Helsinki University of Technology. Faculty of Engineering and Architecture.
Department of Applied Mechanics. Series AM
Teknillinen korkeakoulu. Insinööritieteiden ja arkkitehtuurin tiedekunta.
Sovelletun mekaniikan laitos. Sarja AM
Espoo 2009, FINLAND TKK-AM-FF

577=89BH˙5B5@MG=G/˙H<9˙HCC@: CF˙F=G?˙9J5@I5H=CB

P^ãjáŚã¦ˇÊŚãį ÁÙæ|{ ã

.

Leverage from the EU 2007–2013

TEKNILLINEN KORKEAKOULU
TEKNISKA HÖGSKOLAN
HELSINKI UNIVERSITY OF TECHNOLOGY
TECHNISCHE UNIVERSITÄT HELSINKI
UNIVERSITE DE TECHNOLOGIE D'HELSINKI

European Union
European Regional Development Fund

Helsinki University of Technology. Faculty of Engineering and Architecture.
Department of Applied Mechanics. Series AM
Teknillinen korkeakoulu. Insinööritieteiden ja arkkitehtuurin tiedekunta.
Sovelletun mekaniikan laitos. Sarja AM
Espoo 2009 TKK-AM-FF

Helsinki University of Technology
Faculty of Engineering and Architecture
Department of Applied Mechanics

Teknillinen korkeakoulu
Insinööritieteiden ja arkkitehtuurin tiedekunta
Sovelletun mekaniikan laitos

Distribution:
Helsinki University of Technology
Department of Applied Mechanics
P.O. Box 4100
FIN-02015 TKK
Tel. +358-9-451 3501
Fax +358-9-451 4173

© N.N.

ISBN 978-952-248-182-5
ISBN 978-952-248-183-2 (PDF)
ISSN 1797-609X
ISSN 1797-6111 (PDF)

Printed in Multiprint Oy
Espoo 2009, FINLAND

HELSINKI UNIVERSITY OF TECHNOLOGY PO Box 1000, FI - 02015 TKK http://www.tkk.fi/		**ABSTRACT** 30.10.2009	
Faculty Engineering and Architecture		Department Applied Mechanics	
Author(s) Kiuru Heini, Salmi Kim			
Title Accident analysis; the tool for RISK evaluation			

Abstract

This is third report of work package 1 of METKU-project, which is studying safety measuring and impact of ISM-code to safety in Finnish maritime transport.

The aim of this report is to show how accident analysis can be used for developing risk indicators and how by using these indicators, the evolution of risk during ISM-period can be presented.

The development of overall risk in Finnish maritime transport is shown in light of realized accidents. Causes behind these accidents are itemised and their weight on deriving of accidents is presented.

The traditional concept of risk as a combination of severity and frequency of harm is substituted in part of the analysis approaches by combination of severity and accident leading factor. This accident leading factor includes frequency, but also the weight of the cause by its influence on deriving of accident. This weighting of causes was considered important due accidents are rarely caused by a single cause, but instead by combination of different causes.

Major findings of this report: the negative influence of inadequate incident reporting to safety could be presented; The general risk level has decreased, but the average severity of accidents has increased; The greatest effect of general risk reduction has concerned ISM related accident causes, but these causes are still responsible for the majority of realised accidents; Technical advances help to improve safety, but they also bring new threats concerning for example understanding of malfunctions of new equipment.

Results of this report will help the next phase of Metku WP-1, by defining what indicators should be able to measure from statistics: Negative behaviour and disrespect for rules and instructions, which both come from absent safety culture of seafarer and shipping companies.

Keywords (and classification) Safety, Maritime safety, Indicator, Accident, Risk, Accident leading factor, Accident leading cause, Accident analysis			
Place Espoo, Finland	Month - Year October 2009	Language English	Number of pages 37
ISBN (printed) 978-952-248-182-5	ISBN (electronic) 978-952-248-183-2	ISSN (printed) 1797-609X	ISSN (electronic) 1797-6111
Serial name Series AM		Serial number or report code TKK-AM-11	
Distribution of the printed publication Helsinki University of Technology, Department of Applied Mechanics, P.O. Box 4100, FIN-02015			
Internet access http://appmech.tkk.fi/fi/julkaisut/TKK-AM-11.pdf/			

<table>
<tr><td colspan="2">TEKNILLINEN KORKEAKOULU
PL 1000, 02015 TKK
http://www.tkk.fi/</td><td colspan="2">TIIVISTELMÄ

30.10.2009</td></tr>
<tr><td colspan="2">Tiedekunta
Insinööritieteiden ja arkkitehtuurin tiedekunta</td><td colspan="2">Laitos
Sovelletun mekaniikan laitos</td></tr>
<tr><td colspan="4">Tekijä(t)
Kiuru Heini, Salmi Kim</td></tr>
<tr><td colspan="4">Julkaisun nimi
Accident analysis; the tool for RISK evaluation</td></tr>
<tr><td colspan="4">Tiivistelmä

Tämä on METKU projektin, turvallisuuden mittausta ja ISM-koodin vaikutusta Suomen merenkulun turvallisuuteen tutkivan työpaketti 1:sen, kolmas raportti.

Raportin on tarkoitus esittää millä tavoin onnettomuus analyysiä voidaan käyttää riskiä mittaavien indikaattoreiden rakentamiseen ja miten käyttämällä näitä indikaattoreita, voidaan riskin kehittymistä ISM-aikana kuvata.

Yleistä riskikehitystä Suomen merenkäynnissä on kuvattu toteutuneiden onnettomuuksien valossa. Onnettomuuksien syytekijät on eroteltu ja niiden painoarvo onnettomuuksien syntyyn on esitetty.

Perinteisesti riskin on käsitetty kuvaavan vahingon vakavuuden ja frekvenssin tuloa, mutta osassa tämän raportin analyysejä frekvenssi on korvattu "onnettomuuden syykertoimella". Onnettomuuden syykerroin koostuu frekvenssistä, mutta myös onnettomuuden taustalla olleiden syiden painoarvosta onnettomuuden syntyyn. Syiden painottaminen katsottiin tarpeelliseksi, sillä onnettomuudet ovat harvoin vain yhden syyn aiheuttamia, vaan yleensä useiden syiden kombinaatioita.

Roportin tärkeimmät löydöt ovat: Huonosti toimivan poikkeama raportoinnin negatiivinen vaikutus turvallisuuteen pystyttiin osoittamaan; Yleinen riskitaso on laskenut, mutta onnettomuuksien keskimääräinen vakavuus on kasvanut; Suurin vaikutus yleisellä riskin laskulla on ollut ISM-koodin vaikutuksen alaisiin onnettomuuden syytekijöihin, mutta laskusta huolimatta ne ovat edelleen suurin tekijä toteutuneissa onnettomuuksissa; Tekniikan edistyminen auttaa parantamaan turvallisuutta, mutta se on myös luonut uusia uhkia, jotka koskevat esimerkiksi uusien laitteiden toimintahäiriöiden ymmärtämistä.

Tämän raportin tulokset auttavat Metku projektin työpaketti 1:sen seuraavaa vaihetta. Raportti auttaa rajaamaan tilastollisessa analyysissä osa-alueet joita indikaattoreiden tulisi mitata: Häiriö käyttäytymistä ja sääntöjen ja ohjeiden huonoa noudattamista, jotka ovat molemmat osoitus merenkävijöiden ja varustamoiden puutteellisesta turvallisuuskulttuurista.</td></tr>
<tr><td colspan="4">Avainsanat - asiasanat (ja luokat)
Turvallisuus, Merenkulun turvallisuus, Indikaattori, Onnettomuus, Riski, Onnettomuuden syykerroin, Onnettomuuden syytekijä, Onnettomuus analyysi</td></tr>
<tr><td>Julkaisupaikka
Espoo, Suomi</td><td>Vuosi
2009</td><td>Julkaisun kieli
English</td><td>Sivumäärä
37</td></tr>
<tr><td>ISBN (painettu)
978-952-248-182-5</td><td>ISBN (elektroninen)
978-952-248-183-2</td><td>ISSN (painettu)
1797-609X</td><td>ISSN (elektroninen)
1797-6111</td></tr>
<tr><td colspan="2">Sarjan nimi
Sarja AM</td><td colspan="2">Osan numero tai raporttikoodi
TKK-AM-11</td></tr>
<tr><td colspan="4">Painetun julkaisun jakelu
Teknillinen korkeakoulu, Sovelletun mekaniikan laitos, P.O. Box 4100, FIN-02015</td></tr>
<tr><td colspan="4">Julkaisun www-osoite
http://appmech.tkk.fi/fi/julkaisut/TKK-AM-11.pdf</td></tr>
</table>

TABLE OF CONTENTS

ABSTRACT 3

TABLE OF CONTENTS 5

ABBREVIATIONS AND DEFINITIONS 7

1 Introduction 8

1.1 Background 8

1.2 METKU Research Project, MERIKOTKA, and TKK 9

1.3 Work package 1 (WP1) 10

1.3.1 Conclusions of the literature review 10

1.3.2 Conclusions of the interview study 11

1.4 Content of this report and the partition of work 12

2 Methodology and materiel 13

2.1 Introduction and materiel 13

2.2 The accident leading factors and the accident leading number 14

2.3 Accident frequency and type comparison 14

2.4 The accident severity and frequency 16

2.5 Approaching water busses 16

2.6 Application of findings of previous studies 17

2.7 Example of methods in use 17

3 Results 19

3.1 Results of cause leading value, accident leading number and accident leading factor approaches 19

3.1.1 The reliability analysis and evaluation of results in light of previous studies 21

3.2 Results of accident frequency and type comparison 22

3.2.1 The reliability analysis and evaluation of results in light of previous studies 22

3.3 Results of the accident severity and frequency analysis 23

3.3.1 The Risk appraisal by accident causes 23

3.3.2 The Severity of accidents categorised by primary cause 26

3.3.3 The Severity of accidents proportion to yearly traffic 27

3.3.4 The reliability analysis and evaluation of results in light of previous studies 29

3.3.5 Combination of accident severity and frequency approach to estimation of future traffic trends 30

3.4 Results of the water bus accident analysis 32

4 Conclusions 33

4.1 Conclusions of overall Risk development 33

4.2 Conclusions by leading cause 34

4.3 Accident analysis as lagging indicator generator 34

5 Summary and Further Research 35

Acknowledgements 36

References 36

APPENDIX 1 37

ABBREVIATIONS AND DEFINITIONS

AHP	***Analytic hierarchy process***
ALF	***Accident Leading Factor, a factor that represents not only the frequency but also the leading weight of an accident leading cause***
FMA	***Finnish Maritime Administration***
FSA	***Formal Safety Assessment***
GOF	***Gulf of Finland***
INDICATOR	***A tool which presents variation of value of monitored subject***
ISM	***International Safety Management (-code)***
RISK	***Measurable indicator of combination of frequency and severity of harm, in this report frequency is substituted by ALF***
SOLAS	***Convention for the Safety Of Life At Sea***
TKK	***Teknillinen korkeakoulu (= Helsinki University of Technology)***
VTS	***Vessel Traffic Service***

1 Introduction

Maritime safety has improved a lot in the last 100 years. Every major accident has led to discussion about safety at the sea and authorities came up with new regulations based on the accident. For instance after RMS Titanic's sinking a set of rules about ship design and lifesaving equipment was generated (SOLAS). Also MV Estonia's sinking in the Baltic Sea and M/S Herald of Free Enterprise's sinking just moments after leaving a Belgian port are examples of recent accidents that have paced the generation of new safety rules.

It's easy to see how safety can be improved by actions of each maritime operator. Ship-owners' instructions, dockers' mistakes on cargo handling, pilots' difficulties with different navigation devices and mistakes made by the crew are just examples of reasons that might cause an accident at sea. Technical failures and humane errors are considered the most common causes of accidents [Kristiansen, 2005]. Many changes in causes of accidents have occurred in the past 15 years. Results from the years 1994-2008 are introduced in this report.

ISM code came into effect during this time period. It gives instructions on how to act safely at sea. ISM codes influence on maritime safety is, additionally, estimated in this study. Clearly, it is very important to have inclusive set of maritime safety rules but the dilemma is to get maritime operators to obey them.

1.1 Background

The METKU research project evaluates the impacts of the ISM Code on the maritime safety culture in Finland (METKU – Developing Maritime Safety Culture). The program started at Kotka Maritime Research Centre in the first quarter of the year 2008. The project lasts for 2,5 years. The METKU project is funded by the European Union and other financing comes from the European Regional Development Fund of Southern Finland, Regional Council of Päijät-Häme, City of Kotka and private companies.

The purpose of the METKU Project is to study how the ISM Code has influenced the safety culture in the maritime industry. The project attempts to find the best practices for the shipping companies while improving their operations by implementing and developing their safety management systems.

The International Safety Management code (ISM) was established in three phases between 1996 and 2002, to improve safety in seas. After its implementation there have been several attempts on evaluating its true impact, but its actual weight has not been successfully defined as [Anderson, 2003] also concludes. The interview study concluded by [Lappalainen and Salmi, 2009], confirmed that ISM has influenced in change of safety culture in Baltic Sea and especially in Finnish shipping. The measurable impact of this change however has not been previously isolated from other influencing factors.

1.2 METKU Research Project, MERIKOTKA, and TKK

The METKU-project consists of the following work packages and responsible research partners:

- *WP1: Statistical measurements of maritime safety, Helsinki University of Technology, The Department of Applied Mechanics*
- *WP2: Study the development of the Finnish Maritime Safety Culture, University of Turku, Centre for Maritime Studies*
- *WP3: Comparing ISM –OHSAS practices in shipping companies and port operations (ISM – OHSAS),Kymenlaakso University of Applied Sciences, Maritime Studies*
- *WP4: Exploring the Best Practises in shipping companies, Turku University of Applied Sciences, Ship Laboratory*
- *WP5: Safety management practices in Finnish maritime and port authorities, Kymenlaakso University of Applied Sciences*
- *WP0: Project management and communications, Kotka Maritime Research Centre*

Kotka Maritime Research Centre is a rapidly growing research centre located in Kotka, in Southeast Finland by the Baltic Sea and the Gulf of Finland. The research centre consists of professors, researchers, project managers and administrative staff, currently of over 20 person's altogether. The research staff belongs administratively to the Helsinki University of Technology, the Kymenlaakso University of Applied Sciences, the University of Helsinki and the University of Turku. Kotka Maritime Research Centre conducts research related to the maritime industry, maritime safety and marine environment especially in the Gulf of Finland and the Baltic Sea. Maritime transport and environmental safety threads have substantially increased in the Gulf of Finland and the Baltic Sea. Kotka Maritime Research Centre aims at reducing these threats through research and education. Maritime transport and port operations and their economic impacts are also important areas of research at the Centre.

The work package 1 is conducted by Marine Technology of the Helsinki University of Technology (TKK). TKK is the main university of technology in Finland. Since the organisational changes in 1.1.2008 the Marine Technology (ex. Ship Laboratory) belongs to the Department of Applied Mechanics, which is a part of the Faculty of Engineering and Architecture. The Marine Technology provides degrees and carries out research in naval architecture; ship design and ship structures, ship hydrodynamics, marine engineering, marine traffic safety and arctic marine technology. Marine Technology has four professors, together with research scientists and technical staff of 20 persons. Additional personnel include about 5+10 graduate students and postgraduate students aiming at doctor degree. Current research activities are connected to light structures, fatigue of laser welds, analysis of ship grounding and collision process, simulation of the marine traffic in GOF to evaluate the risks, progressive flooding of large passenger vessel , hydroelasticity of large vessels, CFD development and use in naval hydrodynamics and dynamic stability of intact ship. Ship Laboratory has been the coordinator and/or a participant in many EU-funded projects, e.g.: ARCOP, EFFICIENSEA, EFFORT, IRIS, INTERMODESHIP, DISCO, MSGOF, SAFEICE, SAFEWIN, SAFGOF, SANDWICH and SAND.CORe.

1.3 Work package 1 (WP1)

The purpose of work package 1 is to find and develop quantitative measuring methods for the use of maritime safety development. The research is concluded in 5 phases:

- *Literature review, which was published May 2009, concerned on present measuring methods in maritime and other industry branches.*

  SAFETY PERFORMANCE INDICATORS FOR MARITIME SAFETY MANAGEMENT – Literature review, Risto Jalonen and Kim Salmi, ISBN: (printed) 978-951-22-9944-7 / (electronic) 978-951-22-9945-4

- *Interview study, made in co-operation with work package 2, which was published Sept 2009.*

  SAFETY CULTURE AND MARITIME PERSONNEL´S SAFETY ATTITUDES – Interview Report, Jouni Lappalainen and Kim Salmi, ISBN: (printed) 978-951-29-4043-1 / (electronic) 978-951-29-4044-8

- *Accident analyse, concerning on ISM effect on accidents that have happened to Finnish vessels and foreign vessels in Finnish coastal waters.*

- *Statistical analyse of incident, accident, near-accident, and violation data acquired from administration and from private companies.*

- *Final report will summarize findings of earlier phases with expert commentary. It will include proposals for private sector as well as for officials according to these findings and expert commentaries.*

1.3.1 Conclusions of the literature review

The literature review of work package 1 [Jalonen and Salmi, 2009] presented the value of statistical approach in maritime safety development. Especially the importance of safety performance indicators in safety evaluation was estimated high. The use of these indicators in other industry branches was studied. Following conclusions were maid according to these studies:

- *Aviation has been considered as a forerunner in safety maters. The set of safety indicators in use is very large and full of aviation particularities. The indicator system seems to be efficient but also heavy and thus is not likely to be accepted as it is by maritime community. The most important example for maritime use is the reporting culture of aviation. This "blame free" reporting culture assures the flow of correct information for statistical analyses.*

- *Nuclear industry which presents the most safety focused part of process industry has outstanding level of safety. This level is maintained with relatively simple set of general quality tied safety indicators, table 1. By chancing nuclear particularities to maritime specifics, indicators in table 1.1 could be seen in use on maritime sector. The need of accurate data flow is considered as important factor for preventive risk reduction in nuclear industry.*

Table 1.1 Safety sectors and indicators of Finnish NPPs. Presented by [STUK, 2008].

A.I Safety and quality culture
1. Failures and their repairs
2. Exemptions and deviations from the Technical Specifications
3. Unavailability of safety systems
4. Occupational radiation doses
5. Radioactive releases
6. Keeping plant documentation current
7. Investments in facilities

A.II Operational events
1. Number of events
2. Direct causes of events
3. Risk-significance of events
4. Accident risk of nuclear facilities
5. Number of fire alarms

A.III Structural integrity
1. Fuel integrity
2. Primary and secondary circuits integrity
3. Containment integrity

- *Authorities have developed excellent set of measuring methods for road transport. Particularly the constant use of LEADING indicators, such as speed and traffic flows measured by cameras or quantity of drunken drivers stopped by police, should be adopted to maritime traffic. This type of approach would need greater contribution in future from officials of the international maritime community. Ongoing study in METKU WP1 has already found one existing tool for developing data for this type of approach. Finnish Maritime Administration VTS operators use incident/violation reporting about vessels in their observation areas and these reports can produce a set of leading indicators.*

- *Off-shore industry has similarities with maritime traffic and their development in occupational safety, with statistical approach, during the last 10 years can be seen as encouraging. Even though their statistical approach has proven efficacy on occupational safety the off-shore industry admits that it does not necessarily predict as well risks of major catastrophes.*

A common observation between the different industry branches is the reconnaissance of the importance of correct information flow to back up analyses. And as [Hänninen, 2007] pointed out, non satisfying reporting culture exists in maritime industry, thus the information flow is not adequate.

1.3.2 Conclusions of the interview study

Interview study [Lappalainen and Salmi, 2009] was made with participation of seafarers and companies presenting all major sectors of Finnish maritime industry, dry cargo, tankers, special services and passenger traffic. Interview questions concerned the influence of ISM-code and safety culture in Finnish maritime industry in Baltic Sea area in particularly.

Attitudes towards safety have improved both in managerial level and among seafarers during the last 15 years. The change of attitudes can be seen in managements support, materiel and moral, for safety and security issues. Seafarers show their changed attitude by following and complying safety measures, rules and regulation most of the time. Both management and personnel feel that safety is part of their day to day work.

The influence of ISM-code was considered mainly positive, but the growing bureaucracy was pointed as a major defect. Major benefits of ISM were estimated to be, the better organisation of operations and the systematic approach to safety management which both lead to helping personnel to assimilate instructions and safe working methods. Seafarers also considered that the coming of ISM-code forced companies to participate and to take responsibilities concerning the safety.

Interviews highlighted the following major lack in current situation concerning safety development:

Gathering of safety information concerning near-accident, incidents and violations is still suffering from reluctance of seafarers to report their own mistakes. This missing information is hindering efforts made to prevent future incidents and accidents. Some reasons for this misbehaving are: the old punishment culture still existing at least in seafarers minds; clear reporting limits are not established; seafarers don't understand, thus are not correctly explained the importance of this information.

1.4 Content of this report and the partition of work

This report consists of analysis of accident reports. The report is structured so that first the classification and division of materiel is explained with used research methods and statistical tools. The application of findings of previous studies will also be introduced.

Results of each research method will be presented separately. The comparison of these results against previous study information with reliability analysis will also be presented individually.

Discussions will gather different results and compare and analyse their differences and weight for conclusions.

Conclusion will shortly introduce significant findings.

At the end, report will be summarised and future research will be introduced. The summary includes:

- *the estimation of development of safety and risk levels in Finnish coastal waters*
- *the estimation of impact of ISM-code in qualitatively and quantitatively*
- *the estimation of needed actions for effective risk assessment for administrative and private use*

The primary analysis with development of accident leading causes, as well as the "accident frequency and type comparison" and "leading number" approaches, were made by Kiuru. The" accident leading factor" and the "accident severity factor", used for "accident severity and frequency analysis" were developed by Salmi. Salmi was also responsible for reliability analyses and validations of results in light of previous studies. The introduction; methodology and materiel; and conclusions were developed and written together. The weighting by AHP criterions was induced by Salmi, but the primary estimation of need of weighting was presented by Kiuru. The summary and future research chapter was made by Salmi.

2 Methodology and materiel

This is the first report in WP1 of METKU-research project, where statistical tools are used regularly. The two previous studies in the project, made with qualitative methods, have pointed the direction and frames for this study. The purpose of WP1 is to evaluate measurable the impact of ISM-code to the safety of maritime transport. To do the evaluation of impact of one factor the whole field of safety with its multiple factors has to be evaluated and for this the set of appropriate indicators have to be developed. This report will induce methods for RISK evaluation with LAGGING indicators from accident reports. Later these RISK indicators will be used for SAFETY modelling.

2.1 Introduction and materiel

The study was carried out by using various literature sources and computational methods on data processing. The primary material used for this research was waterborne accident reports that are published by Accident Investigation Board of Finland [AIBF].

All the accident reports published by Accident Investigation Board have been scrutinized. These reports compose of accidents that have occurred in Finland's territorial waters or in which a Finnish vessels have been involved. Accidents were categorized and causes that led to these accidents were identified.

In order to find the impact of ISM-code, the classification, according to whether the accident happened before or after the ISM code came into effect was made. The individual implementation time of ISM to vessels in question was respected. A comparison of early and late ISM influence period was also made.

Analytic hierarchy process (AHP) [Saaty, 1980] was used for weighting leading causes and severity factors.

Part of the accident reports were not considered beneficial for this study so the following categorising was made:

The number of accidents taken into account and analysed by multiple methods was 92. These suitable accidents are all the waterborne accidents and incidents in which a vessel bigger than 500 gross tonnage has been involved in and also such smaller vessels that are used in commercial purposes. Some of the fishing boats have been left out of this study mainly because they are commonly quite small. Small shuttle-like passenger vessels, referred as water busses, are discussed in a separate paragraph and they are not taken into account in other parts of the study. Because accidents involving these shuttle-like passenger vessels are quite similar to each other, it is better to discuss them separately to reach a definitive conclusion.

Accidents with corresponding analysis values are induced as an appendix 1.

2.2 The accident leading factors and the accident leading number

Accident leading number is based on cause leading values which are developed from different causes for accidents. The causes for accidents were sorted to the table of suitable accidents. Then all the causes were weighted based on their impact in arising of the accident. The Analytic Hierarchy Process (AHP) [Saaty, 1980] was used for weighting. In AHP, causes are ranked from 1 to 9 by their importance. Ranks over 5, which by verbal statement [Pöyhönen and Hämäläinen, 1999] is "Strongly more important", were not used due:

> *Uncertainties in acquired data and in subjective conclusions made from it, could have influenced extreme values of 6-9 (verbally; Very strongly more important-Extremely more important) and thus it was decided to rather flatten results than have possible over weighting. The data group is relatively small and high value single anomalies could thus result in twisted conclusions.*

The topmost reason was weighted with 5 points (AHP; strongly more important), secondary cause or causes with 3 points (AHP; slightly more important) each and a cause or causes that had some influence in the accident got each a 1 point. After this all the points were summed and the total was used as an accident leading number. The accident leading number tells how predictable the accident or incident would have been. A large accident leading number indicates that there were multiple causes behind the accident and it would have been easy to see that the situation just before the accident was hazardous. If for instance only cause for accident would have been a technical failure the accident leading number would have been 5, which is very low. In the accidents chosen for this study the accident leading numbers vary between 5 and 16. In this report, all the accidents that had an accident leading number bigger than 10, were considered foreseeable.

After evaluating each accident the causes were investigated and analyzed separately. Causes influencing on accidents were summed and in that way it *was easy to see which cause* has *been involved in how many percent of the accidents.*

The Accident Leading Factor (ALF) was developed on base of leading values of different causes. In each accident the leading values of individual causes were divided by leading number giving ALF the maximum value of 1 (in the case of one single primary cause without any other influencing causes). ALF is used to separate the influence of different causes in deriving of accident.

2.3 Accident frequency and type comparison

There are several types of accidents and incidents that may occur in seafaring. Most of the accidents are groundings. Other types of accidents that have occurred in the Gulf of Finland or to Finnish vessel operating elsewhere are collisions between two vessels, collisions to fixed structures such as bridges, fires on board, pollution, keeling and sinking and cargo getting loose. There have also been a couple of severe accidents that occurred when life boats have been tested. All other accidents discussed in this report are more or less occasional. Table 2.1 gives descriptions on different accident types.

Table 2.1 Accident types /2 s.22 partly adopted/

Accident type	***Description***
Collision	*Striking between ships*
Colliding in something	*Striking between ship and other surface objects*
Grounding and stranding	*Hitting the seabed or shore*
Fire	*Fire on board*
Technical failure	*Hull or machinery failure is directly responsible for the accident*
Keeling	*Enduring inclination of the vessel*
Sinking	*Whole vessel sinks*
Cargo getting loose	*Cargo moves on board*
Pollution	*Release of dangerous goods*
Accidents with life boats	*Accident related directly to life boats*
Other miscellaneous	

Accident types were considered either serious or less serious. Sinking, collisions both between two ships and with structures were considered as serious accidents in figure 3.1. Those three were picked as serious accident types because in those accidents many lives are threatened always and consequences of these types of accidents are never slight. The rest of the accidents were considered less serious.

Maritime transport contains a lot of risks. There are many bodies involved in maritime transport, from whose remiss actions an accident may occur. In addition, there are factors that cannot be directly influenced, like the weather. When investigating a marine accident, one must estimate which factors affected the arising of the accident, instead of trying to find a single reason to have caused the accident. All the causes that were presented in the accident reports [AIBF] were evaluated as explained in chapter 2.2, which introduces the accident cause leading values. In this report the effect that the ISM code had on maritime safety is evaluated. The change in different causes for accidents when comparing situation before ISM code and the situation after it was introduced is analyzed.

The causes were sorted into nine categories originally; Humane mistakes, co-operation, technical failure, lack of education, route planning, actions and mental resources, lay out/devices of bridge, weather and other cause. Later in this study other causes were divided in two new categories, other ISM related cause and other cause. The sorting was done mainly based on the frequency of the cause being mentioned in accident reports. Same type of problems were put under the same heading, for example the layout of the bridge and the appliances on bridge could have been also separate categories but discussing them as a one cause type result can be shown in a more effective way. Also falling asleep or just being tired or absentminded could have not been discussed separately because presenting the results

would have been more complicated even though the conclusion would have been the same as now when they are considered humane mistakes altogether. Also reasons behind one type of cause are the same in each category.

All the charts in this study that represent causes are based on the accident leading numbers and the sorted cause data. All the data about traffic amounts and statistics on accident types are from Finnish Maritime Administrations sources [FMA].

2.4 The accident severity and frequency

The accident severity and frequency analysis was made on base of "accident leading factor" approach, introduced in chapter 2.2. The severity of each accident was categorised with following limits:

- *Catastrophe: accident that causes death / permanent invalidity, or materiel damage worth 1+ million €, or severe environmental disaster.*
- *Severe accident: accident that causes serious injury, or materiel damage worth from 10k to 1 million €, or notable environmental impact.*
- *Slight accident: accident that causes slight injury, or materiel damage worth 10k€ or less, or slight environmental impact.*

For statistical approach a weighting by severity, equal to weighting by cause distribution, was made. This lead to weighting of catastrophes by 5, severe accidents by 3, and slight accidents by 1. The severity could now be used for multiple types of statistical approaches, from which the following three were chosen:

- *Severity of accidents proportion to yearly traffic. (Comparable with results of approach presented in chapter 2.3)*
- *The Risk appraisal by accident causes*
- *The Severity of accidents categorised by primary cause*

2.5 Approaching water busses

The water bus accidents were evaluated using the same methods as with other accidents discussed in this study. First the causes behind each of these water bus accidents were weighted based on the method presented in chapter 2.2.

> *The topmost reason was weighted with 5 points (AHP; strongly more important), secondary cause or causes with 3 points (AHP; slightly more important) each and a cause or causes that had some influence in the accident got each a 1 point. After this all the points were summed and the total was used as an accident leading number. The accident leading number tells how predictable the accident or incident would have been.*

After the evaluation was done with previously presented method, the results were analyzed with the average accident leading number and compared to the results received from the other accidents.

Water busses were chosen to be discussed separately in this study because of the unique nature of these accidents. They are similar to each other and the causes behind these water bus accidents are standing out so they should not be

compared with other accidents. This way the study will give a more definite conclusion on both, the water bus accidents and other accidents.

2.6 Application of findings of previous studies

The research made earlier in METKU project will be compared to results of analysis made for this report. This comparison is made to validate and where seen necessary, object appraisals obtained with chosen methods. Some potential explication for obtained statistics is given on bases of earlier studies.

Reliability of both, used methods and acquired data, will be analysed either qualitatively or quantitatively.

Other research data (non METKU), particularly some estimations of the future traffic quantities, will be induced to give some insight for safety development and possible risks in future.

2.7 Example of methods in use

To facilitate the understanding of multiple terms in this report an example case is presented for calculation of:

- *Accident leading number*
- *Accident leading factor (ALF)*
- *Risk as product of ALF and accident severity factor*

The grounding of M/S Pamela July 12th 2006, presented in table 2.2 is used as an example.

Table 2.2 M/S Pamela accident analyse

Name	yyyymmdd	AIBF-id	Tiredness or other human related cause	Co-operation	Technical failure	Lack of Education	Route planning	Actions and mental resources	Lay out/ devices of bridge	weather	Other ISM related cause	Other	Accident Leading Number	Severity factor
MS Pamela	20061207	C 3/2006 M	3	0	0	0	0	3	0	3	3	0	12	1

Four accident leading causes were identified as responsible of this grounding:

- *Tiredness or other human related cause (Master shut down the electronic chart)*
- *Actions and mental resources (The speed was kept the same while not knowing the exact position)*
- *Weather (Not favourable, heavy wind)*
- *Other ISM related cause (No lookout on the bridge)*

In this accident there was no single reason that could have been stated as the primary cause for the accident but all the four causes mentioned were considered as having important influence on deriving of the accident: all the four causes were distributed the leading value of 3.

The accident leading number (=12) was calculated by summing all the leading values of the accident.

The accident leading factor, which states the weight of single leading cause in deriving of accident, is calculated by dividing the leading value of each leading cause by the leading number. In this case the ALF of four leading causes presented is 3/12 = 0,25 and the rest of the leading causes have ALF value of 0.

Accident was given the severity factor of 1: Accident caused no injuries to ships crew, the ship didn't get any damage that would force it to immediate reparations, nor did it leak any substances to sea.

The calculated risk value by leading cause is, ALF multiplied by the severity factor. In this case for the four presented leading causes, the risk value is 0,25 and the other leading causes have the risk value of 0.

3 Results

This chapter consists of results of all the different analyse approaches presented in chapter 2. The use of multiple methods was chosen to validate or object result acquired by single methods. Used values of ALF and severity factor by accident can be found in appendix 1.

3.1 Results of cause leading value, accident leading number and accident leading factor approaches

The accidents constituting this study were studied based on the accident reports [AIBF]. Each cause behind each accident was weighted using Analytic hierarchy process (AHP) [Saaty, 1980]. The amount of points given to each cause is termed the cause leading value. Cause leading values vary between zero and five as presented in chapter 2.2. This cause leading value tells the main cause of the accident because it is weighted with five points. Also the value tells if the accident has causes that are important in the arising of the accident or if they have some influence on the accident.

When cause leading values of each accident are summed, we get the accident leading number for that accident. Accident leading numbers in this study vary between 5 and 16. As mentioned in chapter 2.2 if the accident leading number of an accident is bigger than 10, the accident can be considered foreseeable. The time period investigated in this study is mainly the same time as the ISM-code has been valid. In this research time period was divided into three parts; Years 1997-2000, 2000-2004 and 2005-2008. Each of these three periods is 4 years. To get some results, the average accident leading number of each time period was calculated. The results of these calculations are shown in table 3.1.

Table 3.1 Average accident leading number by period

Time period	Average accident leading number
1997-2000	8,4
2001-2004	9,6
2005-2008	9,5
1997-2008	9,1

The average accident leading number has increased based on the data on table 3.1. The result from years 2005-2008 is not really reliable, because there is lot less accidents valued in that time period compared to other two. But when comparing first two time periods the trend of growing amount of causes behind one accident and the fact that the accidents are more and more foreseeable is shown. Also, the average accident leading number of third period is almost the same as that of the second period. This shows that at least the average accident leading number hasn't started to decrease.

Also, these average accident leading numbers were calculated for different accident types. The results of this comparison are presented on the table 3.2.

Table 3.2 Average accident leading numbers by accident type

Accident type	Average
Grounding	9,24
Collision	8,2
Fire on board	5,7
Sinking	11,5

What this approach shows is that a ships sinking is an accident that should have been foreseeable. It also shows that groundings could have also often been seen before hand. That makes sense because groundings are often caused by carelessness and other expectable causes. Collisions are not as easy to see before hand as sinking or grounding. In accidents where two vessels collide, there is always two sides to the story and it often comes to the point where accident investigators can name the participant whose fault the most of the accident was. Then when calculating the average the ships that did not necessarily do anything wrong but ended up colliding with another ship tend to have low accident leading numbers and that decreases the average. Fires on board are according to this approach hard to prevent. Often this is true, because for example in some of these accidents where there was fire on board, passenger or company had delivered flammable goods on board without reporting them to the ships personnel.

What could help to turn this trend of increasing average accident leading number to decreasing, is ship-owners own inner audition and development of own safety culture. The average accident leading number that is over 9 is really close to the limit when the average accident is definitely foreseeable. Also efficient safety check ups on board and other self evaluation could have prevented a great deal of these maritime accidents and incidents.

The final part of this approach is the development of accident leading factor (ALF), by dividing cause leading value of accidents with corresponding accident leading number. ALF is a tool that is used to evaluate risks in later parts of this study. It shows the deriving proportion of each cause in a specific accident. The accumulated ALF by leading causes, presented in table 3.3 and figure 3.1, shows high variations in respect of time periods.

Table 3.3 Accumulated Accident Leading Factor (ALF) values

ALF	Tiredness or other human related cause	Co-operation	Technical failure	Lack of Education	Route planning	Actions and mental resources	Lay out/ devices of bridge	weather	Other ISM related cause	Other
NO ISM/SMS	2,50	3,09	1,25	0,38	1,38	0,91	0,67	1,92	2,71	3,18
ISM/SMS	16,03	8,80	11,08	2,76	3,31	5,50	5,50	10,23	12,80	12,00
97-00	4,66	3,70	4,67	1,08	1,75	1,41	1,79	4,83	4,53	5,59
01-04	6,38	3,07	4,29	1,40	0,93	2,66	2,92	3,45	5,81	4,08
05-08	4,99	2,04	2,12	0,27	0,63	1,43	0,79	1,95	2,46	2,33
NO ISM/SMS	13,89 %	17,18 %	6,97 %	2,08 %	7,64 %	5,08 %	3,70 %	10,69 %	15,08 %	17,68 %
ISM/SMS	18,21 %	10,00 %	12,59 %	3,13 %	3,76 %	6,25 %	6,25 %	11,62 %	14,55 %	13,64 %
97-00	13,71 %	10,88 %	13,73 %	3,19 %	5,15 %	4,14 %	5,27 %	14,19 %	13,31 %	16,43 %
01-04	18,23 %	8,76 %	12,27 %	4,00 %	2,67 %	7,60 %	8,34 %	9,85 %	16,61 %	11,67 %
05-08	26,24 %	10,73 %	11,14 %	1,44 %	3,29 %	7,55 %	4,15 %	10,27 %	12,94 %	12,27 %

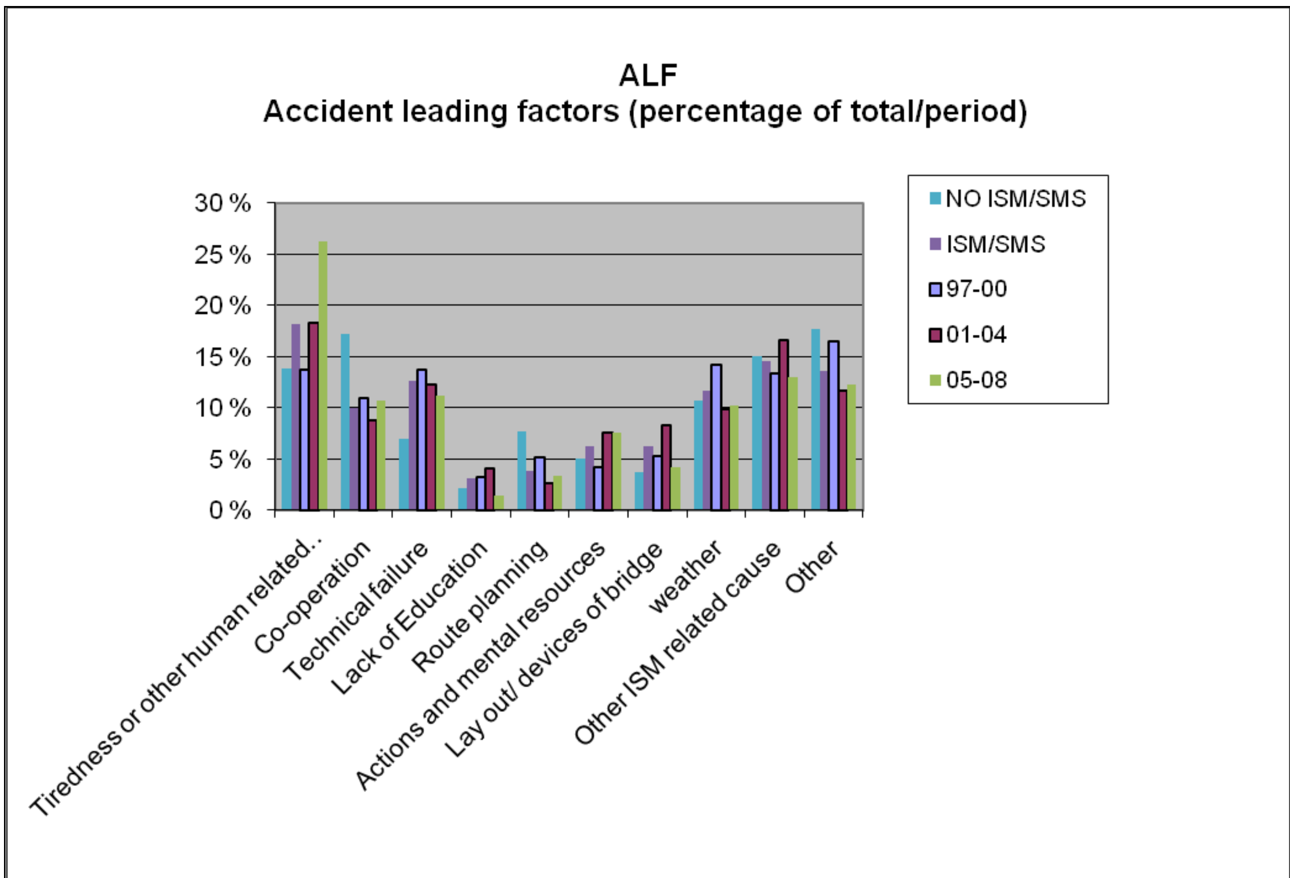


Figure 3.1 Distribution of accumulated ALF

3.1.1 The reliability analysis and evaluation of results in light of previous studies

Approaches presented in chapter 3.1 are based on interpretation of information from written reports of which may have suffered from in worst case falsified information from apart of seafarer behind the accident cause. Especially values of human related causes may have been influenced of falsified information. Due the doubts concerning reliability of the information, it is not recommended to use this information as the only source when estimating safety and accident levels in Finnish shipping and in Finnish coastal waters. Even with these reliability doubts, results of these approaches give relatively good estimations of accident evolution in the concerned area. These approaches don't deliver risk estimation, due the severity of risk is not induced.

Previous studies [Lappalainen, 2008], have displayed that company safety culture has a big role in order to prevent future accidents. The Leading number approach shows that, even though the coming of many accidents could be predicted and thus prevented, the company safety culture was not developed enough to use these clear warnings for its own favour.

3.2 Results of accident frequency and type comparison

Over the past decade the average severity of accidents has steadily increased. That can be explained with the fact that traffic amounts have increased so the risk of collision has increased with it. Another possible reason for the perceived growth is the corresponding decrease in less severe accidents as well as the overall increase in traffic amounts. The total amount of accidents has decreased a lot and compared to that, these conclusions are inevitable. The decrease of accident amounts in general and the slight decrease of serious accidents are shown in figure 3.2 (Statistics from [FMA]). As can be seen from figure 3.2 the quantity of severe accidents is staying almost unchanged and thus the decreasing quantity of all accidents derives to increase of average accident severity.

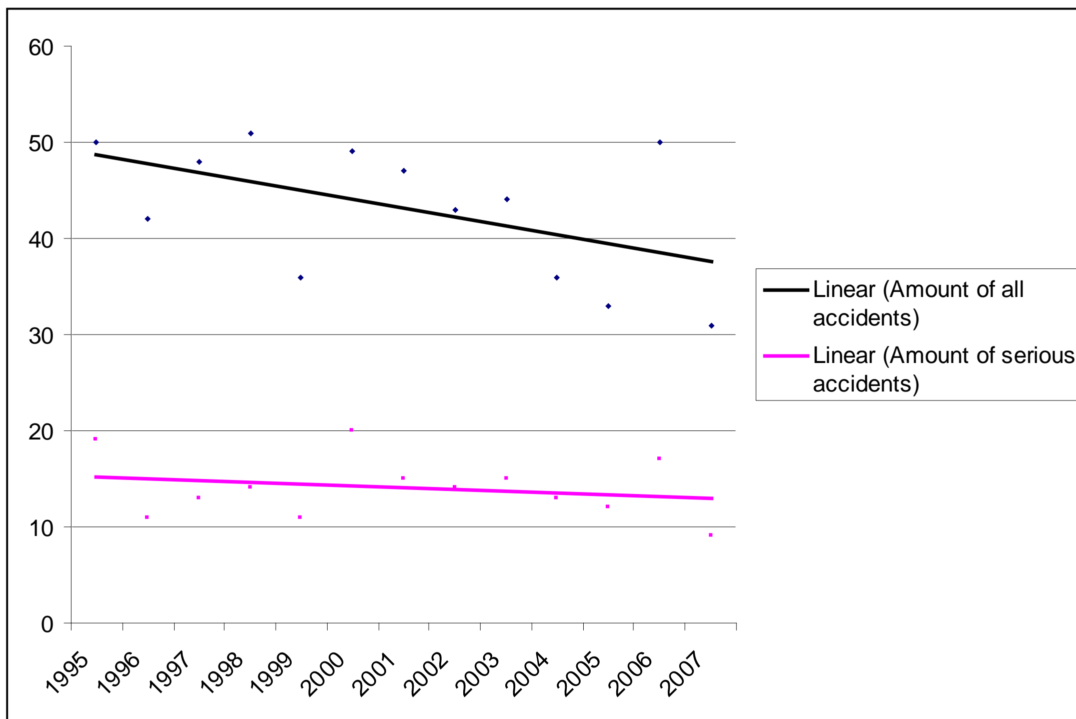


Figure 3.2 Changes in amount of all accidents compared to serious accidents

Traffic amounts have increased a lot and ships are bigger than they used to be. That leads to situation where routes and ports are too small for both traffic amounts and new bigger ships. This causes increase in the risk of collision between two ships and the risk of groundings. But on the other hand navigation devices are more efficient these days too, so the risk of collision or grounding is theoretically decreasing at the same time.

3.2.1 The reliability analysis and evaluation of results in light of previous studies

Previous studies have presented the overall increase of safety mainly by the proportional decrease of accident frequency. This is unquestionable fact, but it does not tell anything about causes behind safety or accidents. In the frequency approach by the simple isolation of severe and potentially severe accidents from the mass of all accidents, can be presented that: even though the general frequency is decreasing fast, the proportional frequency of severe

accidents have decreased only marginally. This different velocity of diminishing can be connected to ISM's demand of constant development and particularly to incident and near miss reporting:

[Lappalainen and Salmi, 2009]: "Even in the companies where reporting is already everyday work, a consistent reporting failure exists. Minor mistakes and all the technical problems are reported (due crew wants the management to notice these problems), but mistakes that cause near-accident situations (often navigational) are still considered TABOO and are not reported unless forced by circumstances."

-Which leads to situation were slight hazards are informed thus they are studied and avoided in the future, while NO LESSONS are learned from potentially catastrophic hazards.

There is no reason to question the reliability of FMA traffic statistics and the classification of accidents is transparent and simple.

3.3 Results of the accident severity and frequency analysis

In statistical approach the chosen variables play important role and the result often relies on point of view. To give as comprehensive presentation as possible, the severity variable was given in two different forms. The severity was presented as a cumulated weighted severity of accidents by main cause; and by total cumulated weighted cause. Besides these two "cause" induced approaches, a general accumulated accident severity versus amount of traffic approach, was used to evaluate general safety trends in time.

3.3.1 The Risk appraisal by accident causes

In the approach of "Risk appraisal by accident causes", figure 3.3, both, the "accident leading factor" on vertical axe and "accident severity factor" on the horizontal axe, are equal distributors of the risk. In many accidents there is not only one causing factor but several that together have finally caused an accident. For this reason, in this approach causes are weighted by their overall influence and thus all influenced factors are given their share of total RISK appraisal.

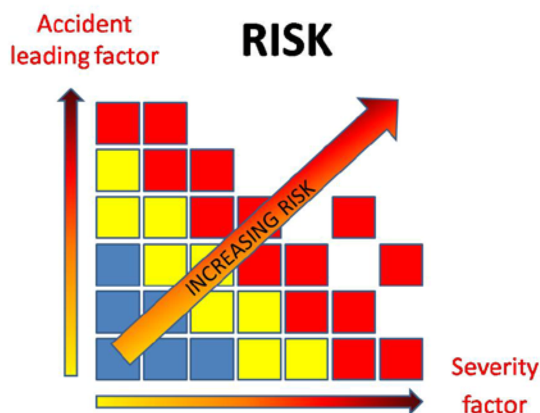


Figure 3.3 Risk presented by ALF and Severity factor

The "Risk factor" is calculated by multiplying the individual ALF by accidents "Severity factor". Received "Risk factors" were summed by period). Results can be seen in table 3.4.

Table 3.4 Accumulated Risk factor by period

	Tiredness or other human related cause	Co-operation	Technical failure	Lack of Education	Route planning	Actions and mental resources	Lay out/ devices of bridge	weather	Other ISM related cause	Other
NO ISM/SMS	5,22	7,81	3,23	0,38	5,32	2,42	2,00	5,75	10,64	11,23
ISM/SMS	45,76	26,18	32,83	6,65	10,44	15,34	17,99	31,89	39,45	33,46
97-00	8,34	8,01	13,03	1,83	5,78	3,73	5,12	13,90	14,83	13,43
01-04	21,26	11,71	13,91	4,00	2,79	7,31	9,60	12,14	16,69	13,59
05-08	16,16	6,45	5,89	0,82	1,88	4,30	3,27	5,85	7,92	6,45
Percentage /period										
NO ISM/SMS	9,67 %	14,46 %	5,98 %	0,69 %	9,85 %	4,49 %	3,70 %	10,66 %	19,71 %	20,79 %
ISM/SMS	17,60 %	**10,07 %**	**12,63 %**	2,56 %	**4,02 %**	5,90 %	**6,92 %**	12,27 %	**15,17 %**	12,87 %
97-00	9,48 %	9,11 %	14,80 %	2,08 %	6,57 %	4,23 %	5,82 %	15,79 %	16,85 %	15,26 %
01-04	18,81 %	10,37 %	12,31 %	3,54 %	2,47 %	6,47 %	8,50 %	10,75 %	14,77 %	12,02 %
05-08	**27,39 %**	10,94 %	9,99 %	1,39 %	3,18 %	7,29 %	5,55 %	9,92 %	13,42 %	**10,93 %**

*Results of table 3.4, drawn in figures 3.4 and 3.5 help to visualise the development of risk. Figure 3.4 consists of only post-ISM implementation data due: The confusion could appear due post-ISM implementation categories are limited to **4 year periods** with **standard reporting** system, and "No ISM/SMS" does not comply with either of these **criterions**. Thus accumulated RISK factor of "No ISM/SMS" is not comparable with others.*

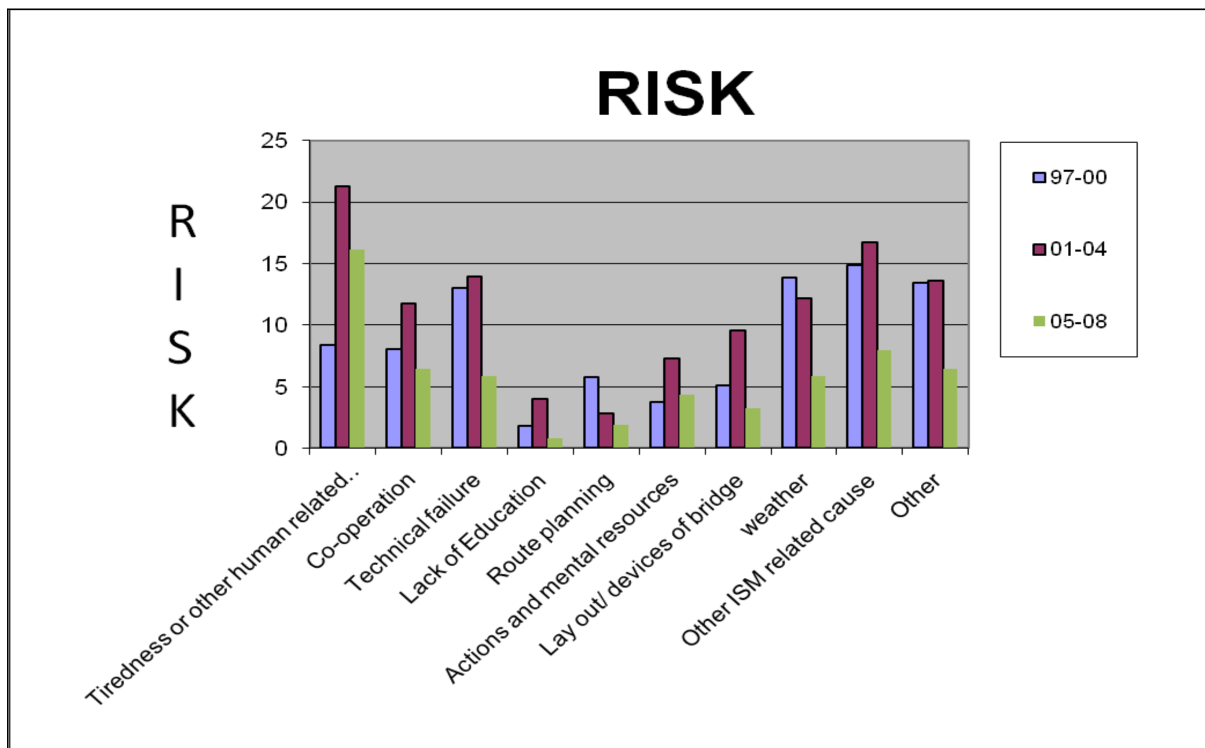


Figure 3.4 Post-ISM implementation: Accumulated realized Risks by accident leading causes

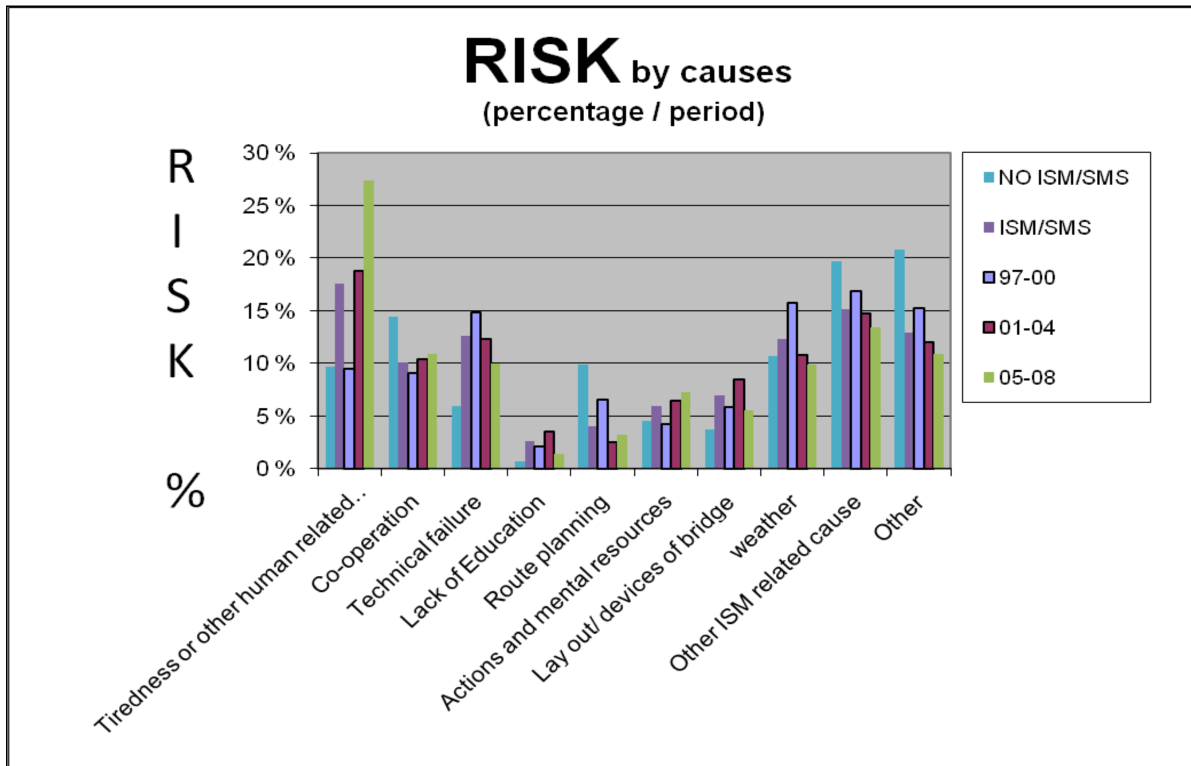


Figure 3.5 Distribution of Risk between different accident leading causes by period

Following conclusions can be made from table 3.4 and figures 3.4 and 3.5:

- *The portion of "Tiredness or other human related causes" has tripled from pre-ISM period till the last (05-08) period. Possible reasons are induced in chapter 3.3.4.*
- *The portion of problems with "co-operation" (mainly in bridge work) has diminished by one third and that of "route planning" by two thirds. These could be interpreted as benefit of ISM-code. The administration has also concentrated considerable effort on fighting these problems.*
- *The portion of both "technical failure" and "layout / devices of bridge" has increased significantly after implementation of ISM. Possible reasons are induced in chapter 3.3.4.*
- *The weight of "lack of education" and "actions and mental resources" has been relatively marginal, though the portion of them is increasing. Possible reasons are induced in chapter 3.3.4.*
- *The "other ISM-related causes" (mainly organizational and instruction related problems) has decreased steadily during the whole observed period. This should be considered as benefit of ISM-code.*
- *The "weather" preserves its portion of approximately 10% of all realized risk during the observed period.*
- *The "Other" has decreased to half during the observed period which can be considered as improved indication of accident causes due better safety culture.*

3.3.2 The Severity of accidents categorised by primary cause

The severity of accidents was categorised by leading causes and implemented to "accident leading factor approach". In this approach only the severity of main cause was calculated. This approach was chosen to see which kinds of single leading causes rise the ships risk of serious accident the most. The calculated RISK factor based on main cause severity and total cause frequency, in table 3.5.

Table 3.5 Risk factor presented by severity factor of the primary accident leading cause

	Tiredness or other human related cause	Co-operation	Technical failure	Lack of Education	Route planning	Actions and mental resources	Lay out/ devices of bridge	weather	Other ISM related cause	Other
No ISM/SMS Acc.	1,93	6,11	1,37	0,00	0,63	0,00	0,00	0,00	4,79	6,39
Percentage of total	9,1%	28,8%	6,5%	0,0	3,0%	0,0	0,0	0,0	22,6%	30,1%
97-00 Accumulated	5,67	3,96	3,96	0,00	0,53	0,00	0,00	2,90	6,91	6,29
Percentage of total	18,8%	13,1%	13,1%	0,0	1,7%	0,0	0,0	9,6%	22,9%	20,8%
01-04 Accumulated	10,33	2,30	4,48	0,14	0,00	0,00	2,70	0,94	8,57	1,97
Percentage of total	32,9%	**7,3%**	14,2%	0,4%	0,0	0,0	8,6%	3,0%	27,3%	6,3%
05-08 Accumulated	6,14	2,89	2,04	0,00	0,00	0,00	0,71	0,00	1,34	2,25
Percentage of total	**40,0%**	18,8%	13,2%	0,0	0,0	0,0	4,6%	0,0	**8,7%**	14,6%

*Table 3.5 is presented graphically in figures 3.6 and 3.7. From figure 3.7 the category: "No ISM/SMS" have been left out to avoid confusions. The confusion could appear due other categories are limited to **4 year periods** with **standard reporting** system, and "No ISM/SMS" does not comply with either of these **criterions**. Thus accumulated RISK factor of "No ISM/SMS" is not comparable with others.*

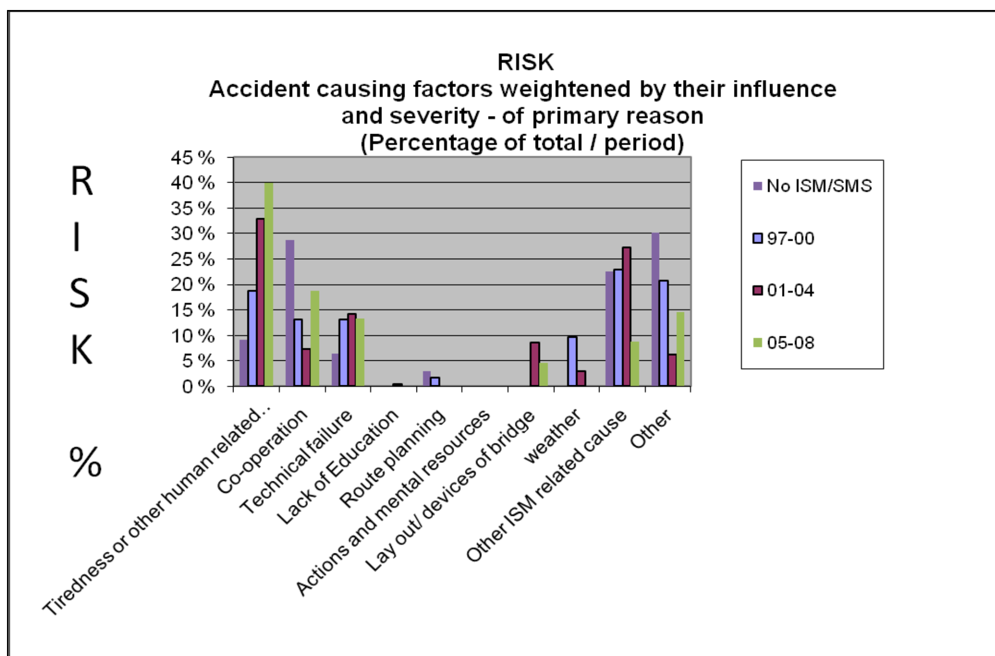


Figure 3.6 Distribution of Risk between different primary accident leading causes by period

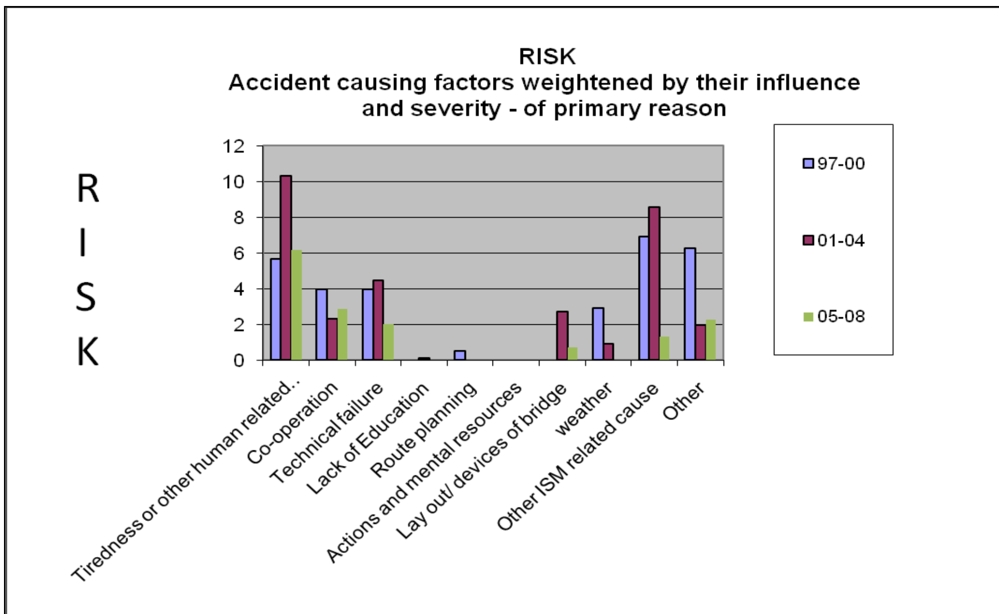


Figure 3.7 Post-ISM implementation: Accumulated realized Risks by primary accident leading causes

Conclusions from this approach are multiple and in some cases incoherent with conclusions of other research. When comparing the RISK factor between Non ISM "period" and the rest, following observations can be obtained:

- *The "Other" category has diminished greatly from pre-ISM period, which could indicate that accident causes can be and are been indicated better. (By seafarers and by inspectors)*
- *Problems with CO-operation have been decreasing up until the last 4 year period: - Here have to be remembered that in this (05-08) period total accident frequency has lowered decisively and thus single accident weight is higher (Potential error is higher). All investigations of this period are not yet concluded, which could still change the distribution.*
- *"Tiredness and other human related causes", "Technical failure", and "Layout / devices of bridge" categories have increased decisively post-ISM implementation. These rises can be explained by various philosophies and few of these will be highlighted in chapter 3.3.4.*

3.3.3 The Severity of accidents proportion to yearly traffic

In the approach of severity of accidents proportion to yearly traffic, the total accumulated "accident severity factor" of all accident vessels was proportioned to yearly traffic. The amount of arrivals of ships in foreign traffic, [FMA] was used for amount of yearly traffic. Results of this approach can be seen in table 3.6.

Table 3.6 Accident severity factor

Year	(Accidents/Traffic)*10^4	Severity factor (accumulated)*10^4 / traffic	Severity factor / accident (yearly average)
1997	3,92	9,79	2,50
1998	4,42	11,38	2,57
1999	0,59	1,18	2,00
2000	1,65	4,95	3,00
2001	2,73	7,64	2,80
2002	2,38	6,08	2,56
2003	1,86	6,65	3,57
2004	2,20	9,05	4,11
2005	1,49	3,98	2,67
2006	1,51	5,05	3,33
2007	0,77	2,32	3,00
2008	1,10	3,83	3,50

Table 3.6 result plotted with linear trend lines in figure3.8 .

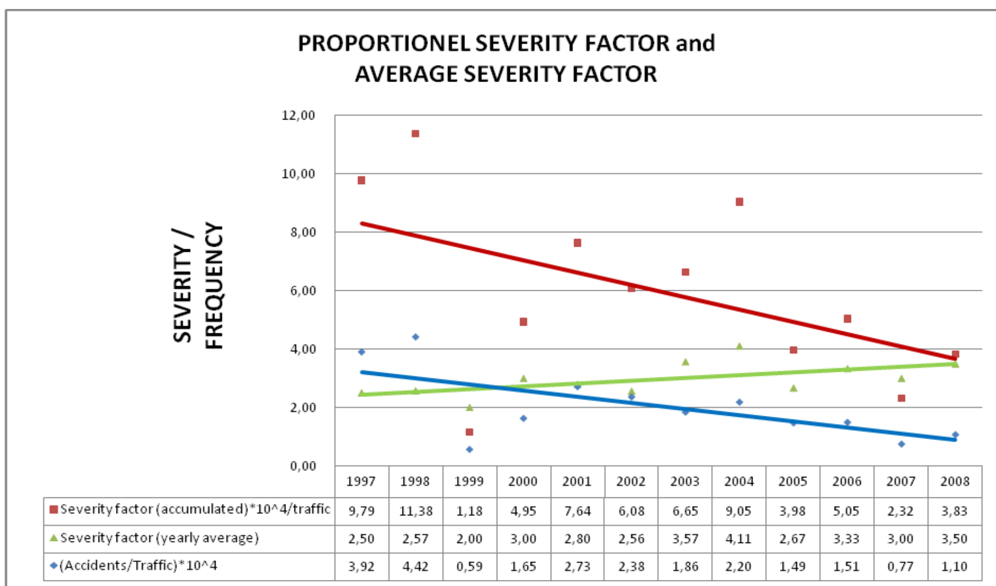


Figure 3.8 Evolution accident severity factor

Following conclusions can be made from figure3.8:

- *The accident frequency has **decreased** to one third during the observed time period of 1997-2008.*
- *The total severity factor has **decreased** to one third during the observed time period of 1997-2008.*
- *The average severity of accidents has **increased** by one third during the observed time period of 1997-2008.*

3.3.4 The reliability analysis and evaluation of results in light of previous studies

Previous studies have brought out doubts that "everything is not written in official papers", this is to say that, to get better legal standing seafarer don't always give all the facts to investigators. During the interview study expressions like "everything is not written in official papers" and "everybody (seafaring community) knows what there really happened" were elicit. This kind of speculation gives reason to believe that accident reports made by Accident Investigation Board are in some cases influenced by lack of correct information. Results of this study may suffer considerable lack of reliability due all analysis in this report are based on statistics made from these accident reports. The biggest impact of doubted deficit of information would have caused descent of significance of category: Tiredness or other human related cause. This category is already the most influencing single cause with over 15% portion of Risk appraisal (40% during the last 4 year period), presented in chapter 3.3.3. On the other hand categories which would have suffered complementary weight would concern things that cannot be influenced directly by the crew: Weather, Technical failure and Bride layout / equipment.

The proportional increase of category "Tiredness or other human related cause" may be due to the true increase, but in the light of the interview study [Lappalainen and Salmi, 2009] it could also be that: due the new better safety culture the correct information is finally been written into accident reports. The low proportion of risk factor in this category during the pre-ISM period as well as during the early ISM-period could be seen anomaly from generally accepted fact that approximately 80% (75-90%, [Kristiansen, 2005]) of all accidents are human mistakes. This lack of correct information could also influence other human related categories: "lack of education" and "actions and mental resources". The lack of education is a new problem in the way that for using safely modern sailing equipment and being able to follow all the time complicating rules, need much greater knowledge than during previous eras.

The risk of technical problems and problems related to bridge layout and equipment is a new ISM-period problem. There may be several reasons for these problems from which three will be presented here:

- *Technical equipment (from navigational equip. to ships engine room) has developed fast during the last 15 years. Some of this equipment is so complicated, that ordinary seafarer doesn't understand how equipment functions. This leads to situations were malfunctions of the equipment are not recognised or they are recognised but their use is continued due the understanding is not adequate to develop a replacing method. The new equipment makes also the work of safety service personnel, such as the pilots, more challenging. Sometimes pilots have to learn to use new equipment within minutes of boarding the ship: even though pilots job is to "assist the ship crew" in many cases pilot is forced to take the control (but not the responsibility) of the vessel to assure its safety.*
- *The new generation of seafarers have to take responsibilities with inadequate training.-During the interview study [Lappalainen and Salmi, 2009] some commentary was given concerning the new maritime educational system in Finland. The quantity of practical training was considered inadequate. Some comments were also given concerning basic mechanical skills of the "NINTENDO-GENERATION", meaning that the new generation of seafarer should be trained also to basic "bolt tightening" and not only to see from the computer if a system is losing the pressure.*
- *The maintenance of equipment used to be done by ships own personnel, which meant that this personnel knew their equipment and all the particularities. Nowadays a large part of this maintenance is done by sub-contractors that may know well the one item they come to fix, but don't necessarily know or care about the functioning of the whole process.*

3.3.5 Combination of accident severity and frequency approach to estimation of future traffic trends

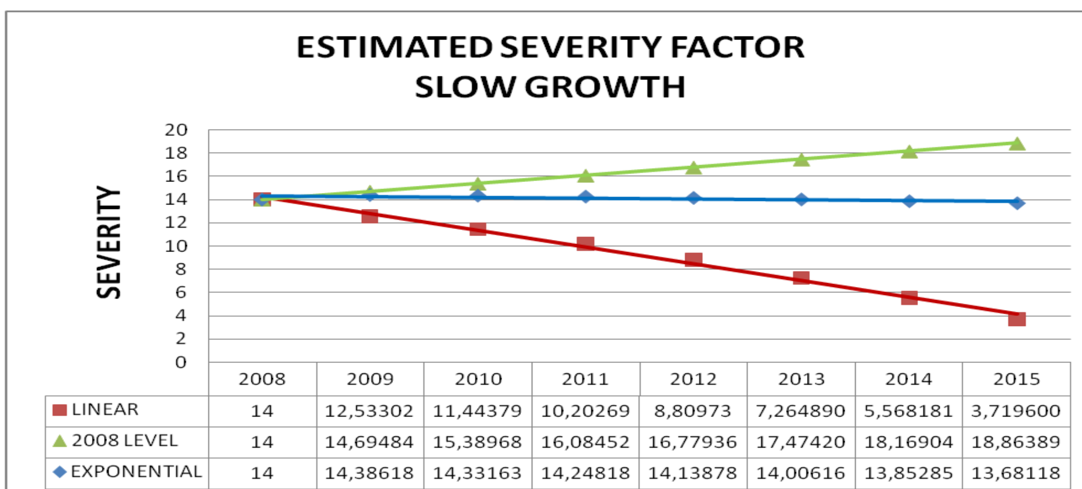
By adding results of yearly severity from chapter 3.3.1 to [SAFGOF] estimation for growth of traffic in Baltic Sea and especially in GOF, some estimations of future accident trends can be made. Three different estimations were proposed for growth of traffic between 2007 and 2015:

- *the "slow growth" which was estimated to be 27% from 2007 level to 2015.*
- *the "average growth" which was estimated to be 40% from 2007 level to 2015.*
- *the "strong growth" which was estimated to be 63% from 2007 level to 2015.*

In figures 3.9, 3.10 and 3.11 the increase of traffic quantity is supposed to be linear from 2007 level to 2015. The accumulated severity factor is presented by three different estimations:

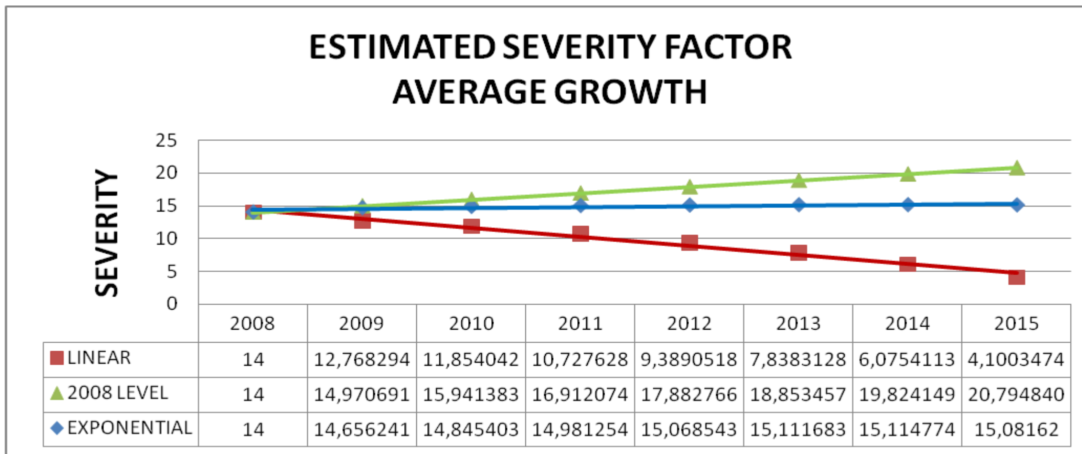
- *Using the linear decreasing trend adopted from figure 3.3 (chapter 3.3.1). With this approach: 2015 only in strong growth scenario there is a slight possibility of catastrophe level accidents. This could be considered too optimistic.*
- *Using 2008 level -assuming that the safety is in its peak and thus the proportional severity vs. traffic quantity is not decreasing any further. This estimation could be defended for example with the statement that it takes in count the possible effect of higher traffic density of water ways.*
- *Using exponential trend based on the data of table 3.6, from chapter 3.3.3. In this approach the slight deceleration of improvement in severity levels gives half term results between the optimistic linear approach and the harsh 2008 level approach.*

Comparisons of accumulated severity factors to traffic quantities presented in figures 3.9, 3.10 and 3.11.



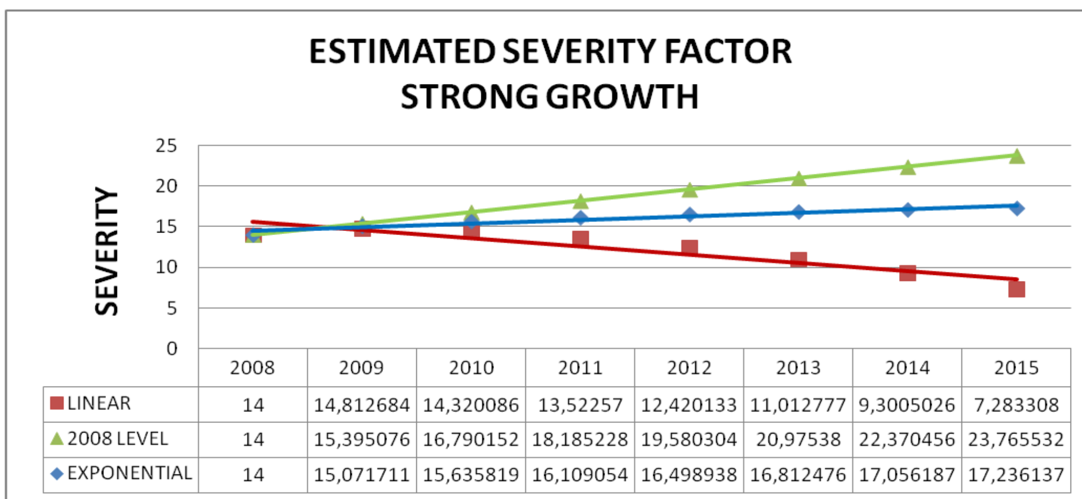
	2008	2009	2010	2011	2012	2013	2014	2015
LINEAR	14	12,53302	11,44379	10,20269	8,80973	7,264890	5,568181	3,719600
2008 LEVEL	14	14,69484	15,38968	16,08452	16,77936	17,47420	18,16904	18,86389
EXPONENTIAL	14	14,38618	14,33163	14,24818	14,13878	14,00616	13,85285	13,68118

Figure 3.3 Estimated accumulated accident severity with slow traffic growth



	2008	2009	2010	2011	2012	2013	2014	2015
LINEAR	14	12,768294	11,854042	10,727628	9,3890518	7,8383128	6,0754113	4,1003474
2008 LEVEL	14	14,970691	15,941383	16,912074	17,882766	18,853457	19,824149	20,794840
EXPONENTIAL	14	14,656241	14,845403	14,981254	15,068543	15,111683	15,114774	15,08162

Figure 3.4 Estimated accumulated accident severity with average traffic growth



	2008	2009	2010	2011	2012	2013	2014	2015
LINEAR	14	14,812684	14,320086	13,52257	12,420133	11,012777	9,3005026	7,283308
2008 LEVEL	14	15,395076	16,790152	18,185228	19,580304	20,97538	22,370456	23,765532
EXPONENTIAL	14	15,071711	15,635819	16,109054	16,498938	16,812476	17,056187	17,236137

Figure 3.5 Estimated accumulated accident severity with strong traffic growth

With all of these approaches the total severity of accidents stays approximately in the levels of this decade. Accumulated severity between 1997 and 2008 is given in table 3.7.

Table 3.4 Accumulated yearly accident severity from 1997 to 2008

Year	Accumulated Severity
1997	30
1998	36
1999	4
2000	18
2001	28
2002	23
2003	25
2004	37
2005	16
2006	20
2007	9
2008	14

Estimations presented in this chapter are very general and simple and they are shown only to highlight the possibility of using accident analysis in statistically and probabilistically to safety modelling and measuring. More detailed probabilistic approaches to accident modelling can be found from Kotka Maritime Research Centre projects:

- *SAFGOF: http://www.merikotka.fi/uk/SAFGOF.php (October 5th, 2009)*
- *EFFICIENSEA: http://www.efficiensea.org/ (October 5th, 2009)*

3.4 Results of the water bus accident analysis

The accident analysis of water busses was done as described in chapter 2.5. The results are, as assumed, concerning.

These water bus accidents have significantly larger average accident leading number than the average of rest of the accidents. The average accident leading number for water bus accidents is 10,75. The average is closer to the average of sinking accidents than the average of accidents in general. This result shows that there is definitely room for improvement on water bus safety.

These results tell the story of inadequate safety culture in water bus traffic. Water busses are often owned by some small company and these companies have not moved to the modern safety oriented period as other parts of the maritime community. Everything is still done as it was done decades ago. They might not even have any operators' safety rules for these water busses and that is shown via dark statistics. They don't often put effort on planning routes. Instead, they navigate based on the masters' memory. Water bus accident reports show that often masters' actions are impulsive and the master might even take orders from passengers. Conscious risks are taken every day in water bus traffic.

4 Conclusions

Accident data can be used to indicate safety and risk levels, but if used as single source it can also conduct to faulty conclusions. In this study the accident reports were approached with multiple methods to assure as many angles of view as possible. These results were compared against previous studies. Final conclusions of:

- *development of risks in Finnish maritime transport*
- *distribution of realized risks by cause, in Finnish maritime transport*
- *use of accident analysis as indicator for safety measuring*

; are induced in this chapter.

4.1 Conclusions of overall Risk development

The overall accident risk in Finnish shipping and in Finnish coastal waters in general has decreased within ISM-period. Of course due the random nature of accident evolution, there are years which don't fit into any linear graphical presentation, but the decreasing trend can still be noticed. Major changes in traffic arrangements in the Gulf of Finland have certainly influenced also the safety development in studied the area. The safety development has lead to situation where annual accident quantities are predicted to stay in reasonable level during the next 5 to 6 years even with increasing traffic quantities.

The average severity of accidents is increasing. The increase can be explained with industries general development of risk management concerning occupational safety, which has lead to considerable reduction of small accidents. While occupational safety has taken great leaps towards safe working environment, the safety development in vessel traffic safety has been slow. One significant reason for this has been the negligence of incident reporting concerning human related near-accident causes. When these incidents are not reported and/or studied, nothing is learned to avoid them in the future. This trend has to be stopped and it can be done by molding the safety and the reporting culture of seafarers and shipping companies.

The leading number approach brought up the observation that significant part of accidents are predictable. Which signifies that due misfunctioning safety management: many vessels sail with obvious and present risk factors, taking conscious risks in their daily traffic and in worst case trying to hide these obvious endangering elements.

The coming of ISM has improved instructions and organization. These improvements have influenced positively to accident statistics. This positive development has not and should not stop and companies and administrations should continue their efforts in safety development despite of economical regression.

4.2 Conclusions by leading cause

Besides the ”other ISM-related”-causes there are other accident leading causes which development can be distributed directly to benefit of ISM-code, these are:

- *“Route planning”; due better safety management the route planning is correctly done and followed. This have influenced positively on decreasing of groundings.*
- *“Co-operation”; due better safety management and also administrations concerns the co-operation namely in the bridge is developing, this include co-operation among ship crew and between ship and officials (eq. pilots, VTS-operators etc.)*
- *“Tiredness and other human related”; In the light of acquired statistics it seems that this category has had negative impact during ISM-period, but by using qualitative analyse the conclusion is that reporting culture has developed, thus this is a positive impact of ISM.*
- *“Other”; have decreased during ISM–period due more organized and truthful reporting, actual accident leading causes are noticed and thus accident reporting have became more accurate.*

Even though accident leading causes having most of the positive impact brought by ISM-code are those connected to ISM or to human factors, they are also causes that still produce most of the accident risk. This means that the direction is good and that the targeting have been successful, but there is still much development to be done. The continuance of positive development is connected to successful implementation of the new safety culture. The change of seafarer generation will most likely produce a positive impact on implementation, due the new generation are not aware of the old” free sailing culture”.

The fast development of technology has surely improved safety, but in the same time it has developed new threats concerning complicacy of equipment. These threats should be taken into account when plans for new ships and their maintenance are made as well as when maritime education is planned.

4.3 Accident analysis as lagging indicator generator

Accident analysis and statistics can be used as indicators for risk. When using information acquired by accident analysis to develop lagging indicators, following precautions have to be made:

- *Results of this kind of accident analysis should not be used as single source of information. Due reliability doubts of the original information.*
- *Qualitative analysis have to be made for acquired quantitative results in order to eliminate obvious statistical anomalies and possible misinterpretations.*
- *Accident analysis demand relatively important labor contribution, due each accident needs to be investigated separately and in preference by the same person or at least by same precision and orientation. This demand of similar processing is to assure that possible misleading subjective views, which generate anomalies in results, are more easily identified when they produce peaks in the data, than when they distribute in larger area due different opinions.*

- *The group of accidents analysed should be large enough to flatten anomalies by force of numbers. If this can't be done as in the case of this report, results should be flattened artificially. Artificial flattening causes some information to be lost, but it assures rightfulness of general trends.*

5 Summary and Further Research

The accident analysis support findings of previous studies; the state of safety In Finnish maritime transport have improved during ISM-period. Positive development can be seen especially in ISM related accident leading causes. The development of reporting culture could also be recognised via results of this analysis.

Measurable information was acquired by this analysis, this information can be used as it is but is recommended being used in combination with information acquired by other means. These other means can be qualitative or quantitative or both. By using cross examination of different methods, details of risk factors can be made apparent.

The contribution of information for safety development is the key element for successfully risk assessment. This information has to come from "both sides of the coin": from administration as well as from shipping companies. The administration should not only provide information for such research, but it should be the flag bearer of safety development: It should actively support private sector safety efforts with up to date information and recommendations. – This approach needs a significant contribution of labour from administration.

The WP 1 of METKU project will continue with statistical analysis of both administration and private company acquired reports and data. This next phase of research will be concluded in two steps:

- *Targeting and identifying misbehaving vessel and their accident susceptibility.*
- *Targeting and identifying accident leading causes of these vessels. Differentiate concrete problems that make a vessel prone to accidents.*

After statistical analyses an expert seminar will be held to validate or object findings of the whole METKU WP 1 research. After the expert seminar, final report with recommendations for both administration and private sector will be delivered.

Acknowledgements

Authors present their warmest thanks to the European Union, European regional development fund, Regional council of Päijät-Häme, City of Kotka, Kotka Maritime Research Association Merikotka, and the Kotka Maritime Research Center Corporate Group with its members for their support.

Authors want also to present their gratitude to members of maritime safety research group of TKK for their advices and help.

Jason Stevens is thanked for his help for making the English of this report legible.

In Otaniemi, 30.10.2009

References

AIBF: http://www.onnettomuustutkinta.fi/2606.htm October 5th 2009

Anderson, P., 2003: Cracking the Code – The Relevance of ISM Code and its impact on shipping practices, The Nautical Institute, London, ISBN: 1-87-007763-6

FMA: http://portal.fma.fi/sivu/www/fma_fi_en/ October 5th 2009

Hänninen, H., 2007: Negotiated risks – Estonia accident and the stream of bow visor failures in the Baltic ferry traffic, Helsinki School of Economics, A-300, HSE Print 2007, ISBN: 978-952-48-8127-2

Jalonen, R. and Salmi, K., 2009: Safety Performance Indicators for Maritime Safety Management, Helsinki University of Technology, TKK-AM-9, Espoo, ISBN: 978-951-22-9944-7(printed) / 978-951-22-9945-4(electronic)

Kristiansen, S., 2005: Maritime Transportation – Safety Management and Risk Analysis, Elsevier Butterworth-Heinemann, ISBN: 0-75-065999-8

Lappalainen, J., 2008: Transforming Maritime Safety Culture, Publications from the Centre for Maritime Studies, A46/2008, Turku, ISBN: 978-951-29-3776-9(printed) / 978-951-29-3777-6 (electronic)

Lappalainen, J. and Salmi, K., 2009: Safety Culture and Maritime Personnel's Safety Attitudes, Publications from the Centre for Maritime Studies, A48/2009, Turku, ISBN: 978-951-29-4043-1(printed) / 978-951-29-4044-8 (electronic)

Pöyhönen, M. and Hämäläinen, R., 1999: On the convergence of multiattribute weighting methods, European Journal of Operational Research, Volume 129, Issue 3, March 2001, doi:10.1016/S0377-2217(99)00467-1

Saaty, T., 1980: The Analytic Hierarchy Process, McGraw-Hill, New York, ISBN: 0-07-054371-2

SAFGOF: http://www.merikotka.fi/uk/SAFGOF.php October 5th 2009

STUK, 2008: Regulatory control of nuclear safety in Finland, Annual report 2007, STUK-B 92 / June 2008, ISBN: 978-951-47-8372-9

APPENDIX 1.

															ALF	ALF	ALF	ALF	ALF	ALF	ALF	ALF	ALF	ALF	RISK	RISK	RISK	RISK	RISK	RISK	RISK	RISK	RISK	RISK
Name	yyyymmdd	AIBF-id	Tiredness or other human related cause	Co-operation	Technical failure	Lack of Education	Route planning	Actions and mental resources	Lay out/ devices of bridge	weather	Other ISM related cause	Other	Accident Leading Number	Severity factor	Tiredness or other human related cause	Co-operation	Technical failure	Lack of Education	Route planning	Actions and mental resources	Lay out/ devices of bridge	Weather	Other ISM related cause	Other	Tiredness or other human related cause	Co-operation	Technical failure	Lack of Education	Route planning	Actions and mental resources	Lay out/ devices of bridge	Weather	Other ISM related cause	Other
Estonia	19940928	MV ESTONIA	0	0	5	0	0	3	0	3	0	3	14	5	0,000	0,000	0,357	0,000	0,000	0,214	0,000	0,214	0,000	0,214	0,000	0,000	1,786	0,000	0,000	1,071	0,000	1,071	0,000	1,071
M/S Tallink	19950422	2/1995	0	5	0	0	3	0	0	1	0	0	9	5	0,000	0,556	0,000	0,000	0,333	0,000	0,000	0,111	0,000	0,000	0,000	2,778	0,000	0,000	1,667	0,000	0,000	0,556	0,000	0,000
Laura	19950527	3/1995	0	3	0	0	0	0	3	3	0	0	9	3	0,000	0,333	0,000	0,000	0,000	0,000	0,333	0,333	0,000	0,000	0,000	1,000	0,000	0,000	0,000	0,000	1,000	1,000	0,000	0,000
Katarina	19970313	C 1/1997 M	0	5	0	0	0	0	3	1	0	0	9	3	0,000	0,556	0,000	0,000	0,000	0,000	0,333	0,111	0,000	0,000	0,000	1,667	0,000	0,000	0,000	0,000	1,000	0,333	0,000	0,000
ms marjesco	19970411	C 2/1997 M	1	0	0	0	0	0	0	3	0	5	9	3	0,111	0,000	0,000	0,000	0,000	0,000	0,000	0,333	0,000	0,556	0,333	0,000	0,000	0,000	0,000	0,000	0,000	1,000	0,000	1,667
MS Sofia	19970512	C 8a/1997 M	5	0	0	0	0	0	0	0	3	0	8	1	0,625	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,375	0,000	0,625	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,375	0,000
Finnmaid/ mergus	19970616	C 4/1997 M	0	0	0	0	0	0	3	3	0	0	6	3	0,000	0,000	0,000	0,000	0,000	0,000	0,500	0,500	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	1,500	1,500	0,000	0,000
MS Najaden	19970712	C 8/1997 M	5	0	0	0	0	0	0	0	5	0	10	3	0,500	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,500	0,000	1,500	0,000	0,000	0,000	0,000	0,000	0,000	0,000	1,500	0,000
Silja Europa	19970728	C 7/1997 M	0	0	5	3	0	0	0	0	0	0	8	1	0,000	0,000	0,625	0,375	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,625	0,375	0,000	0,000	0,000	0,000	0,000	0,000
MS Hälsingland	19970814	C 6/1997 M	0	0	0	0	3	0	0	0	5	0	8	5	0,000	0,000	0,000	0,000	0,375	0,000	0,000	0,000	0,625	0,000	0,000	0,000	0,000	0,000	1,875	0,000	0,000	0,000	3,125	0,000
Flanör/ M/S Silja Europa	19970820	C 7/1997 M	3	0	0	0	0	1	1	3	0	0	8	1	0,375	0,000	0,000	0,000	0,000	0,125	0,125	0,375	0,000	0,000	0,375	0,000	0,000	0,000	0,000	0,125	0,125	0,375	0,000	0,000
Ms grimm	19971001	C 11/1997 M	5	3	0	0	1	0	0	0	0	0	9	1	0,556	0,333	0,000	0,000	0,111	0,000	0,000	0,000	0,000	0,000	0,556	0,333	0,000	0,000	0,111	0,000	0,000	0,000	0,000	0,000
MS Greta	19971118	C 14/1997 M	0	0	0	0	0	0	0	0	0	5	5	3	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	1,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	3,000
Marie Lehmann	19971121	C 15/1997 M	0	0	0	0	5	1	0	0	0	3	9	3	0,000	0,000	0,000	0,000	0,556	0,111	0,000	0,000	0,000	0,333	0,000	0,000	0,000	0,000	1,667	0,333	0,000	0,000	0,000	1,000
MT Crystal amethyst	19971201	C 16/1997 M	0	5	0	0	0	3	0	3	3	0	14	3	0,000	0,357	0,000	0,000	0,000	0,214	0,000	0,214	0,214	0,000	0,000	1,071	0,000	0,000	0,000	0,643	0,000	0,643	0,643	0,000
Mega/motti	19980105	C 1/1998 M	0	5	0	0	0	3	0	0	0	0	8	1	0,000	0,625	0,000	0,000	0,000	0,375	0,000	0,000	0,000	0,000	0,000	0,625	0,000	0,000	0,000	0,375	0,000	0,000	0,000	0,000
Ms Julia	19980107	C 2/1998 M	0	0	0	0	0	3	0	3	0	3	9	3	0,000	0,000	0,000	0,000	0,000	0,333	0,000	0,333	0,000	0,333	0,000	0,000	0,000	0,000	0,000	1,000	0,000	1,000	0,000	1,000
MS Oihonna	19980131	C 3/1998 M	0	0	3	0	0	0	0	3	0	5	11	3	0,000	0,000	0,273	0,000	0,000	0,000	0,000	0,273	0,000	0,455	0,000	0,000	0,818	0,000	0,000	0,000	0,000	0,818	0,000	1,364
MS Ulsund	19980227	1/2000 J	0	1	3	0	0	3	0	5	0	0	12	5	0,000	0,083	0,250	0,000	0,000	0,250	0,000	0,417	0,000	0,000	0,000	0,417	1,250	0,000	0,000	1,250	0,000	2,083	0,000	0,000
MS Gerda	19980407	C 4/1998 M	0	5	0	0	0	0	0	3	0	1	9	3	0,000	0,556	0,000	0,000	0,000	0,000	0,000	0,333	0,000	0,111	0,000	1,667	0,000	0,000	0,000	0,000	0,000	1,000	0,000	0,333
Ms Baltic merchant	19980421	C 5/1998 M	0	3	0	0	3	0	1	3	0	1	11	3	0,000	0,273	0,000	0,000	0,273	0,000	0,091	0,273	0,000	0,091	0,000	0,818	0,000	0,000	0,818	0,000	0,273	0,818	0,000	0,273
Laura	19980604	B 1/1998 M	0	0	0	0	3	0	1	3	0	1	8	3	0,000	0,000	0,000	0,000	0,375	0,000	0,125	0,375	0,000	0,125	0,000	0,000	0,000	0,000	1,125	0,000	0,375	1,125	0,000	0,375
Pamela	19980803	C 7/1998 M	5	0	0	0	0	0	0	0	3	0	8	3	0,625	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,375	0,000	1,875	0,000	0,000	0,000	0,000	0,000	0,000	0,000	1,125	0,000
MT Natura	19981013	C 8/1998 M	0	0	5	0	0	0	0	0	0	0	5	3	0,000	0,000	1,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	3,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Ms gabriella	19981024	B 2/1998 M	0	0	3	0	0	0	0	1	0	5	9	3	0,000	0,000	0,333	0,000	0,000	0,000	0,000	0,111	0,000	0,556	0,000	0,000	1,000	0,000	0,000	0,000	0,000	0,333	0,000	1,667
Ms Christa	19981123	C 9/1998 M	5	0	1	0	0	0	0	0	0	3	9	1	0,556	0,000	0,111	0,000	0,000	0,000	0,000	0,000	0,000	0,333	0,556	0,000	0,111	0,000	0,000	0,000	0,000	0,000	0,000	0,333
Dimitris	19981129	C 10/1998 M	3	3	0	0	0	0	0	3	0	0	9	1	0,333	0,333	0,000	0,000	0,000	0,000	0,000	0,333	0,000	0,000	0,333	0,333	0,000	0,000	0,000	0,000	0,000	0,333	0,000	0,000
Ms Gardwind	19981205	C 11/1998 M	5	3	0	0	0	0	0	1	0	3	12	3	0,417	0,250	0,000	0,000	0,000	0,000	0,000	0,083	0,000	0,250	1,250	0,750	0,000	0,000	0,000	0,000	0,000	0,250	0,000	0,750
Ms Trenden	19981217	C 13/1998 M	0	3	0	3	0	0	0	0	0	3	9	1	0,000	0,333	0,000	0,333	0,000	0,000	0,000	0,000	0,000	0,333	0,000	0,333	0,000	0,333	0,000	0,000	0,000	0,000	0,000	0,333
M Cinderella	19990520	C 1/1999 M	0	0	0	0	0	0	0	0	0	5	5	1	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	1,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	1,000
Inowroclaw	19991125	C 6/1999 M	0	0	5	0	0	0	0	0	0	0	5	3	0,000	0,000	1,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	3,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
ms Ocean Pride	20000306	C 1/2000 M	3	0	5	0	1	0	3	1	3	0	16	3	0,188	0,000	0,313	0,000	0,063	0,000	0,188	0,063	0,188	0,000	0,563	0,000	0,938	0,000	0,188	0,000	0,563	0,188	0,563	0,000
MS Aurora	20000306	C 2/2000 M	0	0	3	0	0	0	0	5	0	1	9	3	0,000	0,000	0,333	0,000	0,000	0,000	0,000	0,556	0,000	0,111	0,000	0,000	1,000	0,000	0,000	0,000	0,000	1,667	0,000	0,333
MS Finnfellow	20000402	B 2/2000 M	0	0	3	0	0	0	3	1	0	0	7	3	0,000	0,000	0,429	0,000	0,000	0,000	0,429	0,143	0,000	0,000	0,000	0,000	1,286	0,000	0,000	0,000	1,286	0,429	0,000	0,000
Mt Crystal rubino	20000720	B 3/2000 M	0	0	0	3	0	0	0	0	5	0	8	3	0,000	0,000	0,000	0,375	0,000	0,000	0,000	0,000	0,625	0,000	0,000	0,000	0,000	1,125	0,000	0,000	0,000	0,000	1,875	0,000
MS maria	20001107	B 4/2000 M	3	0	0	0	0	0	0	0	5	0	8	1	0,375	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,625	0,000	0,375	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,625	0,000
MV Janra	20001223	B 5/2000 M	0	0	0	0	0	0	0	0	5	0	5	5	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	1,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	5,000	0,000
Finnreel	20010314	Ro-ro FINNREEL	0	0	5	0	0	0	0	0	0	1	6	3	0,000	0,000	0,833	0,000	0,000	0,000	0,000	0,000	0,000	0,167	0,000	0,000	2,500	0,000	0,000	0,000	0,000	0,000	0,000	0,500
Cinderella	20010321	C 2/2001 M	3	0	0	0	0	0	0	0	5	0	8	3	0,375	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,625	0,000	1,125	0,000	0,000	0,000	0,000	0,000	0,000	0,000	1,875	0,000
Alfa/ Para-Uno + Sormovskiy	20010515	C 4/2001 M	0	0	0	5	0	0	0	0	5	0	10	1	0,000	0,000	0,000	0,500	0,000	0,000	0,000	0,000	0,500	0,000	0,000	0,000	0,000	0,500	0,000	0,000	0,000	0,000	0,500	0,000
Ms Antares	20010705	C 6/2001 M	0	0	5	0	0	3	0	0	0	0	8	5	0,000	0,000	0,625	0,000	0,000	0,375	0,000	0,000	0,000	0,000	0,000	0,000	3,125	0,000	0,000	1,875	0,000	0,000	0,000	0,000
M/S Cindy	20010917	C 9/2001 M	5	0	0	0	0	3	0	1	0	0	9	3	0,556	0,000	0,000	0,000	0,000	0,333	0,000	0,111	0,000	0,000	1,667	0,000	0,000	0,000	0,000	1,000	0,000	0,333	0,000	0,000
MS Pamela	20011002	C 10/2001 M	0	0	5	0	0	0	3	0	1	0	9	1	0,000	0,000	0,556	0,000	0,000	0,000	0,333	0,000	0,111	0,000	0,000	0,000	0,556	0,000	0,000	0,000	0,333	0,000	0,111	0,000
MS Traden	20011019	C 13/2001 M	0	0	3	0	0	0	0	3	5	0	11	3	0,000	0,000	0,273	0,000	0,000	0,000	0,000	0,273	0,455	0,000	0,000	0,000	0,818	0,000	0,000	0,000	0,000	0,818	1,364	0,000
Ms Iran Sarbaz	20011101	C 12/2001 M	0	0	3	0	0	3	0	3	0	0	9	1	0,000	0,000	0,333	0,000	0,000	0,333	0,000	0,333	0,000	0,000	0,000	0,000	0,333	0,000	0,000	0,333	0,000	0,333	0,000	0,000
Voima	20011121	C 14/2001 M	0	3	3	3	0	0	0	0	0	3	12	3	0,000	0,250	0,250	0,250	0,000	0,000	0,000	0,000	0,000	0,250	0,000	0,750	0,750	0,750	0,000	0,000	0,000	0,000	0,000	0,750
Isabella	20011220	B 1/2001 M	3	3	0	3	0	0	3	3	0	0	15	5	0,200	0,200	0,000	0,200	0,000	0,000	0,200	0,200	0,000	0,000	1,000	1,000	0,000	1,000	0,000	0,000	1,000	1,000	0,000	0,000
MS city of sunderland	20020101	C 2/2002 M	0	0	0	0	0	3	3	3	5	0	14	3	0,000	0,000	0,000	0,000	0,000	0,214	0,214	0,214	0,357	0,000	0,000	0,000	0,000	0,000	0,000	0,643	0,643	0,643	1,071	0,000
Steel board	20020101	C 4/2002 M	5	0	0	0	0	0	0	0	3	0	8	3	0,625	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,375	0,000	1,875	0,000	0,000	0,000	0,000	0,000	0,000	0,000	1,125	0,000
M/S Fjord pearl	20020102	C 1/2002 M	3	0	0	0	0	0	0	3	0	3	9	3	0,333	0,000	0,000	0,000	0,000	0,000	0,000	0,333	0,000	0,333	1,000	0,000	0,000	0,000	0,000	0,000	0,000	1,000	0,000	1,000
Douro Chemist	20020219	C 3/2002 M	0	5	0	0	3	0	0	0	0	3	11	3	0,000	0,455	0,000	0,000	0,273	0,000	0,000	0,000	0,000	0,273	0,000	1,364	0,000	0,000	0,818	0,000	0,000	0,000	0,000	0,818
Tebo olympia	20020227	C 5/2002 M	0	0	0	0	0	3	0	0	5	0	8	1	0,000	0,000	0,000	0,000	0,000	0,375	0,000	0,000	0,625	0,000	0,000	0,000	0,000	0,000	0,000	0,375	0,000	0,000	0,625	0,000
Ms Kajen	20020318	C 13/2002 M	0	1	0	0	3	0	0	0	0	5	9	1	0,000	0,111	0,000	0,000	0,333	0,000	0,000	0,000	0,000	0,556	0,000	0,111	0,000	0,000	0,333	0,000	0,000	0,000	0,000	0,556
Finnmerchant/Eaton	20020812	C 9/2002 M	5	0	0	0	0	1	0	3	0	0	9	3	0,556	0,000	0,000	0,000	0,000	0,111	0,000	0,333	0,000	0,000	1,667	0,000	0,000	0,000	0,000	0,333	0,000	1,000	0,000	0,000
Vingaren /Garden	20021002	C 11/2002 M	5	0	0	0	0	0	0	0	0	3	8	3	0,625	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,375	1,875	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	1,125
Ms Traveberg	20021126	C 12/2002 M	0	0	0	0	0	0	3	3	3	0	9	3	0,000	0,000	0,000	0,000	0,000	0,000	0,333	0,333	0,333	0,000	0,000	0,000	0,000	0,000	0,000	0,000	1,000	1,000	1,000	0,000
Ms Camilla	20030123	B 1/2003 M	0	0	5	0	0	0	0	0	5	0	10	5	0,000	0,000	0,500	0,000	0,000	0,000	0,000	0,000	0,500	0,000	0,000	0,000	2,500	0,000	0,000	0,000	0,000	0,000	2,500	0,000
MS Bianca	20030331	C 3/2003 M	5	0	3	0	0	0	0	0	3	0	11	3	0,455	0,000	0,273	0,000	0,000	0,000	0,000	0,000	0,273	0,000	1,364	0,000	0,818	0,000	0,000	0,000	0,000	0,000	0,818	0,000
Voima	20030411	C 4/2003 M	1	3	0	0	0	3	0	1	0	1	9	3	0,111	0,333	0,000	0,000	0,000	0,333	0,000	0,111	0,000	0,111	0,333	1,000	0,000	0,000	0,000	1,000	0,000	0,333	0,000	0,333
M/S Pamela	20030423	C 6/2003 M	5	0	0	0	0	0	0	0	3	0	8	3	0,625	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,375	0,000	1,875	0,000	0,000	0,000	0,000	0,000	0,000	0,000	1,125	0,000
Silja Opera	20030917	C 8/2003 M	0	3	0	3	0	3	0	0	0	3	12	3	0,000	0,250	0,000	0,250	0,000	0,250	0,000	0,000	0,000	0,250	0,000	0,750	0,000	0,750	0,000	0,750	0,000	0,000	0,000	0,750
Spoven	20031108	C 9/2003 M	5	0	0	0	0	0	5	1	0	3	14	3	0,357	0,000	0,000	0,000	0,000	0,000	0,357	0,071	0,000	0,214	1,071	0,000	0,000	0,000	0,000	0,000	1,071	0,214	0,000	0,643
Pegasos	20031113	B 2/2003 M	3	5	1	0	1	0	0	0	0	3	13	5	0,231	0,385	0,077	0,000	0,077	0,000	0,000	0,000	0,000	0,231	1,154	1,923	0,385	0,000	0,385	0,000	0,000	0,000	0,000	1,154
Finnclipper	20040120	B 1/2004 M	3	3	0	0	3	0	0	0	3	0	12	5	0,250	0,250	0,000	0,000	0,250	0,000	0,000	0,000	0,250	0,000	1,250	1,250	0,000	0,000	1,250	0,000	0,000	0,000	1,250	0,000
Herakles-Bulk	20040303	B 2/2004 M	0	0	0	0	0	0	0	5	0	1	6	5	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,833	0,000	0,167	0,000	0,000	0,000	0,000	0,000	0,000	0,000	4,167	0,000	0,833
Sea Gull	20040527	B 3/2004 M	3	0	0	0	0	0	0	0	0	5	8	5	0,375	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,625	1,875	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	3,125
M/S Isabella/Rospiggen	20040830	C 7/2004 M	3	0	0	0	0	3	0	0	0	3	9	3	0,333	0,000	0,000	0,000	0,000	0,333	0,000	0,000	0,000	0,333	1,000	0,000	0,000	0,000	0,000	1,000	0,000	0,000	0,000	1,000
M/S Global Freighter	20040921	B 5/2004 M	0	3	0	0	0	0	5	0	1	0	9	5	0,000	0,333	0,000	0,000	0,000	0,000	0,556	0,000	0,111	0,000	0,000	1,667	0,000	0,000	0,000	0,000	2,778	0,000	0,556	0,000
MS Superfast VIII	20041109	B 6/2004 M	0	0	3	0	0	0	0	0	5	0	8	3	0,000	0,000	0,375	0,000	0,000	0,000	0,000	0,000	0,625	0,000	0,000	0,000	1,125	0,000	0,000	0,000	0,000	0,000	1,875	0,000
MS Superfast VII	20041112	B 7/2004 M	0	3	0	0	0	0	3	1	3	0	10	3	0,000	0,300	0,000	0,000	0,000	0,000	0,300	0,100	0,300	0,000	0,000	0,900	0,000	0,000	0,000	0,000	0,900	0,300	0,900	0,000
M/S Casino express	20041124	C 9/2004 M	0	3	3	3	0	0	0	3	0	3	15	5	0,000	0,200	0,200	0,200	0,000	0,000	0,000	0,200	0,000	0,200	0,000	1,000	1,000	1,000	0,000	0,000	0,000	1,000	0,000	1,000
M/S Alandia	20041209	B 8/2004 M	3	0	0	0	0	0	5	0	0	0	8	3	0,375	0,000	0,000	0,000	0,000	0,000	0,625	0,000	0,000	0,000	1,125	0,000	0,000	0,000	0,000	0,000	1,875	0,000	0,000	0,000
M/S Pauline Russ	20050120	C 1/2005 M	0	5	0	0	0	0	0	3	0	3	11	1	0,000	0,455	0,000	0,000	0,000	0,000	0,000	0,273	0,000	0,273	0,000	0,455	0,000	0,000	0,000	0,000	0,000	0,273	0,000	0,273
M/S Amorella	20050519	B 1/2005 M	3	0	0	0	0	0	0	0	0	1	4	3	0,750	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,250	2,250	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,750
Translandia	20050831	C 3/2005 M	3	0	0	0	0	0	5	3	0	0	11	5	0,273	0,000	0,000	0,000	0,000	0,000	0,455	0,273	0,000	0,000	1,364	0,000	0,000	0,000	0,000	0,000	2,273	1,364	0,000	0,000
MS Silja serenade/kbv 046	20051004	C 4/2005 M	3	0	3	0	0	0	0	0	0	0	6	1	0,500	0,000	0,500	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,500	0,000	0,500	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Prostvik 1 /Kuha 26	20051110	C 7/2005 M	3	0	0	0	0	0	3	0	3	0	9	3	0,333	0,000	0,000	0,000	0,000	0,000	0,333	0,000	0,333	0,000	1,000	0,000	0,000	0,000	0,000	0,000	1,000	0,000	1,000	0,000
M/T omega af donsö	20051210	C 5/2005 M	0	3	5	0	0	1	0	0	0	0	9	3	0,000	0,333	0,556	0,000	0,000	0,111	0,000	0,000	0,000	0,000	0,000	1,000	1,667	0,000	0,000	0,333	0,000	0,000	0,000	0,000
MS Singeldiep	20060111	B 1/2006 M	5	0	3	0	0	0	0	0	3	0	11	5	0,455	0,000	0,273	0,000	0,000	0,000	0,000	0,000	0,273	0,000	2,273	0,000	1,364	0,000	0,000	0,000	0,000	0,000	1,364	0,000
MS Pamela	20060701	C 3/2006 M	3	0	0	0	0	0	0	0	5	0	8	3	0,375	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,625	0,000	1,125	0,000	0,000	0,000	0,000	0,000	0,000	0,000	1,875	0,000
M/S Hoburgen / M/T Arctica	20061007	C 4/2006 M	3	0	0	0	3	3	0	0	0	3	12	3	0,250	0,000	0,000	0,000	0,250	0,250	0,000	0,000	0,000	0,250	0,750	0,000	0,000	0,000	0,750	0,750	0,000	0,000	0,000	0,750
MS Nordlandia	20061028	C 6/2006 M	0	0	0	3	0	0	0	3	5	0	11	3	0,000	0,000	0,000	0,273	0,000	0,000	0,000	0,273	0,455	0,000	0,000	0,000	0,000	0,818	0,000	0,000	0,000	0,818	1,364	0,000
Finnbirch	20061101	C 7/2006 M	3	0	0	0	0	3	0	3	3	0	12	5	0,250	0,000	0,000	0,000	0,000	0,250	0,000	0,250	0,250	0,000	1,250	0,000	0,000	0,000	0,000	1,250	0,000	1,250	1,250	0,000
MS Pamela	20061207	C 3/2006 M	3	0	0	0	0	3	0	3	3	0	12	1	0,250	0,000	0,000	0,000	0,000	0,250	0,000	0,250	0,250	0,000	0,250	0,000	0,000	0,000	0,000	0,250	0,000	0,250	0,250	0,000
M/S Kristina regina/ carrier 5	20070529	C 1/2007 M	3	0	0	0	0	3	0	3	0	1	10	3	0,300	0,000	0,000	0,000	0,000	0,300	0,000	0,300	0,000	0,100	0,900	0,000	0,000	0,000	0,000	0,900	0,000	0,900	0,000	0,300
MS Claudia	20071023	C 2/2007 M	0	0	0	0	3	0	0	0	0	5	8	3	0,000	0,000	0,000	0,000	0,375	0,000	0,000	0,000	0,000	0,625	0,000	0,000	0,000	0,000	1,125	0,000	0,000	0,000	0,000	1,875
M/S ålandsfärjan	20071023	C 3/2007 M	5	0	0	0	0	0	0	0	0	5	10	3	0,500	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,500	1,500	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	1,500
MS Tali	20080129	B 1/2008 M	0	0	3	0	0	0	0	3	0	3	9	3	0,000	0,000	0,333	0,000	0,000	0,000	0,000	0,333	0,000	0,333	0,000	0,000	1,000	0,000	0,000	0,000	0,000	1,000	0,000	1,000
MS OOCL Nevskiy	20080227	C 1/2008 M	3	5	0	0	0	0	0	0	0	0	8	3	0,375	0,625	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	1,125	1,875	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
MS Serena	20080306	C 2/2008 M	0	0	5	0	0	3	0	0	3	0	11	3	0,000	0,000	0,455	0,000	0,000	0,273	0,000	0,000	0,273	0,000	0,000	0,000	1,364	0,000	0,000	0,818	0,000	0,000	0,818	0,000
MS Anne Sibum	20080402	C 3/2008 M	3	5	0	0	0	0	0	0	0	0	8	5	0,375	0,625	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	1,875	3,125	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000

Helsinki University of Technology. Faculty of Engineering and Architecture.
Department of Applied Mechanics. Series AM

TKK-AM-10 Arsham Mazaheri
PROBABILISTIC MODELING OF SHIP GROUNDING; LITERATURE REVIEW

TKK-AM-9 Risto Jalonen; Kim Salmi
SAFETY PERFORMANCE INDICATORS FOR MARITIME SAFETY MANAGEMENT; LITERATURE REVIEW

TKK-AM-8 Tommi Mikkola
SIMULATION OF FORCES ON SHIP-LIKE CROSS-SECTIONS IN BEAM WAVES

TKK-AM-7 Sören Ehlers
A THIN SPHERICAL PLATE UNDER HEMI-SPHERICAL PUNCH
An experimental study of a plate subjected to a displacement controlled punch

TKK-AM-6 Jutta Ylitalo; Maria Hänninen; Pentti Kujala
ACCIDENT PROBABILITIES IN SELECTED AREAS OF THE GULF OF FINLAND

TKK-AM-5 Arughadhoss, Sankar
FLOW SIMULATION OF BOX COOLER
An Experimental Study of Buoyant Water Flow in a Box Cooler

TKK-AM-4 Maria Hänninen
ANALYSIS OF HUMAN AND ORGANIZATIONAL FACTORS IN MARINE TRAFFIC RISK MODELING: LITERATURE REVIEW

TKK-AM-3 Aleksi Laakso; Jani Romanoff
TYHJIEN JA TÄYTETTYJEN TERÄSKERROSLEVYPALKKIEN NELIPISTE-TAIVUTUSKOKEET

TKK-AM-2 Ragnar Linnas
MODEL TESTS OF SPRINGING TYPE WAVE LOADS ON CRUISE VESSEL IN REGULAR HEAD SEAS

TKK-AM-1 Jun Wang
UNDERSTANDING VALUE IN THE SHIPBUILDING INDUSTRY
A study of buyer and seller perceived value in business relationships

ISBN 978-952-248-182-5
ISBN 978-952-248-183-2 (PDF)
ISSN 1797-609X
ISSN 1797-6111 (PDF)