aspects of the technical system design cause the accidents. Reason (1997) states that the causes lie within organisational culture, while Rasmussen (1997, 2000) also includes aspects of the society. Also within the professional domains conflicts have emerged. When the belief in precise modelling of human performance stagnated during the early 1990s, the focus shifted towards a conflict between different approaches. The analysts either belong to the school of human reliability or to the cognitive (Hollnagel, 2000; Fragola, 2000). At the late 1990s it was acknowledged that two decades of research into safety culture had neither results in valid tools nor established proves that support its assumed high importance (Cox & Flin, 1998; Hale, 2000; Guldemund, 2000; Sorensen, 2002). Also here the focus was instantly shifted to whether the functional or an interpretive viewpoint is most correct (Glendon & Stanton, 2000). Consequently accident investigations have induced that human errors cause them to occur. It is however difficult to deduce that a certain behaviour will cause an accident. Simultaneously accident investigations have induced that safety culture are extremely important. It is however not yet deduced what safety performance that is the result of given safety culture.

FOCUS ON RECURRENT ACCIDENT SCENARIOS

Frankhauser (2001) proposed another fundamental worry by stating "*In today's applications there is an ever-increasing demand for components with higher and higher reliability. As a result of this the statistical basis for failure rates inferred from* *corresponding field data diminishes, with the ultimate consequence that the uncertainty in this information increases more and more*". Even though this statement referred to component reliability, this is a matter of concern because out present knowledge is based on findings from the 1970s and 1980s. At this time the world economy was very volatile and management was concerned with increasing globalisation and competition. As a consequence of this management the focus on quality assurance (Costin, 1999) increased during the 1990s (Cameron & Quinn, 1999). As a result, the organisations of today are managed in another way than they were when our present knowledge was formed. Consequently, the knowledge is only valid for those accidents scenarios that reoccur. Waagenaar (1997) suggests that an accident analysis should only focus on the causes that may reoccur. Reason (1998) states that a recurrent accident scenario included at least three elements. The Universals (1) represents the ever-present hazards, the Local traps (2) are the characteristics of the work place that lure people into repeated patterns of unsafe acts and the Drivers (3) that make people do erroneous behaviour. Reason indicates that, while there might be a multitude of Local traps, the number of Drivers is limited, focusing on economical variables and production pressure. Also the number of Universal hazards is of a limited character. This indicates that the recurrent scenario may be divided in two separate phases, a diverging phase where the consequences of the Driver expand, and a converging phase where the Universal hazards are released by the Local traps. A detail of the analysis is also that the Local traps be manifested by perceived dangers that not contribute to the development of the accident scenario. It is likely that some of the Conditions that are listed in table 1 are of such a character.

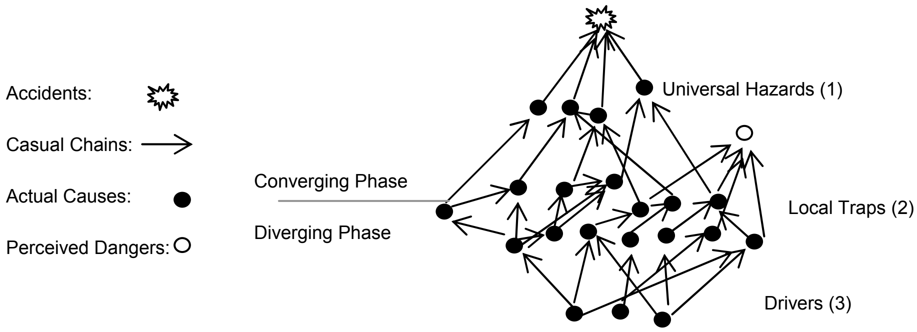

Figure 7: Conceptual illustration of a complex recurrent accident scenario

The characteristics modern high-risk domains like nuclear power, offshore and process industries differ between plants, nations and over time. These differences restrict the possibility in collecting uniform empirical data that may reveal the characteristics of recurrent accident scenarios. Shipping on the other hand is known for its conservatism and takes place in an environment under a uniform international regulation. In additions the differences between the best and poorest performing shipping companies, with respect to safety, is perceived as relatively large (Donaldson, 1994). The hazards (1) that govern today were also present centuries ago. The characteristics of today's workplace have also centuries of history, even though the equipment has been improved. The international shipping market matured a century ago (Koopmans, 1939; Zannetos, 1966; Stopford, 1997). Therefore it is might be that the drivers (2) in the market have been stable. The drivers behind the crew's behaviour may have changed. Anyhow, there is a fear chance that ship accidents for several decades have been formed by a scenario that is of a recurrent character.

Analysis of Recurrent Accident Scenarios

Given that the analytical focus should be aimed at recurrent accident scenarios, this may give certain restrictions in the analytical approach. Hovden (1998) has outlined a general way of modelling of risk information. He describes five different sources of information about accident risk (risk = $f(X_1, X_2, X_3, X_4, X_5)$) where the five sources are presented in table 2.

Table 2: Summary of main features of information dealing with risk problems (Hovden, 1998)

	Property	Notations	Modelling	Inference Rules
X_1	Deterministic Certainty	X_1=a	Empirical	Logical
X_2	Stochastic Probability	$F(X_2) = P(X_2<x_2,\lambda)$	Analytical	Statistical and
X_3	Uncertainties in values	$X_3 \rightarrow [X_n\text{-}X_m]$	Both	Mathematical
X_4	Uncertainties in parameters	$-\infty \leq X_4 \leq +\infty$	Expert judgement	Heuristics, intuition
X_5	Lack of knowledge	$X_5 \rightarrow$?	Heuristic	and dialogue

In summary Waagenaar (1998) has stated that the important knowledge is related to the accident causes that reoccur. Reason (1998) describes the elements of the recurrent accident scenario. Hovden (1998) has outlined broad range of main features of risk information. Then the task is to select which analysis approach in table 2 that is most suitable for analysis and identification of recurrent accident scenarios. Fragola (2003) have proposed an approach for identification and analysis of *"Emerging Failure Phenomena in Complex Systems"*. He states that "*In these cases, .. , the underlying system is neither orderly enough to be considered regular, nor disorderly enough to be considered random, and can therefore be defines as being "complex" because it will succumb to neither deterministic analysis nor probabilistic analysis*". Consequently, Fragola suggest that such that recurrent accidents scenarios in complex and high-risk systems should be analysed with what he calls data "interrogation" (X_4 and X_5 in table 2). According to Fragola this approach *" involve a means of evoking subtle patterns from data or from the physical phenomena themselves by "interrogating" the data until it yields it secrets".* In as broad sense the induction of rules that cause accidents (Jonhson, 2000 a,b,c), incidents and near misses may fall under this description (Schaaf & Lucas & Hale, 1991). Even though Fragola considers the data "interrogation" as a proactive technique, it may very well be used on historical data to search for characteristics of recurrent maritime accident scenarios.

Deming (1982, 1986, 1991) claims that he was not the first one that put emphasis on the distinction between "*special causes"*, in terms that they are not under the responsibility of management and in contrast to the "*common causes"* that are produced by the system. In the context of analysing recurrent accident scenarios, common causes are high relevance. Deming indicated that the common causes constitute 94 % of the total volume of causes. While Deming's theories are aimed at quality control, there exist several theories that also consider consequence of the accidents. It is common to make a distinction between those accidents that have an impact solely on the element that fail itself and those accidents that directly damages or threatens the safe functioning of whole systems or ship functions, or expose other humans for danger. The first type of accident is typically an occupational accident. Reason's (1997) "*individual accident*" or Perrow's (1999) "*component accidents*" are of similar nature. The second type of accident is more hazardous as it has the potential to develop into disasters resulting in extensive damage to assets, loss of human life and pollution. This high-risk accident is called a "*concept accident*" Kristinasen (2000), "*organisational accident*" (Reason, 1997) or "*system accident*" (Perrow, 1999). For a ship, this type of accident is typically grounding, a foundering, a collision, a fire, an explosion or a breakdown.

DEFINING BLUE-CHIP AND SUB-STANDARD

In other industrial domains the utilisation of quantitative risk analyses (QRAs) and safety cases were becoming regular during the 1980s. Examples of risk acceptance criteria are the ALARP (As Low As Reasonable Practical), De minimis (risk of event < 10^{-4}) and various utility-based criteria (Krappinger, 1971; Morgan, 1990; Reason, 1997; Skjong, 1998, 2001; Floyd, 2000). Within shipping there exist several criteria describing a ship's unsatisfactory safety standard. Commonly used criteria have been poor seamanship, unseaworthiness, non-compliance or being sub-standard. Anderson (1998) refers a judge's description of unseaworthiness: "*To be seaworthy, a vessel must have that degree of fitness that an ordinary careful and prudent shipowner would require his vessel to have at the commencement of the voyage having regard to all probable circumstances of it*" Another definition is described in the Seaworthiness Act (§ 2): "*A ship is considered unseaworthy when, because of defects in hull, equipment, machinery or crewing or due to overloading or deficient loading or other grounds, it is in such a condition, that in consideration of the of the vessel's trade, the risk to human life associated with going to sea exceeds what is customary.*" Customs, which also is used in the considerations of poor seamanship, is however an imprecise norm. Non-Compliance became a more specific criterion, as it address the norm represented by precise regulations. If a ship does not fulfil the regulations it is per definition Non-Compliant. Non-Compliance can be identified through deficiencies in ship inspections or non-conformities in ISM audits. However, as the typical ship has a couple of deficiencies in a Port State Control Inspection and a couple of non-conformities in an ISM-audit, the majority of ships in commercial trade are in fact Non-Compliant. Therefore the term Sub-Standard has been acknowledged. *In general, a ship is regarded as substandard if the hull, crew, machinery, or equipment; such as for lifesaving, fire fighting, and pollution prevention; are substantially below the standards by laws or international conventions* (US Coast Guard, 1993).

Simultaneous as the norms for safety acceptance advanced, the subject of the assessment has changed. From focusing on the technical and regulative subjects, the trend the latest 25 years have been to address the company behind the ships. It has been common to state that behind any Sub-Standard ship there is a Sub-Standard owner or manager (Cahill, 1990; Crainer, 1993; Everard, 1995; Donaldson, 1998). This utilisation of the criterion dilutes its explicitness as there are few regulations governing how owners or managers are to conduct their daily tasks. If it is accepted that some companies have a poorer ability or motivation to focus on safety, this intuitively indicates that the safety standard of both ships and companies follows some level of gradation. It is then interesting to ask what type of companies that is at the opposite side of the scale, being unusual safe. LaPorte and Consolini (1991) defined the term High Reliability Organisations (HRO). The definition of HROs is however relatively limited. The term "quality" owners, managers and companies are used, but the term "quality" do in fact encompass more than safety (Soukas & Rouhiainen, 1993; Costin, 1999). The term "Blue-Chip" companies are used by inventors on a stock that is considered reliable both with respect to dividend income and capital value. Cox and Flin (1998) drew the line between "Blue-Chip" companies and their superior focus on safety. In this study the terms Blue-Chip and Sub-Standard represents the extreme poles in the scale of an organisation's safety level. To get a more hands-on understanding of the terms, it can be stated that each of the terms encompasses 20%-30% of the world fleet.

OVERVIEW OF STUDY

The objective of this thesis describes the characteristics that distinguish shipping companies that have a superior safety standard, called blue-chip, from those being sub-standard. The different characteristics of the companies having different safety standard are important to be aware of, as they indicate how safety may be improved in ship transportation. With reference to the previous section, the scope of the study is limited to focus on recurrent high-risk accident scenarios arising in ship organisations and systems that are assumed to be of a complex nature. In order to establish this insight safety is considered in a broad context, ranging from what happens at the operational scene, back to the strategies and tactics adopted by the shipping companies. Therefore this study follows a thematic structure as presented in figure 8.

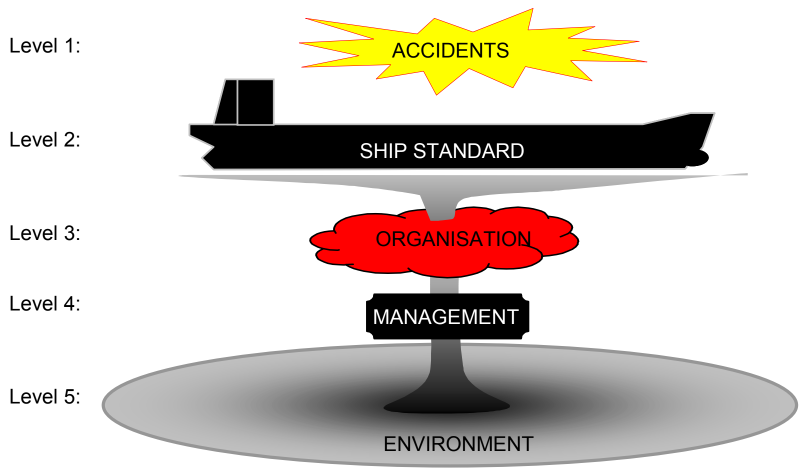

Figure 8: Outline of thematic structure

It is assumed that the explanation of accidents follow an organisational dimension from the scene where the actual losses take place to the basic causes within the top-level management or even the environment (Heinrich, 1931; Bird, 1969; Kjelle'n & Hovden, 1993; Wagneaar, 1997; Reason, 1997; Rasmussen, 1997; Hollnagel, 1998; Cooper, 1999; Koster, 1999; Ayeko, 1999). Each of the five levels introduces various types of knowledge, data sources and influences from different stakeholders. At the top of this figure we have the knowledge about the actual losses. This information is objective as it can be described in terms of injuries, deaths, insurance claims, damage to assets or lost ships. In order to prevent losses it is necessary to address the immediate casual level like the operational scene onboard a ship (figure 8, level 2). Such knowledge can be inspection findings, observation of unsafe acts, audit findings and near miss reports. As described earlier the investigative perspectives (figure 4) have suggested that the observable deficiencies at the operational scene are results of more distal organisational factors. Safety culture is one example of the content of organisational factors (level 3). The last 20 years considerable research have been accomplished to establish insight into the organisational factors (table 1). It is believed that the organisational factors are related to the decisions taken and the commitment demonstrated at the top-level management level through business strategies and tactical decisions (level 4). At last these management decisions have to be seen in relation to the environment in which the company act (level 5).

In order to understand how aspects of the environment, management, organization and onboard workplace influence on the safety performance, the thesis both address aspects within each level, between several levels and the model in its entirety. A series of ten papers have been written. Some of these are published in conference proceedings and some are submitted to relevant journals. The title of the papers, and their scope are presented in table 3.

Table 3: Papers with title and reference to levels in figure 8

Paper	Level	Title of paper
Paper 1	1 to 5	What are the causes of ship accidents?
Paper 2	1 to 5	Modelling the safety performance of maritime operations–aggregation of symbolic knowledge
Paper 3	1 & 2	Ship safety standard classification based on accident history and port state control findings
Paper 4	1 to 5	Safety Assessment of Ship Operators – A Neural Network Approach
Paper 5	3	The relationship between safety cultural factors and the safety standard of shipping companies
Paper 6	3	Measuring the safety standard of organizations
Paper 7	3	Measuring the Quality of Safety Cultures
Paper 8	4 & 5	A Search for Risk Drivers in the Freight Market (Commercial ship accidents - a macro level perspective)
Paper 9	4 & 5	Risk Drivers in the Liner Market (Commercial ship accidents - a micro level perspective into the passenger ship market)
Paper 10	4 & 5	Risk Drivers in the Tramp Market (Commercial ship accidents - a micro level perspective into the tanker market)

DATA INTERROGATION

Data "interrogation" is the process of data collection and investigation from a variety of perspectives, alternatively dissecting it into its underlying (yet often unknown) patterns…Some of the techniques employed are slicing the data set according to known underlying variables, or overlaying data gathered from different perspectives, or imbedding data into previously established logical or phenomenological structures." (Fragola, 2003). In this way data interrogation has similarities with a heuristic search technique. There seems to be four relevant types of heuristic search mechanisms (I, II and III and IV), whereof the three first are of a manual character. In these three (I, II and III) approaches the analyst search to reveal structured patterns in the dataset. When there exist no predefined knowledge there is still the possibility to use heuristic search through more automated computer techniques (IV). With reference to figure 2, these approaches go through loops where first a candidate Rule is produced (induction figure 2), then its quality is assessed through deduction and the candidate Rule is improved. Then the process is started over again until a satisfactory Rule has been induced.

I. Consider parts of the datasets according to known underlying variables
II. Consider parts of the datasets relative to an overlaying data gathered from different perspectives.
III. Consider data relative to previously established logical or phenomenological structures.
IV. Allow a computerised heuristic search to reveal possible patterns.

In a safety perspective the first three approaches (I) can be exemplified with the analysis of near misses, audit findings, incidents or deficiencies. When applying the first approach, the dataset is assessed relative to known underlying variables e.g. table 1. In this (abductive) way it can be found that certain underlying variables may have higher relevance (at a lower level in figure 2). This process can also be done through software like Tripod-delta (Shell, 1994). If however, the data is assessed relative to overlying data (II) such as of collisions, groundings, capsize, foundering, fire, explosion etc. this may also reveal some pattern within the considered data (at a higher level in figure 2). The idea of considering the dataset relative to figure 2 is in itself an example of the third approach (III). Analysis through LCM (Bird, 1967), SMORT (Kjell'en et.al. 1987); CASMET (Koster et.al., 1999) are other examples. Wagenaar (1997) and Koster et.al. (1999) compare some of these approaches. Another approach is Johnson's (2000 a,b,c) Evidence-Analysis-Consequence (EAC) analysis approach. There exist examples of data interrogation of the latest example (IV). Luxhøj & Williams (1999) have presented a project where they use neural networks and expert system technology to analyse aircraft maintenance databases with the objective of defining "*more refined "alert" indicators for national comparison purposes that can signal potential problem areas by aircraft type for safety inspector consideration*". In a maritime safety context Hashemi (1995) and his colleagues used an artificial neural network to predict the type of accident that would occur under different combinations of navigational conditions on the lower Mississippi River.

In both the manual and automated interrogation there are no leading assumptions about what the next step or the result will be. In contrast conventional statistical inference are governed by the defined apriory assumptions or hypotheses, the carefully selected variables and the inflexible statistical inference rules. In this way data interrogation may represent a more objective results possibly at the expense of the barrier against induction of spurious Rules. Spurious Rules may be induced because many independent variables (white conditions in figure 2) may together arbitrarily describe a dependent variable (Performance), without being valid in a general situation. The combination of several perspectives does however reduce the likelihood of entering this pitfall. While data interrogation (IV) may apply the same techniques as within artificial intelligence, expert systems, machine learning and knowledge based methods, it differs from these approaches as it do not attempt to replicate human decision making (Fukunaga, 1990; Michie, Spegelhalter & Taylor, 1994; Ripley, 1996; Nilsson, 1998). Today tools for data interrogation like artificial neural networks, pattern recognition, data mining and learning Bayesian networks are available in standard professional software packages like SAS, SPSS, Hugin and MatLab.

It is difficult to strictly classify the thesis as a descriptive or an explorative study. It is descriptive because the resulting characteristics that distinguish the safe companies from the less safe are linked to the importance of variables and the relationship between variables. The study may also be considered as explorative because of its broad context, its use of data interrogation and search for characteristics of maritime recurrent accident scenarios. There are in fact few doctorate studies that address this broad view even though experts like Heinrich (1931), LaPorte and Consolini (1991) Wilde (2001), Perrow, (1999), Reason (1997) and Rasmussen (1997) all express that safety involves something more than fragmentary knowledge.

COLLECTING BACKGROUND KNOWLEDGE ABOUT ACCIDENT SCENARIOS

The two first tasks was to collect existing data on that is needed to apply a data interrogation approach within safety is to collect existing knowledge of what the causes of ship accidents are, and how they develop into accidents. These two tasks respectively forms the two first papers (table 2). In the context of data interrogation the results of these studies may form one important source of background knowledge for all approaches (I, II, III and IV).

The first paper outlines the stat-of-the art knowledge of causes of ship accidents. The paper especially focuses on the Investigative perspective and the Statistical perspective in figure 4 (Perspective 1 and 2). However, the contradictions presented in figure 6 are discussed with reference to the perspectives outlined in figure 4.

While the first paper focus on causes of accidents (Conditions in figure 2), the second paper focus on the development of accidents from these conditions (Rules in figure 2). As earlier described there exists a range of models describing why accidents take place based on more distal factors (figure 2), typically of operator or organisational nature (figure5). Some thirty of these models are compared. These models represent much expert insight and therefore a good basis for aggregation of causal relationships (symbolic rules). This paper takes the Investigative perspective and the management perspective in figure 4 (Perspective 1 and 3). Because a significant share of these models focus on the understanding of operator errors (figure 5) these rules are held separate. Besides knowledge that actual models represents, there exists knowledge that makes it possible to assess the relevance of these models (Rasmussen, 1997). Therefore the models are assessed, and based on this assessment a new model is aggregated (presented in figure 8).

DEVELOPING A NORM FOR ASSESSMENT OF SAFETY STANDARD

While the two foregoing studies collect background knowledge that can be used in approach (I) and (III) there exists no intuitive norm that indicates the safety standard of an organisation (overlaying data in II). Contradicting knowledge as presented in figure 4, in addition to the stochastic element of an accident scenario makes any reasoning about safety uncertain and vulnerable for critics. It would be favourable if a norm of distribution in safety standard was developed, analogous to the norm the Gaussian distribution represents for the distribution human's intelligence quota (IQ). If such a norm existed, actual safety performance may indicate what the real safety standard of the organisation is, like the performance of an IQ-test indicates a person's intelligence. This study (Paper 3) first develops this norm distribution, and then develops and validates two classification techniques that indicate a ship, or a shipping company's, actual benchmark within this norm. The two techniques respectively apply accident statistics and safety inspection findings. This study is important especially in the second (II) and (IV) data interrogation approaches where it is required that the overlying data (Performance) e.g. safety level or loss is fairly reliable.

INTERROGATION BASED ON ARTIFICIAL NEURAL NETWORKS

The first full data interrogation approach (Paper 4) was to train an artificial neural network to reveal the dependency patterns in a given dataset. In artificial neural networks the dataset is divided into two parts, a set of independent variables (level 2 to 5) and typical one dependent variable (Performance in figure 2) like losses (Level 1) or safety inspection results (Level 2). Then a training procedure applies a heuristic search to adjust the network structure to optimally represent the relationship between the dependent variables and the independent variables. In this way the resulting network structure represents the Rule (figure 2) that describe how the data can determine the Performance. At this stage of the research it was believed that artificial neural networks were advantageous to produce insight into how safety can be described thorough organisational factors. If the datasets are of sufficient size artificial neural networks have the potential to represent any relationships. A main obstacle was the required data size. Therefore the symbolic knowledge aggregated in Paper 2 was incorporated in the structure of the neural network. This lead the neural network to interrogate the data relative to the previously established structures outlined in figure 8. In this context the artificial neural network is a hybrid between the (III) and the (IV) data interrogation approaches. With reference to the language used within neural network literature it represents an hybrid between symbolic and sub-symbolic networks.

Considerable efforts were assigned to this work, probably of about twenty percent of the total workload. Even though it only is presented in a single paper the obtained insight was large. A yet unpublished study on datasets reaching 2500 randomly selected ships it was found that the networks were efficient in combining data but still the predictable abilities were not considered to be sufficient.

INTERROGATION OF ORGANISATIONAL FACTORS

During the last two decades extensive research into organisational factors have been accomplished. The finding of these studies are simplified and presented in table 1 and figure 5. This part of the thesis focuses on Rule 5 in figure 5 (Safety Culture). Guldenmund (2000) summarises the situation on research into safety culture: *"Although safety culture and climate are generally acknowledged to be important concepts, not much consensus has been reached on the cause, the content and the consequence of safety culture and climate in the past 20 years. Moreover, there is an overall lack of models satisfying either the relationship of both concepts with safety and risk management or with safety performance".* Given this unsuccessful history, it might be wise to consider alternative, or unconventional, approaches in the analysis of safety culture. Therefore the situation in safety culture research gives free rain to the demonstration of the possibilities in data interrogation.

This part of the thesis consists of three papers (5, 6 and 7). The approach is to combine the data interrogation approaches II and III. With reference to figure 2 the questionnaire responses represents the Conditions. The safety standard developed from the techniques in Paper 3 represent the Performance. Then the task is to find the Rule that represents the link between the Conditions and the Performances. In this context the approach is a mix of data interrogation II and III. In paper 5 first nine shipping companies are ranked according to their safety standard (Performance), and then existing techniques and conceptual models (Rules) are searched to find a relationship between questionnaire response data and the known safety standard.

In paper 6 a type III interrogation is applied with a new developed principle of data interrogation. Because the Rules in Paper 5 only marginally described the relationship between the questionnaire responses and the safety performance, a new Rule was proposed. The idea is that improved safety management reduce the stochastic character of safety performance. Therefore a poorly managed organisation, experience that different types of incidents and failures occur in an independent manner. This phenomenon can be explained with reference to established knowledge. Within statistical inference it is known that conventional distributions like gamma and Poisson, the variance decrease with decreasing event rate. Hence if safety management is improved the failure rate is decreased and the variation in failures from one time period to another is reduced. Because the stochastic element is reduced, the relative influence of the deterministic character of the safety performance is improved. In a real situation one may experience that the time series of different safety performance parameters tend to correlate. Correlation indicates that the processes are governed by a common variable e.g. Reason's (1998) earlier described elements in the recurrent accident scenario. Hence the proposed Rule was based on reasoning with correlation matrixes. Based on the new Rule of Paper 6, the approach in Paper 5 was repeated in Paper 7 with great success revealing some important cultural characteristics involved in a maritime recurrent accident scenario.

INTERROGATION OF VARIABLES DESCRIBING MANAGEMENT AND BUSINESS ENVIRONMENT

The underlying cultural patterns that were identified in the papers 1 to 7 indicate that the top-level management commitment and tactics have a large impact on safety. Because the task of the top-level management is to make the company running and produce profits and at the same time allocate resources it is intuitive that there may be a connection between economical parameters and accident statistics. In Paper 8 the type III of data interrogation is applied where the time series of both market accident statistics (Performance) inspected with reference to the pattern of conjectures in the freight market (Conditions) back to late 19th century up until today. Given the long distance between the onboard work conduction, where the accidents take place, and the fluctuations of the freight market or even world economy, it was not obvious that the relationship could be revealed even if it existed. However, the study was successful and indicates a certain mathematical relationship between the series (Rule).
This study indicates that there is a reverse relationship between economy and the likelihood of accidents i.e. when the freight market drops the accident rate increase.

In order to be sure that this relationship is not spurious a variation of tests were tried out. First the second derivatives of the series were compared in order to be sure that the negative correlation also is present for yearly fluctuations. While Paper 8 have a macro perspective on this relationship it was also tested that the relationship was valid at a micro level for individual shipping companies. Paper 9 and 10 do this for passenger ship companies and tanker companies respectively.

DATA SOURCES

In this type of analysis any obtainable data can be assessed. The data that is used on this study is presented in table 4 defined for each of the levels in figure 8. The first row represents the Performance in figure 2. To increase the reliability of the Performance also safety inspection findings are used to represent the data on the Performance (Paper 3). The remaining rows include data of Conditions that may explain why or how recurrent accident scenarios take place onboard ships.

Table 4: Types of applied data and their relevant level in figure 8.

Level in Figure 3	Types of data
Level 1	Accident data, total loss, serious accidents and insurance claims
Level 2	Safety Inspection data, ship design data
Level 3	Safety attitude data
Level 4	Annual reports, Organisational structure
Level 5	Fleet size data, freight rates

ACCIDENT DATA

The accident statistics is mainly collected from a database held by the Lloyd's Maritime Information Service (LMIS). This database contains data on accidents onboard commercial ships over 50 gross tons for the whole world fleet. Lloyd's Register until has held the database recently when it shared the ownership with Fairplay. The accidents are categorised either as total losses, serious or severe accidents and non-serious accidents.

Total loss are accidents where the ship ceases to exist after a casualty, either due to it being irrecoverable (actual total loss) or due to being subsequently broken up (constructive total loss). The latter occurs when the cost of repair would exceed the insured value of the ship. Statistics of total losses are available from the latter part of the 18^{th} and up until today. There are numerous of interface to this database. In this study the majority of total loss data are collected from the written publications of the database. This publication have changed name over time from Lloyd's Casualty Return to World casualty Statistics. In order to calculate total loss frequencies the size of the world fleet is collected from the World Fleet Statistics. Serious accidents are breakdowns resulting in the ship being towed or requiring assistance from ashore; flooding of any compartments; or structural, mechanical or electrical damage requiring repairs before the ship can continue trading. In this context serious casualty does not include total loss. Non-serious incident are any event reported to LMIS and included in the database, not being categorized as serious or total loss. Each accident is also categorised according to the accident types:

Also insurance claim statistics for ships insured by Norwegian companies. Only hull insurance claims excess of the own-risk limit for 1985 to 2002 are included. These data cover roughly 62000 ships and 21000 claims. In 1990 the own-risk limit was increased.

Table 5: Categorisation of losses (Lloyd's World Casualty Statistics, 1994)

Type	**Description of loss**
Foundering	Includes ships that sank as a result of heavy weather, springing of leaks, breaking in two, etc., but not as a consequence of the categories listed below.
Missing	After a reasonable period of time, no news having been received of a ship and its fate being therefore undetermined.
Fire/Explosion	Includes ships lost as a result of fire and/or explosion where it is the first event reported.
Collision	Includes ships lost as a result of striking or being struck by another ship, regardless of whether under way, anchored or moored.
Contact	Includes ships lost as a result of striking an external substance – but not another ship (collision) or the sea bottom (wrecked/ stranded) e.g. drilling rigs/ platforms.
Wrecked/ Stranded	Includes ships lost as a result of touching the sea bottom, sandbanks or seashore, etc. as well as entanglement of underwater wrecks.
Other	Includes war loss (and encompassing loss occasioned to ships by hostile acts), hull / machinery damage or failure which is not attributable to any other category.

INSPECTION DATA

The ParisMOU database (http://www.parismou.org) presents the type of deficiencies or detentions from all inspections in European and Canadian ports. The Equasis database (http://www.equasis.org) presents the number of deficiencies and detentions on sailing ships that have been inspected by PaisMOU, TokyoMOU and US Coast Guard. The search engines vary slightly between these databases. Both databases contain inspection data for about the last four years and ships that have been involved in a total loss are rejected from the Equasis database. Hence, only the ParisMOU inspections are available for lost ships.

ADAC Motorwelt is a German magazine written for the members of the ADAC Automobile Association. Each spring since 1998 this magazine performs an inspection of European ferries and ro-ro passenger ships. The inspection variables are listed below and are assessed on a five point linguistic scale (Very good, good, satisfying, defective, very defective) measured on six areas. These are Safety Information, Construction, Fire Protection, Emergency Equipment, Telecommunication / public address equipment, Safety Management. At last an overall score is compiled based on a weighted sum of the individual scores.

SAFETY ATTITUDES DATA

Risø, the Danish Maritime Institute (DMI), and the University of Texas (NASA/FAA) Aerospace Crew Research Project developed the Ship Management Attitudes Questionnaire (SMAQ) as a joint project. This questionnaire is part of a study aimed at understanding maritime operations attitudes and is derived from the *Flight Management Attitudes Questionnaire (FMAQ)*, developed by the University of Texas. The FMAQ is widely used in aviation to diagnose organisations in the areas of organisational culture, safety, and human factors practices. It contains items that relate to employees' opinions and attitudes about management, morale, safety issues, automation and teamwork, as well as general work values.

The FMAQ and the SMAQ questionnaires are instruments to assess organisational culture. In particular emphasis is assigned to the perception by employee groups of their organisation's safety values and system and their attitudes to and awareness of human factors issues. In aviation, the data are used to determine what actions, if any, are needed to enhance the organisational structure and safety system and to define training needs. Findings from the survey are presented in confidential reports to individual companies, but published works, like this one, will describe results in anonymous form, de-identifying the participating companies. A questionnaire survey has already been carried out among seafaring personnel in several shipping companies. The SMAQ questionnaire was distributed to seafaring personnel in five shipping companies during 1997 (four Scandinavian companies and one Asian company). The database has later been expanded with data from an American company, and two more Asian companies.

MANAGEMENT VARIABLES

This is a difficult are to obtain larger datasets for this area. Compared to other domains it is however some possibilities. The management decisions related to the type and age of their ship and the uniformity of their fleet is obtainable. Also the decided flag of registry is known to be of significant relevance and is a factor representing concentrated insight into the management strategies. Flags of convenience are often used to relax control of crews and ship standards in additions to the pure economical rationality. Also the membership of associations, applied classification society and insurance company may be of relevance. There have been three main sources for information about the organisations behind individual ships. These are the Internet interface to the LMIS database (http://www.sea-web.org), the Equasis database (http://www.equasis.org) and annual reports. In the Sea-Web portal it is possible to get an understanding of the ownerships of a vessel, the ship manager and who manages the ship in a larger fleet and at last the holding company of the vessels. In addition it is possible to get and overview of the ships technical features, and the history of the managers, owners and Flags of registry and Classification Societies.

ENVIRONMENT VARIABLES

Also this area has scare data. In a historical perspective however, data from the freight market, technological evolution, changes in regulation among some of the data that is available. Annual reports from individual companies have been collected to get a deeper understanding of these companies strategies, economical performance and changes to the organisations. In some cases the economical performance is supported with stock values that have been downloaded from the relevant stock market. Also data on freight rates have been applied from various sources (Fernley's, 1985)

WHAT ARE THE CAUSES OF SHIP ACCIDENTS?

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ABSTRACT
Maritime safety work has for a century been dominated by two conflicting principles. The first is the higher frequency of operator errors relative to technical failures. The second principle is then emphasis of improving safety through technical upgrading, such as incorporating double hulls. This study addresses this inconsistency, and describes the general evolution of insight into the causes of maritime accidents. While the main cause of accidents in the early 1900s were recorded as being unavoidable and of external character, it is concluded that today's typical ship collision, grounding, foundering or extensive fire is a result of an organizational failure. Relevant empiric evidence and theory is outlined. Factors, which may describe some of the variance in accident rates, such as flag of registry and ship age, are also described in an historical perspective. It will be demonstrated that the ship age do not describe the vessels' intrinsic technically accident risk, as earlier assumed. Small, relatively inexperienced management companies have significantly higher age of their fleets. Their policy and inexperience is therefore most likely the real cause behind the significance of ship age.

KEYWORDS : Ship safety, properties of maritime accidents, business strategies and policies

1. ARE WE MAKING ANY PROGRESS?

During a newspaper search for information about maritime safety, it was evident that the main focus was aimed at old tonnage and poor maintenance. Ship detentions were proclaimed as one measure to cope with these problems, as well as banning of vessels older than 20 years. It was further suggested to improve regulation, build experience, improve competence and incorporate organizational redundancy into the shipping organizations. Human errors and adequacy of resources was pointed out as important factors. This mind-set could probably be compiled from today's newspapers, especially subsequent to the Erika and the Prestige accidents. The surveyed newspapers were however about 100 years old [1], [2].

Even though the socio-technical understanding of maritime safety commenced at least a decade prior to the historical Titanic accident, today's safety efforts are apparently struggling with the same level of detail. If the applied safety improving strategy is effective is therefore a matter of discussion. On a theoretical level the most important innovation is the concept of safety culture. Although knowledge on safety cultures still not is fully developed, this concept may at least be seen as one step forward. Insight into human and organizational safety has also increased significantly. Potential hazards have been introduced by the increased size and complexity of ships and the significant decrease in crew size. During the last 50 years the Flags Of Convenience (FOC) have hampered the motivation for improving ship safety. It is however expected that our current modern society has resulted in more than marginal improvements in ship safety in a 100-year perspective.

It is possible to roughly evaluate the last century's safety improving process. In 1891 about 0.9 % of the British seamen were killed on duty each year [2]. This percentage was reduced to the half about 15 years later, and the British fleet was considered as the safest of the world. A century later we are experiencing about 0.62 fatalities per 1000 workers year (Norwegian figures for 1990-94) indicating a yearly improvement of about 2.6%. The average yearly improvement in the world's total loss ratio is 2.4% [3]. Figure 1 shows, however, that these improvements have been sporadic [4]. Apparently, the total loss ratio dropped about 30% during a few years around 1930, and the period from mid 1930s until the late 1970s seems to vacillate around a loss ratio of 0.65%. From the late 1970s until 1990 the yearly improvement again speeded up to nearly 10% each year.

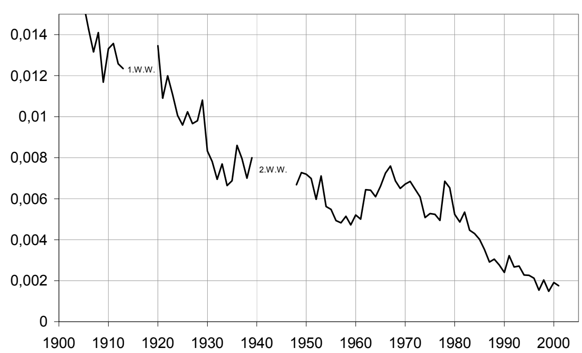

Figure 1: World fleets' total loss ratio (steam and motor ship larger than 100 gross tons)

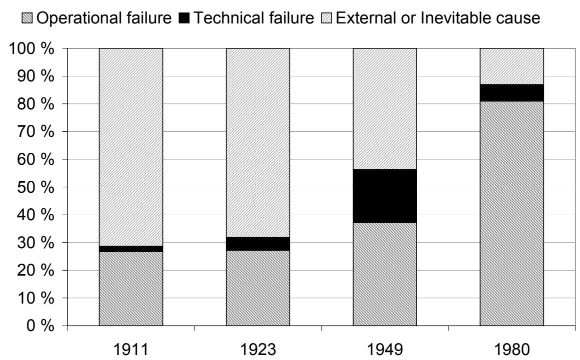

Figure 2: Historical progression of causal interpretation

There may be several reasons for these short lasting, but drastic improvements. The International Maritime Organization (IMO) was established in 1948, but its regulative influence did not take effect before the late 1970s. Det Norske Veritas's classification rules for new building projects were of 12 pages in 1865, and it expanded to 356 pages in 1955, and the year later it was of 400 pages [5]. In 2003 the new building rules are defined on 1550 pages, in addition to the rule-guides of about the same volume. The development of these regimes and their prescriptive rules does however not implicitly explain the decrease in accident frequencies.

2. Causal factors of ship accidents

Defining the causes of an accident is difficult. In a philosophical perspective the definitions of causes have been an issue of discussion all the way back to Aristotle's "doctrine of the four causes". In strict terms it is common to describe individual causal events as *insufficient but necessary parts of unnecessary but sufficient conditions* that result in losses. Hence, an event is a cause of an accident, if the elimination of the event would have prevented the accident from occurring. Causes of ship accidents have been recorded for the last hundred years by maritime authorities. In contrast to the earlier referred newspapers, these early recordings describe inevitable factors as the dominating causes of ship accidents (Figure 2). As recording of causes proceeded, it was soon recognised that every accident had a unique character with a multiple of potential causes and numerous of possible combinations. Because recording of causes is carried out to learn and prevent reoccurrence, this characteristic had to be addressed. Therefore two simplifying principles have been formed.

The first principle is to generalize failures. Division between operator and technical failure is one example. According to the recorded causes of accidents on Norwegian vessels [6] the dominance of operator failure relative over technical failure has been clear for considerable time. The most apparent trend is the reduction of causes considered to be external of the ship (e.g. other ships or foreign pilot) and unavoidable (e.g. storms, sea, ice, self ignition or misfortune). In 1911 to 1913 the navigational operator failures on Norwegian vessels were defined as (translated) Careless navigation, Reckless navigation, Wrong navigation, Incompetent navigation, Lacking experience with fairway, Wrong interpretation, Drunk on watch and Fell asleep. The descriptions varied somewhat from each year and the difference between some of these causes is difficult to understand. Today we have generalized operator failures to be either as slip, lapse, a violation or a knowledge- or rule based mistake [7]. These disjunctive and complete set of operator failures aids both the safety manager [8] and the accident investigator [9]. In 1959 Heinrich [10] estimated that 88% of industrial accidents were caused primarily by dangerous operator acts. Several independent studies demonstrate that operator failure counts for at least 80 to 90 percent of today's maritime accidents, while technical factors accounts for the remaining part [11], [12], [13], [14] (Figure 2).

During the 1930s an organisational researcher, Heinrich, proposed an iceberg model to understand how accidents occur. This model implies that there are a certain number of non-injury incidents behind the more serious ones. The frequency of these incidents increases as their criticality decrease. Although this philosophy has been criticised, it is also well recognised within safety management [15]. In figure 3 empirical data are compiled to obtain a simple iceberg model for various years. The figures demonstrate that for each ship accident causing human losses there are a certain number of totally lost ships (black), a certain and a somewhat larger number of serious ship accidents

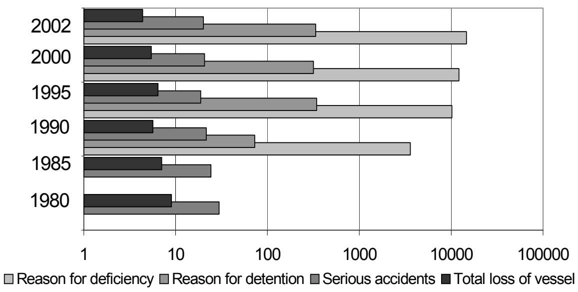

Figure 3: Progress of maritime iceberg models

Figure 4: The general progress of iceberg models

(dark grey). For the four most resent time categories, the estimated number of ships with reasons for Port State Control (PSC) detention and deficiencies are included [16]. These figures are based on ParisMOU statistics aggregated to be representative for the world fleet. The figure illustrates that while the number of accidents behind each fatality is reduced, the number of reasons for detention and deficiency increases. The increasing number of ships having reasons for PSC deficiencies may imply that the subjective general acceptance of risk is lowered, which in term increases the inspectors' awareness. A similar tendency can be observed when comparing iceberg models from various industries and moment in time (1996:[17], 1993:[18], 1975:[19], 1969:[20] and 1930:[21]) presented in figure 4.

The most ad-hoc interpretation of the iceberg model is to consider pyramid shape only as statistical relationships. In this interpretation the fatal accident is causally independent of the less critical incidents and deficiencies. The accident is then typically called component- or individual accidents. The individual failures are caused by one single isolated event or condition e.g. a slip by a navigational officer. In some cases, however, it seems narrow minded to consider the accident as causally independent of the more latent deficiencies in the organisation. The accident is then typically described as a system- or organizational accident, assuming that the less critical injuries and conditions may cause graver accidents. While the individual accidents are characterized by victimizing the single or few persons that caused it to happen, the organisational accident involves several systems or individuals that prior to the accident were assumed to be independent. In contrast, the organizational accidents have a catastrophic outcome that affects uninvolved populations, assets and the environment [22]. In order to learn from the organisational accidents it is most effective to understand how the most basic deficiencies took place. Besides calling these failures for system or organizational failures, they are also referred to as parent-, distal-, indirect-, basic-, common-, root- or latent failure. One of these failures may cause a range of more directly or proximal failures. Both Reason [22] and Perrow [23] assumes that organizational- or system accidents are rare but have large damage potential. In 1987 Wagenaar [12] published the findings of his investigations of 100 ship accidents, all heard by the Dutch Shipping Council between 1982 and 1985. This study indicates that the system or organizational aspects are evident for the causal chain of maritime accidents. The typical ship accident has more than 20 causes, whereof several have an independent nature. Wagenaar stated that the root causes of operator errors are dependent of the activity's work environment, rather than personal and situational related factors. The major types of operator errors contributing to the occurrence of accidents are wrong habits, wrong diagnoses, lack of attention, lacking training and unsuitable personality. A study conducted by Karlsen and Kristiansen [24] concluded that the external conditions, relating to weather and sea are contributing factors to navigational accidents. Technical problems, on the other hand, are not important, especially compared to the problems related to work conditions, human performance and neglect. Failure or deviation is often related to normal activities in contrast to abnormal situations, which are rare as a triggering factor. The accident process is therefore typically initiated long before the more dramatic scene appears.

3. DIAGNOSTIC SAFETY INDICATORS

A few years ago it was revealed that an insurance company had introduced higher premiums for sports cars with a red colour. This caused some debate, because the colour of a car does not seem to have an intrinsic relation to safety. The insurance company did however base their decision upon compilation of several years of data and experience. A proposed explanation was that those referring red cars generally were higher risk takers. This example seems simple, but testing of any statistical relationship introduces uncertainties about its real meaning.

For about one hundred years ago, three statistical findings dominated to debate about maritime safety. This was the vessels flag of registry, the age of the vessel and the ship type. Sail ships had in general two to three times higher accident frequency compared to steam and motor ships. Later the hazardous ship types changed to Liberty ships and fishing vessels while bulk carriers, single hull tankers and old passenger ships are currently being explicitly monitored. During the 1930s it was also proved that smaller vessels had a relative higher loss frequency. In 1974 it was however proven that ships flying under a FOC, were generally smaller in size [25]. Nearly 90 years ago, the significance of a ships' age caused the Norwegian Ship Owner Association to ban investments in foreign ships older than 20 years [2]. Even though the causal explanations at that time were addressed to the management policies of the companies, a widespread interpretation today attributes technical issues. Therefore, old ships are now being discriminated regarding freight rates, targeted for PSC inspections and banned by the EU, irrespective of its owners and managers. To illustrate the age's statistical significance the accident rate for various age categories is plotted in figure 5. It is obvious that the loss ratio (ships being totally lost due to an accident scenario) have a linear relationship to age, while the serious accident rate also seems to increase as the vessel ages. Serious accidents are those ship accidents requiring assistance or repair in a yard [4]. A sample of 2225 randomly selected vessels was collected from the Equasis database [26] to estimate the relationship between age of vessel and number of deficiencies revealed through safety inspections (Figure 6). The PSC have a large focus on technical conditions and seek conformance with IMO's regulative. Represented on the same categorical axes, all the three independent types of data indicate that safety performance decline as a ship ages.

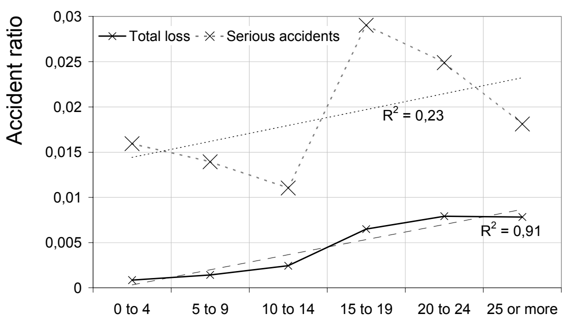

Figure 5: accident statistics of age categories

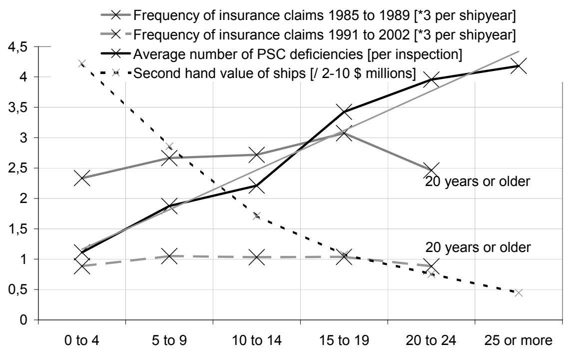

Figure 6: various characteristics of different age groups

In figure 6 there are two curves representing claim statistics for ships insured by Norwegian companies [26]. Only hull insurance claims excess of the own-risk limit for 1985 to 2002 are included. These data cover roughly 62000 ships and 21000 claims. In 1990 the own-risk limit was increased. This caused the total frequency of claims to be reduced, and eliminated the higher claim frequency for the 15 to 19 year age category. This may either imply that this group have a higher frequency of small claims, or that the change in own-risk limit scared off the most sub-standard ships to other, less selective insurance companies. The plots demonstrate that the claim frequency seems relatively independent of age, and that old ships may even be safer then their younger sisters (Figure 6). On a world fleet level, it is common knowledge that the portion of old ships increase each year, while the loss ratio is continuously decreasing [4]. At last but most significantly it is earlier in this study demonstrated that at most 20% of the causes of ship accidents are related to technical factors. There is in average a nine-year age difference [3] between the world fleet and the totally lost vessels. This high difference in age can impossibly be explained by the 20% of technical related accidents. Consequently, it has to be non-technical aspects that especially make old vessels more risky.

Apart from slope of the regression lines, the plots in figure 5 and PSC deficiencies plotted in figure 6 have another common characteristic. The three first and the three last age categories seem to form two identical concave shapes. Because the residuals have equal likelihood of being above or under the regression line, it is highly unlikely that the same shapes spuriously appear on three independent plots. It can be calculated that there is a dependency between the patterns (significance level of 1%). If we consider the safety performance along the life cycle of a ship, it seems as if something happens when it reaches an age over 15 years. The graphs show that the accident and deficiency rate escalates at this age. As the vessel continuous to age the safety performance follow a slope similar to it's youth, but on a poorer absolute level.

The task is then to understand what happens with a vessel when it reaches an age over 15 years. Some might pinpoint that they are designed differently. The double hull ships are for instance mainly represented in the three youngest age categories, while the single hull ships are dominating the last ones. Others may indicate that vessels are typically built for an age of twenty years causing the rate to escalate when reaching this age. But again, these explanations are inconsistent with the human and organisational emphasis. It is therefore interesting to consider the management company behind the various age categories. Figure 7 shows that the five largest management companies have in average been in businesses about ten times longer than the world's single ship managers. They have also a significantly younger fleet and obtain significantly fewer deficiencies and detentions in port state control. A younger fleet implies that they sell off old ships and buy new ones directly from the yard. The ships being lost through accidents have managers that are far more similar to the small and young companies than the large and old companies. The shift identified in figure 5 and 6 may therefore be a reflection of change in ship management.

It is obvious that there has to be a logical reason behind the differences in management companies illustrated in figure 7. This may be related to the business philosophy of the various companies. There are two stereotypes of business philosophies within shipping. The shipping industrialists have a long business horizon and attempt to avoid market risks through time-charter agreements. The opposing stereotype is the ship speculator who is specifically interested in the risks related to market fluctuations. The shipping industrialist's time-charter agreements make it possible to build a new ship that has a determined earning the next few years. This reduces the risks related to new building projects, making it easier to get financial support. Because the freight rates from time to time are extremely high, the potential for large benefits is an eminent characteristic of shipping. This fluctuation attracts the speculators. Their strategy is to have ships available in the spot market not being tied up in agreements. When the freight market is good they can cash out high earnings from both the freight market and the second hand ship market. The age of the vessel do not affect the obtained freight rates when the demand for transportation is high and the relative increase in second-hand values is better for old ships. Consequently, it is rational for a speculator to employ old ships.

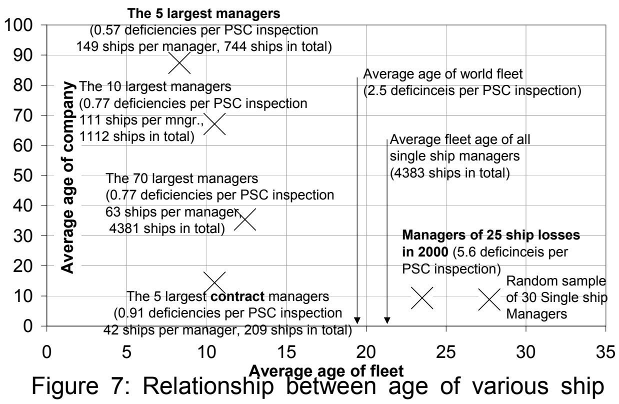

Figure 7: Relationship between age of various ship management companies and the age of their fleet

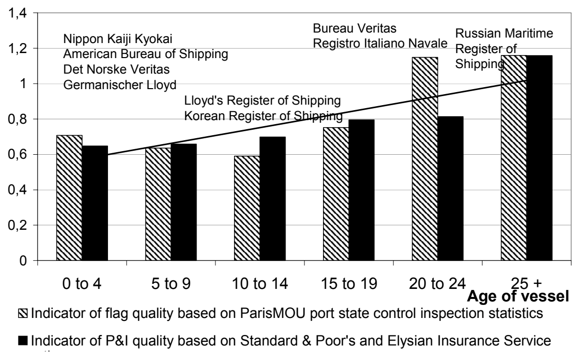

Figure 8: Quality of flag of registry, P&I insurance company and characteristic classification societies for various ship age categories

In an historical context the attribution to business philosophies within maritime safety seems valid. During the 1930s and the 1980s the two largest market depressions of the 20th century took place. According to several sources the harsh market pushed the speculators out of the market [28], [29]. Also the early 1920s was unattractive for speculations, because there was a balance between shipping demand and transport [29]. It is already demonstrated in figure 1 that these periods precisely represent the few large drops in accident risk. The age of the ships may therefore be statistical related to safety performance because the ship speculators favour old ship and the industrialists considers newer ships to be more attractive. Any ship, independent of its age has to be related to an insurance company, classification society and flag of registry. Figure 8 illustrates that the selection of these attributes also support the pattern revealed in figure 5 and 6. It seems to be a shift in quality of flag, classification society and P&I insurance at the age of 15 years.

4. CONCLUSIONS AND DISCUSSION

This study reveals that human failures have dominated over technical failures for at last one hundred years. After the 2.W.W., the belief in accident prevention escalated. The typical ship accident of today has a causal chain with characteristics of system or organizational failures. In a historical perspective there are three factors that are reliable indicators of accident risk. These are the ship type, its age of the flag it is sailing under. While it is believed that the flags' significance is a manifestation of the crew quality, working conditions and management quality, the age's significance is typically believed to be a manifestation of the ships' technical standard. This study rejects this interpretation by illustrating that it is a specific type of shipping company that engross the older vessels. Young companies, typically operating few ships, seem to be the typical company behind old tonnage. Older and larger companies have a significant younger fleet. They buy ships directly from the yard and sell off old tonnage when it reaches a specific age. This indicates that the age-effect is a manifestation of an organizational aspects and not only technical degradation.

There exist several safety management paradigms that are relevant for the understanding of organisational accidents. The most noticeable are the Risk Homeostasis Theory (RHT) fronted by Wilde [30], the Normal Accident Theory (NAT) proclaimed by Perrow [23], the High Reliability Organisation Theory (HROT) formed by LaPorte and Consolini [31], the Organisational Accident Theory (OAT) pedagogical described by Reason [22], and at last Rasmussen's Proactive Risk Management Theory (PRMT)[32]. While the two first theories respectively address the human and the technical element the three remaining paradigms have an organisational perspective. The PRMT pinpoint that the influences from the regulative regimes have to be known in order to understand safety in an organisational perspective. Even though the NAT considers aspects of the technical systems to be most important, all these five core literatures accepts that safety culture is a key issue in improvements of organisational safety. If the culture makes the crew take safety as an implicit aspect of the job, this makes them take responsibility and autonomously incorporate safety values in their conduction.

In the discussion of causes of ship accidents, aspects related to blame and politics have to be addressed. There are several extremely strong stakeholders that may influence the way accident knowledge is coded and interpreted. On an international and regional level, strong stakeholders such as the UN, the OECD and the EU have ship trade and transport on their political agenda. The ILO is strongly involved in securing the seamen's work conditions. Traditionally, it has been easier to get insurance cover for technical failures and the classifications societies are mostly concerned with technical aspects. On a national level, juridical aspects and distribution of blame are likely to be reflected in the way investigations have been conducted. The traditional attribution to technical factors has to been seen in this context. Technology is easy to regulate. It does not interfere with common understandings of free trade and competition. The acceptance of safety as an organisational aspect increases the barrier for entering a market, and makes it difficult to accept that all companies should have the right to provide services. Technological enhancements secure labour at yards and keep the seamen, companies and regulators free from accident blame. Technical failures are difficult to predict and manage, which makes the business easier for both the insurers and the classification societies.

In summary this study sharpens the organisational perspective of ship accidents. It is demonstrated that opposing factors, such as the significance of the vessels' age, in fact are related to organizational aspects. There are therefore three areas that have to be addressed to understand the accident risk within the maritime domain. First of all it is crucial to understand the safety culture of a shipping organisation. It should be possible to empirically demonstrate what distinguishes a sub-standard company from a blue-chip one, rooted in their respective safety cultures. The second area is to understand how a company's policy and strategy influence on the safety culture and safety performance. What is it that specifically makes the small and young companies that operate old vessels more risky? The last and most important task is to understand how it is possible to relate characteristics of the freight market and influences from maritime stakeholders to the shipping company and the fleet in general.

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MODELLING SAFETY PERFORMANCE
- aggregation of symbolic knowledge

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ABSTRACT

A critical challenge in prevention of losses is to understand how aspects of daily operation, organisational factors, management decisions and the society in general influence on the activity's safety level. There exist several conceptual models describing such relationships, which are typically used in accident investigation, understanding of human performance and in safety management. This paper considers more than 30 of these conceptual models. Even though their purpose vary slightly, all describe how accidents occur and how they may be prevented. Until now the symbolism in these models has been a reflection of the developers' individual experience and professional background, the scope of the research and limitations related to the application of the models e.g. availability of data. The idea is to develop a suitable safety performance model that is aggregated from the expert knowledge represented in exiting models.

1. INTRODUCTION

Symbolic knowledge is a representation of the relationships between variables. These relationships may be cause-effect chains, processes or influences. The variables range from actual losses to human and organisational factors (HOF) and even aspects of society. One illustrative example is the Common Performance Model (Figure 1), which is part of Hollnagel's [1] Cognitive Reliability and Error Analysis Method (CREAM). The understanding of why accidents happen and how they might be prevented is still not very well developed. This fact can partly be explained by the complexity of the accident sequences and the multitude of causal factors. Even the *cause* as a concept, is a source of confusion in the sense that it might be defined and analysed in different and often competing scientific perspectives [2]. The emphasis on conceptual models within safety management has prospered since Heinrich applied this approach in the 1930s [3]. During the 1980s the several new theories describing the basic causes of accidents commenced. There were, however, no available data to prove the importance of more distal or basic organisational causes. Consequently, the experts generalised their insight and presented them in conceptual or symbolic models. In lack of precise theoretical understanding and variations in perceptual approaches, a multitude of conceptual or symbolic models describing safety performance have been developed.

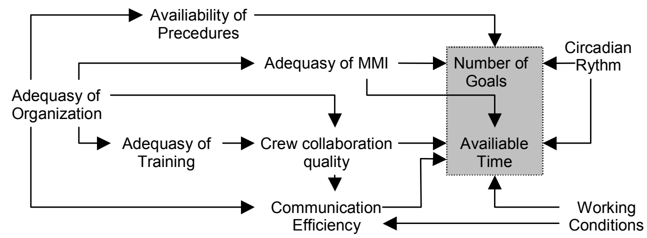

Figure 1: Common Performance Model in CREAM [3]

One of the models that have obtained significant attention in safety management is James Reason's Swiss-Cheese model (Figure 2)[4]. This model describes how latent failures in the organisation reduce the resistance against losses. Another model that is widely recognised is Jens Rasmussen's AcciMap model (Figure 3) [5]. In contrast to the Swiss-Cheese Model neither of these models directly describe the development of losses, but how hazardous situations can be related to organisational factors and even the society in general.

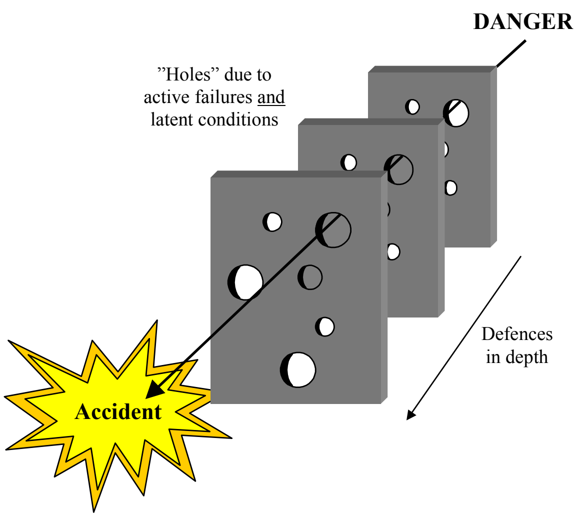

Figure 2: Reason's defence in depth model [4]

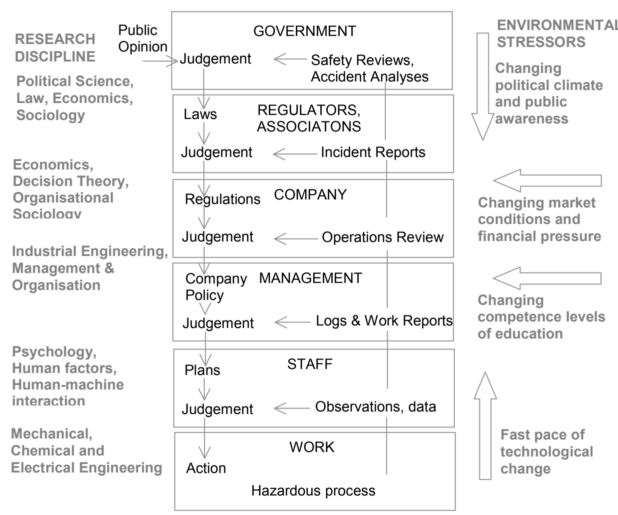

Figure 3: AcciMap Model [5]

2. OBJECTIVES AND SCOPE OF STUDY

This study outlines the state-of-the art in symbolic representation of safety performance models. First the structural relationships of 33 models are considered. These models describe the accident process, operator performance and organizational performance.

Because some of the available knowledge is not represented in the sampled models, an additional literature study supports the model development. The objective is to aggregate knowledge from these models in order to develop a symbolic model that has the potential of describing the safety performance of shipping organisations during normal operation. This model should attempt to unify operator performance considerations of various established theories e.g. cognitive and behavioral aspects, organizational influences and cultural elements. Because the model emphasize on the operational phase, accidents at the yard or during demolition are not considered. Latent failures from design and assembling that may affect the performance of the operation are however included.

3. PRESENTATION OF SAFETY PERFORMANCE MODELS

3.1 Set of safety performance models

A sample of 33 different models relevant for safety assessments is collected from a literature review. The models are also selected in the view of new advances within this area, and are selected because of their ability to relate operational factors to the organisational. Their area of validity is generally defined through their purpose. As a consequence even similar models varies slightly with respect to differences in validity approach. In order to perform a comparison between the models, they are arranged into three groups based on their area of purpose. The purpose of the Accident Process Models' (table 1) is to guide the accident investigation to obtain a satisfactory understanding of the accident's progress. In contrast to these models more or less general considerations of losses the Operator Performance Models (table 2) focus specifically on the human element. The last group of models labelled Organizational Performance Models (table 3) is used for management and control of organizations. The boundaries between the three groups of models are vague. Some attempts have been made to apply a model outside its area of validity. Waagenaar [6] argued for that Tripod Delta (model 27, table 3) should be used as an Accident Process Model. Another example is the duality in the name of Kjellén's [7] Safety Management and Organisational Review Technique (SMORT) indicating something more than its real diagnostic purpose (Table 1, model 6). It is outside the scope of this study to review each validity process for the different models in detail. Consequently the three areas are threaded separately. A detailed assessment of each of the 33 models is above the scope of this study.

Table 1: Accident Process Models (Accident Causation and Investigation Models)

1.	Social Environment → Fault of Person → Unsafe Action → Accident → Injury	*(Domino model [7])*
2.	Presence of Hazards (Energy Source) → Broken barriers (Release of Energy) → Presence of target victims (Unintended energy transformation)	*(Gibson, [8], Haddon [9])*
3.	Upper Management → Projects → Daily operation → Sequence of events / Risk situation	*(SMORT [7])*
4.	Source failure types → Functional failure types → Condition tokens → Unsafe acts → Accident and Incident	(*Reason [4]*)
5.	Lack of control → Basic causes → Immediate causes → Incidents → Loss	*(Loss Causation Model [10])*
6.	Organizational factors → Local workplace factors → Unsafe acts	*(Reason [11])*
7.	Basic casual factors relating to Management and allocation of Resources → Basic casual factors relating to Daily operation on board → Accident Event → Casualty event	*(CASMET [12])*
8.	Root Cause → Causal Chain → Critical event → Accidental flow of effects → Target Victims	*(Rasmussen [5])*

Table 2: Operator Performance Models(Decision, Human Behavior and Performance Models)

9.	Social Context → Information and Experience → Attitudes → Behavior	*(Staw [13]), (Martin [14])*
10.	Strain(Rules, Subject, Instrument, Community, Division of labour) →Object (Outcome)	(*Human Activity Model [15]*)
11.	Operator, Interface to Organization, to Equipment, to Procedures and/or to Surroundings → Operator Error	(*SHEL-model [16])*
12.	Interpretation → Selection of actions → Action Execution → Result Observation	*(Pyy [17])*
13.	Observation → Interpretation → Planning /Choice → Action / Execution	(*Model of Cognition [1])*
14.	Adequacy of Organization, Working Conditions → Adequacy of training, collaboration, communication, availability of procedures etc. → Number of Goals, Available Time → Human performance	*(Common Performance Model in CREAM [1])*
15.	Intention → Actions → Consequences	*(Reason [11])*
16.	HF root causes → HF mediating indicators across multiple ship hazards → HF involvement in specific ship hazards	*(Neumann [18])*
17.	Organizational standards and objectives → Behavior prescribed by rules and procedures → Human Performance →Process being controlled → Occasional incidents & accidents	*(Reason [11])*
18.	Target level of accepted risk > perceived level of risk → more risky behaviour (and vice versa)	(*Wilde [19]*)

Table 3: Management, Strategy and Organizational Performance Models

19.	Management(Principles, Goals, Criteria) → Organization and Information System (Resources, Information, Control) → Production (Interaction between Technical system and Operating procedures)	*(Soukas [20])*
20.	Society (Economy market, laws and regulation, authorities) → Industrial Organization (management, Policy and resources, Structure, cultural patterns) → Safety System (management, goals, structure, motivation, measures) → Safety Level, Productivity and profits	*(Saari et al [21])*
21.	System Climate → Organization & Management → Communication & Control → Operator Reliability → Engineering Reliability	*(HSE – mode [22])*
22.	External Environment → Leadership (↔)Mission and strategy (↔) Organizational culture → Factors influencing lower organizational levels	*(Model of organizational Performance and change [23])*
23.	Policy level → Regulatory level → Organizational level → Direct level → Failure level → Abnormal event / accident	*(IMO, [24])*
24.	Planning Process (Strategy) → Information and Communication Process (Structure) → Business Process (Process) → Control and Reward Process (Performance) → Culture	*(Strategic Management Framework [25])*
25.	Input, Resources, Controls → Action transformation (Activity) → Output	*(Structured Analysis and Design Technique [26])*
26.	Specification → Design → Construction → Commissioning → Operation → Maintenance & Modification → Decommissioning → Dismantling	*(Life Cycle Model [27])*
27.	Statement of goals → Organisation → Management → Design → Build → Operate → Maintain	*(Tripod delta [11 28])*
28.	Pressures(Economy, Work Load relative to Safety) → Degree of resistance against errors	(*Space of possibilities [29])*
29.	Governmental Judgement → Judgement of Laws → Judgement of Regulations → Judgement of Company Policy → Judgement of Plans → Actions	*(AcciMap, [5])*
30.	Policy level → Implementation → Performance influencing factor level → Influencing factor level	*(Influence Diagram Appr. [4])*
31.	Environment → Management → Implementation → Operation	(*Markov model [30]*)
32.	Quality Planning (Goals, Policies, Resources) → Control → Improvement	*(TQM [20])*
33.	New Design Control → Incoming Material Control → Product Control	(*TQM [20]*)

4. AGGREGATION OF KNOWLEDGE

A conceptual model is a manifestation of the developer's understanding of a real world phenomenon. The real phenomenon may however not be properly understood by the developer. For example, it is statistically proved that old ships are more frequently involved in accidents. Therefore, models used for targeting of hazardous ships emphasise on degradation of technical standard. This interpretation is widely accepted by maritime authorities, insurance companies and classification societies. As a result one of the safety measures issued by the European Union after the Erika, Prestige and Express Samina accidents are age-limits on ships sailing within European territory. In an earlier study [31] it was demonstrated that this interpretation contradicts other statistical evidence and organisational insight. It was also demonstrated that there were a different type of managers behind old ships that have a shorter business perspective and a higher attribution to ship speculations. This illustrates that models based solely on statistical evidence might be invalid. Another approach is therefore to consider causes of real accidents, like a substandard safety culture. During the late 1970s and 1980s a series of investigations it was perceived that the common safety attitudes of the organisation were of an immature quality. Therefore, safety culture was segregated out as an individual research area. The results of

20 years of research into safety culture are however limited to improved insight with little practical utility [32]. During the model's four-decade age range new insight has been achieved into behaviour control and management of risks. An overview of these advances is summarised in the following text.

4.1 Theory of basic safety modelling approaches

There is a multitude of possible modelling approaches to safety management [33]. Experience has showed that some modelling approaches are more correct than others. Rasmussen [29] describes the changes from normative models emphasizing on control by rational instructions, to descriptive models focusing on deviations from the norms (descriptive-dev). A third evolutionary step also applies descriptive models, but in terms of actual behaviour (descriptive-act). The trend of modelling scopes seems to converge against models of behavioural shaping features and criteria. Hence the approach has advanced from models describing ideal behaviour to models that describe how correct behaviour is shaped. As an example the Normative approach focus on the task procedures, the descriptive-dev approach focus on less than adequate job conduction and the descriptive-act approach focus on the context of the task that makes the operators able to carry out the job safely. The presented version of the model of cognition (Model 13) and the Structured Analysis and Design Technique (model 25) are examples on an example of Normative models. Most models belong to the group of Descriptive models focusing on deviations. "Lack of…" variables are typical for this kind of models (model 5). The CREAM model (model 14) may be considered as a descriptive-act model. Model 18 and 21 may also fall under this category. Reason [11] makes similar considerations by giving extensive support to William's [34] Human Error Assessment and Reduction Technique (HEART). HEART is a technique for predicting the human error probability by modelling elements of the context of the task, in contrast to the task itself. This evolution is also evident in Jersin's [35] reflections of the management concepts. He describes the evolution from a rule–based bureaucratic approach after the Second World War to a value-oriented approach today empathizing on values and ethical motives.

The models are based on two different reasoning logics. The Diagnostic logics focus on known unwanted events, e.g. accident, and base the models on diagnostic reasoning to identify the path to the root causes of these events. This reasoning is evident in the Accident Process Models, which are based on experience from accidents and typically culminate in a loss or unwanted event. The alternative is the Causal logic that focuses on how to maintain an un-failed state and implicit how to avoid the causes of accidents. Both the Operator – and Organizational Performance models have a mix of these two reasoning logics. It is difficult to state if either the Diagnostic or the Causal reasoning backgrounds are better than the other. The examples of the age-limit measures and the belief in safety culture are two examples indicating that Diagnostic insight alone is insufficient. It is not difficult to imagine the difficulties related to pure causal models. The normative models are for instance based on a causal reasoning. It does not consider how the actual work conduction is, but rather on how is should be. The descriptive–dev approach is of a more diagnostic nature, as it focuses on deviation from norms based on insight from actual incidents and events. The descriptive-act approach is again more associated to a causal logic, as it attempts to represent actual behaviour that may be hazardous. These models are based on conceptual understanding of cognition and organisational processes and not on accident insight. If it is correct that the models converge against models that shape behaviour, it seems as the causal reasoning is most appropriate logics of the two. Even though, the diagnostic reasoning is crucial for validation of the causal models.

4.3 Outline of schematic model

Aside for the diagnostic and causal reasoning, there are also a variety of applied variables. These are the basic environmental conditions, the responsible parties, organisational functions and outcomes e.g. goals. These distinctions are important to be aware of. For a given collision accident, it is important to focus on the responsibilities of the officer on watch, the navigational function, the outcomes e.g. speed and courses, or the context of the navigators themselves? Each of the variable has its important aspect and it is difficult to state which is the better. In the earlier discussion about normative and deceptive models, it was assumed that it was a need to consider the context of the tasks. In this sense the basic environmental conditions are most important. It is possible to apply all types of variables as described in the following model. For a shipping company the organizational structure is relatively explicit. Responsibly of the top-level management, the line-management and the crews have not only different responsibilities. They may also have different professional background and be located at different parts of the world. Hence, a first suggestion of the model is to apply organizational structure as a main dimension. The strategic level administers funds, defines objectives, develops policies and strategies, as well as the organizational structure. The tactical level manages and control necessary resources. They implement operational criteria and priorities in instructions, take decisions related to personnel recruitments, manning standards, cargo logistics, safety management etc. The operational level is onboard the ship. They operate the shipboard functions based on the developed standards and requirements form the external environment.

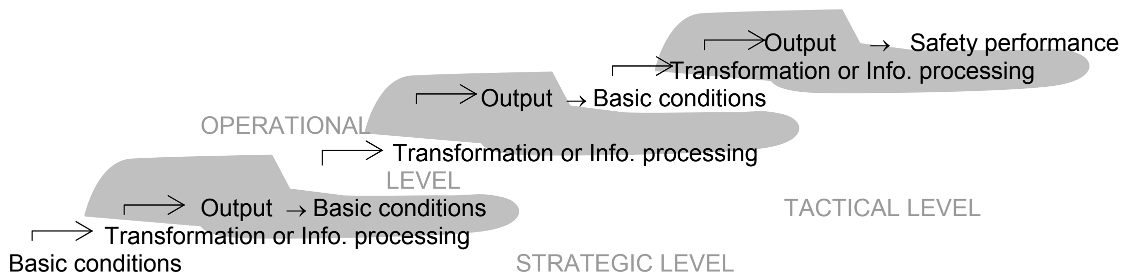

Figure 4. Schematic representation of aggregated symbolic knowledge

The scope of the models also varies between the models. The scope has to be broad enough to include all the important features. Model 19 and 28 includes elements of the environment outside the organization itself. These may be considered as the lower Basic conditions in figure 4. Most models start at a management or organizational level, while some of the operator model start at the environment of the operators. It is natural to include the conditions embracing the organisation, but it is outside the scope of this study to map this environment in detail. One weakness with the model outlined in figure 4 is lacking direct influence the environment has on the tactical decision level. Another weakness is the biased model structure relative to present state knowledge and obtainable data. Relatively much of the model describes what happens on the managerial levels. An enhanced version of the model is therefore developed outlined in Figure 5. This model is more pragmatic as it fits the available data and knowledge to a better degree.

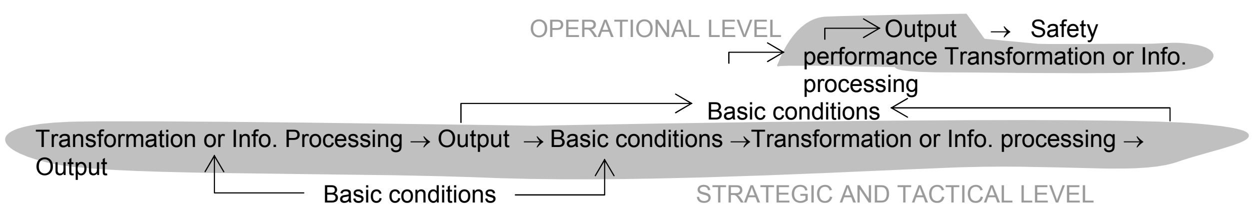

Figure 5: Pragmatic representation of aggregated symbolic knowledge.

The model presented in figure 5 can be simplified and assessed in more detail. Safety performance is a relatively undefined concept. Some relates inspection findings and observations in addition to core loss avoidance to this concept. In a strict term safety is related to the prevention of accidents. In this context safety performance is interpreted with reference to actual objective losses (Level 1 figure 6). Hence, the proactive efforts taken by the crew is more related to details the process and not an output in itself. Proactive efforts taken by the crew and aspects of the daily operation are included in the Level 2 of figure 6.

Near misses, inspection findings, audit non-conformities and observations are some examples of data collection techniques at this area. The basic conditions produced by the strategic and tactical level in figure 5, is more commonly understood as organizational factors (Level 3). Safety culture and competence are examples of organizational factors. As figure 5 indicates this is a result of the output from the strategic and tactical levels. These levels can be considered as higher management (Level 4). In shipping this is the land-based organization. At the contiguous level it is assumed that the environment of the company, especially the business environment have a relevant influence on the management (Level 5).

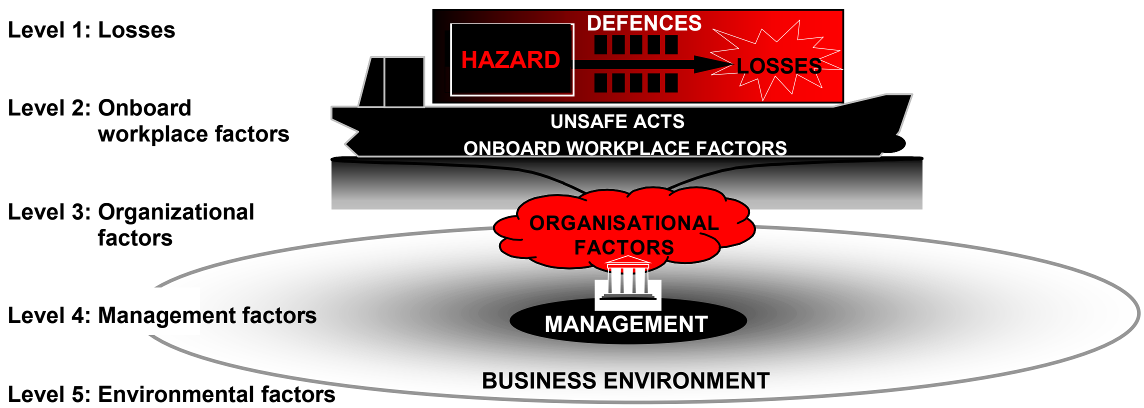

Figure 6: Aggregated symbolic model

5. Conclusion and discussion of results and further work

This paper has showed how knowledge from 33 models describing the occurrence of accidents, operator and organizational performance can be aggregated to form a new conceptual model. This model constitutes a framework for implementation of information related to safety performance of a maritime organization. This model is not controversial in itself. It is however aggregated from a set of existing models and therefore has evidence that justifies its relevance. The model structure is developed to represent levels of organisational responsibility, the functionality within each level and the impact one level has on the others. Even though the model it outlined, details of the variables are not outlined in detail. Even so, the assessment of the models in the battery indicates that the content should be focus on actual behaviour. Potential content is outlined in Table 4. The content of the two first rows are of an outdated nature. The first Normative content based on Causal logics describes how the ideal work conduction should be accomplished. Because the real world not is of an ideal character, and especially because it is the factors that deviate from the ideal that causes accidents, the Normative models are abandoned.

Table 4: Examples of content for various approaches

	Level 5	Level 4	Level 3	Level 2	Level 1
Normative Causal	Develop comprehensive regulations	Produce detailed task procedures	Educate the crew in the job content	Make all required esources available	oided Loss
Descriptive-Dev Diagnostic	Insufficient regulation	Lack of management control	Less than adequate motivation	Deviation from navigational procedures	Collision
Descriptive-act Diagnostic	Poor economy	Low commitment to safety. Re-organization and outsourcing.	Fatigue, stress, low work oral, high absenteeism.	ficiencies on safety features	Accident
Descriptive-act Causal	Regulations, economic cycles and competitive pressure	The commitment to safety and human resources in general	The resources, responsibility and attitudes to safety and the job in general.	nduction quality of operation and maintenance	ikelihood of losses

Although the next row of table 4 is of an improved version, still the content refers to norms. A common description of the content of the higher level is ”Latent failures” [1]. In order to define something as a failure it is necessary to know what the norm for an un-failed condition is like. As this knowledge is not yet available the version of the swiss-cheese model (Figure 1) is a hybrid between the two higher rows. The newer version of this model [11] enhances it to a Descriptive-act model as it describes actual behaviour and violations based in a diagnostic view. The two lowest rows are examples of potential content that makes. It would be favourable to know the content of these rows in more detail and to provide some quantified prove that the aggregated model and the suggested content are valid.

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SAFETY STANDARD CLASSIFICATION

based on accident statistics and safety inspection findings

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ABSTRACT

In a risk analysis the probability of accidents is estimated, typically at a planning stage, through a structured analysis of the involved systems. It is however widely accepted that when the system reach an operational stage, the risk is significantly influenced by the quality of management, maintenance and operation. In spite of this, there exist few risk assessments techniques that efficiently take into consideration the quality of the organisation. Therefore, this study develops a statistical framework that estimates the risk of accident at an operational stage. The framework has similarities with the traditional test framework applied within psychology e.g. an IQ tests framework. First, a statistical distribution of the accident rate is estimated for the world fleet in analogy to the Gausian distribution's description of the variance in IQ within a population. While IQ test scores together with the gausian distribution is used to estimate a person's real IQ, safety performance data together with the estimated distribution of accident rate is used to estimate a ship's real safety standard. The applied safety performance variables are experienced accidents and safety inspection findings. Based on these two variables it is possible to extract characteristics of the 25% safest ships (class A), the 50 % middle standard ships (class B) and the 25 % most substandard ships (class C). The distribution shows that the class A vessels only cause 7% of the world accidents, while the corresponding value for class B and C vessels are respectively 42% and 51%. The analysis also indicates that the sub-standard ships not only to a greater extent disobey international safety regulations, but also have a generally lower compliance with the most central safety requirements.

1. INTRODUCTION

The focus on organisational and cultural safety has increased since the early 1980s. Even though experts have been addressing related issues for nearly a century [1], they were now conceptualised and generally accepted. Naturally this shift had extensive effects upon the perception of what distinguished safe from hazardous. Earlier the risk acceptance of a prudent ship owner represented a norm for assessment of a vessel's seaworthiness [2]. After the 2.W.W. the volume of the regulations increased and the norm shifted towards regulative compliance. During the two latest decades the term sub-standard is as labels of ships and shipping companies that are considered to be unsafe [3]. This term refers to a norm that in fact is undetermined. Some norms have also been adopted from other industrial domains like de-minimis, e.g. likelihood of accident is less than 10^{-4}, or as low as reasonable practically (ALARP). While all these norms refers to the lowest acceptable risks on a dichotomous scale (acceptable or not), the concept of High Reliability Organisations [4] and Safety Culture Maturity Model [5] indicates that the safety standard of organisations vary on a finer scale from the poorest to the safest [6].

Simultaneous as the emphasis on organisational and cultural safety has enhanced, the available data on safety performance has increased [7]. Loads of data from safety audits, inspections, near misses, observations and incidents are systematically recorded. This may provide the managers with an extensive insight into the potential of safety improvements. Even though it is known that the various performance data may reveal latent dangers [8], there exist few statistical norms that make it possible to assess the safety performance or risk in an absolute context, or relative to other organisations. Many are sceptical to the comparison or benchmarking of companies based on these performance data. The frequency of near-misses may say more of the reporting culture of the company than of its actual safety level [9]. Accidents are rare and therefore both the occurrence and absence of accidents might be explained away as bad luck or fortune. The number of non-conformities and deficiencies respectively identified through audits and inspection are influenced by the competence and motivation of the auditors and inspectors. This study accepts that these measuring difficulties exists and tries to develop a method that copes with them. Instead of using the involved uncertainties as arguments for not comparing the data, it is more constructive to try to quantify the uncertainties themselves. In order to do so, it is necessary to know something about how the safety standard varies within a fleet of ships or a population of organisations.

Within psychology, ability and personality tests has been used for decades. These statistical approaches (e.g. IQ tests) first develops a norm distribution for the population (Gausian distribution), and then apply tests scores to measure an individual's level of ability (IQ) or type of personality relative to this norm. As the norm distribution reflect the distribution of scores for the population, absolute scores of personality or ability can be calculated. This framework could in principle also be adopted within safety management. First the distribution of safety standard for the population of similar system or organisations has to be developed. Then test scores or experienced safety performance can be applied to indicate the risk of an accident for a specific system e.g. a ship or a fleet of ships (e.g. within a company).

Within shipping there exist both accident data and safety inspection data on the world fleet of ships. If we accept that the individual ships in the world fleet have a varying likelihood of accident (λ) it would be of interest to describe this variation. It is however impossible to observe or measure this variation directly and there exist several potential norm distributions (fig. 1). A symmetric distribution indicates that the incident rate of the various ships have a tendency to centre towards an average value. The average value may represent the accident likelihood governed by the regulation, competence and environment. Alternatively, one might argue for that some organizations try to minimise risks, while some are less concerned, resulting in a skewed or even a skewed-two peak distribution (fig. 1).

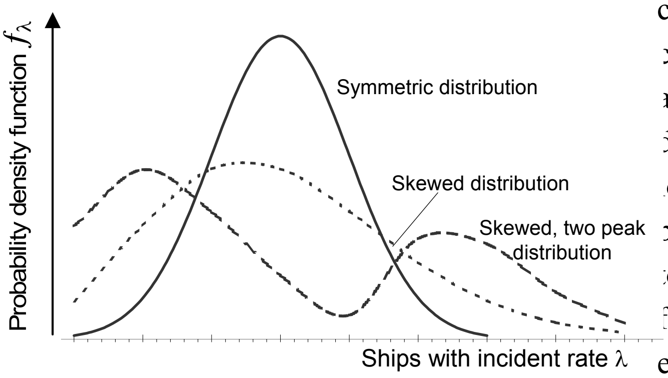

Fig. 1: Potential incident distributions

If it was possible to estimate the correct distribution of the real incident rate for the world fleet of ships, then this could in fact represent a norm that simplified the comparison of the safety performance data from various ships. The actual number of accidents within a given fleet of ships, within a defined duration of time, would be enough information to roughly classify its likely location on the theoretical distribution. For example, instead of stating that a fleet of ships has e.g. one accident in one year, it would be possible to state that it, with a specified uncertainty, is among the 25% best. It would also be able to link other safety performance data to this theoretical incident rate distribution. This study tries to develop this method.

2. Objectives and Scope of Study

The objective of this study is to estimate the real distribution of accident rate for the world fleet. There are two sources of accident data that both are assumed to be reliable as they are recorded by a third party [10] (Lloyd's Maritime Information Service - LMIS) and are difficult to conceal. Total Loss accidents are typically collisions, groundings, foundering, fires and explosions, which have such a devastating consequence that the ship is lost or scrapped. Serious accidents are breakdowns resulting in the ship being towed or requiring assistance from ashore, flooding, structural-, mechanical- or electrical damage that requires repairs before the ship can continue trading. The term incident is used to cover both total losses and serious accidents.

When the incident rate distributions are estimated it should be straightforward to develop scoring technique for localization of a given ship or group of ships within the distribution, based on its incident statistics. It is also manageable to develop a link between records of safety inspections and the incident distribution. This link does off course assume that the scope of the safety inspections is of relevance for safety.

The source for safety inspection data is mainly the ParisMOU database [11] covering Port State Control (PSC) inspection records of ships visiting European and Canadian ports. In some cases it will be necessary to use the Equasis database [12] that also include inspections from the US coastguard and the TokyoMOU. The inspections try to find non-conformities with the international regulations and conventions held by International Maritime Organisation (IMO) and International Labour Organisation (ILO).

3. ESTIMATION OF CANDIDATE DISTRIBUTIONS FOR THE INCIDENT RATE OF THE WORLD FLEET.

It is impossible to directly observe or measure the theoretical incident distribution for the world fleet, f_λ. Therefore, the estimation is divided into three tasks. First a discrimination variable is selected. This variable is selected based on its ability to describe the variance in the world fleet accident statistics. The assessed candidates were the ship type, size, age, flag of registration and class society. The most effective discriminating variable was found to be the ships flag, closely followed by the ships age. The suitability of the ships flag for description of safety variability has been well known for decades [13]. Some flags see the benefits of having large fleets and therefore attract shipping companies with low taxes, cheap labour and a relaxed attitude towards ensuring compliance with regulations. These flag are called Flags of Convenience (FOC). The average incident rate within each flag ($\bar{\lambda}_{flag}$) was calculated. The next task is to describe the variation of incident rate within each flag of registration, ($f_{\bar{\lambda}flag}$). This task involves a more heuristic approach that might involve more uncertainty. Therefore, several candidate distributions were assessed. When the distribution of accident rates within each flag is estimated, it is possible to aggregate these distributions to a world fleet level. This last task used stochastic simulation to sample incident rates (ships) from each flag to form a distribution for the full world fleet. If the three flags N,G and S were considered then the process would be as described in fig. 2.

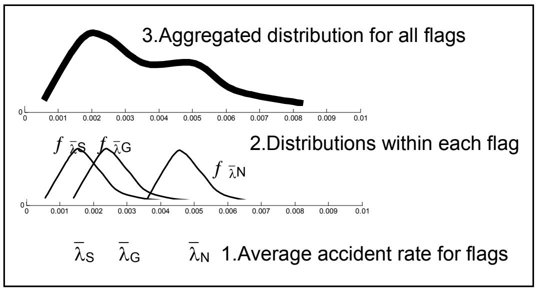

Fig. 2: Aggregation of world fleet distribution

There are several techniques to represent the probability density (pdf) distributions $f_{\bar{\lambda}flag}$ at level 2 in fig. 2. Bar-charts are commonly used for this representation but that involves subjective assessment of the number and width of the bars. An alternative approach is to estimate the parameters of a continuous distribution e.g. Gausian distribution or Poisson distribution. The selection of the distribution type does, however, also introduce uncertainties. A kernel density estimate [14] is a non-parametric alternative for representation of the pdf. Four relevant parametric distributions were assessed for representing the variation in accident rate within each flag. The three first are the Gamma-, Poisson- and Gausian distributions. The fourth distribution is a Gausian (Normal) distribution with a standard deviation that increases with its average value. It is known that flags having a higher accident rate have a larger variability in accident ratio from one year to another. It is also reasonable to assume that the variability in incident rate within a group of ships sailing under a specific FOC is higher compared to the flags having a lower frequency of accidents. It is also known that the minimum value of the incident rate is 0. The aggregated plots are showed in figs. 3 and 4.

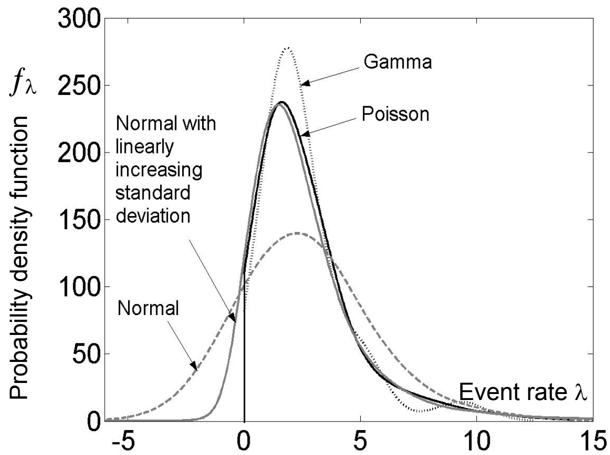

Fig. 3: Kernel estimated of the world fleet's event rate distribution for total losses f_λ

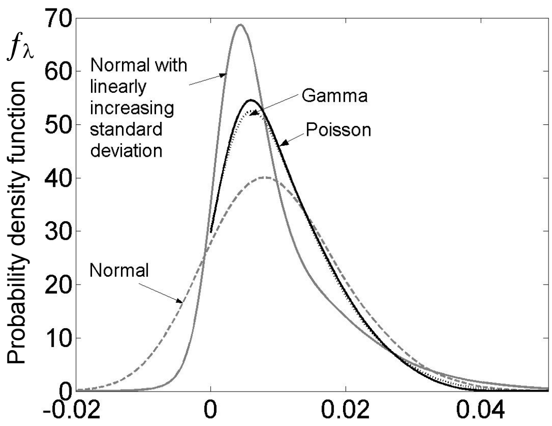

Fig. 4: Kernel estimate of the world fleet's event rate distribution for severe accidents, f_λ

4. SELECTION AND TESTING OF THE WORLD FLEET'S INCIDENT RATE DISTRIBUTION.

The plots shows that the various distributions within each flag, $f_{\bar{\lambda}flag}$, produce slightly different aggregated plots for the world fleet. When assuming that a gamma distribution describes the distribution of accident rate within the flags, there is a slight trace a two-peak distribution in fig. 3. When it is assumed that the Gausian distribution is appropriate several negative accident rates occurs. The Poisson distribution produce stable aggregations and is relatively similar to the aggregations from the Gamma distribution and the adjusted Gausian (Normal) distribution. Hence, it was decided that the Poisson aggregations should be used. In the following calculations only the average accident rates for the 25% safest ships (Class A), the 50% average ships (Class B) and the 25% most substandard ships (Class C) were applied. These average values are labelled $\bar{\lambda}_A$, $\bar{\lambda}_B$ and $\bar{\lambda}_C$. Even though the real distribution might differ slightly from the estimated, the plots demonstrate that the various aggregations have a relatively similar shape. Therefore these figures are relatively reliable.

Table 1: Estimated norm values of λ_k

	$\bar{\lambda}_A$	$\bar{\lambda}_B$	$\bar{\lambda}_C$
Total losses	7.39e-4	0.0022	0.0054
Severe accidents	0.0032	0.0081	0.0194

It is now possible to test the estimated values presented in table 1. For a world fleet population of 88,455 ships the experienced number of accidents was obtained. The total losses are relatively rare. Therefore a four-year period (1998 to 2001) was considered for this accident type while the values for 2001 was presented for serious accidents.

Table 2: Comparison between estimated and actual number of total losses

Class A	Class B	Class C	All classes
(7.39e-4·0.25+0.0022·0.5+0.0054·0.25)·88455=			
16 +	97 +	119	= 232
(7 % +	42 % +	51%	=100%)
Experienced number of losses:			= 244

Table 3: Comparison between estimated and actual number of serious accidents

Class A	Class B	Class C	All classes
(0.0032·0.25 + 0.0081·0.5+ 0.0192·0.25)·88455=			
71 +	357 +	425	= 853
(8 % +	42 % +	50%	=100%)
Experienced number of losses:			= 844

The calculations in both table 2 and table 3 seem to correspond to the actual values. Similar calculations on the average accident ratios resulted in 0.0026 and 0.0097 for respectively total losses and serious accidents. The experienced values were 0.0028 and 0.0096. The tables also demonstrate that the 25% most substandard ships of the world fleet are involved in approximately 51% of all losses while the 25% of the highest quality vessels are involved in only about 7%. The same values for severe accidents are 50% and 8 %. This indicates that the 25% safest ship in general is seven times safer than the 25% most sub-standard.

5. SCORING TECHNIQUE BASED ON ACCIDENT HISTORY

The data presented in table 1 represents the conditional probability of accident frequency given class of safety standard. In a practical classification situation it is necessary to know the conditional probability of class given an experienced accident rate. This transformation can be calculated through Baye's formula.

$$P(T_k \mid R) = \frac{P(R \mid T_k) \cdot P(T_k)}{P(R)} = \frac{P(R \mid T_k) \cdot P(T_k)}{\sum_{k=A,B,C} P(R \mid T_k) \cdot P(T_k)} \quad (1)$$

Where :

$P(T_k)$ = Probability of theoretical safety standard T_k

$P(R)$ = Probability of real safety perform. R

$P(R \mid T_k)$ = Probability of safety perfo. given T_k

$P(T_k \mid R)$ = Probability of T_k given safety perfor.

It is common to assume a Poisson distribution [15] for calculation of number of accidents given a safety For a given accident history of a ship or a fleet the likelihood of belonging to a certain safety standard can be estimated by incorporating equation (2) into (1).

$$P(R \mid T_k) = e^{-\lambda_k \cdot n \cdot \tau} \cdot \frac{(\lambda_k \cdot n \cdot \tau)^{\nu}}{\nu!}$$

(2)

Where:

τ	=	Time at risk per ship [Years]
n	=	Number of ships
ν	=	Number of accidents
λ_k	=	Accident rate in table 1 (k=A,B or C)
$P(R \mid T_k)$ =		Likelihood of performance R Given that the ships belong to class T_k

The discrete distribution $P(T_k)$ is relatively rough compared to the nuance in the Poisson distribution. Therefore the real accident performance may have a low probability even for the most correct theoretical class T_k. Because it is interesting to find the most correct class the following weighting is performed to obtain a sum of 100%.

$$P(T_k \mid R)' = \frac{P(T_k \mid R)}{\sum_{k=A,B,C} P(T_k \mid R)} \quad (3)$$

6. SCORING TECHNIQUE BASED ON SAFETY INSPECTIONS

The classification of safety standard based on accident history is relatively straightforward because both the theoretical safety standard and performance variable is described in terms of accidents. It is more controversial to relate safety inspection findings to the norms for accident rates T_k. The task is to develop the discrete distribution $P(R|T_k)$ where R is described in terms of inspection findings. There are several approaches to estimate this discrete distribution. Two approaches are applied in this study.

The most straightforward approach is to establish a representative sample of ships from the world fleet that is sorted according to the inspection performance. Then the pattern of performance that is typical for the 25% best, 50% average and 25% poorest records can be extracted. About 3600 ships were randomly selected from the world fleet. Of these 2250 had been subject to port state control inspections available at the Equasis database. These ships were sorted according to their average number of deficiencies per inspection. A detention was considered to be equivalent with 30 deficiencies.

The second and more challenging approach is to extract the $P(R|T_k)$ from the samples of accidents. First the inspection records for the accident vessels were collected. Then the sample was sorted according to their inspection performance. It has already been estimated that approximately 7% of this sample is of class A, 42% of class B, and 51% of class C. Hence the 7% best inspection performance should represent 25% bets performance of the world fleet. The next 42% represents the performance of the 50% average of the world fleet and son on. If the extracted performance in this approach roughly match the result of simpler approaches, this is indicates that the earlier calculations are correct. Because it is crucial to establish confidence to these calculations two independent accident samples are applied. First the earlier sample of total losses during the three-year period 1998 to 2000 was considered. This sample was of 732 ships and had been subject to a total of 242 inspections (m). 52 vessel having experienced severe accidents and being subject to 82 PSC inspections constitute a second sample.

An obstacle is that the group characteristics of the ships inspected by PSC may be slightly biased compared to the world fleet population, mainly because these vessels are built and managed for international trade. The group of ships available for PSC controls may therefore a subset of the population behind the accident statistics. By using a sampling- rejection procedure this bias may be corrected for. Randomly selected candidate ships from the samples are only included into a corrected sample if they reduce the bias. The considered variables were ship type, age, size and flag.

The two distributions of $P(R|T_k)$, which were aggregated from the accident samples, were very similar. Even though the samples can be considered to be independent, the aggregated distributions were dependent. With exception from the distribution of class B, the chi-square test proves dependency between the distributions ($P(R|T_A)=1.0$ for both, $\chi^2_B=0.44$, $\chi^2_B=1.0$). The strength of the dependency between the whole patterns is high (correlation of $\rho=0.95$). It is likely that the PSC pattern for total losses is more accurate than the pattern arising from severe accidents because it is based on a larger sample. Hence, a scaled average of the two patterns are calculated by giving 2/3 higher importance on the total loss pattern (table 4). The correlation between the resulting pattern from accident samples and the pattern extracted from the world fleet is 0.96. The chi-square tests demonstrates convincing results ($\chi^2_B=1.0$, $\chi^2_B=1.0$).

Table 4: Conditional probabilities of inspection findings given class of safety standard, $P(R|T_k)$.

	PSC	World fleet (3600 sh.)			Accidents (800 sh.)		
j	def.	A	B	C	A	B	C
1	0	0.85	0.52	0.30	1.0	0.40	0.16
2	1-2	0.15	0.22	0.17	0.00	0.25	0.14
3	3-5	0.00	0.18	0.21	0.00	0.26	0.26
4	6-15	0.00	0.08	0.26	0.00	0.09	0.33
5	16-30	0.00	0.00	0.05	0.00	0.00	0.07
6	>30	0.00	0.00	0.01	0.00	0.00	0.05
7	Detet.	0.00	0.00	0.15	0.00	0.00	0.26

Def. = Deficiencies, Detet. = Detention, sh. = ships

The correct probability distribution of deficiency findings, P(R) is known (table 5) from the whole world fleet. The distribution of $P(T_k)$ is also known ($P(T_A)= P(T_C)=0.25$, $P(T_B)=0.5$). Therefore, when the correct conditional distribution, $P(R|T_k)$ is known, equation (1) can be solved to estimate the discrete distribution of $P(T_k|R)$. The law of probability also represents certain restrictions. The sum of the probabilities of safety standard given inspection findings has to equal 1, and now all probabilities have values between zero and one. Therefore, the average of the two patterns in table 4 form a basis for searching (Newton search applying forward derivatives and tangent estimates) for a pattern that satisfy these restrictions. The resulting discrete distribution of $P(R|T_k)$ is presented in table 5. It is worth taking notice of, that the resulting pattern is more similar to the distributions extracted from the accident sample compared to the distribution extracted from the world fleet sample. Also the calculated distribution of $P(T_k|R)$ is presented in table 5.

Table 5: Resulting conditional probabilities

PSC def.	P(R)	P(R | T_k) A	B	C	P(T_k | R_i) A	B	C
0	0.48	0.94	0.42	0.13	0.49	0.44	0.07
1-2	0.16	0.06	0.22	0.14	0.10	0.68	0.22
3-5	0.17	0.00	0.22	0.24	0.00	0.65	0.35
6-15	0.16	0.00	0.15	0.33	0.00	0.47	0.53
16-30	0.03	0.00	0.00	0.12	0.00	0.00	1.0
>30	0.01	0.00	0.00	0.04	0.00	0.00	1.0
Detet.	0.09	0.00	0.00	0.37	0.00	0.00	1.0

Def. = Deficiencies, Detet. = Detention

The distribution of $P(R|T_k)$ indicates that a master that know his vessel is in class C still has 13% chance that the inspectors do not find any deficiencies at all. The conditional probability distribution of theoretical safety standard, given a certain safety performance, $P(T_k|R)$, is of practical importance. This distribution indicates that it in the inspectors view is a 7% chance that the vessel is of class C even he has not identified any deficiencies. If however the inspector identify a range of deficiencies it is highly unlikely that the ship is of class A. For a file of r inspections, the probable safety standard can be calculated according to equations (4). In order to directly compare the probability of the three classes, equation (3) is applied.

$$P(T_k \mid R) = \prod_{i..r} P(T_k \mid R_i) \qquad (4)$$

Where :
r = Number on inspections.
$P(T_k|Ri)$ = Probability of safety standard k given Inspection i (table 5)
$P(T_k|R)$ = Probability of safety standard k whole inspection file.

It is reasonable that the distribution $P(T_k|R)$ relies more on objective observations than absence of observations. Even a pedantic and motivated inspector may not find any deficiencies simply because they might be difficult identify. The nature of Port State Control inspections does however also involve another portion of uncertainty. For instance do detailed inspections by the Norwegian Maritime Authorities have a tendency to find considerably more deficiencies then in regular Port State Controls. The impact from this source of unreliability is not well known. It is however questionable to consider a 3-5 deficiencies as a certain indication of that the ship is not in class A as equation (4) indicates. Therefore the calculations may be relaxed so that several deficiencies contribute to a higher likelihood of a poorer class, but do not eliminate the chance of classifying it as good safety standard if as long as the inspection file is dominated by no-deficiency inspections. Such an analysis can be performed by considering the correlation (ρ) between the real set of inspection findings and the various patterns $P(R|T_k)$ for various classes of safety standard. The pattern of the safety standard that correlates highest with the experiences set of inspection findings is likely to be most correct. To make the correlation most efficient the pattern of experienced deficiencies per inspection should be considered relative to the general distributions of deficiencies (P(R)). Also these values are favourable to scale with equation 3.

$$P(T_k \mid R) = \rho\left(R/_{P(R)}, P(R \mid T_k) \right) \qquad (5)$$

Where :
R = Pattern of real inspections
$P(T_k|R)$ = Probability of safety standard k whole inspection file (table 5).
ρ = Pearson Correlation
P(R) = Probability of real safety performance R

7. TESTING AND VALIDATION OF SCORING TECHNIQUES

There exist a number of ways to test and validate the described scoring technique. The criterion validity of the scoring techniques is assessed for three criterions. The first criterion is to confirm that the scoring techniques actually distinguish the 25% safest and the 25% most hazardous ships from the 50% average. Secondly, inspection statistics from the three groups are considered to see if the groups are of an independent nature. Afterwards both scoring techniques are applied on the same companies to assess conformity between the two classifications. The fourth criterion is to classify ships, companies and associations that are assumed to belong to a certain class. For instance is the tanker vessel Erika who foundered and causes severe oil spills on the French coast in 1999, believed to be substandard. In contrast the vessels having a membership in interest associations claiming to have a low accident risk. Also two passenger ship companies having experienced disasters are classified. The fifth criterion is to confirm that the dynamics of the scoring techniques are consistent. The performances of the Belizean and Norwegian flags of registries are assessed.

7.1 Criterion 1: Agreement with class sizes

Both the classification based on accident and the safety inspections are supposed to distinguish the 25% best and the 25% most substandard from the 50% average. It is favourable to control that the real scoring techniques has this ability. The results in Table 2 indicate that the incident rates produce reasonable unbiased results. Therefore the remaining task is to test the scoring technique for safety inspections. The random sample of 2250 ships from the world fleet that has been inspected by port state control (Equasis) is used for assessment of bias. A chi-square-test is used to assess the performance. Table 6 illustrate that the results of equation (4) is biased. Too many ships were classified as substandard. This might be related to its discussed straightness. Equation 5 calculates unbiased classifications. Hence, this equation is used in the later calculations.

Table 6: Classification results [%]

Class:	A	B	C	Chi-test
Real distribution	25	50	25	
Equation (4)	29.8	22.8	47.5	0,803
Equation (5)	21.3	52.7	26.0	0,996

6.2 Criterion 2: Difference between classes

In a multiple discriminate analysis on 936 ship accidents Le Blanc and Rucks [16] concluded that the causes behind 51% of the navigational accidents were of a special characterise. The causal sequence behind these accidents was relatively simple and would therefore be easy to prevent. The content of the causes were related to poor onboard conditions. It might be that the content of the deficiencies also vary between the groups A, B and C assessed in this study. The most obvious difference is the magnitude of deficiencies per inspection. Class C vessels have in average 9 deficiencies per inspection while the corresponding values for B and A vessels are 2 and 0 respectively. These averages are significant. Even though the difference in number and seriousness of the deficiencies have been of the major concern in this study, it is also interesting to consider the types of deficiencies. The distribution of the deficiency types for the ships of safety standard B and C is presented in table 7. This table also presents the distributions for all the considered total losses and Paris MOU's yearly statistics for 2000. The statistics indicates that the deficiency types of class C vessels have stronger correlation with Paris MOU's statistics then the deficiency types obtained from class B vessels. For the statistics obtained during year 2000 the types distribution of class C correlated with a coefficient of ρ=0.96 while the class B vessels obtained a coefficient of ρ=0.81. A chi-test on the partial sums also demonstrates dependency between the PSC data and the C distribution (χ^2 =0.999) while this hypothesis has to be rejected for the distribution of class B types (χ^2 = 0.985) with a significance level of 1%.

This was expected because the class C vessels obtains most deficiencies and therefore dominates the overall statistics. The independency of the two classes B and C can be demonstrated by a chi-test on the partial sums (χ^2 = 0.980).

The most obvious differences between the content of deficiencies from ships of safety standard B and C, is that the class B vessels have reduced the relative percentage of some deficiency types down to zero. In more general terms the deficiencies related to core safety aspects (Accident prevention, ISM, Life saving appliances, Safety in general) are tuned

Table 7: Comparison of deficiency content [%]

	Accident prevention						Work environment				Cert-ificates		Operation and equipment									Comparison of content				
	Accident prevention (ILO)	ISM (safety management)	Fire fighting appliances	Alarm signals	Life saving appliances	Safety in general	Crew and accommodation	Food and catering	Mooring arrangements	Working space	Training certification for seafarers	Ship's certificates and documents	SOLAS operation	Marine pollution / MARPOL	Safety of navigation	Radio communication	Carriage of cargo	Propulsion and aux. machinery	Load lines	Tankers	**Accident prevention**	**Work environment**	**Certificates**	**Operation and equipment**	Overall sum
P. MOU	2	1	13	1	16	14	3	2	1	1	2	5	2	9	12	4	1	5	6	0	46	7	7	39	100
Class C	4	1	13	1	14	20	3	1	1	1	2	5	1	6	10	3	1	6	7	1	53	6	7	35	100
Class B	0	0	13	0	9	17	10	4	3	6	3	6	1	7	13	1	1	4	4	0	39	23	9	31	100

down relative to the deficiencies related to work environment (e.g. crew and accommodation and food and catering) for the vessels of class B safety standard.

7.2 Criterion 2: Agreement between scoring techniques

The accidents and PSC findings for 17 shipping companies in the period 1998 to 2001 are considered to assess agreements between the classifications based on accidents and safety inspections. Both scores from the accident statistics technique and the safety inspection techniques are assumed to be aspects of the company and not the ship. In reality it is known that there exist differences within the fleet of a company. In fact it can be demonstrated that the techniques can be used to identify sub-groups of ships within a company that has a significant higher accident risk. Anyhow, as the safety standard is a result of management decisions [1;3;8], it is expected to be a rough agreement between the classifications from the two scoring techniques. A chart indicating the classification results is plotted in fig. 5. The 17 companies are sorted according to their likelihood of being of an A class based on the inspection findings. The correlation between the different likelihood of being respectively an A Class, B class and C class are respectively 0.64, 0.66 and 0.89. The average chi-square value is 0.85 and only three of these values are less than 0.80. A single value measure may be the P(A)-P(C). This value has a correlation of 0.81 between the two classification results.

7.3 Criterion 3: Agreement with domain insight

Insight into the maritime domain gives some indications on which ships are safe and who are not. It is generally accepted that the disaster tankers Erika and Prestige were substandard. It is also widely accepted that the companies behind the disaster passenger vessels Express Samina (86 fatalities) and Sleipner (16 fatalities) were of a poor standard. In contrast it is believed that the vessels being members of certain industrial associations introducing safety systems and requirements are above average standard.

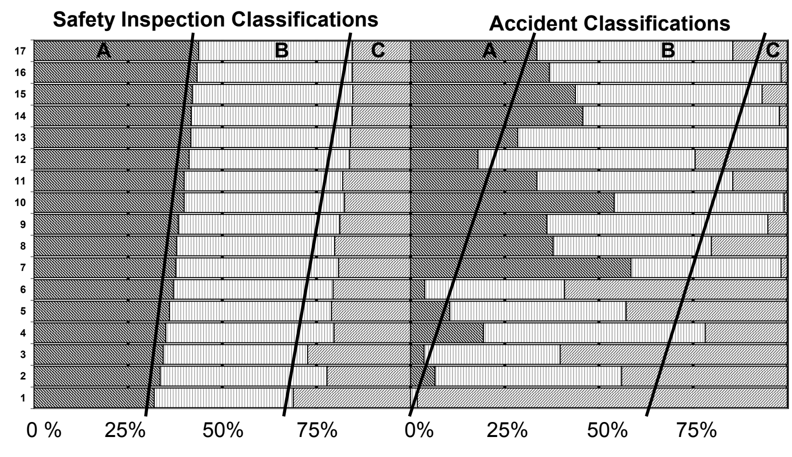

Fig. 5: Agreements between classifications

The considered associations are Green Award, Intertanko and ISMA (International Safety Management Association).

At the time of the Erika and Prestige accidents their inspection files were collected from the Internet interface of ParisMOU. These recordings showed the Erika had been subject for three inspections, where respectively zero, four and 13 deficiencies. Without the scoring techniques developed in this study, it would be difficult to relate these findings to safety standard. The corresponding figures for Prestige was one inspection where 3 deficiencies were identified. By using this scoring technique on Erika and Prestige it can be shown that these vessels were definitely not of class A. Erika was most likely substandard (class C) and the single inspection on prestige indicates that it most likely was of class B. More inspections would more precisely classify their standard. It has for instance been recognised that older inspections have detained Erika on several occasions.

The accident statistics for the companies behind Sleipner and Express Samina were assessed. The fleet size of the respective fleets was 32 and 86 ships. During the years 1998 to 2001 these fleets had experienced respectively 9 and 10 serious accidents. The resulting classifications indicate that both companies are of a class C. The company behind Samina had some ships that had been subject to PSC. The classification based on these inspections is relatively vague, favouring a class B standard.

The inspection records of the whole Green Award fleet of 502 ships representing 685 inspections were considered. The sample of Intertanko and ISMA ships were collected from a random sample of the world fleet holding 76 Intertanko ships and eight ISMA ships representing samples of respectively 408 and 61 inspections. If the objectives of the organisation are effective this should results in a larger likelihood of belonging to class A compared to class C. This is conformed by the scoring technique. The classification illustrate that the ships from these associations are safer than the average (Table 8)

Table 8: Estimates of probable safety standard[1]

	P(class A)	P(class B)	P(class C)
Erika Insp.	26 %	36 %	38 %
Prestige Insp.	26 %	38 %	36 %
Sleipner's co. Acci.	0.0 %	0.3 %	99.7 %
Samina's co Acci.	0 %	2 %	98 %
Samina's co. Insp.	32 %	37 %	31 %
Green Awards Insp.	41 %	42 %	16 %
Intertanko Insp.	39 %	42 %	19 %
ISMA Insp.	41 %	42 %	17 %

7.4 Criterion 4: Sensibility to changes

It is earlier assumed that it is monotone increasing relationship between safety inspection deficiencies and increased accident risk. If the assumption holds changes in the PSC findings for a specific fleet should have been reflected in the experienced accident rate. The two classifications measures are calculated for the fleets of the Belizean and Norwegian

[1]Classifications based on inspection findings (Insp.) and accident statistics (Acci).

flags for the period 1998 to 1999 and 2000 to 2001. It was found that the Norwegian loss ratio was stable and that the loss ratio for the Belizean fleet had been changed. Table 9 shows an analogue tendency in the PSC inspection finding material. The fact that the constant level of the Norwegian fleet and the changes in the Belizean fleet can be found in both accident statistics and PSC findings give credit to the assumed relationship between PSC performance and safety performance.

Table 9: Relationship between loss ratio and PSC findings for the periods 1998-1999 and 2000-2001

	Norway	Belize
Loss ratio	Unchanged (95% confidence level)	Changed (95% confidence level)
PSC pattern	Unchanged (95% confidence level)	Changed (95% confidence level)

8. Discussion and Conclusions

This study has developed a new framework for reasoning about a ships' safety standard by means of safety inspection findings and accidents. The basis for the techniques is an estimated density distributions, which describe the accident rate for the world fleet. Based on these distributions, simple calculations showed that the 25% of the ships having highest safety standard are involved in only approximately 7% of the total losses and severe accidents. In contrast, the 25% most substandard vessels cause approximately 51% of these accidents. The most significant result is the classification of safety standard based on PSC findings, where the information needed for the classification is available on existing updated web pages (Lloyd's Register and ParisMOU or Equasis). This scoring technique has along with the scoring technique based on accidents, demonstrated to be valid and is suitable to proactively pinpoint substandard ships like Erika.

An analysis of the types of PSC deficiencies demonstrates that the most substandard vessels have far more deficiencies per inspection then the two other classes. The 25 % most sub-standard vessels have in average 9 deficiencies per inspection and are detained in 26 % of the cases. The 50% average standard ships have in average 2 deficiencies per inspection and are relatively better on areas involving general safety like accident prevention, ISM and emergency preparedness.

A critical aspect is for how long these scoring techniques are valid. The annual decrease in accident rates of approximately 2.4% should cause reductions in poor PSC files. Improvements of individual flags like Belize should according to Alderton [13] not be given significant attention in this context because there is a continuous dynamic introduction of new flags of convenience covering substandard shipping. Because there very few vessels lost in 1998 having a PSC file, the classification scoring technique presented in this study is most fit to the ships lost in year 2000. Consequently, the bias introduced by using the scoring technique due to limitation of durability should have no practical implication until at least 2004.

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SAFETY ASSESSMENT OF SHIP OPERATORS – A NEURAL NETWORK APPROACH

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ABSTRACT

Techniques from Artificial Intelligence and Knowledge Based Systems are well suited for analysis and diagnosis of complex relationships. Especially powerful are the Neural Networks (NN) that have the ability to identify any underlying functional relationships. This paper is based on a study of how management and organisational factors influence the safety performance in ship operation and illustrates how NN can be used in the search for deeper knowledge about organisational and other factors relevant for the safety. Such knowledge is expressed in terms by the importance of the factors' descriptive ability on the safety level. These calculations also include the joint effects of heterogeneous sources of information e.g. ship design, yard experience, organizational factors and the quality of the classification societies. Different information sources are assessed: Accident reports, Port State Control findings and consumer organisation reports.

KEYWORDS

Safety Assessment, Safety Management, Neural Network, Shipping Company Organisation

1. INTRODUCTION

The control of safety at sea has traditionally focused on the technical standard of the vessel and the formal competence of the crew, and has mainly been enforced through Flag State Control and Ship Classification. The basis for this regime is IMO regulations, but also some coordination of classification requirements through IACS. Various industry standards, like INTERTANKO's guidelines for operation of tankers, have also contributed to improved safety. The safety regime is now subject to important changes. The limited success of Flag State Control lead to the agreement of setting up Port State Control (Paris MOU), use of blacklisting and increasing use of unilateral legislation (OPA '90, EU Directives). Another important step is the introduction of the ISM Code. It should also be pointed out that insurance, shippers and port authorities undertake their own inspections and audits. These initiatives have lead to an increased focus on the standard of the ship manager and not only the vessel and the crew. The term 'substandard owner' is frequently used but one may question what this really means. It is on the other side some agreement on what is required to operate safely: Culture, top management attention, adequate resources, organisation, routines and competence. Very little systematic knowledge is available on the relationship between management style and safety performance in commercial shipping. One source of information is accident and incident databases that contain information about causal mechanisms. The CASMET database approach [1] focused on operator behaviour through event modelling and management behaviour from basic causal factors. Management related factors are to some degree incorporated in risk analysis models [2], but the knowledge basis is still rather limited and the findings therefore also highly questionable. Therefore we are far from knowing the relative importance of these factors, or how top level decisions influence middle management and ultimately the safety behaviour onboard.

2. INFORMATION REVIEW

The maritime sector has suffered from a poor safety reporting culture. Hence it has been difficult to undertake credible safety assessments. The situation has however improved somewhat through the recent introduction of quality assurance, safety management, Port State Control (PSC) and independent consumer assessments. Some of the key sources of information are listed in Table 1.

Table 1. Sources of information and possible content

	Latent Conditions			Experienced Conditions		
	Organisational Deficiencies	Technical Deficiencies	Non-conformities	Near Misses	Accidents	Losses
Accident Data	(X)	X	X		X	X
Maritime Declarations		X	X			
Insurance Data		X				X
Near Miss Reporting		X	X	X		
Safety Auditing	(X)	X	X	X		
Class Survey Report		X				
Safety Inspections		X	X			
Consumer Assessment		X	X			
Attitude Measures	X					
Behaviour Observation	X	X	X			

There are four especially promising sources of information, namely Near Miss Reports, Safety Audit findings, Port State Control reports and Consumer Assessments. Near misses are still underreported in most companies and are therefore not a reliable safety indicator. Safety audits are mainly undertaken in relation to ISM certification and generally not available for research purposes. The PSC is getting increased acceptance and is a key source for assessment of organisational safety [3].

Three of the most serious accidents recently in European waters, namely the tanker *Erika*, high speed vehicle *Sleipner* and the ferry *Express Samina* may be used to illustrate both strong and weak aspects of present safety inspection approaches. A PSC inspection in 1998 revealed 13 deficiencies on *Erika*, and thereby placing her among the substandard vessels. Another illustrative example is the consumer assessment of *Express Samina* that resulted in a warning to "Greek island hoppers" [4] about her poor condition. A more questionable PSC inspection of Erika was undertaken by the Italian maritime administration that found her to be in acceptable condition only seven months before her foundering. The Flag State inspection and safety audit of *Sleipner* also failed to find any serious deficiencies less than half a year before her fatal voyage. These examples reveal both the potential and the weaknesses of these inspections. They may target substandard ships and operators, but there is a need for better tools to enhance their use and improve the reliability of their results. This can be achieved by getting a better understanding of latent organisational deficiencies and non-conformities revealed through audits.

3. ORGANISATIONAL MODEL

The supporting organisation behind a ship may typically involve several managing companies. Secondly, the organisation may be seen as a hierarchy with at least three distinct decision levels [5]: Strategic (SL), tactical (TL) and operational (OL). Strategic decisions focus commercial objectives, allocation of resources and organisation. Tactical decisions are taken within the company's functional areas e.g. safety management. Finally, operational decisions are related to daily operation of the vessel. Each level may further be modelled in terms of basic conditions (BC), qualifications (Q) and outcomes (O) [6] as outlined in Figure 2 of the operational level.

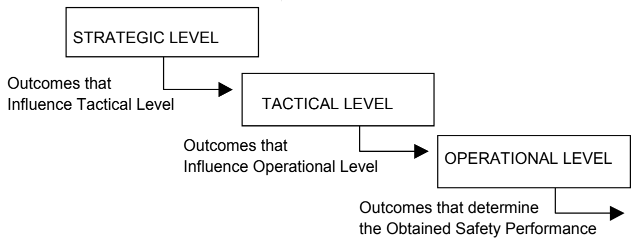


Figure 1. Organisational levels

The dimensions are selected to reflect the needs related to causal and diagnostic reasoning in safety management. The model assumes that the actions of one organisational level determine or at least strongly influence the context of the lower level. The model is assumed to explain all relevant cause-effect relations. This makes the model suitable for both causal and diagnostic reasoning.

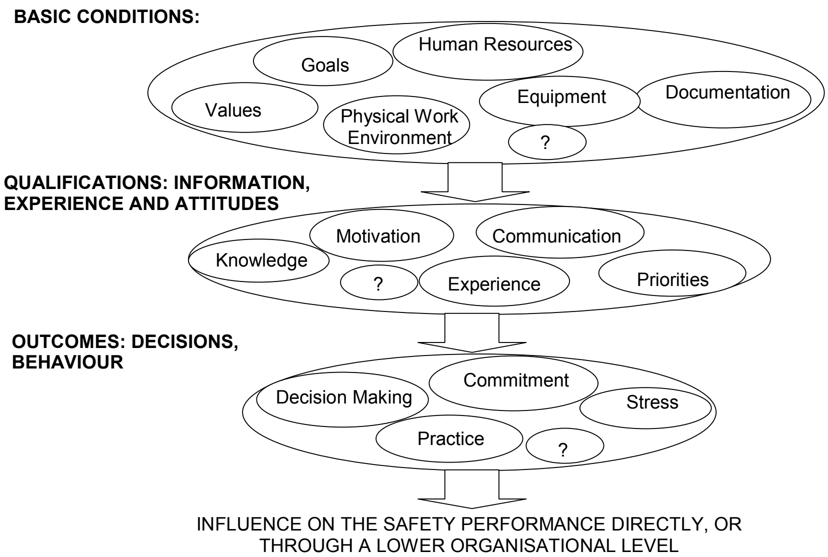
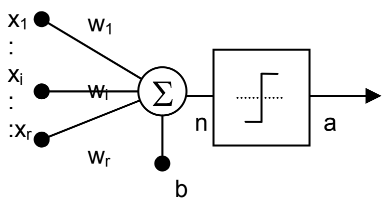


Figure 2. Processes on the operational level

4. Neural network technique

A NN consists of interconnected nodes constructed with some analogy to the principles in nervous systems. Neurons contacts and collects signals from other neurons, integrate signals and generate responses that are transmitted to other neurons. Biological neurons may be connected with several tens of thousand other neurons. In artificial NN more than 100 neighbour neurons are considered as relatively complex. In general the application of NN involves training of the network to obtain a desired output for a given input. In order to understand the application of NN the basic neural mechanism has to be discussed in some detail.



x_i = Input value i

w_i = Weight to scale the input value

b = Bias

a = Output of the neuron

n = Weighted sum of inputs corrected for bias b

$$n = b + \sum_{i=1..R} x_i \cdot w_i$$

= A Threshold Function (Transfer Function)

Figure 3. Single neuron design

A single neuron is presented in the Figure 3. The transfer calculates the output (a) from the weighted sum of inputs from other neurons (x_i). The individual neurons are connected to each other in several layers. The *Backpropagation* network is the most common network structure. This kind of network is a layered feed forward network (i.e.

has no cycles like e.g. recurrent networks). It is trained by adjusting the weights and biases as a function of the difference between the calculated output and a predefined target value (d). Figure 4 shows a simplified description of a Backpropagation network [8].

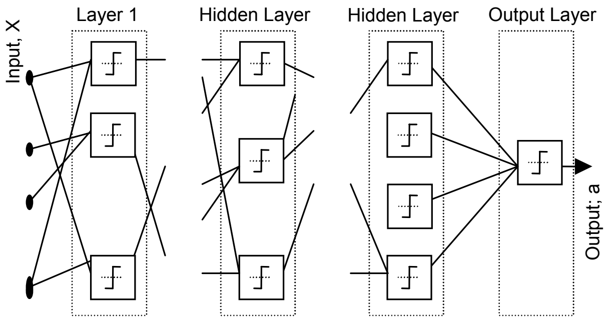


Figure 4. Backpropagation neural network

The ability to learn is one of the most important characteristics of NN. There are several approaches to learn the network to produce the desired output. The learning of the NN is performed in principle by adjusting the weights (and biases) of the neurons in the view of new data. There are typically two different approaches to update weights. These are global- and local learning. The global learning updates the weights in the view of the output (a) of the network. The weights are adjusted to minimize the difference (ε) between the target value, which is desired output (d), and the obtained output (a). The alternative local approach updates the weights only by considering the input to each individual neuron. Back-propagation applies the global learning and some key characteristics that will be outlined. The most common learning technique is referred to as the *Gradient Descent* method, which updates the weights by considering the partial derivatives of the NN's error (ε). In the following calculations the bias is not included (b=0).

$$\frac{\partial \varepsilon}{\partial W} = \left[\frac{\partial \varepsilon}{\partial w_1}, \ldots, \frac{\partial \varepsilon}{\partial w_i}, \ldots, \frac{\partial \varepsilon}{\partial w_R}\right] = \frac{\partial \varepsilon}{\partial s} \cdot \frac{\partial s}{\partial W} = \frac{\partial \varepsilon}{\partial s} \cdot X = -2 \cdot (d-a) \cdot \frac{\partial a}{\partial s} \cdot X$$

X = Matrix of inputs
W =Matrix of weights
s = X · W

The derivation of the obtained output with respect to the dot product is the last unknown variable in the equation. In summary the weights are changed to describe the relationship between the input variables and the target value and approximated by:

$$W_{new} = W_{old} + \eta \cdot (d-a) \cdot \frac{\partial a}{\partial s} \cdot X$$

η = Learning rate (0..2)
d = Desired output
a = Obtained output

In order to calculate the parameter δa/δs as a function of the dot product (s) a transfer function a(s) has to be selected (where n = s when b=0). When the transfer functions are selected the degree of freedom (DOF) of the NN (the sum of the total number of weights in the network and the number of biases) has to be considered in the NN design. If the DOF equals the number of training sets (M) it is possible to find an optimal set of weight values. For complex problems it is, however, difficult to establish that many training sets. In such cases the NN is said to overfit the weights to the input, i.e. the weights are optimised to the training sets presented to it, but may have a moderate or high error when presented to new data sets. If the DOF is smaller then the number of training sets (most favourable in the area when M ≈ 10·DOF) the network is underfitted. An underfitted network has the ability to generalise. In this situation the network is able to calculate reasonable outputs based on input never presented to it before. The DOF governs the practical application of NN to complex problems with little available data unless some initiatives are taken to reduce it.

$$RMS = \sqrt{MSE} = \sqrt{\frac{1}{M} \cdot SSE} = \sqrt{\frac{1}{M} \cdot \sum_{m=1}^{M} \varepsilon_m^2} = \sqrt{\frac{1}{M} \sum_{m=1}^{M} (d_m - a_m)^2}$$

ε = Error
d = Desired output
a = Obtained output
M = Size of training sets

The error of the network is typically measured as the Sum of Squared Error (SSE) between the desired output, d, and the obtained output a (alternatively Mean Squared Error (MSE) or the Root Mean Squared (RMS)).

5. DATA ASSESSMENT

In this study four dependent target variables were assessed for a group of Ro-Ro passenger ships (M=100 cases) that had been subject to a kind of consumer assessment by the German automobile association - ADAC (Allgemeiner Deutscher Automobil Club) [9]. ADAC's safety assessments are performed with a five-point scale in six areas (safety information, construction and stability, fire protection, emergency equipment, public address and telecommunication, and safety management). The score based on these areas was on a scale from one to five with five as best. The second and third target variables were the average number of PSC deficiencies [3] and the number of immaculate PSC inspections (no deficiencies found) respectively. The PSC inspections are performed by the administration of the individual Paris MOU member states [3] while guidelines shall ensure a uniform approach by the different states. These inspections have a broader scope the ADAC inspections and have also a more detailed character. The last target variable is the number of accident reports for each vessel [10].

This variable is measured on a three-point scale (zero accidents - one accident - more than one accident). The correlation between these measures are presented in Table 2.

Table 2. Correlation between safety perform. measures for Ro-Ro passenger vessels in European waters

	# ACCIDENTS (M = 100)	# DEF PSC (M = 51)	# IMMAC PSC (M = 51)
ADAC Score	ρ = 0.15	ρ = 0.10	ρ = 0.15
# ACCIDENTS		ρ = 0.36	ρ = -0.08
# DEF PSC			ρ = -0.63

The low correlation between the ADAC score and the number of accidents can be explained by a few outliers. Hence it can be proved by hypothesis testing (significance level $\alpha = 0.1$) that the average number of accidents is larger for the vessels assessed to be sub-standard by ADAC in contrast to the vessels with a satisfactory standard. The average number of Immaculate PSC inspections is higher for the group of vessels assessed to have satisfactory ADAC score but the difference is however not statistically significant. When considering the group of vessels that has had one or more accidents it can be proved that they had a higher average number of deficiencies per PSC inspection than the group with no accidents (α=0.15). The same groups had no significant difference in the average number immaculate PSC inspections. By considering the occurrence of accidents as a 'real' safety performance indicator, the number of deficiencies per PSC inspection is found to be the best proactive safety performance indicator of those considered in this study.

The input variables (x) were selected to reflect the range of potential organisational factors. Because the NN can implement and assess the importance of any quantified input, the insight and creativity of the researcher and the availability of data were the real limitations in the design of the NN model. The variables applied in this preliminary study are presented in Figure 5. The data was collected from Lloyds Register [10], IMO [11] and ILO [12]. The target values were collected for the period 1998 to 2001 and the input variables were collected in the spring of 2001.

6. Network construction and analysis

In this study the number of input vectors (M=100) is relatively small in a NN context. Hence the NN has to be designed as efficient as possible to allocate its calculative power where it is most needed. By implementing a priori knowledge (Figure 1 and 2) into the network the DOF can be reduced and thereby allowing the network to use a smaller data set [13]. The simplest NN design that makes use of this knowledge is illustrated in Figure 5. Based on experience from several NN training sessions on the same data, the variables of minor importance could be removed from the data set giving further reduction the DOF. The analysis included three different approaches:

1. Analysis of each organisational level (strategic, tactical and operational level) separately to assess whether the input of the level could describe the target values.
2. Analysis of the all organisational factors (Figure 5) to assess which variables that were important for the target value.
3. Simultaneous analysis of the three organisational levels allowing competition among all factors meaning that the links between the organisational levels in Figure 5 were removed.

The NNs were trained on the different target values with various numbers of neurons in layer 1 to 6. The most suitable learning rate, η, was in the area 0.05- 0.15.

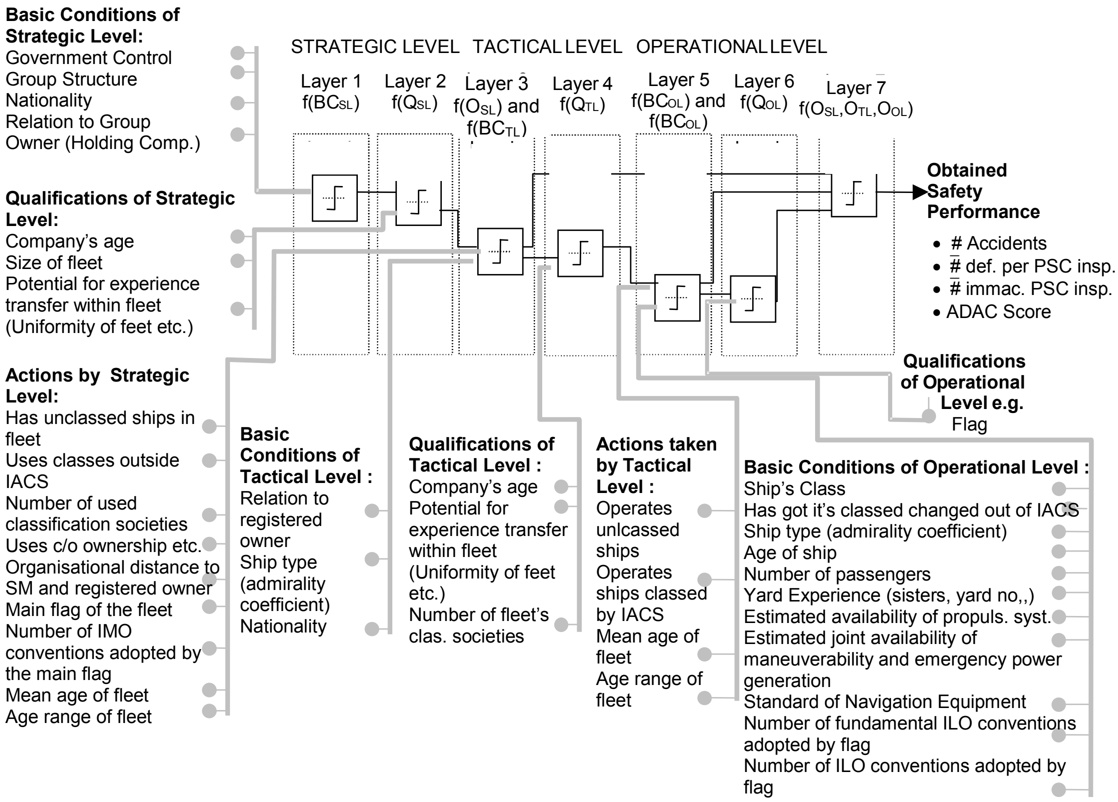


Figure 5. Neural network of organizational influence on safety performance

7. Discussion of results and further work

A trained NN could in 90 –100% of the instances estimate the vessel's true performance based on the input variables (MSE = 0.04..0.7). In general the *Outcome* variables gave better characterisation of the safety standard of the ship than the *Basic Conditions* and *Qualifications*. Another interesting finding was the fact that the *Strategic Level* gave almost equally good description of the safety standard as the *Operative Level* despite being a set of inputs of a more general and top-level nature. The relative importance of each input variable (x) with respect to describing the safety performance (d) were calculated for each performance variable (ADAC score, number of accidents, number of deficiencies per PSC inspection and number of immaculate PSC inspections). It was found that the same factors were the most effective ones for describing all four performance variables. They gave a correlation in the order of : $\rho = 0.61 - 0.75$. The most and least effective variables are presented in Table 3.

Table 3. Most and least important description variables (x)

MOST IMPORTANT VARIABLES	LEAST IMPORTANT VARIABLES
Number of ILO conventions adopted by vessel flag (BC_{OL})	Government Control (or owned by) (BC_{SL})
Estimated availability of propulsion system (BC_{OL})	Vessel has got its class changed out of IACS (BC_{OL})
Main flag of the Strategic Level's fleet (A_{SL})	Has non-classed ships in Strategic Level's fleet (A_{SL})
Uses c/o ownership (and/or adapted the companies country of register) (A_{SL})	Size of Strategic Level's fleet (Q_{SL})
Strategic Level uses class. societies outside IACS (A_{SL})	Tactical Level operates ships not classed by IACS (A_{SM})
Mean age of Strategic Level's fleet (A_{SL})	Size of Strategic Level's fleet (Q_{SL})
The vessel's ship type (Admirality Coefficient) (BC_{OL})	
The vessel's flag (Q_{OL})	

As in any quantitative analysis the selection and interpretation of the variables, scales and obtained values should be carefully validated. The Admirality Coefficient is for instance likely to reflect the company's market orientation in terms of speed and ship type (Ro-Ro ferry, cruise ship, etc.). The estimated availability of the propulsion system may reflect the complexity of the vessel and even its age or size. Another fundamental implication of using a NN to describe these complex relationships is that it is difficult to decide whether an isolated variable has a general positive or negative effect on the safety level. By considering the influence of marginal changes in the *Uses of co-ownership* variable the effect may either be positive or negative depending of the condition of other variables like organisational structure and nationality at the Strategic Level. This fact may reduce the possibility to define robust research conclusions. On the other hand it may be argued that the NN approach has shed some light on how the complex interactions in a real organisation work. Another important implication is related to the objective to find the most efficient way to give an overall assessment of the ships safety standard. Hence the apparent low importance of the variable *Vessel has got its class changed out of IACS* may be explained by the low number of vessels having this characteristic (only 3) and the fact that several ships are substandard even without this characteristic.

Because the number of input variables is relatively small in the obtained NN it is over-fitted and not able to be used on vessels not included in the input. In order to improve the general validity of the model, a common approach called early stopping was used in a cross-validation procedure (MSE_{goal} limit of 0.4). Hence 100 different NN were generated on the basis of 100 minus 1 (99) sets and the NN was validated against the data set left out. As 100 different data sets could be left out this procedure gave 100 NN alternatives. This cross-validation showed that the NN could calculate the correct ADAC score (on a five point scale) in 43 % of the cases and the correct accident level (on a three point scale) in 61 % of the cases. These preliminary results may be improved even more by experimenting with different values of the MSE_{goal} limit. This study will at a later stage use a larger input set (M = 2 - 5000) selected to reflect a broader range of ship types and organisations. It is also the ambition to supplement the study with other knowledge sources such as questionnaire responses on detailed organisational matters and tests on safety culture to mention a few.

8. CONCLUSION

By entering knowledge about organisational solutions into a Neural Network (NN) this study has showed how the network can generate models of sufficient simplicity for practical applications in safety assessments. The study also provide some interesting results related to the relative importance of both the organisational levels and the individual input variables. Information about the *Strategic Level* of the organisation may be as significant as for the *Operational Level* in describing the safety standard of a ship, despite the apparent organisational distance and its general character.

The NN was trained on four different target values. These were consumer assessment score, accident rate, number of immaculate Port State Control (PSC) inspections and average number of deficiencies found by PSC Inspections. This pre-study found the latter of these parameters to be the most efficient proactive safety performance indicator. By comparing the importance of the various organisational variables it was found that the same set gave the best result for all target values and correlation in the order of ρ=0.61- 0.75. This study has also showed that the Neural Networks (N) have the potential to give reasonable good proactive safety assessments of Ro-Ro passenger ships based on organisational variables. The validity of the assessment can be controlled by the error of the network (MSE), cross-validation and content validity of the input vectors.

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EXPLORING SAFETY CULTURE THROUGH DATA INTERROGATION

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ABSTRACT

Safety culture has been considered as a core aspect of organizational safety for the last two decades. Even though considerable research has been conducted, the relationship between organizational culture and safety performance has not yet been determined. Consequently, traditional analysis approaches fail to capture the essence of complex cultural patters. Joseph Fragola [1] has suggested that analysis of complex pattern should be analysed through data interrogation, implying that the data are considered with relative to established knowledge. This study first ranks a set of shipping companies according to their safety standard. The ranking is based both on accident statistics and safety inspection findings. Secondly, the responses on the Safety Management Attitude Questionnaire (SMAQ) are interrogated with various perspectives (Leadership Style [2], Continuous Improvement [3], Competing Values Framework [4] and Normal Accident theory [5]) to find the cause behind the variance in safety standard. At last the patterns are explored through a principal component analysis. The study demonstrates that the companies having a good safety performance have critical employees that take more responsibility. They have an internal focus on the organisational processes and dynamic organisational process. It is also demonstrated that representation of safety culture based on scores on Principal components is invalid. At last attitudes towards safety commitment is a result of attitudes towards Job Satisfactions, Safety Rehearse and Communication. At last it is shown that attitudes towards the management's genuine interests in safety have a central position in the extracted cultural patterns.

1. INTRODUCTION

Even though the concept of "safety culture" has been explored for nearly 20 years it is still ongoing academic debate concerning its definition, measurability and utility [6]. A range of conflicting definitions of safety culture has been formed [7]. Hale [8] describes it as "*Culture's confusion*". The critical problems are however related to the measurement of safety culture. A state-of-the-art work written by Sorensen [9] says: "*no performance indicators to gauge safety culture and its impact on safety of operation appear to have been* *identified and validated*". Intuitively, if safety culture is as important as it is assumed to be, it should be relatively explicit and easy to identify.

When attempting to measure the maturity of the safety culture, it is important to understand the impact of the environment [6]. Because culture is a shared pattern of attitudes, beliefs and values that are formed from feedback and experience, several professionals have started to consider it as impossible to directly compare the safety culture of one organisation with another [8]. The difficulties of identifying cultural patterns may be related to the applied experimental context. Two organisations may theoretically develop different safety cultures that both are effective in controlling the risks of their respective environment. Therefore, in an ideal experiment, several organisations should be allowed to work in the same environment. They should be exposed to the same hazards, operate in the same business setting, apply the same equipment, being exposed to the same requirements and have equivalent formal competence. In addition the experiment should run a considerable time until the cultural patterns within each organisation had the opportunity to converge. Then, if the organisations experienced significantly different safety performances it should be possible to more precisely distinguish the patterns of mature safety cultures from the less mature.

The world of shipping is one of the few domains that have these characteristics. The 25% most hazardous ships have a seven times higher accident rate compared to the 25% safest ships [10]. All ships comply with international regulation and manage the same hazards with the same technology. There are few differences related to professional culture and different impacts from national cultures can be taken account for. Hence, the maritime domain might have the potential to empirically break the code for measurement of safety cultural maturity. This study takes the assumption, that the environmental context of various shipping organisations is similar. If this assumption holds, the cultural patterns should be able to explain the difference in safety performance.

2. OBJECTIVES AND APPROACH

The objective of this study is to explain the differences in safety standard of shipping companies based on their shared pattern of values, attitudes and beliefs i.e. safety culture. Because earlier research has experienced difficulties in meeting similar objectives, this study applies another analytical approach outlined by Fragola [1] under the title *"Emerging Failure Phenomena in Complex Systems"*. He states that "*In these cases, .. , the underlying system is neither orderly enough to be considered regular, nor disorderly enough to be considered random, and can therefore be defines as being "complex" because it will succumb to neither deterministic* *analysis nor probabilistic analysis*". In these cases he suggest that data interrogation is more suitable.

3. Data Interrogation

"Data "interrogation" is the process of data collection and investigation from a variety of perspectives, alternatively dissecting it into its underlying (yet often unknown) patterns" [1]. A data interrogation typically involves one of the four listed approaches (I, II, III, IV).

Table 1: The data interrogation approaches

I	Consider parts of the datasets according to known underlying variables
II	Consider parts of the datasets relative to an overlaying data gathered from different perspectives.
III	Consider data relative to previously established logical or phenomenological structures.
IV	Allow a computerised heuristic search to reveal possible patterns.

In this study, first a set of shipping companies are selected and then assessed according to their safety standard (approach II). Then questionnaire responses from shipping companies are considered relative to previously established perspectives towards organisational and safety management (approach III). These perspectives are towards the Leadership Styles [2], Continuous Improvement [3], Competing Values [4] and Normal Accident theory [5]. At last the earlier described approach II is combined with approach IV. In this heuristic search both Principal Component analysis and Learning Bayesian Networks are applied.

The interrogated data material is responses on the Ship Management Attitudes Questionnaire (SMAQ). The SMAQ was developed as a joint project by Risø, the Danish Maritime Institute (now Force Technology), and the University of Texas (NASA/FAA) Aerospace Crew Research Project from the Flight Management Attitudes Questionnaire (FMAQ). The FMAQ is widely used in aviation to diagnose organisations in the areas of organisational culture, safety, and human factors practices. It contains items that relate to employees' opinions and attitudes about management, morale, safety issues, automation and teamwork, as well as general work values. Findings from the survey are presented in confidential reports to individual companies, but published works, like this one, will describe results in anonymous form, de-identifying the participating companies. The SMAQ questionnaire was distributed to seafaring personnel in five shipping companies during 1997 (four Scandinavian companies and one Asian company). The database has later been expanded with data from an American company, two more Asian companies and two Norwegian companies. This study includes eight companies.

4. Safety Standard: The overlying data.

Approach II implies that the data are interrogated with respect to an overlying data variable. When interrogating safety attitudes it is natural to use the safety standard of the organisation as an overlying data variable. Based on a newly developed classification technique eight companies are assessed based on their accident statistics and safety inspection findings [5]. Both approaches provides the likelihood of a ships' safety standard to be among the 25% most quality ships (A), the 50% average standard (B) or the 25% most substandard vessels (C) of the world fleet. These values are presented in fig. 1 for all companies. They are ranked according to the average of the two techniques and the company having the highest safety standard is Z1 while Z8 is the most substandard.

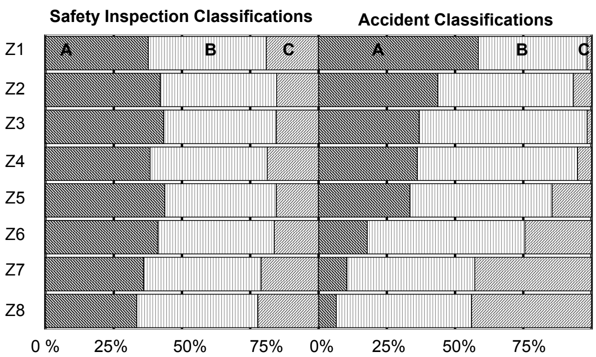

Fig. 1. Classification of safety standard based on safety inspections and accident statistics

The classification based on accidents in Fig. 1 applies the number of serious accidents per ship year the last four years. Serious accidents are breakdowns resulting in the ship being towed or requiring assistance from ashore, flooding, structural-, mechanical- or electrical damage that requires repairs before the ship can continue trading. These accidents are collected from a database held by the Lloyd's Maritime Information Service (LMIS) [11].

The main source for safety inspection data is the ParisMOU database [12] covering Port State Control (PSC) inspection records of ships visiting European and Canadian ports. In some cases it will be necessary to use the Equasis database [13] that also include inspections from the US coastguard and the TokyoMOU. The inspections try to find non-conformities with the international regulations and conventions held by International Maritime Organisation (IMO) and International Labour Organisation (ILO).

While as the classification based on accidents statistics discriminates relatively strict among the three safety standards, the classification technique considering PSC findings is more relaxed because of the lower reliability of this data source. Anyhow, although the more relaxed classifications the tendency of the safety inspection classification corresponds to the classifications based on the accident statistics (Fig. 1). The correlation between the two performance variables is 0.67. It would be favourable to keep all eight companies in the analysis of their cultural factors. There is however one obstacle that makes this difficult. The companies have crews from different nations. To avoid that the differences in questionnaire response between the companies are related to national cultures four of the companies (Z3, Z6, Z7, Z8) are analysed in detail. These have all a Scandinavian national culture and reflect the range of safety standard from the most substandard to the highest quality. The two described indicators ranks the four companies in the equivalent order with respect to safety standard.

5. A PERSPECTIVE ON LEADERSHIP

It has earlier been suggested that management decisions have a crucial impact on safety [14]. Therefore is it of interest to see if various leadership styles also are important. The crews of the four companies were first asked what leadership style they preferred to work under and then how the actual leadership style was. The scale consisted of four styles ranging from extreme authoritarian to extreme democratic. The four styles were described as in table 2.

The response on this item is presented in fig. 2. It can be seen that Z3 respond that they have a slightly more autocratic leadership compared to the others (Style 1 and 2). The most preferred leadership style is the third one that represents some degree of involvement. It seems however, that Z8 prefers to work under the two first styles.

Table 2: Description of Leadership styles

Style	Description
1	Usually makes his decisions promptly and communicates them to his subordinates clearly and firmly. Expect them to carry out the decisions loyally without raising difficulties.
2	Usually makes his decisions promptly, but, before going ahead, tries to explain them fully to his subordinates. Gives them the reason for the decisions and answers whatever question they may have.
3	Usually consults with his subordinates before he reaches his decisions. Listens to their advice, considers it, and then announces his decision. He then expects all to work loyally to implement it whether or not it was in accordance with the advice they gave.
4	Usually calls a meeting of his subordinates when there is an important decision to be made. Puts the problem before the group and invites discussion. Accepts the majority viewpoint as the decision.

A natural question is to ask why this difference exists. Therefore attributions related to relationships to the superiors are presented in Fig. 3. This chart

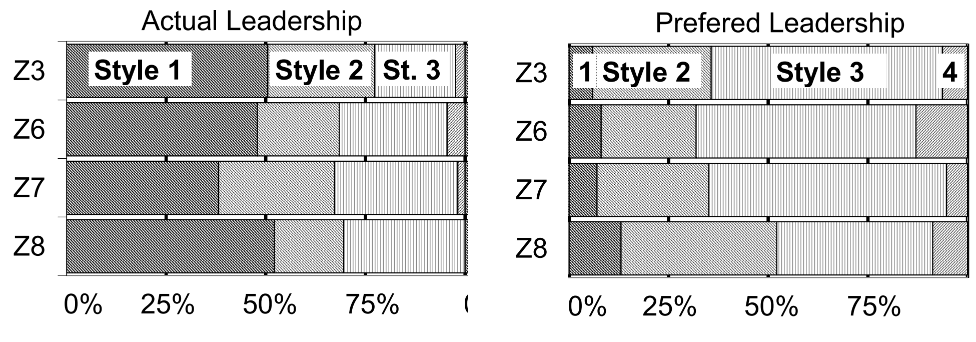

Fig. 2: Actual and prefers leadership style

indicates that there is a strict hieratical level in Z8, where relationships are perceived as little importance.

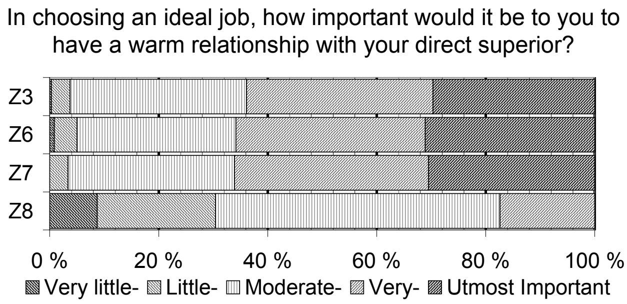

Fig. 3: Relationships to superior in ideal job

6. A PERSPECTIVE ON CONTINUOUS IMPROVEMENT

During the 1990s the focus on continuous improvement increased. The application of Deming's [3] plan-do-check-act loop prospered. An effective safety management system has to rely upon certain plans arranged in the safety manuals. Because the governing regime of safety audits actually force the employees to act in accordance with these manuals, their quality is important. Fig. 4 show that the most substandard company Z8 distinguishes itself by its low portion of very satisfied responses. The same questions were asked for the operational manuals and the current checklists, which gave the same answers as for the safety manuals ($\rho > 0.9$). These responses show that the most substandard companies are less satisfied with the formal safety plans.

The lower right corner of fig. 4 indicates that also the procedures are followed to a lower degree for the most substandard company. The tendency demonstrated in this chart corresponds to other questions designed to measure fulfilment of the procedures. An item representing the degree of fulfilment of checklists is presented in fig. 4's lower left corner. This item demonstrate that the degree of fulfilling a checklist follow increasing relationship to safety standard. At last the upper left corner of fig. 4 illustrate that the crew of Z8

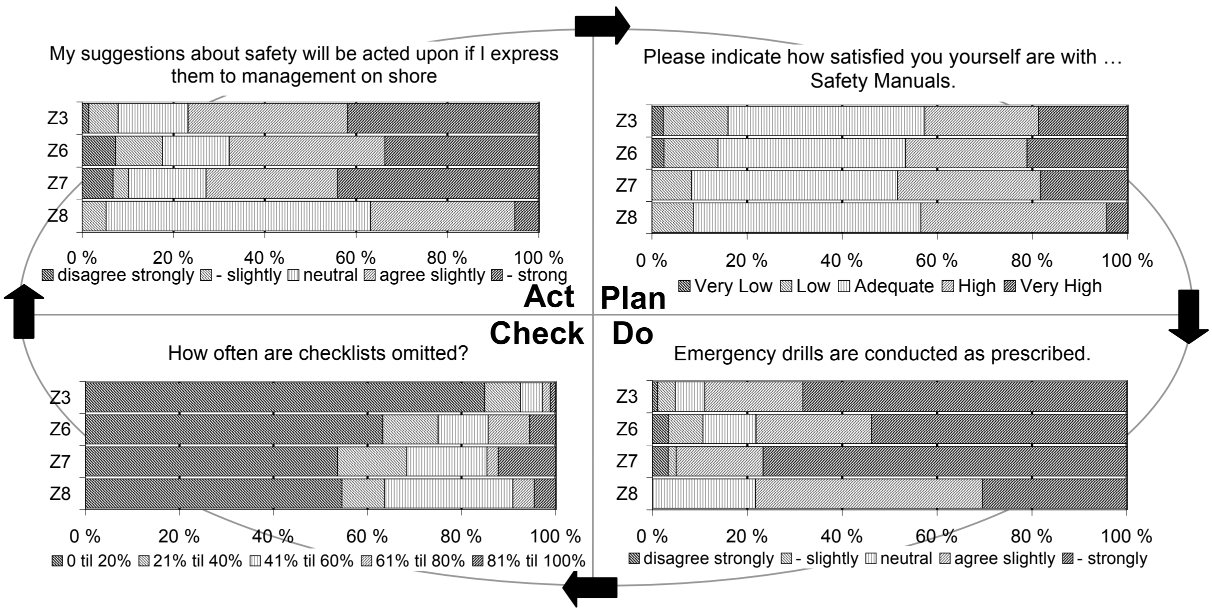

Fig. 4: Questions arranged in a continuous improvement loop perspective

perceives that the shore-based management is less willing to take actions on feedback. The same question was given with reference to onboard management, which gave responses corresponding to the presented but with slightly lower agreement scores. Hence the crews of all companies have most positive experience with the shore-based management.

7. A PERSPECTIVE ON COMPETING VALUES

Schein [15] deified culture as *"... a pattern of basic assumptions, invented, discovered or developed by a given group, as it learn to cope with its problems of external adaptation and integral integration, that has worked well enough to be considered valid and, therefore, is to be taught to new members as the correct way to perceive, think and feel in relation to those problems.*" If the group is defined by the organizational boundaries it is considered as the organizational or corporate culture. As Schein indicates in his definition, culture can be explained based on the external and internal focus and on how the cultural pattern fit (adaptation / integration) with the environment. This idea has lead to a framework that measures the internal versus external orientation of the organizational focus and its stable versus flexible processes. The same framework is used within psychology to measure a person's locus of control. The theoretical model is entitled Competing Values Framework (CVF) and is widely used within organizational analyses [4, 16]. Covin and Slevin [17] describes the stable organizational process as mechanistic while the flexible were labelled organic. Based on their research they relate these attributes to how well they are suited for changes; "*"organic" structures permit rapid organizational responses to changing external environments, while 'mechanistic' structures are better suited to predictable environments where rapid organizational responses are not typically required*". The idea is therefore to consider items of the SMAQ that can be related to organisational orientation and processes. Normally these features are measured from a management perspective. As the SMAQ takes an employee perspective the questions addressing organisational orientation is somewhat different.

First two questions related to the process were selected. The responses on these items indicate that the flexibility seems to be strongly related to safety standard (Fig. 5). The crew of Z3 have higher attributions to dynamic processes, and this attribution decrease with the safety standard. Organisational orientation is a more ambitious scale because there are so many levels that may be considered. The crew of Z3 have a more intense individual desire to feel personal sense of accomplishment (Fig. 6), while the crew of Z8 felt a greater need to obtain good cooperation.

Attitudes towards totally external aspects such as prestige showed a falling trend for the three best companies, while the crew of the most substandard company felt this as very important.

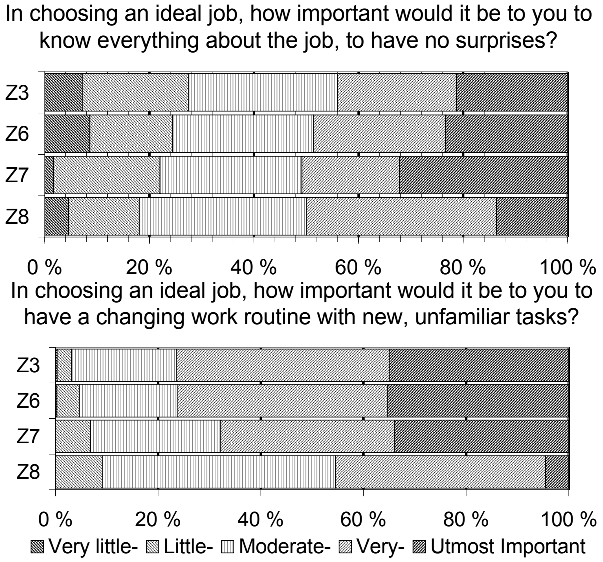

Fig. 5: Distributions of responses related to stable versus dynamic organizational processes.

8. A NORMAL ACCIDENT PERSPECTIVE

Charles Perrow [15] has developed a paradigm within safety management that address aspects of modern system design. A special feature about this theory is that it tune down the importance of organisational culture, stating that it is the tight system couplings and complex system interactions is the core contributor to risks. It is accepted that a good culture has a positive effect, but that it never can balance the risks introduced by the system. Automatic or "cybernetic" control is exemplified as a source for hidden interactions between systems. It is difficult to fully understand how an automatic system responds to a given

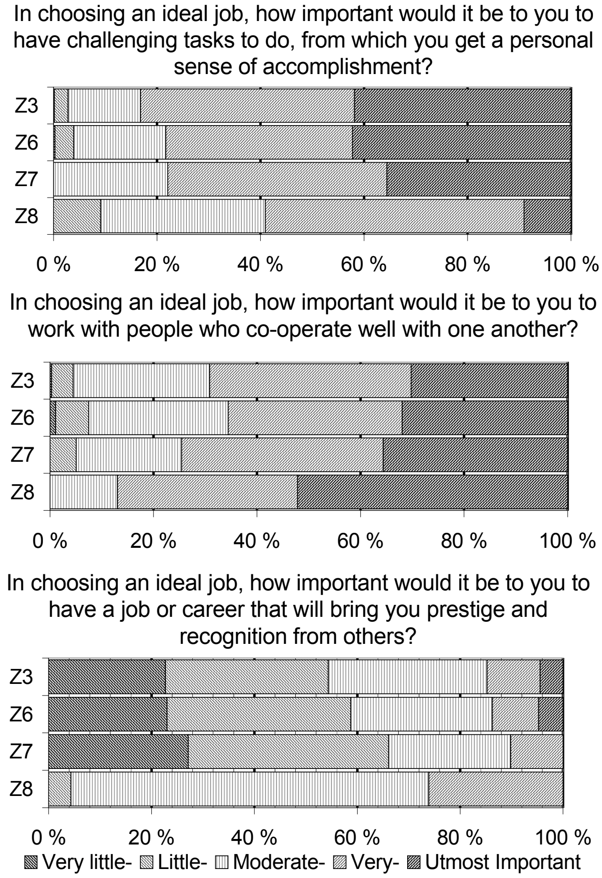

Fig. 6. Distribution of responses related to internal versus external focus

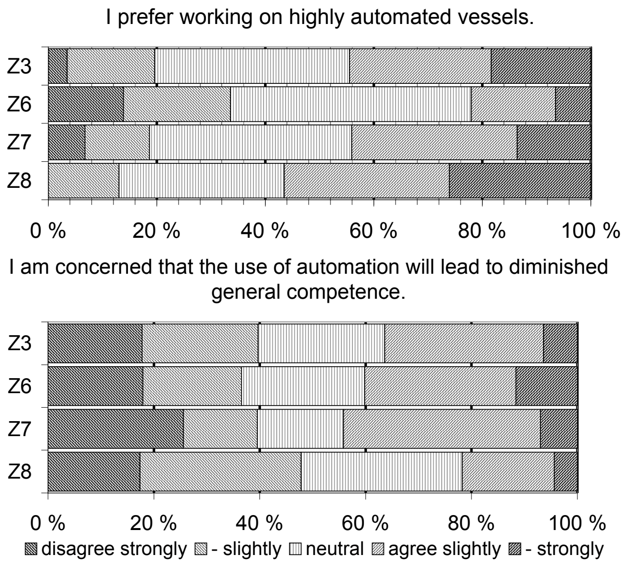

Fig. 7: Distribution of responses related to automation

input or how it interacts with other systems. It is then natural to ask if some cultures have a higher attribution to automatic controls.

9. A PRINCIPAL COMPONENT PERSPECTIVE

A principal component analysis reduces the number of variables by merging correlated variables into principal components. A principal component analysis was performed on 32 questions, which have identical assessment scales. Based on a Scree-plot it was decided to extract seven principal components. The KMO test and Bartlett's test of sphericity showed satisfactory results (0.85 and 0.000 respectively). The items that constituted the principal components are presented in Table 3. Based on the characteristics of these items, each principal component was given a name. The table also includes factor loads (fl) and the communalities (indicated by c). The communalities are the proportion of variance in that variable that is explained by the common factors.

The principal components that explained the most variance was Safety Rehearse, including items related to the daily conduction of safety issues. On second place was Job Satisfaction, which focused on items related to general satisfaction of the workplace. The next component is called Acknowledgement of Personal Limitation and includes items describing the attribution the crewmembers have towards their own and their colleagues' performance under extreme situations. The fourth component is called Communication and includes both communication that specifically address job issues and communication of a more social level. The fifth component is of a similar character, but is aimed at the context of the communication i.e. how colleagues and management tackle requests for help and suggestions for improvement. Therefore this component is called Commitment. The sixth principal component is called Work Integrity and address attitudes towards abuse of alcohol and drugs. The last principal component is called Power and Dignity and includes items that address attitudes threatening professional roles and personal image.

In data analysis of questionnaire surveys it has become common to not only apply the principal components for reduction of data size, but also use the responses to calculate a score on each principal component. In this practice it is assumed that the quality can be reflected in how positive the responses are [18] i.e. the responses on questionnaire follow a monotone increasing relationship to quality (Rule 1). The average scores of each component are plotted in fig. 8 for each of the four companies. If Rule 1 is valid, then the average score of the components should reflect the ranking of the companies. It can for instance be seen that the company Z8 has significantly lower average score on the Communication component. It can also be seen that the Power and Dignity component roughly represents the ranking of the companies. If however Rule 1 holds on an item level, it should also hold on a component level. Because the principal components per definition are linearly independent, there are no linear dependencies between the components. Therefore the safety standard of the organisation should be calculated from a weighted sum of the scores on the principal components (Safety Standard = $w_1 \cdot X_{s.r.} + w_2 \cdot X_{j.s.} + w_3 \cdot X_{a.p.l.} + w_4 \cdot X_{cu.} + w_5 \cdot X_{ct} + w_6 \cdot X_{w.i.} + w_7 \cdot X_{p.d.} + b$). Because, there are only four companies in this study, the exact values of the eight variables (w_1, .., w_7, b) can not be estimated. It is still possible to apply a more relaxed consideration. If the scores on the Communication component (fig. 8) is considered relative to the safety standard (fig.1) it is seen that the score of Z8 in unreasonable low. This low value has to be outweighed by the score of other components, implying that either the importance of the Communication components is zero ($w_{cu}=0$) or that the importance of the Acknowledgement of Personal Limitation component is relatively high ($w_{cu} << w_{apl}$). Both solutions seem to be inadequate. In both cases the low score of the Communication is a poor indicator of safety standard. These characteristics are crucial to understand, because they indicate that Rule 1 in fact is invalid for assessment of the quality of safety culture.

10. Some alternative interpretations of principal components

Despite use of average scores (Rule 1) has become a common approach to interpret principal components, it is not certain that this approach is the most correct. If we use average scores to present the results we assumes that each variable can be measured on a monotonically increasing scale from poor to good. To assess whether there are other differences than the ones related to the score's central tendency the distribution for the principal components were represented by kernel estimates (fig. 9). Differences in average value and variance were tested. These tests took into account the varying

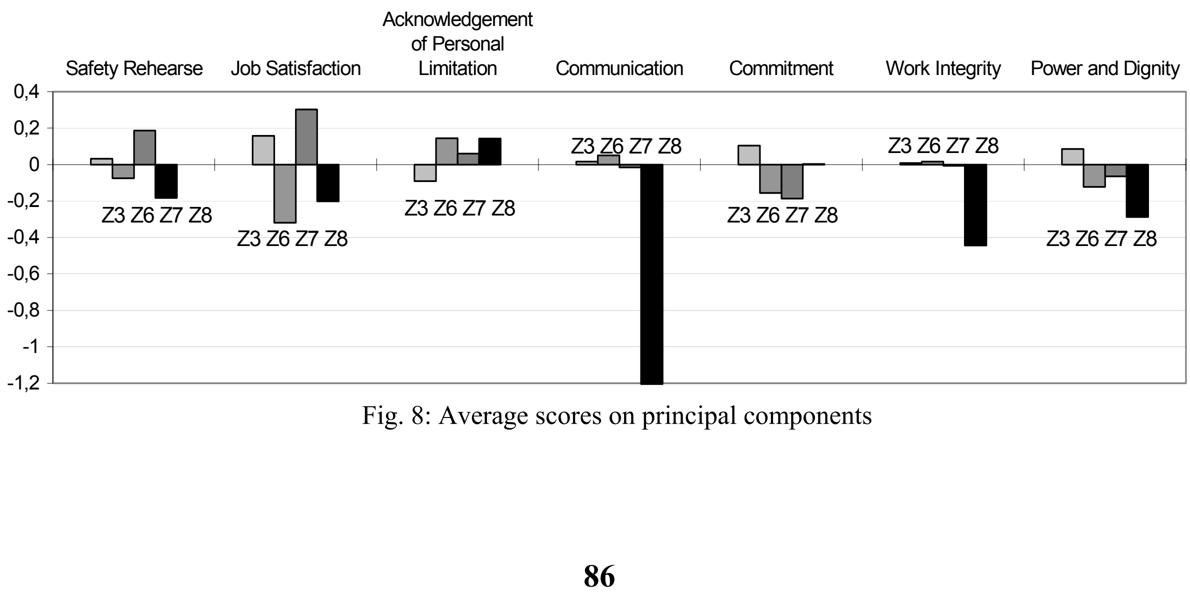

Fig. 8: Average scores on principal components

number of responses from the different companies.

It was found that the most substandard company, Z8, had relatively high scores on the Acknowledgement of Personal Limitation (Fig. 8). Because it should be expected that the cultures of the most substandard company has more a poorer Acknowledgement of Personal Limitation, the distribution of the scores are presented in fig. 9. This distribution illustrates that the crew of Z8 actually have a poorer Acknowledgement of Personal Limitation except from a subgroup that has extremely high values.

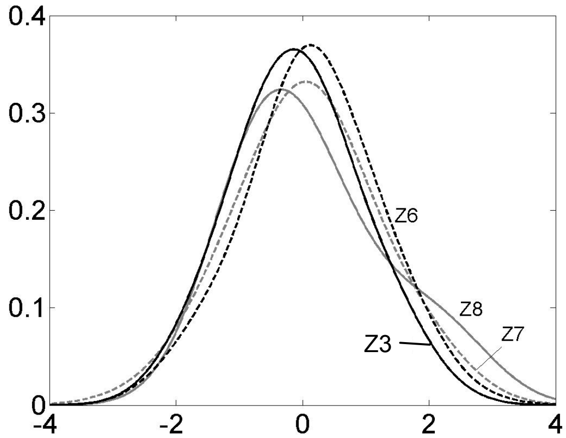

Fig. 9: Acknowledgement of personal limitations

An alternative to the consideration of average scores is to consider the pattern of items constituting the components. A Learning Bayesian Network search for dependencies between variables and presents the results in a directed acyclic graph (DAG). In the graph arrows indicate it can be read that the values of one variable determine the values of other variables. Arrows represent these relationships. The knowledge of relationships between items may represent new insight into the attitude patterns of safety culture. Therefore, first the Bayesian Learning Network searches for the optimum DAG of the items within each principal component. It is recognised that certain items are common for different principal components. Therefore, it is possible to combine the DAG's of some principal component into a larger graph. The graph that includes the Commitment, Communication, Job Satisfaction and Safety Rehearse components is presented in fig. 10.

The DAG presented in fig. 10 should be interpreted in the following manner. A responded value on the root item in the Safety Rehearse component (*Our training has prepared the crew…*) give certain dependencies in the responded values of its three child items. If the DAG of items within the Safety Rehearse component is considered these demonstrate that arrows follow a time perspective. The root node indicates what has been done. The next six items describe how the current condition is. At last the four lowest items represents attitudes towards a potential future situation. It is also worth interesting to consider the relationship between the items "*I am sure management will never compromise safety for profitability*" and the item "*My suggestions about safety will be acted upon if I express them to management on shore*". This relationship is a junction for three of the principal components. This structural characteristic indicates that it is vital for the completion of the whole pattern. Its content does also address aspects of the management's genuine interests in safety. The whole graph indicates that attitudes towards commitment are a core aspect of the cultural pattern, because it is a child feature of the other three components.

11. CONCLUSION AND DISCUSSION OF FINDINGS

This study has considered various ways to represent the relationship between the safety culture of maritime companies and their safety standard. First eight shipping companies were ranked according to their safety standard. This ranking was based on safety performance findings both from accident statistics and safety inspections. Then four companies all having a Scandinavian national culture was analysed in more detail.

In a leadership perspective it was found that the leadership styles of the various companies were relative similar and can be described as authoritarian. The crew of all companies wished to be more involved in decision-making, but the most substandard company was most satisfied. In this context is should be recognised that the crew of the most substandard company have various national backgrounds. Even though only the Scandinavian crewmembers are analysed, these may have higher hierarchal positions in the crew, typically officers.

The attitudes were considered in a continuous improvement perspective. Items that reflected the commonly known Plan-Do-Check-Act loop were considered. It was found that the company having the highest safety

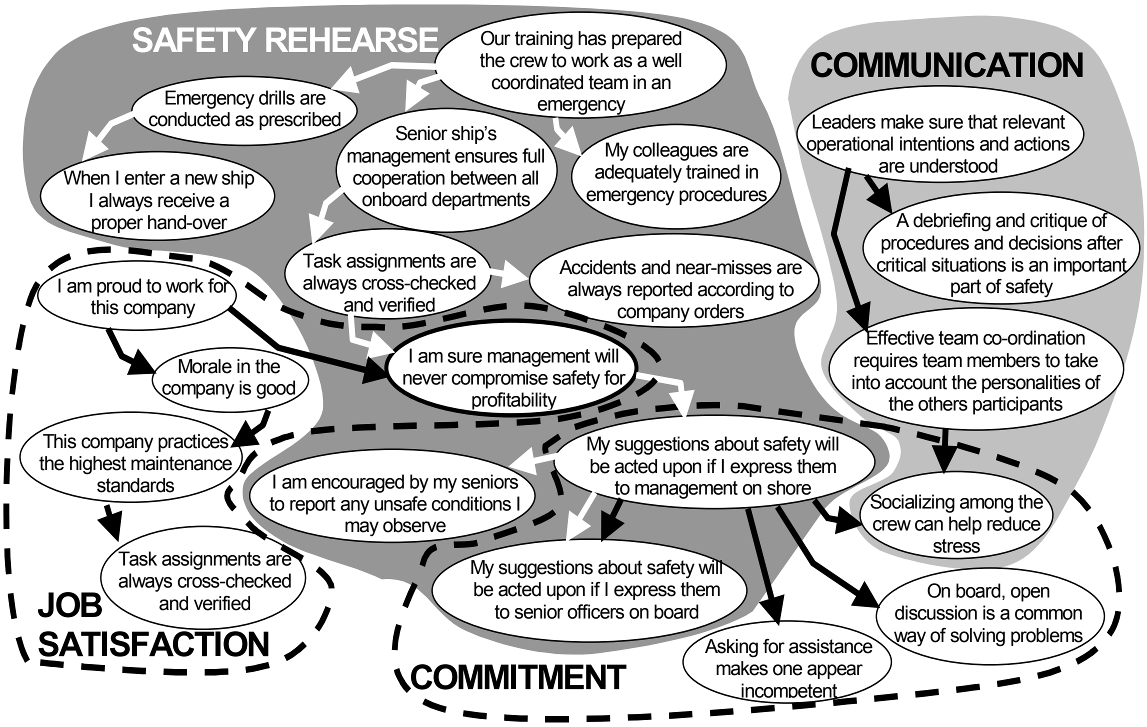

Fig. 10: Combined DAG of four principal components

standard was somewhat more critical to the safety and operational manuals. The responses indicated, however, that the best company to a higher degree followed the plans. Also the omission of checklists could follow the companies' safety standard. At last the attitudes towards the management's willingness to act upon suggestions were better followed the ranking of their safety standard.

Then items representing aspect of the Competing Values Framework were considered. The competing values framework measures organisational culture on two scales. One scale represents dynamic versus stable processes and the other represents internal versus external focus. The charts indicated that the ideal job involved more stable processes for the more substandard companies. Also the focus was different for the various companies. The crew of the company having the highest safety standard had a more intense individual wish to do a good job, while the crew of the most substandard company felt a greater need to obtain good cooperation. Attitudes towards totally external aspects such as prestige showed a falling trend for the three best companies, while the crew of the most substandard company felt this as very important. In sum the company that had the highest safety standard had higher attributions towards dynamic processes with an internal focus. The lower the safety standard was, higher attributions were for the more external processes and stable focus. Even though the response explicitly follow the safety standard it is not known how the actual jobs are for the various companies. It might be that the crew of companies being extremely strict and clean has higher attributions towards more loose circumstances, and that the crew of companies of a more chaotic character have high attributions towards stability.

One of the theories within safety management that is most critical towards the belief in cultural development is the Normal Accident Theory developed by Charles Perrow [5]. He, pinpoint features of the complex and tight coupled systems as the most important contributor to high risks. In particular are automatic control system criticised because they are difficult to understand and undermines the importance of system insight. Therefore attitudes towards automation were considered. It was found the company having a high safety standard was most critical towards automation. This rise the question of what is the most important. Do, for instance, cultures having an immature organisational culture apply more automation, or are they substandard because they are not sufficiently critical to automation?

The last part of the study address analysis based on Principal component analysis. The rule *that the responses on questionnaire follow a monotone increasing relationship to quality* (Rule 1) is assessed. Three examples justify that this rule is invalid. First the average scores on principal components demonstrate that the rule contradicts a relationship to safety standard. Secondly it fails to meet the definitions of safety culture. High average scores do not necessarily imply that the values, attitudes and beliefs are shared. It was then empirically demonstrated that high scores might be related to inhomogeneous in responses. Third, empirical evidence from Rundmo et.al. [19] shows that when safety commitment tend to decrease with improved standards.

In order to find an enhanced technique the dependencies between the items within each component were found by a Learning Bayesian Network technique. A Learning Bayesian Network search for dependencies between the items and represent these dependencies as arrows in a graph. It was also known that various principal components had some items in common. Therefore an outline of the relationship between principal components could be developed. This graph indicated that Commitment was a result of attitudes towards Safety Rehearse, Communication and Job satisfaction. In specific the relationship between the items "*I am sure management will never compromise safety for profitability*" and the item "*My suggestions about safety will be acted upon if I express them to management on shore*" represented a link between the three of the components. The content of these items address the management's genuine interests in safety. Therefore, the management interests in safety have both a high logical and a structural importance.

In summary the explorations accomplished in this study indicates that it is important to have a dynamic and internal focus in order to obtain a high safety standard. This should be verified in later studies. Crews that are critical to leadership and automation also seem to have a better performance. Also the content of the principal components should be inspected in more detail. If it is true that the safety cultures of different companies have similar characters, then the characteristics of the similarities and the differences may give more insight into what is important for developing a mature safety culture.

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Table 2: Content of principal components

Principal components (Minimum factor load ≈ 0.40, Total variance explained 49.1 %)	Co.	Load	ρ
Safety Rehearse 12.0 %			
Our training has prepared the crew to work as a well co-ordinated team in an emergency	0.56	0.72	0.86
Emergency drills are conducted as prescribed	0.50	0.70	0.81
When I enter a new ship I always receive a proper hand-over	0.41	0.62	0.80
Senior ship's management ensures full cooperation between all onboard departments	0.41	0.55	0.49
My colleagues are adequately trained in emergency procedures	0.39	0.54	0.59
Accidents and near-misses are always reported according to company orders	0.36	0.52	0.62
My suggestions about safety will be acted upon if I express them to management on shore	0.63	0.52	0.95
I am encouraged by my seniors to report any unsafe conditions I may observe	0.43	0.51	0.95
My suggestions about safety will be acted upon if I express them to senior officers on board	0.62	0.45	0.94
Task assignments are always cross-checked and verified	0.44	0.44	0.77
I am sure management will never compromise safety for profitability	0.48	0.42	0.72
Job Satisfaction 8.1 %			
Morale in the company is good	0.61	0.72	0.83
I am proud to work for this company	0.58	0.69	0.69
This company practices the highest maintenance standards	0.56	0.67	0.42
I am sure management will never compromise safety for profitability	0.48	0.54	0.08
Task assignments are always cross-checked and verified	0.44	0.46	0.93
More attention should be paid to sleep and sleeping possibilities on board	0.35	0.42	0.27
Acknowledgement of Personal Limitation 6.6 %			
Even when fatigued, I perform effectively during critical times of operation	0.55	0.68	0.80
I am less effective when stressed or fatigued	0.51	-0.64	0.56
I am more likely to make errors in an emergency	0.49	-0.61	0.84
My decision making ability is as good in emergencies as in routine conditions	0.49	0.53	0.27
A truly professional crewmember can forget personal problems while on duty	0.35	0.44	0.56
Crewmembers are well trained to cope with fatigue	0.49	0.44	0.08
Communication 5.6/%			
Leaders make sure that relevant operational intentions and actions are understood	0.50	0.67	0.99
Effective team coordination requires team to take into account the personali. of the others particip.	0.46	0.66	0.87
A debriefing and critique of proced. and decisions after critical situ. is an important part of safety	0.45	0.65	0.96
Socializing among the crew can help reduce stress	0.48	0.44	0.96
Commitment 5.6%			
My suggestions about safety will be acted upon if I express them to senior officers on board	0.62	0.58	0.99
My suggestions about safety will be acted upon if I express them to management on shore	0.63	0.53	0.97
On board, open discussion is a common way of solving problems	0.39	0.51	0.91
Asking for assistance makes one appear incompetent	0.50	-0.49	-0.80
Socializing among the crew can help reduce stress	0.48	0.45	-0.79
Work Integrity 5.5 %			
Drugs present a safety problem in my company	0.73	0.85	0.97
Alcohol presents a safety problem in my company	0.71	0.83	0.99
Leaders who encourage suggestions from crew members are weak	0.42	0.33	0.95
Power and Dignity 5.2 %			
I am reluctant to disagree with my superiors	0.50	0.69	0.78
I am ashamed when I make a mistake in front of other crewmembers	0.50	0.68	0.63
Asking for assistance makes one appear incompetent	0.50	0.43	0.94
A truly professional crewmember can forget personal problems while on duty	0.35	0.36	0.48
Leaders who encourage suggestions from crew members are weak	0.42	0.35	0.92

Co.: Communality, Load: Factor load on rotated solution, ρ: Correlation with standard chart

MEASURING THE SAFETY STANDARD OF ORGANIZATIONS

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ABSTRACT

This paper describes a new general method for measuring the safety standard of an organization. It is assumed that a high safety standard is a result of systematic management and control. The principal idea is therefore to focus on the systematic pattern of safety performance variables in the measurement calculations, which is in sharp contrast to common measuring techniques. The paper focuses on description of the principal idea and some examples for calculations. The most important finding is the methods' efficiency in measuring the safety culture maturity of eight shipping companies. The method uses a database of nearly 3000 responses on the Ship Management Attitude Questionnaire (SMAQ) held by Risø National Laboratories. The analysis show that the maturity of the safety culture can describe about 50% of the variation in a accident performance indicator and more than 60% of the variation of a Port State Control performance indicator.

1. INTRODUCTION

The term substandard and blue chip organizations have become frequently used labels of companies being respectively very poor and extremely good in safety issues. It has also become common practice to conceptually distinguish between an organizations' experienced safety performance and its safety standard, which focus on its resistance against accidents. This shift in focus is caused by a need for more efficient prevention of losses. The safety standard of an organization is commonly measured through rating schemes or similar methods. This paper describes a new general method for measuring the safety standard of an organization. It is assumed that a high safety standard is a result of systematic management and control. The principal idea is therefore to focus on the systematic pattern of safety performance variables in the measurement calculations. Focus on pattern is in sharp contrast to common measuring techniques like ranking scheme, regression analysis and factor scores, which all threat individual variables independent of each other. Even artificial neural networks, which is commonly used in pattern recognition, does not efficiently capture the dependency between pairs of variables (Soma & Kristiansen, 2001). However, most conceptual models used in safety management, accident investigation and human error and reliability analysis agree upon that there is a dependency between some distal core safety factors and the performance variables commonly used in measuring techniques e.g. incidents, audit and inspection findings.

Several authors have realized that we have serious measuring problems within safety management, safety research and safety analysis. The uncertainties involved in measuring safety performance. There has been a shift towards more proactive methods attempting to measure safety standard of an organization Incident happens too rear within an organization to be a basis for common statistical inference. It is also realized that the statistics drawn from investigation reports are unreliable due to subjective interpretations and questionable scope (Pedrali et.al. 2002) (Wagenaar et.al.,1997) (Reason, 1987). Hence the importance of near miss reporting has been emphasized. The reporting frequency of near-misses is however too unreliable to form a basis for evaluation of performance (Scaaf et.al., 1991). Expert judgment is assumed to have a large measuring potential, but has also been staggered due to lacking reliability (Skjong & Wenthworth,). We have diagnosed a number of accidents as being a result of poor safety culture. Therefore the importance of a mature safety culture is stressed. No technique has however yet been able to measure the maturity of an organizations' safety culture (Cox &, Flin, 1998) (Sorensen, 2002). We know that the majority of the accidents are caused by operator errors (Wagenaar & Groeneweg, 1987,). Quantitative analyses of human factors have probably stronger influence on safety through their ensuing discussions and disputes (Fragola, 2000) (Hollnagel, 2000) than their quantitative results. Within maritime transport rating techniques has become popular for targeting and screening purposes. This reaction on accidents like Erika is unlikely to have any effect over longer periods as they only emphasize on the present general characteristics of substandard managers and not their essential safety management problems. We also know that the techniques fail to pinpoint catastrophe vessels such as Estonia and Exxon Valdez.

Despite of the problems, the situation is not too pessimistic. The public focus on safety has forced more safety information to be generated, collected and made public available. Today safety inspection findings, accident history and ship characteristics are available on the Internet even for individual ships. When we still are unsatisfied with the applied quantitative safety measurements it might seem reasonable to take two steps back and critically consider the applied measuring techniques. It might bee that the problems are related to very essence of the used computations.

2. PRINCIPAL IDEA

Commonly used quantitative approaches apply a linear ($Y=w_i \cdot x_i$) model for evaluation of the safety characteristic. These models treat the variables (x_i) independent. In a rating scheme like

International Marine Safety Rating System (DNV, 1995) the weights (w_i) may be estimated through approaches like statistical inference or expert judgment. By regression analysis the weights (w) are typically optimized on the basis of minimal least squared sum of the residuals. In factor analysis the scores on each factor is a weighted sum of responded values within each principal factor. Also neural networks apply independent calculations of the input (x_i).

The lack of consistency related to the independent evaluation of variables may be described through an example. The German magazine ADAC Motorwelt (ADAC, 1998-2001) performs an annual safety assessment of ro-ro passenger ferries sailing in European waters. This assessment is carried out through a six-item rating scheme. Typical items are the quality of Safety Management (X_1), the quality of the Emergency Equipment (X_2) and the quality of the Fire Protection system (X_3). Imagine two ships A and B with the following scores. Ship A is judged to have an extremely poor quality of safety management, but has extremely good quality of the emergency equipment. Ship B on the contrary, is judged to have extremely good safety management, but defective emergency equipment. Both ships have a satisfying fire protection. What is then the likely safety standard of these two ships? Lay people might consider the three items to have equal importance ($w_1=w_2=w_3$), whereas more experienced safety analysts may consider safety management to have higher importance ($w_1>w_{2,}, w_1>w_3$). Both evaluations however, miss the crucial fact that neither of the ships demonstrates control of safety management. Because the efficiency of the Emergency Equipment is highly dependent of the quality of the Safety Management is might seem unreasonable to assess these factors independently. Despite ship B is judged to have extremely good Safety Management the contradicting scores for Emergency Equipment is not reflected in the obtained for safety management.

Another example can be drawn from the world fleet accident statistics. A scatter diagram of the world fleets loss ratio due to collisions versus wreckings is showed in Figure 1 (Lloyd's Register of Shipping, 1970 to 1993). Letting each year from 1939 to 1996 (excluding 2. World War figures) be one point in a scatter diagram, the relation between the two loss categories can be computed. The diagram shows that there were no linear relationships between these events prior to 1971. In the 1970s, after about 20 years of existence, the International Maritime Organization (IMO) started to demonstrate some regulative power. Among other achievement it developed a set of traffic regulations for prevention of collisions named COLREG. It is evident that the accident rates decreased after implementation. However, most importantly, the dependency between these two incidents raised from zero to very high (0.90). Navigation has traditionally been very focused on keeping control of the ships' position relative to land. The new regulations may have reduced this bias in focus, causing the same mechanisms to influence on these two aspects of navigational control.

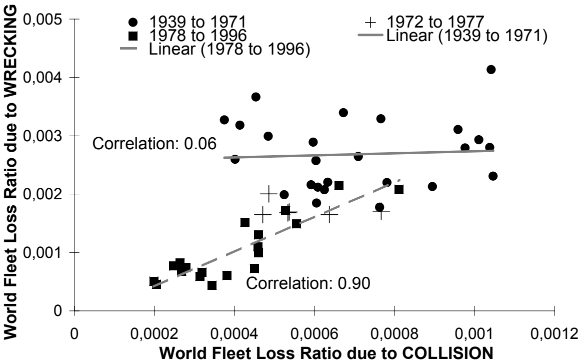

Figure 1: Scatter diagram of the world fleet loss ratio due to Collision and Wrecking (Grounding, Stranding and Contact) before, during and after COLREG 72 implementation

This example indicates that there are two ways of measuring improvements in risk control. The common technique uses independent absolute values, while the dependency between the values may provide additional knowledge, namely that they are controlled by a joint core factor. In order to develop a measuring technique that also evaluates the dependency between the variables a deeper understanding of organizational safety is necessary.

3. CONCEPTUAL BASIS

Reason (1997) presents a framework for understanding organizational accidents. His models have one important similarity with the large majority of models used within safety management, accident investigation and human error and reliability analysis. This common characteristic is the dependency between the incident chain of events, and a more basic element of the organizational system. A survey of more than 30 conceptual models (Soma, to be published a) shows that the root casual factors in these models are either Organizational Factors or Culture, External or Social Environment, Lack of Control, Upper Management, Working Conditions, Statements of Goals and Objectives etc. The variation in the definition of these Core Safety Factors (CSF) may be related to the specific purpose of the various models. However, the consensus of the idea that there is one, or at least a few, CSFs that influence or determines the safety performance of the lower level of the organization is interesting in itself. If this understanding of organizational safety is correct, these CFSs should influence the lower level of the organization and even the unsafe acts (Figure 2). Despite the dependency of the CFSs seems to be accepted by most professional domains involved in safety management, research and analysis it is not reflected in the commonly applied measuring techniques.

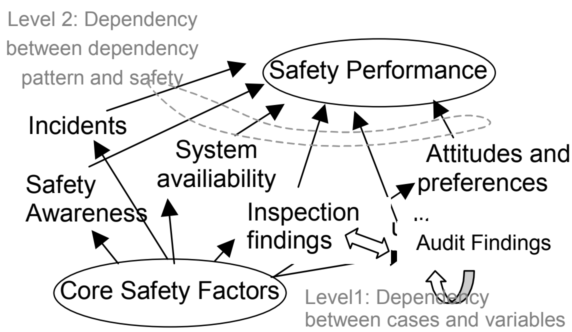

Figure 2: Conceptual model for safety influence

According to the graph outlined in figure 2 the organizations' CSFs influence the safety variables used in measuring techniques. In principle an organization having a high safety standard should have strong dependencies between the CSFs and the variables. Strong dependencies are therefore an indication of control. On the contrary, if the organization is sub-standard the CSFs are weak. Therefore is the safety level of substandard shipping organizations more dependent of other governing ship characteristics like its age, type or size and external factors like classification society or flag of registration.

4. QUANTIFICATION OF SCORES

When developing a measurement tool for safety standard it is extremely important to have some basic understanding of measurement theory. This chapter describes general measuring principles used in item analysis and neural networks. The two last sections describe how the new methods' relationship to this theory.

THEORY OF MEASUREMENT

Successful questionnaires or rating schemes can be developed through selection of suitable items, variables and scales. For inspections the formal requirements are the basis for selection of items, variables and questions while the scales are typically dichotomous (compliance or not). In an analysis each questionnaire response, inspection result or audit finding is considered as a case (Table 1).

Table 1: Examples of cases, variables and values

Cases	Measurement variable	Scale	Core Safety Factor
Different time series	Safety inspections	Complianc e or not	Compliance to requirements
Different respondents	Questionnaire items/ variables	Degree of agreement	Safety culture
Different time series	Audit findings	Practice according to plans	Safety practice / plans
Different years	System availability	Operates or not	Maintenance management
	Incidents	Happens or not	Safety management

In order to optimize the set of selected items, variables and values it is common to carry out an item and discrimination analysis (Anastasi & Urbina, 1997). In this way the most suitable items can be selected and their scales can be optimized for the measuring purpose. Artificial neural networks also use this, although this process is automatically learned through network training. Both in item analysis and in neural network sigmoid functions (I and II in Figure 3) are considered to be powerful for this purpose. These continuous functions effectively divide the low from the high (passing) values. The most effective way to measure the performance through a test is to select items that only 50% of the respondents pass. However, if we want to disguise the very few best or the very few worst from the group other functions may be effective. The convex and concave exponential functions (III and IV) are for instance used to distinguish the few worst and the few very best respectively. After collection of data a measurement tool has to be validated to confirm it measures what it is supposed to do. Also the reliability has to be considered in order to assess the how accurate the tool is.

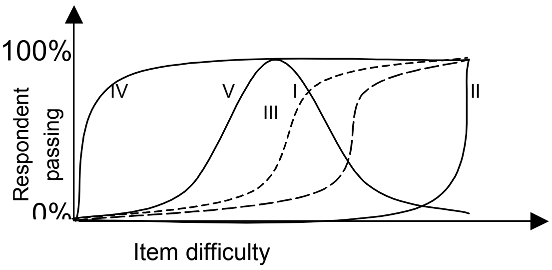

Figure 3: Examples of Item discrimination functions

There are several ways to quantify indicators of the safety standard of an organization. The number of deficiencies of a safety inspection, the number of non-conformities identified through a safety audit or the number of fulfilled items of a check-list are some examples. In contrast to incidents these indicators are a result of a more or less formalized test with a specific and often restricted purpose. Therefore, the obtained correlation coefficients from such data also include the reliability and the different scope of these approaches. The correlation coefficients should therefore be interpreted with care.

Two indicators are used to validate the results of this study (Soma, in review). One indicator is based on severe accidents collected in a Lloyds Register database. The other is based on Port State Control findings collected in Paris MOU's database and the Equasis database. The PSC regime is a measure to counteract the relaxed attitude towards fulfillment of international regulations of some flag states. Both indicators provides the likelihood of a ships' safety standard to be among the 25% highest quality, the 50% average standard or the 25% most substandard vessels of the world fleet. These figures are combined into a single safety performance measure P_d. P_d has values from –100 to 100 where 100 reflects a probability of one for being among the 25% highest standard vessels and vice versa.

LINEAR DEPENDENCIES

In theory dependencies can take many forms. Linear dependencies are considered most feasible when describing the dependency between variables and the computation is straightforward. The measuring method outlined in this paper uses a two-stage dependency calculation. The first stage is to calculate the organization's pattern of dependencies between variables. This is the first level in Figure 2. This pattern of dependency has certain linear characteristics to variables of similar scope and similar influence from the CSFs. The next stage is to assess the safety effects of this dependency pattern. Therefore the similarity between the organizations' dependency pattern and a pre-established norm pattern is calculated. This norm pattern reflects how efficient CSFs should influence on safety variables. This similarity is also expressed through a linear model. The dependency to safety performance may however be non-linear.

The correlation coefficient expresses the degree of linear correspondence, or relationship between the values of two variables. Because the correlation coefficient varies from –1 to 1, it can be used to compare the strength of the linear relationship between the variables. Two variables with a correlation of either –1.0 or +1.0 are highly correlated because knowledge of one variable provides precise knowledge of the other. Independent variables have a correlation of zero. There are several ways to calculate the correlation. The two most common types are the Pearson's correlation, ρ_P, for variables having values on an interval or ratio scale and Spearman's correlation, ρ_S, for ordinal value. The correlation coefficients are defined as:

$$\rho_P = \frac{\sigma_{xy}}{\sigma_x \cdot \sigma_y} \qquad \rho_S = 1 - \frac{6 \cdot \sum d^2}{n \cdot (n^2 - 1)}$$

Where :

σ_{xy} = Covariance of the variables x and y

σ_x, = Standard deviation of the variables x and y respectively

n = Number of data points

d =Difference between the most discriminating ranking of the variables when each have a sum of n(n+1)/2

An example of the estimated linear dependencies between safety variables for a large tanker company is outlined in table 2. The cases are taken from different ship management departments and years. The accident history and port state control findings for this specific company indicates that its fleet is among the worlds 25% highest safety standard.

Table 2 is an example of the dependency pattern developed through the first stage of the measuring technique (level 1 in Figure 2). The table shows that the incidents related to operational aspects (LTI and oil pollution) are dependent of the number of audit non-conformities. The incidents related to more technical aspects (Process availability) are more dependent of the number of inspection findings. The norm pattern, which could be used to assess if this organization is a good safety performer or not, is however not yet developed (Level 2 in Figure 2). The similarity or correlation between a norm pattern would provide estimates of the companies' absolute safety standard. This second stage is later carried out for incident patterns and safety culture survey results. More detailed assessments of the individual dependencies are however considered first. The objective is

Table 2: Example of dependencies between variables

	INCIDENTS			INSPECTIONS			SAFETY AUDIT	
	Oil Pollution	Property loss freq.	Process availab.	Vetting	PSC	In house	External	Internal
LTIF	-0.30	0.22	0.30	-0.04	-0.01	-0.69	0.88	0.94
Oil pollution incident		0.01	-0.37	0.48	0.01	-0.07	-0.75	-0.78
Property loss frequ.			0.04	0.55	0.21	-0.38	0.17	0.31
Process availability				-0.68	-0.64	-0.26	-0.02	0.11
Vetting					0.75	0.61	-0.12	0.22
PSC						0.30	-0.01	0.04
External Audit								0.97

now to start the next dependency level. In such an analysis knowledge of how the dependencies are for high standard and sub-standard organizations has to be developed.

5. INCIDENT CORRELATIONS

Within the ship management as for aviation and train transport, offshore and land based industry there is today regulative requirements for continuous safety improvement activities. A stochastic process governs the occurrence of incidents. It is for instance common to describe the occurrence of accidents through a Poisson process. A Poisson process can be described as a counting process where the occurrence accidents is dependent of an accident rate, λ, and a time window. Within an organization there are several stochastic processes that may be of relevance for the safety. A graph demonstrating the relationships between two incident processes, namely Lost Time Incidents and Process disturbance incidents is shown in Figure 4. The first 63 weeks the safety management is only involved in reducing the lost time incidents. Consequently, the process disturbances are independent of the CFSs and also independent of the LTI -rate. However, because the organization has no control over process incidents it is not having a satisfactory safety management.

After 63 weeks, however, the safety management's scope is increased and a risk control measure is implemented to also handle the process disturbances. From this stage both risks are under improvement. This results in higher correlation between the time series. After a period the process disturbance rate has been reduced considerable and they experience weeks with no events of either kind. The correlation is now reduced again because the time window is too small relative to the event rate ($\lambda \cdot t < 3$).

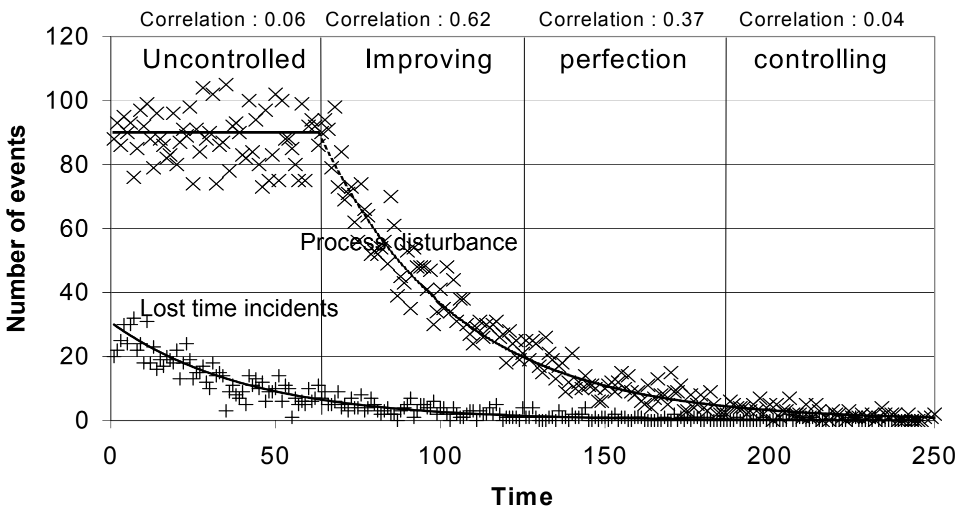

Figure 4: Principles of incident correlations

Hence both the uncontrolled and controlled states have low correlation.

A relatively new discriminating function used in neural network analysis is the bell-shaped function (V in figure 2). When applying a bell-shaped function only the average pass the item. On a single item this may seem ridiculous because it do not distinguish the best from the worst. However, in combination with other items, it is possible to distinguish between the three groups instead of two. Experience in neural networks show that this is more effective because fewer neurons (items) are required. From figure 3 it can be seen that the correlation between incidents have a similar nature. Both the most substandard and the highest standard level have in fact correlation coefficient of zero (see table 3).

Table 3: Logics of σ_P in figure 4

Low: at least one uncontrolled OR at least one controlled
Moderate: one under perfection AND one under improvement
High: both under improvement

6. Incident correlations reasoning

The incident statistics for the fleets of twelve different flags of registration is presented to describe the measuring principle.

Table 4 Incident dependencies.

	Cs	Gr	Ja	Li	Ne	No	Pa	SK	Uk	US	De	Sp
Cyprus		0,6	0,6	0,3	0,4	0,5	0,4	0,3	0,4	0,5	0,3	0,3
Greece	0,6		0,5	0,5	0,3	0,2	0,4	0,4	0,6	0,4	0,2	0,5
Japan	0,6	0,5		0,5	0,6	0,4	0,5	0,4	0,4	0,5	0,5	0,5
Liberia	0,3	0,5	0,5		0,5	0,3	0,3	0,4	0,4	0,4	0,3	0,7
Netherl.	0,4	0,3	0,6	0,5		0,6	0,3	0,3	0,3	0,6	0,7	0,4
Norway	0,5	0,2	0,4	0,3	0,6		0,2	0,2	0,4	0,5	0,6	0,2
Panama	0,4	0,4	0,5	0,3	0,3	0,2		0,5	0,4	0,4	0,3	0,4
S. Korea	0,3	0,4	0,4	0,4	0,3	0,2	0,5		0,3	0,5	0,3	0,4
UK	0,4	0,6	0,4	0,4	0,3	0,4	0,4	0,3		0,6	0,4	0,3
USA	0,5	0,4	0,5	0,4	0,6	0,5	0,4	0,5	0,6		0,5	0,4
Denmark	0,3	0,2	0,5	0,3	0,7	0,6	0,3	0,3	0,4	0,5		0,4
Spain	0,3	0,5	0,5	0,7	0,4	0,2	0,4	0,4	0,3	0,4	0,4	
Average	0,4	0,4	0,5	0,4	0,5	0,4	0,4	0,4	0,4	0,5	0,4	0,4

σ_S LOGICS	
Low	Dissimilar regulative pattern
Moderate	Some similarities in regulative pattern
High	Similar regulative patterns

The numbers is the average correlation between the time series from 1970 to 1996 for the flags ratio of losses due to collision, foundering, wrecking and fire. A high correlation indicates that both flags are under improvement (figure 4). A low correlation is as shown earlier an indication of at least one is uncontrolled or both controlled. In order to perform a complete evaluation the flags have to be discriminated. For this purpose the correlation between the accepted safety resolutions adopted by the IMO is used. High values indicate that the pair of flags has accepted a similar pattern of resolutions.

Table 5 Regulative dependencies.

	Cs	Gr	Ja	Li	Ne	No	Pa	SK	Uk	US	De	Sp
Cyprus		0,6	0,5	0,5	0,5	0,5	0,5	0,5	0,3	0,4	0,4	0,3
Greece	0,6		0,3	0,3	0,4	0,4	0,6	0,5	0,2	0,5	0,4	0,3
Japan	0,5	0,3		0,4	0,5	0,4	0,6	0,3	0,2	0,2	0,4	0,3
Liberia	0,5	0,3	0,4		0,3	0,4	0,4	0,3	0,2	0,3	0,2	0,5
Netherl.	0,5	0,4	0,5	0,3		0,2	0,5	0,2	0,3	0,1	0,1	0,2
Norway	0,5	0,4	0,4	0,4	0,2		0,4	0,4	0,0	0,4	0,4	0,4
Panama	0,5	0,6	0,6	0,4	0,5	0,4		0,3	0,2	0,4	0,4	0,4
S. Korea	0,5	0,5	0,3	0,3	0,2	0,4	0,3		0,5	0,5	0,2	0,4
UK	0,3	0,2	0,2	0,2	0,3	0,0	0,2	0,5		0,1	0,0	0,1
USA	0,4	0,5	0,2	0,3	0,1	0,4	0,4	0,5	0,1		0,3	0,3
Denmark	0,4	0,4	0,4	0,2	0,1	0,4	0,4	0,2	0,0	0,3		0,1
Spain	0,3	0,3	0,3	0,5	0,2	0,4	0,4	0,4	0,1	0,3	0,1	
Average	0,5	0,4	0,4	0,4	0,3	0,4	0,4	0,4	0,2	0,3	0,3	0,3

σ_P LOGICS

Negative:	Low σ_P - High σ_s , AND Low σ_P - High σ_s
Positive	High σ_P - High σ_s , AND Low σ_P - Low σ_s

The complete ranking of the flags is then the correlation between the patterns of the two matrixes (table 6). This value is a measure of the flags' safety performance. Negative values indicate that the flags having similar regulative pattern has low incident correlations and those with moderate or high incident correlations have dissimilar regulative patterns. According to the logical tables this indicate a flag within a Perfecting or Controlling phase (Figure 4). Similar argumentation can be used to identify those having positive values as being under Improvement. The estimated performance measurements are in correspondence with other performance measures. The correlation with the Flag State Conformity Index (FLASCI) Score (Alderton, 2001) is 0.82 and the correlation with the flags total loss ratio for 1998-2001 is 0.61.

Table 6: Correlation between dependency patterns

Cyprus:	0.67
Greece:	-0.04
Japan:	0.27
Liberia:	0.29
Netherlands:	-0.45
Norway:	-0.29
Panama:	0.21
South Korea:	0.19
United Kingdom:	-0.15
United States	-0.56
Denmark	-0.21
Spain:	0.33

7. Analysis of CSF influence

The dependency between the CSFs and the safety level illustrated in figure 2 could be assessed through another approach. As already described a substandard organization is assumed to have weak CSFs. Therefore the safety performance are dependent of other factors, like the age of the ship. In order to assess this hypothesis a sample of 1700 ships selected randomly from the fleet having class society within the International Association of Classification Societies (IACS) covering more than 90% of the world tonnage. These ships were assessed according to their PSC findings. The correlation between the PSC indicator and various measurable characteristics of the ship is estimated.

Table 6: Correlation between ship characteristics and PSC performance (Soma, to be published b)

	PSC Performance		
	25% best N=426	50% average N=799	25% worst N= 462
Gross Tonnage	-0.01	0.20	0.16
Ship type	0.02	0.01	-0.04
Age of ship	0.03	-0.21	-0.17
Flag	-0.04	0.05	0.09
Classification Society	-0.05	0.04	0.06
P&I	0.00	0.05	0.06
External membership	-0.06	0.06	0.07
Sum of abs. values	0.21	0.62	0.64

Table 6 shows that there is a significant reduction in correlation for the most quality operators. Especially the correlations between the PSC indicator and age and ship size are significantly lower for the 25% best. Also the correlation between the indicator and the selected flag and Protection and Indemnity Insurer is lower for the most quality vessels. This means that factors like the ships age, flag and size may be suitable indicators for identification of the most substandard, but that these factors have little potential for identification of the best ships. More precisely, the commonly used age factor is statistical significant because it is relevant for 75% of the fleet (average and substandard). To asses whether the correlations described in table 6 also can be an indicator for individual companies seven organizations are selected for assessment. The sum of the absolute correlation values for the companies and their PSC indicator score are presented in figure 5. The scatter plot indicates that the dependency between the ship characteristics and the PSC indicator may be a suitable indicator for estimating the companies CSF quality.

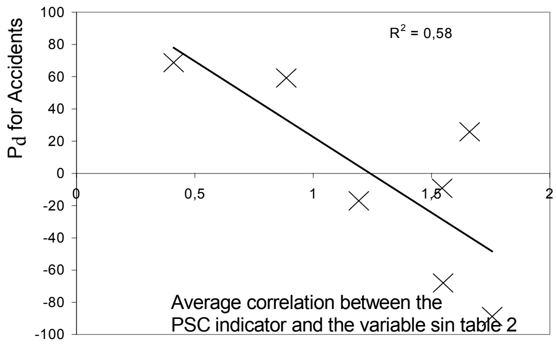

Figure 5: Relationship between the sum of absolute correlation values and the PSC indicator.

8. SAFETY CULTURE PATTERNS

There is a range of definitions of safety culture (Cox &, Flin, 1998) (Sorensen, 2002). Their common characteristic is the involvement of a system or pattern of believes, values, symbols, attitudes, etc. that influence the way the members of the culture act and work with safety. The common attempt to measure safety culture is to perform a questionnaire survey. The responses are analyzed in a factor analysis to group correlated items into groups called factors, dimensions or principal components. If the analysis includes several groups, ships, departments or companies the score on each factor describes the cultural variation between these groups. Several authors (Zohar, 1980) (Itoh &, Andersen,1999) have attempted to quantify the relationship to the companies safety level but only with marginal success managed to quantify such factors (Cox &, Flin, 1998) (Sorensen, 2002). The trend in fighting this problem seems to be towards combining factors and conceptual models (Cooper, 2002) (Alistair & Cox & Amparo & Tomas, 1998). All these attempts seem to ignore the fact that safety culture only includes the common patterns of safety attitudes in contrast to individual safety attitudes independent of the others. In the majority of the approaches the scores of each factor are added together as a weighted sum. Hence, in principle, adding more individuals who give positive responses to the questionnaire items improves the score independent of the cultural influence. When using a questionnaire survey to measure safety culture we assume that the cultural pattern can be reflected into the way the respondents answer it.

σ_P LOGICS

Low:	non-common perception of at least one variable OR independent variables OR neutral responses to at least one vari.
Moderate:	dependent variables AND portions of common perceptions
High :	common perception of the variables AND dependent variables

	Strongly Disagree	Slightly Disagree	Neutral	Slightly Agree	Strongly Agree
Safety training is important				√	

At the most basic level the pattern can be represented by the correlation between the variables in the questionnaire as a level 1 in figure 2. There is established some experience that makes us able to interpret the obtained correlation coefficients. Zohar (1980) has proved that high safety level imply that the respondents answer higher level of agreement on safety related questions compared to organizations having lower safety level. In a measuring context this is advantageous because values far from the average increase the vale of the correlations coefficient. It should be remembered that it is common to design both positive and negative questions. The item describe above is therefore followed up by a negatively stated question e.g. *Training is not very important.* Therefore, according to Zohars's findings organizations having high safety standard should obtain higher correlations between dependent variables.

A recent study on safety attitudes of four shipping companies having the same national culture has found that the organizations having lower safety performance not only give responses of lower absolute values but answer in a more neutral manner (Soma, to be published c). Hence, in principle when asked if safety training is important the respondents of a sub-standard organization may not only answer lower agreement but has also a tendency to be more neutral. A high portion of natural responses causes the correlation coefficient to be low because the difference between the individual scores and the average value is small.

The correlation matrix alone does however not represent a measurement value because there is not any norm to measure it against (Level 2 figure 2). Therefore a norm is developed based on inter-organizational correlation of the correlation matrix. This norm represents to which degree the pattern of attitudes towards safety issues correlates with other organizations. Some might disagree with this norm because they believe that there are several patterns describing a mature safety culture. That might be theoretically true, but experience show that the patterns drawn from the questionnaire surveys of blueprint organizations are similar for all domains. Safety commitment is for instance measured to be a significant factor within aviation, railway, nuclear- process- and offshore industry, medical institutions, and also within the maritime domain. Similarly are factors like communication, training etc. general factors. It would be methodological impossible to identify these in several companies, nor domains, if the correlation matrixes of the various companies or domains were different.

To quantify the suitability of the technique the dependency between 39 SMAQ variables were expressed by their correlation matrix. The obtained scores are expressed by the average correlation between the matrixes as shown on the abscissa of Figure 6 and 8. The critical 95% confidence level of the correlation coefficient is 0.316. The ordinal values of figure 6 and figure 7 are the accident and PSC indicator respectively. As indicated in Figure 6, the safety culture indicator can explain 53% of the variance in the accident statistic indicator. The Pearson correlation between the two measures is 0.73. Figure 7 shows that the dependency between the PSC indicator and the safety culture indicator is even higher. The inter-organizational safety culture score can explain 65% of the variance in the PSC indicator. The Pearson correlation is significantly 0.81. The sensitivity of national cultures is also calculated. The standard deviation of the score due to national variation was estimated to be 0.04 and insignificant variations with a 95% level confidence.

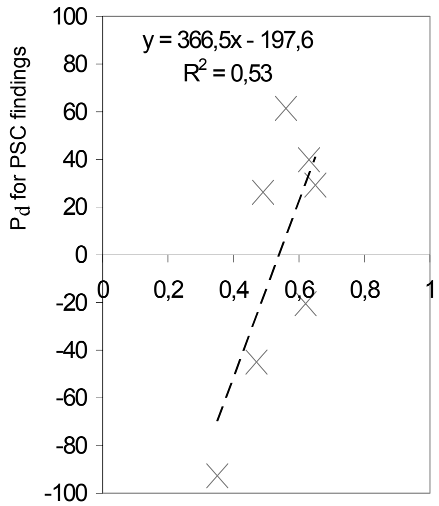

Figure 6: Estimated linear dependency between accident statistics indicator and safety culture indicator.

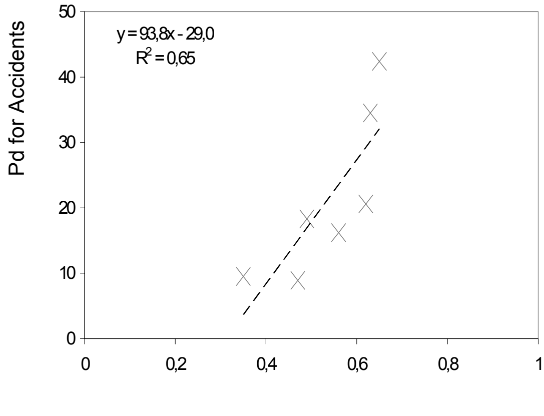

Figure 7: Estimated linear dependency between PSC indicator and safety culture indicator.

9. DISCUSSION AND CONCLUSIONS

This study has presented and validated a new general safety measuring principle. In contrast to existing techniques, which threat the variables independently, the new approach focus on the pattern of dependencies between variables. In addition to valid quantifications, it is stressed that the method is more in line with the conceptual understanding of organizational safety as well as definitions of safety culture.

It is believed that this method can be used as an alternative to existing safety standard measuring techniques. It is especially fit for measuring safety culture maturity and aspects of safety management within organizations.

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MEASURING THE QUALITY OF SAFETY CULTURES

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Abstract

Although definitions of safety culture diverse considerably, it is a general agreement upon that it involves a shared pattern of attitudes, values and beliefs. There are however various ways to interpret what a patterns actually is. It is common to analyse safety culture based on considerations around isolated factors or principal components. Pattern does however also involve relationships between isolated factors, and the trend is to draw attention towards the common drivers of the culture. In this perspective, the target has shifted from observable behaviour towards the underlying pattern of core values. These advances require new analytical approaches. This study relaxes the analytical assumptions inherited from the analysis of safety climate, to develop and validates two techniques that target the advanced understanding of safety culture. The input for the maturity measurement was responses on the Ship Management Attitude Questionnaire (SMAQ). The results demonstrate that items related to normative behaviour were more explicitly descried by the underlying cultural pattern of organisations having an average safety standard. Such behaviour involves uncritical compliance to procedures, emphasis on hierarchal levels and disregarding of individual qualities. The companies having a high safety standard distinguished themselves on an underlying pattern that emphasised on handling of extraordinary situations, job satisfaction and commitment. These situations involve fatigue, emergencies and communication about errors and worries.

Keywords: Safety culture maturity, analysis of patterns

1. EXPLORING QUALITY OF SAFETY CULTURE IN SHIPPING

The concept of safety culture commenced at the early and middle 1980s based on the insight into numerous disasters. A range of modern high-risk systems had during the late 1970s and early 1980s been put under more commercialized management which resulted in restricted resources and a high production pressure. Nuclear power plant accidents such as Three Mile Island (Kemeny, 1979) and Chernobyl (IAEA,1986) were investigated in detail. The Piper Alpha accident in 1989 was one of its time most well documented accidents (Cullen, 1990; Pat'e Cornell, 1993). Also other accidents on offshore installations pinpointed organisational features, such as the Bravo blowout in 1977 (NOU, 1977). Within space shuttling the Challenger accident in 1986 (Vaughan, 1996) was the worst of its kind, also being extensively investigated. The negative effect of the governing management ideology could also be found in more traditional domains such as shipping and rail e.g. the Clapham crash in 1988 (Hidden, 1989) and the King's

Cross accident (Fennel, 1988). Examples from shipping are the capsizing of Herald of Free Enterprise in 1987 (Sheen, 1987) and the Scandinavian Star accident in 1990 (NOU, 1991). The insight into this extensive series of accidents revealed that the availability of resources was unsatisfactory and that the organisations had been under serious commercial pressure manifested through cost saving, downsizing, outsourcing, contracting and reorganisation. Another characteristic was that the management and employees of these organisations had inadequate attitudes, beliefs, priorities and values related to safety issues. This latest feature was singled out as a separate concept called safety culture.

A range of professional milieus within several domains acknowledged the importance of safety culture. Over time however, some difficulties have surfaced. First of all it is difficult to fully understand what safety culture really is. Different domains and professional milieus developed conflicting definitions of safety culture. Secondly, its distinction to the concept of safety climate is neither explicit nor fully accepted. These characters have led several to consider safety culture as a "catch-all" concept. The stressed importance of safety culture was also in conflict with more practical issues. If safety culture really is important it should be relatively easy to measure how good or how mature the safety culture of a specific organisation is. Regardless of this assumed high importance, the measuring practice has almost remained unchanged. Pioneer studies on organizational safety climate from the early 1980s (Zohar,1980) roughly match today's best practice on measuring safety culture. This stagnation would be acceptable if the approach had demonstrated successful results. That is however not the case (Hale, 2000; Cox, Flin, 1998; Sorensen, 2002). It seems to be no measurements that confirm the assumed importance of safety culture. The obstacle for a breakthrough may be related to empirical difficulties. It is difficult to directly compare the cultures of different organisations. The characteristics of one safety culture may both be a reflection of its given environment and obtained experiences. Because the effect from differences in environment is unknown, it is difficult to assess the safety cultures' isolated influence on safety performance.

Shipping might however be an almost ideal field for experiments into safety culture maturity due to two reasons. The primary reason is the uniformity of the organizations' environment. Even thought there are few fully identical ships, they are all relatively similar. The operation of different ship is also conducted in similar ways. The avoidance of water ingress, safeguarding of stability and manoeuvrability has to be ensured through proper maintenance, loading and navigation. The norms for technical standard is relatively uniform due to international new-building requirements and inspections throughout the ships' lifetime. The required competence of the crew is equal for all ships. This uniformity is provided through certificates and international schools. Even the safety management systems have identical functional requirements. There also exists common requirements for how and how often drills are to be performed and what kind of emergency equipment that should be available. All Individual ships are insured in clubs having uniform rules and being mutually liable for compensations.

The second reason is related to empirical aspects. Within shipping there is a large variation in safety standard. Unlike domains like aviation, nuclear-, offshore- and chemical industries, where the variation in safety level seems to be relatively small between organisations, the variation in safety standard between shipping companies is large. The difference in accident rate is estimated to be about 1 to 7 for the 25% safest ships relative to the 25% most sub-standard ships (Soma, to be published 1). This significant variation justifies assumptions of large variations in safety culture maturity. Worldwide it is registered more than 90,000 vessels. At least one half of these ships are in commercial trade operated by about 10,000 companies. It is typical that each ship has more than 10 crewmembers, making them suitable for questionnaire surveys. The last and experimentally favourable characteristic is the availability of safety performance data. Safety inspection findings and accident statistics on both ship and company level is collected and stored by independent bodies and are available on the Internet.

2. Scope of study

Several authors have attempted to develop frameworks that describe the quality of safety culture. There are certain principles that govern the development of such measurements or tests. First, the scope of the test has to be defined according to the measuring purpose and relevant definitions. Then, an item analysis is performed in order to select the most suitable questionnaire items. Thirdly, the responses of the test have to be analysed in order to develop scores. At last the reliability and validity of the test has to be assessed. During a study exploring various measuring principles it was found that average scores on principal components neither is consistent with the definitions of safety culture nor provide reasonable scores (Soma, to be published 2). It was however found that the content of the principal components and the dependencies within and between components could form a more valid measuring basis. The objective in this study is therefore to explore this in more detail. Even though aspects of all four principles of the described process are addressed, emphasis is assigned to the measuring principles.

The developed techniques attempt to specifically address the central aspects of definitions and state-of-the art knowledge. However, in order to validate the principles nine shipping companies are first ranked according to their safety standard. Subsequently the techniques are allowed to explain the variations in safety standard based on their responses on attitude questionnaires. The estimated safety standard is based on two scoring techniques that are respectively based on accident statistics and safety inspection findings (Soma, to be published b). Both techniques quantifies the likelihood of the companies' fleets being among the 25% safest ships of the world fleet, the 25% most hazardous ships or the 50% average. Because the ranking of the companies are based on two sources of data it is considered to be reasonably reliable. The safety culture characteristics are based on more than 2200 respondents of the acknowledged Ship Management Attitude Questionnaire (SMAQ). The study also address questions related to weather it is possible to directly compare the cultures of one shipping company with another.

3. THE CONCEPT OF SAFETY CULTURE

Schein (1990) defines culture as "*...a pattern of basic assumptions, invented, discovered or developed by a given group, as it learns to cope with its problems of external adaptation and internal integration, that has worked well enough to be considered valid...*". This definition is to cover a range of cultural forms such as national-, organisational-, professional and safety culture. There are, however, several conflicting perspectives of safety culture in published literature. The functionalist perspective focus on targeted safety ambitions (Glendon and Stanton, 2000). This is an all-or-nothing approach, indicating that an organisation either has a safety culture or not. In this perspective safety culture is an ideal to which organisations should aspire. The interpretive perspective does on the other hand consider all organisations to have their particular variant of safety culture. This perspective considers the safety culture to be a shared pattern of meanings that have emerged through experience to its current unique blend. A few examples of applied definitions and explanations are presented in table 1.

In summary, there are three characteristics that dominate safety culture definitions. These three characteristics will be referred to as constituent one, two and three. The first refers to the subject of the definitions. It seems to be common to consider safety culture as an attribute of a group of people, typically an organisation, in contrast to focus on individuals. It can be questioned what kind of group that it is reasonable to consider. While a safety manager is interested in understanding the safety culture in his organisation, a researcher might be more interested in groups having a shared pattern of attitudes irrespective of organisational boundaries (Hale, 2000).

The safety culture definitions' second constituent is the object. It seems to be an agreement upon that the group has a shared pattern of rudiments. The rudiments range from observable aspects such as behaviour and symbols down to the underlying assumptions and values. Some researchers (Glendon & Stanton, 2000; Guldenmund, 2000) argues for that more emphasis has to be assigned to the underlying pattern of attitudes and values. Such a shift increases the distinction to safety climate. Irrespective of which rudiments that are included in the pattern, it is the shared pattern or system of it that matters. It is therefore invalid to base assessments of safety culture upon a particular isolated rudiments, such as an attitude towards a specific issue or artefact independent of other attitudes. Similarly, it is invalid to assess a safety culture based on the attitudes of individuals independent of the attitudes of the other group members.

Table 1: Examples of safety culture definitions and explanations

Definitions and explanations of safety culture
"*The safety culture of an organisation is the product of individual and group values, attitudes, perceptions, competencies and patters of behaviour that determine the commitment to, and the style and proficiency of, an organisation's health and safety management..*" Advisory Committee on safety in Nuclear Installations (ACSNI) (HSC, 1993)
"*The set of beliefs, norms, attitudes, roles and social and technical practices concerned with minimizing the exposure of employees, managers, customers and members of the public to conditions considered as dangerous or injurious*" (Turner et.al. , 1989)
"*The assembly of characteristics and attitudes in organisations and individuals which establish that, as an overriding priority, nuclear plant safety issues receive the attention warranted by their significance*" International Atomic Energy Authority (1986)
"In *a total safety culture (TSC), everyone feels responsible for safety and pursues it on a daily basis*" (Geller , 1994)
"*A high reliability culture supposedly involves autonomy of worker; a questioning, sceptical attitude; an emphasis on upon safety, professionalism; and skills*" (Perrow, 1999)
"*The concept that the organisation's beliefs and attitudes, manifested in actions, policies, and procedures affect its safety performance*" (Ostrom et al..,1993)
" *the ideas and beliefs that all members of the organization share about risk, accidents and ill health*" The conference of British Industry ()
"*constructed system of meanings through which a given worker, or group of workers understands the hazards of their world*" Pidgeon (1991)
"*the attitudes, beliefs and perceptions shared by natural groups as defining norms and values, which determine how they act and react in relation to risks and risk control systems*" Hale (2000)
"*Safety culture reflects the attitudes, beliefs, perceptions, and values that employees share in relation to safety* " (Cox & Cox, 1991)
"*The collective mental programming towards safety of a group of organisation members*" Berends (1996)

The two described constituents are relatively typical characteristics for describing any culture such as national and organizational culture. The characteristic that distinguishes safety culture from the more general definitions of culture is the third constituent. The purpose of the group's shared pattern is related to a target e.g. "overriding priority", "minimizing exposure" and "commitment to". Safety cultures that are believed to have a strong influence on a good safety performance are typically called positive, enriched or mature. This third constituent is the essential characteristics that make it possible to test or measure how mature the safety culture is. There exist alternative ways to describe levels of safety culture maturity (Westrum, 1995; Keil Center, 2001; James Reason, 1997; Topf, 1998). Some descriptions are compiled into figure 1.

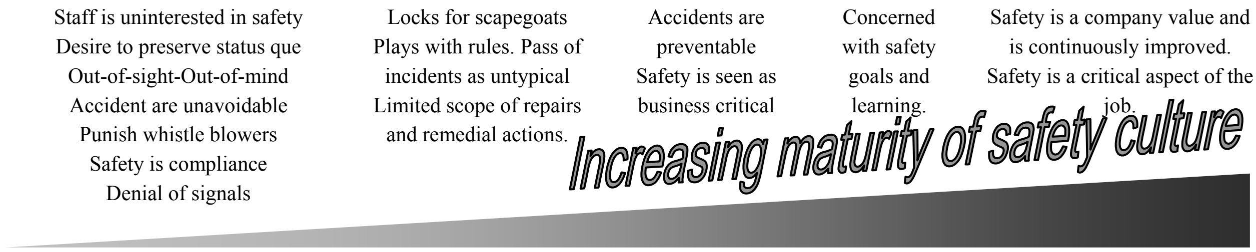

Figure 1: Examples of descriptions of different degrees of maturity of safety cultures

4. SETTING UP A SAFETY CULTURE SURVEY

In a measurement context the functionalist and the interpretive perspectives imply different approaches. The task for a functionalist is to assess whether the group's shared pattern really has a genuine interest in safety or that safety has a secondary status (Hudson, 1999). An interpretive devotee has a more ambitious task. In order to assess if the safety culture is mature, the characteristics of the culture have to bee seen in relation to the environment. If the group's shared pattern of meanings is deficient in relation to the real nature and exposure of hazards it is immature. Because the questionnaires applied on safety culture and climate are indistinguishable, the most efficient way to identify this pattern on existing data is to modify the analysis techniques. Literature reveals that principal component analyses in different domains extract components that are surprisingly similar. Typically components are Management commitment, Safety communication, Importance of competence and training, Job satisfaction, Personal safety commitment, Perceived risk and Status of safety authorities. Even though these factors are relatively easy to pinpoint, they are independent by nature (Figure 2). There are various ways to interpret what a pattern or an underlying pattern is. What is certain is that patterns involve more than isolated and unrelated components. Therefore, a complete pattern has to also include the underlying relationships (Figure 2). As the input analysis and results of both safety culture and climate surveys are similar, the components can only reflect a superficies level. In this context the underlying relationships, whatever the rudiments it encompass is of a more core cultural character.

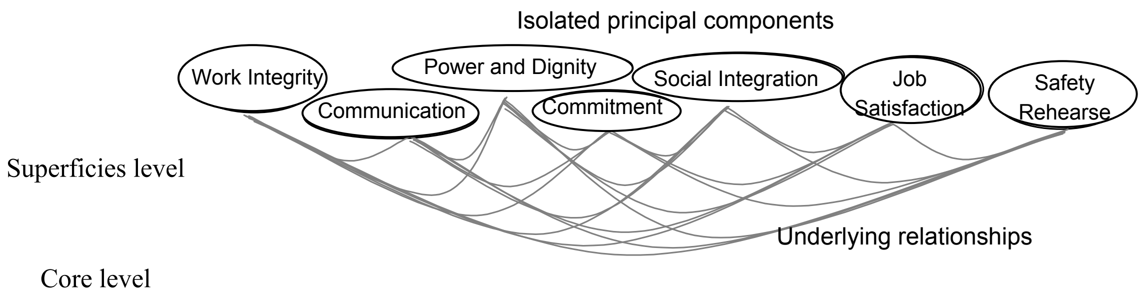

Figure 2: Two levels of safety cultural patterns.

. For simplifying the various approaches the real hidden patterns of cultural rudiments three simplified patterns are presented din figure 3. Even though there exist knowledge about typical principal components, the real pattern of a specific organisation is assumed to be unknown (pattern 1,2 and 3). These attitudes can theoretically have variations in intensity (pattern 1 and 2), and variations in rudiments and variations in structure (pattern 1 relative to 3). If we assume that the features of the pattern determine the safety performance (constituent three) there are alternative ways to interpret the pattern aspect. Is it the contrast, the content or the structure of the patterns that determines performance, or is it a blend of all these features? In the following study it is assumed that the tool for collecting data of the hidden pattern of attitudes is a questionnaire survey (Figure 3). In reality there are other approaches, like interviews and observations. The remaining parts of the figure will be addressed later.

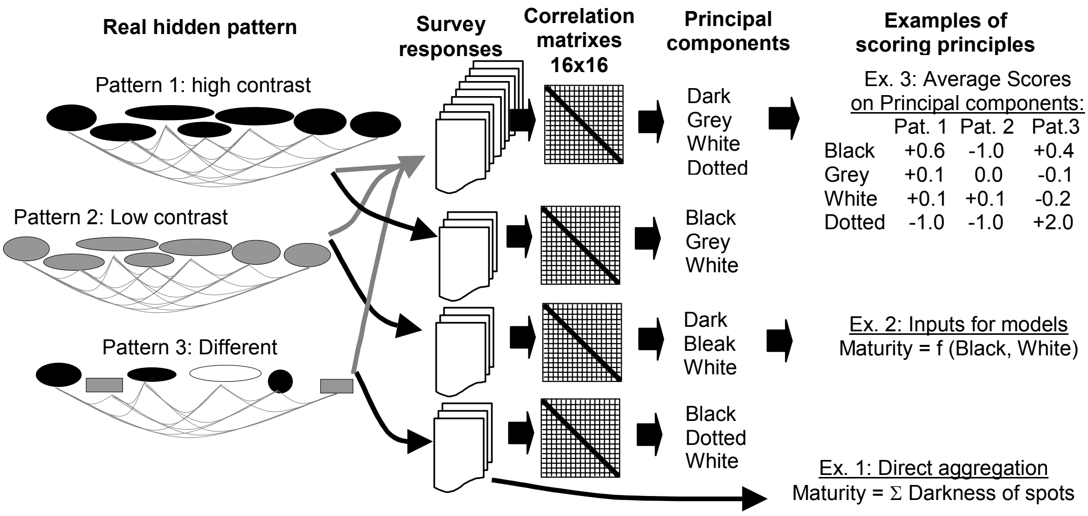

Figure 3: Possible approaches in measurement of organisational patterns

4.1 TYPE OF QUESTIONS IN QUESTIONNAIRE

When measuring safety culture maturity it is necessary to be aware of the purpose of the questionnaire. To act in accordance with constituent one of the definitions the questionnaire has to be responded by a representative sample of the group. When the sample is used for development of a test, the samples have to reflect the population that the test is aimed for. A test developed to capture aspects of Pattern 1 and 2, is for instance invalid when applied on pattern 3 (Figure 3). Next, the items have to be developed to catch as much of the cultural pattern as possible. It might be that the characteristics of the patterns vary between different levels of maturity. In reality the patterns that are relevant for safety is one of a range of patterns and systems of understandings within a group. Therefore, nuances in types of questions and scales might cause the item to address patterns outside the scope of the survey. For example the two items presented in figure 4 seems to address similar issues. The charts illustrate the response distribution of respondents having the same national culture in four companies Z3, Z6, Z7 and Z8. Z3 is a company having a very high safety standard, while the standard decrease down to the standard of company Z8. It can be seen that the responses of the left item is relatively stable, while the disagreement increase with falling standard in the right question. The fact that the responses of the left item are stable for respondents of the same national culture is taken advantage of by Hofstede (2000) in his descriptions of national cultures. It would be difficult to state that the two items addressed two different cultural patterns without empirical evidence.

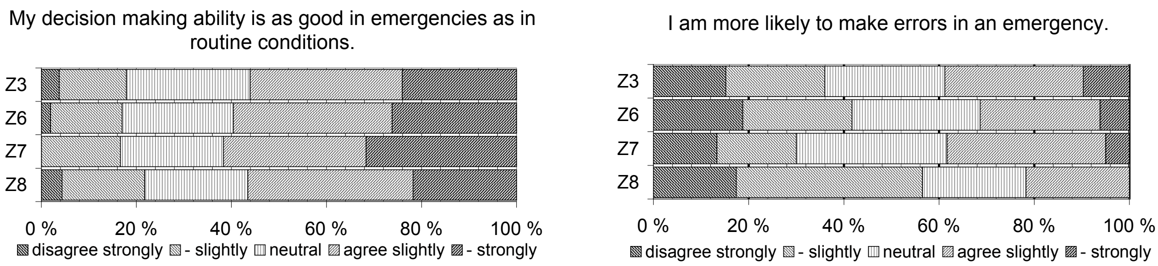

Figure 4: Similar questions addressing different patterns

4.2 TYPE OF SCALES IN QUESTIONNAIRE

Another issue that cause some discussions is the applied ordinal scales. The two types of scales that are most applied are the Likert scale and the Ipsative scale. The Likert scales measure a group's agreeability on an absolute scale i.e. if two different respondents answer equally, their absolute agreement on the statements can be assumed to be equal. The two items in figure 4 are examples of responses of Likert scales. The advantageous ability in comparing results from different individuals on absolute scales has given the Likert scales a strong endorsement within safety culture analysis. With reference to figure 4, the contrast of pattern 1 and 2 can be precisely measured. In ipsative scales the importance of different statements are directly assessed. The statements are typically arranged in pairs in which each statement is paired with all other statements. In this testing approach the importance of each statement is not expressed in absolute terms, but in relation to other statements. Hence, the groups having pattern 1 and 2 in figure 2 may obtain equal responses, which is different from the responses from the group having pattern 3. The frame of reference of is therefore the individual respondents. Two respondents that answer equally may still consider the statement's importance different in absolute terms.

The questionnaires addressing safety culture are of a similar character (MaTSU, 2001), and the Likert scale seems to be mostly applied. In measurement of organisational culture, however, the ipsative scales are widely used. In a study trying to compare and collect questionnaires aimed at safety culture all applied Likert scales. One of the most known questionnaire applying ipsative scales is the Competing Values Framework (Cameron & Quinn, 1999). Items addressing aspects of the Competing Values Framework, but assessed on Likert scales, were found to efficiently distinguish between the four companies in figure 4 (Soma, to be published 2). This indicates that it is possible to measure similar features on both types of scales. Anyhow, the difference between the scales should be assessed in more detail in relation to what features of the cultural pattern that actually determines safety performance. If the contrast is important, the use of Likert scales are most suitable, but if it is variations in pattern structure that is important Ipsative scales should be used. In order to search for patterns based on responses from Likert scales, the items has to be arranged in some sort of system that represents the characteristics of the hidden pattern. This system might be correlation between the items, typically represented through a principal component analysis. Other systems might be to conceptual models exemplified in (Soma, 2004; Soma , to be published 2).

4.3 Selection of questionnaire items

In a typical item analysis the items are selected based on their ability to distinguish between the good and poor responses. Regarding safety culture, however, what features that distinguish good or poor is unknown beyond the rough outline in figure 1. Instead of considering the items' ability to distinguish good from poor responses, selection based on their internal consistency has been practiced. Through a cronbach–alpha technique it is possible to assess if an index (set) of similar items provide reliable measurements based on the internal consistency. If for example the responses of an index of questions related to communication has a high internal consistency it is assumed that this items actually measure the same thing e.g. quality of communication. Based on the cronbach-alpha values it is possible to select the indexes that are most reliable, knowing that it measures some isolated feature. For instance may an index of items measure how dark the black spots of the patterns in figure 3 are. Hence, analogous to the use of Likert scales the items effectiveness also focuses on the contrast of isolated rudiments. It should however be noticed that even precise knowledge about isolated features gives few hints about the structure of the whole pattern. At last, even though an index demonstrate that they measure safety communication, there are no evidence proving that it contribute to *overriding priority* of safety, *commitment* to or *minimizing exposure* of hazards which are core characteristics of the definitions of safety culture.

5 Safety culture maturity score analysis: a search for patterns

In the James Reason book "Managing the Risks of Organizational Accidents" (1997) there is a chapter called "*Safety Culture: Far more than the Sum of its Parts*". In the following text various applied calculation techniques are demonstrated with reference to figure 3.

5.1 Direct aggregation

This first discussion address the approach outlines in example 1 in figure 3. To demonstrate how addition is used in measurements of safety culture maturity an index addressing "Belief in accident prevention" is presented in the following figure. The item consists of two questions, and a five point Likert scale with values from zero to four. The maximum score of each question is four, making it possible to obtain a highest score of eight. This scoring principle seems advantageous because of its simplicity. However, the relationship between the response to the first question and the overall safety culture maturity score is determined independent of what the same respondent answers to other questions, and more controversial, independent of what the other respondents of the group answer. This is in conflict with constituent one and especially constituent two of the safety culture definitions.

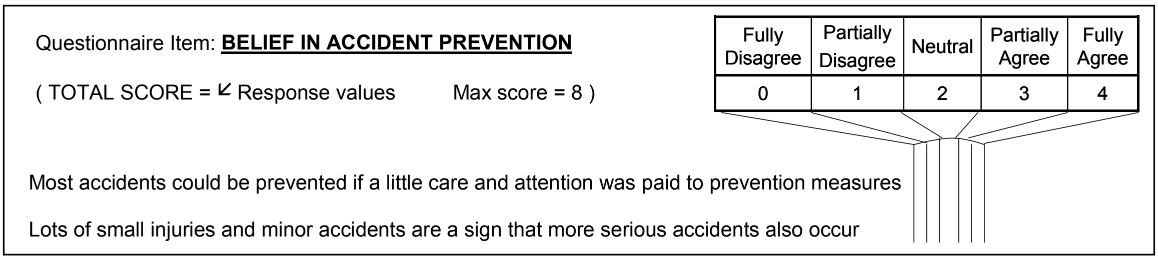

Figure 5: Example of calculation of scores

5.2 Modelling of factors and principal components

The next example (example 2 of figure 3) applies models for the calculation of safety culture maturity. These models may typically apply factors obtained through a principal component analysis, expert judgement or both. Within safety climate there exist examples where first the principal component analysis is performed and then the components are incorporated in an expert judgement model (Cheyne et al., 1998). Within safety culture measurement Cooper (2002) has developed one proposal. This model is based mostly on the modelling on expert judgement. In the case of applying principal components or other independent factors into a common, model there are certain issues that have to be notified. A principal component analysis groups correlated items into principal components. Hence, the correlation between different principal components is close to zero. In a statistical point of view this indicates that it at least is no linear dependencies between principal components. The existence of principal components may be interpreted as evidence of their mutual independence. Therefore the model should not either have linear dependencies between the components, as attempted by some. This indicates that the knowledge represented on principal components have lost some possibilities to reflect the structure of the hidden patterns to the left in figure 3.

5.2 Scores on principal components

The last and relatively common approach is to first perform a principal component analysis, and then calculate the average scores on each component for various departments (Zohar, 1980; Itoh and Andersen, 1999), experiences (Lee, 1998) or organisations (Soma, 2004). The average scores are useful in understanding of variations between the groups. In some examples, however, there might be subcultures within a group that have totally different scores. Such, differences are not reflected in an average value. It has also been found that it in fact is questionable to directly assess good and poor average scores for determination of safety standard ().

It is natural to ask why it has been widely accepted to apply the sum of responses. The pioneer research on safety climate performed by Zohar (1980) proved that the summing of responses gave some indication of the quality of the safety climate. Despite of the fact that safety climate is a slightly different concept than safety culture, the questionnaires claiming to measure these two concepts are indistinguishable (Flin, 1998). Zohar (1980) verified that also the variance in the responses between different departments is differs by using a one-way analysis of variance. Therefore, the distribution of scores from the four companies in figure 4 is considered in more detail. The typical character of the two items that had the highest factor loads on each of seven principal components was extracted. These items should be the most important items in describing the variation in the dataset. The average responses of all these 14 items were lower for the most sub-standard company and therefore at first seem to confirm Zohar's finding. However, the lower sum of responses was found to be caused by an almost three times as high portion of neutral responses. The fact that the crew of the most substandard company has no opinions regarding the item statements is different from assuming that they have a lower degree of agreement. For example, the minimum value of the score in figure 5 should not be for the "Fully Disagree" value, but rather on the "Neutral" value. Based on the descriptions in (Figure 1) it can also be imagined that some immature cultures want to present them selves as better then they actual are. Respondents of such an organization may easily replica such a false image by giving more positive responses to the questionnaire.

6. Alternative measuring approaches

The illustration presented in figure 4 indicates that a pattern consists of contrast, structure and content. It seems as if most of the existing research has aimed at contrast, through a wide use of Likert scales, cronbach-alpha assessments and principal component analysis. Even though this uniformity is criticised, literature reveal few alternative approaches. There exist a range of possible alterative techniques that address the pattern structure. First, it might be interesting to consider the correlation between all items in a questionnaire, typically presented in a matrix. This correlation matrix is the intermediate basis in a principal component analysis (Figure 3) and reflects the linear relationships between all items. Given that the questionnaire items are effective in addressing various features of the real cultural pattern, the correlation matrix might be a representation of it. Identical correlation matrixes produce identical principal components, which is close to what is experienced in reality (Figure 2). Further, given that the correlation matrixes from different questionnaires or groups of respondent are of a similar nature, it would be interesting to relate nuances of difference to safety performance. Because the environment in shipping is similar for all organisations, it might be expected that there are fewer cultural patterns structures that are effective than those who are not. Therefore, out of a sample of correlations matrixes representing the patterns from different organisations the ones that have most in common with the others might be the ones being most mature.

While the described technique address the completeness of the superficial cultural level in figure 2, it is more interesting to directly measure aspect of the underlying relationships. weaknesses of the Another approach is to pinpoint on the items that forms the glue between the principal components. Some items reoccur on several components, and thereby represent a link between them. There are two ways to find these items. The most pragmatic approach is to simply count the reoccurrence of items in various components. A more sophisticated approach is to consider the variations in communalities between the safe organisations and the hazardous ones. The communality of an item reflects the portion of its variance that is common with other items. High communality values indicate that the item is suited, together with the other items to form principal components. A low value indicates that the items variance is independent of the other items. Given that the correlation matrixes are of similar nature, differences in communalities may reflect what this difference is related to.

6. Empirical evaluation of test theory; a retrospective approach

There are few retrospective studies into safety culture. The typical approach is to first perform a questionnaire survey, and present the scores on principal components. At last it is tempted to validate the scores by obtaining some safety performance data. This study takes the opposite approach. First a study is performed to have a fear idea about how good the companies' safety standard is relative to each other, and then this variation is described based on their safety culture. Because the performance data have references to the world population of ships, it is possible to imagine the general variations of safety culture within the maritime domain.

6.1 RANKING OF ORGANISATIONS BASED ON SAFETY PERFORMANCE

Based on a newly developed classification technique, nine shipping companies are ranked based on their accident statistics and safety inspection files (Soma, 2004). Both techniques estimate the fleet's relative likelihood of belonging among the 25% safest ships of the world (A), 50% average (B) and the 25% most hazardous ships (C). In figure 5 the companies are plotted based on the excess likelihood of being in the safest class (P(A)-P(B)) for each indicator. The company Z1 is ranked as the safest company while Z9 is the most substandard. Earlier four of the companies that had the same national culture were compared. The advantages of applying two independent safety performance indictors are obvious because the reliability of a single indicator can easily be questioned. The two indicators are known to produce reasonable consistent ranking of the companies (Soma,), which can be verified in figure 5. For the given companies their whole fleet is included in the search for accidents and inspection findings. The timeframe for both the inspections data and the accidents statistics are four years. The source for accident statistics is collected from a database held by Lloyds Maritime Information Service (LMIS). The database include those accidents which result in structural damage, rendering the ship unseaworthy, such as penetration of hull beneath sea surface, immobilization of main engines, extensive damage etc., electrical breakdown, the vessel being totally lost or any other undefined situation resulting in a damage or financial loss which is considered to be serious. The safety inspection findings are collected from an Internet database holding Port State Control (PSC) inspections. These inspections are carried through at ports onboard visiting vessels to verify compliance to international conventions issued by the UN body International Maritime Organisation (IMO) and the International Labour Associations (ILO). The data for the PSC findings are collected from the Equasis (website) and Paris MOU (website). Both the safety inspections and the accident statistics are collected, stored and made available by independent bodies. The ranking was based on the average of the two indicators and are supported by correlations of respectively 1.0 from the accident indicator and 0.75 from the inspection indicator. The values themselves have a correlation value of 0.62.

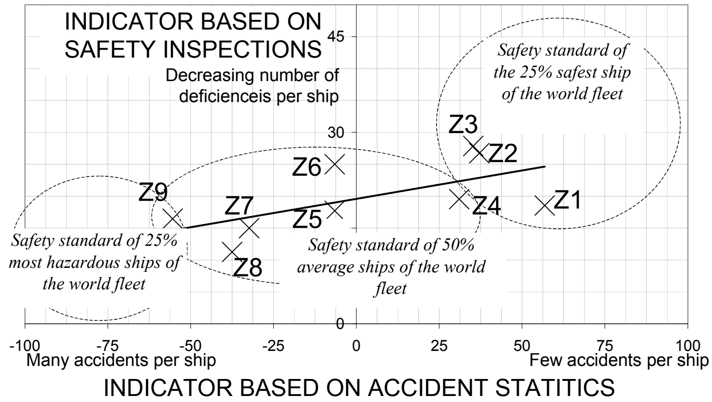

Figure 6: Relationship between indicators of safety inspection and accident history

The applied questionnaire for the survey was the Ship Management Attitudes Questionnaire (SMAQ), which was developed by Risø National Laboratory, the Danish Maritime Institute (DMI), and the University of Texas (NASA/FAA) Aerospace Crew Research Project as a joint project. This questionnaire is part of a study aimed at understanding maritime operations attitudes and is derived from the Flight Management Attitudes Questionnaire (FMAQ), developed by the University of Texas. The FMAQ is widely used in aviation to diagnose organizations in the areas of organizational culture, safety, and human factors practices. It contains items that relate to employees' opinions and attitudes about management, morale, safety issues, automation and teamwork, as well as general work values. The questionnaire consists of totally eight indexes. Of these only two are considered in this study. These indexes are called *Degree of agreement with statements related to organizational issues* and *Degree of agreement with statements related to ship management.* These two indexes both apply a Likert scale. Findings from the survey are presented in confidential reports to individual companies, but published works, like this one, will describe results in anonymous form, de-identifying the participating companies. Risø National Laboratory and DMI have already carried out a questionnaire survey among seafaring personnel in several shipping companies. The SMAQ questionnaire was distributed to seafaring personnel in five shipping companies during 1997 (four Scandinavian companies and one Asian company). The database has later been expanded with data from an American company, and two more Asian companies. In this study two additional Scandinavian companies are also included. In total, nearly 3000 questionnaires (out of 4700 distributed) have been returned. Since excess questionnaires were placed aboard ships, the response rate cannot be determined precisely; however, the rate of response is almost certainly above 30%, and it appears to be well above 40% for deck and engine officers. The number of valid responses from the eight companies is presented in Table 4 (the American company is not included).

Table 2: Respondents included in the further analysis

Company	Nationality	Number of Respondents	Data collector
Z1	Asian	114	Risø National Laboratory
Z2	Asian	278	Risø National Laboratory
Z3	Scandinavian	652	Risø National Laboratory
Z4	Asian	653	Risø National Laboratory
Z5	Scandinavian	364	Risø National Laboratory
Z6	Scandinavian/ Asian	70	Soma / DNV
Z7	Scandinavian	60	Risø National Laboratory
Z8	Scandinavian	72	Risø National Laboratory
Z9	Scandinavian / Asian	13	Soma / DNV
	Sum	2276	

6.2 Search for cultural patterns in correlation matrixes

When a questionnaire survey is applied to measure safety culture maturity it is assume that the respondents cultural context influence their answer and that this influence can be extracted in an analysis. In this study three analysis approaches are demonstrated. The first approach takes advantage of the fact that research in several domains find similar principal components that described their datasets e.g. Commitment, Job satisfaction and Communication. It is also recognised that the crew's context onboard various ships are similar across company borders. Both these to observations indicates that there should be one type of cultural pattern that reoccurs in different organisations. Because the environment is relatively equivalent for various ships there might be some unique blend of this pattern that is more efficient. It is assumed that the cultural patterns that are effective in accident prevention are similar, relative to an indefinite number of cultural patterns that are not effective. Based on this argumentation the cultural pattern of the safest companies should be relatively similar relative to the cultural patterns of the most substandard companies. A suitable starting point for such an analysis is the correlation matrix of the responses. Identical correlation matrixes produce identical principal components in a principal component analysis. The correlation matrix of 56 items, having equivalent Likert scales was compared relative to each other. The correlation matrix for each company was compared to all other companies. The comparison technique applied a spearman correlation between the matrixes. This value varied from 0.135 to 0.820. Because the number of data point is large ($56 \cdot 55 = 3080$), all these correlations were statistical significant with a 1% confidence level. This implies that there exists a common pattern of responses across company borders and national cultures. It is now assumed that having the cultural pattern that is most similar to the others have the most mature pattern. Hence, a score was given to each company based on the sum of the correlation values to all other companies. This indicator, plotted in scatter diagram with the indicators of safety standard is plotted in figure 4 and 5. The scatter diagrams seem to justify the assumption. The correlation coefficient between the correlation matrix indicator and the accident indicator was 0.61, and the same figure for the safety inspection indicator was 0.65. Even though these values isolated are not statistical significant, it is unlikely that two independent analyses produce spurious correlations of this high value. If it is assumed that the coefficients are not spurious then it can be concluded that the safety culture maturity indicator can explain a significant share of the correlation between the two performance indicators.

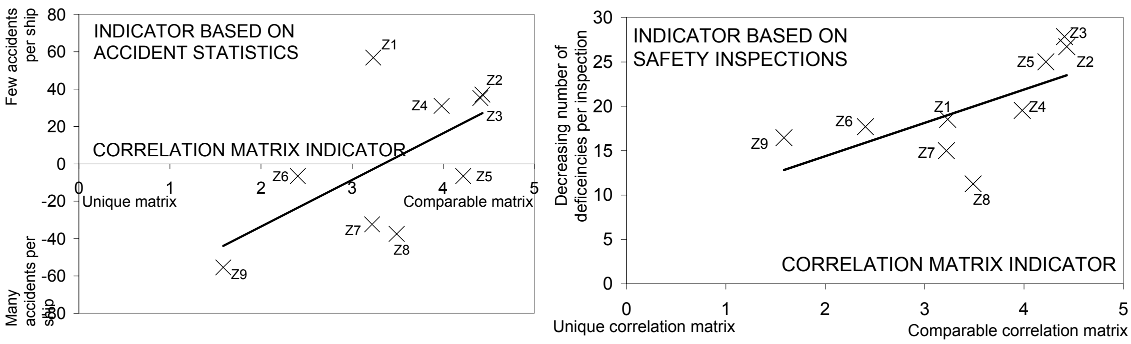

Figure 7: Relationship between safety standard and correlation matrix indicator

Figure 7 presents the regression line of the correlation between the correlation matrixes for all nine companies. It can be seen that all companies have higher correlations to the safer companies relative to the unsafe. The second analysis approach is performed on the results of a principal component analysis performed on each individual company. In all analyses seven components were extracted. The seven components were rotated with a Varimax method including Kaiser Normalization. The total variance explained by the principal components varied from 40 to 85%. One major finding was that the principal components across companies were very similar. The components were called Safety Rehearse, Commitment, Communication, Job Satisfaction, Acknowledgement of Personal Limitation, Work Integrity, Social Integration and Power and Dignity. Table 3 presents the items in the principal component, Safety Rehears. This component was the one that described most of the variance. Even though there are some variations across company borders, there is a core of items that seems to be common.

Table 3: Items in Safety Rehearse components for different companies

	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9
Task assignments are always crosschecked and verified	0,66	0,73	0,47	0,60	0,46	0,80	0,68	0,63	0,66
Our training has prepared the crew to work as a well-coordinated team in an emergency	0,67	0,72	0,63	0,65	0,60		0,49	0,67	0,80
My colleagues are adequately trained in emergency procedures	0,64	0,49	0,45	0,74	0,59	0,73		0,62	0,77
Emergency drills are conducted as prescribed	0,67	0,58	0,54	0,58	0,57	0,89	0,70	0,70	
When I enter a new ship I always receive a proper hand-over	0,63	0,58	0,46	0,53	0,46	0,78	0,42	0,65	
Accidents and near-misses are always reported according to company orders	0,50	0,61	0,61	0,43	0,50		0,70	0,43	
My suggestions about safety will be acted upon if I express them to senior officers on board	0,60	0,42	0,52	0,53	0,69		0,51		
My suggestions about safety will be acted upon if I express them to management on shore		0,50	0,63	0,49	0,78		0,61		0.85
Senior ship's management ensures full cooperation between all onboard departments		0,54	0,54			0,53	0.44	0,47	0,87
The catering services for the crewmembers are good	0.52	0,45	0,42				0,51	0.64	0,59
This company practices the highest maintenance standards	0.50	0,62		0.50	0,47		0.67	0.42	
I am proud to work for this company	0.58	0,52				0.58	0.70	0.58	
It is the practice to report colleagues who can not perform their duties due to alcohol or drugs		0,41	0,50			0,45	0,44		0,66
I am encouraged by my seniors to report any unsafe conditions I may observe		0,62	0,66		0,65			0,60	0,66
I am sure management will never compromise safety for profitability		0,42			0,51		0.70	0.44	0.48
I am normally consulted on matters that affect the performance of my duties.		0,48			0,47		0,59	0.42	0.91
I know the proper channels through which questions regar. Safety procedures should be routed			0,46	0.48	0,47	0.45			
I like my job	0.46					0.44	0.68		0.80
Items in three companies		2		1			2	1	
Items in two companies	1		1	2			3		1
Item in only one company	1	1				1	2	1	5

1: Based on two factors in where one is in *italic* font. An additional commitment factor was identified but not included in the table

6.2 Search for cultural patterns in communalities

The regression lines of the correlation between the various matrixes are plotted in figure 8. The lines indicate that all companies have higher correlations with the safer companies irrespective of variations in national cultures. This indicates, as assumed that there are more variations among culture of the less mature natures. A similar approach is presented in the right chart based on the correlation between the rankings of the communalities. The communality of an item reflects the portion of its variance that is common with other items. High communality values indicate that the item is suited, together with the other items to form principal components. A low value indicates that the items variance is independent of the other items. Items having communalities lower than 0.5 are removed in a typical principal component. In this study however, it is assumed that the communalities reflects the structure of the principal components. This indicates that the communalities of the less mature companies are more similar the other companies of low standard. Together the two charts illustrate that the variations among mature cultural patterns are less than the variation among immature cultural patterns.

However, there are also some common aspects of the variations in the immature cultures.

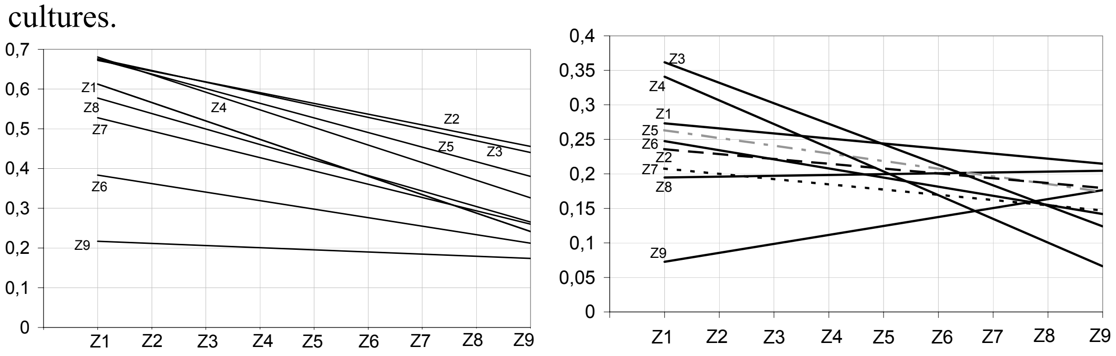

Figure 8: Relationships between different companies.

Now the correlation between the rank order of the communalities for various companies and the ranking of the companies were calculated. High positive correlation values indicate that lower standard companies (Z9 is most unsafe) have higher communality ranking (rank order 1 is the smallest communality). Vice versa high but negative correlation values indicates that the communalities are higher for the safety companies. For some items their varying communalities seems to be stable across company borders. The item having an absolute correlation value larger than 0.3 is presented in table 4. It can be seen that six of the items in the left column describes operational aspects relative to prescribed procedures (row 1, 3, 7, 8, 13 and 14). In addition row 15 is related to checklists. Three items describe address aspects of hierarchal levels (row 5, 9 and 10). Two items are related to recognition of individual aspects (row 5 and 11). At the right column the content is of another character. While the items in the left column is related to normative behaviour in relation to procedures, the right column address descriptive aspects of the safety related to fatigue and tackling critical situations (row 1, 3, 4 and 12) and communication (row 7, 10, 13 and 14). Items related to Job Satisfaction are explicit (Row 1, 2, 5, 11) In fact none of the items in the right column are addressing normative behaviour.

Table 4: Items distinguishing the lower safety standards and the higher safety standards

	Higher communalities for lower safety standard		Higher communalities for higher safety standard	
1	Accidents and near-misses are always reported according to company orders	-0,86	Crewmembers are well trained to cope with fatigue.	0,79
2	The catering services for the crewmembers are good	-0,73	It makes no difference to me which company I sail for.	0,73
3	My colleagues are adequately trained in emergency procedures.	-0,65	Even when fatigued, I perform effectively during critical times of operation.	0,64
4	People should be aware of and sensitive to the personal problems of other crewmembers.	-0,62	Our training has prepared the crew to work as a well co-ordinated team in an emergency.	0,63
5	Many junior officers are reluctant to assume full responsibility for their assigned tasks.	-0,58	I am proud to work for this company.	0,56
6	This company practices the highest maintenance standards.	-0,56	I support attempts to reduce the manning level on board ships.	0,54
7	The organization's rules should not be broken - even when the crewmember thinks it is in the company's best interest.	-0,46	Briefings important for safety	0,52
8	My colleagues frequently carry out secondary tasks while on watch.	-0,44	Drugs present a safety problem in my company.	0,48
9	I am reluctant to disagree with my superiors.	-0,43	Alcohol presents a safety problem in my company.	0,47
10	Seniors should delegate responsibilities to junior crews as parts of their training.	-0,37	Asking for assistance makes one appear incompetent.	0,40
11	Effective team co-ordination requires team members to take into account the personalities of the others participants.	-0,37	I like my job	0,39
12	I am normally consulted on matters that affect the performance of my duties.	-0,35	I am ashamed when I make a mistake in front of other crewmembers.	0,34
13	During the nightwatch I stick strictly to written orders, whether I agree with them or not	-0,34	My suggestions about safety will be acted upon if I express them to management on shore	0,33
14	Emergency drills are conducted as prescribed	-0,34	I know the proper channels through which questions regarding safety procedures should be routed.	0,31
15	Checklists are essential for safety	-0,31		

Table 4 suggests that attitudes towards compliance have a stronger emphasis in the more substandard companies. In table y it can also be seen that the only item that is more frequent among the safer companies is "*My suggestions about safety will be acted upon if I express them to senior officers on board*". The similar shore item aimed at shore-based management is seen in row 13 of table 4. Both these items are typical items reflecting the crew's perceived commitment towards safety. The principal components were searched for the most explicit items related to compliance (row 7 and 13). The concentration of the two compliance items was significantly higher in the companies of lower safety standard as presented in table 5.

Table 5. Occurrence of items in different principal components

Concentration of compliance items	Company								
	Z1	Z2	Z3	Z4	Z5	Z6	Z7	Z8	Z9
The organization's rules should not be broken - even when the crewmember thinks it is in the company's best interest	0	0	1	0	0	1	1	2	2
During the night watch I stick strictly to written orders, whether I agree with them or not	0	0	1	0	0	3	1	1	1

7. DISCUSSION OF RESULTS

There are several aspects of this study that require discussion. It has been demonstrated that the principal components are similar for different companies having different nationalities and safety standards. The dependencies between the item correlation matrixes from different companies were all statistically significant. The most general components were called Safety Rehearse, Commitment, Communication, Job Satisfaction, Acknowledgement of Personal Limitation, Work Integrity, Social Integration and Power and Dignity. These principal components are also seen within organisations from other domains. This might in fact indicate that there exist a restricted number of universal components that can be found in most organisations. Taking this view the results of a principal component analysis may be restricted to confirm that the analysed group fits the universal norm. These traditional approaches may therefore bee seen as normative. This confirms Guldenmund's (2000) point of view that it is needed to consider the underlying patterns in greater detail. Instead of asking what the principal factors of a dataset is, it might be more interesting to describe what actually differ from the universal norms. Such a shift makes the concept of safety culture more precise and makes the distinction to safety climate more explicit. It is then necessary to see what the effects of this shift are. It might imply a different type of questionnaires that includes items that are designed to address these underlying values. Another approach is to develop techniques that more specifically analyse underlying patterns. It would be strange if Spearmann's Factor Analysis and Pearson's Principal Component Analysis, developed more than 100 years ago, would precisely address the features of a concept we even today have problems of defining. Safety culture is a new concept that has its special and unique characteristics. Probably are both new questionnaires and techniques necessary to fully analyse the maturity of safety culture. It seems, however, as if there is a need for techniques that are tailor made for safety culture. This justifies the idea behind the techniques developed in this study, without claiming that they are optimal.

The first of the developed techniques give attention to variations in the dependencies between items in a questionnaire. These dependencies are represented as correlation coefficients calculated from the item responses. It is first assumed that environment and governing hazards are universal for different shipping companies. In the long run it is probably one or a few cultural patterns that appear as efficient in handling this environment. Therefore, it is fear to imagine that the variations in the pattern of correlations between companies having a high cultural standard is smaller compared to the variation in pattern between companies having a low safety standard. If one company have more similarities to a range of other companies compared to another, this indicates that the first company has a more optimal pattern. Because the correlation values have the possibility to reflect far more variations than the extracted principal components, they are considered to be of a raw or unrefined quality. This is necessary in order to detect underlying patterns. In a theoretical point of view this method may therefore seem to be more in line with definitions of safety culture compared to existing techniques.

The techniques do however also need to demonstrate to be efficient in a real context in order to justify its validity. The scatter diagrams in figure 6 demonstrate that the resulting indicator has a relationship to safety performance. In order to be confident in these relationships alternative explanations has to be out ruled. Alternative explanations might be that the variation in samples size or national culture correlated with the ranking of safety standard. The national cultures are known to wary along the axis including Singaporean, Indonesian, Scandinavian and other national cultures in an unstructured order. It is known that different national cultures are known to influence the strength of response. The applied measurement does however not address the absolute values of responses, only the correlation between items. Further, if national cultures should explain the dependencies, the correlation between the companies of similar nationality would be even higher than the estimated ones. Even though such high dependencies would invalidate the indicator, it would also invalidate our present understanding of safety culture. Such high dependencies imply that the universal safety cultural pattern have almost no variations across company borders. Such a universal pattern can not explain variations in performance between companies and safety culture would then be unimportant. If the indicator is invalid it is therefore more likely that the dependencies are related to variations in sample sizes.

The correlation value should always be seen in relation to the applied scales and the number of data points. As the number of data points increase, both the coefficient and criterion for significance is reduced. It is known that the significant value of correlation coefficients reaches an elbow at 50 to 70 data points. This implies that the sample size has to reach this level in order to converge to reliable estimates. Therefore, there is a chance that the correlation matrixes from companies of poorer safety standard include more spurious correlations. Especially the relevance of company Z9 may be criticized. On the other hand, because the correlation coefficient decreases with increasing sample size, it might be questionable to compare the matrixes of the larger samples with samples of average size. In order to answer these questions random samples of 80 respondents were taken from the larger samples, and then the excise was carried through again. As all companies now have about the same number of respondents variations in sample size can be ignored. Now the correlations between the matrix indictor and the accident statistics indicator increased to significantly 0.84. The correlation with the safety inspection indicator was 0.67. If the company Z9 was excluded the correlations were respectively 0.78 and 0.80. These number shows that there is a relationship. Earlier the correlation between the two performance indicators was estimated to be 0.62. If we assume that the latter correlation matrix indicators are true, this indicates that safety culture maturity describe all of the correlation between the two performance indicators (0.62-0.80·0.78=0). Hence, the safety culture maturity may alone explain all the correlation between the two performance variables. Therefore, the importance of safety culture can be justified based on quantified estimates. As figure 4 show that company 1 to 5 might represent characteristics of about 30% to 40% of the ships in the world fleet quantification is also confirmed. It is possible to estimate what the effect will be if the safety performance of the remaining 60% to 70% of the worlds ships were improved to what is typical for a committed culture. Based on an estimated distribution of accident rate for the world fleet (Soma, to be published), it can be concluded that such a lift would prevent about 50%to 60% of today's accidents from occurring.

The next method illustrates that the less mature cultures do not only include spurious responses but also follows some sort of pattern. The idea of identifying the items that distinguished the safe companies and the less safe based on communalities may seem strange at first. However, as pinpointed earlier, the items having a high communality are typically present in several principal components and the other items explain a relatively high portion of their variance. These items do therefore in fact represent an underlying pattern beyond the principal components. In order to justify the content of these variables in a maritime context some descriptions of the maritime organisational cultures have been collected from literature. The managing director of the Central Union of Marine Underwriters (CEFOR) Forsmo's (2002) reflection of the history of maritime safety regulation during the 1980s was *" ... developing a maritime safety consciousness was needed. Terms such as "compliance culture" and "evasion culture" were introduced as opposites to the ultimate panacea "safety culture*". Holt's (1989) description of the typical shipping culture is that it is "…*characterised by quick decisions in buying and selling, short-term solutions, emphasis on technology and tonnage, and neglect of people and human values*". These descriptions can be considered as expert judgments from the professionals in the domain and are probably not based on empirical evidence. The content of the extracted items seems to catch these features. The content of the items sorted out by this technique indicate that the underlying pattern of the less safe companies attribute normative behaviour. This normative pattern focuses on uncritical compliance to procedures, explicit hierarchal levels and ignorance of individual needs. In contrast the underlying pattern of the safest companies address tackling of abnormal and critical situations. Abnormal situations involve fatigue, emergencies and communication about errors and worries. Also items related to commitment were more explicit in the pattern of these companies. Therefore the results from the techniques are consistent with real expert observations. Both underlying systems of meaning are within the concept of safety culture, but are of different characters, efficiency and direction of interest. When the system of meaning acknowledge that safety is important it catches interests and if safety improvements is interesting it has a meaning beyond compliance to regulations. The underlying systems of meanings for the less mature safety cultures are imbalanced and do not sufficiently comprise the human element, which is needed when controlling the governing hazards. What is the central difference between a culture commitment to safety and compliance culture? While a compliance culture is anxious to not meet prescribed rules and procedures, a committed culture lives in a constant worry of not meeting the relevant hazards. Gerald Wilde addresses this issue in his Risk Homeostasis theory (2001). He argues that focus has to be reached towards a future goal at all times, and not on conserving aspects such as rules, in order to continuously move the individuals levels of target (or optimal) risk. If the individuals' levels of target risk remain constant, fulfilment of strict procedures may give the operators an impression of unnecessary high safety, causing them not to avoid, or even seek, hazards not covered by the procedures. An opposing argument, experienced from one recent discussion into the importance of safety culture, was that *"it is irrelevant what the crew on a ship thinks, as long as they do what they are supposed to do"*. The problem is that in at least 80% of the ship accidents, the crew did not do what they were supposed to do. This was not because they did not want to act correctly, but rather that their context forced, or lead them, to do so. It is also recognized that human failure has dominated over the technical failures for at least hundred years within the maritime domain. Considering the vast technological innovations that have taken place, it does not seem reasonable that further improvements in technology efficiently improve safety. In an economical perspective it is even rational to withdraw some of the technological artefacts and instead use the saved resources on making the context of the operators more advantageous (Krappinger, 1971). Jens Rasmussen describes this as behaviour shaping features and criteria in his theories of Managing Risks in a Dynamic Society. He stresses that given the rapid changes in technology, competence, market conditions and political climate in combinations with the high loss potential in our current society, it is not rational to control behaviour through a normative approach e.g. through rules of safe conduct. Charles Perrow's Normal Accident Theory may also support the focus on interests. Even though he refuses to accept that it is possible to totally control high risks solely through management, he recognizes that the theories of High Reliability Organizations, headed by La Porte and Consolini (1991), have a positive effect. Besides stressing the importance of group interests he is also addressing the relationship between power and interests in a risk perspective.

There are other studies supporting the distinction between commitment and compliance cultures. In analysis of organizational cultures Quinn and Rohrbaugh (1983) classified four stereotype cultures based on two dimensions. These dimensions were Organizational Process ('Organic' versus 'Mechanistic') and Organizational Orientation ('Internal' versus 'External'). The four stereotypes of organizational cultures are the Adhocracy culture, the Clan culture, the Hieratical culture and the Market Culture In a analysis (Baker and Hawes,) of the organizational cultures of 173 different U.S. land based companies, the four stereotypes in table 7 were identified. However, the most significant clusters were the cultures having an 'Organic' process versus the cultures having a 'Mechanistic' processes. In this context the Commitment culture revealed in this study seems to have similarities to the 'Organic' cluster, while the Compliance cultures have relations to the 'Mechanistic'. Covin and Slevin (1989) described the differences between the two Organizational Processes as " *'Organic' structures permit rapid organizational responses to changing external environments, while 'mechanistic' structures are better suited to predictable environments where rapid organizational responses are not typically required*". Baker and Hawes found that the adaptability of the 'Organic' cultures made a good combination with a high degree of market orientation, which in turn resulted in a higher economical performance relative to other combinations of culture and market strategy.

The results of the study seems to be in line with existing knowledge within safety management, such as risk homeostasis theory (Wilde, 2001), safety management understandings provided by James Reason (1998) and Jens Rasmussen (1997), High Reliability Organization (LaPorte and Consolini, 1991) theories. Because focus on compliance ignores the possibility of unforeseen system interdependencies and may take away the need for understanding the systems real functioning, even aspects of Charles Perrow's Normal Accident Theory (1999) may support the results of this study. It is also worth noticing that this study actually validates the distinction between two levels of the Keil Centers, Safety Culture Maturity Model (2001) as the main difference between the compliance and commitment culture is involvement of the crew. It is also worth noticing that the involvement level is quantified as slightly better than the average.

7. CONCLUSIONS

This study has presented and validated a new tactic for measuring safety culture maturity. In contrast to existing techniques, which treat the cultural factors as independent aspects, the new technique focuses on the underlying pattern of dependencies between variables. In addition to valid quantifications, it is stressed that the method is more in line with the conceptual understanding of organizational safety, as well as definitions of safety culture. Even though it is demonstrated that the developed indicator describe all of the relationship between safety inspections and accidents, it is believed there is still potentials for improvement. It has been proved that organisations having different nationalities and safety performance have a similar superficial safety cultural pattern. The variations in the shared pattern are smaller among organisations having a high safety standard compared to organisations of lower safety standard. The underlying cultural pattern of the less safe organisations put emphasis on normative behaviour, hieratical levels and lacking acknowledgement of individual needs. The safer organisations have an underlying pattern that put emphasis on tackling of abnormal situations like fatigue, emergencies and communication of errors and worries. This pattern also explicitly comprises rudiments of job satisfaction.

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A SEARCH FOR RISK DRIVERS IN THE FREIGHT MARKET

Commercial ship accidents - a macro level perspective

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ABSTRACT

This paper explores the relationship between the cycles of the shipping freight rates and time of ship accidents for the whole 20th century. In 1939 Koopman published his discovery that the cycles of the freight rates were determined by the overbuilding of ships during peak freight rates. Because it takes some months to build the ships, they are launched when the market is in recession causing the freight rates to decrease. For this book Koopman received a Nobel price. Even though his theories have been improved by several later contributions, there have been few (if any) studies that explore if the same dynamics have an effect upon the daily operation of ships. This is surprising because the costs of even small delays may be extreme during a market peak, while a ship loss or lasting docking may be profitable during a market depression. It is therefore fear to assume that the commercial interests in safety follow the freight rate cycles. This study demonstrates that the shipping market, probably through strategic and tactical decisions, in fact has dominated the occurrence of ship accidents for more than a century. While variances in strategy, in average causes some companies to double its accident risk, the various tactical decisions foretell when accidents will occur. The findings are discussed with reference to other industries, concepts like safety culture and risk homeostasis theory.

Keywords: Safety culture, maturity, analysis of patterns

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1. THE FRAGMENTED WORLD OF SAFETY MANAGEMENT

The 1980s was full of disasters. Chernobyl, Piper Alpha, Alexander Kjelland, Challenger, Bophal, King's Cross, Herald of Free Enterprise and Estonia are some examples. The investigations into the range of these disasters revealed several characteristics. Human failures dominated the accident scenarios. Safety culture was assumed to be essential, because the organisations demonstrated impoverished attitudes towards safety (Reason, 1997). Organisational changes were considered to be of importance because several of the companies behind the disasters had economised on organisational resources prior to the accidents (Pat'e-Cornell, 1993; Vaughan, 1996). The increased focus on buzz-codes, like "outsourcing", "downsizing", "contracting" was by some seen as hazardous tendencies (Hovden, 1996) (Rasmussen, 1997). At last Perrow (1999) propose that it is normal to fail for any complex, tight-coupled system.

Therefore these designs require an intense safety commitment from both the managers and the operators on order to avoid accidents. Reason (1998) states that a recurrent accident scenario included at least three elements. The Universals (1) represents the ever-present hazards, the Local traps (2) are the characteristics of the work place that lure people into repeated patterns of unsafe acts and the Drivers (3) that make people do erroneous behaviour. Waagenaar (1997) suggests that an accident investigation should only focus on the causes that may reoccur. Rasmussen (1997) even indicates that it is unintelligent to focus on anything else than the Drivers of the recurrent accident scenarios.

Even though disasters seemed to be relatively frequent during the 1980s, the causal attribution to organisational factors is old within shipping (Soma, 2003). In contrast to new technologies like aviation, nuclear power plants, space shuttles and large industrial plants, ship technology has a long history. Today's Universal dangers within shipping also dominated a century ago. The task is then to understand what the Drivers behind these accidents actually are. In 1907, following a year of extremely high Norwegian losses focus was not only assigned to equipment and organisation but also the relationship between management commitment to safety and their commercial strategies. Emphasis was assigned to short business horizons and some even suggested that the over-insured ships deteriorated the aversion towards accident risks (Kysten, 1907). Even a former prime minister of Norway, Michelsen, openly stated: "*the best business a ship owner could do with his new bought ship was to let it be lost in an accident*" (translated).

While organizational factors have been an issue for a whole century, a modern interpretation is linked to segregation of management responsibilities triggered by cost-cutting motives. The segregation of the traditional shipping organizations can be demonstrated by the Independent's (1996) description of accidental vessel called Sea Empress "*Built in Spain; owned by a Norwegian registered in Cyprus; managed from Glasgow; chartered by French; crewed by Russians, flying a Liberian flag; carrying an American cargo, and pouring oil onto the Welch coast*". As a response to this negative focus the most recognized association for contract managers, the International Safety Management Association (ISMA), has formulated the following description of the 1980s and 1990s on their web page: "*Ship managers had been made scapegoats for perceived deterioration in shipping standards over the proceeding two decades. The argument ran that, with the replacement of the traditional ship owner structures by new types of owner such as K/S investors, third party managers had become the instrument of cost-cutting and shoddy operations.*". These statements tacitly indicates that the relationship between economical parameters, management structure and operational safety. Even though these expressions have not been supported by sound accident investigation findings nor empirical evidence. This study provides this evidence.

2. THE STRATEGIES FOR UNDERTAKING COMMERCIAL RISK IN SHIPPING

"*If you don't get your market right, you don't do anything right*", states Tronstad in his report of commercial risk taking in shipping. Commercial risk can be separated into financial risk and business risk. While financial risk is associated with financing and investments, the business risk is associated with the employment of the resources provided by the investments (Tronstad, 1980). There are at least three stereotype strategies to manage the commercial risks in shipping (Norman, 1981). These are labeled the ship speculators, the industrialists and the visionaries. The typical shipping speculator chose to carry a significant share of the financial risk and earn profits on asset play. Asset play is to buy a ship when its market value is believed to be below its future value, and sell it off when the market value is believed to be over its value in a future market. A fifteen-year old vessel can be bought to one third of the new-building alternative, and its value is relatively stable in a stable market. Because the speculator's ships are old, they have relatively less time to get profit on their investment. Therefore they attempt to await the market with untied ships in the tramp markets. Ships are only tied up in irresistible time-charter or bare-boat agreements. The time perspective on their investments is typically from a few weeks up to a few years. They are dependent of a high earning within the remaining lifetime of the vessel. Because the asset values are of most concern they register their ships in Flags Of Convenience (FOC). This allows them to sail with ships that not comply with the regulative requirements and reduce the cost of the crew. They know that when the transport demand increases, their reputation and safety standard is of secondary importance. They consider the value of the vessels, and the risk of accidents, to be covered by insurance. Even though old ships have higher maintenance costs, this can be justified by their lower investments costs. In sum this strategy opens for the possibility of huge benefits for a reasonable price.

The second stereotype is the shipping industrialist. These stable and large companies have a long business horizon, up to several decades into the future. Financial risk is avoided, but they are competitive in controlling business risk. They buy new ships directly from the yard and sell off when they reach a high age, typically over fifteen years. The newbuildings enter a signed time-charter agreement or a specific liner route. They may also have several ships in the spot market, because this is beneficial in the long term or to fine-tune their commercial risk. Their large size requires solid management. Their strength is their well-established trademarks, giving them competitive advantages. Because of their large market share these companies also obtain advantageous treatment by cargo owners, in ports, by insurance and by classification societies. They have a relatively new fleet, which in average is younger then 15 years (Soma, 2003). The new ships may have some deficiencies from their birth. As the experience with the ship increases these problems are dealt with and improved, while also new problems occur.

While the industrialists engross the majority of the worlds' tonnage, and the speculator controls a considerable smaller portion, the shipping visionaries are in significant minority. These companies are similar to the industrialists in terms of ignoring the current state of the freight market, but more comparable to the speculator when it comes to market strategies. They are called visionaries in this text, because they are disciples of their forecasts and think they understand the market far better then their competitors. It is extremely difficult to be in the lead in international trade. On a specific route or specialized trade it is far easier to outline money-spinning forecasts. Their strategies of buying and selling ships are rooted in their own predictions and not the present market state. Therefore, these companies can find rational arguments to buy ships even at peak values. While the speculators have a narrow time perspective, and the industrialist's plans far into the future, the forecasted scenarios determine the visionaries' focus. In contrast to the industrialists, the visionaries are willing to carry considerable financial risks. Their foresights often imply a fast growth and aggressive acquirement of ships and competing companies. Therefore external finance is also expended. Because such finance has a short horizon, from a year to five years, it is necessary to produce money fast. The forecasted scenarios, determines their purchase policy.

Table 1: Simple characteristics of various commercial strategies

The shipping stereotypes	Market forecast	Organizational Focus	Success criteria
The visionaries	"I know best"	External: Future market conditions	Reach targeted goals
The speculators	"I know something"	External: Current market conditions	Produced gains
The industrialist	"I know-nothing"	Internal	Smooth running

3. THE THEORIES BEHIND THE CYCLES OF SHIPPING FREIGHT MARKET

The shipping markets can roughly be divided into the liner market and the tramp market. In a liner market the shipping company have a fixed route between defined ports, sailing according to a given schedule. In this market type there are many customers that each have relatively small portion of the total cargo. The liner companies therefore decide their freight rates based on what the customers are willing to pay independent of the transportation expenses. In contrast, the freight rates of the tramp markets are compelled by the dynamic relationship between supply and demand of transportation. The spot freight rates are given per ton of commodity carried on single voyages. The time-charter agreements are typically give on a stipulated rate of hire, typically for several months, according to the carrying capacity of the ship. Although the spot and time-charter rates may vary on an hourly basis, the large fluctuations are more rare. Occasionally, in a cyclical manner, the freight rates suddenly grow significantly. During a market-peak a shipowner in the spot or tramp market may in a few months earn enough to finance his new-launched 70 million-dollar VLCC (Very Large Crude Carrier). The second-hand value of ships may at the same time rise 300%. The reason behind such peaks may of course be related to both a reduced transportation supply and an increased demand.

There are three theories explaining the cyclical tendencies. Koopmans (1939) stated that the demand for shipping transportation was relatively stable. Therefore he argued for that the cycles were generated within the shipping market itself. He focused on the delay from a ship is being ordered until it is put into service as the explanation. Because the ships are typically ordered when the rats are high and launched in large quantities when the market is in recession the weak markets turn into more serious depressions. Although some shipowners need additional tonnage during a depression, the poor market opens for the alternative to charter cheap bare-boats. The future investment in new ships has also a smaller net present value and it is easier to get external financial support in a good market. In some cases the market is so overconfident that more than 100% financial cover is obtainable.

Zannethos (1966) expanded Koopman's theory. Zannetos's argument was that Koopmans's theories should produce gentle symmetric cycles and not peak cycles as are experienced in reality. Therefore, he added the market's over- and under- confidence to the explanation of the cycles. While ordinary supply-demand curves has a single equilibrium, the over and under confidence in the shipping market produced two additional, but unstable equilibriums at respectively very high rates and very low rates. These theories have later been verified with more advanced computing (McConville, 1999; Veenstra and de la Fosse, 2003). Stopford (1998) has a more ad-hoc explanation for the peaks in freight rates. Even though the demand for transportation is stable, a war or political decisions increase the transportation distance. If for instance the Suez- or the Panama channel close this will significantly increase the sailing distance and the available shipping supply is suddenly insufficient.

4. The 20.th century's development of the shipping market

Although the shipping market is known for its possibility of generating large profits in short time the long time perspective is quite different. In general the profits on the investments would be larger in the average stock market (Stopford, 1998). During some depressions the shipowners pay the shipping out of their own pocket. Other vice, the ships are put in lay-up, scrapped or sold for remarkably low prices. The spot market rates for the 20th century and the world fleet size are plotted in figure 1. These rates are collected from four different sources (Stopford, 1998). The relative difference between these periods (1890-1914, 1921-1939, 1947-1997 and 1997-2003) is not known.

Therefore are values on the ordinal scale not included. The graphs do however distinguish between good and poor shipping market conditions.

According to Stopford (1998) the large market peaks typically have a return period of seven years. The first nine market cycles in the 20th century are presented high in figure 1. These cycles are ranked based on its explicit shape and strength. In the figure the sinus shape is multiplied by its ranking order (9 is the most explicit and strongest, 1 is relatively indistinct). A real cycle may be of a more unsymmetrical or skewed nature. Anyhow it worth taking notice of that cycle five was the strongest and one of the shortest cycles. This cycle was both initiated and ended with exceptional high freight rates. Cycle three and nine reflects the most depressed market cycles. Fearnleys Annual Review (1985) described the later period as: *"The last ten years of capital drain in the tanker industry have no historical precedent and we have witnessed a decimation of shipping companies which has probably no parallel in modern economic history, even taking into account the depression of the 1930s. The surviving member of the Independent tanker fleet must be akin to those of the of the world's endangered species whose survival appeared questionable in a changing and hostile environment, but instead shown a remarkable ability to adapt."*. In other words the companies with a long perspective on their business remained in the market i.e. industrialists. Stopford also described the 1920s as a stable market with no room for asset play.

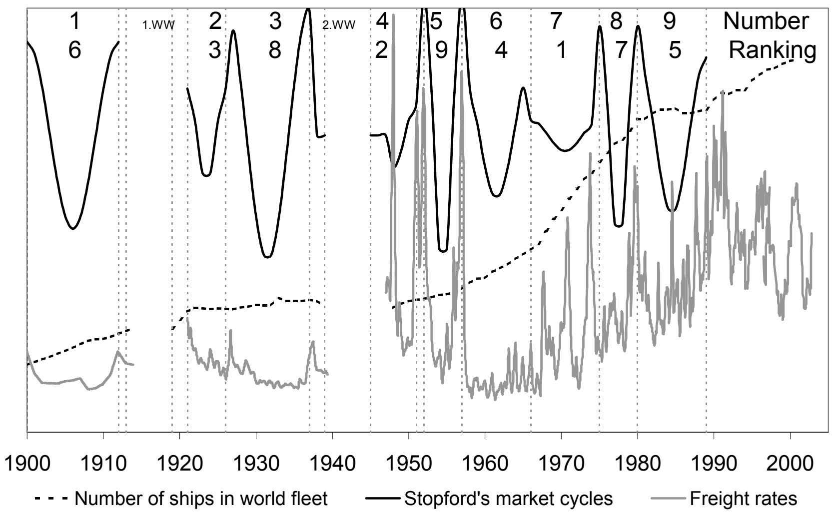

Figure 1: Freight rates, market cycles (Source: Stopford, 1998) and size of world fleet (Source: LMIS)

Zannetos (1966) demonstrated that the freight market determine the shipping supply. While the building of a new ship typically takes a year, the delay of scrapping and docking has sudden effect. It is therefore three data sources that reflect the market condition. The freight rates on the spot rates reflect the daily market state. Freight rates for time-charter agreements roughly follow the spot rates but are generally lower and more volatile as they include expectation into the future market conditions. The difference between these rates may indicate the confidence in the market. If the difference is high, the conjecture indicates a belief in lower freight rates in the near future, and vice versa. The third data source is the changes in fleet size. If the order books at the yards are full and few ships are being scrapped, this indicates a good market, and vice versa. Because it is cheaper to build new ships in a poor market, there are examples that ships are build on speculation of higher rates in the near future. Even though it is most common to build ships that fit a specific time charter agreement or a specific route. Because it takes some time to build a ship, the fleet size data responds slower to changes. On the other hand a confident market may not be reflected in the freight rates if there is a parallel growth in shipping supply. Consequently, a market drop is most efficiently identified by a fall in freight rates, while growth in fleet size dominates an improving or confident market.

5. Strategic influences on safety

The different commercial strategies imply different attributions towards commercial risk taking. It is therefore tempting to assess if the various approaches commercial risk have an impact upon safety. The total loss ratio for the last century is plotted in figure 2. This data reflects the ratio of the motorised vessels over 100 gross tons that are lost due to an accident scenario (Source: LMIS). This plot demonstrates that there has been a significant reduction in the loss ratio the last century. In average, the yearly improvement is 2,4% (Ponce, 1990), but as the plot in figure 2 illustrate these improvement have been sporadic. After the 2.WW it was a huge emphasis on increased international safety regulation. The period from mid 1930s until the late 1970s seems, however, to vacillate around a loss ratio of 0.65%. The major improvements occurred in the 1920s, the 1930s and after 1980. These time periods have earlier been pointed out as the periods when the long strategically time perspective governed the market. It should be noted that some percentages of the world fleet was laid–up during the 1930s and the 1980s. Due to the lower activity level the real drops in loss ratio may stretch over a few more years. For instance the world laid up tonnage was 35% higher in 1932 compared to 1929 (League of Nations, 1939). However, 1936 the laid-up tonnage was back to the level prior to the depression. If we consider the improvement from the early 1920s to the mid 1930s, the drop is roughly 50%. A similar drop appeared during the 1980s.

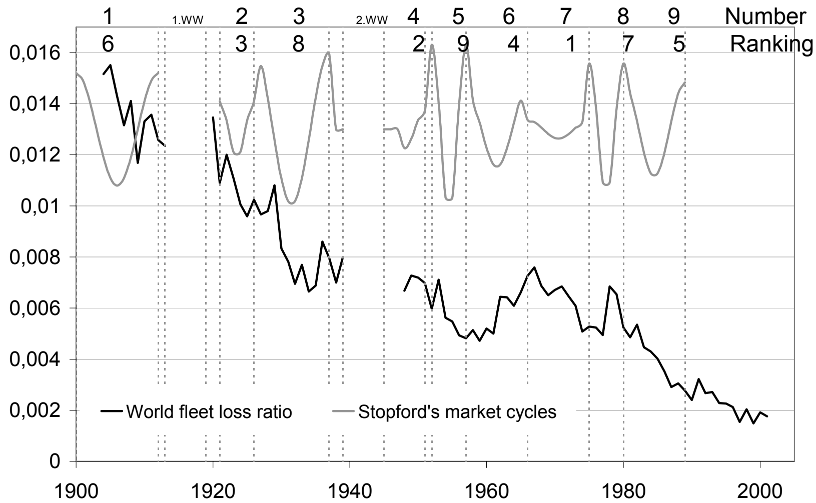

Figure 2:Total loss ratio (Source: LMIS) and market cycles (Source: Stopford, 1998)

Because the industrialists have the motivation to survive depressed market conditions these companies are in general older then the speculators. Since the industrialist buy more ships from the yards they have a younger fleet. A small company may buy and sell their whole fleet based on speculations. Extremely large companies have relatively less possibility to gain on such short time speculations. An interview survey on shipbrokers accomplished by Tamvakis and Thanopoulou (2000) found that the vessels age were the most trusted quality criteria. They further concluded that 15 years represented an age where the quality shifted. But the most interesting finding was that the bulk market was not willing to pay for quality, giving no motives for the shipping companies to invest in quality and safety. In the post Erika tanker market old ships obtain somewhat lower rates in a poor market. It might be suggested that the reduced loss ratio during the two depressions (figure 2) were related to a new fleet. This hypothesis can be rejected when considering figure 3. The chart shows that the main improvement during these periods was related to improved navigational standard (Collision and Wrecked). As these accidents are highly caused by human failures it seems as if the companies that have a long business horizon have organisations with higher human reliability.

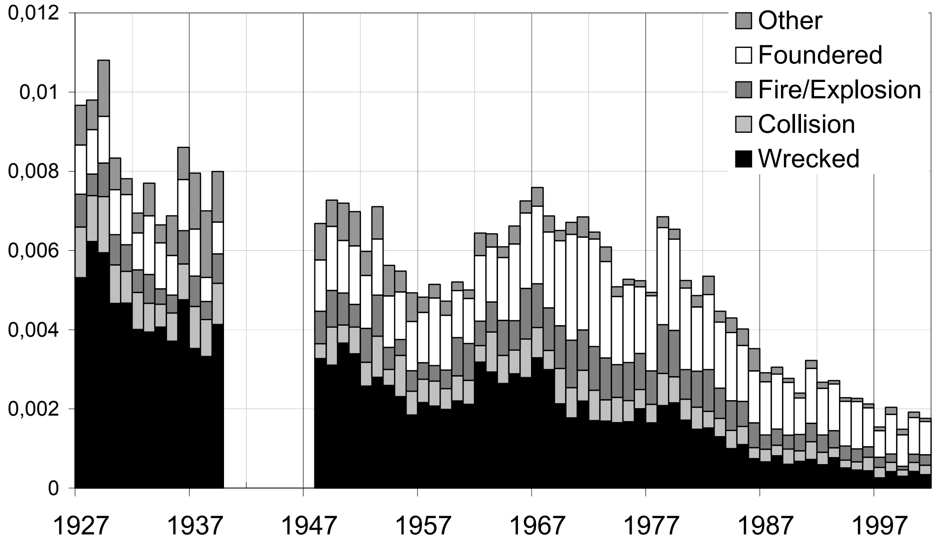

Figure 3: Categories of the world fleets' total loss ratio (steam & motor ship larger than 100 gt.) (Datasource: LMIS)

6. ARE THERE INDICATIONS OF A RELATIONSHIP BETWEEN MARKET STATE AND ACCIDENT RISK?

Intuitively one may expect that any extreme market situation have a bad effect upon the accident rate. It could be assumed that good times causes companies and operators to take unnecessary high risk because of the great profits involved. During depression it is also believable that the safety focus is reduced and thereby increasing the risk of accidents. In figure 4 the annual change in total loss ratio and the annual change in freight rates are plotted together. The chart illustrates that prior to the second world war the fluctuations seems to be in phase. Peaks on freight rate series seems to roughly match peaks in total loss ratio series. In 1906 for instance, when the decrease in freight rates leveled out the total loss ratio nearly 170%. After the Second World War the relationship changes, however. The dips in the freight rate series seem to match the peaks of the total loss series.

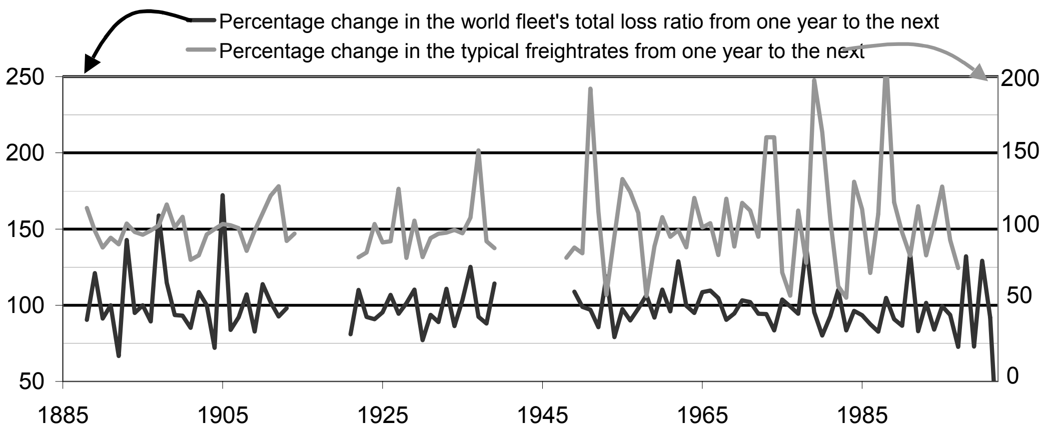

Figure 4: Annual percentage change in freight rates and total loss ratio for the world fleet

To verify the relationships that vaguely can be seen in figure 4 several studies have been accomplished. For instance the freight rates are plotted along with the last century's major ship accidents. The accidents causing more than 100 fatalities are included before 1970. After 1970 all accident causing more than 250 fatalities are included. It was found that years representing peaks and dips each roughly stands for 30% of the of the total time period. The improving and decreasing market years each stand for 20% of the years. When taking account for these differences in time exposure, it can be found how the market situation influences the accident risk. After the 2.W.W. the accident risk is almost perfectly moved towards an opposite phase (figure 5). This means that depressing years involves the highest risk, while the safest years are when the market improves.

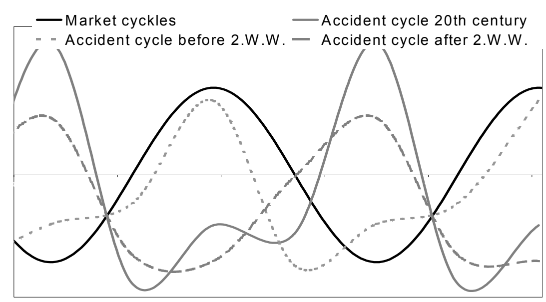

Figure 5: Relationship between market cycles and accident risk

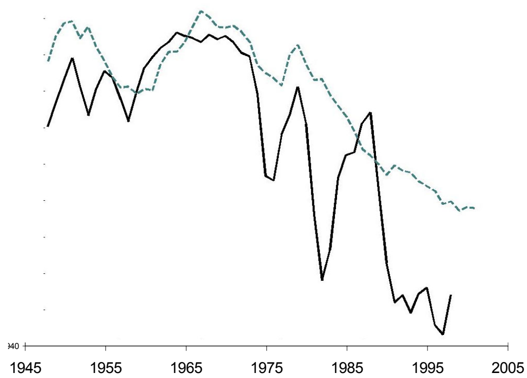

Figure 6: Total loss ratio and freight rates (inversed)

To roughly test the negative relationship between economy and accident frequency the post 2. w.w. freight rates series are compared with the total loss ratio. Because the freight rates are volatile the relationships are difficult to see. Therefore, the fluctuations were tuned down by use of a moving average approach. Each data point represents the average of the last few years. The new series is then inversed and put on top of the total loss ratio. The inversion is done to assess the negative phases found in figure 4 and 5. As figure 6 illustrates, the relationship between the loss statistics (dotted plot) and freight rates (solid plot) may also be seen at this approach. The peak to the right in figure 6 is the only fluctuation that is not reflected in the loss statistics. It should be recognized that this peak is the inversion of the market drop that forced the speculators out of the market (cycle 9 figure 2). This indicates that the companies that have a long time perspective have a safety-standard that is relatively insensible to a poor market. It should however be mentioned that the late 1980s and the early 1990s a number of disasters such as Herald of Free Enterprise and Dona Paz in1987, Exxon Valdez in 1989, Scandinavian Star in 1990, Agip Abruzzo, Haven and Salem Express in 1991, Aegan Sea in 1992, Braer in 1993. Simultaneously the insurance claims increased by 200%. These characteristics indicate that there is a peak in accidents seriousness also during the 1984-1993 peak (figure 6), even though the frequency of losses decreased (dotted line).

7. ANALYTICAL APPROACH

There is one problem in directly comparing data from the freight market with accident statistics. The freight rates are increasing over time (Figure 1) while the corresponding characteristic for the accident frequency is decreasing (Figure 2). It is therefore advantageous to analyze the series with respect to more short term fluctuations. Both the slope of the world fleet size series and the loss series have varying strength. By focusing on this strength, the relationship between market condition and accident frequency can be considered in more detail. Therefore the analytical focus in the subsequent study is concentrated on the curvature of the time series. The whole series are therefore sorted in convex and concave segments through calculation of the approximate second order derivative (δ^2X/δ^2t). A positive value indicates a convex curve segment ($\cup$), while negative values indicate a concave curve segment ($\cap$). The approximate second order derivative of the series are calculated by a Matlab 6.1 software.

As indicated in figure 5 it was suggested that the accident frequency and market cycle before the 2.W.W. followed the same phases. The second derivatives of the freight rate, the world's loss ratio for sail and steam ships with respect to time is plotted in figure 7. The plot for the steam ship has the most stable characteristic. The correlation between the freight rate series and the sail ship loss series is significantly 0.59. If the three last years were rejected the correlation would grow to 0.66. Even though the plot for the steam ships is less stable, it still follows the same phases. This tendency is not properly reflected in the correlation coefficient. Also national fleets follow the pattern illustrated in figure 7.

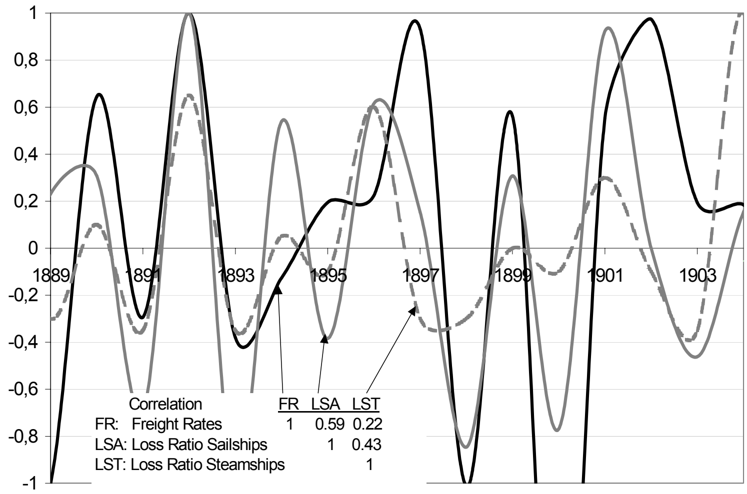

Figure 7: 2.derivate of total loss ratio, fleet size and freight rates 1889-1904.

It is not certain when and why the relationship between the market state and accident likelihood changed from following the same phase to the opposite one. Some explanations will later be provided. During the 1930 the relationships become more complex. The same analysis performed for this time period indicates that the accident frequency follows the freight rate when the market drops and then shift to follow the fleet size when the economical conditions improve. As suggested earlier this shift is expected, but makes the quantitative relationships difficult to compute. Figure 8 illustrates the 2. derivatives in the period 1923 to 1938. Figure 9 presents the same plot for 1972 to 1985.

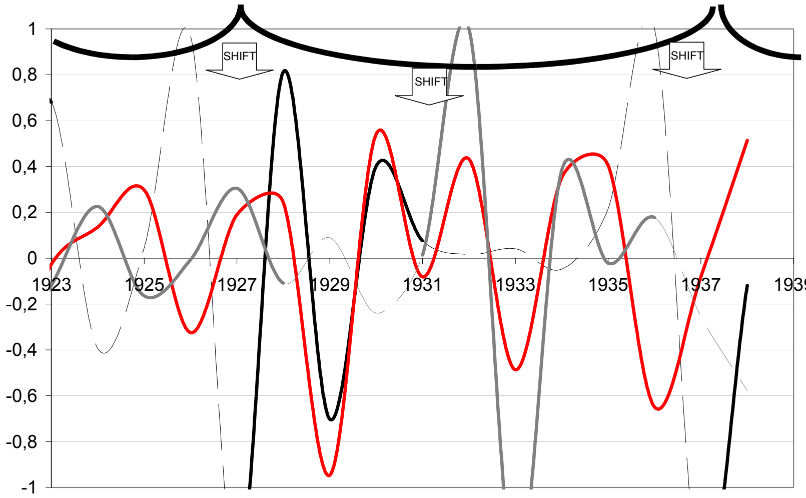

Figure 8: 2.derivate of total loss ratio, fleet size and freight rates 1923 – 1938.

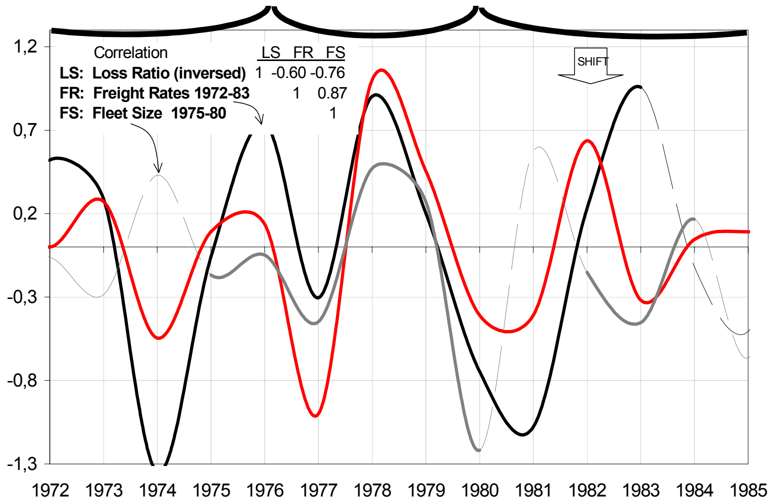

Figure 9: 2.derivate of total loss ratio, fleet size and freight rates 1972-1985

The described relationship between the growth of the world fleet size and loss ratio improvements should be inspected in more detail. If this dependency is strong it should also be evident for individual ship types. The two ship types involving large risks to respectively environment and human beings are the oil tankers and the passenger ships. Figure 10 show that the tanker fleet size had a peak at the late 1970s and a dip at the late 1980s. The growth of the fleet carrying passengers (Passenger General Cargo, RoRo passenger, Passenger liners and cruise and ferries) is more stable. There is however are also a varying growth rate for this fleet segment.

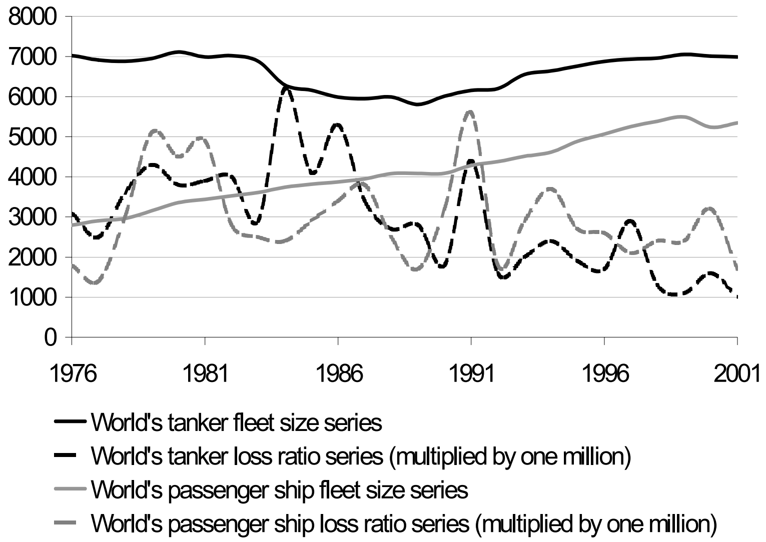

Figure 10: Loss ratio and fleet size for passenger and tank ships

While tankers often are built to fit a general market need, the passenger ships are built to fit a specific route. The passenger ships are therefore considered to be more individualist then their tanker sisters. A passenger ships first route is therefore likely to be her optimal environment. If however, a passenger ship later is moved outside her planned route the design mismatches are more obvious then for tankers. During a period of large needs for passenger transport a large portion of old vessels are being put into new routes.

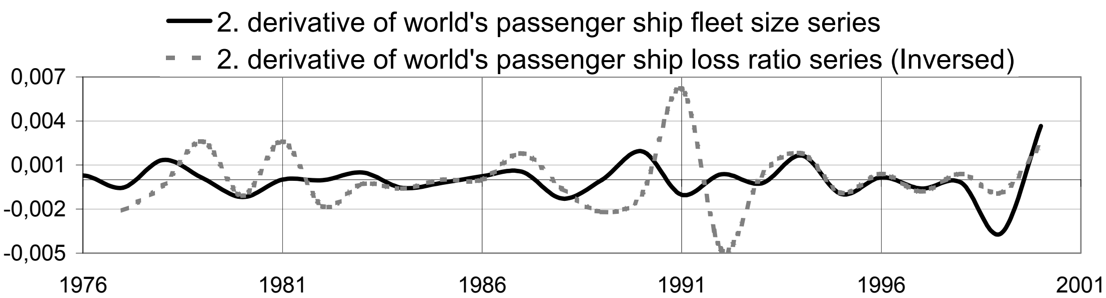

Figure 11: Passenger ships 1976-2000

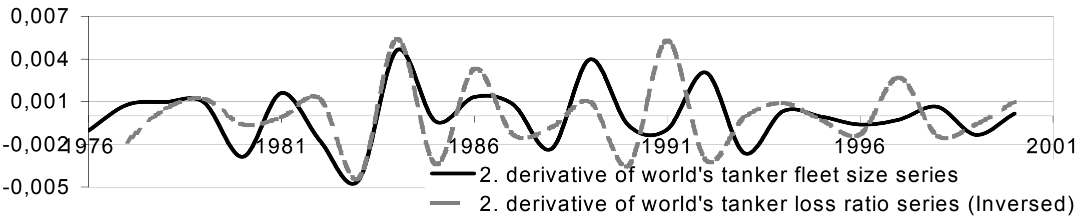

Figure 12: Tankers 1976 - 2000

In statistical terms we know that increase in world fleet size is a result of more ships being birthed relative to ships being scrapped. Full new-building order books and a reduced scrapping rate is therefore a certain indicator of a lucrative shipping market. Because it takes about one and a half year from a ship is ordered until it is launched, new building decisions are rooted in a longer time perspective. A delay in scrapping date is however immediate. This is an advantage for companies emphasizing on short time speculations. A fleet of old ships is therefore more likely to catch the benefits related to short time peaks in transport demands. Old ships also require less capital and therefore involve less investment risk. Besides gambling on freight rates these companies get a high profit if they sell off their old ships when the freight rates are high. These ships are off course also bought of companies attracted by older ships. Because the freight rates follow rapid changes the new built ships are typically set into the market when the peak is over, causing the rates to decrease even faster. A good freight market is therefore relatively more stressing for the business of companies having old ships.

The calculated second order derivate of the worlds' yearly ratio of ships lost due to respectively foundering, fire or explosion, collision, and grounding. The graphs are relatively volatile and generally out of phase. Five times, however, the four curves are in equal phase. The fact that they are in phase five times is not surprising, because it is a fair chance that they should be that within the specified time. What is more noteworthy is that the series are in phase exactly on five out of six of the most severe depressions within the given time frame. The collision curve was the only curve out of phase on the sixth depression (dark gray arrow). Anyhow, it is highly unlikely (significance level << 0.001%) that a procedure that randomly selects five periods should all match the serious depressions. It is therefore proved that the in-phase characteristics between different types during depressions are not random.

8. Summary of Results

The periods when speculator strategies are forced out of the shipping market the loss ratio drops with 50%. The increases in loss ratio when the market recovers are on some trades of the same size. Because the speculators have some differences regarding the age of their fleets, it is also possible to estimate differences between the speculators and industrialists by comparing various age segments. It is recognized that the total loss ratio, serious accident ratio and average number of safety inspection finding increases with 50% when considering old ships (older than 15 years) relative to the new ones (younger than 15 years).

Before the First World War changes in the total loss ratio was positively correlated with changes in the freight market. The general characteristic after the Second World War is that the same variables are negatively correlated. Between the world wars it seems as if the freight market correlated during a market fall, while the growth in world fleet correlated during recovery of the market. The fact that the world fleet grew before the freight rates recovered indicate that there was built ships on speculation. If however, this period represents a general shift in commercial strategies is however not known. When the market was really depressed during the 1980s, indicating low grade of speculations, the total loss ratio seemed to again be positively correlated with the freight rates. During a depression all types of accident scenarios are affected (Fire/Explosion, Foundering, Collision and Wrecking).

There are in summary at least three important results that can be drawn based on the preceding analysis. The first is related to strategic focus. The second outlines the continuous relationship between market condition and total loss ratio. At last it is proved that this relationship affects all types of accidents. The casual explanation behind the identified relationships is unknown. Therefore these results are discussed with reference to various paradigms within safety management. From shipping we know that during periods of poor markets there is a tendency to downsize the organization through outsourcing various functions to contracting firms. Therefore the economies of for instance ship owners and contract managers are in opposite phase. If this is the causal explanation behind the opposite phases of in figure 18 is unknown.

9. DISCUSSION OF RESULTS

The findings of this study raise several questions. Knowing that there is a statistical relationship between economical conjectures and operational safety, what is the then casual relationship? This is necessary to understand in order to take implement this knowledge in daily operation. Even though the true explanations are unknown, the results are discussed with reference to established theories. Because the rise in accident frequency is dependent of economical parameters, the first issue to discuss is the decision making of the top-level management. One approach is to consider risk homeostasis theory. Risk Homeostasis is a psychological concept that is claimed to govern human behavior towards risk (Wilde, 2001). The concept assumes that any person has an inherent optimum level of tolerable risk. This level is called the target level of risk. If a person perceive that his risk exposure deviate from the target level, he will instinctively and unconsciously correct this deviation by changing behavior. An implemented safety measure that is perceived to be extremely effective, may therefore have a minor or even negative effect, if the operators target level of risk is not simultaneously lowered. Wilde (2001) assumed that the target level of risk was determined by the following four categories of motivating factors (table 2)

Table 2: Factors determining the target level of risk

Factor	Relationship to economical perspectives
A	The expected **advantage** of comparatively **risky** behavior alternatives.
B	The expected **costs** of comparatively **risky** behavior alternatives.
C	The expected **benefits** of comparatively **safe** behavior alternatives.
D	The expected **costs** of comparatively **safe** behavior alternatives.

Wilde has studied risk homeostasis within traffic safety. His study considers the relationship between a population's prosperity and traffic deaths. That approach is therefore in principle similar to the one applied in this study. Wilde found, however, that wealth had an increasing effect upon the accident frequency, which is the opposite of the conclusions of this study. If the employment is high there is a tendency to drive more hazardous. Even though organizations consist of individuals this does not necessarily imply that the risk homeostasis principal is valid in organizational safety. With reference to the motivating factors (A-D) Wilde have complied the following explanation: "*When the economy is in a recession, the benefits expected from risky behaviour are reduced, because time is worth less money. There is less to be gained from driving many km and from driving fast. There is less to be gained from driving through a red or amber light or from cutting corners in other ways*".

Table 3: Examples of Risk Homeostasis theories

Factor	Car	Shipping in a good market	Shipping in a poor market
A	Gaining time by speeding	Increase profits	Cost saving
B	Repair expenses, insurance surcharges	Potential disruption in income	Insurance coverage
C	Insurance discount for safe driving	Higher income, branding	Branding
D	Uncomfortable seatbelts	High operational expenses	High operational expenses

Based on the rationality presented in table 3, the operational tactics may change with the market conditions. In turn the tactical decisions influence the organisation thorough organisational changes, cost cutting and reduced manning. According to Cameron and Quinn (1999) changes that are carried thorough without a concurrent change in the organisational culture will fail. He states that: "*This dependence to organizational improvement on culture change is due to the fact that when the values, orientations, definitions, and goals stay constant – even when procedures and strategies are altered- organizations return quickly to the status quo. ... failed attempts to change, unfortunately, often procedure cynicism, frustration, loss of trust, and deterioration in moral among organizational members*.". Schein (1990) deified culture as "... *a pattern of basic assumptions, invented, discovered or developed by a given group, as it learn to cope with its problems of external adaptation and integral integration, that has worked well enough to be considered valid and, therefore, is to be taught to new members as the correct way to perceive, think and feel in relation to those problems.*" If the group is defined by the organizational boundaries it is considered as the organizational or corporate culture. As Schein indicates in his definition, culture can be explained based on the external and internal focus and on how the cultural pattern fit (adaptation / integration) with the environment. Based on this duality four different stereotypes of organizational cultures can be defined (figure 14).

There are several characteristics of the shipping environment that determine or at least influence the presence of the cultural stereotypes in figure 13. There is a range of hierarchal levels within the company from the owner, managers, masters, officers and down to the able seamen. The increasing regulatory regimes, that originated at the early beginning of the 20th century and grew significantly after the Second World War, has caused an extensive volume of compulsory rules and procedures that govern all sea born operations. The work onboard is today governed by professional rules and procedures. Before the 20th century the know-how was given by principles of "good seamanship", which were passed on from the old hand to the recruits through training, supervision and correction of unacceptable behaviour. The change over the century therefore represents a shift in organisational focus from the internal flexible (clan) to a more internal stable (hierarchal). This shift is typical for any organisational cultures. Over time it has a tendency to become more stable (Cameron & Quinn, 1999). While the seaborn organisations are of an internal-stable format, the land-based organisation can be of an extremely external and flexible character. These cultural elements might be extremely present for speculating strategies. For example several enormous investments are based solely on the managements' intuitions. Ships may be bought one day and sold the next. The stable internal organisational focus onboard the ships facilitate the process in changes in ownerships, as new qualified crews can easily be put together on new ships. The visionaries are typically of a more stable external focus. The main external criterion is market share, while the internal organisation can also be arranged to simulate a market.

The internal-flexible elements are known to be of a poorer standard within shipping. Holt described the typical shipping culture "*...characterised by quick decisions in buying and selling, short-term solutions, emphasis on technology and tonnage, and neglect of people and human values*". The lacking crew participation and job satisfaction have been identified by Parket et. Al (19xx) and Keltner (1995). It is natural that different commercial strategies result in different organisational cultures. For instance, is it likely that a shipping speculator need a more flexible management compared to an industrialist. The organisational focus onboard the ship is governed by international conventions such as solas, marpol, colreg and stcw. Therefore is the stable internal characteristic similar from one ship to the other. The investment in crew involvement varies from one company to another, but if the managers do not continuously put efforts in keeping it flexible, it will over time be more stable

(Cameron). Covin and Slevin (1989) describes the stable organizational process as mechanistic while the flexible were labeled organic. Based on their research they relate these attributes to how well they are suited for changes. *“”organic” structures permit rapid organizational responses to changing external environments, while ‘mechanistic’ structures are better suited to predictable environments where rapid organizational responses are not typically required*”. This indicates that the modern organizational cultures within shipping are less suitable to changes in the environment, such as an unpredicted hazardous situation or a sudden drop in the freight market.

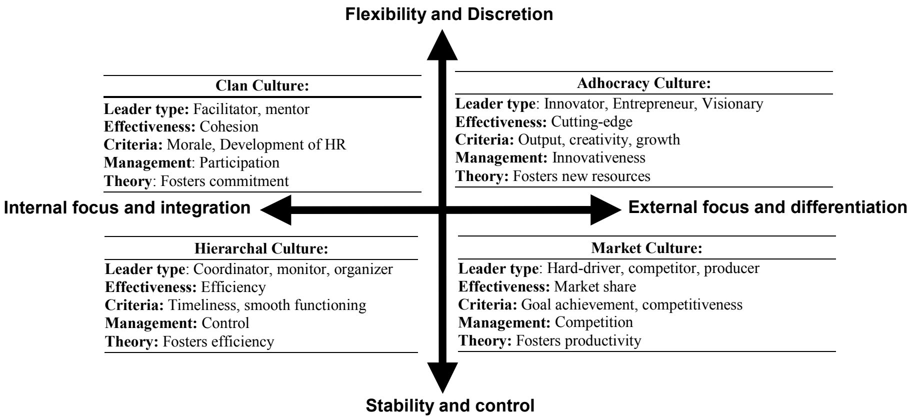

Figure 13: Outline of Competing Values Framework

The impact of economising on organisational features, such as reorganisation, outsourcing and contacting should be assessed in more detail. Such changes have both an immediate hazardous element and a more long lasting uncertainty. The immediate hazards are related to wholes in the experience and responsibility for the new structure. The uncertainties of a more long lasting effect are related to lacking communication and transfer of knowledge across the outsourced activates. It is possible to assess the importance of the first hazard. We know that Titanic founded at her virgin voyage and Scandinavian Star only sailed seven days in her new route before she became a disaster. Sleipner had been in operation for six months before she grounded and was not considered fully ready for service by the authorities. The Express Samina had been operated only nine moths under its new management before it hit some rocks outside Paros taking more than 80 lives. If experience influence on safety performance this may have an effect upon Port Stat Control inspection findings. Hence a random sample of nearly 400 passenger-carrying vessels is drawn from the International Association of Classification Societies (IACS) member fleet. The IACS member fleet covers about 98 % of the world fleet tonnage. PSC data for this sample is collected from the Equasis database. It is a common policy to target passenger ships having new managers for inspection. Therefore 45% of the sample had changed manager within the last four years. Data is collected for ships having the same manager throughout the four-year period, the group of prior managers and the group of new managers. The PSC distributions for the three groups are presented in table 4.

Table 4: Importance of changes in ship management

		Deficiency findings [%]						Detention [%]	Chi-Test		
		0	1 and 2	3 to 5	6 to 15	16 to 30	31 or more		Un-changed	Prior	New
Unchanged	938 inspections on 215 ships	43,4	16,8	17,2	17,5	3,9	1,2	7,4	1	0.92	0.79
Prior managers	586 inspections on 177 ships	43,9	15,4	14,5	19,3	4,8	2,2	6,0	0.92	1	0.87
New managers	304 inspections on 111 ships	38,8	15,8	19,1	20,7	3,9	1,6	7,9	0.79	0.87	1

The table illustrates that there are some differences in PSC distributions for the three groups. These differences are not large enough to be statistical significant, but it is however not believed that the poorer performance of the new managers is spurious. The new managers had about 5% fewer inspections with zero deficiencies relative to the prior manager. With a large significance value of roughly 15%, it can be showed that the new managers have more deficiencies per inspection then the other two groups. It should be noticed that it is the same ships, which form the basis of both the old and new manager groups. The four-year time frame is relatively small. Therefore the drop in performance is related to the managers, and not the ships degradation.

The passenger vessels being totally lost in Europe during the period 1985 to 1998 is analysed based on information from Lloyds register. Only 40% were carrying passengers at the time of the incident. This is also an indication of that non-routine operations may impose the largest risk. 30% of the vessels were lost under severe weather conditions. 34% had been taken out of operation and were lost during repairs etc. These non-routine conditions and the fact that any accident scenario by nature is unrealistic have given foundation for conspirator theories and rumours of insurance frauds. Over time it is recognized that several shipowners have earned large profits on the loss of over-insured ships. Given the huge amounts involved, it is in some cases likely that the champagnes pop at the investor's office, when their ship hits the seabed. In some cases it is even suggested that the companies deliberately lose their ships.

10. RELEVANCE FOR OTHER INDUSTRIAL DOMAINS

It has earlier in the text been indicated that the theory behind the findings in the maritime environment is likely to be found in other domains. In fact there are several domains and accidents that easily fit to the picture outlined in this study. The several Russian nuclear submarine losses are probably not independent from their reduced budgets. Fargola (2001) describes how the conjectures of the oil prices influence on the oil companies' willingness invest in operational features. One of the major findings in the Norwegian risk monitoring of offshore installation, are the uncertainties related to budget cuts (Oljedirektoratet, 2002). It has also been speculated upon the almost simultaneous electric power losses in Sweden, Italy, Denmark and USA at the spring in 2003 was a result of the competitive pressure on production. NASA is another candidate. The Columbia investigation report (CAIB, 2003) seem to emphasized on parallels to this theory by concluding that *"Throughout the decade, the Shuttle Program has had to function within an increasingly constrained budget. Both the Shuttle budget and workforce have been re-duced by over 40 percent during the past decade. The White House, Congress, and NASA leadership exerted constant pressure to reduce or at least freeze operating costs. As a result, there was little margin in the budget to deal with unexpected technical problems or make Shuttle improvements."* In both the Chernobyl and Seveso disasters the exact knowledge of what happened is unavailable. In Chernobyl, it is assumed that the accident was triggered by a series of six violations. In addition, safety was not prioritized in the design and selection of location for the state owned nuclear power plant. In Seveso the operators also failed to comply with the operating procedures. In both disasters the evacuation was delayed due to late announcement to the public.

Table 5: Summery of external characteristics for some major disasters

	Economical parameters and other external goals
Three Mile Island	The maintenance force was overloaded at the time of the accident and had been reduced in size during an economizing drive (Kemeny, 1979)
Piper Alpha	Economic pressure (Pate-Cornell, 1993), The government required that the platform should be fitted with a Gas Conservation Module, which had to be located at the available but an unfortunate location (Cullen, 1990)
King's Cross	..it is my view that the level of resources and degree of vigour they applied to enforcements ... were insufficient. It was in this climate that poor housekeeping and potentially dangerous conditions in underground stations were allowed to persist. (Fennel, D., 1988)
Challenger	Economic difficulties had focused the attention of NASA decision makers on the launch schedule, which became the means to scarce resources for the space agency (Vaughan, 1996)
Columbia	The organizational causes of this accident are rooted in the Space Shuttle Programs history and culture, including the original compromises that were required to gain approval for the Shuttle, subsequent years of resource constraints, fluctuating priorities, schedule pressures, mischaracterization of the Shuttle as operational rather than developmental, … (Columbia Accident Investigation Board, 2003)

The listed examples in table 5, and several more have already been related to cost cutting. It would therefore not provide much new insight in detailed analysis of these. James Reason has found a more incomprehensible development in UK (Reason, 1997). He describes the progress in the British industrial accidents: *"Between 1971 and 1980 there was a clear downward trend in overall numbers of both fatal and non-fatal accidents…. But from 1980-81 onwards, the UK industrial accident rate leveled out and then began to increase. More people were being seriously injured in the manufacturing 1981-85 period the and construction industries at the end of then in then beginning. The causes of this upturn are still obscure."* Obscure causes give opportunities to demonstrate the applicability for new theories. Therefore, the trends in accidents for the UK are selected for more detailed analysis. The UK is highly internationalized and is large enough to provide solid data, but at the same time enough concentrated to assume that different industries are acting in a similar environment. The Health and Safety

Executives (HSE) has been a significant player in the development of European safety policies and provide available data on the Internet.

Since the 1950s and the 1960s the UK's economy was stable. The inflation rate had a small peak in 1951 of 12%, but the remained under 5% most of period. The Gross Domestic Product (GDP) had continually increased, generally more than 2% each year (figure 15). Unemployment had been stable at 2%. At the turn of the 1970s the inflation increased somewhat. The growth in the GDP peaked to a value of 7% in 1973. Then suddenly, in 1974 the world economy turned downwards. For the first time on several decades there was a negative growth in the GDP. Inflation grew to a value of 15% in 1974 and peaked to a value of 25% in 1975. Unemployment rose slightly, but stabilized and had a decreasing tendency in 1978 and 1979. The growth in the GDP turned back to a stable positive level in 1976 and onwards. In 1979, however, the British economy was again hit by the conjuncture of the world economy. Again the growth in the GDP turned negative and the unemployment doubled on slightly more than one year. The inflation rate, which had been decreased significantly since 1975, also doubled in 1980. Again, the world economy recovered and by 1983 the economy had again stabilized. Unemployment, however, kept increasing until 1986 when it again showed a decreeing tendency. The British economy managed to be uninfluenced by the fall in world economy in 1985 –86. But, just when the economy seemed to have stabilized another shock appeared in 1988, when the growth in GDP again turned red. Inflation again peaked, but to a somewhat lower level then earlier. The decrease in unemployment rate again flatted out and nearly doubled during a few years. The periods 1974-75, 1979-81, and middle 1988-92 represent the only three periods with a negative growth in GDP after the 2.WW. In 1956 to 1958 the growth of the UK's GDP was below one percent, which remained the lowest record until 1974. In 1957 the second worst train accident in the 20th century where 90 people were killed and more than 170 were injured.

The large economical impacts in during the described periods required new measures. It is natural that cost saving, is the most ad-hoc alternative. "*British industry is seen as being too partial towards its shareholders and top managers at the expense of investments, its workforce and its customers*"(Gower, 1989). One can than speculate into why the UK's major accidents occurred during these periods. A small crack on a tank at the chemical plant Felixborough resulted in improvised repairs to keep up production. The insufficient repairs resulted in an explosion that destroyed the whole plant and killed 36 people in June 1974. As Reason has indicated the continuous decrease in accident rates turned in the early 1980s. While three of UK's 29 most serious train accidents after the 2.WW occurred in the first period (1974-75), nine of these accidents occurred in the latest period (1988-92). While these depressions represents about 16% of the time more than 40% of the accident train occurred within these time periods. It is statistically improbable too randomly select nine out of 55 years that catches 12 out of 29 accidents (5% significance level). In addition the fire at King's Cross took place a few months prior to the 1988-92 period (November 1987), resulting in 31 deaths. The Herald of Free Enterprise capsized in March 1987, killing 192 people. The Piper Alpha platform exploded in 1989, killing 165 workers. The number of serious accidents within airborne traffic is smaller. However, even by ignoring the airplane bombed over Locerby 1989, there is a slightly higher density within of accidents in the 1988-92 period.

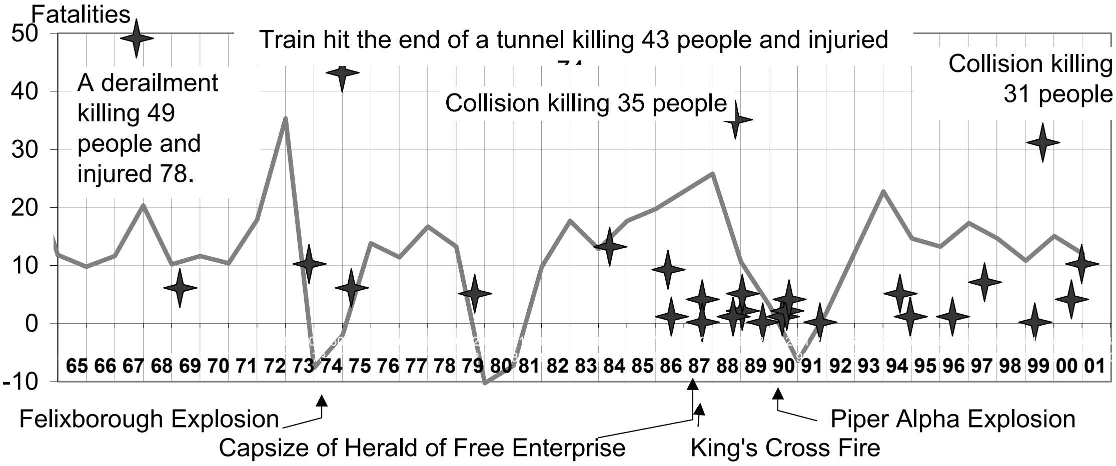

Figure 14: Changes in UK's GDP [*5], their major train accidents and some disasters plotted with respect to time

What seems strange is that the 1979 to 1981 period seemed relatively safe. Reason, however, claimed to see a change during this period. The political situation changed significantly at the mid 1980s. The European Community challenged the barricade against free competition. The idea behind the EC was to establish a space without inner frontiers, in which the freedom of movement of goods, people, service and capital is ensured. However, still in the middle 1980s, the border controls within the EC where relatively stringent. Proposals for opening the inner market were getting more support, and in 1985 a white paper that outlined realisation of the four rights of freedoms was presented. The EC policies, together with the Thatcher regime caused an increased economical pressure in the later 1980s.

Figure 15 gives a hint of what James Reason (1987) called obscure causes really was about. In this plot the annual fatal injury rates (per 100 000) as reported to all UK's enforcing authorities for respectively employees and self-employed industrial workers are plotted with solid lines. The annual change in GDP presented in figure 15 is inversed and adjusted to fit the scales of the fatal injury rates (figure 16). It can be seen that there was a significant decrease in GDP in 1980-81 and in 1988-92 (plot is inversed). It seems as if the self-employed are the ones most sensitive to economical conditions, which is what one would expect.

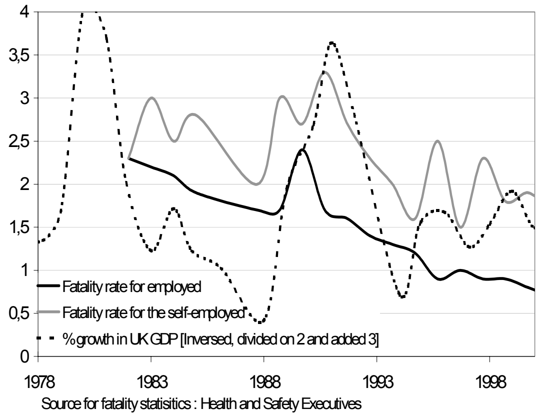

Figure 15: Uk's growth in GDP and industrial fatal injury rate

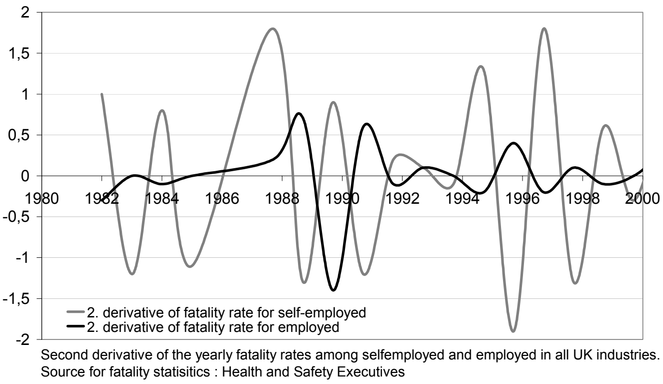

Figure 16: curvature of Uk's employed and self-employed industrial workers.

It has been demonstrated that today, the accident risk and the economical conditions are in opposite phase. Earlier it was demonstrated that the ship accidents at the late 19th century was in phase with the economy (figure 4,5) opposed to today. Also Wilde (2001) demonstrated that car accidents have a tendency to be in phase with a society's wealth. The fatal injury rate for the UK's employees and self-employed also has a tendency to be in the opposite phase (Figure 16). There are at least two feasible explanations behind these changes. The first explanation is that there are opposite phases between organizational or system accidents and individual or component accidents. Car accidents, and occupational accidents are typical individual accidents. According to Perrow accidents in the more traditional simple systems, like 19th century ships, are caused by component failures and not system failures. Modern ship designs are however of a more complex and tight coupled character. For shipping, the changes in phase may also be related to economical and regulatory parameters. For the last century the shipping market has changed dramatically. Before the First World War shipping was not well regulated. Ships in international trade had to comply both with their own national requirements and with the requirements of their visiting countries. This made the juridical and operational situation complex. Stopford describes the market: "*Although in the period before First World War the shipping market was intensely cyclical, conditions were generally prosperous, and freight market booms more than compensated owners for the difficult times during recession.*" During the latest decades however, the ship owners would in general earn more money through investments in the open stock market (Stopford, 199). The dotted line in figure 1 illustrates that the world fleet had an exponential growth in the period 1947 to 1980. During the 1980s the growth in the world fleet was marginal, but in 1991, the growth speeded up again. 1991 can be considered as a turning year. First the tankers spot rates at dropped by nearly 30%, before it again grew by 50%. During 1992 the rates again dropped 60%. Such enormous fluctuations attract ship speculators represented an end to the drop in total losses from the early 1980s. The dry cargo time-chartered rates also dropped about 40% in 1992. For the first time in almost a decade the total loss ratio increased (figure 2). This tendency can also be seen on the plots for the tanker and passenger ships in figure 10.

11. CONCLUSIONS AND FURTHER WORK

This study has demonstrated that there is a relationship between economical conditions on a macro level and the average accident frequency. For ships the relationship prior to the 1.WW was positive indicating that good economy resulted in increased accident risk. The same relationship has been found for cars (Wilde, 2001). On the other hand ships after the 2.W.W. have a negative relationship. When the economy is good the accident frequency is low and vice versa. This negative relationship was also found for large-scale accidents during the 1980s. The UK's fatal injury rate also has a negative relationship when the economical conditions change significantly. Is should be noted that fatal injury rates both included organizational accidents and individual accidents which might have different characteristics influence. In summary, the considered ship accidents and several of the major disasters may very well be named system accidents, organizational accidents, or even normal accidents. But this study also puts them in an economical perspective, which is even closer to the core causes. It is therefore justifiable to call these accidents "commercial accidents".

The true casual explanation behind the identified relationships are yet unknown. However, the established literature within safety management seems to support the findings on a qualitative level. The explanation that seems to be most reasonable is that stable controls such as rules and procedures are effective in limitation of the risk related to overproduction in a good market. When the economy is good the management can demonstrate commitment to their employees through extra resources, promotions etc. Employees that are involved indecision making and perceive a management commitment towards safety, have a tendency to have a better safety performance. This informal safety engagement is called flexible control. When the economy turns, the managers se a need for cost reduction. Decisions are taken without the involvement of the employees. Resources are held back and the salaries are frozen. Reorganization and manning reductions further reduce the responsibility, motivation and attention towards safety issues. Several accident investigators relate these characteristics to an immature safety culture. The stable controls are less effective during organizational changes. Hence the efforts of cost saving may deteriorate the flexible controls at the time when the stable controls are less effective. This causes the risk of accidents to increase.

To become more familiar with the casual relationships, a study should be carried out on a micro level for individual companies. This in the process of being finalized for a range of passenger and tanker companies. Also other industries should be investigated in more detail. Even though the relationships demonstrated in this study have not been outlined in such a detail earlier, the qualitative understanding of the relationships has been known. In the end the effective measures that make the managers able to control risk also during commercial changes have to be developed. Another issue that should be understood is why some systems have an accident frequency that is

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RISK DRIVERS IN THE LINER MARKET

Commercial ship accidents

- a micro level perspective into the passenger ship markets

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ABSTRACT

An earlier study has demonstrated that the intensity of maritime disasters increase in a depressed market. While that study pinpointed this relationship on a macro level, this study considers ten individual passenger ship companies. Based on economical performance such as net income or stock values and the point of time accidents occurred, it was estimated that the accident rate increased by a factor of 20 when the economical conjuncture turn from a good state to poor state. Even though this value is uncertain the last depression of the world economy can be read out of the companies' accident statistics, thereby proving that there is an inverse relationship between economical performance and accident risk.

Keywords: Safety culture, maturity, analysis of patterns

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1. INTRODUCTION

There are six well-defined conditions that might give a company a competitive advantage (Porter, 1980). These conditions include characteristics like high barriers for market entry (1), the uniqueness of the products (2), the customers (3) and the suppliers (4) dependence on the products and destructive rivalry among other competitors (5). At last, a large market share (6) is generally a competitive advantage. Larger companies have higher possibilities to compete on price and survive from a depressed market. In a free competitive market the relevance of the five first characteristics are reduced, increasing the relative importance of large market shares. However, Cameron and Quinn (1999) argue for that the suitability of the organizational culture often makes a difference. According to their Competing Values Framework, organisations that have a biased concentration towards market shares are too stable to efficiently tackle organisational changes. As a result homogenous free competitive market favours the companies that have large market shares, but at the same time the organisations that are too centred towards market shares are less suited for fast growth. Another aspect is that the allocation of resources for growth implies fewer resources allocated for operation and maintenance. In this context the decision makers are forced to make a trade-off between high commercial risk and high operational risk.

Roughly 80% of the accidents are caused by human failures, while the remaining part is of a technical nature. Statistics also indicates that the majority of ship accidents occur at times when the circadian rhythm of the operator is at a minimum level or is disturbed. Because it is difficult to assess if operators are fatigued or behave hazardous, it is relatively easy to unnoticeably or unknowingly cutback on safety. As a result the concept of safety culture was defined during the mid 1980s. Simultaneously, changes in the organizational structures were considered as hazardous. Buzz words like "outsourcing", "downsizing", "contracting" and "re-organization" worried the safety experts (Hovden, 1996; Cameron & Quinn 1999). Also inadequate resources and cost cutting had been evident in several of the disasters. These trends triggered the quality assurance reaction during the 1990s, but the totality of these characteristics and their relationship are yet unexplored. The missing feedback on actual accident risk has made Rasmussen (1997) propose a model describing how a company continuously move operation towards the boundary of functionally acceptable performance. When reaching this limit Rasmussen states that: "*Ultimately, a quite normal variation in somebody's behaviour can then release an accident. Had this particular 'root cause' been avoided by some additional safety measure, the accident would very likely be released by another cause at another point in time. In other words, an explanation of the accident in terms of events, acts and errors is not very useful for design of improved systems*". Therefore, in a qualitative sense, there exists a link between commercial strategies, safety culture, fatigue and accidents.

During an earlier study of the relationship between ship disasters and the state of the shipping market it has been demonstrated that these parameters are negatively correlated. In a poor market the frequency of disasters increase. This relationship was demonstrated on a macro level for segments of the world fleet at various periods during the 20th century. Because economical conditions seem to determine the likelihood of accidents, they are labelled "commercial". The relationships were both found on long time trends over several decades and the development from one year to another. To pinpoint on the yearly changes, comparisons were done on the curvature of the time series (second derivatives). Figure 1 presents the relationship between the curvature of the tanker fleet size (dotted and inversed line) and the fraction of ships being lost each year due to accidents. In a good market the fleet size increases (Koopmans, 1939; Zannetos, 1966; Stopford, 1997).

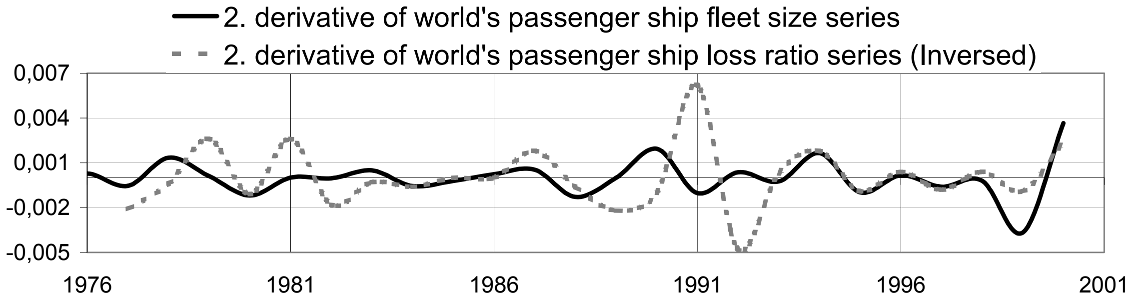

Figure 1: Dependency between fleet size and TLR for passenger ships on a macro level.

2. SCOPE OF STUDY

It has earlier been demonstrated at a world fleet level that disasters are more frequent in a falling market (Soma, to be published b). Detailed causal knowledge behind this relationship is not directly accessible even though there exist considerable research that may be relevant. The objective of this study is three folded. First, this study is to assess if it actually is an inverse relationship between economical parameters and safety performance at a company level. Secondly, potential causal explanations behind this relationship are assessed within an organisational context. Thirdly aspects of regulative and customer demands that may trigger the inverse relationship are explored.

Six passenger ship companies are considered in detail in this study. Of these companies Stena Line is the only considered company that has not been directly been involved in any disasters, and has over time obtained an image related to quality and safety. The development within Stena Line over time is however of special interest. The remaining five passenger ship companies are White Star Lines, Towsend Thoresen, Hardanger Sunnhordlandske Dampskipselskap (HSD) and Minoan Flying Dolphin (table 1). The economical development of the companies is described in terms of investments, stock values or annual results. Because the disasters themselves are a small dataset, both serious and non-serious accidents are collected from the Lloyd's Fairplay LMIS (Lloyd's Maritime Information Service) database. Both of these accident types are of a technical nature. Serious accidents represent those events when the ship requires assistance, such as collisions, extensive fires, groundings and loss of propulsion. The non-serious accidents are the reported incidents that are of a milder nature. In this way the relationship between the accidents and the economical power of the companies can be assessed. To control for possible placebo effects related to the accidents impact on economy two of Minoan Flying Dolphin's competitors, NEL and ANEK are also assessed. Similarly are three of HSD's competitors Troms Fylkes Dampskip Selskap (TFDS), Sogn og Fjordane Fylkeskommune (Fylkesbaatane) and Ofoten Vesteraalens Dampskip Selskap (OVDS) are assessed (table 1).

Table 1: Considered companies, their geographical area and scientific relevance

Area	Company	Scientific Relevance
Atlantic	White Star Line	Titanic (1912). 1500 fatalities
English Channel	Towsend Thoresen	Herald of Free Enterprise (1987). 197 fatalities
Kategatt	Stena Line	Retrospective
Mediterranean	Minoan Flying Dolphin	Express Samina (2000). 83 fatalities
	NEL	Placebo control of disaster impact
	ANEK	Placebo control of disaster impact
North Sea	HSD	Sleipner (1999). 16 fatalities
	TFDS	Placebo control of disaster impact
	Fylkesbaatane	Placebo control of disaster impact
	OVDS	Placebo control of disaster impact

3. REGULATING THE PASSENGER SHIP MARKET

The shipping markets can roughly be divided into the liner market and the tramp market. While the tramp market are governed by the tons of commodity carried or a rate of hire, the liner market is governed by the willingness to pay for transportation in a fixed route between defined ports, sailing according to a given schedule. Passenger ships are typically operated in a liner market. In regional and international routes (Transatlantic, English Channel and Kategatt) the liner companies act in a competitive environment, in contrast to the more lenient character of the traditional domestic routes. In Europe the governments has considered it reasonable to subsidise the domestic routes and control them through a licence system (Mediterranean and North Sea). In a safety perspective, the advantage of a liner market is the stable conditions that make it easier to learn about the governing hazards. Learning is crucial, as a passenger ship is typically specially designed for a given route, has frequent port leaves and typically crosses the sailing pattern of long distance cargo ships. In some cases the government also holds owner interests in the shipping companies. Actually all routes have periods of increased competition (table 2), generally influenced by the authorities.

Table 2: Considered companies, their geographical area and scientific relevance

Area	Time of increased competition	Regulatory factors influencing on competition
Atlantic	Late 19th and early 20th century	Increased transport, national competition
English Channel	Middle 1980s	Increased transport, privatization, tunnel, break-up of cartels
Kategatt	Late 1980s and early 1990s	Abolition of the duty-free sales, introduction of Flags of Convenience with low cost crews, bridge
Mediterranean	Late 1990s and early 2000s	EC compulsory tendering system, break-up of cartels.
North Sea	Late 1990s and early 2000s	EC compulsory tendering system, compulsory cost saving programs, bridge.

After the Herald Of Free Enterprise accident Crainer (1993) stated that "*Competition is traditionally based on the ability to meet timetable demands rather than on quality of service and safety. If a company fails to compete on these terms, it is simply fails to compete. Safety is not unusually deemed to offer a 'competitive edge'.* Even though safety and competition was seen as a critical combinations this was not considered when the EC compulsory tendering systems replaced the licence system at the late 1990s. A licence system implies that only one accredited company can operate in a given connection. Even though the licenses are given over a restricted number of years, it became common to automatically renew these licences. The disadvantage with a liner market is that the operation may be too stable. A secured market position, stable time schedules and a predictable environment might in fact produce an organisational inertia. Monopoly characteristics can also reduce the customer's opportunities to directly influence the decision making of the companies. In order to increase competition the European Community (EC) challenged the license barricades in the domestic routes. The idea behind the EC is to establish a space without inner frontiers, in which the freedom of movement of goods, people, service and capital is ensured. Even though this process started in 1968, there were still stringent border controls between the European communities in the middle 1980s. In the maritime arena this policy was strengthened in 1985 and 1992 (table 3).

Table 3: Some years of increased EC market regulation

Year	Topic
1968	Process of inner market started
1985	A white paper that outlined realisation of the four rights of freedoms was presented
1986	Council regulations (4055, 4056, 4057, 4058) were adopted to ensure freedom to provide services in ocean trade.
1992	A regulation (3577/92) specifically aimed at maritime cabotage (domestic transp.) was adopted. Even though the regulations should be implemented within 1998 there are still European routes sailing on licence.

For the ferry operators the article four of the 1992 regulation was of special interest, as it stated that the license system was to be revealed by a compulsory competitive tendering system, ideally within 1998. In principle this means that a ferry company may loose its right to operate on a specific route, if a competing company could offer a more attractive service. The article further states that all the Community shipowners should be treated equally. Therefore the allowed tender obligations were limited to concerning *what ports to be served, regularity, continuity, frequency, capacity to provide the service, rates to be charged and manning of the vessel*. Safety was seen as irrelevant, since safety should be ensured by other requirements and regulative regimes. In a shipowners' point of view, however, the obligations represent a ticket to trade.

Consequently, the strategies for the whole European ferry fleet had to be adapted to the competitive situation and the stated obligations.

4. ORGANIZATIONAL ASPECTS

In order to theoretically understand how the relationship between the market strategies influences on organisational features it is necessary to familiarise with the concept of organisational culture. Schein (1990) deified culture as "... *a pattern of basic assumptions, invented, discovered or developed by a given group, as it learn to cope with its problems of external adaptation and integral integration, that has worked well enough to be considered valid and, therefore, is to be taught to new members as the correct way to perceive, think and feel in relation to those problems.*" If the group is defined by the organizational boundaries it is considered as the organizational or corporate culture. As Schein indicates in his definition, culture can be explained based on the external and internal focus and on how the cultural pattern fit (adaptation / integration) with the environment. The theoretical model is entitled Competing Values Framework and is widely used within organizational analyses (Quinn and Rorbraugh, 1983) illustrated in figure 2. Based on these two variables Organizational Orientation and Organizational Processes it is possible to roughly describe the organizational culture within a company. The Organizational Culture Assessment instrument (OCAI) is a six-item ipsative questionnaire that is developed based on the CVF (Cameron and Quinn, 1999).

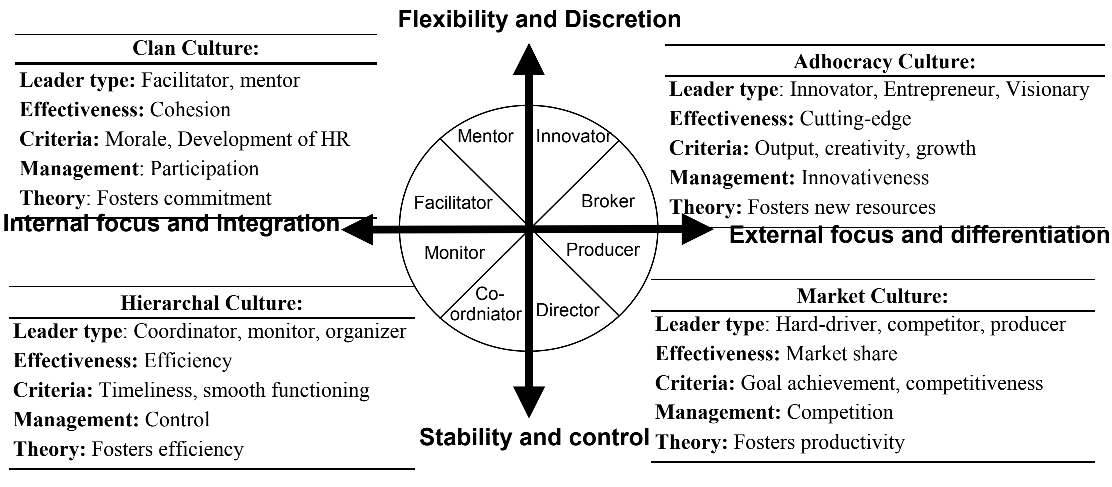

Figure 2: Outline of Competing Values Framework

Cameron pinpoint that the nature of the rapid changes in our dynamic society and the complexity of the organizations in principle favour specific organizational cultures. It is fear to assume that the organisational processes of a liner company adapt to the stability of its environment. In fact, it is known that over time the processes of any organisation tend to adapt processes of a stable and inflexible character (Cameron and Quinn, 1999). The relaxed business pressure, the invariable surroundings and the stable operation should further increase the stability of these organisations. Baker and Hawes (?) explored the organizational culture behind various market strategies and organizational performance. They found that the firms obtaining the optimal performance were those who had a high level of market strategies combined with an organic (flexible) culture i.e. Clan or Adhocracy. These cultures are also far better in tackling changes. A Clan culture involves management commitment and a decentralised organisation causing each employee to take responsibility and feel an ownership of the company's service or products. In (Soma, 2004) it is indicated that commitment is crucial to obtain a good safety performance. The operators perceived responsibility is in principle one of the major findings in LaPorte and Consolini's (1991) research into High Reliability Organizations.

5. The development of the Trans Atlantic competition

During the late 19th century the cross Atlantic traffic increased significantly. The international trade had been increasing and the American economy matured. Even though there was an open competition, there was also sharpened national struggle between the German, American and British steamers. Throughout the 1880s, speed was the key competitive factor. The Spanish-America war and the Boer war absorbed huge volumes of shipping tonnage. At the same time America export increased causing the cross Atlantic market too prosper. From 1900 to 1902 the number of passengers increase by 24%, and the annual number of passengers turned one million. Some shipowners realised that speed had been pushed to the limits, and that it would be favourable to relax the competition through development of a company structure that could dominate the market. These shipowners obtained financial support from an American magnate Pierpont Morgan who acquired the International Navigation Company, the White Star Line, the Belgian Red Star Line, the Domino Line, the Atlantic Transport Line and the Leyland Line, and formed his International Mercantile Marine Company (IMMC). When the war ended the market declined. This was observed prior to the formal takeover. It was realised that the acquisitions turned out to be twice as expensive as estimated. However, the public attention and the involved prestige pushed the process forward. As a result the IMMC collapsed soon after its formation, recover and again went into a bankruptcy in 1915. Even though the White Star Line continued to produce profits, its market share declined relative to the Cunnard Line and the Germans.

The step to compete on luxury and comfort instead of speed seemed to be a failure. Ismay, under pressure from the American co-director, ordered the Olympic to sail faster than her original schedules. A few months after the Olympic's maiden voyage in 1909 she collided with a warship. Also the Baltic, operated by White Star Line, grounded in dense fog this year. This ship had earlier been ignited by an exhausted watchman, but was by pure luck recognized and distinguished. Her captain, Edward J. Smith, who was held responsible for the Olympic collision was also in charge onboard Titainc on her maiden voyage. Even though several authors have recognized the harsh competition, it is difficult to directly relate this to the series of accidents.

The Titanic had a safe design with several watertight compartments giving her the nickname "*the unsinkable ship*". The high belief in the vessel's safety standard resulted in several awkward decisions and habits (Håvold, 1999; Caridis & Tsitsonis 1998). The ship had a lifeboat capacity cowering only about one third of the people onboard and was also insured for only one third of its real value. He further writes that "*It seemed important for the National Administrator's to maintain an national industry and therefore did not push for << costly>> safety measures. The incentives for the decision makers seem to be more of on short term financial and survival criteria, rather than on long term safety impact.*" support this view. Also emphasis is assigned to the rapid paste of new technology (Cahill, 1990). The Titanic hit an iceberg on her maiden voyage and subsequently foundered resulting in more than 1500 deaths. Table 4 presents some findings categorised in the competing values framework.

Table 4: elements of the competing values framework for White Star Line

Clan	Hierarchal	Market	Adhocracy
Not found. The crew had not been satisfactory trained. The captain had a history of accidents. The ignorance of the ice warnings contradict flexible controls.	Traditional shipping organisation with explicit hierarchy. Safety is incorporated in rules and procedures and in passive safety devices such as watertight compartments	The competitive strategies were the driving forces for the company. Even the merge was known to be costly the stability of the organisation brought it forward. The high speed, and the unwillingness to change courses even being aware of the ice indicate strong goal orientation.	It was a visionary and innovative strategy to consider comfort as a competitive factor and to build large, relatively fast and safety ships.

6. THE DEVELOPMENT OF THE CROSS CHANNEL MARKET

The United Kingdom became a member of the EEC in 1973. For some years the UK's trade pattern shifted towards the Continent of Europe. Because the southeast part of England could provide the most efficient transport routes to the mainland, this area became the zenith of British trade. The motorway capacity on both sides of the channel had been increased for several years. These characteristics, in addition to the short sailing distance, made the efficient loading and unloading of Roll on-Roll off (Ro-Ro) vessels far more competitive compared to containerised transport. In fact, the channel between England and the continent of Europe became one of the world's most heavily travelled waterways (Boyd, 1996) where Ro-Ro vessels carried a great deal of the traffic (Branch, 1988). During the early 1980s several factors affected these routes. While Ro-Ro vessels are extremely efficient in loading and unloading the design is extremely vulnerable for the free surface effect of water ingress. According to Branch, the shipowners were very aware of the cross channel growth from the early 1960s. The Daily Telegraph (10.mars, 1987) describes the Governments decision in 1979 to break up what they called "*the unofficial cartel by which channel companies liased on fares and sailing*" as the real opening for the cross channels competition. The newspaper further writes: "*Competition is reaching suicidal levels among ferry firms with some collapsing and all making big economics*". Companies such as the British and Irish Steam Packet was making heavy losses. Hover Lloyds and SeaSpeed had been force to merge. Sealink was demanding manning cuts and the P&O London-Ostend hydrofoil route were closed. The government had also contributed to a more competitive situation when it kicked off the privatisation of SeaLink UK Ltd in July 1984, which previously was a subsidiary of the government owned British Rail. At that time SeaLink UK, its European state-owned counterparts and a private company called Townsend Thoresen dominated the cross-channel operations. The competitive pressure was further stressed in 1986 when the plan for the tunnel between England and France was accepted.

The company structure of Townsend Thoresen was relatively complex. In 1968 there was a merge between the two companies Townsend Brother Ferries and Thoresen Car Ferries. Together they form the European Ferries Group and become the largest independent ferry company in Europe. In 1971 the Atlantic Steam Navigation Company was purchased for £5.5 millions. The P&O Normandy Ferries was acquired in 1985, which operated five ships. By the mid 1980s Towsend Thoresen had been diversifying its corporate aims and had invested in various ventures, such as Airship Industries and an ambitious building project in Denver, Colorado. The costs of the later investment grew beyond the company's capacity. Therefore fresh capital was necessary and American investors became leading shareholders. Peninsular and Oriental Steam Navigation Company (P&O) had also accumulated shares in the company and struck a deal to buy out the Americans. The whole group became a subsidiary of the P&O on the 5.th December 1986. Although the ownership changed at this date, the company remained unchanged for a whole year. However, a few moths after the acquisition the Herald of Free Enterprise disaster took place. Townsend Thoresen was relatively early strategically preparing itself for a more competitive position. A heavy new- and "jumboising" programme responded the end of cross-company collaboration in 1979, meaning in principle that the size of the vessels was significantly increased. A new vessels design called the Spirit class was the basis for three new Ro-Ro vessels. The old ships that were not rebuilt were sold off. One of the subjects for jumboising was the five-year-old Ro-Ro vessel European Gateway, accomplished in 1980. It seems that another wave of investment takes place in 1985, when the P&O Normandie Ferries was acquired and the remaining part of the old ships were jumboised. Herald of Free Enterprise (HFE) was a Sprit class vessel that was launched in 1980. The 433 feet long, 7,950 gross ton vessel was the largest of her kind and was specifically designed to operate the route between Dover and Calais. Also the route between Dover and Zeebrugge was within her operational plan. She accelerated rapidly to 22 knots and could carry 1400 passengers. The 10th of July, two months after delivery from the yard, the Herald of Free Enterprise managed to take the speed record for conventional ferries sailing between Dover and Calais. To obtain a maximum efficiency, the ports at Dover and Calais had arrangements to simultaneously load and unload her two main vehicle decks.

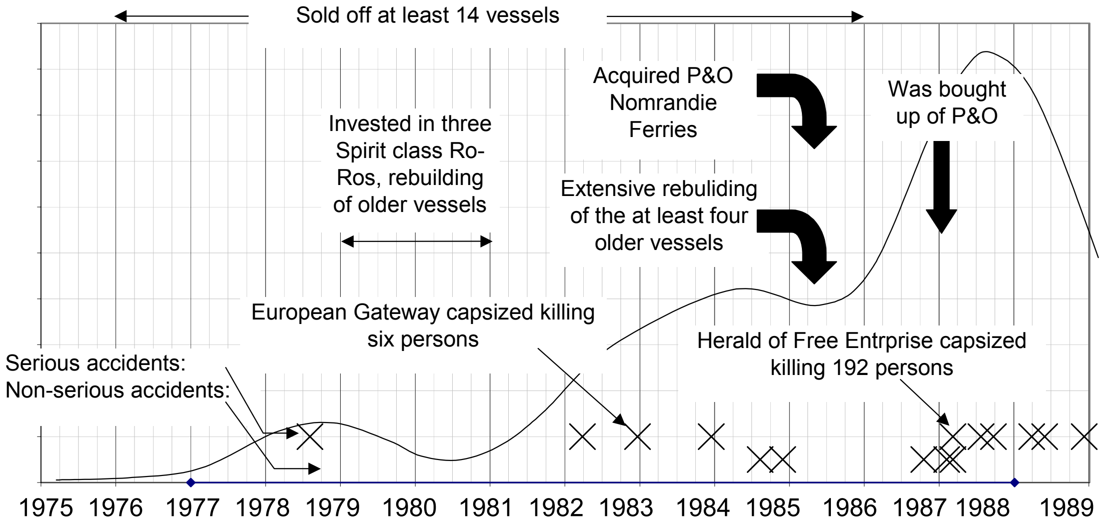

Figure 3: The relationship between economical conditions and accident density for Towsend Thoresen

In December 1982 the first sign of insufficient safety within Towsend Thoresen became publicly available. After leaving berth at Felixstowe the master onboard the European Gateway decided to abandon the practice to pass the incoming vessel Speedlink Vanguard, owned and operated by SeaLink U.K., on her port side. Besides the time gained on such a manoeuvre is marginal, the European Gateway's master did only inform the Traffic Control centre about his intentions. The captain onboard Speedlink Vanguard observed European Gateway, but being unaware of her initiative to pass at her starboard side, he decided to stick to international accepted procedures for collision avoidance (COLREG). When he realised that European Gateway did not manoeuvre as he expected, he managed to reduce the speed significantly before the encounter. European Gateway was hit in her starboard side. Her crew had left three watertight doors open, causing the situation to escalate rapidly (Spouge, 1985). She listed, flooded, and soon broke free from Speedlink Vanguard's embedded bow. Fortunately the rescue response was immediate. A pilot vessel nearby managed to evacuate most of the passengers through her pilot launch. Some more were saved after the vessel had capsized in shallow water. The following investigation considered it remarkable that only six lives were lost.

The management did not take the company's problem of closing watertight doors seriously. In contrast to most Ro-Ro vessels, that have bow visors to prevent water ingress on the vehicle decks, the Spirit class vessels were fitted with clam doors. This type of doors is impossible to visually observe from the bridge. In order to ensure water tightness, one of the crew had to enter the vehicle decks before leaving port, to ensure that the doors were closed, and then report to the master. Both the HFE and her sister the Pride of Free Enterprise (PFE) started visiting the port at Zeebrugge, which did not have the adequate ramps on land. The single ramp reduced the port efficiency and was slightly too low to reach the upper decks. Therefore these vessels' bow had to be trimmed down by pumping in ballast water. At the port in Dover, the time schedule was too tight to allow proper discharge and loading. Consequently, the company's crew and management, felt their need to gain some surplus time at other operational phases. The most efficient strategy was to urge the leave from Zeebrugge. As soon the ship was fully loaded, it had to leave, independent of its planned departure. The stress can be exemplified by the announcing of the crew to go to their positions even before the loading was complete (Crainer, 1993). The written procedures required some of the crew to be at two locations at the same time. In this stressing situation it became regular for the masters to assume that the doors were closed if not the contrary was reported. On a few occasions this negative reporting failed. In 1984 the PFE left Dover with both bow and stern doors open because the assistant bosun had fallen asleep and failed to carry out his duty. The masters then several times requested the onshore management to install indictor lights had to be installed on the bridge, in more easily ensure that the doors were closed. These requests were rejected. On the 6th mars 1987, Herald of Free Enterprise sailed from Zeebrugge with 459 passengers onboard. Because of the inadequate ramps at the berth, the ship had a forwardly trim. The bow doors had not been closed. Within only a few minutes the car deck had accumulated enough water to capsize the ship in shallow water. The ship was rapidly filled with water and at least 150 passengers and 38 crewmembers lost their lives. The characteristics of Towsend Thorsen in a CVF context is summarised in table 5.

Table 5: elements of the competing values framework for Towsend Thoresen

Clan	Hierarchal	Market	Adhocracy
Not Found: Factors that disagree with this culture: Initiatives nd responsibility taken by the captains on two occasions to implement bow visor indicators were not only rejected by the management, but also responded in an arrogant phrasing. Crews were pressured to work	The traditional shipping hierarchy existed. Rules and procedures were supposed to dominate the work onboard. However, these procedures were in conflict with each other and were in practice impossible to follow. A practice of negative reporting emerged. Therefore, the elements of this cultural type were present, but deteriorated.	The acquirement of competitors indicates a focus on market share. Competition was also aimed against other ship designs such as RoRo train ferries, Container vessels and the cross channel tunnel. Goal oriented: Extreme pressure to keep time schedule. In the competitive lead	Were ahead of the competitors through "jumboising" the old vessels and was early at the yards to modernise their fleet. The marketing was innovative with a reliable time schedule and extra services such as subsided drivers meals, vouchers for us in shop or bar, free cabins and driver's clubs, computerised reservation, documentation, billing and customs, etc.

7. The development in the Kategatt routes

The Kategatt is located between Denmark and Sweden and is an important line of transport between these two countries. Its adjacency to the Baltic sea and the coast of Norway, Germany and Poland further increase the intensiveness of the transport across the Kategatt. One of the major players in the RoRo shipping in this area is the Stena Line. The history of Stena Line can be tracked back to 1939 when the Swede Sten Allan Olson inherited a freight boat from his father. In 1960 the company operated 15 freight boats. In 1962, a radical strategic change took place by the acquired the Gothenburg-Skagen ferry route. This was a successful move. During the 17 first months the net profit was of 22 million (Swedish Crowns), which is on of the company's best results in history relative to the size of the operation. In 1982 they acquired the Sessan Line, which significantly increased the company size. This was the first move of a long lasting expansion. From 1983 to 1989 the net profit of the company grew by 600%. A range of subordinates was developed comprising RoRo vessels, bulk and tanker vessels, offshore contracting, international finance, property management, hotels, restaurants and information systems.

Even though cheap food and tax-free products were their main tactical success factor much of the profit making emphasis was given to speculations into buying and selling ships. According to Holt (1989) "*it was more interesting to buy and sell ships at the second hand market than to carry passengers …At the bottom is the traditional shipping culture, characterised by quick decisions in buying and selling, short-term solutions, emphasis on technology and tonnage, and neglect of people and human values*". In 1982, however, a change in leadership took place. The new leadership rejected this market strategy. The "New Stena Line" had objective of generating profit from the ferry operations as the main source of income. To attract passengers and to make them come back several market-oriented measures were implemented. Stena Line and Towsend Thoresen had several similarities. They both expanded during the early 1980s, they applied large RoRo-passenger ferries, "jumboised" their older ferries and were using an innovative marketing apparatus of a similar nature. However, Stena's market orientation implied employee involvement, which was in sharp contrast to Towsend Thoresen.

Stena's tactic was to transform the old autocratic technology driven company to a decentralised market driven service organisation. Consequently a market oriented organisational culture had to be developed. In 1983 all 2000 employees were coursed by an external consulting company and attended to a conference. In 1984 a one-day seminar was arranged where the employees were directly involved in the process of developing a market orientated culture. The results of this process will be described later. As the manager did not feel that the obtained effect of this effort was satisfactory, all supervisors and middle managers had meeting and seminars on how the culture should be further improved over the subsequent few years. Later new follow up projects were added. Holt (1989) summaries the development as this *" "It really represents a cultural clash". A decentralised, market oriented culture with emphasis on profit generation through increased income represents a radical change from the autocratic, technology oriented traditions with top down order giving emphasis on cost saving."*

Because, Stena acquired SeaLink, the only competitor of Towsend Thoresen, the cross channel tunnel was another competitive element. Also the sound bridge between Sweeden and Denmark would significantly influence the importance of the Kattegat routes. The opening of the European market indicated abolition of the duty-free sales. In 1989, Stena Line pinpointed the dangers related to ships sailing under flags of convenience "*It is of vital importance for the Swedish ferry transportation that the Nordic ferry companies compete on similar conditions*". In 1990 the VR DaNo ferry named Scandinavian Star went into competition on the Oslo-Fredrikshavn route sailing under Bahamas flag. The ferry had untrained and incompetent crew and turned into a disaster after seven days of operation, killing 158 peoples. In 1991 Stena Line presented ferry operators with crews from low-cost countries as one of the most important competitive threats. Under the following year there were several changes in managements and strategies. The company was listed on Stockholm Stock Exchange from 1988 to 2001.

The significant emphasis on the participation of the employees can be seen in the objectives stated in 1988/89 annual report (table 6). But in 1995 however, the objectives had changed somewhat away from the employees to technological aspects, effectiveness and a secure workplace. While the efforts in the mid 1980s had references to a Clan culture, these new objectives are typical elements of a Bureaucratic culture. During 1998 a serious reorganisation took place. In 1999 the objectives had been changed even further indicating elements of a Market culture (figure 1). The same year nearly 700 employees were given notice to resign. The following year the lift-on/lift-off container service between Harwich and Zeebrugge was closed down. In the 1999 annual report the objectives had again shifted towards elements of a market culture.

Table 6: Stean Lina's business objectives over time

Goal and strategy (translated 1989)	Business concept, objectives and strategy (1995)	Vision, objectives and Business Concept (1999)
The economical objectives is going to be achieved through development of service cultures that attract more customers within the concern's various activities (volume goal) and meet the increasing demand of more refined products and services (refinement goal) The expansion of the service industry is dependent of the initiatives of each individual employee. It is the teamwork of the individual human's that generates the company's results. The concern's strategy is therefore to create organisations having simple structures that give room for the potential of every individual employee.	Running an attractive route network… Using modern, well maintained, safe ships adapted to customer's requirement Providing a service which is perceived by the customer as positive and friendly, and as providing value for money. Constantly trying to be more efficient than our competitors in every sphere of operations Constituting a secure, developing and attractive workplace in which decentralisation and personal responsibility are the keys to the staff policy.	Become profitable Maintain market position both in volume and price Increase company value by producing a health return on investments Attractive proposition to employees and all other stakeholder

The adjusted objectives are likely to be a result of changes in the market. Therefore are two economical parameters plotted with respect to time in figure 4. In the same plot serious and non-serious accidents recorded by Lloyds Register are presented as individual crosses. The accumulated density of these accidents is also presented. When the density is high, it is registered many accident per time and vice versa. To be certain that the variation in accident occurrences is not related to changes in fleet size it should be noted that in 1990 the company operated 14 routes with 30 ships. In 1996 the number of routes had increased to 17 but still with 30 ships. In 2002 the number of routes was still 17, but the fleet had increased to 33 ships. Even though the fleet size has varied somewhat this variation does not justify the cycles in accident illustrated in figure 4.

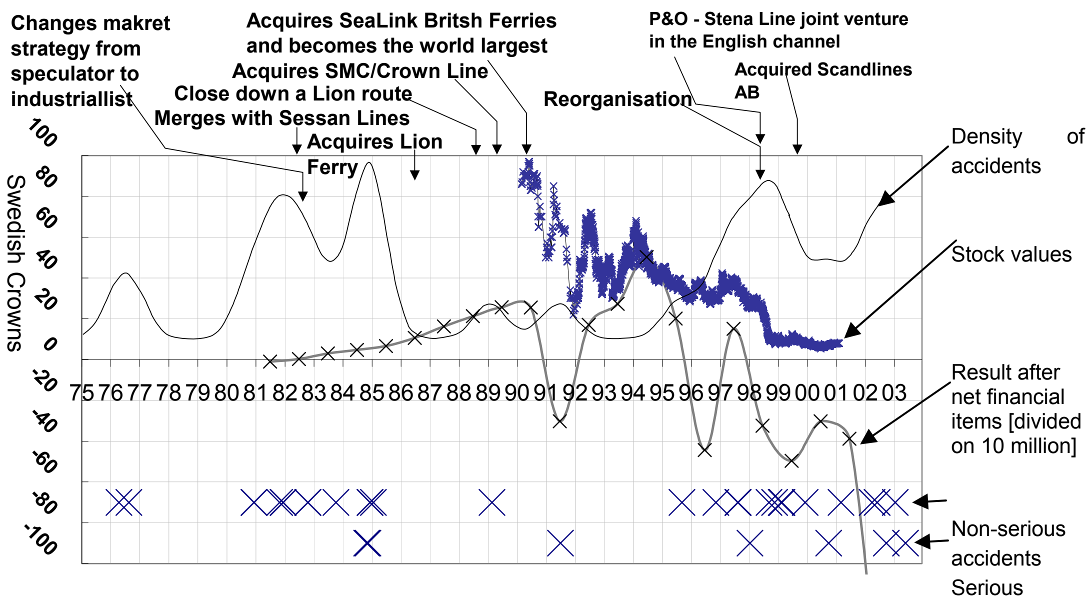

Figure 4: The relationship between economical conditions and accident density for Stena Line

The figure illustrate that a cascade of accidents occurred simultaneous to the strategic change in the early 1980s. But after the change process there was almost a decade where hardly any accidents occurred. The two accidents in 1989 were related to the ship involved in a local closure of a ferry route between Helsingborg in Sweden and Grenaa in Denmark. The 1991 accident occurred under tough economical circumstances. A summary of the findings related to the CVF is presented in table 7.

Table 7: elements of the competing values framework for Stena Line

Clan	Hierarchal	Market	Adhocracy
Weak prior to 1982, strong after 1984 and then weaker again in the mid 1990s.	The traditional shipping hierarchy existed. Rules and procedures were supposed to dominate the work onboard. However, these procedures were in conflict with each other and were in practice impossible to follow. A practice of negative reporting emerged. Therefore, the elements of this cultural type were present, but deteriorated.	The acquirement of competitors indicates a focus on market share. Competition was also aimed against other ship designs such as RoRo train ferries, Container vessels and the cross channel tunnel. Goal oriented: Extreme pressure to keep time schedule. In the competitive lead	Were ahead of the competitors through "jumboising" the old vessels and was early at the yards to modernise their fleet. The marketing was innovative with a reliable time schedule and extra services such as subsided drivers meals, vouchers for us in shop or bar, free cabins and driver's clubs, computerised reservation, documentation, billing and customs, etc.

8. The opening of domestic routes for competition in the Mediterranean

In the early and mid 1990s the first competitive adjustments (table 3) could be observed in other European countries. The date for lifting of the ban of foreign operators to enter Greek domestic transport was first as late as 1. January 2004. Already in 1997, however, an Italian company tried to enter the market. The following two years involved large changes. In 1998 the Minoan Line went on the stock marked and was soon followed by the ANEK line. Similar to the break off of the cross-channel cartels in 1979, the EC imposed fines on seven Greek companies for colluding at fix prices. Simultaneously a new company called Minoan Flying Dolphin (MFD) entered the market. This company was originally a subsidiary of the Minoan Lines, called Minoan Highspeed, which bought a majority of 60 per cent stake in a company named Ceres Hydrofoils. This 100 million dollar investment represented a first move in an extremely aggressive acquisition policy. Emboldened by the stock market boom in 1999, the Greek operators announced a slew of orders for new vessels and buy-outs. Within 2000 the many merges, buy-outs and alliances created three groups of companies that each claimed a distinct share of the market. This year represented a terrible change in the market. The stock marked dipped, and a MFD experienced its first retreat by cancelling the partnership deal with the NEL Lines. Later, the September 11 attack resulted in fewer passengers and a 600% increase in insurance premiums. The oil price raised and the companies had agreed with the government on a fixed supply of transportation independent of the transport demand. Consequently, several routes carried larger crews then passengers. MFD got into a serious dispute with the Panhellenic Seamen's Federation about overtime payment. The initiatives to merge now speeded up again to reduce administrative costs and obtain monopoly on some routes. The domestic routes were opened for free competition in November 2002, more than one year prior to its initial date.

In contrast to the hurried opening for free competition in the Greek ferry market, the government postponed the introduction of international requirements for safety management (ISM-code). The ISM-code, that generally was mandatory for all passenger ships from its entry date the 1. July 1998, includes basic functional requirements for safety management. Later it was also revealed that maritime authorities had been issuing false fire certificates. An investigation demonstrated that all of the 15 considered vessels held by MFD had false fire certificates. In this context it should be noted that this company have lost a vessel due to fire, and that the holding company, Minoan Lines, experienced three fires out of a total of eight accidents (represented as stars in figure 5) the last 20 years.

Since the market entrance in 1998 MFD grew at an astronomical speed. In 2001 it operated about 70 ships and had liabilities that exceeded more than 105 million euros. It was however not only the growth of MFD that turned in 2000. Whereas Lloyd's register only registered that the ferry *Pasiphae* hit a reef on her maiden voyage in a speed of 27 knots in 1998, not any serious or non-serious accidents were recorded in 1999. In 2000, however, four grim accidents took place, whereof one was disastrous. The 12. December a Greek seafarer was killed and another ten were injured when a broken mooring struck them onboard *Express Aprodite*. The 22. August the hydrofoil ferry *Flying Dolphin V* was lost due to a fire. The 69 passengers on board and the crew of 7 all survived the accident. The 29. September *Express Artemis* ran aground in shallow waters with 1081 passengers on board resulting in a 30 minutes blackout. The disaster happened, a few days earlier, at the 26. of September, when the Ro-Ro cargo ferry *Express Samina* hit some rocks in restricted waters. She sustained hull damage, flooded, listed and sank soon after taking 84 lives.In 2001 Lloyds recorded five serious and non-serious accidents in the companies fleet. In 2002 the corresponding figure was ten accidents and at October 2003 as much as fourteen accidents were recorded this year. All these accidents are represented with crosses in Figure.

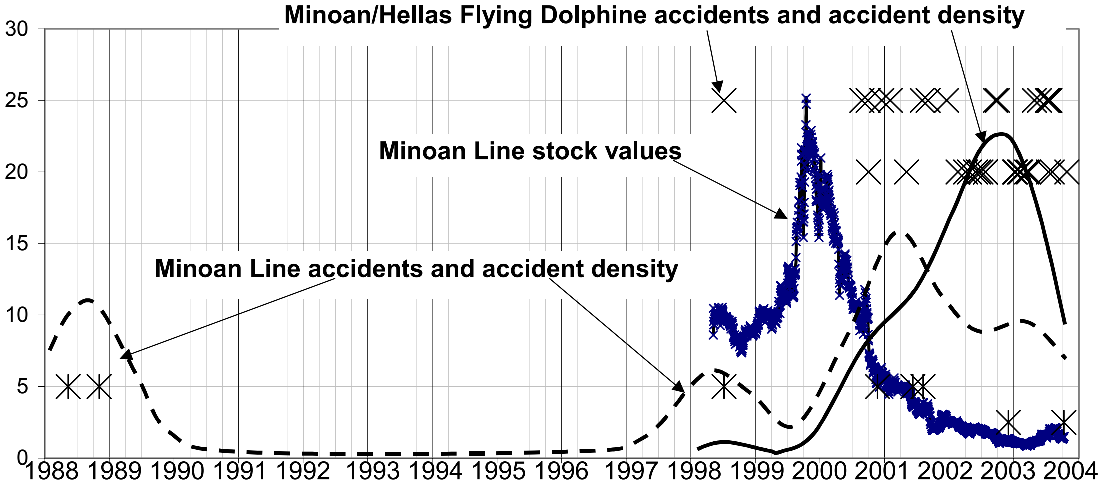

Figure 5: The relationship between economical conditions and accident density for MFD and Minoan Line

The Express Samina and her sister Express Naias were two of the oldest ferries in Greek domestic fleet. Samina was built in 1966 and operated in Greece since the mid 1980s. She operated in Greece from the mid 1980s. Until early in 2000 she sailed as the Golden Vergina. Both Samina and Naias were bought for a very low price by the MFD in the late 1999 and early 2000. Golden Vergina was then renamed Express Samina and her passenger facilities were refurbished. Unlike other passenger ship disasters the Express Samina had a record of public available warnings of her poor safety condition prior to the accident. A Greek travel guide book (Greek Island Hoppers) described her as *"…this dreadful boat is arguably the worst Greek ferry afloat…she is definitely a boat to be avoided."*. Another media (ADAC Motorwelt) pinpointed Express Naias in 1998 as especially substandard through their yearly safety inspections of about 30 European ferries and ro-ro passenger ships.

The Portes Islet is about 25m high, is topped with a navigation light that is visible for 12 km. Thanks to this easily spotted landmark, it is a natural navigation target for boats entering and leaving Paros. It is therefore likely that the bridge crew set the automatic steering on the ferry, targeting the Portes Islet, with the intention of later assuming manual control as the vessel closed in on Paros. For some reason this appears not to have happened and the Express Samina was left to steam at full speed into the rocks. At the time of the collision the crew had left the bridge to watch the replay on one of the ship's TVs of a goal in an important local soccer match.

When the ship got of the rock and headed for port the power supply failed which made the evacuation extremely difficult. The emergency equipment was in extremely poor condition and the crew failed to organize the evacuation. The presence of several ships in the area, the proximity to shore and the relatively calm weather allowed most of the passengers to be picked up of the sea and from the rocks. The investigation revealed that the watertight doors, which could have closed of the flooded area, were left open. This caused the vessel to sink within only 45 minutes. 82 of the 550 passengers were lost. One of Minoan Flying Dolphins' superintendent engineers revealed that the company was aware of serious mechanical problems on Samina's speed and steering control. Samina's captain had a few years earlier been in charge of a vessel called Nereus, which sank after a similar scenario as Samina. He was also in charge when Samina collided with another ferry short time prior to the accident. A summary of the findings in a CVF conext is summaries in table 8.

Table 8: elements of the competing values framework for MFD

Clan	Hierarchal	Market	Adhocracy
Weak: Dispute with the employees about overtime payments. The crew did not take responsibility.	Hierarchal structures and authorities, but did not emphasis on control.	Strong: Market shares and growth were the governing goals of the company.	The visionary belief that it was necessary to be large and grow fast might be an adhocracy element.

NEL plot ANEK. Of the16 Port State Control safety inspections recorded in ParisMOU in 2001 there were found 11 deficiencies and 1 detention. Minoan Flying Dolphin had at the same time 10 inspections resulting in 55 deficiencies and two detentions. ADAC Motorwelt (1998-2001) inspections Minoan Line vessels (six inspections) were in general in good conditions. Stena vessels (five inspections) were somewhat better than ANEK's, (three inspections) both obtaining average scores. The condition of Minoan Flying Dolphin (eight inspection) vessels was in general poor. The PSC findings on these vessels roughly confirm the ADAK scores.

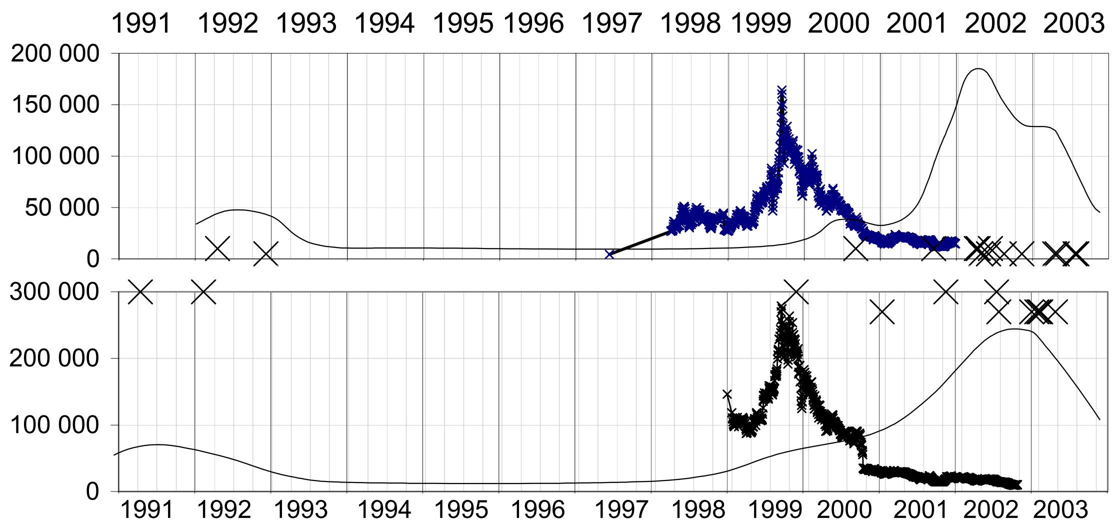

Figure 6: The relationship between economical conditions and accident density for NEL (high) ANEK (low)

9. THE OPENING OF DOMESTIC ROUTES FOR COMPETITION IN THE NORTH SEA

Norway's decentralised population and its many fjords and islands has been a prospering basis for domestic ferry routes. Even though shipping is an extremely important for Norway, the safety and security of the maritime transport in Norway is distributed on practically all government departments. The Maritime Authorities is for some reason located under the Department of Trade. This segregation has resulted in several conflicting approaches. For instance, a governmental consideration of the challenges for the society's safety and emergency preparedness specifically addressed the organizational culture of the shipping companies as a core improvement factor in the maritime segment (NOU, 2000). In contrast the models used to assess the risk of domestic ferry traffic at an operational level considers aspect of the company to have low importance relative to aspects of the traffic, fairway and technical features (Norwegian Maritime Directorate, 1999). The domestic ferry routes are under a license system and most of them receive subsidisation. The decision making into the requirements and amount of subsidisation is decentralised to the administration of the counties, employed and managed by a staff without any safety related competencies. This administration also enforces the earlier described tendering system. From time to time the segregated decision-making and the lacking focus on safety has developed hazardous situations and deteriorated safety standard.

After entering the stock market in 1992, HSD's stock values seemed to grow relative stable until mid 1997 when it suddenly doubled its value (Figure 7). To get an overview of HSD's strategies some text are translated from its 1998 annual report. The company is presented under to motto: *HSD - a competitive company*. The stated business idea was: "*HSD seek to be a competitive and profitable provider of goods and services related to transportation. The company is to be in the lead, within the traditional routes due to its good service, quality and effectiveness*". Something special about that years' annual report is an added section called "*Increased competition*" following the presentation of their business idea, even before the presentation of the organization. This section states that: "*During the last years HSD has moved towards services in the open market. Earlier a larger share of the activities has been related to public services. Tenders are becoming regular within the transport sector, and HSD is preparing itself on additional upcoming changes in market conditions. Customer service, marketing, cost-cutting and effective management is therefore in focus for the companies' work and organization*". HSD had as the far majority of Norwegian and European domestic ferry companies, received subsidization from the government. In 1995 HSD agreed with the authorities to economise on their activities. In this agreement it was accepted to rationalize the high-speed ferry operation with an annual amount of 0,6 million within 1999 (Figure 7). HSD's organization was structured as an internal market place where the four divisions Fast ferry, Ferry, Transport and Buss bought their administrative services from different departments. The adaptability of the organizational structure was also emphasized.

In 1999 two new fast ferries, Sleipner and Baronen went into operation. Sleipner had only been operating for three months, when she was involved in a fatal accident. Because drills had not been satisfactory carried through, the Maritime Authorities limited the operational license of the vessel to only be valid under calm sea. This restriction was violated. The bad weather reduced the radar efficiency, and the experienced captain did not detect that the vessel entered two red sectors from lighthouses nearby. The rock was detected some seconds before the impact, allowing the captain to slow down from its 33 knot operating speed. The crew had poor or little training in emergency situations and evacuation. The public address system failed and the emergency rafts could only be released manually by executing 24 operations in the correct order, and the automatic release equipment was not yet installed. Hence, only one of the rafts was released. The life jackets were of an old design and were difficult to put on and fasten, which caused several passengers to jump to sea without it. The poor weather reduced the efficiency of the rescue and the cold water resulted in rapid and fatal cold shocks.

The structure of the personnel safety representatives was divided into one organization for the land based activities and one for the seafarers. These organizations were separated because there are different regulations for the two areas. The Health, Environment and Safety (HES) work was summarized on two pages in their annual report. One of these pages illustrated the organization of the compulsory personnel safety representatives. Even though the committee of the safety delegates came forwards with safety issues, the top-level management had in practice no active role or responsibility in this process. Already in 1995 the safety management of the HSD was criticized. The investigation into the loss of a buss from their ferry revealed a lack of commitment from the management. After the Sleipner accident the management was confronted with the simple question *“Who is responsible for safety in HSD?”*. Even though the manager was open for questions, this one could not be answered. This has to be seen with reference the reports from the board of directors from 1995 to 1999 that barely mentioned safety. In the 1989 annual report, no quantitative safety goals, criteria, or references for improvement was mentioned, but rather that is will remain a on its present standard. The objective also included emphasis on procedures and routines indicating stable elements. Besides the employees health and work environment was given attention, green measures were presented. According to the annual report, the EHS education that had been given to the fast ferry crews were: service training, a navigational refreshment course and an English course for the whole crew. The only effort related to the employees’ attitudes and responsibilities was a project focusing on prevention of intoxication.

It is strange that the company did not assign more resources and attention to safety. Already in 1998 two of the companies' catamarans were sailing in high speed, in dense fog, at a head-on collision course. At the last second the ferries managed to take an avoidance manoeuvre, which significantly reduced the criticality of the impact. Only one of the 139 passengers onboard the two ships were injured. Again questions about HSD's safety management were raised, but no serious actions were taken. The Sleipner investigation opened for the possibility to get an insight into how the company worked with safety management. According to this investigation the company had recorded 6,1 collisions for the fast ferries each year of the 5,7 considered years. The causes of the accidents were recorded as "unsatisfactory ship control" and "factors beyond the ships' control". "Navigational failure" and "Inattention" was each only recorded once. The relatively high portion of external causes was relatively common for maritime authorities a hundred years ago (Soma, 2003). Today, it is well accepted that more than 90% of navigational accidents are related to operator failures. The company had only recorded one near-miss each of the considered years. Representatives from the shipping company inspected the Sleipner three days before the accident and found 34 non-conformities but still considered the ship as seaworthy. The immature reporting and learning culture could also be read out of the newspapers. When the twin hull ferry Baronen stroke a rock at full speed outside its planned sailing route in the beginning of January 2000, the incident was intensely denied by the company's representatives. When divers the following night picked up one of the vessels propeller from the specified rock the company had to admit openly that it tried to cover up the incident. On several occasions subsequent of the Sleipner accident, those employees that officially questioned the company's safety practice were punished. In three occasions after the Sleipner accidents crewmembers have tested positive on alcohol while on duty. In summary HSD was a company that implements advanced technological features with little systems for adaptation, training and learning. They punished whistle-blowers and explained away incidents as unavoidable or caused by external factors. The feedback in terms of near misses was almost absent. The safety organisation, the safety objectives and even the training had a clear external focus by referring to regulations and how the company wants to be seen. There were few signs of management commitment or structured continuous improvement. Both in economical terms, and with respect to accidents, the year 2000 was depressive for HSD (figure 7). With respect to safety it should be noted that more than 50% (34 mill. NOK) of the deficit was directly used in EHS activities. Figure 7 illustrates that the Sleipner accident was one of a cascade of accidents occurring over a short duration in time. The density of accidents and the economical result before tax follow an inverse relationship.

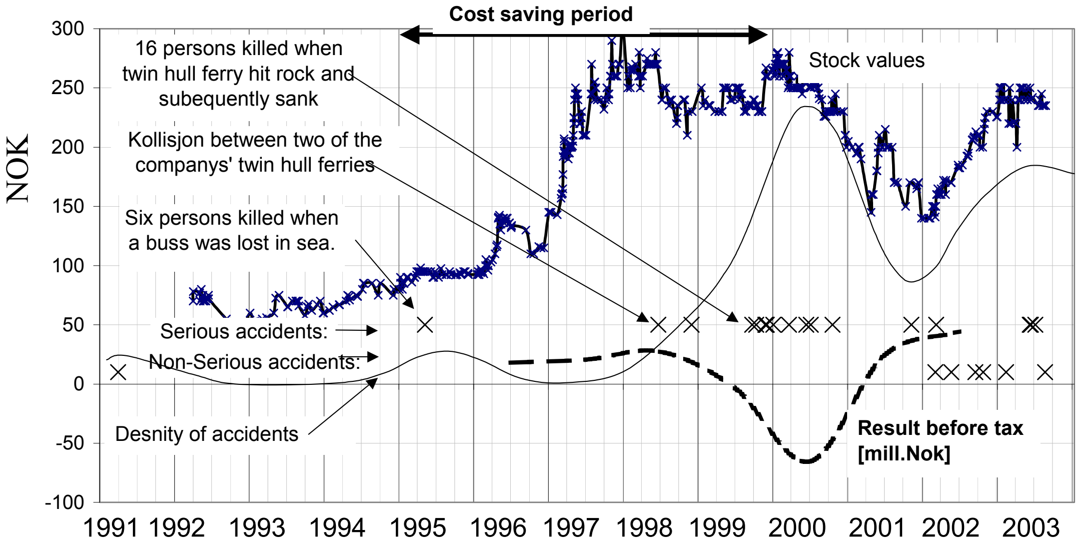

Figure 7: The relationship between economical conditions and accident density for HSD

In the following text the development of the safety management function within HSD is considered in more detail. In 1999, the year of the Sleipner accident, several changes occurred. Minor clauses were added to the objective statement. A range of measure were proposed and implemented. One of these actions was to form a committee that should review the philosophy of their EHS activities. The committee's work was, however, restricted to follow a four-item guideline. The objective of the three first items was to obtain sufficient insight through a full system review (1), risk analysis (2) and collection of external experience (3). The forth item was aimed at implementation of improvements and is translated: "*Suggest measures that will increase effectiveness and improve the company's EHS work, in such as way that HSD will be known for being the best in this field.".* Consequently, the written goals indicate that safety measure that did not have a direct link to the external image of HSD should be ignored. Therefore, even after the Sleipner accident HSD held onto its external focus on safety. Later the zero-risk philosophy was adopted. In theory this criterion is unreachable. However, governmental departments and companies use it to break through old habits and mind sets to promote no tolerance for accidents in any operations. Later, HSD has also started using targets for the annual performance goals, which is an acknowledged approach.

All employees were involved in a process into the development of a new philosophy. This process ended in February 2001. The result was a poster containing seven bullet points. These statements are presented in table 9. In this table the results of a similar process that took place in 1982 within the Stena Line is also presented. The Stena Line process had a slightly different scope as it was addressing the development of a market oriented culture. The process within Stena Line has been described earlier in this paper, and indicated their strong internal focus. While Stena Line's statements are aimed at details in the practical conduction of the employee's daily tasks, HSD's statements are of a more distal character. The superficial statements have parallels to objectives or advertisements. While a research institute published "the nine hard Stena commitments", HSD's statements was printed on the first page of their annual report 2000. According to the managers the involvement of the personnel had a good effect on their safety attitudes. In 2001, the year following the internal process was almost without reported accident (Figure 7).

Table 9: Comparison between HSD's EHS poster and the nine hard Stena commitments

HSD's EHS poster	**The nine hard Stena commitments**
• A safe workplace is clean and orderly • We cancel activities that not can be carried though completely safe. • We emphasize on the well-being and personal development for all employees. • We carry through work aimed at protection of the environment. • We work for a continuous improvement within EHS. • We obtain competitive advantages through good EHS results. • We take responsibility for a good work environment and a safe workplace.	We shall : • be professional in our jobs • see to it that there is a real cooperation between the manager and his people • mutually recognize our contributions • see to it that the communication between the departments work • take the responsibility of profitable operations • eliminate obstacles that prevent the customer from perceiving us as a real service company • demonstrate that we care about the customer • offer the customer more friendliness and individual service • work hard to make all our customers so satisfied that they want to come back

In June 2001 a new manager of the concern took place. In the 2001 annual report he described himself as a tough competitor. He announced that it was time for change, and that the future competitive environment was going to be harsh. He further announced strategic changes. Probably due to the change process his business ideas was not printed in the annual report. The focus within the EHS department changed from safety, towards environmental issues and the employees' well-being. The new manager was giving high priority to the personal development of the individual workers. He considered this as crucial for further market orientation and to turn the growing absence due to illness. The new vision of the company is that "*the harmony between our customers and our employees will make HSD a winning company…because we care*". This vision has an obvious relation to the attributes internal and external elements. Table 10 summarise some of the development within HSD.

Table 10: elements of the competing values framework for HSD

Clan	Hierarchal	Market	Adhocracy
Until 2001: Poor alcohol habits indicate a poor work morale. Training was not carried through. From 2000: Employees were involved and became a key issue in their vision for the future.	Hierarchal structures and authorities, but did not emphasis on control. The company violated the restricted operational requirements. The instructions had to be improved.	Market share has been the governing goal of the company, except for the time subsequent of the Sleipner accident	The visionary belief that it was necessary to be large and grow fast might be an adhocracy element.

In order to assess if the development within HSD was unique and independent of its competitors, the accidents and economical parameters for the three companies Troms

Fylkes Dampskip Selskap (TFDS), Sogn og Fjordane Fylkeskommune (Fylkesbaatane) and Ofoten Vesteraalens Dampskip Selskap (OVDS) is presented in figure 8. The charts show that also these companies had weak annual results (black solid line) in 2000 and 2001. The frequency of accidents was also higher when the economical parameters vanquished.

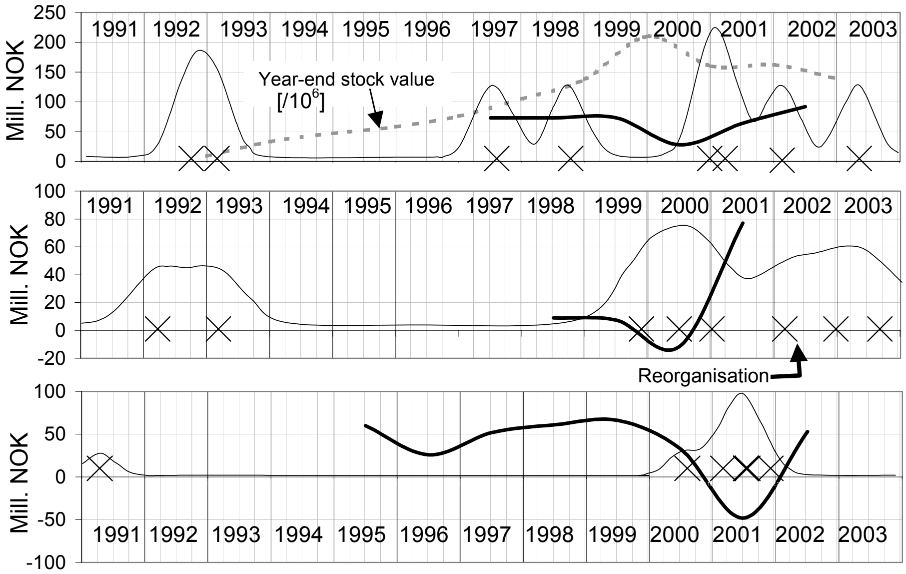

Figure 8: Annual result before tax and accidents for TFDS (highest), Fylkesbaatane, and OVDS (Lowest)

10. RESULTS

The sources for the applied information are based on accident statistics and the annual reports of the companies. The accidents represent incidents like collisions, fires, groundings, foundering and loss of propulsion. The analytical approach is to see wetter the occurrence of accidents are more frequent during market recession. Periods of promising market conditions can in some cases be manifested through solid positive net incomes and increasing stock values. Periods of recession can be manifested through falling stock-values or stable and low or even negative net incomes. When the net income is high, no closing of routes or cost saving are necessary the economy is said to be good.

Table 11: Classification of economical conditions for various years

	Poor economy	Good economy	Unknown or unclassifiable
Stena Line	[1981,1983], 1991, [1995,2003]	[1986,1990], [1992,1993]	[1984,1985], 1994**
Minoan Lines	[2000,2003]	{most of 1999}	[1988,1998]
M. Flying Dolphin	[2000,2003]	{1998, most of 1999}	-
NEL	[2000,2003]	{most of 1999}	1998
ANEK	[2000,2003]	{most of 1999}	-
HSD	{1999, 2000}	[1996-1997], 2002	[1992,1995], {1998**,2001***, 2003}
TFDS	{2000,2001}	[1997-1999]	2002
Fylkesbaatane	1999,2000	2001	
OVDS	1996, 2000, 2001	1997-1999, 2002	
Towsend Thoresen	[1988,1989]****	{1979,1980,1986}	[1975,1978],[1981,1985],{1987}

* The two accidents in 1989 were on the route that was closed down. These accidents are assigned to the poor economy account.
**HSD 1998, and Stena 1994 are a difficult year to classify. The net result was solid, but the stock values were falling, in addition the end of the cost saving period was closing in. In order to be conservative this year is described as unclassifiable.
***2001 was very volatile on the stock market. Even though the rates were at bottom the volatile characteristics indicated some uncertainty.
**** Everything stayed on statuesque after P&O takeover.

The numerical values in table 12 demonstrate that the risk of accidents is about 20 times higher during times of poor economy. There are uncertainties related to the classification of economy in table 11 and therefore this value should be interpreted with care. It can however be concluded that the risk increases significantly in a depressed market. The validation of this statement is simple. If the plots in figure 3 to 8 are considered (in total nine companies) it can be read out that there was increased accident intensity in 1988 to 1993. This is the exact duration of the last depression in the world's economy, which can be manifested in decreased world trade, falling stock indexes and decreased gross domestic product on a national level.

Table 12: Classification of economical conditions for various years

	Poor economy		Good economy		Unknown		Total	
	Acc.	S-Y	Acc.	S-Y	Acc.	S-Y	Acc.	S-Y
Stena Line	23	333	0	143	5	53	28	529
Minoan Lines	3	55	0	11	3	116	6	182
M. Flying Dolphin	15	291	1	125	0		15	416
NEL	5	42	0	8	1	8	6	58
ANEK	3	61	0	12	2		6	73
HSD	10	77	1	113	7	244	18	434
TFDS	2	66	2	94		34		194
Fylkesbaatane	3	68	0	36				104
OVDS	5	93	0	124				217
Towsend Thoresen	6	44	0	80	4	245	10	369
Total	65	1086	2	666	22	455	89	2207
	65/1086=0.060		2/666=0.003		22/455=0.048		89/2207=0.040	

11. Conclusions and discussion of results

There are several conclusions that can be drawn from this study. First it is demonstrated that the characteristics of "commercial accidents" can be identified on a micro level within the passenger ship companies. This implies that it is inadequate to assess commercial risk and accident risk independently. This again implies that it is inadequate to regulate a market and its safety standard independently. In sum this study produce quantitative proofs behind a great deal of the theories developed by Jens Rasmussen (1997).

On a qualitative level this study demonstrates that the national governments and the EU have a central role in the creation of market conditions that undermine safety. The EU has forced the development of a more competitive domestic passenger transportation market within Europe without giving significant attention to safety implications. The Stena Line expressed their fear for increased competition from ships flying Flags of Convenience in 1989. The next year their Bahamas registers competitor Scandinavian Star burned down partly due to their incompetent and untrained crew, killing 157 people. The breaking up of cartels, reduced subsidisation, developing competing transportation structures and the abolition of the tax- and duty-free sales may isolated seem rational, but the simultaneous increased competition through imposing a tendering system reduce the possibilities to compensate the lost income. In contrast to the public EU tendering system the private oil cargo owners have safety as the key issue for allowing shipping companies to submit tenders. The fact that the various European shipping nations have an interest in allowing their own shipping companies to be competitive in the inner market may also vaguely be observed. The maritime authority in Greek hurried the opening of the competition and postponed the requirements for safety management systems. The Norwegian Authorities have developed a risk analysis system that ignore the quality of management (Norwegian Maritime Authorities, 1999) and allowed Sleipner to sail with a series of deficiencies. The investigation revealed several deficiencies made by the management of the company. This study demonstrates that the Sleipner accident should not bee seen independent of the other accidents within the company.

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RISK DRIVERS IN THE TRAMP MARKET

Commercial Accidents

– an assessment of four leading tanker companies

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ABSTRACT

This study first demonstrates how the market conditions influence on the accident frequency of four of the world's largest tanker companies. It is demonstrated that the accident frequency increases with a factor of three when the freight rates turn from a positive to a negative development. This difference is significant, but far lower than what was found within the passenger ship market.

1 COMMERCIAL ACCIDENTS

During an earlier study of the relationship between ship disasters and the state of the shipping market it has been demonstrated that these parameters are negatively correlated. In a poor market the frequency of disasters increase. First this relationship was demonstrated on a macro level for segments of the world fleet at various periods during the 20th century. Later an additional study found the same characteristics on a micro level within several passenger ship companies such as Towsend Toresen (Herald of Free Enterprise), Minoan Flying Dolphin (Express Samina), HSD (Sleipner). The negative relationship between accident risk and economical conditions were also found within companies that not had experienced fatal accidents. Because economical conditions seem to determine the likelihood of accidents, they are labelled "commercial". The relationships were both found on long time trends over several decades and the development from one year to another. To pinpoint on the yearly changes, comparisons were done on the curvature of the time series (second derivatives). Figure 1 presents the relationship between the curvature of the tanker fleet size (dotted and inversed line) and the total loss ratio (TLR). In a good market the fleet size increases [1]. The total loss ratio represents the fraction of ships being lost each year due to accidents [2].

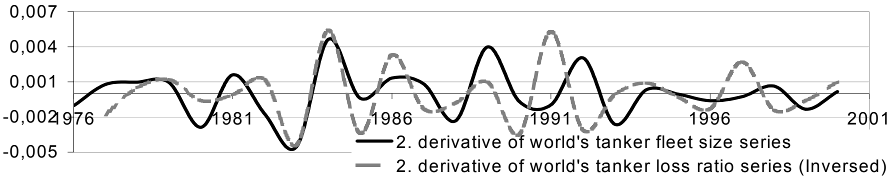


Figure 1: Dependency between fleet size and TLR for tankers on a macro level.

The described negative relationship is statistical valid. To understand the casual relationship is however ambiguous. The suggested causal relationship is explained by risk homeostasis principles at a top-level management [3]. When the economy is in recession it represents an increased commercial risk. Consequently, a more optimal overall risk level is obtained through economising on organisational features. The impact on organisational factors can be described through the Competing Values Framework developed by Quinn and Rohrbaugh [4]. It is known that that shipping companies base their safety controls on stable (or mechanistic) controls such as hierarchies, rules and procedures. Stable controls are not suited when the organisation is exposed to interfering austerity measures [5]. Flexible controls are obtained when the operators do not only know the correct task procedures, but also feel a responsibility and autonomously endorse safe operation. In the process of achieving this, several authors have described commitment from top-level management as the most important factor [6]. The organisations having both stable and flexible controls do in fact fall within the concept of High Reliability Organisations described by LaPorte and Consolini, [7]. When organisations become a target for austerity measures the operators are seldom consulted and feel no ownership for the measures. This results in a reduced motivation, weakened self-image, increased absenteeism, lowered morale etc. Consequently these changes deteriorate the flexible controls. Because the remained stable controls are not very effective during changes, the likelihood of accidents tends to increase.

2 SCOPE OF STUDY

Four large tanker companies were considered. These are TeeKay, Bergesen, Frontline and Odfjell. Bergesen and Odfjell are old and well developed companies. Odfjell is the largest shareholder of the chemical tanker market, claiming to hold 24%. They have a uniform fleet and own several ports. Bergesen is one of the largest tanker companies in the world with several large oil tankers and have a 2% share of the gas tanker market having several VLGCs (over 70.000 cubic meters of loading capacity (cbm)), LGCs (between 50 and 70.000 cbm), MGC (between 20 and 40.000 cbm) and Handy/Igloo size (between 8-20.000 cbm). They have declared that shipping of gas is to become their largest business focus. Frontline and TeeKay have during the last decade grown to become the largest shareholders of their respective oil tanker segment. Frontline has become the largest company within the Suezmax (ranging from 120-165.000 dead weight tons (dwt)) and the VLCC market (Very Large Crude Carrier 200-300.000 dwt). TeeKay has become the largest shareholder of the Aframax market. (about 80-105.000 dwt.)

The sources for the applied information are based on port state control inspections, accident statistics, freight rate statistics and the annual reports of the companies. The accidents represent incidents like collisions, fires, groundings, foundering and loss of propulsion. The analytical approach is to see wetter the occurrence of accidents are more frequent during market recession. Periods of promising market conditions can in some cases be manifested through solid positive net incomes and increasing stock values. Periods of recession can be manifested through falling stock-values or stable and low or even negative net incomes. During the analysis it was found that the economy of Frontline and TeeKay were comprehensible. They have a uniform fleet and a focus on growth. Therefore, their profits are gained from transportation. Their stock-values, net results, and the freight rates for oil tankers seem to correlate. The economies of Bergesen and Odfjell were more complex. Non-transportation factors such as ships sales, changes in tax systems, strength between the US$ and the Norwegian Crown (NOK) seemed to have a significant influence on their profits. In some cases it was even claimed that profits were partly due to cost saving programmes. This made it difficult to apply their stock values and annual profits as economical indicators. Therefore their economical considerations were solely based on the relevant freight rates.

3 COMPARISON OF TANKER COMPANIES

There are several differences between the various tanker markets, the companies' organisational structures and their strategies. The chemical and the gas tanker markets are small and require advanced technology. The barriers for entering these markets are consequently high. While the oil tanker market can be considered as a perfect competitive market, the gas and chemical tanker markets have also some oligopoly characteristics. Bergesen and Oddfjell have a traditional organisational structure, integrating both ownership and ship operation. In 2000 Odfjell merged with Ceres Hellenic Shipping. Hence both Odfjell and Ceres are responsible for the management of their distinct share of the fleet. Bergesen and Odfjell favour one flag and one classification society. Oddfjell has 3200 employees and Bergesen has 2700. In contrast, Frontline has 40 employees and retains a range of contract managers, flags of registries and classification societies. This magnitude of associates creates competitive environments that Frontline can gain advantages from. TeeKay is in between the two structures, issuing most of the contract management agreements to a range of their own, competing subordinated. TeeKay have 4100 employees. They favour two classification societies and one flag.

3.1 Fatal accidents

Three of the shipping companies have been involved in disasters. Bergesen lost their ore-oil carrier Berge Istra back in 1975. Only two of the 32 crewmembers survived. Even though the exact causes of the accident are unknown, it is believed that hot work in the ships double bottom triggered an explosion causing the ship to founder in a few minutes. A similar accident occurred in 1979 onboard Berge Vanga. Nobody survived this accident. Frontline have not directly been involved in any disasters, but have links to the Sea Empress that caused major oil spills in 1996. Sea Empress was owned by the major shareholder of Frontline, registered and managed by Frontline's contract managers and is today in the Frontline fleet sailing under the name Front Spirit. The investigation of this accident concluded however that the pilot and a failed salvage operation caused the spill. Odfjell was involved in a disaster in 2003, when the Bow Eagle collided with a fishing vessel. Well aware of the encounter no assistance was provided as the ship continued its course towards Rotterdam.

3.2 Port State Control performance

A tanker is a target for inspection. The flags of registry have the responsibility for certifying that the ships comply with international regulations provided by the International Maritime Organisation (flag state control). Because some flags of convenience have neither motivation nor competence to ensure compliance, port nations have began to carry out inspections on visiting vessels (port state control (PSC)). In addition the classification societies, cargo owners and the companies themselves carry out safety inspections [8] Table 1 presents the PSC performance on the applied ship management companies. It ca be seen that Frontline favour the contract managers having most detentions while the largest share of TeeKay's fleet is assigned to the best-performing manager.

Company	Ship Manager (mng.)	Company ships	Total fleet	No. of inspections	No. of detentions	% of inspection with	
						Deficiencies	Detentions
TeeKay	TeeKay S. Canada	53	52	317	1	25%	0,3 %
	Remaining nine mng.	23	177	636	4	31.6%	0.6%
Bergesen	Bergesen		66	224	3	33.93 %	1.34 %
Odfjell	Odfjell		30	179	5	27.4 %	2.79 %
	Ceres Hellenic Ship.		39	209	1	32.54 %	0.48 %
Frontline	V. Ship UK	20	61	277	5	30.3%	1.8 %
	Golar Mng.. UK	10	6	45	1	28.9%	2.2%
	Quimica Naviera	9	9	52	5	75.0%	9.6%
	Total for three largest	39	76	374	11	36.3%	2.9%
	Remaining 14 mng.	43	314	864	7	32.0 %	0.7%

Table 1: Port State Control performance for the ship managers

4 RELATIONSHIPS BETWEEN ECONOMY AND ACCIDENTS

In order to assess if there is a relationship between the economical conditions and the occurrence of accidents, their freight rates, stock values or the annual net income is plotted with respect to time. Also the time of the accidents are plotted as crosses in the chart. A solid line indicates the density of these accidents. Figure 2 presents Odfjell's accidents and the freight rates. It can be seen that the accidents occurs in clusters either prior to or after freight rate peaks. No accidents occur at peak freight rates.

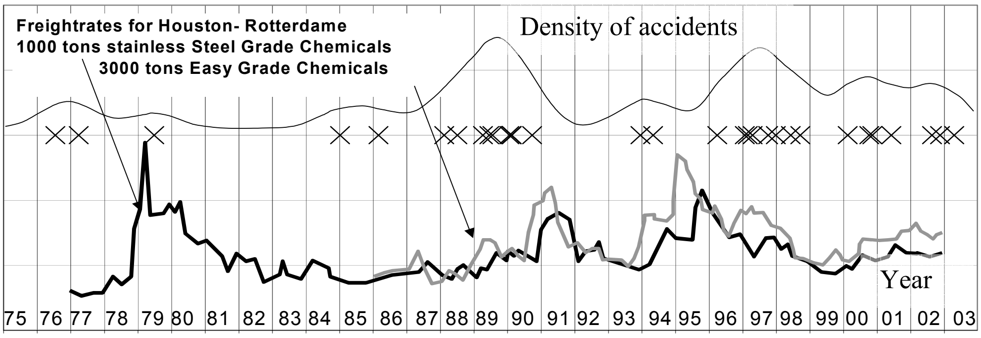


Figure 2: The relationship between freight rates and accident density for Odfjell

Also Bergesen's accidents were plotted along with the freight rates for the various gas fleet segments (figure 3). The cluster of four LGC accidents in 1997 and 1998 occurred during a relatively high freight rates, but the earning (including waiting time and offhire) only seemed to stabilise in a more or less continuous decline since 1995 (dotted line). No accidents were recorded by Lloyd's Register after the decline in 2001, but the annual report mentioned two fires and one engine breakdown in 2001 and a collision and hard weather damage in 2002. These resulted in the two worst years since 1997 with respect to unplanned offhire.

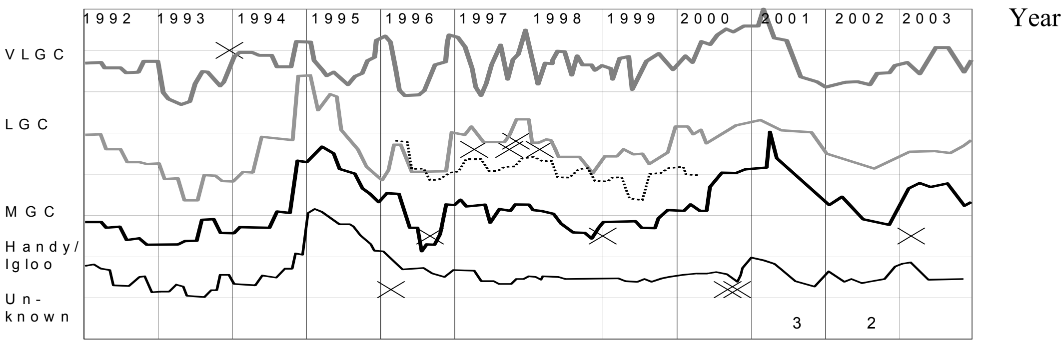
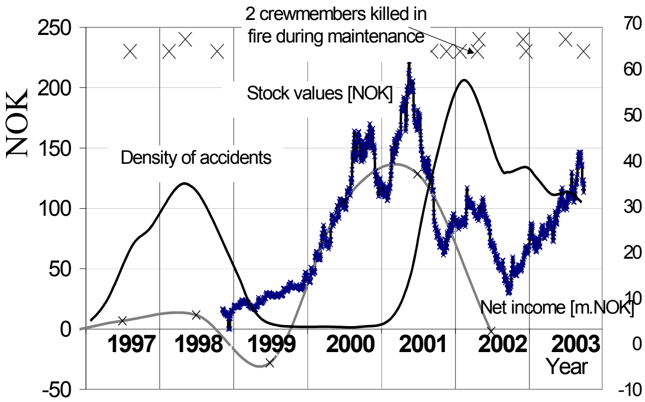


Figure 3: The relationship between freight rates and accident density for Bergesen

The negative relationships between accident risk and economical parameters can more easily be observed for Frontline. The chart indicates that when the company had strong economical growth in 2000 and most of 2001 no accidents occurred. However, when the conditions turned at the end of 2001 and 2002, a peak of accidents took place. In 1997 and 1998 the stock values was unavailable. The freight rates for oil tankers in general were growing in 1997, but turned downwards during 1998 and 1999. Even though the net income was positive for both Frontline and TeeKay (figure 5) the market was on downturn.



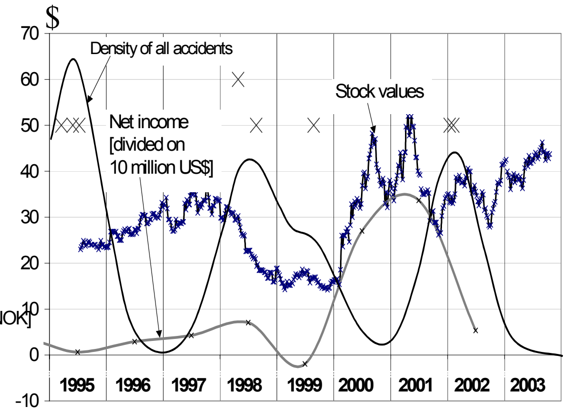


Figure 4: Frontline's time series

Figure 5: TeeKay's time series

Event though the figures 2 to 5 visually illustrates that accidents (acc.) have a tendency to occur during a poor market, this dependency is quantified. Table 2 illustrates how the years are coded with respect to economical parameters. Based on this information and the relevant ship-years (S-Y) are compiled into table 3.

	Poor economy	Good economy	Unclassifiable
Frontline	{1998, 1999, last half of 2001, 2002}	{2000, first half of 2001, 2003}	{1997}
TeeKay	{1995, 1998, 1999, 2002}	{1996,1997,2000,2001, 2003}	{}
Bergesen	[1995,first half of 1999] {1992,2001,2002} to 2003 for Igloo	[first half of 1993, 1994],{last half of 1999, 2000}	{first half of 1993, 2003}
Odfjell	[1995,2000]	{1994}	[2001-2003]
Frontline	{24, 35, 61, 69}	{58, 61, 77}	{19}

Table 2: Classification of economical conditions for various years

	Poor economy		Good economy		Unclassifiable		Total		
	Acc.	S-Y	Acc.	S-Y	Acc.	S-Y	Accidents	S-Y	Frequency
TeeKay	8	254	0	349	0	0	8	603	0.013
Bergesen	14	473	1	167	1	96	16	736	0.022
Frontline	10	158.5	2	165,5	1	19	13	343	0.038
Odfjell	10	228	2	31	4	138	16	397	0.040
Total	42	1113.5	5	712.5	6	253	53	2079	0.025
Frequency	24/1113.5=0.038		2/514..5 =0.0070		6/ 253 = 0.024		53/2079=0.025		

Table 3: Classification of economical conditions for various years

4 CONCLUSIONS AND FURTHER WORK

This study conforms that the negative relationship between accident risk and economy that was found on a fleet level can also be found on a company level. The calculations indicate that the when the market turns from good to poor the tanker accident risk three doubles. This is far lower than the figure found for group of passenger ship companies indicating that the strength of this difference is still uncertain. If only Frontline and TeeKay were considered the difference between good and poor economy would increase from three to seven times as risky. It is worth taking notice of that not only the net income, and stock values but also the time of accidents seem to correlated between the tanker companies. The year 1998 for instance, is a year with high accident density for all four companies. TeeKay and Bergersen have the lowest accident ratios and the best PSC performance. Even though the difference in safety performance between the companies is considerable the dependency to economical conditions seems to be common. Some investigation has been accomplished to see if the principle off "commercial accidents" is valid within other industrial domains. This is confirmed but there is needed research to fully develop this concept.

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MAIN CONCLUSIONS AND RESULTS

This thesis describes what characteristics that differ from the ships and shipping companies having a high safety standard, called blue chip, from those having a lower standard. This chapter summarises the findings of the thesis. The thematic structure of the thesis is indicated in the five levels of figure 8 (p.14). The first level includes the actual losses and the causes are described in the subsequent levels. The second level describes the onboard workplace factors, typically assessed through a safety inspection or a safety audit. The third level describes the safety standard based on organisational factors, with a specific focus towards safety culture. The fourth level considers the management's strategic and tactical decisions in relation to the environment (level 5). The environment specifically considers at the business environment, but also addresses regulative and societal factors. Each of the ten papers addresses various aspects of this model. The two first papers form a background for the model itself based on the state-of- the-art knowledge. The third paper is a first attempt to quantify important relationships between the levels. The next papers relate aspects of the various levels to safety standard.

MAIN RESULTS

In figure 1 relationships between safety relevant variables are mapped into the model presented in figure 8 (p.14). The grey lines (line 1 to 15) indicate relationships that are validated in published literature. The black lines indicate relationships that are validated in this thesis. The variable names on white background are variables that are generally accepted as relevant for ship safety. The variable names on grey background are variables that this study has proved to be relevant. The figure illustrates that considerable of the exiting knowledge is centred towards the Flag, Ship Type and Ship Age. Published literature relates these variables to the new cluster of three variables in the lower right corner of the figure. It can also be demonstrated that these variables are related to safety performance.

It is intuitively accepted that there exist a relationship between Safety Inspections, carried out by Port State Control, and risk of accidents. This relationship has earlier been demonstrated through an intermediate variable like the Flag of the vessel (Kristiansen & Olofsson, 1998; Alderton & Winchester, 2000). In Paper 3 this relationship is validated (relationship 16 in figure 1). This paper estimates a norm distribution for the variation in safety standard of the world fleet, analogous to the normal (gaussian) distribution represents the variation of Intelligence Quota (IQ) in a population. While an estimate of a person's actual IQ is based on IQ test scores, estimates of a ship's safety standard is based on measures of experienced safety performance i.e. accident frequency and safety inspection findings. These measures are calculated through validated frameworks. This paper also demonstrates that the substandard ships do not only obtain more deficiencies in Port State Control inspections, but also has more deficiencies related to core safety requirements.

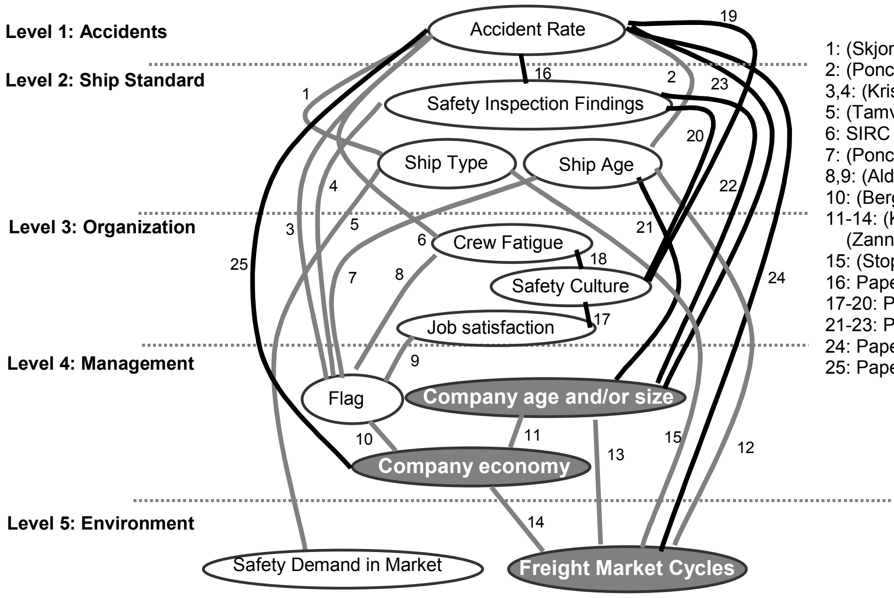

Figure 1: Mapping of relationships of relevant variables into figure 8 page 14.

Safety Culture is an acknowledged safety concept that still has little empirical evidence. In Paper 5 difficulties with existing measuring principles are demonstrated. Measures of safety culture are typically obtained from questionnaire responses. In existing measuring principles it is common to calculate scores based on how positive the responses are. At the same time it is known that a characteristic of a poor safety culture is to present themselves as extremely positive. Therefore, the assumption that positive responses manifest a good safety culture is discarded. Instead, focus is aimed at the pattern of the questionnaire responses. It is assumes that the employees of an organisation that have a good safety culture have more consistent responses and that the pattern of a poor safety culture is of a more odd nature. A technique (paper 6) that measure these two features produce scores that correlates with safety standard estimates (Paper 3). In the last approach (paper 7) a technique is developed, that extract an underlying pattern of questionnaire responses. This pattern demonstrates that the good safety cultures have larger focus on abnormal situations like tackling of fatigue, explicit communication about errors and worries and a higher job satisfaction (relationship 17, 18 in figure 1). The average safety cultures have a relatively stronger focus on normal situations, like uncritical compliance to rules. There was also a stronger focus on hierarchal levels in the organisation and less room for individual needs.

At the lower right part of figure 1 there are three variables that are highlighted. These are *"Company age and/or size"*, *"Company Economy*" and *"Freight market Cycles"*. Literature have illustrated that these variables do not only have a relationship to each other but also with the variables that have an acknowledge relationship to safety e.g. Ship Age. Paper 1 illustrates that there both is a relationship between the size (and age) of the ship management company and the ship age (relationship 21 in figure 1) and a relationship to safety performance (relationship 22 & 23). Paper 8 shows that the there is a relationship between the freight market cycles and the accident rate (relationship 24). In order to be sure that this relationship was not spurious, it was also searched for and identified on a company level (relationship 25 in figure 1 from Paper 9 & 10)

MAIN CONCLUSION

This thesis has found that the typical ship accident follow a recurrent accident scenario. This scenario describe what characteristics that distinguish ships and shipping companies that may be called sub-standard from those demonstrating a superior safety standard (called blue-chip). Reason (1998) states that a recurrent accident scenario included at least three elements. The Universals (1) represents the ever-present hazards, the Local traps (2) are the characteristics of the work place that lure people into repeated patterns of unsafe acts and the Drivers (3) that make people do erroneous behaviour. Within shipping the Universals are the hazards that have been present in shipping forever; rocks, shoals, currents, tides, loose cargo and equipment, free surface effect, burning materials, poor water integrity, lack of stability, etc. The Local traps are the neglect of the human element in general and emphasis on normative behaviour (paper 5 & 7). The staff of blue-chip companies is more satisfied with their job, has a culture that is more focused on abnormal situations like tackling of fatigue and communication about worries. The Drivers are related to commercial considerations (strategies and tactics) stimulated by the dynamics of the freight market (paper 8 to 10). The terms commercial accidents is described in the subsequent text.

COMMERCIAL ACCIDENTS

During the last decades, the understanding of accident causes has advanced significantly. Studies from the 1960s, like Beer (1968), focused on technical descriptions and weaknesses related to the enforcement and content of regulations. During the 1970s focus was moved to the human element (Quaille, 1974; Cashman, 1977). Even though it became common knowledge that at least 80 % of all ship accidents was a results of operator errors (Gardenier, 1976; Wagenaar, 1987; Carver (Lord), 1992). Over time, however, it was realised that accidents in several domains were results of a multitude of independent operator errors and technical failures. Therefore it seemed awkward to only focus on the human elements. There had to be a more fundamental cause that triggered, or allowed the multitude of failures to occur. These types of accidents were therefore called Organisational (Reason, 1997) or System accidents (Perrow, 2001). The main difference between the Organisational and System accidents is the acknowledgment of cultural and technical aspects. Reason emphasis on explanations of failures that are results of organisational weaknesses, while Perrow emphasise on the complexity and tight coupled features of system designs. Both draw the distinction to the accident scenarios of a simpler character called Individual (Reason) or Component (Perrow) accidents (Table 1).

COMMERCIAL ACCIDENTS VERSUS EXISTING KNOWLEDGE

Rasmussen (1997) has defined a related hypothetical conceptual model of Functional Abstraction. He describes the daily operation as an adaptive search in the Space of Possibilities (Figure 2). "*During the adaptive search the actors have ample opportunity to identify 'an effort' gradient and management will normally supply an effective 'cost gradient'. The results will very likely be a systematic migration towards the boundary of functionally acceptable performance and, if crossing the boundary is irreversible, an error or an accident may occur.*" This model also describes the cascades of accidents within the same organisations in periods of poor economy (paper 9 and 10). Given that the operation is close to the boundary of functional acceptable performance Rasmussen states that: "*Ultimately, a quite normal variation in somebody's behaviour can then release an accident. Had this particular 'root cause' been avoided by some additional safety measure, the accident would very likely be released by another cause at another point in time. In other words, an explanation of the accident in terms of events, acts and errors is not very useful for design of improved systems*".

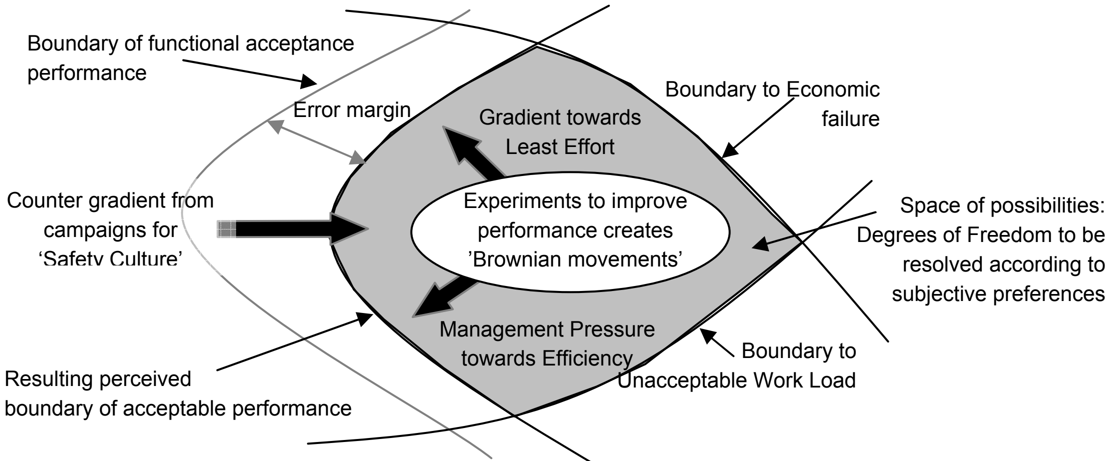

Figure 2: Functional Abstraction: Migration toward the boundary (Rasmussen, 1997)

Figure 2 outlines how various needs within an organisation may result in a migration towards the boundary of functionally acceptable performance. However, this thesis (figure 1) indicates that these needs are not of an independent nature. Management

Pressure towards Efficiency (figure 2) may exploit ruthlessly on human resources and therefore the Gradient towards Least Effort (figure 2). Management Pressure towards Efficiency (figure 2), in a market where safety has little commercial value, may also weaken the management commitment towards safety (Keil Centre, 2001). This will therefore again deteriorate the Counter gradient from campaigns for 'safety culture' (figure 2). Therefore, various existing conceptual knowledge, incorporated into the structure of figure 1, may together describe the deterioration in greater detail (figure 3). The applied knowledge sources are Risk Homeostasis (Wilde, 2001), the Competing Values Framework (Quinn & Rohrbaugh, 1983), and the Common Performance Model (Hollnagel, 1998). The volatility of the freight market, together with the low safety demand from the maritime stakeholders, influence the way management make decisions (Risk Homeostasis in level 4). Management decisions influence the organisational processes (flexibility versus stable) and their orientation (external versus internal) (Competing Values Framework, level 3). In a poor freight market the management may implement cost saving measures to reduce costs. The result of the cost-saving measures tends to be a reduced internal organisational focus and less flexible organisational processes. The comprehensive international prescriptive requirements do probably also influence on this shift, towards an External-Stable character. In sum, these characteristics determine the Adequacy of Organisation, Working Conditions and disturbance on the Circadian Rhythm (Common Performance Model, Level 2). At last these characteristics may determine the likelihood of losses (Level 1).

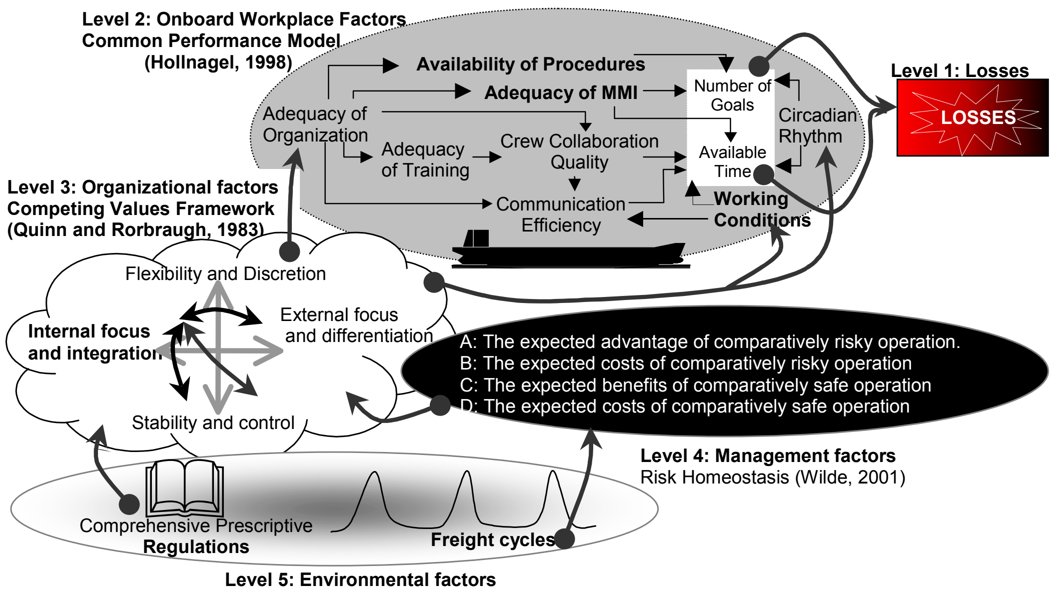

Figure 3: References to existing knowledge about safety

In sum figure 3 demonstrates that the findings from this study show that the maritime recurrent high-risk and complex accident scenarios are related to commercial considerations, stimulated by the volatility of the freight market. The ships may be modern complex and tight coupled or old, simple and deteriorated. The dependency to commercial pressure seems to occur both for sub-standard and blue-chip companies (paper 8-10), but as figure 2 indicates, blue-chip companies have a stronger counter gradient from safety culture. Both the Organisational and System accidents seem to focus on the Local trap elements of the recurrent accident scenario. As Rasmussen states "*an explanation of the accident in terms of events, acts and errors is not very useful for design of improved systems*". This indicates that the Drivers of the recurrent accident scenarios are of greater importance to fully understand and effectively prevent these accidents. Therefore the term Commercial Accidents is proposed. This term is not proposed to confuse or challenge existing definitions, but rather because these accidents are manifestations of a biased focus on short horizon profit aims at the expense of the principles for safe shipping. Both the System- and Organisational accident distinguish themselves from respectively Component- and Individual accidents in terms of the severity of the performances (table 1). The consequences of the Commercial Accidents are typically of a limited character because the ships typically are in open sea, in calm weather or in an area of little traffic. These accidents are typically recorded as a blackout, engine failure, loss of navigational control, or a heel. The exact same combinations of onboard failures may however in some cases result in a disaster if the surroundings are less friendly (e.g. busy fairway, wind, current, high sea, rocks, etc.). Because the severity of the performances is determined by factors external to the ship organisation it seems awkward to label the disasters as Organisational accidents and the less serious accident as Individual accidents. Similarly, as the performances is determined by factors external to the ship's systems it seems awkward to label the disasters for System accidents and the less serious accident for Component accidents. As the definition of the Commercial Accidents base its definition on the root cause of the accidents, rather than its outcome (Table 1).

Table 1: Characteristics of Individual, Component, Organisational and System Accidents.

Type of Accident:	**Individual or Component**	**Organisational**	**System**	**Commercial**
Frequency:	Frequent	Rare	Rare	Rare cascades
Consequences:	Limited	Widespread	Widespread	Varying
Defences:	Few or no	Many	Many 'fixes'	Typically many
Number of Causes	Limited	Multiple	Multiple	Multiple
Root Cause	Slip, trips, lapse, technical failure	Product of new technology	Complex and tight-coupled systems	Commercial pressure
Length of Scenario	Short	Long	Short/Long	Varying
Lifespan	Centuries	Ca. 30 years	Ca. 30 years	At least 100 years

SUMMARY OF RESULTS

In the following text a summary of results are presented at a more detailed level. However, as this thesis consists of 10 papers that can be considered independent from the complete story, there exist results that are not included in this text. The presentation of results follows the same thematic structure as the presentation in the Overview of thesis chapter (figure 8, page 14).

EXPERIENCE WITH DATA INTERROGATION

In this study the term data interrogation is used to describe the analytical approach. Even though Fragola (2003) describes the features of this approach, few (if any) studies have openly or knowingly applied this approach. The approach is however very old. The idea is to combine data with other background knowledge to reveal patterns. Although a data interrogation involves numbers, it is not fair to call it a statistical analysis. An excellent statistician may not be able to conduct the analysis, as it requires knowledge of the domain (e.g. maritime safety). For instance, the Norwegians used data interrogation in 1907 to understand why the Norwegian ships experienced heavy losses compared to other flags. In the search for insight the accidents were plotted on top of other logical knowledge to identify patterns. The back ground knowledge structures were geographical maps, trade pattern, ship age, cargo, class notations, ship type, human causes, insurance agreements, commitment from the maritime authorities, owner history of the ship and organisational factors. This search resulted in an in depth understanding of how organisational factors were linked to owner history, ship age and trading pattern with only a small data material. It was concluded that the companies that were speculating on ship values were linked to the root cause. To mitigate the root cause, a 20-year age limit of ships purchased from foreign countries entered to force some years later. Today, almost a century later, age limits are still used as a response to accidents like Express Samina, Erika and Prestige, but with no reference to the causes determining why old ships have a higher accident rate. Therefore it seems as modern safety regulation have a biased focus towards statistical inference relative to reasoning based on cause-effect chains. There exists however exceptions such as MAIB's data interrogation of 65 navigational accidents to demonstrate the significance of watchkeeping fatigue (MAIB, 2004)

BACKGROUND KNOWLEDGE ABOUT ACCIDENT SCENARIOS

This part of the thesis collects, review and interrogates knowledge about maritime recurrent accident scenarios. These scenarios are described in terms of Causal Conditions, Rules and Performances (Figure 2, p. 4). Reason (1998) defines three elements that may describe the Conditions of a recurrent accident scenario. The Universals (1) represents the ever-present hazards, the Local traps (2) are the characteristics of the work place that lure people into repeated patterns of unsafe acts and the Drivers (3) that make people do erroneous behaviour. According to Rasmussen's (1997) model in figure 2, there is little need to focus solely on the prevention of Local traps (2).

THE PERFORMANCES

The Performances of ship accidents have changed over the last century. It is possible to roughly evaluate the last century's safety improvement process. Over the last century the average annual reduction in accident rate is in the area 2-3 percent (Ponce, 1990; Paper 1). Figure 4 (from paper 1) shows, however, that these improvements have been sporadic (compiled from LMIS). Apparently, the total loss ratio dropped about 30% during a few years around 1930, and the period from mid 1930s until the late 1970s seems to vacillate around a loss ratio of 0.65%. In this context it is worth noticing that IMO was constituted in 1949. From the late 1970s until 1990 the yearly improvement again speeded up to nearly 10% each year.

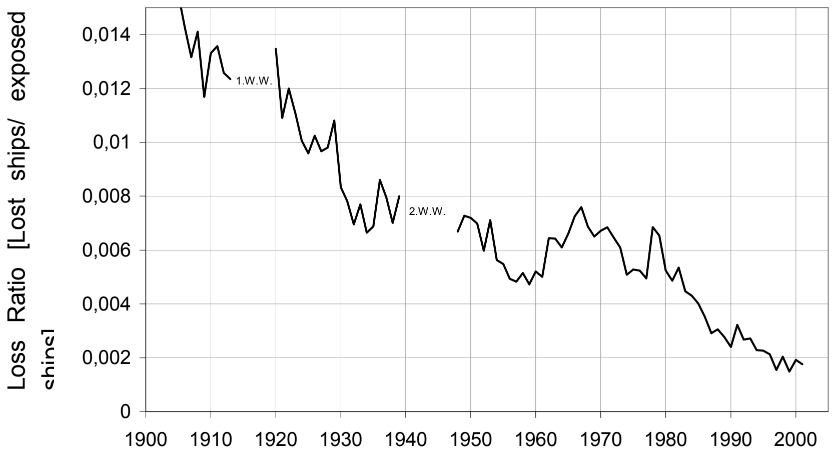

Figure 4: World fleets' total loss ratio (steam & motor ship larger than 100 gt.) (Data source: LMIS)

During the 1930s and the 1980s the two largest market depressions of the 20th century took place. The instant drops in loss ratio may therefore be explained by a reduced shipping activity. From 1929 until 1932 there was about a 35% increase in laid up ships. In 1936, however, this laid up tonnage was back to level of 1929 (League of nations, 1939; Hegna, 1936). Therefore, a reduced activity level does not necessarily explain the improvements. An alternative explanation is that the ships were managed and operated differently. According to several sources the harsh market pushed the ship speculators out of the market (Fearnlay, 1985; Stopford, 1998). Also the early 1920s was unattractive for speculations into ship values, because there was a balance between shipping demand and transport (Stopford, 1998). It is already shown in figure 4 that these periods coincide with large drops in accident frequency.

In figure 5 the loss ratio is considers with respect to the four underlying categories Wrecked, Collision, Burnt and Foundered. It can be seen that the loss ratio of foundered ships have not decreased significantly during the last 70 years. However, the loss ratio of wrecked ships are have decreased most significantly. In 1927 more ships were lost due to collision than to fire, but this tendency turned in the years around the 2.W.W.

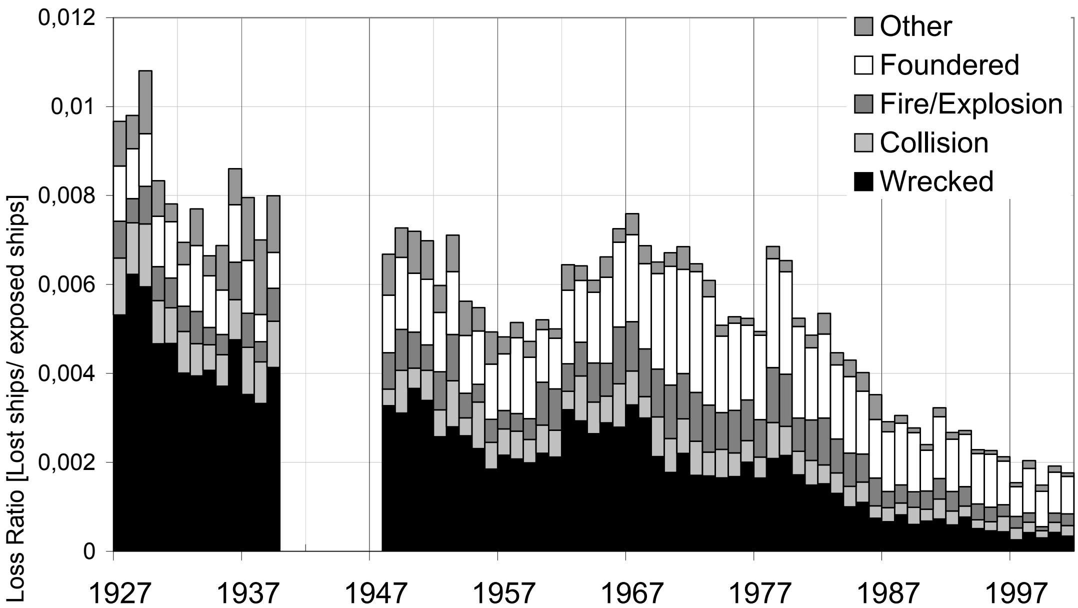

Figure 5: Categories of the world fleets' total loss ratio (steam & motor ship larger than 100 gt.) (Data source: LMIS)

There are some characteristics that are worth noticing. The reduction in loss ratio during the early 1930s and the 1980s are due to reductions in the wrecked ships. Early in the period more than 60 % of the losses were categorised as wrecked, and on average for the period 1927 to 1939 it represented 55% of the losses. In 1996 only 17 % of the losses were in this category and on average for the period 1978 to 2001 it represented 24% of the losses. The average values for foundering for the same periods (1927-39 and 1978-01) were 14% and 43% respectively. The relative number of losses due to collisions has been 11% during the whole period, while the corresponding values for the Fire/Explosion category are 8% and 15% respectively. Another characteristic is that the loss series correlates during some periods. The correlation between the collision and wrecked loss ratios vary over time (figure 6). High correlation values indicate that there is a dependency between the categories. If various accident categories occur interpedently of each other this might be an indication of lack of safety control and vice versa. As a result a search for dependencies, i.e. correlation, might be a new metric within safety management. This characteristic is explored in paper 6.

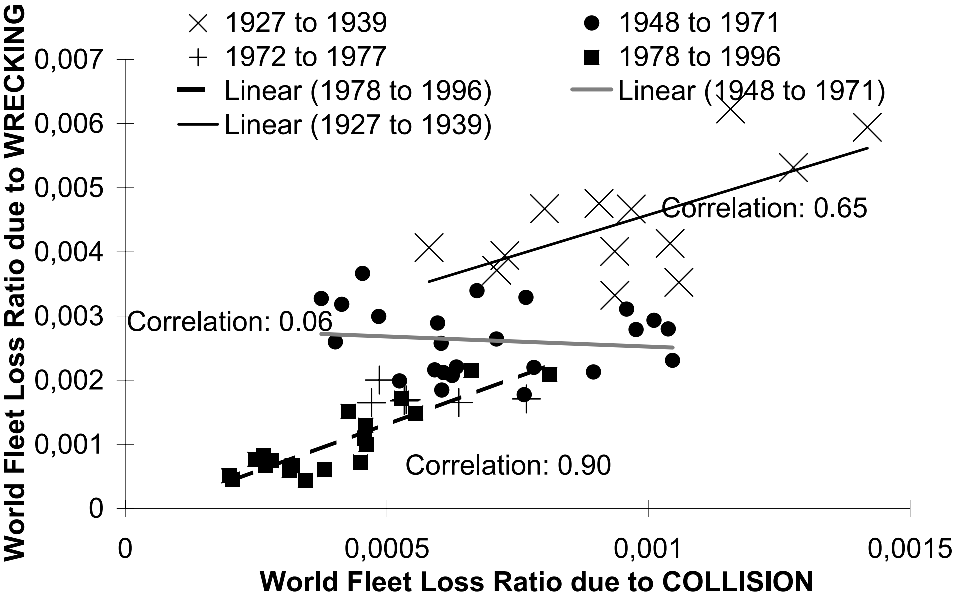

Figure 6: Dependency between the world fleets' total loss ratio due to collision and wrecked from 1927 to 2001 (steam & motor ship larger than 100 gt.) (Data source: LMIS)

THE CAUSAL CONDITIONS

It is known that operator (human) errors constitute at least 80% percent of the accident causes (Heinrich, 1959; Gardenier, 1976; Wagenaar, 1987; Carver (Lord), 1992). The dominance of operator errors over technical failures as accident causes have been evident for almost a century (figure 7). The major change in the recording of accidents is that fewer accidents are considered to be unavoidable and caused by factors external to the ship itself. The most apparent trend is the reduction of causes considered to be external of the ship (e.g. other ships or foreign pilot) and unavoidable (e.g. storms, sea, ice, self ignition or misfortune). However, even though the recorded causes often were of this kind, experts expressed a century ago that organisational factors were most important (Kysten, 1907). It is also worth noticing (figure 7) that while the reduction in accident rate is 75%, the reduction in operator causes is only 44%. This indicates either that the investigators knowledge has matured and therefore perceive more causes as operator errors today, or that the safety improvement efforts during the last century has been biased towards technical and external / inevitable factors.

In contrast to the emphasis on the human element there is also significant statistical evidence proving that the accident likelihood of a ship correlates with its age (paper 1). This was earlier demonstrated in figure 6 (p.9). The causal explanation behind this correlation has attributed deterioration of technical features. Therefore it seems as if there exists two conflicting basic interpretations that both are supported with statistical evidence. Figure 15 confirms that older ships are more risky, but that the causal explanation behind this relationship can be explained by differences in the company characteristics. Smaller and younger companies are more often managing old ships. Old ships are relatively more often in a spot market were the business horizon is shorter (Stopford, 1998). This indicates that the typical ship accident is a result of failures within the organisation, management or aspect of the whole socio-technical system.

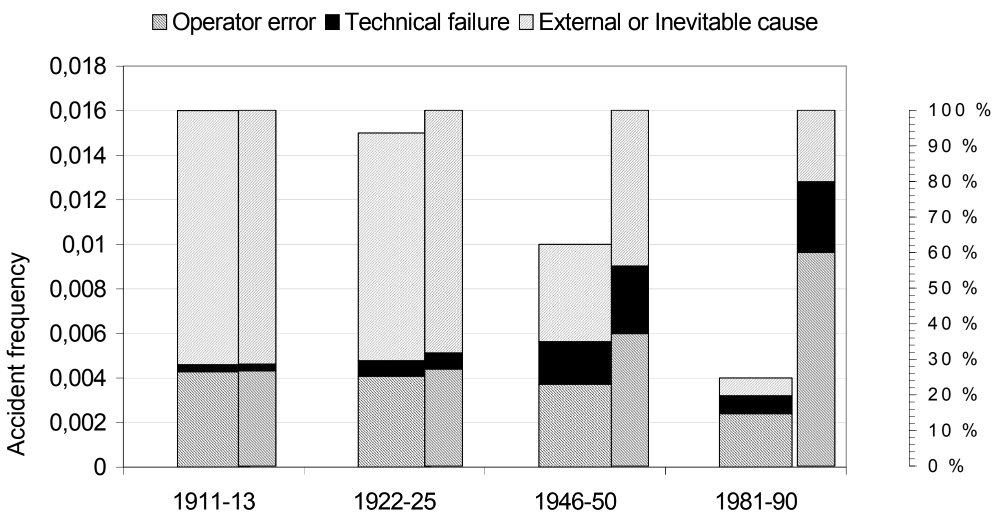

Figure 7: Recording of accident causes for the Norwegian fleet over 100 gt. (Data source : Sjøfartskontoret, 1911-50; DAMA, 1990)

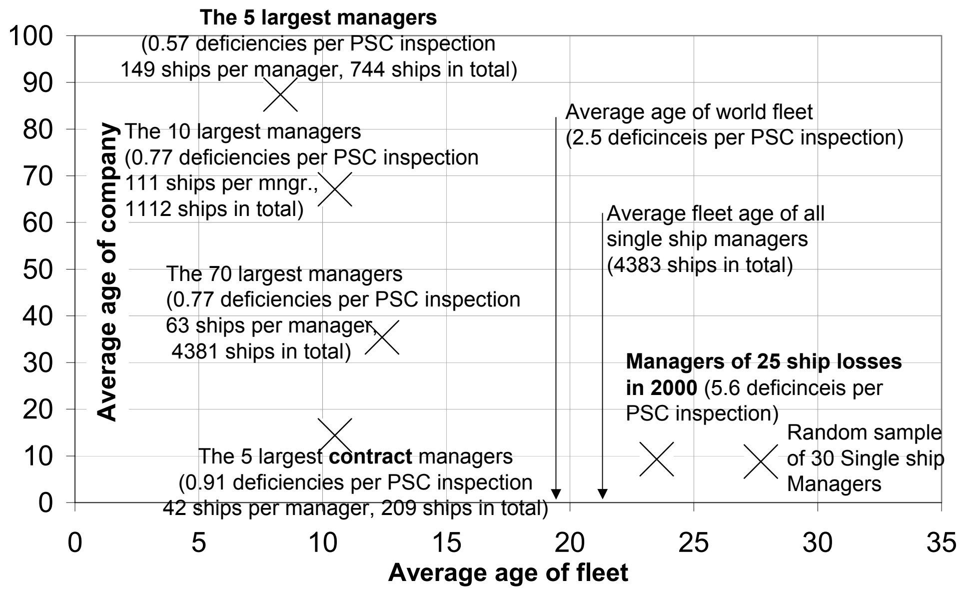

Figure 8: Company age versus fleet age (Sources: fairpaly, LMIS)

In order to more precisely define the link between accidents and organisational, management and socio-technical system more than 30 symbolic models were assessed (paper 2). Based on the assessment of these models, it was suggested that a five level model (Figure 8, p. 14) was suitable for representing this link. This study also concluded that the model should aim at variables that describe actual behaviour and not normative behaviour e.g. regulation.

Another interesting finding was that the iceberg models, first proposed by Heinrich (1931) might change over time. Figure 9 presents models from land-based industries. The figure 9 shows that the total volume of indicators increases with time, while there tend to be fewer non-injury accidents per major injury. In this context the iceberg models tend to be higher and sharper.

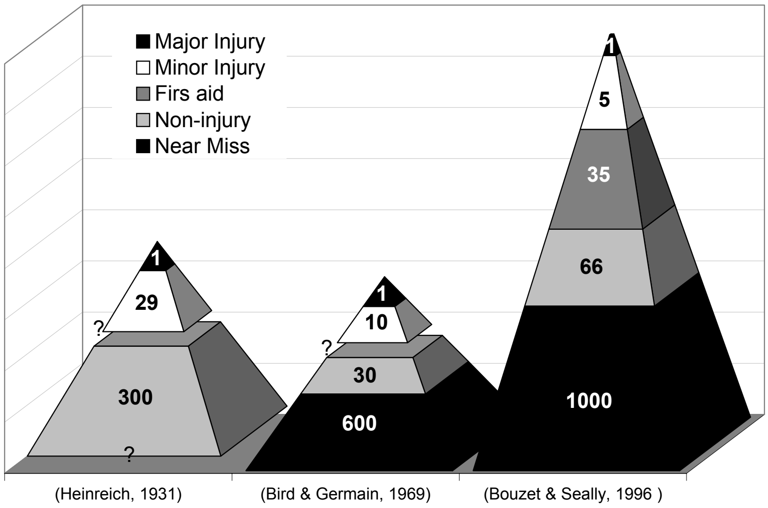

Figure 9: Comparison of three iceberg models from different time periods

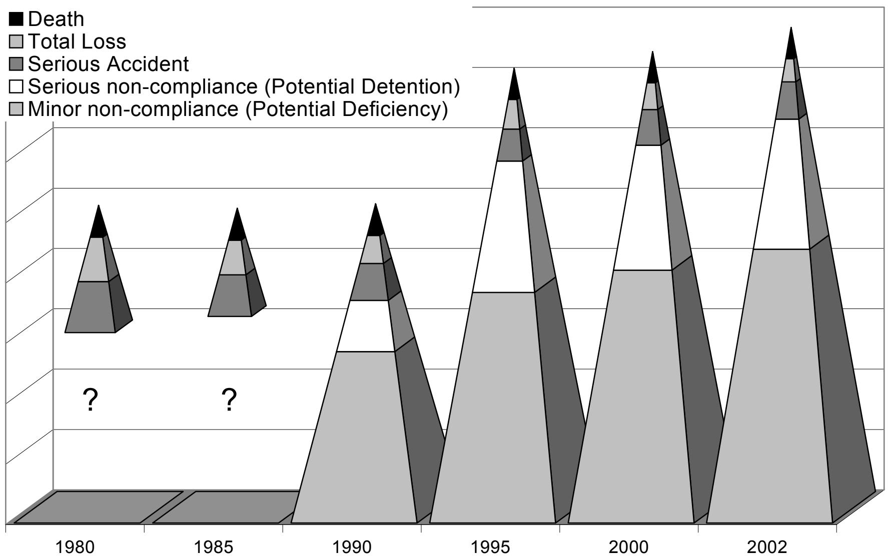

Figure 10: Constructed simplified maritime iceberg models

This trend can also be seen in the accidents prepared by LMIS (the three highest levels in figure 10). The three highest levels in figure 10 tend to be sharper. At the same time the port state control inspectors find more deficiencies and failures (paper 1).

THE RULES OF THE SCENARIOS

The results this far can be summarised briefly. Figure 7 shows that a lower percentage of the Norwegian ship accidents are recorded today with factors external to the ship or being of an unavoidable nature. This indicates that it is an increased belief in prevention of accidents. According to Kristiansen (2000) "*It is often more easy to identify failures in the last stages of an accident than in the initiating stage. Decision makers therefore tend to look for measures that limit the damage rather than avoiding the accident*" (ref. figure 3, p.5). Regulators therefore repair direct causes, typically of a technical nature. It has also been common to blame the individuals involved in the accident (Wagenaar, 1997; Pidgeaon & Leary, 2000). Over time the accident rate has decreased. However these reductions seems to be independent of regulatory efforts. Figure 4 show that the major improvements in accident ratio occur during a stable or depressed market. These periods are characterised by its need for a long business perspective and its poor possibilities for asset play[2] (Stopford, 1998). This indicates that the Drivers of the recurrent accident scenario are related to economical motives (figure 11), which may have an effect upon a multitude of organisational aspects (diverging phase). Laid-up vessels may on a short time basis explain the drops in accident rate during these market states. However, small and young companies have less possibility to survive these depressions and often have to leave the market (Stopford, 1998). When the freight market improves the accident rate tend to remain at a low level (figure 4). It has been known for a century that old ships have a higher likelihood of being involved in an accident (paper 1). It has been believed that this relationship is related to technical degradation (figure 6, p. 9). This is in sharp contrast to the finding presented in figure 14. However, figure 8 indicates that old ships also seem to be managed by a different kind of company being younger and smaller. Knowing that it is this type of companies that leave shipping during market depressions these findings are consistent. It is suggested that ship age is a Perceived danger (figure 11), with no actual involvement in the causal sequence and that the company characteristics are more relevant in the recurrent accident scenario.

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[2] Asset play means to speculate with buying and selling ships i.e. to buy a ship when its market value is believed to be below its future value, and sell it off when the market value is believed to be over its value in a future market.

The improvements in accident rate during the depressions in the early 1930s and the 1980s were due to a reduction in wrecked ships. Wrecked ships are most likely a result of navigational errors (Gardenier, 1976; Kristiansen & Soma, 1999). According to Goossens & Glansdorp (1998) who investigated more than 300 navigational incidents "*…in two-thirds of the cases, incidents began with a tactical event, meaning relatively close to the point-of-no-return. … Errors involving decision-making and implementing a new course and speed seems to be minor (substantially less than 10 percent)*". Wagenaar (1987) has showed in an investigation of 100 ship accidents that it is impossible for a operator to see in advance that the error or decision is critical, because other failures (that makes it critical) are hidden or unidentified (Perrow, 1999) (converging phase in figure 11). The scenarios are complex and evolve over time during normal operation (Karlsen & Kristiansen, 1980; Wagenaar, 1987). Because the regulators focus on the direct causes of the accident (fainted, high in figure 11), and not the organisational causes or the Drivers of the scenario (figure 11) there may be fewer observable indications of the high risk-accidents (figure 9 & 10). Underneath the observable indications however the total magnitude of latent failure may still diverge for other accident releases (figure 9 & 10).

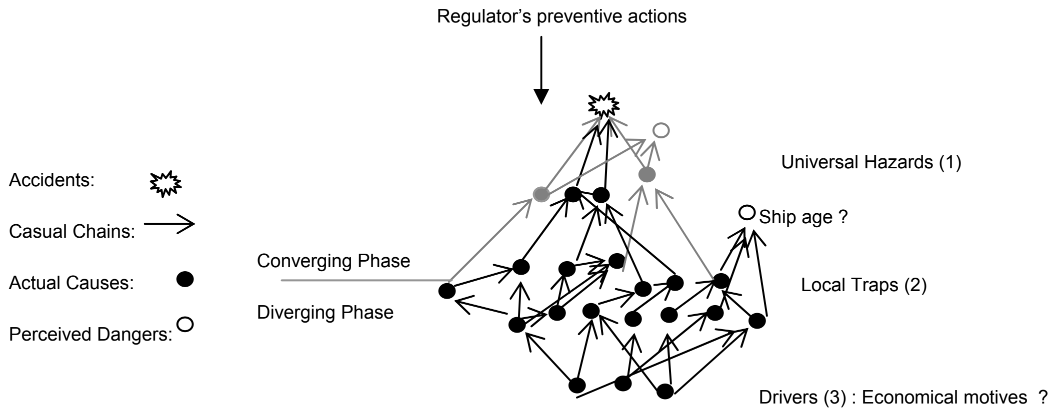


Figure 11: Refinement of figure 7 p. 10

RESULTS OF DATA INTERROGATION WITH ARTIFICIAL NEURAL NETWORKS

The interrogation approach implies that relationships are identified through heuristic searches with techniques like artificial neural networks and learning Bayesian networks. Figure 11 indicates that certain causal conditions, when combined in certain complex ways (rules), has an accident as the outcome (in figure 2 p.4 : condition + rule → performance). If it is assumed that data on any possible Conditions were available, and it was possible to identify any combinations of these data (Rules) that produce the performance (accident or not) the actual causes in figure 11 could be identified. This is the task of a neural network. A first attempt (Paper 4) in finding variables that distinguished the safe ships from the less safe was to develop a hybrid artificial neural network. The network is labelled hybrid because certain limits were built into the network in order to fit the symbolic model in figure 1. Because the relationships in this model were assumed to be valid, the idea was to force the network to emphasis on the relationships that were still unknown. Input variables were information about the ship and the companies. The network was then trained to describe the known safety performance of various ships based on these variables. This approach was effective, but did not have the ability to explain the total variation. This was related to limitations in the data. A simpler approach that was found to be efficiency was to compare data patterns. For instance the time of an accident for a shipping company may alone present an irregular pattern. However, when the time of the accident is considered in relation to the economical performance of the company, a regular pattern could be identified (paper 8, 9, 10). It was also found a correlation was a suitable metric for evaluating the quality of the safety management (paper 6) and safety culture (paper 7)

NORM FOR ASSESSMENT OF SAFETY STANDARD

In order to find robust rules and conditions that govern a recurrent accident scenario it is necessary to not only consider accidents (figure 3 p.5), but also the organisations that do not experience accidents (in figure 2 p.4 the term Performance may also be good i.e. absence of accidents). If the safety performance can be assessed both for Sub-Standard and Blue-Chip companies it is possible to extract the organisational differences between them. In order to assess if a ship or company has a good safety performance, it is necessary to know what the general safety standard of the world fleet is. In order to describe this norm analogies are drawn from the measurement of IQ. Similar to the distribution of IQ, a skewed distribution is estimated to represent the distribution of accident rates for the world fleet. This distribution, shown in figure 12, was developed both for total losses and serious accidents. Based on this distribution it was concluded that the ships being among the 25% having the highest accident rate (C: Sub-standard) have roughly seven times as many accidents as the group of ships 25% having the lowest accident rate (A: Blue chip). Consequently, the safest ships (A) only experience 7% of all accidents, while the most substandard (C) are involved in more than 50% all accidents.

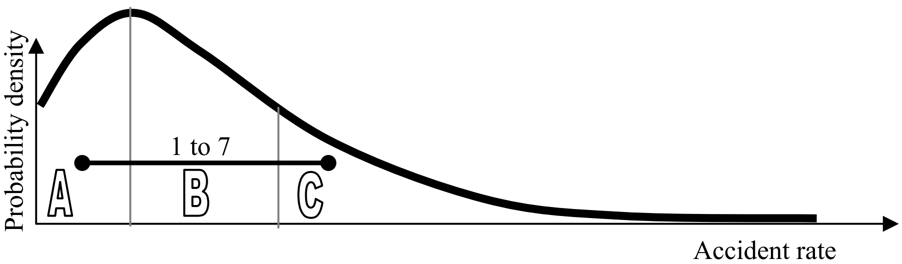


Figure 12: Performance characteristics of various safety standards for the world fleet

Having identified the groups A, B and C, the characteristic of their safety inspection records was considered. In this analysis the Port State Control inspections were used as a data source. The type of safety inspections findings (e.g. unsatisfactory documentation, fire equipment, etc.) was considered to compare the 25% most sub-standard (C) with the 50% average (B). It was concluded that also the types of deficiencies varied between these groups. The most sub-standard ships did not only have more deficiencies, but the relative frequency of deficiencies related to core safety issues was relatively higher (Figure 13). These deficiency types were related to accident prevention, International Safety Management (ISM) code, lifesaving appliances and safety in general. This indicates that the most substandard ships not only have a general lower degree of compliance, but that especially core safety requirements are ignored.

Figure 13: Portion of ships in world fleet and their portion of accidents

Knowing the distribution of accident rate for the world fleet, it was possible to state how likely it is that a given fleet belong to each of these groups based on its experienced accident statistics and safety inspection findings. This technique was fully validated and found to be reasonable consistent. It was also found that accidents like Erika and Express Samina could be foreseen if their performance data had been analysed prior to the accidents. On the contrary ships being a member of International Safety Management Association (ISMA), Green Award and Intertanko were found to be better than the average. Figure 14 presents the scatter plot of results from nine shipping companies Z1 to Z9. Company Z1 is ranked as the safest company, while Z9 is the most sub-standard company.

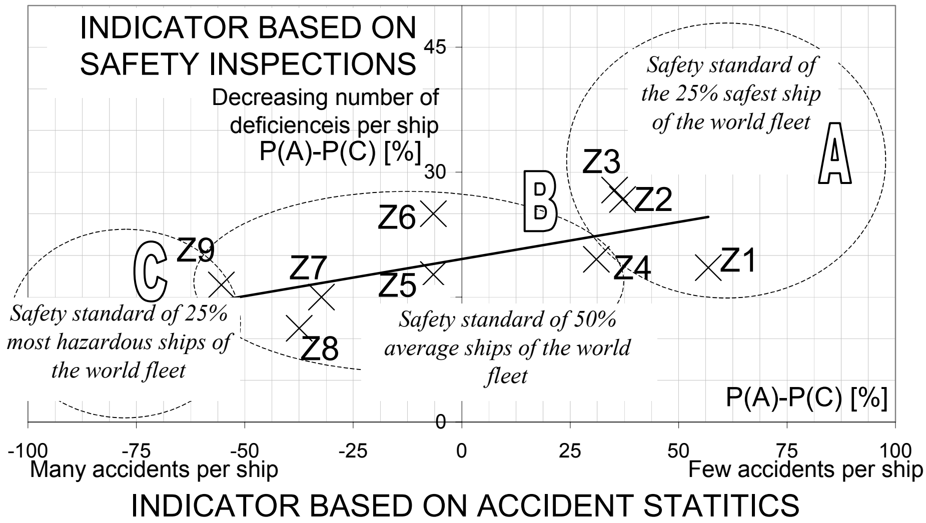


Figure 14: Relationship between indicators of safety inspection and accident history

The value in figure 14 is the likelihood that a company belongs in class A (25% best) minus the likelihood that it belong in class C (25% worst) (P(A)-P(C)). On the abscissa this estimator is based on the accident statistics, while the values on the ordinal axis are based on safety inspection deficiencies.

RESULTS OF DATA INTERROGATION INTO ORGANISATIONAL FACTORS

Three articles in this thesis address organisational factors. The first compares the responses on the Ship Management Attitude Questionnaire (SMAQ) from four companies having the same nationality (Z3, Z6, Z7, and Z8 in figure 14). The response distributions of various questionnaire items were extracted to fit various conceptual models within safety management (paper 6). As an example various items that fit the continuous improvement loop (Deming's (1991) Plan-Do-Check-Act) are presented in figure 15. At first these distribution of responses seems to be relatively independent of the ranking of the companies. It can however be seen that the most company Z8 in general is more neutral to the questions. The selected Plan-item at the higher right section of figure 15 it can be seen that a lower portion of the responses have a very high satisfaction with the safety manuals. At the lower right section, the selected Do-item is presented. This item illustrates that the portion of strongly agreement with the statement "*Emergency drills are conducted as prescribed*" seem to fall with from Z3 to Z8, with the exception of Z7. This indicates that Z8 to a lower degree than the other companies do what they are supposed to do. At the lower left section of figure 15 it is shown that the portion of responses indicating that checklists are omitted "only" 0-20% of the cases fall with decreasing safety standard. At the higher left section the selected Act-item is presented. This illustrates that company Z8 has a different pattern of responses.

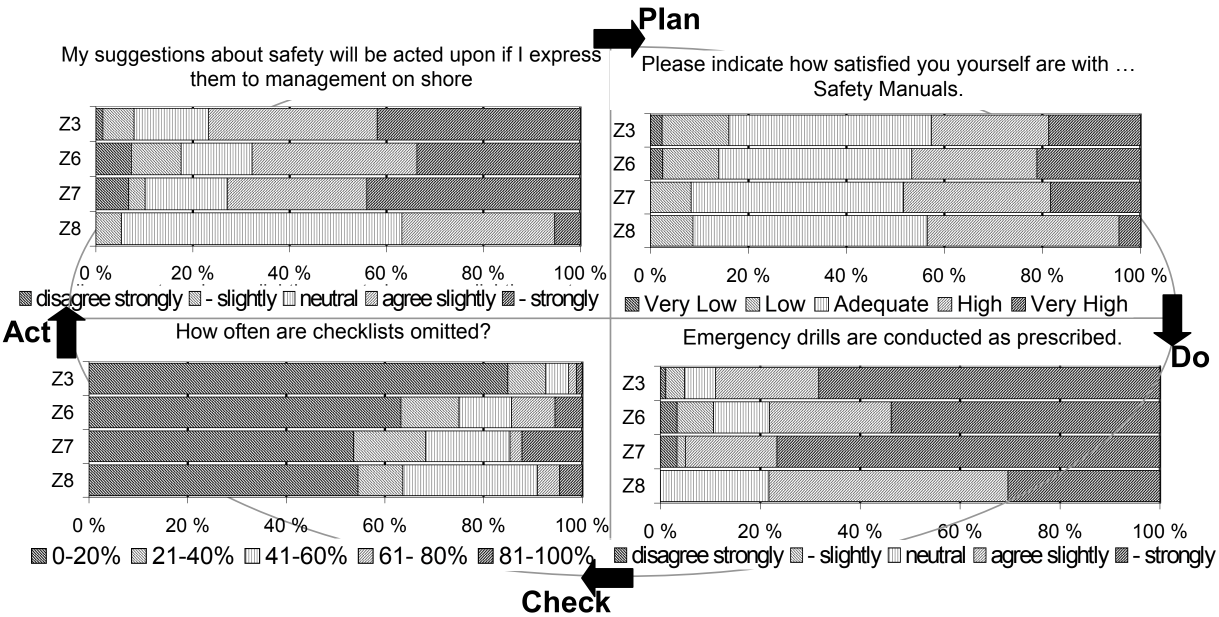


Figure 15: Item responses arranged in a continuous improvement loop perspective

Other conceptual models and perspectives were also considered. The perspective that most efficiently discriminated between the safety standards was the Competing Values Framework developed by to Quinn and Rohrbaugh (1983) and Cameron and Quinn (1999). The idea behind this framework is that organisational culture can be measured on two scales representing the internal versus external orientation of the organizational focus and its stable versus flexible processes. Even though it was developed questionnaires that measure these features directly, items from the SMAQ that correspond with the two scales were considered. In figure 16 items that describe stable versus flexible focus are presented. The left distribution shows that the wish to have a stable work condition increase with falling safety standard. Asked in the opposite direction the right distribution shows that the wish to have a changing work condition fall with decreasing safety standard.

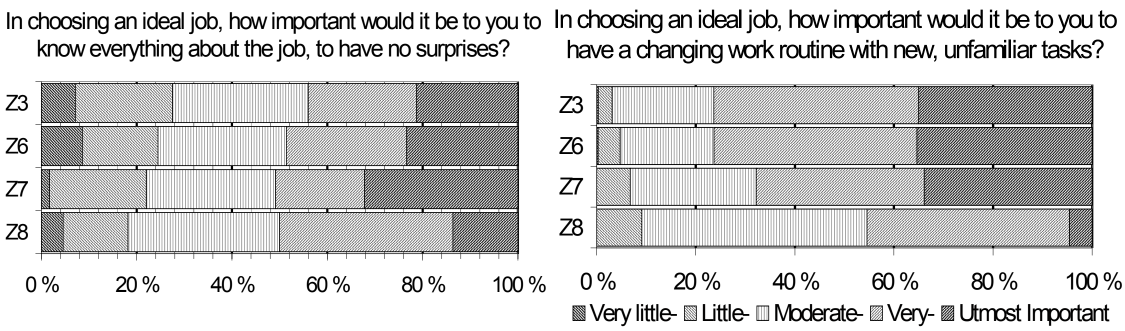


Figure 16: Distributions of responses related to stable versus dynamic organizational processes.

Figure 17 shows perceived values related to the job itself (internal) versus aspects focusing on more external aspects. The right distribution shows that the desire to obtain a personal sense of accomplishment (internal) fall with falling safety standard, while the right shows that the Z8's dominating desire is to be recognised by others (external).

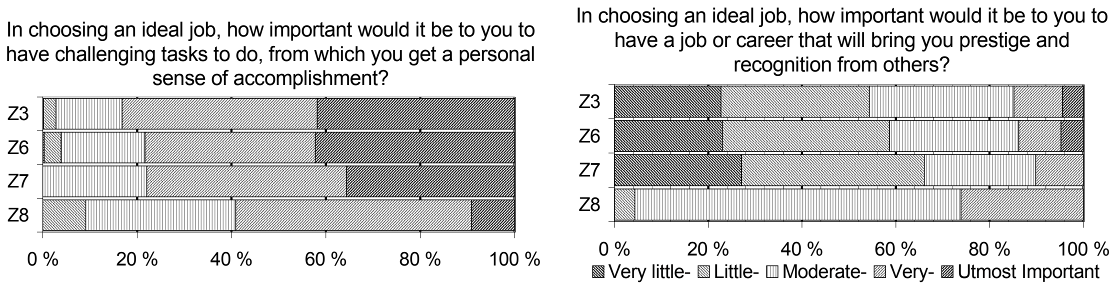


Figure 17: Distribution of responses related to internal versus external focus

Paper 6 culminated in a principal component analysis to describe the differences in safety standard. This analysis groups correlated items into independent components. The name of the seven components is presented in figure 18. From figure 14 the relative difference in safety standard between the companies were known. Even though the average scores on some components correlated with the ranking (Figure 18), it was argued that these scores were invalid for representing such a relationship.

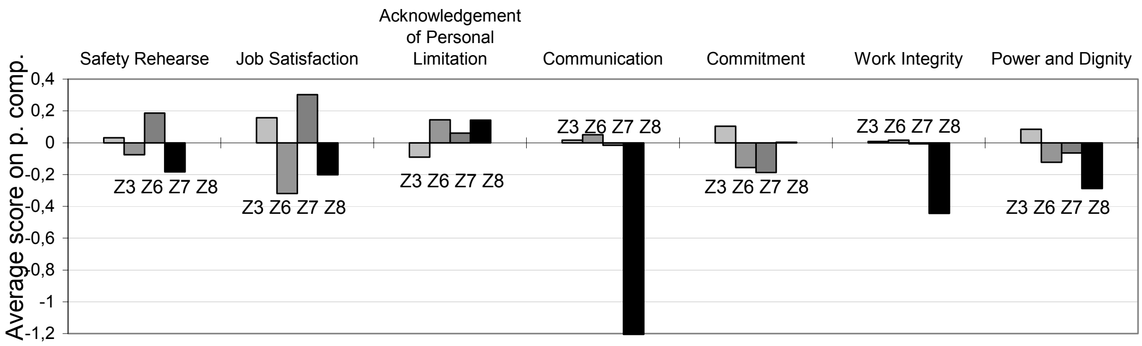
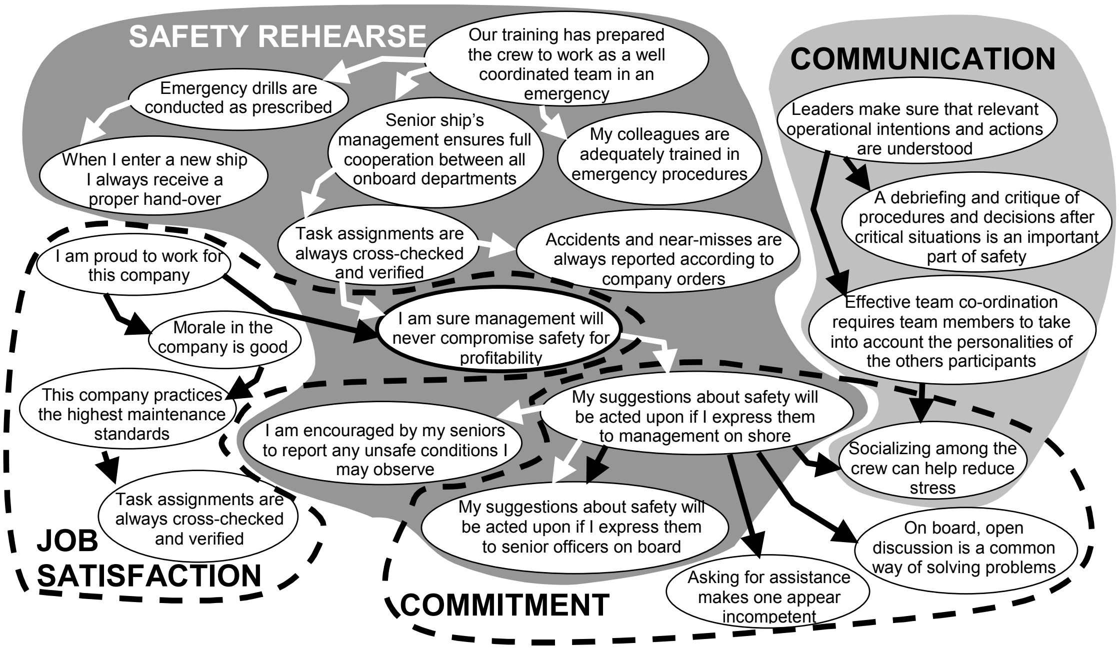


Figure 18: Average scores on principal components

By using a Learning Bayesian Network, the relationships between the items within a principal component could be found. Arrows between items represent these relationships in a network called a Directed Acyclic Graph (DAG). The DAG indicates that the response on one item, determine the responses on the items that the arrows point to. It was found that there were common items in several components. Hence, it was possible to put the DAGs from individual components into larger structures. The four principal components called Safety Rehearse, Communication, Job Satisfaction and Commitment formed a common DAG presented in Figure 19. This structure indicates several issues. Focusing on the Safety Rehearse DAG, it can be seen that experiences from the past determines the attitudes towards the present condition, which again determines the attitudes towards potential future situations.

Figure 19: Combined DAG of four principal components



The insight obtained from the paper 6 indicated that the traditional measuring technique of safety attitude data through scores on principal components (figure 18) was insufficient. Alternative techniques had to be developed. Two approaches were applied. The first technique is based on the finding that principal components like Commitment, Motivation and Job Satisfaction are identified in different organisations and different domains. The fact that similar components are identified in different organisations indicates that there is a universal core of attitudes towards safety issues across national cultures and companies. In shipping the environment, technology, regulation, competencies and several other factors are common for all commercial ships. This uniform context indicates that there should be dependencies in experience and attitudes between different companies. This can be illustrated by a norm of principal components, which should be identifiable in a shipping organisation (figure 20).

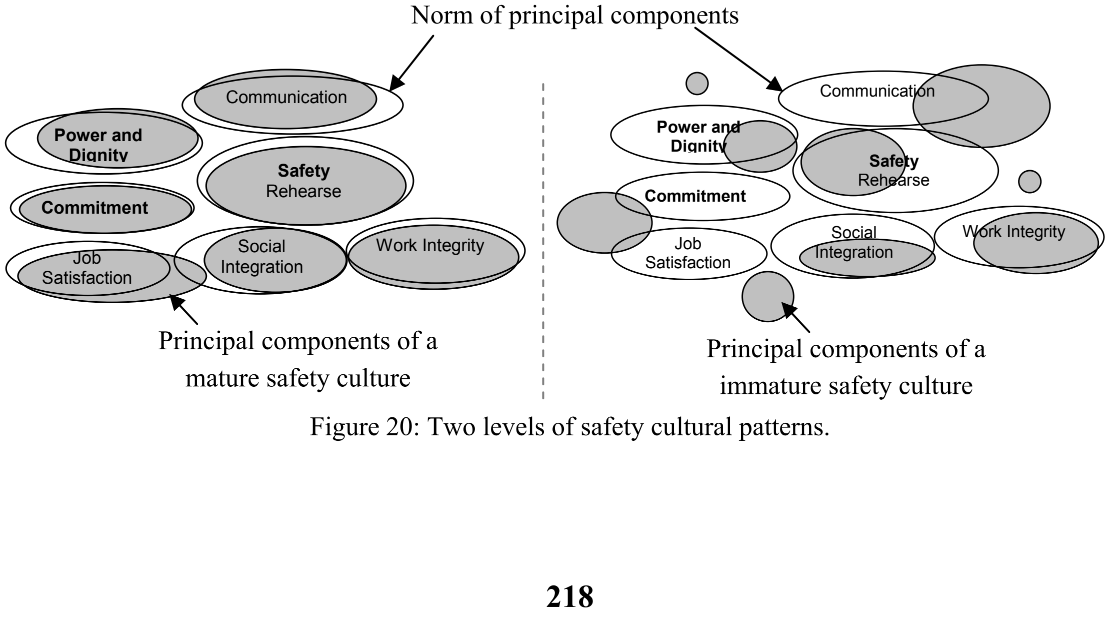


Figure 20: Two levels of safety cultural patterns.

It was proved that there is a dependency between pattern of attitudes across nationalities and companies. This justifies the assumption that a norm of principal components is true. It was then assumed that there are smaller variations among the cultural pattern of the mature cultures relative to the less mature (grey components in figure 20). Therefore, an immature culture is of a more unique character. The similarity of cultural pattern between the companies was therefore used as a measure of safety cultural maturity. The relationship to the indicators in figure 14 is presented in figure 21 and 22. The ordinal axis in figure 21 represents the abscissa axis in figure 14, while the ordinal axis in figure 22 represents the ordinal axis in figure 14. The abscissa axis in figure 21 and 22 is the average correlation of the attitude pattern between different companies. High values indicate that other companies within the sample has similar attitude patterns (left in figure 20), while low values indicates that the attitude pattern is of a unique character (right in figure 20).

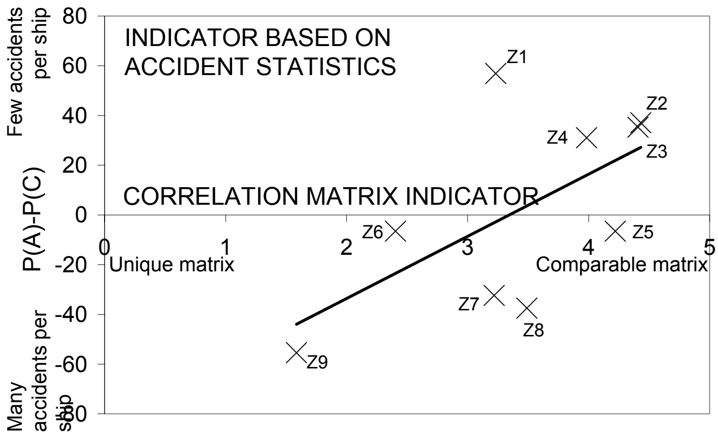


Figure 21: Relationship between accident statistics indicator and correlation matrix indicator

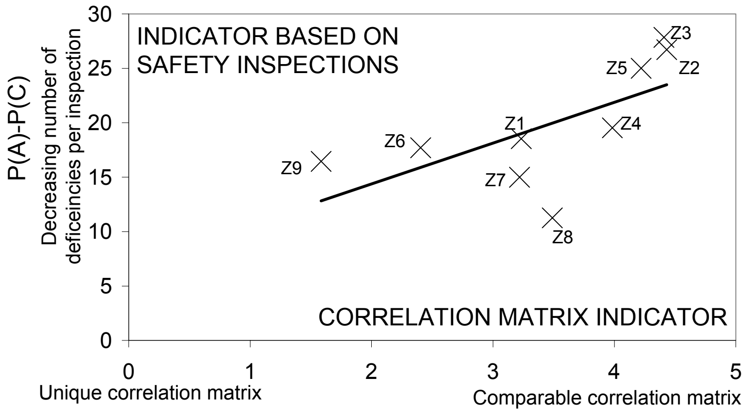


Figure 22: Relationship between safety inspection indicator and correlation matrix indicator

By definition the principal components are independent as illustrated in figure 20 and left in figure 23. However, the fact that the principal components in figure 19 can form a reasonable structure of a dependent character indicates that it might exist an underlying level of relationships (figure 23). This underlying pattern can not directly be estimated by a principal component analysis.

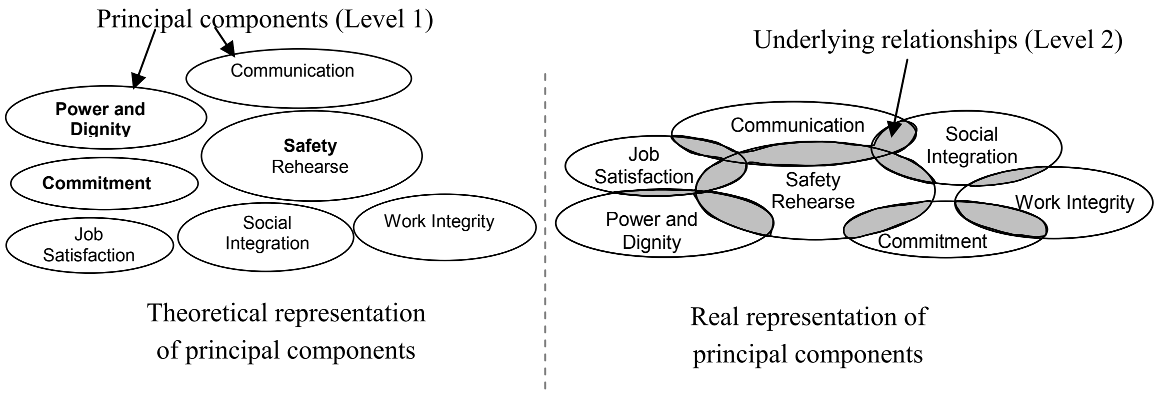


Figure 23: Two levels of safety cultural patterns.

The described technique applies the whole pattern of attitudes extracted from item responses. The next technique focuses on the items that both are central to the cultural pattern and the safety standard. Key items are present in different principal components and their variance is well described by the principal components (high communality values). It was found that items related to normative behaviour were more explicitly described by the underlying cultural pattern of the poor performing organisations. Such behaviour involves uncritical compliance to procedures, emphasis on hierarchal levels and disregard for individual qualities. The companies having a high safety standard distinguished themselves on an underlying pattern that emphasised on handling of extraordinary situations, job satisfaction and commitment. Such situations involve fatigue, emergencies and communication about errors and worries.

In order to justify the content of these variables in a maritime context some descriptions of the maritime organisational cultures have been studied in the literature. The managing director of the Central Union of Marine Underwriters (CEFOR) Forsmo's (2002) reflection of the history of maritime safety regulation during the 1980s was *" ... developing a maritime safety consciousness was needed. Terms such as "compliance culture" and "evasion culture" were introduced as opposites to the ultimate panacea "safety culture*". Holt's (1989) description of the typical shipping culture is that it is "*…characterised by quick decisions in buying and selling, short-term solutions, emphasis on technology and tonnage, and neglect of people and human values*". These descriptions can be considered as expert judgments from the professionals in the domain and are not based on empirical evidence. The content of the identified items seems to catch these features.

RESULTS OF DATA INTERROGATION INTO MANAGEMENT AND ENVIRONMENTAL FACTORS

The most important business variable for management is the freight rates. The freight rates in shipping are extremely volatile but also follow long terms cycles (Koopmans, 1939; Zannetos, 1966; Stopford, 1998). It was found that the total loss ratio was significantly reduced two or three times during the last century (figure 24). These periods were the early 1920s, the early 1930s and the 1980s. These periods have one thing in common. There were no room for speculation in buying and selling of ships. During the early 1920s the market was relatively good, but the increased shipping demand combined with increased new buildings kept the rates at a stable level. The 1930s and the 1980s were the two most serious and long lasting depressions in the market. A high portion of the tonnage was laid-up indicating that the drop in loss ratio in reality was somewhat less instant than illustrated in figure 4. During these periods only the companies' with a long-range perspective remained in the market. The chart also indicates that during the 30 years after IMO's establishment (1950 to1980), no significant improvement was achieved.

Based on several smaller studies it was concluded that the accident rate followed an inverse relationship to the development of freight rate at the late 20th. In figure 24, for example the general freight rates after the 2.W.W is inversed and then put on top of the total loss ratio series. It can be seen that, except for the 1980s that is earlier described, the inverse relationship can be seen.

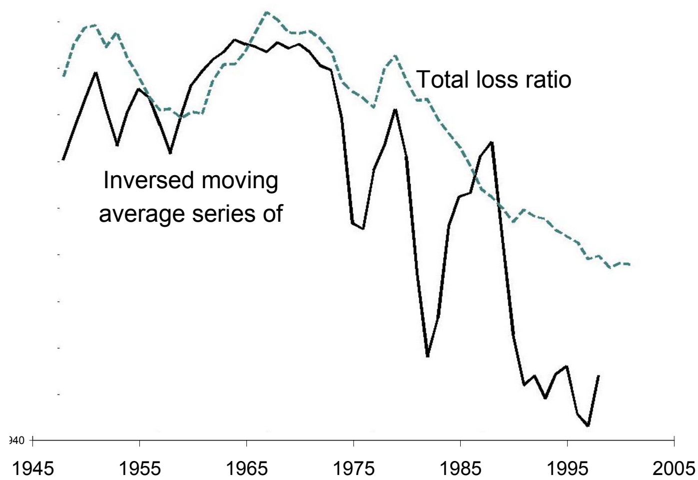


Figure 24: Total loss ratio and inversed freight rate series

It is known that over time the accident rate follow a decreasing trend, while the freight rates typically increase. Therefore it was necessary to be sure that the inverse relationship between accident rate and freight rates was not spurious. The short time variations was therefore analysed with reference to the second order derivatives of the series. These yearly fluctuation also followed the earlier descried relationships (Figure 25). At the late 19th century however the relationship was not inverse, but followed the freight cycles. Hence, a good market indicated increased A shift was indicated in the 1930s.

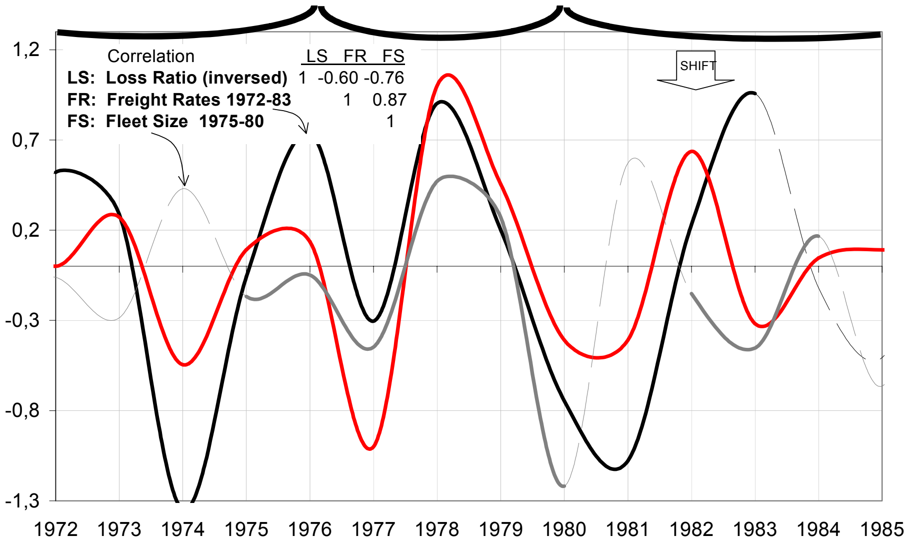


Figure 25: 2.derivate of total loss ratio, fleet size and freight rates 1972-1985

Finally the study found inverse relationship between accidents and economical conditions at a company level. Figure 26 presents the stock values of Minoan Lines, the holding company of Minoan Flying Dolphin that experienced the Express Samina accident. The crosses indicate the time of accidents and the continuous plots the aggregates density of these accidents. The plot shows that the accident risk increases after the drop in stock values in year 2000. Similar relationships are evident for the two considered competitors NEL and ANEK. Also the Hardanger Sunnhordlandske Dampskipselskap (HSD) that experienced the Sleipner accident in 1999 has been analysed. This company experienced few accidents during the beginning of the 1990s. In 1995, the company was forced by the authorities to start a cost cutting program. This went well as long as the stock values increased. However, when the market turned in 1998 a full speed head-on collision between two of the companies high-speed catamarans occurred (Figure 27)

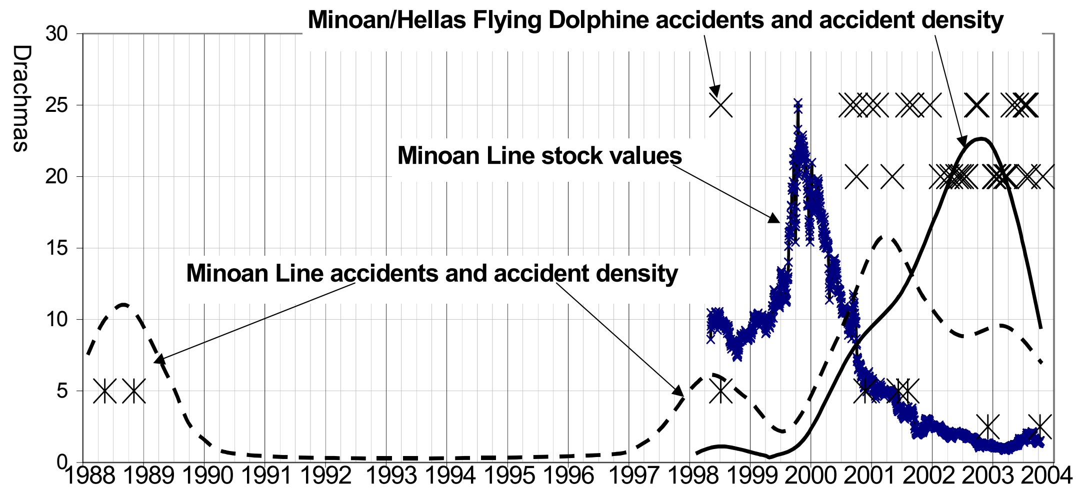


Figure 26: The inverse relationship presented for Minoan Flying Dolphin and Minoan Line

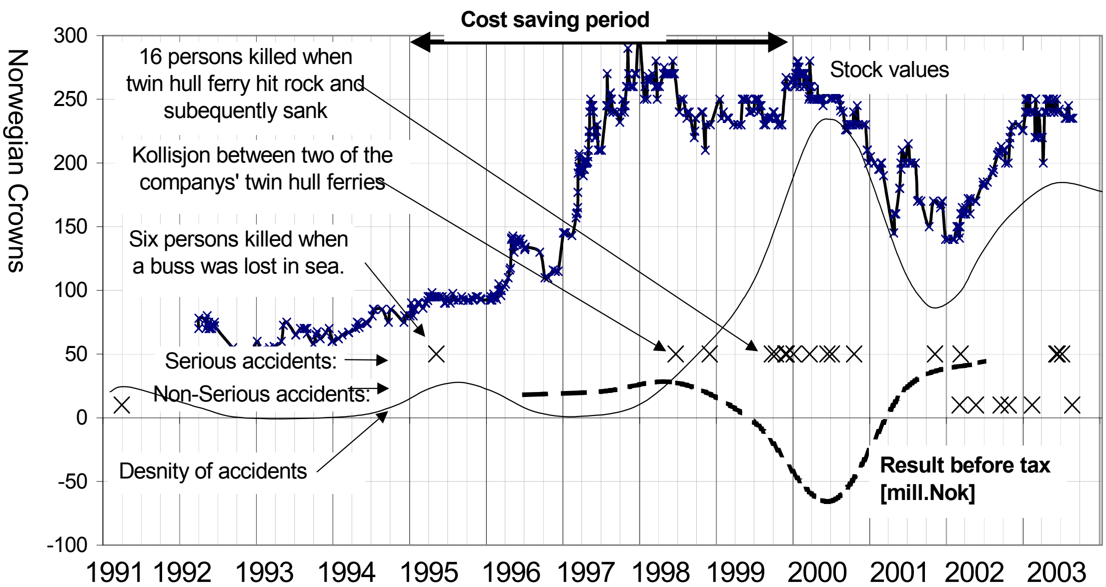


Figure 27: The inverse relationship presented for Hardanger Sunnhordlandske Dampskipselskap

When HSD's economical results dipped during the late 1998, turned negative in 1999 and were even worse in 2000 (figure 27). At the same time a cascade of accidents were recorded, where Sleipner was one of them. Also the involvement by the employees that ended late in 2000 triggered an accident free year in 2001 before a new management took place. These findings are consistent with the findings of organisational values (especially figure 16 and 17). Also within the tanker fleet an inverse relationship was found. Figure 28 and 29 illustrates the relationships for the two largest tanker companies Fronline and TeeKay. For these companies the stock values correlates and not surprisingly the net results correlates. However it is worth noticing that similar to the passenger ship companies the accident density also correlates with peaks in mid 1998 and early 2002.

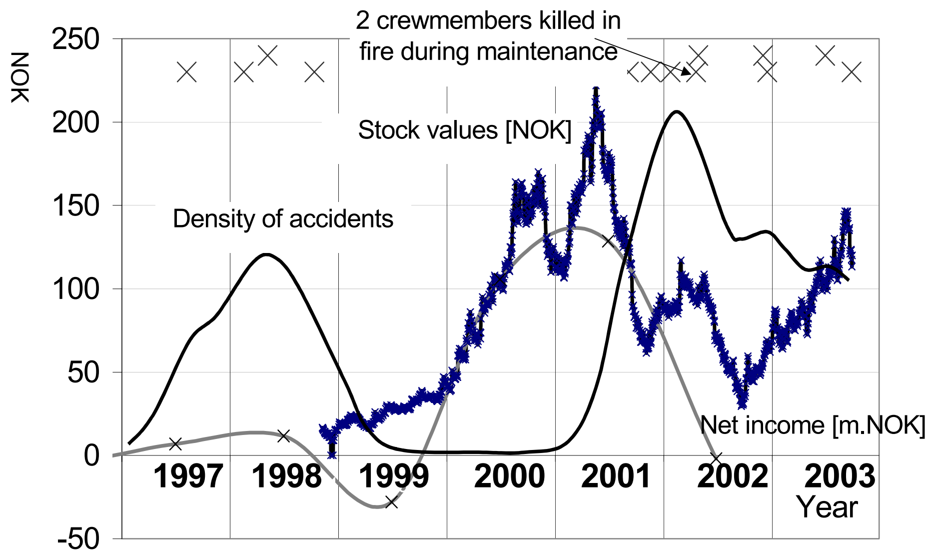


Figure 28: The inverse relationship presented for Frontline

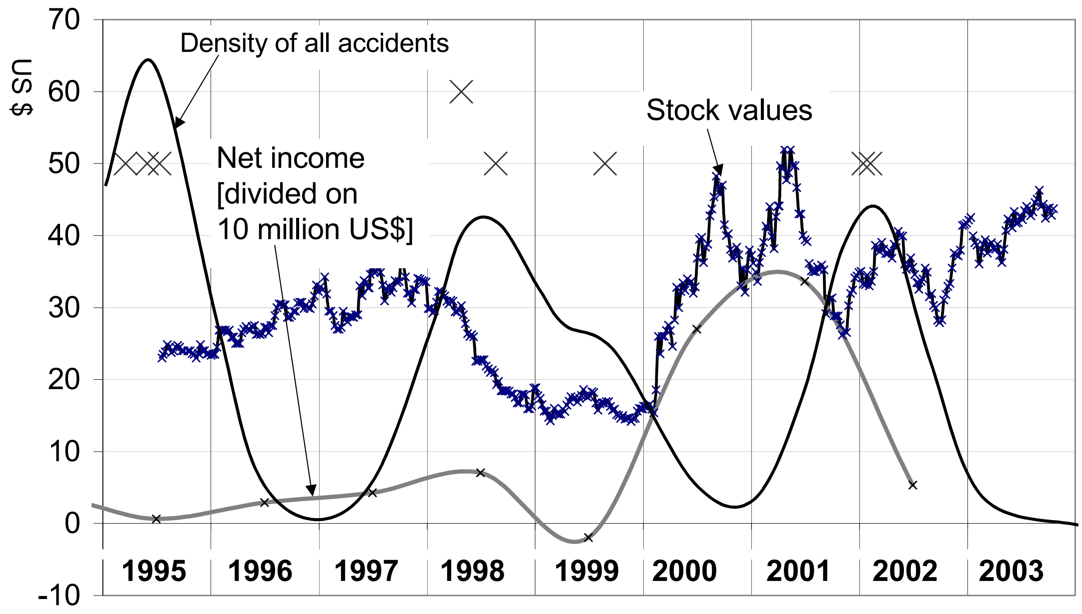


Figure 29: The inverse relationship presented for TeaKay

One of the most interesting companies was the Stena Line. During the early 1980s the strategy of the company was changed. The idea was to become a company that made profits on transportation rather than its earlier focus on ship speculation. An important step in this shift was the stronger involvement of the employees. At the middle 1980s all employees were participating in seminars and meeting specially aimed at developing a decentralised and value driven organisation. During the next decade only three accidents were recorded. Both accidents in 1989 were on a specific route that was about to be shut down. The 1991 accident occurs simultaneously as a transient fall in economical results. During the late 1980s and early 1990s the company focused on the development of their employees (ref. figure 16, 17) in business ideas and objectives. As the economical results were deteriorated the annual reports strengthened the focus on cost effectiveness and saving at the expense of human resources. Figure 29 illustrates that the density of accidents increased as the economical trend became negative. It can be seen that the trends are negatively correlated.

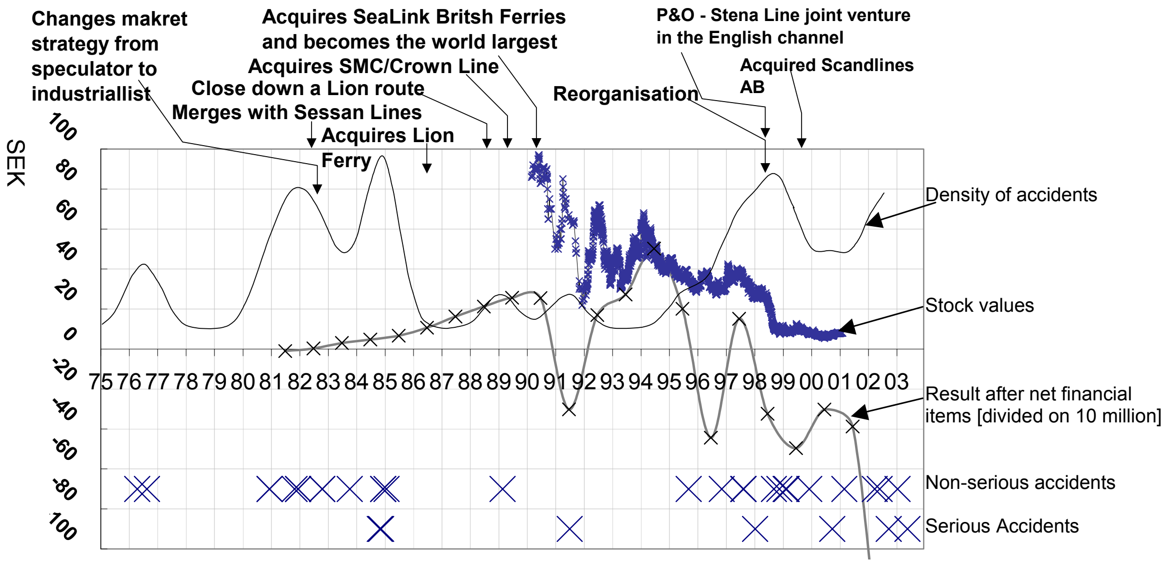


Figure 29: The inverse relationship presented for Stena Line

Based on the findings presented above it can be concluded that the maritime high-risk recurrent accident scenarios have a relationship to market conjectures. Because no shipping company alone can influence on the market state, the causal direction of this relationship is from commercial risk towards operational risk. In this perspective the Drivers of these recurrent accident scenarios are related to Commercial Risk Management. Hence, a Blue-Chip company either keep operational management independent of commercial management or have better safety barriers to prevent operational losses from taking place compared to a sub-standard company. Anyhow neither the terms organisational accidents (Reason, 1997) nor system accidents (Perrow, 1984) address the Drivers of the general ship accidents considered in this study. Therefore the term Commercial Accidents seems to be a more representative term. END

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