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MERITURVALLISUUDEN JA -LIIKENTEEN TUTKIMUSKESKUS
KOTKA MARITIME RESEARCH CENTRE
MERI KOTKA

TKK

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SUMMARY

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A literature survey of uses of accident data in occupational safety was carried out in Turku University of Applied Sciences. The project was funded by the European Union, European Regional Development Fund, the Regional Council of Päijät-Häme and the participants from the industry.

Typically, the risk of injury and death due to occupational accidents is in the order of magnitude ten times higher for seafarers than for general population on land. Various information sources of the phenomenon are available: e.g. shipping companies, flag state administrations, insurers, rescue agencies and medical authorities gather data. The typical accidents are slips, trips and falls while moving around in the ship. In general, the most dangerous types of operation are mooring, engine maintenance at sea, handling of heavy or unwieldy items, working at height, and entry into enclosed spaces. There are differences between nationalities; typically mariners from South East Asia have significantly lower accident rates compared with seafarers from Western Europe.

There are significant problems in collecting comparable statistical data worldwide as the sources are disparate or non-existent. Nationally, or for shipping companies, this is easier; especially oil industry is demanding relevant data from their transports. For demonstrating the challenges of comparisons, the published data of four Nordic countries was reviewed. Further analysis is to be carried out in the future work tasks of the project.

In addition to the statistics of accidents, the amount of exposure to risk for the populations of subjects is required for comparisons. In maritime oil transport, normalisation is based on 24 hours of exposure per day, and rates are calculated per million exposure hours, which can be a suitable solution also for other shipping trades and flag states, as this information can be obtained relatively easily. Consequently, the explication of existing data from published shipping industry sources is a useful research topic for further studies.

Combining occupational and maritime safety for modelling purposes is not straight-forward as safety is a product of random, technical, human and organisational factors. Eventually, the occupational safety information could be simplified to a few factors that measure the company performance, such as LTIF, and used as additional input to maritime safety models.

Further research on occupational accident data is recommended, such as 1) studying occupational and marine safety performance in oil transport with the same factors in the comparable traffic of other commodities; 2) comparing the situations of the flag states which publish occupational safety data regularly; and 3) studying organisations that are co-operating in the field.

TIIVISTELMÄ

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Turun ammattikorkeakoulussa tutkittiin merenkulun työturvallisuustiedon käyttöä. Projektin rahoittivat Euroopan Unionin Euroopan aluekehitysrahasto, Päijät-Hämeen liitto ja alan toimijat.

Merenkulussa työntekijän loukkaantumisen ja kuoleman riski ovat suuruusluokaltaan noin kymmenkertaisia verrattuna samanlaiseen populaatioon maissa. Ilmiöstä on saatavilla tietoa useista lähteistä: mm. varustamot, lippuvaltioiden viranomaiset, vakuutusyhtiöt, pelastusviranomaiset ja lääketieteelliset tahot keräävät tilastoja. Tyypilliset onnettomuudet liittyvät liukastumisiin, kaatumisiin ja putoamisiin laivalla liikuttaessa. Vaarallisimpia työtehtäviä ovat laivan kiinnittäminen laituriin, koneen huoltotyöt merellä, painavien tai muuten hankalien lastien käsittely, työt korkeissa paikoissa ja suljettuihin tiloihin meneminen. Kansallisuuksien välillä on eroja: lounaisaasialaisten merimiesten onnettomuustaajuus on huomattavasti pienempi kuin länsieurooppalaisten.

Maailmanlaajuisesti yhteensopivan tilastoaineiston kerääminen on vaikeata, sillä lähteet voivat olla hyvin vaihtelevia laadultaan tai niitä ei ole lainkaan. Kerääminen on helpompaa kansallisesti tai varustamojen kesken; erityisesti öljyteollisuus saa aikaan työturvallisuustietoja kuljetuksistaan. Tutkimuksessa vertailtiin Pohjoismaissa julkaistuja virallisten tilastojen välisiä eroja. Lisäanalyysiä tehdään tulevaisuudessa.

Onnettomuuksien lukumäärän lisäksi vertailuihin tarvitaan riskille altistumisen määrä. Öljyn merikuljetuksissa tämä normalisointi perustuu yleensä 24 tunnin altistukselle vuorokausittain ja tapaturmataajuudet lasketaan miljoonaa altistustuntia kohden. Tämä voisi olla sopiva tapa myös muille merikuljetusten aloille ja lippuvaltioille, sillä tarvittavat tiedot olisivat saatavissa suhteellisen helposti. Tällaisen tilastotiedon kerääminen ja esittäminen yhtenevässä muodossa on hyödyllinen tutkimuskohde tulevaisuudessa.

Työturvallisuuden ja meriturvallisuuden yhdistäminen mallinnuksessa ei ole ongelmatonta, sillä turvallisuus on tulosta satunnaisten, teknisten, inhimillisten ja organisatoristen muuttujien vuorovaikutuksista. Saattaa kuitenkin olla mahdollista, että työturvallisuuden muuttujia, kuten tapaturmataajuutta (LTIF), voitaisiin käyttää meriturvallisuusmallien lähtötietona.

Työturvallisuustiedon käytön jatkotutkimusta suositellaan, esimerkiksi 1) työturvallisuuden ja meriturvallisuuden vertailua öljynkuljetusten ja jonkin muun vastaavan meriliikenteen välillä, 2) vertailua työturvallisuusaineistoa säännöllisesti julkaisevien lippuvaltioiden välillä ja 3) keskinäistä yhteistyötä tekevien merialan organisaatioiden toiminnan analyysia.

CONTENTS

1 INTRODUCTION

Work onboard ships subjects the personnel to an increased risk of occupational accidents. The increase in the risk of death is in the order of magnitude ten times higher than for general population on land (Roberts 2008). To improve the conditions and work methods onboard, understanding of the previous accidents is very useful. Naturally, statistical data on the phenomenon has been published in many countries, and some worldwide comparisons have been carried out, but further research could prove interesting. Oldenburg et al. (2010) emphasise the hazardous environment onboard as the root cause of several types of fatalities on board, including occupational accidents. In the previous studies of safety onboard (Räisänen 2009, 2010), it was summarised that especially safety benchmarking could be useful for improvements, but that common references for comparisons could be further researched.

The purpose of this short report is to summarise some of the factors related to the occupational accidents onboard, the methods of data collection and the ways of presenting the occupational accident statistics for general merchant shipping. Current public reporting in Nordic countries is used as an example. In addition, some future possibilities of increasing knowledge on the matter are discussed.

2 FACTORS RELATING TO OCCUPATIONAL ACCIDENTS ONBOARD AND THEIR REPORTING

For the research of occupational accidents onboard, various information sources are available. Information is produced internally in shipping companies, but, depending on the severity of the accident, also by outside stakeholders, such as flag state administrations, insurers, rescue agencies and medical authorities. In tanker business, the level of safety and reporting is usually at a higher level than in many other fields of shipping due to the very active role of the clients, i.e. the oil companies. Typically, the availability of official data correlates with the severity of the accident. For instance, long historical data is available on fatalities and analyses of their causes have been carried out.

DEFINITIONS

In shipping, many definitions exist related to occupational injuries and accidents as the standardisation has been difficult in the complex maritime community. Usually, the definition of an accident is related to the severity its consequences. For example, Nielsen and Panayides (2005, p. 155) define the term "occupational accident" as "work related accident occurring at the place of work, suffered by a seafarer which results in death or personal injury." Similarly, the oil industry (Oil companies international marine forum OCIMF 1997, International Association of Oil & Gas Producers OGP 2011) defines fatalities, accidents that produce disabilities and cases where workdays are lost due to incidents as Lost Time Injuries (LTI). Other broader definitions, TRC (Total Recordable Case, OCIMF 1997) or TRI (Total Recordable Injury, OGP 2011), are also used in oil transport. They include the LTIs, but also a number of smaller injuries and other medical cases. Naturally, all serious stakeholders in marine transport have definitions for work-related accidents, but unfortunately they are not standardised. Another example of the definitions can be taken from Denmark, where four types of definitions are used in relation to occupational accidents and injuries (Danish Maritime Authority 2009):

1. Work related accident (occupational accident): “Incident in which a crew member on a ship has died or been injured, either in relation to a marine accident, in relation to the work on board or in relation to other activities, in spare time, etc.”
2. Serious work related accident: “Accident that has resulted in injuries in the form of fractured bones, compound fracture or loss of limb (amputation).”
3. Reportable work related accident: “Accident that has caused disablement for a day or more, not including the day of injury.”
4. In Denmark, the occupational injuries are reported to National Board of Industrial Injuries (DMA 2009) and a “work related injury” is defined there as “an illness developed from prolonged influence of the work or from the conditions under which the work has taken place.”

As can be seen from above, the three sets of definitions are close to each other – not exactly, but probably close enough for initial comparisons. The term “casualty” is used (e.g. Nielsen and Panayides 2005, p. 148) most often to refer to collectively to the accidental death or injury. In contrast, the term “fatality” relates directly to death.

Not all people onboard are necessarily employed there, and thus a definition of a “seafarer” is useful. Nielsen and Panayides (2005, p. 155) define the term as “an individual who is gainfully employed on board a vessel as a member of the ship’s crew and is involved in carrying out the duties that relate to such employment. Not included are people who are e.g. travelling to and from the ship, on shore leave or on sick leave.” Alternatively, the separation can be obtained by defining the people who are not working as passengers, as by the definition of Danish Maritime Administration (2009): “person on board a ship, who has no work function on the ship”.

For defining comparative statistics of occupational safety onboard, a measure for the time at risk for the personnel is needed. Typically, these measures are related to man-years onboard (e.g. Roberts and Williams 2007 p. 39), hours of presence onboard (e.g. OCIMF 1997), performed working hours onboard (e.g. Danish Maritime Administration 2009, p. 15) per ship per year (Nielsen 2002) or number of active seafarers in occupation (Swedish Transport Agency 2010 p. 10). The metrics are further discussed in Chapter 3.

FATALITIES

Work onboard is more hazardous than onshore. Factors such as fatigue, unusual work positions, low illumination, low friction and motions of the workplace can increase the risk. Despite the mandatory identification of hazards and avoidance of risks, fatal accidents do occur. The cases are usually thoroughly investigated, which helps the subsequent analyses for improvements.

Fatalities onboard have been studied in several sets of statistics. Nielsen (2002) refers to occupational accidents as the cause of 10–16 % of all deaths onboard, the other cause categories being maritime casualties, accidents, illnesses, individual persons missing at sea, homicides, suicides, off-duty deaths and unclear causes. Nielsen estimates that in all 2500 deaths occur at sea in the world yearly. Jaremin (2005) reports casualties onboard Polish vessels per 1000 employees per year during 1960–1999. For merchant shipping, the rate is 0,85 for external causes, which includes also drowning, suicides, homicide and unknown causes, such as missing. The time at risk was calculated from the mean number of people employed on board vessels per year. Regarding the acceptable levels, Jaremin refers to 1 death per 1000 employees per year (i.e. 100 per 100,000) as an intolerable level, which requires preventive intervention. From the data provided, it is also possible to calculate the rate for other accidents, which becomes 16 per 100,000 employees per year.

Roberts (2008) reported of fatal maritime accidents of almost a century for the British merchant shipping, and the conclusion was that the fatality rate per seafarer-years has gone down considerably, similarly to land-based occupations. The least improvement was found for deck occupations. Fatalities in shipping disasters, as sinking, have been reduced, as have off-duty fatalities, drowning in docks and deaths in cargo handling (e.g. Bloor 2008). Roberts (2008, p.129) refers to the fatalities of the UK reports from the end of the 19th century and to, from the modern point of view, an outrageous fatality rate of over 1000 deaths per year and 100,000 seafarers in the occupation. When compared with shore-based workers, this was 10 times the rate of railway workers and about 150 times the rate of factory and shop operatives at the time. Although the mortality rates have decreased in recent decades so that current rate is typically 10 to 100 fatalities per 100,000 seafarer-years, the relative difference to other occupations remains. In recent years, the occupational mortality rate for seafarers was from 11 (Denmark) to 12 (UK) times higher than for the general workforce (Nielsen 2002, Roberts 2008 p. 135, Roberts and Williams 2007, p. 8 and Hansen et al. 2002, p. 85). Roberts and Williams (2007) also compared the numbers with other industries, and the fatality rate of shipping was about 3 times higher than in the construction industry and about 9 times higher than in manufacturing.

Roberts and Williams (2007) have compiled an extensive summary of fatalities at sea, in which comparisons were presented for 18 different flag states, some with several sets of data. Typical values for the most recent statistical data range from 10 to 100 fatalities per 100,000 seafarer-years. In a previous work, Roberts and Marlow (2005) studied all traumatic work related deaths among seafarers who were employed in British merchant shipping from 1976 to 2002. They found that of 835 traumatic work related deaths, 530 (63 %) were caused by accidents at the workplace (including maritime disasters), i.e. 46.6 fatalities per 100 000 seafarer-years. The other causes of traumatic deaths were reported as suicide (7%), homicide (2%) and drug or alcohol poisoning (2%). In addition, there were a large set of fatalities (22%), where the circumstances were unclear, including 178 seafarers (21% of the total number of fatalities) who disappeared at sea or were found drowned.

Roberts and Williams (2007) published a table of information on the mortality rates of seafarers, obtained from several sources. They found that comparison between different studies is often affected by differences in criteria, such as the definition of a fatal accident and the metric for the amount of time for seafarers at risk. Similar effects can be found in other publications, but general trends can be discerned. In an earlier, similar study Nielsen (1999) found that occupational accidents are the third biggest cause of deaths after disasters and illness. Also Nielsen and Panayides (2005, p. 157) published comparisons between studies. In the reports, the number of fatalities in maritime accidents compared with fatalities due to occupational accidents varies greatly, relative to flag and ship type. From the data published in Danish analyses (Danish Maritime Administration 2007, Danish Maritime Administration 2009) on fatalities, occupational accidents and accident rates, fatality rates were calculated and added to the table of Roberts and Williams (Table 1) for the purposes of this study.

From the studies, it can be seen that the fatalities are relatively rare for many flag states. Unfortunately, the published statistics are not thoroughly compatible with each other. Therefore, it seems that for shipowners analysis and dissemination of case histories is the easiest method of learning lessons from the fatalities.

TABLE 1. *The fatality rates of seafarers due to occupational accidents (adapted from Roberts and Williams 2007, references relate to their publication).*

Fatal accident rate per 100,000 seafarer- years			
Country	**Period covered**	**Fatal accident rate**	**Reference**
Australia	1990 - 1994	**10**	Survey by Nielsen, D. and Roberts, S., 1998
Belgium	1996 - 2005	**63**	Survey by Nielsen, D. and Roberts, S., 1998
Canada	1996 - 2005	**22**	Roberts and Williams, 2007
Denmark	1998 - 2008	**56**	Current study
Denmark	1996 - 2005	**90**	Roberts and Williams, 2007
Denmark	1986 - 1993	**62**	Hansen, H.L., 1996
France	1990 - 2004	**20**	Survey by Nielsen, D. and Roberts, S., 1998
Germany	1990 - 1994	**39**	Survey by Nielsen, D. and Roberts, S., 1998
Greece	1990 - 1994	**162**	Survey by Nielsen, D. and Roberts, S., 1998
Hong Kong	1990 - 1995	**253**	Registry of Shipping and Seamen (Roberts and Williams, 2007)
Hong Kong	2000 - 2005	**56**	Roberts and Williams, 2007
Hong Kong	1980 - 1989	**48**	Registry of Shipping and Seamen (Roberts and Williams, 2007)
India	1990 - 1996	**426**	Barnes, B.L., 1997
India	1996 - 2005	**18**	Roberts and Williams, 2007
Isle of Man	1988 - 2005	**44**	Registry of Shipping and Seamen (Roberts and Williams, 2007) and MAIB data
Japan	1990 - 1994	**58**	Survey by Nielsen, D. and Roberts, S., 1998
Netherlands	1990 - 1994	**39**	Survey by Nielsen, D. and Roberts, S., 1998
Norway	1990 - 1994	**102**	Survey by Nielsen, D. and Roberts, S., 1998
Poland	1985 - 1994	**100**	Jaremin, B. et al., 1996
Poland	1996 - 2005	**84**	Roberts and Williams, 2007
Poland	1960 - 1999	**72**	Jaremin, B., 2005
Poland (2 main companies)	1990 - 1995	**80**	Tomaszunas, S., Weclawik, Z., 1997
Singapore	1984 - 1989	**162**	Registry of Shipping and Seamen (Roberts and Williams, 2007)
Singapore	1990 - 1995	**99**	Registry of Shipping and Seamen (Roberts and Williams, 2007)
Spain	1990 - 1994	**16**	Survey by Nielsen, D. and Roberts, S., 1998
Sweden	1984 - 1988	**37**	Larsson, T.J., Lindquist, C., 1992
Sweden	1996 - 2005	**13**	Roberts and Williams, 2007
Sweden	1990 - 1994	**10**	Survey by Nielsen, D. and Roberts, S., 1998
UK	1976 - 1985	**53**	Roberts, S.E., Marlow, P.B., 2005
UK	1986 - 1995	**39**	Roberts, S.E., Hansen, H.L., 2002
UK	1996 - 2005	**11**	Registry of Shipping and Seamen (Roberts and Williams, 2007) and MAIB data
UK seafarers in non-UK fleets	1986 - 1995	**66**	Roberts, S., 2000
West Germany	1960 - 1972	**148**	Goethe, H., Vuksanovic, P., 1975
West Germany	1974 - 1976	**92**	Vrcelj, 1981

INJURY IN OCCUPATIONAL ACCIDENTS

Naturally, many more accidents lead to injury than to fatalities. Consequently, more cases are available for the researcher, but on the other hand, often with less detailed reporting. Based on accident data analysis, (Bailey et al 2010) list some common injury types for seafarers:

- strain, sprain or twist
- striking injury
- break or fracture
- bruising
- cut or piercing injury
- crush or trap injury
- a foreign object in the eye or body.

Further, in their study on seafarer hospitalisations, Hansen et al. (2005) found that ratings and officers of small ships were particularly at risk for injury. Hansen et al. (2002) also studied the occupational accidents of crews aboard Danish merchant ships in the period of 1993–1997. The data was obtained from the Danish Maritime Authority and insurance companies, and exact data regarding the time at risk was available. They found a total of 1993 accidents during 31,140 years at sea, and concluded that the risk of having an occupational accident was 6.4 per 100 years at sea, and the risk of an accident causing a permanent disability of 5% or more was 0.67 per 100 years aboard. The time at risk was calculated from the information of the maritime authorities as days spent onboard for each individual. The first and last day of employment were calculated as full days.

Jensen et al. (2004, p. 548) found with a questionnaire study in 11 countries with over 6,000 participants that during the latest tour of duty, 9% of all seafarers were injured and 4% had an injury with at least 1 day of incapacity. They also studied incidence ratios relative to working hours, non-officers compared with officers, the age of seafarers, tour lengths and the main work area. They found no evidence that long working hours alone resulted in higher injury rates. Further, issues such as low self-perceived health, lack of use of personal protection and lack of occupational safety on board were found to correlate significantly with an increased risk of injury.

Related information about injuries has been obtained from the medical emergency contacts of ships to physicians ashore. It was found that violence related to 5% of the injuries, falls and slips to 44%. In 58% of the cases, the seafarer was off work for at least one day or more. They also inquired the number of working days per week and working hours of the respondents and derived the injury incidence rates for cargo ships and tankers as 39.5 per 1 million work hours and 37.6 per 100,000 days. McKay (2007) found that 84% of the cases were medical, 14% were injuries and 2% were purely psychiatric, and that the cases of injury or acute psychiatric problems required more physician interaction and medication than the medical cases. Similarly, in Nielsen's and Panayides's (2005) survey and statistical study of casualties reported to Hong Kong and Singapore, occupational accidents account for a significant proportion of fatalities at sea.

The accident statistics and incident reporting has provided knowledge on the factors that are linked with accidents, such as work tasks, nationality, vessel types and the age of mariners, which are discussed in the following.

MOST HAZARDOUS WORK TASKS

From several studies, it can be summarised that moving around in the ship is causing many injuries. E.g. Jensen et al. (2005) studied slip, trip and fall (STF) injuries by a questionnaire study for seafarers. Of the total reported injuries 43% were found to be due to slips, trips and falls. They found that relative number of STF injuries increased when compared with worker's age; the proportion was higher for more severe injuries. In the data of Bailey et al (2010), the amount of STF injuries was 55.2% (slips, trips and falling from both the same level and from height) based on the data from flag administrations and 36.2% in the data set that was available from two unnamed tanker shipping companies. These are listed below with some other important causes of injury onboard:

- slips, trips or falls on the same level
- falls from a height
- hit by moving (includes flying / falling) object
- handling, lifting or carrying
- drowning / lack of oxygen / overcome by fumes
- exposure to, or contact with, a harmful substance
- struck against something fixed or stationary.

In a Norwegian survey of 2000–2010 (NMA 2011, p. 9) impact and crush occurrences and falls on board were found to be the most frequent types of accidents.

Determining which work tasks are hazardous is also an interesting matter. Bailey et al. (2010) have collected causes and circumstances from maritime administrations and from the industry, and separate between "work tasks" and "overall actions", which is one possibility of categorisation. For example, engine maintenance is one task and rough weather is an overall action. From this data, it can be concluded that most hazardous work tasks, based mostly on data from administration, were related to:

- mooring operations
- engine maintenance at sea
- manual handling of heavy or unwieldy items
- working at height
- entry into enclosed space
- working near open hatches or tanks
- crane operations
- use of ladders or gangways
- working over the side.

When considering the above information, it should be taken into account that the severity of accidents and their commonness do not necessarily correlate with each other. Also inaccurate reporting (typically under reporting, i.e. not reporting all accidents) (Bhattacharya 2009) makes interpretating the results more vague. However, for practical improvement purposes on a general level, we do have enough information. For a single shipping company, however, further detailed benchmarking data would be beneficial.

In their precise treatise on vessels with the Danish flag, Hansen et al. (2002) conclude that "working on deck made up almost half of all notified accidents, half of the accidents causing permanent disability, and half of the fatal accidents", and refer to especially mooring operations, cargo handling, lashing work and operating hatches. They also note that moving around onboard caused about 10% of the notified accidents, but more than one fifth of the serious accidents that caused permanent disability. They report that about half of the moving-related accidents occurred on ladders and stairs. They also compiled a table of occupational accidents on Danish-flagged vessels, which offers a view that the riskiest occupations for serious accidents on board are engineering officers and deck ratings. The least risky occupations in this respect were found to be in the galley and in catering. If all accidents are studied, the distribution is different, the catering work having the second highest accident rate after ships' engineers.

The situation may be different for passenger vessels. Dahl et al (2008) have studied injuries aboard a cruise vessel. During 3 years, 361 injuries (23% women) were reported aboard. Of these, thirty resulted in an absence of one day or more. The hotel crew had a higher rate of LTI occurring during work than marine crew. The most frequently injured body part was the upper limb (51%) and open wounds was the most common injury type (37%). Food preparation was obviously dangerous, as the most common accident location (30%) was found to be the galley.

It should be noted that differences between the reported causes of accidents exist between researchers, and it is unknown whether this is related to the ship types, the reporting practices of the ships, definitions used in reporting or analysis methods.

NATIONALITY AND AGE

Hansen et al. (2008) have confirmed that the differences between the nationalities of merchant seafarers can be considerable, and that mariners from South East Asia have significantly lower accident rates compared with the seafarers from Western Europe. Their analysis is based on several types of information, originating from Danish merchant ships during one year. They used quantitative and qualitative information on occupational accidents as reported to the maritime authorities, accidents as reported to a mutual insurance company, the data of medical costs reimbursed by the government and information of radio medical service of accidents. Time at risk aboard was obtained from a register on all employment periods aboard merchant ships, and they ound the average rate was 84 accidents per 1,000 years aboard. They used the data to compare the relative number of accidents between nationalities. Their result was that accident rate of East European seafarers was 88% and of South East Asians 22–38% of the incidence rate of the West European seafarers. They used ship size (below 3,000 GT, and 3,000 GT and above), rank (officer or not) and age as additional variables. In an analysis including only serious accidents, the accident rate for South East Asians was found to be 26–48% of the Western European seafarers. Similarly, Filipino crews on board a cruise vessel reported less injuries per capita that the rest of the multinational crew (Dahl et al. 2008).

Similarly, Hansen et al. (2002) studied occupational accidents among crew aboard Danish merchant ships based on data from insurance and Danish Maritime Authority. They found that citizens of other nations had a considerably lower recorded rate of accidents than the Danes onboard. Movement of people aboard the ship was found to be a significant contributor in many serious accidents, of which the most serious happened on deck. Similarly, in a recent study, the fatality rates among British subjects were found to be higher than for other nationalities (Roberts 2008).

Also the age of mariners in relation to occupational accidents has been investigated. In their study on Danish merchant shipping, Hansen et al. (2002) found that the age of over 45 years was a risk factor for permanent disability after accidents. They also attributed an increased risk of accidents to new surroundings, such as the change of ship and the first period aboard a particular ship. A major factor for serious accidents was found to be simply walking aboard. The most serious accidents happened on deck.

OTHER FACTORS RELATED TO RISK OF INJURY

Training, manning levels and discipline affect occupational accidents. Roberts and Marlow (2006) compared governmental Royal Fleet Auxiliary shipping with merchant shipping, and concluded that the lower work related fatalities rates of RFA shipping may reflect a lower incidence of hazardous working practices, arising from better training as well as better maintained ships with higher manning levels than in merchant shipping. Also the vessel type has been found to have an effect. E.g. in an analysis of 18 incident datasets, Bailey et. al. (2010) found that for maritime incidents there are clear differences between types of vessels, but that the seafarers' opinions did not reflect these. Further, familiarity with the ship seems to reduce the risk (Hansen et al. 2002), which also seems to decrease during the employment period.

MARINERS' PERCEPTION OF THE RISKS

Bailey et al. (2010) have compared the perception of risk of seafarers with maritime and personnel injury incidents through a questionnaire survey of 2,372 individuals from 50 different countries and incident statistics of from 16 maritime administrations and two shipping companies. They found that the personal injury perceptions of the seafarers of higher rank and managers tended to agree most closely with rankings based on recorded data; they also found that the perceptions of those in the deck department were the closest and those in the engine department the furthest from the rankings based on recorded data. In the issue of the background factor for an injury, seafarers' perceptions on 'working having consumed alcohol and/or drugs' was ranked the most likely, but this factor appeared less important in the datasets. On the other hand, the risks of injury during deck operations, such as mooring, were comparatively estimated too small by the respondents. Overall, the respondents perceived 'working in a hot environment' to be the most likely cause of injury, but in fact 'slips, trips and falls' was the most frequent cause in the incident databases.

PROBLEMS WITH STATISTICS AND REPORTING

Nielsen (2001, 2002) refers to problems in obtaining reliable statistics on maritime occupational accidents. He advocates a "fundamental change in attitude towards the collection of statistics needed" and that "regulators should target the prevention of other causes of death instead of solely focussing on maritime casualties". It seems that many of the flag states do not produce relevant statistics, and that there exists significant under-reporting in the available statistics of occupational accidents at sea. Further, Nielsen and Panayides (2005) refer to their worldwide survey and the difficulties of obtaining compatible data from several flag administrations. In an analysis of incident data obtained from 16 maritime administrations and two shipping companies, Bailey et al (2010 p.(i)) found that only six of the administration datasets were suitable for mutual comparison.

Another type of problem is the large variations in reporting onboard the ships. Oltedal and McArthur (2010) strived to identify the factors determining the reporting frequency of incidents and accidents in Norwegian controlled merchant ships by surveys on 76 vessels. They found that enhanced safety related training, a trusting and open relationship among the crew, safety oriented ship management, pro-active risk identification activities and feedback on reported events were all significant for higher reporting frequency. In contrast, demand for efficiency and lack of attention to safety from shore personnel indicated lower reporting frequency. Not unexpected, they found that bulk and dry cargo vessels to have significantly lower reporting frequency than liquid bulk carriers. It has also been found that incomplete and even falsified working hours documentation due to excessive workload is possible (Ellis 2005, p. 105).

Ellis (2007) also comments on the collection of data on all accidents and incidents in maritime business that the sources "are generally found to be localised, poor in coverage, and/or to contain only very basic data". His data originated from a number of sources, such as maritime administrations, P&I insurance clubs and shipping companies. He made recommendations on the data to be recorded as well as its classification. Systematic bias in mariners' reporting of injuries to maritime administrations around the world is not impossible, the possible reasons relating to issues such as employment continuation and social pressure onboard (e.g. Ellis et al. 2009).

The multiple possibilities of definition, comparing the number of accidents and determining the time at risk, and the lack of established international maritime reporting practices has lead to a situation where comparisons between flags are difficult. An example is discussed below.

PUBLIC REPORTS OF OCCUPATIONAL ACCIDENTS IN NORDIC COUNTRIES

An example of several possible types of reporting can be found in the Nordic countries. In Denmark and Norway, the material at hand is published by the Maritime Authority (Danish Maritime Authority 2009, Norwegian Maritime Directorate 2011), in Sweden by the Maritime Department of the Transport Agency (2010), and in Finland by the Occupational Safety and Health Administration (2010). Examples of the published data can be seen in four figures on the following pages.

The Danish report is based on the data that the Maritime Authority has of officially reportable accidents and the number of seafarers onboard ships, which seems to provide a reliable input source. Decrease in the rate of accidents per million seafarer hours is obvious.

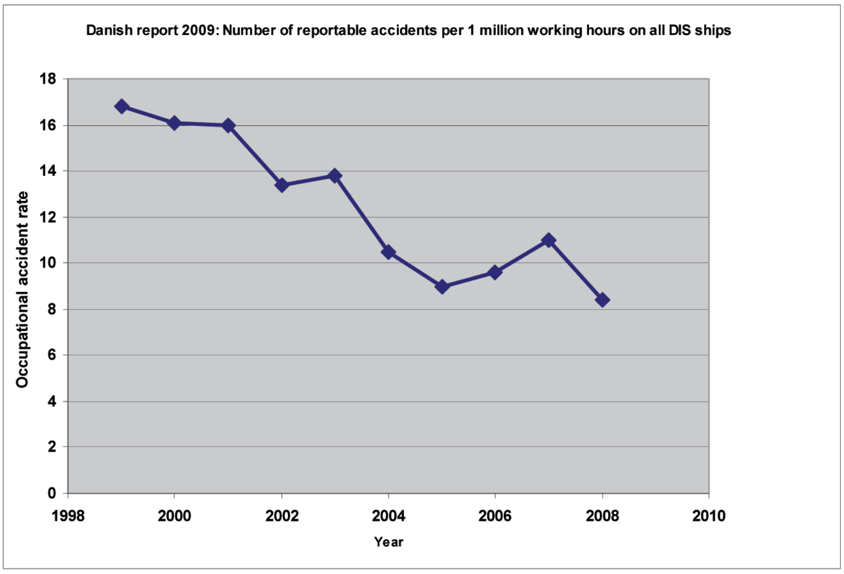

FIGURE 1. *An example of the Danish statistics reporting, 2009: The number of reportable accidents per one million working hours on all ships of the Danish International Ship Register.*

A principally similar graph was obtained from Finnish Occupational Safety and Health Administration (2009) based on information of health insurance claims and working hours reported to the insurance companies. The hours are working hours onboard based on salaried hours, but they also include the hours of the office workers. It can be seen that the rate is much higher than in Denmark – one reason could be different definitions of working hours.

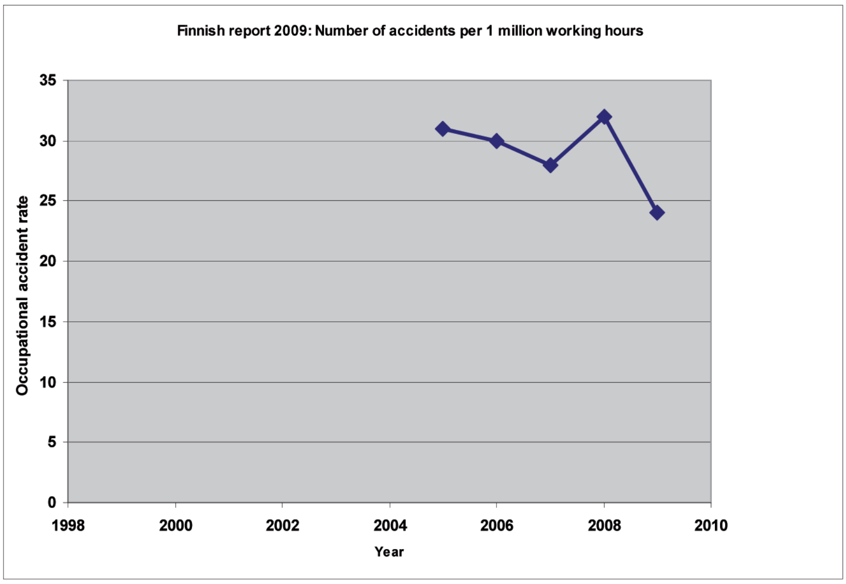

FIGURE 2. *An example of the Finnish statistics reporting, 2009: The number of accidents per one million working hours from Finnish Occupational Safety and Health Administration.*

Remarkably steady positive development in occupational accidents is visible in the Norwegian Maritime Directorate (2011, currently Norwegian Maritime Authority) statistics. Unfortunately, the changes in numbers of people onboard are not given. However, the yearly number of ships is given, and changes are not very large, so the graph is useful. For comparison with other countries, further information of the number of seafarers would be valuable.

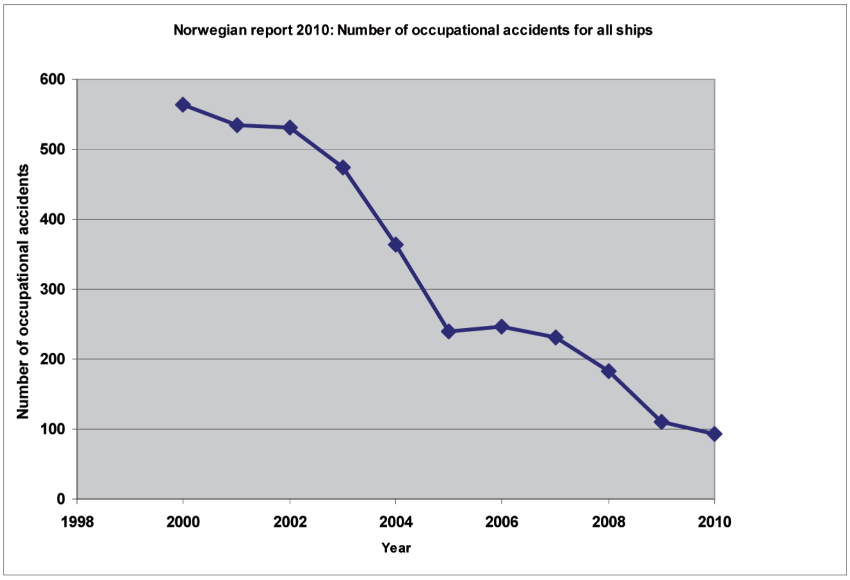

FIGURE 3. *An example of the Norwegian reporting of occupational accidents, 2011, no normalisation.*

In the Swedish reporting, the frequency of injuries is calculated per 100 active seafarers, i.e. a person "who has worked in that capacity for at least three of the preceding 18 consecutive months". (Swedish Transport Agency 2010, p.6). Naturally, this means that the numerical value of the accident rate so derived is not directly comparable with the data of the neighbouring countries.

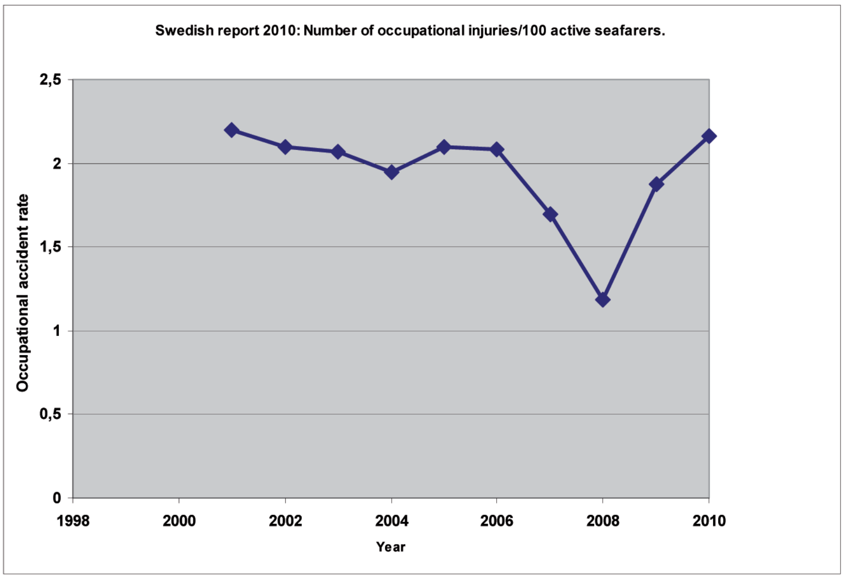

FIGURE 4. *An example of Swedish reporting, 2010: The number of occupational injuries per 100 active seafarers.*

In order to view the development of accidents in these four countries during recent years, all data was normalised by choosing the first data point for each country of 2004 or 2005 to be 100%, respectively, and then calculating the relative change of each. For the Norwegian data, the numbers of occupational accidents were divided with the yearly number of ships. The data for the other countries was used as it was presented in the source reports. From Figure 5, it can be seen that the development since 2004 has been brisk in Norway, and that results from the other countries fluctuate more. However, this may be misleading regarding the actual risk of the seafarers, as it is not possible to read the true accident rates of each country, since the published statistics are not compatible with each other. However, by studying the sources closer and maybe obtaining more data on manning, and accident definitions, a direct comparison could be possible. This is an interesting development target although it is known that obtaining such data from each country may be demanding due to organizational and legislative reasons.

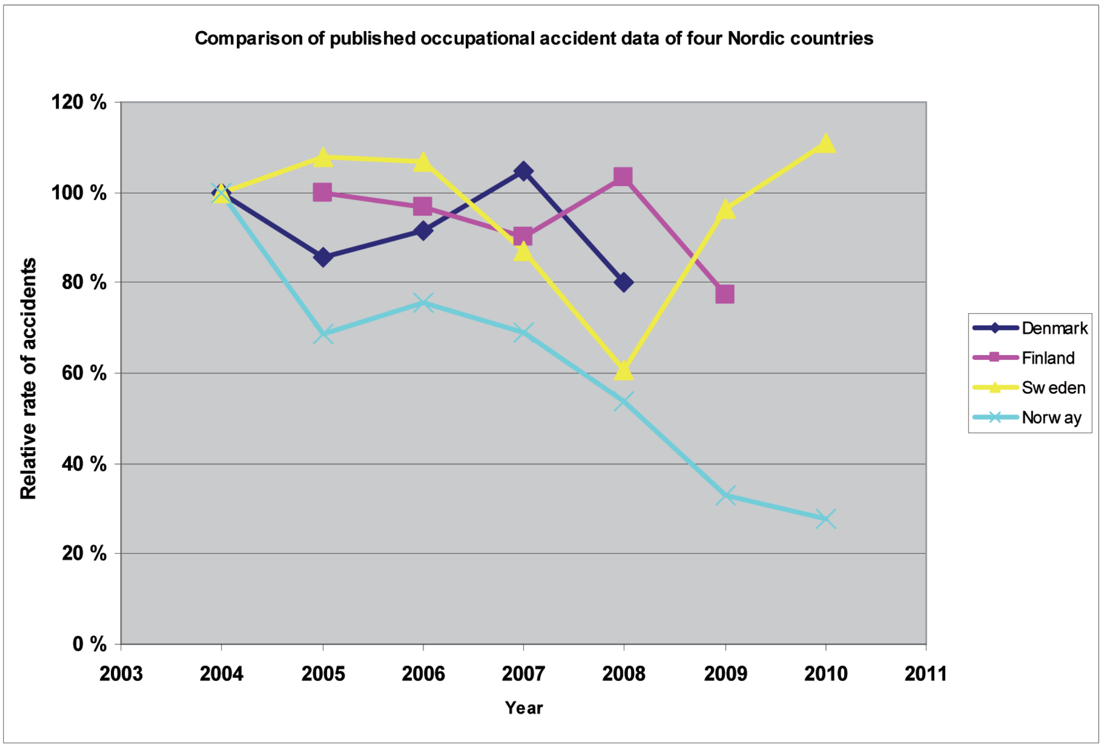

FIGURE 5. *Comparison of published occupational accident data of four Nordic countries.*

3 METRICS OF MARITIME OCCUPATIONAL SAFETY

For the benchmarking of occupational safety, reliable metrics are needed internationally, nationally and in shipping companies. As shown in the preceding example of the Nordic reporting, exactly comparable data may be difficult to find, but suitable normalisation would be important for meaningful comparisons. The currently available sources and methods of analysis are discussed below.

SOURCES OF DATA

There is lack of comprehensive worldwide statistics of loss of life at sea (Nielsen and Panayides 2005 p. 149) and even less is available occupational injuries (Bailey et al. 2010). The statistical data of the International Labor Organization on occupational accidents (2012) or the EU Eurostat (2012), for example, are rather general, and thus less suitable for detailed analyses of shipping. The recent development of the European Maritime Safety Agency's European Marine Casualty Information Platform (EMCIP) is an interesting possibility for the future (2012). Nationally, however, more detailed metrics are available. The source types of data vary, but the most common are based on accidents that are reported to authorities or insurance companies (e.g. Hansen et al. 2002). Also the information obtained from the medical emergency contacts of ships to physicians ashore has been used (e.g. McKay 2007, Hansen et al. 2008). Financial records, such as the medical cost reimbursement records of governments or insurance companies can generate useful information (Hansen et al. 2008).

Naturally, questionnaires have been used as data sources on accidents. Jensen et al. (2002) described seafarers' working and living conditions based on short questionnaires on medical clinics in connection with their mandatory health checks. The oil and gas industry has been collecting accident data (e.g. Hudson 2001), and a similar system is endorsed for the marine transport by the Oil Companies International Marine Forum (1999), which also collects statistics for their members. The International Marine Contractors Association (IMCA) of offshore related companies collects fatalities and injuries statistics from its members. Delivery of data is voluntary. In 2009, for example, about 20% of the companies submitted information to statistics (Offshore Shipping Online 2011).

NORMALISATION

In addition to physical and organizational risk factors, the number of accidents onboard is related to the number of the seafarers and their time at risk. These have been used to enable comparisons between differently sized seafarer populations. The normalisation is usually carried out by dividing the number of occurrences with a measure that is related to the time at risk for the population at hand to obtain a "frequency" or "rate" for the occurrences. For example, the Lost Time Injuries and Total Recordable Cases (see p. 9) can be normalised by dividing the numbers with the time at risk of the personnel, typically per million work hours (OCIMF 1997) to form Lost Time Injury Frequency (LTIF) and Total Recordable Case Frequency (TRCF).

For all branches of shipping, the time at risk may not be similarly available for occupational safety statistics, and number of active seafarers in industry (e.g. Swedish Transport Agency 2010), number of ships, number of ship-years (e.g. Nielsen 1999 p.128, Roberts and Williams 2007, p. 37) or number of worker years (e.g. Roberts and Williams 2007, p. 28) have been used. The choice of factors used for normalisation seems to depend mostly on the availability of data, but also on the ease of processing. Ellis et al. (2011, p. 47) criticise the selection of use of time onboard as a metric in normalisation due to difficulties in obtaining reliable data from some maritime administrations, and propose the use of rates by vessel numbers and rates by gross tonnage, which are easier to obtain from public sources. Below, some examples of normalisation possibilities are given.

Roberts and Williams (2007) present fatalities as a rate per 100,000 seafarer years, using the number of people employed yearly by the industry as reference. If the number of crew is not known, the statistics can be calculated per ship-years. For example, the fatal accident rates can be given per 1,000 ship-years at risk (e.g. Roberts and Williams 2007, p. 37). In a related field, Petursdottir (2007) uses both 10,000 man-years as well as 10,000 fishermen for normalisation of the number of fatalities onboard Icelandic fishing vessels. For fatalities, Standard Mortality Ratio can be used to compare fatalities among populations. For example, Moen et al. (1994) used the ratio between observed and expected deaths between seafarers and the whole male population of the country in question.

Similar principles can be used for normalising occupational injuries as are used for fatalities. Danish Maritime Authority is using for normalisation both 1,000 seafarers per year (2009 p. 4, 2011 p. 18) and million exposure hours (2009 p. 16), but also 10,000 working days (2009 p. 18), depending on the factor to be normalised. By assuming a value for the length of the workday aboard, e.g. ten hours, conversions between the rates can be done. A common alternative for the number the work hours per day is 24 hours, which is also easy to calculate when manning and yearly days in operation for a ship are known. Similarly, Törner and Nordling (1999) have reported accidents per 1,000 fishermen based on Swedish insurance data.

Sometimes the relative performance of populations can be compared against each other, as in Figure 5. For example, Hansen et al (2008) used a crude incidence rate ratio (IRR) where the accident rate for one population is used as a reference. Similarly, Hansen et al. (2005) have studied hospitalisations among seafarers relative to all employees nationally. They calculated standardised hospitalisation ratios (SHR) by dividing the observed number of hospitalisations in seafarers by the expected number of hospitalisations for all employed men.

The order of magnitude of LTIF for oil and gas industry is around 0.5 per million work hours. (OGP 2011, Conoco Phillips 2010). The fatal accident rate is around 3 per 100 million working hours, which represents a LTI / fatality ratio of 17:1 (OGP 2011). For shipping of oil, the typical LTI rates are around one per million exposure hours. E.g. tankers and supply vessels of A.P. Moller-Maersk Group (2011), respectively, have had approximately this rate. The standard achieved in maritime oil transport can be used as an attainable target for other forms of shipping. Consequently, the system of maritime oil transport, where the normalisation is based 24 hours of exposure per day and the rates are calculated per million exposure hours, seems to be the easiest suitable solution for shipping companies and flag states, which can obtain this data relatively easily. Therefore, the explication of existing data from published shipping industry sources in a compatible form can be seen as a useful research topic for the future.

MODELLING OF OCCUPATIONAL SAFETY AND MARITIME SAFETY

The modelling of occupational and maritime safety is not straightforward, as safety is a product of random, technical, human and organizational factors. For risk analysis, multiple methods of risk identification and assessment are available, but producing simple evidence for decision-makers is not easy. E.g. Hansson (2003) has described a risk model for supply ship loading and unloading operations based on the modelling of incidents in the company reporting system by an influence diagram. This kind of modelling helps in identifying risks as well as in preparation and education. However, for predicting the status of occupational safety onboard and for providing input for maritime safety models, further detailing is needed.

Attwood et al. (2006a, 2006b, 2006c, Attwood 2009) have built a quantitative model for predicting occupational accident frequency and the associated costs in the offshore business based on quantitative data and models from literature. They viewed existing models based on holistic approaches, occupational accident data and its analyses, and the modelling of human factors and safety culture. The results look promising. Their model was applied to real projects, and calibrated and validated with published accident data. The model consists of three layers for factors affecting safety that categorise the input to the model: external, corporate support and direct. Similar categorisation could be used for Bayesian models of maritime safety. Eventually, the input could be simplified to a few factors that measure the company performance in occupational safety, such as the company LTIF. Further research on the matter is recommended, for example by comparing occupational and marine safety performance in oil transport with the same factors in the comparable traffic of other commodities.

4 CONCLUSION

The work at sea subjects seafarers to an increased risk of occupational accidents. Typically, the risks of accidental injury and death are in the order of ten times higher than for comparative population on land. Various data sources are available; many shipping companies already publish this information, but depending on the severity of the accident also outside stakeholders, such as flag state administrations, insurers, rescue agencies and medical authorities, gather information. The typical accident modes are slips, trips and falls while moving around in the ship, accounting for about half of the accidents. In general, the most dangerous types of operation are mooring operations, engine maintenance at sea, handling of heavy or unwieldy items, working at height, and entry into enclosed spaces. There are differences between nationalities; typically mariners from South East Asia have significantly lower accident rates compared with seafarers from Western Europe.

There are significant problems in collecting comparable data worldwide as the sources are very variable or nonexistent. Nationally or between shipping companies this is easier, and especially the oil industry is demanding relevant data from their transports. For demonstrating the challenges of comparisons, the published data of four Nordic countries was reviewed. It was found that more information would be needed for in-depth analysis. However, when all data was simply charted by calculating the relative change of each flag state, some conclusions were possible. Further inquiries are to be carried out in the future work tasks of the project.

In addition to statistics of numbers of accidents, the amount of exposure at risk for the populations of subjects is needed for normalisation, which enables meaningful comparisons between all branches of shipping. The time at risk may not be as readily available for occupational safety statistics as for example the number of active seafarers in industry, the number of ships, the number of ship-years or the number of worker years. However, the system of maritime oil transport, where the normalisation is based on 24 hours of exposure per day and rates are calculated per million exposure hours, seems to be a suitable solution for shipping companies and flag states, which can obtain this data relatively easily. Also, conversion to other formats, such as the rate per 100,000 seafarer-years, is easy. Consequently, the explication of existing data from published shipping industry sources is also a useful research topic for further studies.

Combining occupational and maritime safety for modelling purposes is not straightforward, beacause safety is a product of random, technical, human and organisational factors. Eventually, the occupational safety information could be simplified to a few factors that measure the company performance, such as the company LTIF, and used as additional input to maritime safety models.

Further research on the matter is recommended, such as 1) studying occupational and marine safety performance in oil transport with the same factors as in the comparable traffic of other commodities, 2) comparing the situations of the flag states which publish occupational safety data regularly and 3) studying organizations that are co-operating in the field.

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ABBREVIATIONS

DMA	Danish Maritime Authority
LTI	Lost Time Injury (or Incident)
LTIF	Lost Time Injury Frequency
NMA	Norwegian Maritime Authority
OCIMF	Oil Companies International Marine Forum
OGP	International Association of Oil & Gas Producers
OSHA	Occupational Safety and Health Administration
STA	Swedish Transport Agency
TRC	Total Recordable Case
TRCF	Total Recordable Case Frequency
TRI	Total Recordable Injury