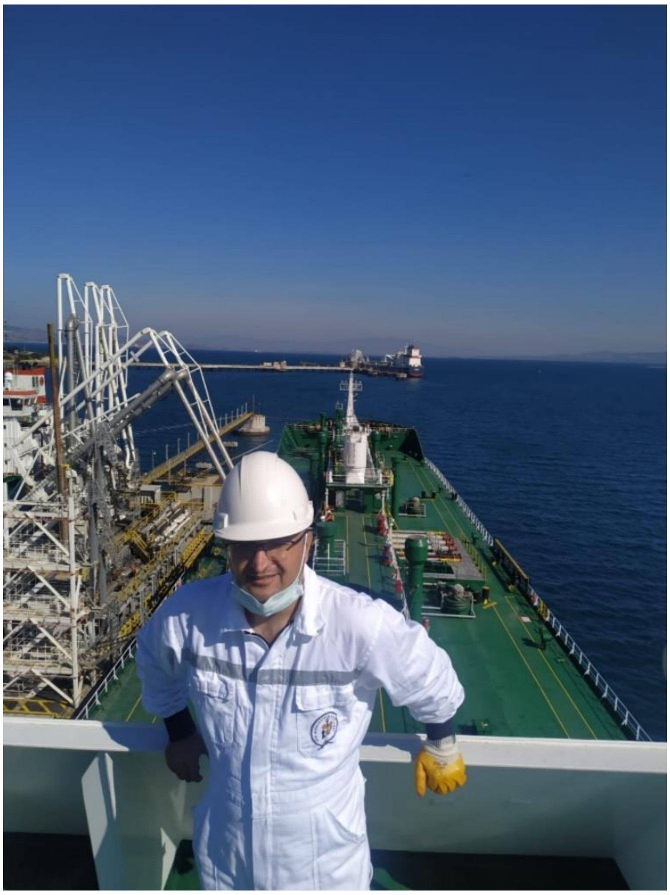
Safety Challenges at Sea: Data and Evidence



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Safety Challenges at Sea: Data and Evidence

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Authors: O. Turan, R. E. Kurt, C. Ramirez Marengo, B. Navas de Maya, O. Okunribido

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CONTENTS

ABSTRACT

This study critically evaluates the maritime occupational injuries and fatalities in international merchant shipping over the last 20 years by reviewing the reported studies and publications; available major data sources and taxonomies around the world; and the most common causes of occupational injuries and fatalities. Having reviewed the publicly available literature around the world, this study adopted a structured approach to seeking more insight into the causes of occupational accidents on board merchant ships over 500 gross tonnage (GT) trading internationally.

The study identified the major data sources with regards to occupational accidents, evaluated the quality of the data, and utilised the data for further insight. Having access to the marine accident database of the UK Marine Accident Investigation Branch (MAIB), the study carried out an exploratory analysis to establish a causal chain within the scope of the study.

The exploratory analyses are carried out by studying the injuries and fatalities separately, in order to have a deeper understanding and better identification of the circumstances leading to them; then the causal factors determined during the analyses are compared to the findings of existing studies in other countries identified during the literature review. Exploratory analyses are performed according to the European Marine Casualty Information Platform (EMCIP) taxonomy operated under European Marine Safety Agency (EMSA).

The study concludes with key findings and recommendations in terms of the quality and completeness of the different data sources, including taxonomies; results of the brief analyses; top causal factors; gaps in the current data and knowledge; and recommendations for addressing the gaps to establish mitigating solutions for occupational accidents onboard merchant ships operating globally.

EXECUTIVE SUMMARY

THE STUDY SOUGHT TO ADDRESS THE FOLLOWING QUESTIONS

Q1: What evidence exists in literature over the last 20 years with regards to occupational accidents, including categories of incidents and causes, trends, taxonomies used and the identification of top occupational accidents?

Q2: What major data sources are available which can be utilised to identify the causal factors of occupational accidents, with an analysis of their relevance, quality, completeness, and taxonomies?

Q3: What further analysis can be utilised using the available data?

In order to answer the above questions, the following approach was used:

1. A review of relevant literature was conducted:
   - 1.1 What evidence exists concerning immediate causes of accidents in the maritime industry?
   - 1.2 What evidence exists concerning the underlying causes of accidents in the maritime industry?
   - 1.3 How far can the results from the studies enable causal chain links to be established between underlying causes and immediate causes?

2. Major data sources for occupational marine accidents were identified and reviewed:
   - 2.1 Which data sources are publicly available?
   - 2.2 Which data sources are held by the marine administrations?
   - 2.3 What type of data is held by voluntary reporting platforms?
   - 2.4 What type of data is provided by commercial data suppliers?
   - 2.5 What taxonomy has been utilised, and how complete is the available data for further analysis?

3. Exploratory analyses of the available data were carried out to determine the top causal factor chains and compare the top causal factors against the existing findings from the literature. This was performed by:
   - 3.1 utilising the MAIB accident database and performing the analysis of injuries and fatalities separately according to the EMCIP taxonomy.
   - 3.2 checking the feasibility of the existing database for occupational accident analysis to determine the causal chains
   - 3.3 comparing the top causal factors obtained from the MAIB database analysis to the causal factors collected from published literature.

4. Evaluation of the gaps in the database was made to perform a structured causal chain analysis with the aim of developing mitigating solutions for occupational accidents.

KEY FINDINGS

Evidence in existing literature

- Most of the published literature has a very focused objective and therefore, without more details, it is extremely difficult to derive further insight and link it to wider issues regarding occupational accidents.

- Many publications present a large collection of data; however, these publications also highlight issues with the quality of data in terms of consistency, taxonomy, compatibility and the availability of relevant details. Therefore, the data is less beneficial for developing mitigating solutions than was initially assumed.
- While the open literature has valuable evidence, field data and very useful findings, due to the taxonomy or terminology used, as well as bundled individual causes or injuries, it becomes difficult to compare the results from different sources and to identify the individual elements and further interpretation is required. Based on the literature search, a systematic study, which addresses the occupational accidents in merchant shipping by taking into account whole causal chains, was not found. This possibly reflects a major gap in this field, and may be due to the unavailability of the complete data sets, which are mainly collected for regulatory purposes.
- The quality of the evidence in the existing literature for identifying the immediate causes is high, and in agreement, i.e., they are generally the last events recorded as leading to injury or reported as leading to injury. However, the quality of the evidence in the existing literature for causal links between underlying factors and immediate factors is very low, i.e. it is more speculative than empirical. This limits how much the results from the studies can be relied upon.
- There is limited quality evidence for underlying causes in some publications, particularly those that were identified through dedicated interviews, well-designed data collection campaigns and/or critical analysis of accident investigation reports.
- The literature review clearly highlights the need for the collection of more comprehensive data using appropriate taxonomy. This includes the human and organisational factors, and environmental factors which cannot be captured easily by the current accident reporting practices.

Data sources

- Accident investigation reports, which are only available for life-threatening injuries, fatalities or significant shipping accidents, are the richest publicly available data source for occupational accidents. Most of these reports are made available to the public by the relevant national administrations.
- Despite over 90% of occupational accidents being less serious (non-life threatening), they are not available on any of the publicly available data sources for analysis.
- IMO-GISIS and EMCIP – the official accident reporting platforms for the International Maritime Organisation (IMO) and for the European Maritime Safety Agency (EMSA) – suffer from significant under-reporting of less serious accidents. EMSA, which receives less serious accident reports on a voluntary basis from national administrations, makes them available to the public for the preceding 12 months. Even these reports in their current form have limited benefits for further analysis because they lack further analysis and therefore cannot be used to develop mitigating solutions.
- Some national administrations have possibly the best data sources (database form) for occupational accidents, which can be used for detailed analyses covering the causal chain. Even national administrations suffer from under-reporting or lack of details when it comes to less serious occupational accidents. Databases held by national administrations are not publicly available.
- The reporting of less serious occupational accidents varies significantly from one administration to another, and even the best accident reporting form is not beneficial for

identifying the underlying causes of the occupational accidents. Voluntary reporting platforms, which hold the voluntary reports of accidents, incidents and near misses, collectively provide a very good source of data but lack consistency and the essential details required for comprehensive data analysis.

- Although accident investigation reports and those held by reporting platforms provide a wealth of data, they need to be reprocessed, analysed and structured as a database covering all causal chains, by following a standardised taxonomy which includes maritime human factors. Such an initiative, unfortunately, requires significant resources and this creates a major barrier to building a dedicated, comprehensive database on occupational accidents.
- Data reporting and collection should be designed to learn from the accidents so as to improve the onboard safety of ships. This means a more comprehensive and standardised taxonomy for data collection is required. However, data should be made available to wider stakeholders to accelerate the knowledge generation from data intelligence for the benefit of the shipping sector.

Exploratory analyses of databases (taxonomy terminologies in bold)

- Incidences of occupational injuries and fatalities show decreasing trends over the years, but are still much higher than land-based industries. Exploratory analyses using occupational accident databases revealed **slips, trips and falls on the same level** as the top immediate causal factor for injuries, while the **fall overboard of a person** is the top immediate causal factor for fatalities. This evidence is supported by the literature review. **Dislocations, sprains and strains**, **bone fractures**, **wounds and superficial injuries** make up over 76% of the occupational injury types. **The back, including spine and vertebra in the back**, **upper extremities**, **head, lower extremities** and **whole body and multiple sites** make up the top five injured body parts.
- **Ship decks**, **accommodation** and **engine room** are the top three locations where the highest number of occupational accidents occur. Dry cargo ships, particularly bulk carriers, have the highest fatality and serious injury rates, while passenger ships appear to have the highest less serious injury rates.
- Current databases provide very good evidence to identify the top immediate causal factors for very serious occupational accidents (fatalities) however, lack the quality and reliable data for less serious injuries.
- The current database used in exploratory studies has missing information and entries at multiple layers with regards to underlying factors, including the human and organisational factors. Therefore, in its current format, it cannot be used effectively to identify the links between the immediate causes and the underlying reasons for occupational accidents.
- Exploratory analyses clearly demonstrate that a structured occupational accident database constructed using a standardised taxonomy will provide the best platform to establish clear links between the injuries/fatalities, immediate causal factors and underlying causal factors. Analysis of databases, however, also revealed that such databases need to be comprehensive to establish the links between different factors, especially the human and organisational factors, environment/design and operations.

Current and previous efforts in dealing with occupational accidents have been valuable for creating awareness, but are too fragmented, limited and isolated, and lack complete data. Considering the number of deaths, serious injuries and long-term disabilities that occur per year, there should be a bigger systemic effort to deal with occupational accidents, beyond the regulatory reporting effort. This effort should be supported by the appropriate and systematic relevant data collection campaigns with dedicated taxonomy, and the involvement of key stakeholders in order to develop the much needed mitigating solutions.

1. REVIEW OF EXISTING EVIDENCE ON OCCUPATIONAL INJURIES AND FATALITIES IN MERCHANT SHIPPING

1.1 Introduction

The review performed here is part of a wider study looking at existing data and evidence relating to incidents resulting in injuries and/or fatalities at sea, in the occupational settings of the merchant shipping sector. The review involved scientific publications, research and industry reports, relevant regulations, periodic publications, guidelines, and grey reports from maritime stakeholders. Furthermore, all the major data sources were identified, reviewed and assessed. In these sections, the review of the publications will be reported by performing a comparative review, while seeking answers to the following questions:

- What evidence exists concerning immediate causes of occupational accidents in the maritime industry?
- What evidence exists concerning the underlying causes of accidents in the maritime industry?
- How far can the results from the studies enable causal chain links to be established between underlying causes and immediate causes?

While the review will be formed based on these three questions, the quality of data and taxonomy will also be included as an integrated part of the review. Following the initial scan of the available evidence, suicide will be covered with a narrow focus on the claims that suicides were recorded as occupational fatalities.

1.2 Causes of occupational accidents in the maritime industry

A review of the publicly available literature shows that the main sources of data utilised in these papers are obtained through: a) surveys from seafarers, shipping company managers and administrations, (Jensen et al. 2004a; Jensen et al. 2004b; Bailey et al. 2007; Bailey et al. 2010; Oldenburg et al. 2010; Akamangwa 2016; Uğurlu et al. 2017; Nævestad 2017; Nævestad et al. 2018; Österman et al. 2020); b) occupational accident data from companies, national maritime administrations or Protection and Indemnity (P&I) clubs (Nielsen 1999; Hansen et al. 2002; Bailey et al. 2010; Raisanen 2012; Ádám 2013; Ádám et al. 2014; Lefkowitz et al. 2018; Sampson and Ellis 2019a; and c) accident investigation reports from maritime administrations worldwide (Roberts et al. 2014; Çakir and Paker 2017; Çakir 2019). The literature is in the form of research reports, journal articles, conference papers, annual reports from administrations (EMSA, 2019; MAIB 2019), P&I Clubs (Swedish Club 2019; UK P&I Club 2012) and industry associations, and the grey reports which are available on various websites. Most of the results are generated using the statistical analyses of the data and presented in the form of occurrence frequencies, while some findings established links between injuries and fatalities using various techniques.

Historical trends of occupational injuries and fatalities

Various studies have indicated that occupational injuries and fatalities have decreased over the years (Nielsen 1999; Roberts and Marlow 2005; Nævestad 2017; MAIB 2019). The Norwegian Maritime Directorate also indicated a significant reduction in occupational marine accidents between 2000 and 2010 (NMD 2011). EMSA's annual period reports indicate that since 2014, marine incidents are increasing while injuries and fatalities are decreasing (EMSA 2019). The Japan Transport Safety Report shows a significant decrease in crew fatalities (data also includes fatalities due to shipping accidents) between 2008 and 2018 (JTSB 2019). However, one P&I Club indicated that the frequency of claims due to occupational accidents has increased over the last five years while the overall cost has decreased (Swedish Club 2019). The fatal accident rate (fatality per 100,000 seafarers) in British shipping decreased eightfold between 1950 and 2003, but has increased by 4.7% per annum from 2003 to 2012 (Roberts et al. 2014). The Seafarers' International Research Centre (SIRC), based on data collected from various administrations, presents a similar increasing trend in fatalities since 2009 (Sampson and Ellis 2019a). It is not clear, however, whether the fatalities reported by SIRC include purely occupational fatalities, or both occupational fatalities and fatalities due to shipping accidents such as collision, grounding, etc. In some cases, these findings may appear to contradict each other, but this may be due to inconsistent, unavailable and incompatible data, as well as the way that the data is presented (i.e. normalised or not, Raisanen 2012).

Causal factors

The IMO has harmonised reporting procedures, which provide a number of steps, high-level taxonomy and the required details to be provided when a marine accident is to be reported to IMO by the member states through their national administrations (MSC_MEPC_3_Circ_4, 2014). The IMO has defined the causal factors of occupational accidents as listed in Table 1.1

Table 1.1: IMO taxonomy for occupational accidents

IMO OCCUPATIONAL ACCIDENTS – CAUSAL FACTORS (MSC_MEPC.3_Circ 4, 2014)
Electrical problems, explosion, fire
Overflow, overturn, leak, flow, vaporisation, emission
Breakage, bursting, splitting, slipping, fall or collapse of material agent
Loss of control (total or partial) of machine, means of transport or handling equipment, hand-held tool, object, animal
Slipping – stumbling and falling of a person overboard
Slipping – stumbling and falling of a person to a lower level
Slipping – stumbling and falling of a person on the same level
Body movement without any physical stress (generally leading to an external injury)
Body movement under or with physical stress (generally leading to an internal injury)
Shock, fright, violence, aggression, threat, presence

The IMO's occupational accidents are adopted as the principal causal factors and defined by EMSA as a deviation: 'Deviation – the last event differing from the normal working process and leading to an injury/fatality' (EMCIP Glossary 2016). EMSA, based on the IMO circular, developed a very detailed taxonomy, which is followed by the EU and associated countries to report marine accidents, including occupational injuries and fatalities, to EMSA's European Marine Casualty Information Platform (EMCIP). EMCIP taxonomy and reporting system are designed to create a database which allows full causal chains of incidents/accidents to be developed and necessary risk assessments to be performed.

The top immediate causal factors for occupational injuries and fatalities are reported in various publications (Bailey et al. 2007; Bailey et al. 2010; Roberts et al. 2014; MAIB 2019; EMSA 2019; Çakir 2019; ABS/LAMAR 2019; Swedish Club 2016 and 2019), as well as industry-based magazines and grey reports (*Alert* 2008; UK P&I Club 2012; *HealthWatch* 2016; *Marine Insight* 2019).

Table 1.2: Comparisons of top ten immediate causal factors for occupational accidents as reported by different sources

Marine Insight (Marine Insight 2019)	Swedish Club (Swedish Club 2016)	Administration data (Bailey et al. 2010)	Company data (Bailey et al. 2010)
Man overboard	Slips and falls (44.55%)	Slips, trips and falls on same level (31.6%)	Slips, trips and falls on same level (31.7%)
Enclosed space accidents	Struck by falling object (15.45%)	Falls from a height (23.6%)	Hit by moving (includes flying/falling) object (21.4%)
Electrical shock accidents	Caught in machinery or equipment (10.30%)	Hit by moving (includes flying/falling) object (15.0%)	Struck against something fixed or stationary (13.3%)
Machinery explosion – generator, compressor, boiler blast etc.	Burns and explosions (6.53%),	Handling, lifting or carrying (10.3%)	Handling, lifting or carrying (12.2%)
Mooring operations	Struck/caught by object(s) (5.74%),	Drowning/lack of oxygen/overcome by fumes (7.2%)	Exposure to, or contact with, a harmful substance (8.9%)
Falls from a height	Strain by pulling or pushing (3.17%)	Exposure to, or contact with, a harmful substance (4.2%),	Falls from a height (5.5%)
Piracy attacks	Strain by lifting (3.17%)	Exposure to, or contact with, a harmful substance (4.2%)	Contact with hot surfaces (2.2%)
Lifeboat testing accidents	Tool injury (non-powered) (1.98%)	Contact with hot surfaces (3.3%)	Acts of violence (2.2%)
Hot work accidents	Strain by carrying (1.78%)	Acts of violence (1.2%)	Contact with moving machinery (1.5%)
Gangway fall	Chemical exposure (1.39%)	Contact with electricity or electrical discharge (0.8%).	Exposure to fire (0.4%)

Marine Insight (*Marine Insight* 2019) reports the ten most common life-threatening accidents on board ships, together with best practices as guidelines to enhance the awareness of seafarers of how to avoid these accidents. Naturally, they do not present the frequencies or ranking as they are not based on a statistical analysis of data. Swedish Club (Swedish Club 2016) presents the frequencies of the top ten occupational injury claims using the claims submitted to them. Bailey (Bailey et al. 2010) reports two sets of top ten causes of accidents provided by the administrations and shipping, respectively.

After examining the immediate causal factors from different sources in Table 1.2, and by scanning all the available information from publications, online grey reports or annual statistics, it is clear that **slips, trips and falls** appears as the top causal factor for injuries and fatalities on board ships. Many similarities can be observed between different data sets, as well as some differences, as the main reason for collecting the occupational accident data may change from one stakeholder to another.

While it is possible to extend the list of the publications or online information with the most common immediate causal factors for occupational injuries and fatalities, it is important to determine how this information can be useful. For instance, slips and falls frequency provided by Swedish Club includes both falls on the same level and falls from a height, while administration data provide them separately. For general awareness purposes, it may be sufficient, but for risk assessment and risk control option purposes, collapsed data will be of very limited use as the accident mechanism will likely be different for each immediate causal factor. Comparative analysis of top causal factors using more extensive results from different sources will be provided and discussed in Section 3.

Injury types

In the public domain, injury types are commonly encountered occupational injuries (taxonomy), which all the stakeholders are familiar with. Injury types are defined by EMSA taxonomy at two levels. Level 1 is provided in Table 1.3, while Level 2, which includes more specific injuries, is provided in Appendix F.

Table 1.3: EMSA taxonomy for injury types

LEVEL 1 INJURY TYPE TAXONOMY (EMCIP Glossary 2016)
Wounds and superficial injuries
Bone fractures
Dislocations, sprains and strains
Traumatic amputations (loss of body parts)
Concussion and internal injuries
Burns, scalds and frostbites
Poisonings and infections
Drowning and asphyxiation
Effects of sound, vibration and pressure
Effects of temperature extremes, light and radiation
Shock
Multiple injuries
Other specified injuries not included under other headings
Unknown or unspecified

Although most of the papers cover immediate causes of injuries, part of body injured, location on board, seafarers' demographics, and mode of injury, a limited number of studies present most common injury types obtained from different sources (Bailey et al. 2010; Ellis et al. 2010; MAIB 2019). Possibly the most comprehensive information about occupational injury types is given by Bailey and Ellis. Both publications have the same data sources, which include data from different maritime administrations and from shipping companies, as well as the perception of seafarers about the injuries and the causes.

The most common injury types, based on the administration database, are listed as **strain, sprain, or twist** (20.4%), **break or fracture** (%18.3), **bruising** (15.5%), **cut or piercing injury** (11.5%) and **burns** (4.9%) (Bailey et al. 2010). In the same publication, company data sets indicate the most common injury types as **striking injury** (24.4%), **strain, sprain and twist** (19.7%), **cut or piercing injury** (14.1%), **crush or trap injury** (8.5%), **foreign body in eye/body** (6.4%), **burn** (4.6%), **bruising** (4.1%) and **break or fracture** (3.6%).

The MAIB 2018 database shows similar trends; **dislocation, sprain and strains** (38%), **bone fracture** (29%), **wounds and superficial injuries** (14%), **traumatic amputations** (loss of body parts) (5.2%) and other specified injuries not included under other headings (6.1%). Some injury types may have significantly different occurrence levels between the administration data and the company data. For instance, the fracture injury rate shows a significantly higher frequency for MAIB (29%) and administration data (18.3%), compared to the company data (3.6%). This may have various reasons, including the prevalence of certain injuries on certain types of ships, and under-reporting of minor injuries to administrations (Bailey et al. 2010; Ellis et al. 2010). Accident rates differ considerably between different ship types. Crew on board small general cargo ships (coasters) and roll-on roll-off ships have the highest risk of serious accidents (Hansen et al. 2002).

It is worth mentioning that the MAIB 2018 injury types may have a slightly different taxonomy compared to the company and administration data set. Since 2011, MAIB, like other EU countries, has been following EMSA EMCIP taxonomy for the reporting of marine casualties, while the data from Bailey was possibly obtained well before 2010.

Table 1.4: Comparison of occurring frequencies of injury types between different sources

MAIB 2018	Administration data (Bailey et al. 2010)	Company data (Bailey et al. 2010)
Dislocation, sprain and strains (38%)	Strain, sprain, or twist (20.4%)	Striking injury (24.4%)
Bone fracture (29%)	Break or fracture (18.3%)	Strain, sprain, or twist (19.7%)
Wounds and superficial injuries (14%)	Bruising (15.5%),	Cut or piercing injury (14.1%)
Traumatic amputations (loss of body parts) (5.2%)	Cut or piercing injury (11.5%)	Crush or trap injury (8.5%)
Other specified injuries not included under other headings (6.1%)	Burns (4.9%)	Foreign body in eye/ body (6.4%)
Burns, scalds and frostbites (1.75%)	Crush or trap injury (3.8%)	Burns (4.6%)
Concussion and internal injuries (1.75%)	Graze (1.1%)	Bruising (4.1%)
		Break or fracture (3.6%)
		Aches (2.1%)
		Graze (2.1%)

Part of body injured

Lefkowitz studied the injury, illness, and disability risk in American seafarers and reported that upper extremities, lower extremities and back injuries make up 77% of the body parts injured (Lefkowitz et al. 2018). The MAIB 2018 annual report also presents that those three body parts make up 85% of the body parts injured, as shown in Table 1.5 (MAIB 2019). No description of the injury mechanism was available in the database regarding the American seafarers. However, this data is necessary in order to study such high rates of injuries and to develop better informed preventive solutions (Lefkowitz et al. 2018).

Table 1.5: Underlying reasons for injuries and fatalities reported by various researchers

Lefkowitz et al. (2018)	MAIB (2018)
Upper extremity (34%)	**Upper extremity (39%)**
Hand/wrist (18%)	
Arm/shoulder (15.9%)	Finger(s) (19%)
Lower extremity (22%)	Hand (5%)
Knee (9.9%)	Shoulder and shoulder joints (6%)
Ankle (3.2%)	Upper extremities, multiple sites affected (2%)
Other (8.5%)	Wrist (3%)
Back **(21%)**	
Head **(7%)**	Leg, including knee (20%)
Other **(7%)**	Ankle (12%)
Chest/abdomen **(5%)**	Foot (4%)
Eye **(3%)**	**Back, including spine and vertebrae in the back (10%)**
Skin burn **(1%)**	**Torso and organs (4%)**
	Pelvic and abdominal area including organs (1%)
	Rib cage, ribs including joints and shoulder blade (3%)
	Head (4%)
	Ear (s)(1%)
	Eye (s)(1%)
	Head, brain and cranial nerves and vessels (1%)
	Head other (2%)

Jensen reported that 66% of total non-fatal occupational injuries were accounted for by the upper and lower extremities (Jensen et al. 2004b). Hansen studied Danish maritime accidents between 1993 and 1997 (Hansen et al. 2002). Among these, 209 accidents resulted in a permanent disability of 5% or more, and 27 were fatal. Hansen stated that chronic lumbar problems, lost finger, chronic knee problems, dysfunctional wrist or hand are linked to 5% of disability and make up 41% of the injuries; chronic lumbar and ankle problems, incapacity of shoulder function, slight brain damage are linked to 8% of disability and make up 25% of the injuries; while severe chronic lumbar problems, severe incapacity of shoulder, wrist or ankle are linked to 10% of disability and make up 10.5% of the injuries (Hansen et al. 2002).

Bailey (Bailey et al. 2010) indicated that '*there is very little reliable information about the incidence of injuries within the workforce and there are incomplete data relating to fatalities*'. This was highlighted by other researchers, and especially the under-reporting of minor injuries is well documented (Ellis et al. 2010). In the same paper, Ellis (2010) presents clearly how the quality of reporting varies from one maritime administration to another. As the causal chain cannot be established, due to the missing data, then the remaining data for that particular accident becomes obsolete. While Ellis presented the injury types, unfortunately, the information about what part of the body is injured is not available. EMSA taxonomy for reporting accidents and occupational casualties is designed to address such deficiencies. However, most of the reporting forms for occupational injuries do not reflect this taxonomy, since free text is required in the section of the form where the injury is to be detailed.

Assessing various marine casualty reporting forms available in the public domain revealed that only the MAIB form is formatted to capture the main body parts which are injured; however, individual body parts such as fingers, eyes etc. should be reported using the free text. Accident investigation reports normally cover serious injuries or fatalities. For minor injuries, however, if the company reporter fails to provide all the details in the form, it is likely that this information will not be available in the chain of reporting activities, from company to maritime administration and then from maritime administration to EMSA for European countries or to the IMO-GISIS system.

High risk locations and activities on board ship

A number of studies provided insights on immediate causes of accidents and/or injury (Hansen et al. 2002; Bailey et al. 2010; Roberts et al. 2014; Çakir and Paker 2017; Uğurlu et al. 2017; Çakir 2019). These insights identified types of accidents, types of locations on ships, types of work situations/activities, and types of mechanical factors. Generally, they were pre-defined variables/factors reported/listed as directly linked to an injury suffered in notified accident reports; factors reported on by seafarers and managers during interviews; and factors identified by content analysis of fatal accident investigation reports. Two of the studies (Jensen et al. 2004a; Lefkowitz et al. 2018) included variables that could be considered immediate causes as pre-defined risk factors which are associated significantly with injury outcomes following statistical analyses.

Hansen et al. (2002) identified the most common locations of occupational accidents and associated activities under four groups;

- Work on deck (e.g. lashing and unlashing of cargo, loading and unloading cargo, mooring and anchoring operations, maintenance and repairs) (44.9%)
- Work in the engine room (e.g. cleaning and clearing up, maintenance and repairs) (16.7%)
- Service functions (e.g. cleaning in accommodation, catering and handling of galley stores) (15.9%)
- Walking from one place to another (e.g. on deck and in cargo holds, in accommodation and galley, on stairs and ladders) (10.4%)

Çakir et al., who identified the risky locations and activities by studying the accident investigation reports, confirm similar locations and activities as Hansen et al. while adding ‘Entrance to enclosed spaces’ as an additional high risk location and activity (Çakir 2019). Uğurlu et al. (2017) also confirm that deck (39.9%), cargo compartment (35.7%), manoeuvring scene/locations (16.1%), and accommodation areas (8.3%) are the riskiest areas of the vessel. Jensen, who collected self-reported injuries from 6,481 seafarers, highlighted that of all the injuries, 70% occurred on the deck or in the engine room (Jensen et al. 2004a).

Bailey et al. (2010) collected a large amount of data from various maritime administrations and shipping companies, as well as conducting a survey among seafarers. Bailey presented very useful comparative data sets between maritime administrations, and between maritime administrations and shipping companies. Table 1.6 shows the comparison of location and activity data sets between the administration and the company, and the findings of other researchers when the occupational accidents occurred. The differences may appear to be large, but such differences are normal as the administration data set includes the data from all the shipping companies under the same flag. Furthermore, the ship types which a company has in their fleet will influence the locations and activities of seafarers at the time when the accidents occur. It is worth mentioning that administration data and the company data include all the injuries, such as minor injuries, while Uğurlu et al. include the injuries experienced by cadets during their trips (survey-based). The other two papers by both Çakir and Hansen focused on serious occupational injuries and fatalities. These differences may influence frequency distribution between different locations and activities.

Table 1.6: Comparison of locations/activities when the occupational accident occurred

Administration data set Location/task undertaken (Bailey et al. 2010)	Company data set Location/task undertaken (Bailey et al. 2010)	Hansen et al. (2002)	Çakir, E, (2019)	Ugurlu et al. (2017)
Engine maintenance at sea (61.7%)	Manual handling of heavy or awkward items (35.8%)	Work on deck (44.9%)	Loading/unloading cargo (20.2%)	Deck (35%)
Manual handling of heavy or awkward items (21.2%)	Use of ladders /gangways (32.5%)	Work in the engine room (16.7%)	Maintenance on deck (20.0%)	Cargo compartments (35.7%)
Entry into enclosed space (13.2%)	Engine maintenance at sea (15.0%)	Service functions (15.9%)	Mooring operations (12.0%)	Manoeuvring scene/locations (16.1%)
Use of ladders /gangways (1.8%)	Opening and closing hatches (5.0%)	Walking from one place to another (10.5%)	Entrance to enclosed spaces (10.8%)	Accommodation areas (8.3%)
Work in a confined space (1.0%)	Use of power tools (5.0%)	Boat and fire drills (1.6%)	Ship drills (10.2%)	
Opening and closing hatches (0.4%)	Rigging of gangway (3.3%)		Maintenance and repair at engine department (10.0%)	
Use of power tools (0.4%)	Work in a confined space (2.5%)		Cleaning in tank/hold (8.4%)	
Welding / gas cutting (0.2%)	Welding / gas cutting (0.8%)		Walking from one place to another (5.7%)	
Rigging of gangway (0.0%)	Entry into enclosed space (0.0%)		Rigging and taking in gangways and ladders (5.4%)	

Different literature sources indicate similar locations and activities where the injuries and fatalities occur. However, none of the publications provide an insight into the relationship between the location/activity and the seriousness of the injury or the fatality. It is possible that available datasets or their structures will be the limiting factor in deriving such useful information.

1.3 Underlying causes of occupational accidents in the maritime industry

While occupational injuries and fatalities and their immediate causes are obvious and evidence-based, there are underlying conditions/causes that contribute to the end results. The safety of complex systems like ships is built on multiple active and passive barriers to eliminate single-point failures. Such barriers include, but are not limited to the design of the ship, the quality of the construction, maintenance and repair activities, the training of people, procedures, manning levels, onboard living and working conditions, management, individual and organisational safety culture, etc. In the case of occupational injury and fatality, it is extremely important to identify which barriers failed. In some cases, it may be easy to identify the barriers that failed, and in other cases, less so.

Various studies (Hansen et al. 2002; Roberts et al. 2014; Akamangwa 2016: Çakir and Paker, 2017; Uğurlu et al. 2017; Nævestad 2017 and Nævestad et al. 2018; Lefkowitz et al. 2018; Çakir 2019; Österman et al. 2020) provided insights on underlying causes of occupational accidents, fatalities and/or injury. Different types of existing situations/factors, including onboard working conditions and human factors, were identified largely through analysis of fatal/serious injury accident investigation reports, surveys and site visits, including participant observations and/or interviews with individuals and groups. Some studies (Jensen et al. 2004a and b; Ádám 2013 and Ádám et al. 2014) present a set of variables considered as pre-defined factors, such as age, rank, and nationality of seafarers, which are associated with injury outcomes following statistical analyses.

Based on the analyses of more than 331 accident investigation reports, Çakir (2019) identified dangerous work practices and ignorance of rules and instructions as the most common underlying causes of serious occupational injuries and fatalities (Table 1.7). A study by Roberts (Roberts et al. 2014) confirms unsafe practices (25.4%) as the most common underlying causes of occupational fatalities. Uğurlu et al. (2017) surveyed over 850 cadets, collected their occupational injuries and experience during their time at sea and had them assessed by 16 maritime experts using Analytical Hierarchy Process (AHP). They found lack of personal protective equipment (PPE) usage (24.2%) and haste (22.6%) as the top two root causes of occupational accidents. Some of the underlying parameters in Table 1.7 are related to the organisation's safety culture and management issues, some are related to skills and knowledge, and some are related to the physical conditions of the systems and operations and maintenance (O&M) deficiencies.

A number of studies, based on the collected data, claimed non-officer crew (ratings) were twice or more as likely to suffer injury (Jensen et al. 2004a; Lefkowitz et al. 2018; Roberts et al. 2014). Roberts stated that the deck department has higher risk work duties, which is confirmed by Lefkowitz (Roberts et al. 2014; Lefkowitz et al. 2018). A recent study, which looked into service crew on board passenger ships, confirmed that they suffer musculoskeletal and psychological disorders, and constitute the largest proportion of long-term sick leave for all departments (Österman et al. 2020).

Table 1.7: Underlying reasons for injuries and fatalities reported by various researchers

Underlying causes for serious injuries and fatalities (Çakir 2019)	**Root causes of occupational accidents** (Uğurlu et al. 2017)	**Underlying reasons for occupational fatalities** (Roberts et al. 2014)
Dangerous work practices and ignorance of rules and instructions (53.2%)	Not using PPE (24.2%)	Unsafe working practices (25.4%)
Insufficient risk assessment or hazard Identification (19.8 %)	Haste (22.6%)	Mechanical failure/deficiencies (23.5%)
Machine/equipment malfunction (11.2%)	Presence in inappropriate places (13.6%)	Negligence/perception of risk (13.7%)
Unsafe working environment and adverse weather condition (7.3%)	Pressure of the manager (10.3%)	Alcohol consumption (13.7%)
Lack of education, experience and training (6.3%)	Slippery floor (9.2%)	Institutional complacency towards safety (11.7%)
Lack of communication and team work (3.6%)	Bad weather (7.3%)	Inadequate training (7.8%)
Deficiencies in instruction and guidance (3.6%)	Fatigue or excessive workload (6.8%)	Weather (3.9%)
	Improper use of ship equipment (6.1%)	

A number of studies confirmed that accident rates differ considerably between different ship types. The crew on board small general cargo ships (coasters) and roll-on roll-off ships have the highest risk of serious accidents, as the crew are often involved in handling and lashing of cargo, which will add to the number of accidents on these ships (Hansen et al. 2002). Lefkowitz confirmed the link between the ship type and the injury type and seriousness of the injury:

> *Our model demonstrated a higher risk of disability for seafarers working on cargo ships and ATBs [articulated tug-barges]. Noting the higher rates of injury on these vessels compared to others, it is possible that some of the risks of disability on these ships are driven by conditions of the work environment leading to injury.* (Lefkowitz et al 2018, 127)

Compared to Western European seafarers, incident ratios are lower in Eastern European (0.53), South East Asian (0.51) and Indian (0.74) seafarers. However, the difference in the rate of serious injuries between nationality groups was found to be smaller than the difference in overall injury rates (Ádám 2013 and Ádám et al. 2014). Foreign, especially Asian seafarers, may be reluctant to report injuries, and this could be the reason for their lower rate of notified accidents (Ádám et al. 2014)

Based on existing evidence in the public domain, the current research about underlying reasons for occupational accidents and fatalities is very limited and not systematic enough to make an impact to trigger changes in design, regulatory framework and ship operations.

1.4 Link between occupational accidents/injuries and organisational and human factors

The study by Jensen et al. (2004a) tested the hypothesis of a relation between the number of work hours per week and the risk of injury, following observation from the literature that though the majority of injuries and vessel casualties were often related to human error, it had also been proposed that the link in the chain of events leading to an injury was actually fatigue. In the same study, Jensen showed that more than 71 hours of work per week was related to a higher rate of injuries for seafarers on merchant ships, but the result was not statistically significant. However, the subsequent study with a much larger collection of data with a higher number of international seafarers did not show any evidence that longer working hours led to injury rate increase (Jensen et al. 2004b). His data revealed however that the average tour of duty on board ship was 7.7 months. This varied between nationalities: 11.2 months for the Philippines and 8.2 for Indonesian seafarers were the highest; 3.5 months for Danish seafarers and 3.4 months for UK seafarers were the lowest (Jensen et al. 2004b). Oldenburg (2010) confirmed that the average onboard ship contract for European seafarers is 3-6 months, while it is 6-9 months for non-European seafarers. This will lead to separation from family and long working hours, resulting in a high stress load which will burn out people and create fatigue (Oldenburg et al. 2010).

The International Safety Management Code (ISM), which came into force in 1998, provides a generic framework for companies to develop their own policies and procedure to support captains to ensure the safe operation of ships and to manage occupational health and safety (OHS) on their ships (Bhattacharya 2012). Bhattacharya stated, however,that ISM has not had the desired impact due to various reasons, including the different perceptions of managers and seafarers on the implementation of the ISM Code, and the significant gap between the expected outcome of ISM and the practice. Compliance culture rather than improvement culture, blame culture and job insecurity are also listed as some of the reasons. Batalden and Sydnes(2014) studied over 94 shipping accident investigation reports to identify the deficiencies in the application of ISM by implementing Human Factors Analysis and Classification Systems (HFACS). Batalden identified that the following sections of the ISM code were the most encountered causal factors for accidents: Section 5: Master's responsibility and authority (14.4%); Section 6: Resource and personnel (28%); Section 7: Development of plans for shipboard operations (13.6%); and Section 12: Company verification, review and evaluation (16.9%). Further insight revealed that 17.8% of the causal factors were attributed to organisational influences, 30.8% to unsafe supervision, 23.4% to preconditions for unsafe acts and 28% to unsafe acts. Although these figures are linked to shipping accidents, similar results are expected if the occupational accidents reports are studied.

Studies with regards to the occupational safety and health of crew onboard ships indicate that they are exposed to negative working conditions compromising their health and well-being adversely (Akamangwa 2016; Österman et al. 2020). Environmental compliance appears to increase the demand of the job on top of an already heavy workload and long working hours, as companies do not increase the number of crew despite an additional workload generated by the environmental compliance regulations introduced by regulatory bodies. Onboard working conditions, which involve the design of tasks, management style, interpersonal relations and career concerns as well as physical conditions, will lead to a high stress load and to potential injury and health issues (Akamangwa 2016). Similary, Österman et al. (2020), who carried out an extensive survey together with interviews, found issues that were creating non-fatal but long-term occupational injuries, resulting in long-term absences, mental and physical health issues, and high service crew turnaround, coupled with a negative work and living environment and less than satisfactory interpersonal relations. Some of these issues can be listed as:

- *Whole-body vibrations and ship movements represent an increased risk of musculoskeletal disorders (MSD), especially in the lumbar spine, neck and shoulders. Noise and vibrations may also have a negative effect on sleep quality*.
- *Design of the workplaces significantly affect the health of people. The service crew are largely associated with high physical load and strenuous working postures, poor workplace design, long working hours, limited time for recovery, and the perceived mental*

> *and emotional load that comes with unclear boundaries between work and recreation and the social interaction with customers and colleagues.* (Österman et al. 2020, 408)

The above conditions do not necessarily cause occupational accidents but cause occupational physical illnesses which are not included in the occupational accident databases.

Nævestad et al. (2018) used a questionnaire survey to examine the safety outcomes (safety behaviours and crew member accidents) of safety culture and working conditions and discuss how safety culture and working conditions are influenced by the type of vessel environment. Results supported the hypothesis that working conditions on coastal cargo vessels are relatively more challenging than on passenger vessels, with high work pressure, little time to rest and irregular working patterns, and the hypothesis that the working conditions in the two types of vessels are directly related to the safety culture scores. Nævestad et al. (2018) found from the study that ships with lower manning coastal vessels experience more personal injuries and more stress, leading to a lower safety culture rating which increases the risk of injury. The regression analyses showed that organisational safety culture was the strongest predictor of unsafe behaviours, indicating that a positive safety culture is related to less unsafe behaviours. Work pressure was the second strongest predictor of unsafe behaviours. Considering work factors are often identified as immediate causal agents of injuries and safety behaviour as underlying causal factors, the observations suggest safety culture as a root cause element for propagation to injuries and fatalities.

1.5 Quality of data

Many researchers who have been dealing with occupational injury and fatality data, highlighted the issues with the availability and quality of the data (Bailey et al. 2007; Bailey et al. 2010; Ellis et al. 2010; Raisanen 2012; Sampson and Ellis 2019).

Despite collecting a large amount of data over a number of years from maritime administrations, Bailey stated:

> *However, our problems were compounded by the different recording and collating practices of Maritime Administrations which made the straightforward aggregation of data into a single dataset impossible. For example, whereas all administrations recorded dates and types of incidents, only 87.5% recorded details of ship type, 75.0% recorded flag, and as few as 37.5% recorded the age of the vessel involved, 25% recorded the cause of the incident, and 6.3% recorded information about environmental conditions.* (Bailey et al. 2010, 4)

The terminology and the construction of the data play important roles in maximising the benefits of such available data. For instance, the Swedish Club report presents burns and explosions under one category for public dissemination (Swedish Club 2016). While this information is useful for public awareness, from a data analysis point of view and for the development of causal chain and risk assessment purposes, these data are obsolete if they are provided together in the database. Bailey gives the same example to highlight the problem with data:

> *For example, whilst many administrations categorised 'fire' and 'explosion' separately, a number of them conflated the two events into a single category 'fire and explosion'. Once data is collapsed into such 'multiple categories', it is impossible to disaggregate in the absence of the original raw information. This further complicates any kind of comparative exercise.* (Bailey et al. 2010, 4)

This example highlights the importance of the taxonomy for research to address occupational injuries and fatalities beyond a very narrow statistical presentation of the occurrences.

Under-reporting of occupational injuries is highlighted as a major problem, which prevents the building of a good understanding of injuries, limits the studies and the performance of robust analyses, and prevents developing mitigating solutions (Nielsen 1999; Hansen et al. 2002; Jensen et al. 2004a and 2004b; Raisanen 2012; Nævestad et al. 2018; Lefkowitz et al. 2018; Sampson and Ellis, 2019).

National administrations are not very good at passing information about accidents and injuries to international common data platforms like IMO-GISIS (Hassel and Hole 2009). This is evident since EMCIP data, which can be accessed by the public, shows a very limited amount of data with regards to minor (less serious) injuries, as less serious injuries are reported on a voluntary basis. Under-reporting in national databases is reported to be over 50% (Hassel 2011), and is a significant barrier to establishing causal chains and a risk assessment approach to developing the mitigating measures to control the risk (Hassel et al. 2011).

1.6 Occupational fatalities and suicide records in shipping

Suicide in merchant shipping is generally addressed under maritime health/illnesses and has been reported and studied by a number of researchers over the years. Various researchers studied the historical suicide frequencies together with the nature of the suicides, the type of ships, the demographic details (Roberts and Marlow 2005; Roberts et al. 2010; Roberts et al. 2014; Sampson and Ellis 2019a and 2019b, and reported underlying reasons (Roberts et al. 2010; Iversen 2012; Mellbye and Carter 2017). A number of researchers developed questionnaire-based studies to capture the mental health of seafarers, including the relation between onboard working and living conditions (Lefkowitz and Slade 2019; Sampson and Ellis 2019b), and identified the most important facilities/activities which would help to improve the happiness of seafarers onboard (Sampson and Ellis 2019b). Some research activities have been aiming to develop techniques to assess the stress of seafarers, including the Psychological General Well-Being Index (PGWBI) (Carotenuto et al. 2013), and the automated screening of mental illnesses using machine learning techniques (Sau and Bhakta 2019). In addition, several industries initiated regulatory developments, and projects and activities have been taking place. The Maritime Labour Convention (MLC), which was prepared in 2006, came into force in 2013 and addresses all aspects of seafaring, including seafarers' health and wellbeing (MLC 2006). Iversen (2012) reported two mental health front-line projects supporting seafarers' depression by providing fully equipped centres near ports, 24/7 hotline support with different language support and published guidelines (International Seafarers' Welfare and Assistance Network (ISWAN) 2016). A workshop was organised by the International Transport Workers' Federation (ITF) Seafarers' Trust on 'Social Isolation, Depression and Suicide' (ITF Seafarers' Trust 2016). P&I Clubs have been trying to increase the awareness of mental health issues and provide support by developing guidelines, reporting mental health-related problems, as well as providing factual information about depression and suicide (The American Club 2019; Pathak 2019; Vandenborn 2018). There are also various online blogs and grey reports to increase the awareness of seafarers' mental health, depression and suicide (UKCoS 2017; Newman 2016; Blake 2017; Martek Marine 2018).

Within the framework of this study, occupational injuries and fatalities in merchant shipping, accurate recordings of occupational fatalities and suicides are fundamental to identify the scale of the problem and then develop targeted mitigating measures. According to the statistics, between 1960 and 2009, 1,011 out of 17,026 seafarer fatalities were due to suicide (5.9%). Compilations of 12 reports between 1992 and 2007 showed that out of 4,573 seafarer deaths due to illness, 590 were suicide (13.1%) (Iversen 2012). Iversen also stated that the aforementioned numbers would be much higher if the seafarers 'missing at sea' were recorded as suicides. Out of 66 deaths on British flagged ships between 2003 and 2012, five (7.5%) were reported as 'suicide', four (6%) as 'drowned' and a further seven (10.5%) were reported as 'missing at sea'. Although some of those 'missing at sea' were likely to be suicides, some were speculated to be homicides (Roberts et al. 2014). If half of these 'missing at sea' and 'drownings' are considered suicides, then suicide rates would be around 12-13%.

According to one P&I Club, 65 deaths, 32 mental illnesses, and 4.6 suicides per year have been observed over the last ten years. These numbers do not include the fatalities recorded as 'missing at sea' and, therefore, the suicide rate may be under-reported (Pathak 2019). A study by Seafarers International Research Centre (Sampson and Ellis 2019b) stated that P&I Clubs may also be overlooking suicides and do not record them as such, but rather as accidents. Otherwise, the families may not get the insurance money and therefore, it is better from both the family and community point of view if they are recorded as occupational accidents (Sampson and Ellis 2019b). According to the UK Chamber of Shipping, suicide rates have tripled since 2014 and 40% of them were of cadets (UKCoS 2017). In the same blog, the comments of a UK P&I Club indicated that crew experience anxiety, social isolation, the pressure of work and disturbed sleep (UKCoS 2017; Vandenborn 2018).

Out of 55 suicide-related deaths between 1976 and 2002 on UK ships, 30 jumped overboard, 20 were found hanged, and three jumped from heights. Of the seafarers who committed suicide, 87% were serving on board large deep-sea ships (Roberts and Marlow 2005). It is suggested that social isolation was one of the main reasons for these suicide-related deaths. Sampson and Ellis (2019b) stated that maritime administrations infrequently recorded suicides as discrete events, which creates difficulties with data analysis and interpretation of the results. Of active seafarers, 37% were found to have experienced a recent-onset deterioration of mental health (Sampson and Ellis 2019b). From all the evidence, it is clear that if records were kept accurately, the suicide rates would be significantly higher and could trigger a stronger reaction by the shipping community.

While 'fall overboard of person' is reported as the top causal factor for occupational injuries and fatalities, the databases, including accident investigation reports, hardly mention suicide. It is generally reported as 'man overboard' and 'missing at sea'. Sampson and Ellis (2019a) stated: *'There are also strong indications that within almost half of this small sample of Maritime Administrations, the recording of suicides is still not undertaken or is obscured via classification processes*'. Based on the evidence from the literature, there may be various reasons for the discrepancy between the actual suicide rates and the reported ones. The Marine Accident Investigators' International Forum has a 'Marine Investigation Manual', and in this manual, the term 'suicide' cannot be found (MAIIF 2014). In the EMCIP taxonomy document it can only be found once, where it is used to define the casualty type (EMCIP Glossary 2016). However, the steps for reporting a suicide using the causal chain taxonomy possibly do not exist. Similarly, IMO-GISIS harmonised reporting procedures do not include the term 'suicide' (MSC_MEPC_3_Circ_4 2014). Furthermore, most of the accident investigation branches around the world may not have surveyors with a behavioural science background who can assess the circumstances. Whatever the reasons, without speculating further, such discrepancies should be addressed, as they will significantly influence the relevant causal chain analyses and risk assessment, and more importantly, any development of mitigation measures. The maritime industry is not alone in this, as the aviation industry is also trying to address a similar problem since a pilot with mental issues deliberately crashed a plane in 2015 (Wu et al. 2016). Considering that 37% of seafarers experience temporary mental deterioration, there is no research on how mental deterioration affects the performance of the seafarer and hence navigational safety. This fundamental issue highlights the need for a more structured new effort.

1.7 Summary of the literature evidence reviewed

Overall, the review of the existing evidence on maritime occupational accidents resulting in injuries and fatalities provides a good picture of the current knowledge, activities over the last 20 years, key data sources, the direction of research and the gaps that exist.

Shipping is a complex socio-technical system involving different safety barriers which are designed to prevent a single point of failure. A maritime or occupational accident occurs only if all the active and passive defence barriers fail. If there is a serious accident, then it requires a good root cause analysis to establish the links between the obvious immediate cause of the accident that we witness and its root causes, through analysing various levels of underlying causes (contributory factors). This is the only way to understand the accident mechanism so that mitigating solutions can be developed. It can be stated that:

- There is quality evidence about the immediate causes of occupational accidents. Such evidence comes from maritime administrations, P&I Clubs, shipping companies, trade organisations and research publications. However, the source of data that leads to the identification of immediate causes is either not available, not complete, or requires significant additional effort to make it usable for root cause analysis, particularly for less serious (minor) injuries.
- The quality evidence for underlying causes is very limited. For serious injuries and fatalities, accident investigation reports provide a rich data source., Such data sources have however to be processed to identify the underlying causes. On the other hand, for serious/non-fatal injuries, the data is very limited (especially if the accident is not investigated), and any available data is not suitable for further analysis. In those cases, some of the researchers collected the supporting evidence through a number of surveys or face-to-face interviews in order to identify the underlying reasons. Some researchers deployed both data and survey to complete the data sets. However, the usefulness of a survey depends heavily on the design of the questionnaire, the participation rate and the quality of answers.
- The quality of the evidence for causal links between underlying factors and immediate factors is generally low, i.e. it is more speculative than empirical. This limits how much results from the studies can be relied upon. As far as the root causes are concerned, only very limited evidence is available, and it focuses in particular on the safety culture, onboard working and living conditions. Although there is a very limited number of papers, the information captured is complementary, powerful and useful for Risk Assessment Models.

A significant number of researchers highlighted the problems with data regarding occupational injuries in terms of availability, completeness, compatibility and accessibility. This severely limits the impact of the research effort. In order to develop the mitigating solutions for occupational accidents for the maritime industry, the accident data is essential as surveys and expert opinions can only complement the injury/accident data, not replace it.

Overall, it can be said that there are a number of very valuable publications which are providing very valuable information and findings on occupational injuries and fatalities. Nevertheless, most of the evidence and publications are based on research focusing on specific topics and carried out in isolation. The study has not identified any large scale/systemic research project(s) focusing on occupational injuries and fatalities of seafarers. The current body of knowledge in the accessible literature does not provide detailed insight into various topics, including but not limited to:

- Links between ship design deficiencies and occupational injuries and fatalities. It is important to emphasise that enhancing the safety through better ship design is much more effective than trying to train the crew to manage the poorly designed ships.
- Links between ship types and occupational injuries and fatalities
- Links between O&M deficiencies and occupational injuries and fatalities
- Links between manning levels and occupational injuries and fatalities
- Deficiencies in PPE use and the connection with occupational injuries and fatalities
- Deficiencies in operational procedures and the connection with occupational injuries and fatalities
- Links between onboard working and living conditions and occupational injuries and fatalities
- Skills and knowledge deficiencies and occupational injuries and fatalities
- Other human and organisational factors vs occupational injuries and fatalities
- Links between organisational safety culture and occupational injuries and fatalities.

2. REVIEW OF MAJOR DATA SOURCES OF MARITIME OCCUPATIONAL ACCIDENTS

A review of major data sources for marine occupational accidents included the IMO Global Integrated Shipping Information System (IMO-GISIS), accident databases of flag administrations, EMSA European Marine Casualty Information Platform (EMCIP), and P&I Clubs. In addition, the review also included voluntary reporting platforms such as the Aviation and Maritime Confidential Incident Reporting Platform (CHIRP Maritime), the Mariners' Alerting and Reporting Scheme (MARS) run by the Nautical Institute, the International Maritime Contractors Association (IMCA) and commercial suppliers. A full review of these data sources is reported in Appendix D.

Hassel has compared various major data sources for all maritime accidents (Hassel and Hole 2009), including the databases of maritime administrations in Canada, Denmark, Norway, Sweden, the Netherlands, UK, and USA. In addition, Hassel studied the IHS Fairplay Sea-Web, as well as the marine insurance statistics database of the Nordic Association of Marine Insurers (CEFOR). Many entries lacked sufficient data to present a complete picture (Hassel et al. 2011). Depending on the category, '*the estimated upper limit reporting performance for the selected flag states ranged from 14% to 74%, while the corresponding estimated coverage of IHS Fairplay ranges from 4% to 62%. On average, the study results document that the number of unreported accidents makes up roughly 50% of all occurred accidents.'* (Hassel 2011; Hassel et al. 2011b)

As far as maritime occupational accidents are concerned, the IMO-GISIS database has almost no entries as it suffers from serious under-reporting and therefore cannot be used for the analysis of occupational accidents. Similarly, commercial maritime intelligence data providers like Lloyd's List or IHS Markit do not cover maritime occupational accidents. P&I clubs collect data through insurance claims, and their system and data are not designed for detailed analysis. European Marine Casualty Information Platform (EMCIP) is a database and data distribution system operated and maintained by EMSA since 2011. EMCIP has been collecting marine casualty details and reports from the EU/EEA member states, and the platform can be accessed publicly. However, as far as occupational accidents are concerned, EMCIP suffers significantly from under-reporting, and if there is no accident investigation report available, it provides extremely limited information that cannot be used for further analysis.

Accident investigation reports provide the richest source of information for serious injuries and fatalities and are available freely in the public domain; They need to be studied, and a database needs to be created. Furthermore, no accident investigation reports are available for less serious occupational injuries. If accessible, the databases of national maritime administrations provide the best data, are ready for analysis and include both less serious and serious injuries, including fatalities. However, as far as occupational accidents are concerned, there may be an issue with the data and its completeness due to the non-standardised reporting systems, particularly for less serious injuries, which are not investigated.

Barriers with regards to the availability and deficiencies of the databases should be overcome by using standard taxonomies and by working with the data holders such as administrations and shipping companies to unlock the significant benefits.

3. CAUSAL FACTORS: EXPLORATORY DATABASE ANALYSIS

The MAIB occupational accident database used for the exploratory analysis is based on the EMCIP taxonomy, and therefore the exploratory analysis of the database followed the EMCIP taxonomy. Further details of Level 1 and Level 2 for some causal and injury-related EMCIP taxonomy are given in Appendix E, while full details can be accessed on the EMSA website (EMCIP Glossary 2016). While exploratory analysis focuses on occurrence frequencies, an attempt is made to determine whether the database is suitable to establish significant relations between various causal factors.

Table 3.1: EMCIP Taxonomy

EMCIP taxonomy extracts for occupational accidents	
LEVEL 1	Level 2
TYPE OF SHIP –LEVEL 1	Type of ship – Level 2
DEVIATION – LEVEL 1	Deviation – Level2
MODE OF INJURY –LEVEL 1	Mode of injury – Level 2
PART OF BODY INJURED – LEVEL 1	Part of body injured – Level 2
TYPE OF INJURY –LEVEL 1	Type of injury – Level 2
PLACE ON BOARD – LEVEL 1	Place on board – Level 2
WORKING CLOTHES/PPE – LEVEL 1	Working clothes – Level 2
CONTRIBUTING FACTORS – LEVEL 1	Contributing factors –Level 2
HUMAN ERRONEOUS ACTION	

3.1. Exploratory database analyses to determine the causal factors

MAIB Database

The MAIB database, which has been collating data about marine accidents since 1991, has more than 7,000 entries related to occupational accidents. Exploratory analyses are carried out under two categories: 1) injuries only and 2) fatalities only. These analyses will provide the opportunity to see the feasibility of generating insight into occupational injuries and fatalities using a database. The analyses presented below include only the occupational injuries and fatalities which occurred on board UK flagged merchant vessels over 500GT worldwide, or on board foreign flag merchant vessels over 500GT while they were in UK waters. Fishing vessel related accidents, fatalities and injuries due to ship accidents such as collisions, grounding, fire etc., are excluded from the analyses.

Worldwide database

This step demonstrates whether it is feasible to build a database using the publicly available accident investigation reports, and determine the top causal factors for serious injuries and fatalities. The CHIRP Maritime reference database was used to access the investigation reports from various national administrations. Initial scans of the reports yielded over 400 investigation reports on occupational accidents from various countries, including Australia, Bahamas, Hong Kong, Marshall Islands, Japan, Germany, Malta, USA, Canada, Denmark, and New Zealand. The database is constructed using EMCIP taxonomy for only the top causal factors, and the results are compared to MAIB causal factors and the other publicly available lists of causal factors.

3.2. Occupational accidents that resulted in injuries

Over 90% of the occupational injuries in the MAIB database are classed as less serious injuries or marine incidents, that is, injuries that incapacitate the seafarer for less than 72 hours during the seven days after the occupational injury, and which do not cause any injury that results in loss of time.

Yearly variation of injury frequencies

MAIB has been recording occupational accidents in shipping since 1991, and it can be seen in Figure 3.1 that injury frequencies have been decreasing steadily over the years. There has been more than a 50% reduction in injury frequencies over the last 20 years, while remaining almost constant in recent years since 2015.

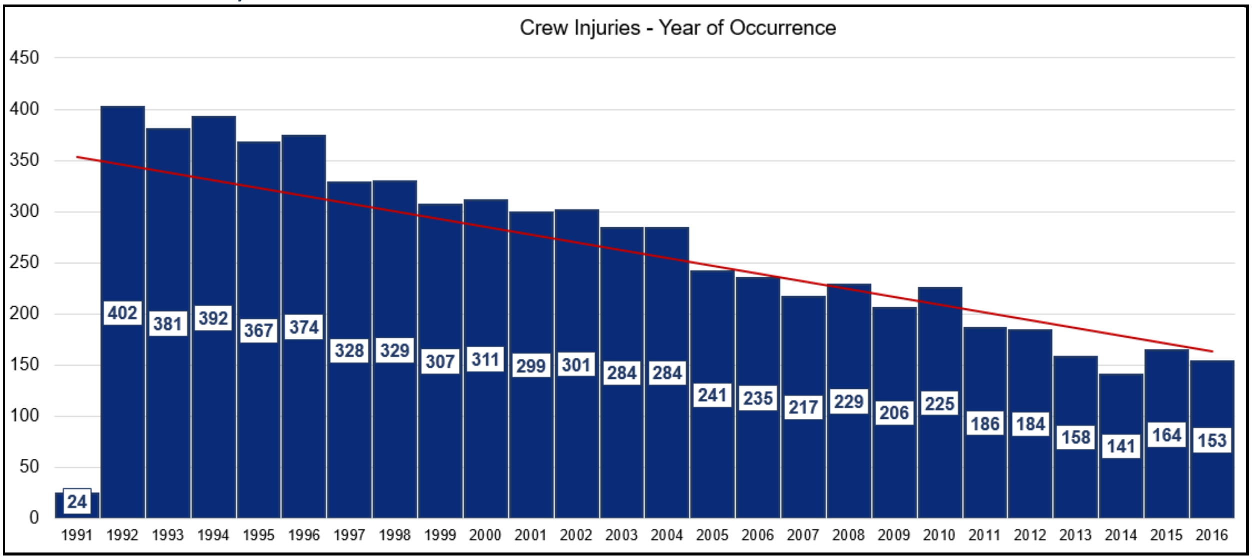

Figure 3.1: Crew injury frequencies on board merchant vessels recorded in UK MAIB database

A similar trend is observed by the Norwegian Maritime Directorate, which reported an almost six-fold reduction of occupational injuries on board cargo ships between 2000 and 2010 (NMD 2011). The EMSA annual review report, which presents the data collected from EU countries since 2011, also shows a slight reduction in occupational injury trends since 2014 (EMSA 2019).

Ship type

Passenger and ro-ro cargo vessels (39.97%) are at the top of the list of ship types with the highest frequency of onboard occupational injuries. They are followed by the solid cargo vessels (15.93%), which include bulk carriers, container vessels, general cargo vessels etc. Passenger-only vessels, including cruise ships (14.48%), are ranked third in the list, followed by liquid cargo vessels, including tankers, oil carriers, product tankers (8.36%), and offshore supply vessels (5.7%). The top five ship types also reflect the composition of UK flagged vessels operating in the UK and international waters.

Top causal factors (deviations) (taxonomy terminologies in bold)

Slipping, stumbling and falling – fall of a person, with 40.67%, is the most common immediate causal factor for occupational accidents on board merchant vessels. With 24.5 %, **loss of control (total or partial) of machine, means of transport or handling equipment, hand-held tool, object,**

animal is the second most common immediate causal factor, followed by, at 18.4%, **body movement under or with physical stress (generally leading to an internal injury)**. When further details of the causal factors of the occupational accidents are analysed (Level 2), **fall of a person on the same level** (21.6%), **fall of a person to lower level** (17.7%) and **loss of control of an object** (13.3%) make up 53% of the occupational injuries (Table 3.2).

Table 3.2: Top ten causal factors for injuries at Level 2 – MAIB database

TOP CAUSAL FACTORS – LEVEL 1	TOP CAUSAL FACTORS – LEVEL 2	%
Slipping, stumbling and falling – fall of a person	fall of a person on the same level	21.6
	fall of person to a lower level	17.7
Loss of control (total or partial) of machine, means of transport or handling equipment, handheld tool, object, animal	loss of control of an object	13.3
	loss of control of hand-held tool	5.38
	loss of control of machine	3.55
	loss of control of transport	2.45
Body movement under or with physical stress (generally leading to an internal injury)	lifting, carrying, standing up	8.23
Overflow, overturn, leak, flow, vaporisation, emission	liquid state – leaking, oozing, flowing, splashing, spraying	3.06
Body movement without any physical stress (generally leading to an external injury)	uncoordinated movements, spurious or untimely actions	2.45
	being caught or carried away by something or momentum	1.89

The causal factors presented above follow the EMCIP taxonomy code based on the IMO guidelines (Level 1). The multi-layer taxonomy is designed by EMSA to allow administrations and safety analysts/researchers to perform risk assessments by collecting the necessary factual details in a systematic way. Without such multi-layer data, it is not possible to link all the essential data in order to perform detailed analysis and develop mitigating solutions to prevent occupational injuries. Sometimes this may not be obvious to people who report the occupational accidents, especially those not investigated, to the national administrations.

Mode of injury

The next level of detailed injury information is called 'Mode of Injury', which has two levels and provides further details about how the injury took place. In general, for serious injury or fatality cases, the information is input into the system by the investigating person from the accident investigation report, and for the less serious injuries, the administration person inputs information from the form which is completed by the reporter (shipping company).

Due to the incomplete reporting forms, 95% of the modes of injury information is not available in the database. This creates a major deficiency in the quality of the database towards understanding the underlying reasons for injuries and developing mitigating solutions. After excluding the missing entries, the remaining 5% mode of injury data is mainly linked to **trapped, crushed mode**, **contact with electrical voltage, temperature, hazardous substances etc.**, and **physical or mental stress** etc.

Level 2 in EMCIP taxonomy provides more specific mode of injuries such as **contact with naked flame or a hot or burning object or environment**, **limb, hand or finger torn or cut off** and **physical stress on the musculoskeletal system**. Again, the unavailability of details creates further barriers to establish proper links between the top causal factors and underlying reasons.

Injury type

Classified investigation of the injury types provides insight into the nature of the injuries sustained by the crew. The medical terminologies are used according to the EMCIP taxonomy, which is also utilised in the MAIB accident report form (MAIB Accident Report Form) to determine the injuries in a standardised form. Frequency analysis indicates that Level 1 injury types – **dislocations, sprains and strains,** 27.71%, **bone fractures,** 25.09%, **wounds and superficial injuries,** 24.88% – make up over 76% of the occupational injury types.

When the specific injury details are examined (Level 2), it reveals that 37 % of the injury details are not available. **Sprains and strains**, **Open wounds**, **superficial injuries**, and **burns and scalds** make up the most common five injury types. These detailed injury types (Level 2) can only be deduced from the free text narratives in the injury reporting form if provided.

Part of body injured

The classification of the part of the body injured has two levels as defined by the EMCIP taxonomy; Level 1 represents the body part groups which are also utilised in the MAIB accident report form (MAIB Accident Report Form), and Level 2 details the specific injured body parts. The part of the body injured was not provided for 75% of the injuries in the database. This is possible for less serious or superficial injuries which are not detailed in the reporting form by the person. This leads to many uncertainties for further investigations and potential solutions to mitigate such injuries. Analysis after excluding the unavailable data reveals that **back including spine and vertebra in the back,** 43%, **upper extremities,** 19%, **head,** 15.0%, **lower extremities,** 13.0% and **whole body and multiple sites,** 5.0% make up the top five injured body parts.

At Level 2, 50% of the data is not available, and this naturally creates a barrier for more robust analysis. The top five specific injured body parts are **eyes,** 7.5%, **fingers,** 6.3%, **legs including knee,** 5.8%, **hand,** 5% and **back including spine and vertebra in the back,**3.2%.

Location of occupational accidents on board ship

According to the EMSA taxonomy, the locations of the occupational accidents are reported at two levels; Level 1 identifies the zones on board ships while Level 2 identifies the specific locations in those zones. **Ship, zone** (41%), which includes all the open decks and stairs, has the highest number of occupational accidents, followed by **accommodation,** 28%**, engine room,** 12.6%, and **cargo and tank spaces,** 8.4%. At Level 2, **freeboard deck,** 21.0%, **galley spaces**, 13.6%, **cabin space,** 8.1%, **stairs/ladders,** 7.6% and **control room,** 6.6% are the top five locations where 55% of the occupational accidents have occurred. 20% of the data was not available at Level 2.

3.3. Occupational accidents which resulted in fatalities

Analysis of fatal occupational accidents in the MAIB database shows a decreasing trend over the years, with only two fatalities in 2018 and 2019. This shows a reduction of 300% compared to 20 years ago.

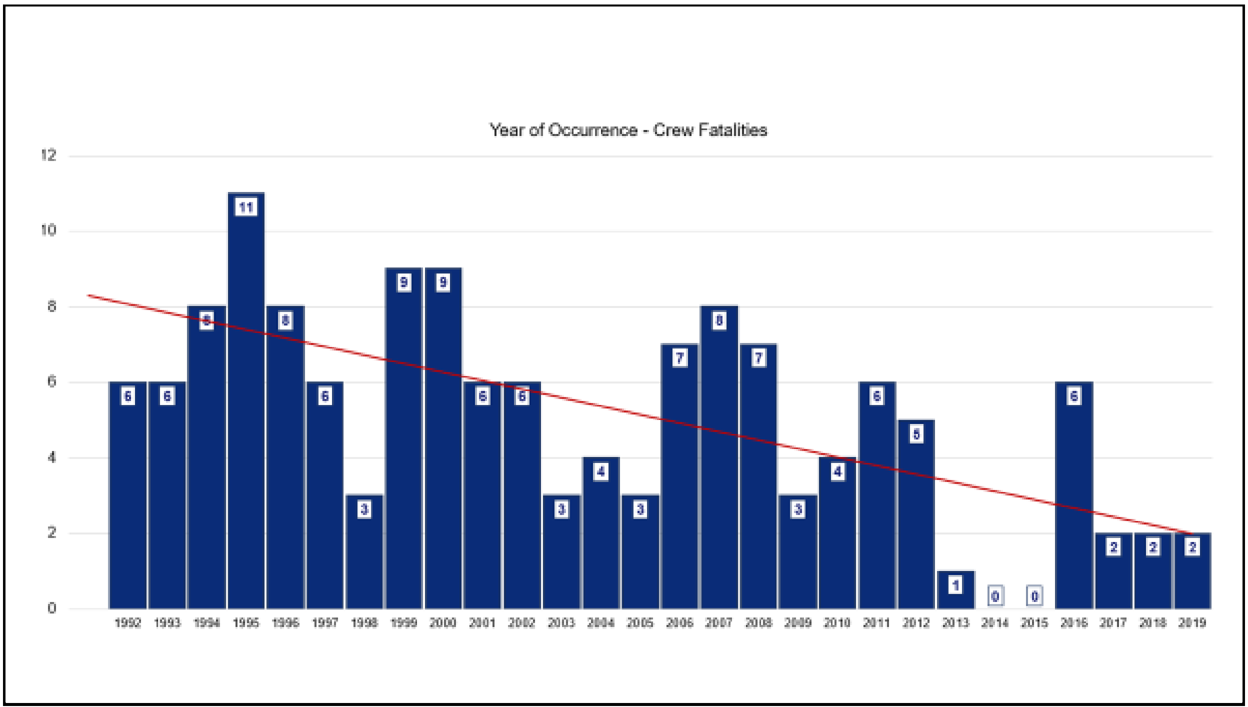

Figure 3.2: Crew fatality frequencies due to occupational accidents on board merchant vessels recorded in the UK MAIB database

Ship type

Analysis indicated that 60.6% of occupational fatalities occur on board solid cargo vessels, which include bulk carriers, container ships and general cargo vessels. Liquid cargo vessels, which include all the product and oil tankers, are ranked second (12.88%), followed by passenger and ro-ro vessels (6.06%), and then passenger-only vessels (6.06%).

Top causal factors (deviations)

Analysis of MAIB fatal accident data indicates that **slipping, stumbling and falling – fall of a person**, at 43.9%, is the most common immediate causal factor for occupational fatalities on board merchant vessels. At 22.7%, **loss of control (total or partial) of machine, means of transport or handling equipment, handheld tool, object, animal** is the second most common immediate causal factor followed by, at 15.7%, **deviation by overflow, overturn, leak, flow, vaporisation, emission**.

When further details of the causal factors are analysed (Level 2), **fall overboard of a person,** 25.8%, **fall of a person to lower level,** 16.7% and **gaseous state – vaporisation formation, aerosol formation and gas formation,** 13.3% make up 55% of the occupational fatalities.

Table 3.3: Top ten immediate causal factors for fatalities at Level 2 – MAIB database

FATALITIES – CAUSAL FACTOR – LEVEL 1	TOP CAUSAL FACTORS – LEVEL 2	%
Slipping, stumbling and falling – fall of a person	fall overboard of person	25.76
	fall of person to a lower level	16.67
Loss of control (total or partial) of machine, means of transport or handling equipment, handheld tool, object, animal	loss of control of an object	12.12
	loss of control of a machine	9.09
Overflow, overturn, leak, flow, vaporisation, emission	gaseous state – vaporisation formation, aerosol formation and gas formation	13.64
	liquid state – leaking, oozing, flowing, splashing, spraying	2.27
Body movement without any physical stress (generally leading to an external injury)	uncoordinated movements, spurious or untimely actions	2.45
	being caught or carried away by something or momentum	3.79
Breakage, bursting, splitting, slipping, fall, collapse of material agent	slip, fall, collapse of material agent – from above (falling on the victim)	2.27
	Slip, fall, collapse of material agent – on the same level	2.27

Mode of injury

In the database, the details for over 90% of the modes of injuries are not available, which might be due to the immediate death of the person. Such lack of details may create a bottleneck in the risk modelling or in developing solutions. Unfortunately, the data sample is too small to make a healthy statistical distribution.

Injury types

Similar to modes of injuries, for over 90% of the fatalities, injury types are not available to study further.

Part of body injured

As expected, over 93% of the fatalities are the result of injuries to 'whole body and multiple sites'. This is directly linked to the top causal factors.

Location of occupational fatalities on board ship

40% of the locations of fatalities on board ship are not available in the database, which affects the quality of the analysis. The location described as **ship**, which includes decks and stairs, makes up 45% of the fatalities, while 15% of the fatalities occur in cargo tanks, followed by the engine department. While 48% of the data is not available at Level 2, more specific locations where the fatalities occur can be listed as **freeboard deck**, 17.5%, **staircases/ladder,** 8.33%, **cargo tanks**, 6.1% and **cargo holds**, 3.8%.

3.4. Comparison

Comparisons of the top ten causal factors between injuries and fatalities (MAIB Database)

Table 3.4: Comparison of the top ten causal factors between injuries and fatalities at Level 2

TOP CAUSAL FACTORS – LEVEL 2	Injury (%)	Fatality (%)
Fall of person on the same level	21.6	
Fall of person to a lower level	17.7	16.67
Loss of control of an object	13.3	12.12
Loss of control of hand-held tool	5.38	
Loss of control of machine	3.55	9.09
Loss of control of transport	2.45	
Lifting, carrying, standing up	8.23	
Liquid state – leaking, oozing, flowing, splashing, spraying	3.06	2.27
Uncoordinated movements, spurious or untimely actions	2.45	2.45
Being caught or carried away by something or momentum	1.89	3.79
Fall overboard of person		25.76
Gaseous state – vaporisation formation, aerosol formation and gas formation		13.64
Slip, fall, collapse of material agent – from above (falling on the victim)		2.27
Slip, fall, collapse of material agent – on the same level		2.27

While six out of ten Level 2 causal factors are the same in both categories, major differences are observed in some immediate causal factors between the two categories. Fall of a person on the same level, with 21.6%, tops the injury category but does not appear in the fatality category. This indicates that the fall of a person on the same level in the majority of cases leads to less serious injuries. In contrast, the top causal factor with 25.76% in the fatality category, **fall overboard of a person,** does not appear in the top ten list of injury category.

Similarly, **lifting, carrying and standing up,** which appears in the injury category with 8.23%, does not appear in the fatality category. However, it should be noted that lifting, carrying and standing up may be causing many long-term injuries such as back problems, which appears prominently in the analysis of the body parts injured. This was highlighted by the reports from the P&I Clubs (Swedish Club 2016 and ABS/LAMAR 2019), American Bureau of Shipping & Lamar University data (ABS/LAMAR 2019) and from a number of articles (Hansen et al. 2002; Lefkowitz et al. 2018).

Comparison of top causal factors (deviations) for occupational fatalities and injuries from different sources

The main analysis in this report was carried out using the MAIB database (1992–2016) covering occupational accidents, supported by the limited database constructed using the investigation reports available worldwide (2000–2020). The comparison of the causal factors identified by various sources was performed using the EMSA (EMCIP) taxonomy. Only the publications which had quality data and comprehensive details and where occupational accidents were studied specifically were used. This approach minimises the assumptions which have to be made during the comparison.

The most comprehensive reports on occupational accidents are published by MAIB (MAIB, 2019) and EMSA (EMSA, 2019) annually and are freely accessible by the public. However, the findings in this report came directly from the analysis of the MAIB data, while EMSA findings are obtained from the published annual reports. For comparison purposes, an academic research report (Bailey et al. 2010) and an article (Çakir 2019) were used since they focused purely on occupational accidents and contained information about the injuries and related circumstances. Other reports utilised for comparison came from two main sources; P&I Clubs' data (Swedish Club 2016 and ABS/LAMAR 2019) and ABS/LAMAR data (ABS/LAMAR 2019). It is worth mentioning that all the reported causal factors by Swedish Club, ABS/LAMAR and Bailey include all kinds of injuries, including fatalities, while the Swedish Club results are based on bulk carriers, container ships and tankers only.

The taxonomy used by the varied sources when reporting the occupational accidents vary; different terminologies may be used; individual injuries may be grouped together rather than reporting them separately; injuries may be mixed with causal factors, or injuries and fatalities due to occupational accidents and shipping accidents are mixed together (such as collision, grounding, contact, etc.) and the necessary details may be unavailable. While reasons may be different for the variations in terms of reporting taxonomy, they create major obstacles for utilisation of data from different sources, comparison of different results and the development of mitigating solutions. A similar problem was faced by researchers, including Bailey et al. (2010). In order to make a comparison of the causes of occupational accidents from different sources, the causes identified by the selected publications were assigned the taxonomy used by EMCIP.

Some of the injuries/causes under different categories were reported together. In these cases, the reported figure is divided equally between the two categories. The comparison of the top causal factors for occupational injuries is made at two levels: Level 1, which provides the groupings of specific causes, and Level 2, which provides the more detailed causes.

Level 1 comparison

Slipping, stumbling and falling – fall of a person is identified by all the data sources as the top causal factor, which accounts for, on average, over 40% of all occupational injuries and fatalities. This also reflects the findings of other sources (Uğurlu et al. 2017; *HealthWatch* 2016; Roberts et al. 2014). UK P&I Clubs reported that the category **slips, trips and falls** represents one in three large insurance claims submitted to the UK P&I Club (UK P&I Club 2012)

The category of **loss of control (total or partial) of machine, means of transport or handling equipment, hand-held tool, object, animal** is ranked by MAIB (fatality), EMSA (fatality) and Çakir (2019) as the second top causal factor for serious injuries and fatalities. The same category is also ranked as second by MAIB (injury) and EMSA (injury), while the Swedish Club ranked it as third, Bailey et al. (2010) ranked it as fourth, and American Club ranked it in fifth place. These different assessments may derive from the fact that some sources included only cargo ships (Worldwide data, Çakir, and Swedish Club) while Bailey's data included both injuries and fatalities combined. Therefore, the data could not be separated.

The causal factor **body movement under or with physical stress (generally leading to an internal injury)** appears to have a very high occurrence with no serious injuries, while its occurrence in the serious/fatality category is almost zero. This causal factor leads mainly to physical stress on the musculoskeletal system, such as back problems. This may not be life-threatening but is detrimental to the quality of life and to being fit for work. On the other hand, the causal factor **deviation by overflow, overturn, leak, flow, vaporisation, emission** has a high occurrence under the serious injury and fatality category compared to the less serious injury category, as exposure to such dangerous conditions (such as enclosed space entry) generally results in multiple deaths, as highlighted by various publications (*HealthWatch* 2016; Roberts et al. 2014).

When the causal factors in Level 2 are analysed, a comparison is made with smaller data sources due to the unavailability of more details – again, under two categories, serious injury/fatality and injury.

Where the serious injury/fatality category is concerned, **fall overboard of person and fall of the person to lower level** appears to be the consistently top-ranked causal factor by three different sources. Indeed six out of ten top Level 2 causal factors are similar among the different data sources. Variations may come from the composition of the ship types in each database and the sample size.

While **fall overboard of a person** is recorded as the top causal factor for fatalities, none of the databases, including accident investigation reports, mention suicide, which is generally reported as 'man overboard' and 'missing at sea'. A study by Seafarers International Research Centre (Sampson and Ellis 2019) stated that maritime administrations infrequently recorded suicides as discrete events, which causes difficulty with data analysis and interpretation of the results. In the same report, it was stated that P&I Clubs may also be overlooking suicides and would not record them as suicide incidents but rather as accidents. Otherwise, families may not get insurance money and therefore, it may be better from the family and community point of view if they are recorded as occupational accidents (Sampson and Ellis 2019).

The under-reporting of suicides as suggested by this report was highlighted in earlier research (Iversen 2012), which indicates that if half of the 'missing at sea' people are included under suicide, the suicide rates would be significantly higher and may trigger more decisive action by the shipping community. A P&I Club presented the suicide statistics and emphasised the under-reporting by referring to the number of seafarers' deaths recorded as **missing at sea** (Pathak 2019).

3.5. Exploratory analysis to check the significant relations between occupational accidents and causal factors

Exploratory analysis was extended in an attempt to capture the significant relations between the immediate causal factors and the underlying factors for occupational accidents. However, as indicated earlier, due to missing/unavailable data for different layers in the database, only a higher level of relations between the umbrella factors can be checked. Chi-square tests were run to check the significant relation between Occupational Accident types (Deviations) and the other umbrella causal factors such as Mode of Injury, Type of Injury, Part of Body Injured, Geographical Location of Accidents, Location Onboard etc. Further exploratory analysis, namely a Symmetric Correspondence Analysis (SCA), was performed for further insight into the possible relations that may exist amongst the variables under umbrella groups. Even the SCA tests suffer from the lack of data entries and therefore, relations identified need to be interpreted further.

Chi-square tests indicated that there is a significant relation between Occupational Accident types (Deviation) vs Mode of Injury, Occupational Accident types (Deviation) vs Type of Injury, Occupational Accident types (Deviation) vs Part of Body Injured, Occupational Accident types (Deviation) vs Severity of Injury, Occupational Accident types (Deviation) vs Location Onboard, Occupational Accident types (Deviation) vs Ship Types. However, chi-square tests indicated that there is no relation between Occupational Accident types (Deviation) vs Weather Conditions.

SCA tests indicated some relation between specific accident types and other underlying factors, including **breakage, bursting, splitting, slipping, fall, the collapse of material (Deviation)** and **trapped, crushed, etc. (Mode of Injury)**; **slipping – stumbling and falling – fall of a person (Deviation)** and **horizontal or vertical impact with or against a stationary object (the victim is in motion)**; **slipping – stumbling and falling – fall of a person (Mode of Injury – Deviation)** and **bone fractures (Type of Injury)**; **body movement under or with physical stress (generally leading to an internal injury – Deviation)** and **back, including spine and vertebra in the back (Part of Body Injured)**; **slipping – stumbling and falling – fall of a person (Deviation)**and **less serious (Severity of the Injury)**.

Symmetric Correspondence Analysis tests indicate a relation between **slipping – stumbling and falling – fall of a person (Deviation)** and **open sea (Geographical Location)**: this can be interpreted as a person falling into the water and generally occurs in the open sea. As far as the location onboard is concerned, **slipping – stumbling and falling – fall of a person (Deviation)** and **accommodation (Onboard Location)**; **body movement without any physical stress (generally leading to an external injury (Deviation)**; **cargo and tank areas (Onboard Location)**; **deviation due to electrical problems, explosion, fire** and **engine department (Onboard Location)** are examples of relations established by Symmetric Correspondence Analysis tests.

As far as ship types are concerned, SCA indicates a relation between **slipping – stumbling and falling – fall of a person (Deviation)** and **passenger ship (Ship Type)**; **deviation by overflow, overturn, leak, flow, vaporisation, emission (Deviation)** and **cargo ship (Ship Type)**.

While these results provide some insight, the exploratory analysis highlighted the importance of the completeness and quality of data, which affect the quality of intelligence gathered to establish the relationship between the immediate causes of the occupational accidents and the underlying factors. Attempts to run different analyses to establish significant relations between underlying factors and the top accident types were not successful due to missing data in the different layers.

For very serious injuries (fatalities), missing data can be supplied by the experts, as there are associated accident investigation reports. However, for less serious injuries, unfortunately, data is permanently missing. This creates a fundamental problem and a barrier to learning from accidents.

Overall, available databases, which are prepared as part of the regulatory framework, in their current form, may not be suitable for identifying the underlying factors, including human and organisation factors, for occupational accidents. A complete taxonomy coupled with a well-structured template may help towards the future collection of occupational data.

4. DISCUSSIONS AND CONCLUSIONS

Based on the review of the evidence and the exploratory data analyses, conclusions can be presented under three different headings: evidence in the existing literature; major data sources with regards to the occupational accidents; and determination of causal factors through analysis of available databases.

Evidence in existing literature

The publicly available literature is mainly based on data obtained through i) surveys from seafarers, shipping company managers and administrations, ii) occupational accident data from companies, national maritime administrations and P&I Clubs, and iii) publicly available accident investigation reports. The results are mostly presented in the form of frequency analysis with some limited established links between injuries/fatalities and causes. Some of the conclusions from the literature review can be highlighted as follows:

- In general, occupational injuries and fatalities have decreased significantly over the years, although some studies have suggested there has been a slight increase since 2009. This contradiction may be due to the quality of data and the way that data is presented.
- Based on the evidence available in the existing literature, the top ten immediate causal factors for occupational accidents can be identified and commonly agreed in the publications by the different researchers and industry stakeholders. However, the quality of the evidence for causal links between the top occupational accident types and underlying factors as well as root causes is generally poor, i.e. it is more speculative than empirical. This limits how much the results from the studies can be relied upon. As far as the root causes are concerned, only very limited evidence is available, and this evidence focuses in particular on the safety culture, onboard working and living conditions.
- 'Slipping, stumbling and falling of a person' is the top immediate causal factor for occupational injuries and fatalities identified by the literature review. The most common injury type identified in the literature is 'Strain, sprain or twist', which is closely followed by 'Break or fracture'. 'Upper extremity of the body', 'arm/shoulder/hand/wrist' has the highest injury rates. The literature review highlighted 'Work on deck' as the most dangerous location onboard the ship, followed by the engine room. Limited publications looking into underlying reasons for fatalities due to occupational accidents highlight the 'Dangerous work practices and ignorance of rules' as the most common underlying reason.
- While existing literature based on the available data does not mention suicide in their analysis of occupational accidents, some literature on maritime health/illnesses highlights the growing concern about suicide among seafarers. Such fatalities are recorded as 'falling from height' or 'missing at sea'. The literature review indicated that over one-third of seafarers experience mental deterioration. Moreover, there is a gap in the body of the knowledge with regards to the effect of mental deterioration on the performance of seafarers.
- The body of knowledge presented in the literature does not provide any link between occupational injuries and 'Ship types', 'Ship design deficiencies', 'O&M deficiencies', 'Manning levels', 'PPE use' and 'Onboard working and living conditions'.

- For non-fatal injuries, the data is very limited (especially if the accident is not investigated) and any available data is not suitable for further analysis. In those cases, some of the researchers collected the supporting evidence through a number of surveys or face-to-face interviews in order to identify the underlying reasons. Some researchers deploy both data and survey to complete the data sets.
- A significant number of researchers highlighted the problems with data regarding occupational injuries in terms of availability, completeness, compatibility and accessibility. Terminology and the taxonomy used in the existing literature vary depending on the data source, creating difficulty with completeness, quality of the data and in the comparison of the results. This naturally limits the development of mitigating solutions for occupational accidents. The literature review clearly highlights the requirement to collect more comprehensive data using the internationally accepted taxonomy, which should also include Human Factors Analysis and Classification System (HFACS) and environment, which cannot be captured easily by the current accident reporting practices.

Available data sources

Publicly or commercially available data sources relating to occupational accidents vary significantly in terms of quality, completeness and accessibility, depending on the seriousness of the accidents, whether an investigation is carried out for a particular accident, the reporting approach adopted by the national authorities, the subsequent process of creation of the database and the taxonomy followed during the process.

Overall, current data sources, at best, cannot be utilised to develop mitigating solutions without further data processes and comprehensive taxonomy. Some of the concluding points with regards to the data sources can be listed as:

- Accident investigation reports, which are only available for life-threatening injuries, fatalities or significant shipping accidents, are the richest publicly available data source for occupational accidents. Most of these reports are made available to the public by the relevant national administrations, and thus, the reports are an excellent source for gaining insight into maritime accidents. Although accident investigation reports and the reports held by reporting platforms provide a wealth of data, they need to be re-processed, analysed and structured as a database covering all causal chains by following a standardised taxonomy that includes maritime human factors. Unfortunately, such an initiative requires significant resources, which creates a substantial barrier to building a comprehensive database for occupational accidents.
- IMO-GISIS and EMCIP – the official accident reporting platforms for the International Maritime Organisation (IMO) and the European Maritime Safety Agency (EMSA) – suffer from significant under-reporting of less serious occupational accidents.
- EMSA, which receives less serious accident reports on a voluntary basis from national administrations, makes them available to the public for the previous 12 months. Even these reports in their current form have limited benefits for further analysis because they lack the details for further analysis and therefore cannot be used to develop mitigating solutions.
- Despite over 90% of occupational accidents being less serious (non-life threatening), they are not available on any of the publicly available data sources for analysis. The unavailability of such data prevents a great opportunity of ‘learning from incidents and near misses’ to develop mitigating solutions to enhance occupational safety in shipping. Reporting practice for less serious occupational accidents varies significantly from one administration to

another, and even the best accident reporting form is not beneficial in identifying the underlying causes of the occupational accidents that have been investigated.

- Some national administrations have possibly the best data sources (database form) for occupational accidents, which can be used for detailed analyses covering the causal chain. Even national administrations suffer from under-reporting or lack of details when it comes to less serious occupational accidents. However, databases held by national administrations are designed to address the regulatory requirements and not necessarily designed for extensive analysis to establish the causal links between underlying reasons and the accidents. National databases are not publicly available.
- Voluntary reporting platforms which hold the voluntary reports of accidents, incidents and near misses collectively provide an excellent source of data but lack consistency and essential details required for comprehensive data analysis.
- Data reporting and collection should be designed to provide opportunities to learn from the accidents, incidents and near misses in order to improve the onboard safety of ships. This means a more comprehensive and standardised taxonomy for data collection and analysis is required. Umbrella organisations such as IMO should lead the way to create the much-needed taxonomy and update ISM/SMS to make sure it facilitates the learning culture.
- In order to gain the benefit from available data, it should be made available to wider stakeholders to accelerate the knowledge generation from data intelligence for the benefit of the shipping sector. However, current confidentiality issues create a barrier to this opportunity and a significant and concerted effort is required to find a way to make the occupational accident data in the anonymised form available more widely.

Exploratory analysis of the available databases

Exploratory analyses of the available existing databases were carried out to determine what insight can be derived from them in their current form. Analyses were carried out under two main headings; very serious occupational accidents onboard commercial merchant ships (fatalities), where generally accident investigation reports are available; and less serious injuries, where generally accident investigations are not carried out.

- Occupational injuries and fatalities onboard merchant ships show decreasing trends over the years. Exploratory analyses using the occupational accident database for fatal occupational accidents clearly indicate that **fall overboard of a person** is the top immediate causal factor for fatalities. Exploratory analyses using occupational accident databases also revealed **slips, trips and falls on the same level** is the top immediate causal factor for injuries. This evidence is also supported by the literature review.
- Exploratory analyses clearly indicate that dry cargo ships, particularly bulk carriers, have the highest fatality and serious injury rates, while passenger ships appear to have the highest less serious injury rates. **Ship decks, accommodation** and **engine room** are the top three locations on board ships where the highest number of occupational accidents occur. Exploratory analyses indicate that **dislocations, sprains and strains, bone fractures**, and **wounds and superficial injuries** make up over 76% of the occupational injury types. Exploratory analyses provide evidence that **back, including spine and vertebra in the back, upper extremities, head, lower extremities** and **whole body and multiple sites** make up the top five injured body parts.
- Current databases can provide excellent evidence to identify the top immediate causal factors for very serious occupational accidents. However, the databases lack quality and reliable data for less serious injuries.

- Exploratory analysis to capture the significant relations between the immediate causal factors and the underlying factors provided only high-level relations between the umbrella factors. Due to missing/unavailable data for different layers in the database, including human and organisational factors, only limited relationships can be established. The current databases, without including the human and organisational factors, cannot be used effectively to identify the links between the immediate causes and the underlying reasons for the occupational accidents, including poorly designed ships.
- However, exploratory analyses clearly demonstrate that a structured occupational accident database constructed using a standardised taxonomy will provide the best platform to establish clear links between the injuries/fatalities, immediate causal factors and root causes.

Every year a high number of seafarers are injured, permanently disabled or lose their lives due to occupational accidents at sea. Based on the review of the evidence and the exploratory analyses carried out, **slipping, stumbling and falling of a person** is the top immediate causal factor, making up over 50% of the occupational injuries and fatalities onboard merchant ships. Indeed, existing evidence from different academic publications, the industry and authorities indicate clearly the top immediate causal factors for occupational injuries. However, there is limited evidence in the published work about the contributory factors as well as the underlying reasons of the personal accidents.

A number of researchers highlighted that shortcomings in the availability, quality, completeness and compatibility of the occupational accident data are a major barrier to building evidence in order to identify the contributory factors and root causes for occupational accidents. While deficiencies with data may be a reality, such deficiencies can be significantly minimised by generating and intelligently combining the different data sources. This study identified the need for a globally adopted comprehensive taxonomy for the maritime industry that includes complete human and organisational factors. Moreover, such a database based on the appropriate taxonomy, coupled with various analysis techniques, can play a very important role in establishing the causal links between different physical and non-physical parameters and conditions and in developing mitigating solutions. The current H2020 project SAFEMODE (SAFEMODE, 2019) is in the process of developing the Human Factors taxonomy for the maritime industry in close cooperation with regulatory bodies to complement EMCIP taxonomy. The globally adopted taxonomy should be used not only by accident investigators but also by the shipping companies, which are required to collect hazardous occurrences, report on them, and use this to enhance OHS onboard ships as part of the International Safety Management Code.

It can be stated that the mental health of seafarers is a growing issue that may have a causal link to occupational injuries and fatalities. This topic should be included in any systemic efforts linked to the occupational safety of seafarers.

The study has not identified any large scale/systemic project(s) focusing on the occupational injuries and fatalities of seafarers. Based on the publications reviewed, there is also very limited international cooperation between different stakeholders/researchers to address maritime occupational accidents. Individual efforts performed in isolation will not generate the much-required evidence and impact on influencing the policymakers, regulatory bodies, ship designers, industry and shipping companies to find solutions, including safer ship designs to stop occupational injuries and fatalities in the maritime sector. Preventing occupational injuries and fatalities is extremely important as the number of seafarers who have been injured and who have lost their lives is very high, and this requires a more collaborative systemic effort supported by all the stakeholders.

APPENDIX A: REFERENCES

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APPENDIX B: MAJOR DATA SOURCES

CHIRP Maritime	https://www.chirpmaritime.org/
EMCIP	http://www.emsa.europa.eu/emcip.html
IMCA	https://www.imca-int.com/alert/alerts/safety-flash/
IMO-GISIS	https://gisis.imo.org/Public/MCI/Default.aspx
MARS	https://www.nautinst.org/resource-library/mars.html
Nearmiss.dk	http://uk.nearmiss.dk/

APPENDIX C: METHODOLOGY

C.1 Key words and phrases

Four groups of terms/phrases were identified for use during searches and analyses of literature, accident reports and databases:

Occupational injuries/fatalities in shipping:
Fatalities/fatal Injuries/incidents/less serious injuries/near misses/serious injuries/suicides

Type of injury and part of body injured:
Sprains and strains/burns and scalds/closed fracture/concussions/dislocation/fracture/loss of body part/open wounds/arm/back/eyes/fingers/foot/hand/head/lower extremities/neck/torso and organs/whole body

Causes of occupational accidents:
Asphyxiation/caught by moving objects/drowning/electrocution/explosion/fire/ falls and trips/fall from height /heat stress/lack of oxygen/loss at sea/loss of control/poisoning/suffocation/toxicity/violence

Types of ships/location of occupational accidents:
Bulk carrier/cargo ships/cruise vessels/ flag state/ferry/offshore vessels/passenger ships/solid cargo/tanker/cabin space/deck/engine room/cargo hold/enclosed space/stairs and ladders

C.2 Types of resources reviewed

In order to compile and compare the information and database related to occupational accidents in merchant shipping, three different sources, which are complementary, were searched using different platforms:

Scientific and industrial literature: These sources were mainly from scientific literature, i.e., published research articles/papers, research reports, as well as industry journals, magazines and newspaper articles on incident reports.

Accident reports and statistical data: These were essentially accident investigation reports and statistical data of official national and international databases. Databases collected by voluntary industry or NGO establishments were also identified and reviewed.

Internet-based grey literature: These sources included information about occupational hazards observed in the merchant shipping sector, including mental health issues on various internet websites, industry forums and associations, as well as internet-based magazines.

C.2.1 Scientific literature review

Web of Science, Science Direct, Scopus and Google Scholar were utilised to search the scientific databases that Strathclyde University has access to, and the database searches were performed for the 2000–2020 timespan by using the key search terms or words related to occupational accidents in merchant shipping.

The scientific literature database searches and online searches were undertaken using the set of search terms/phrases detailed in Section C.1.

Following the initial collection of the articles based on the keywords, all the papers were firstly scanned in terms of relevance by reading the abstracts and the conclusions and the relevant articles and reports were retained for in-depth review. The retained publications were studied, analysed and categorised in terms of the type of data utilised, the severity of the injuries, and whether they dealt with fatality or injury. The literature review sought answers to the following questions:

- What evidence exists concerning immediate causes of accidents in the maritime industry?
- What evidence exists concerning underlying causes of accidents in the maritime industry?
- How far can the results from the studies enable causal chain links to be established between underlying causes and immediate causes?

C.2.2 Identification of statistical databases

Major data sources for occupational marine accidents were identified and reviewed by seeking :

- which data sources are publicly available
- what data sources are held by the marine administrations
- what type of data is held by voluntary reporting platforms
- what type of data is provided by commercial data suppliers
- what taxonomy has been utilised, and how complete is the available data for further analysis.

UK MAIB, EMSA EMCIP and IMO-GISIS are among the major databases which were looked at as part of this study.

C.2.3 Identification and collection of accident investigation reports

The project team identified the available accident investigation reports between 2000 and 2020 from national and international authorities, including UK, EMSA, Hong Kong, Malta, Germany, Japan, Denmark, Sweden, Norway, Finland, Australia, Isle of Man Administration, Marshall Islands, Bahamas, Canada, and the USA. CHIRP Maritime, which holds a list of the accident investigation reports from around the world, provided a good platform from which to reach the accident investigation reports. All the available reports were manually checked online by reading the abstract and identified by the accident investigation reports that are related to occupational accidents. Over 400 occupational accident investigation reports identified worldwide were manually downloaded for further analyses. Accident investigation reports were only available for accidents that resulted in fatalities or serious injuries.

The project team also utilised voluntary reporting platforms, such as IMCA, MARS, Nearmiss.dk, and CHIRP Maritime to capture occupational accidents with less serious injuries.

C.3 Exploratory analyses of the available databases

The study performed exploratory analyses of the available data to determine the top causal factor chains and compare the top causal factors against the existing findings from the literature. This was performed by:

3.1 utilising the MAIB accident database, which was accessible by the project team, and by performing the analysis for injuries and fatalities separately according to the EMSA taxonomy

3.2 checking the feasibility of the existing database for occupational accident analysis to determine the causal chains

3.3 creating the database by studying the investigation reports collected worldwide to identify only the top causal factors for fatalities or serious occupational injuries

3.4 comparing the top causal factors obtained from the MAIB database analysis to the causal factors collected from published literature and grey literature as well as the causal factors identified through analysis of the inhouse database.

C.4 Evaluation of the results to identify the current gaps, and provide future recommendations

Evaluate the gaps with the available data and literature, and make recommendations to eliminate the gaps in the database, including the classification of incidents and taxonomy, to perform a structured causal chain analysis with the aim of developing mitigating solutions for occupational accidents.

APPENDIX D: MAJOR DATA SOURCES OF MARINE INCIDENTS

The following major maritime data sources were identified and studied with a focus on occupational accidents in shipping:

- Marine Accident Databases of flag administrations
- Marine Accident Investigation Branches of the flag administration, if they are separate from the flag administration
- IMO Global Integrated Shipping Information System (IMO-GISIS),
- European Marine Safety Agency – European Marine Casualty Information Platform EMCIP (EMCIP)
- Voluntary reporting platforms
  - CHIRP Maritime, Aviation and Maritime Confidential Incident Reporting Platform (CHIRP Maritime)
  - Mariners' Alerting and Reporting Scheme (MARS) run by the Nautical Institute
  - Safety Flashes – International Marine Contractors Association (IMCA)
  - Nearmiss.dk – joint co-operation between Danish Shipowners' Association and Seahealth (Nearmiss.dk)
- Commercial data suppliers

The individual data sources are studied in terms of content, accessibility, and quality of the database. The assessment is summarised under the advantages and gaps headings, and where possible quick tests are carried out to check the quality of data.

IMO GLOBAL INTEGRATED SHIPPING INFORMATION SYSTEM (IMO–GISIS)

Details:

IMO-GISIS is developed and maintained by the IMO. It allows maritime administrations to provide the required information about marine accidents online to the IMO secretariat, in compliance with IMO's instruments. The collected information is accessible by the public and the other administrations. All marine casualties and incidents should be reported using IMO's harmonised reporting guideline, which is a very detailed and complete document (MSC_MEPC_3_Circ_4, 2014).

Advantages:

- Mainly very serious and serious marine accidents such as collision, grounding, fire etc are reported with investigation reports.
- Investigation reports, if available, can be accessed by the public after creating a registration and can be downloaded.
- Selection of the specific accident types and information is possible.
- The investigation reports and accident database are downloadable in database format.

Gaps:

- On IMO-GISIS, extremely limited information is available about occupational accidents. Some administrations are providing only the minimum required information about the accidents, which is due to limited resources or the fact that the information is not available in the first place.

- Comprehensive taxonomy is not applied to capture all the details of the accidents.
- IMO-GISIS suffers significantly from under-reporting and unavailability of details.
- For occupational accidents, causal details are not available in data format, and therefore investigation reports need to be studied to create a more detailed database for further analysis.
- In its current form, it is impossible to utilise the database for occupational accidents for any insight or statistical analysis.

EUROPEAN MARINE CASUALTY INFORMATION PLATFORM – EMCIP

Details:

European Marine Casualty Information Platform – EMCIP is a database and data distribution system operated and maintained by EMSA since 2011. EMCIP has been collecting marine casualty details and reports from the EU/EEA member states. EMSA produces an annual report which includes trends and annual statistics for major ship accidents and ship types.

Advantages:

- All the data recorded since 2011 is accessible by the public.
- All the EU/EEA countries report to EMCIP using the same taxonomy.
- By selecting the key parameters of interest, quick statistical analysis and results can be generated online.
- All the investigation reports are accessible through the website if the investigation report is available.
- Annual reports, which include statistical analysis of the accidents, are made available by EMSA as an annual public report.

Gaps:

- Information about the accidents is not downloadable in database format.
- Extremely limited information is available for the incidents, which do not have investigation reports.
- For detailed analysis, investigation reports have to be studied, and a new database needs to be created.
- Incidents/accidents without investigation reports are reported as a summary report and can be accessed by the public for only one (1) year.
- Less serious occupational injuries are hardly reported as it is done on a voluntary basis. This creates a significant barrier to gaining an insight into the less serious injuries.

MARINE ACCIDENT INVESTIGATION REPORTS BY NATIONAL ADMINISTRATIONS

Details:

Most of the national administrations allow the public to access the accident investigation reports, which are generally available for very serious and, on some occasions for serious accidents. They are available online via individual administration websites. The key national administrations which provide a large number of reports, among others, are the UK, Hong Kong, Malta, Germany, Japan, Denmark, Sweden, Norway, Finland, Australia, Marshall Islands, Bahamas, Canada, and the

US. The CHIRP Maritime reference database provides a direct link to access some of these databases.

Advantages:

- Investigation reports are the most informative and the most useful source of information to create scientific analysis and studies about the occupational accidents.
- Freely accessible by the public.

Gaps:

- Only the investigation reports are available.
- Other reported incidents, which are not investigated, are not available to the public but stored in the database of each national administration.
- Some of the reports are available only in the national language with English narratives, which may vary in quality and details depending on the national administration.
- All these reports need to be studied and converted to the database using a common taxonomy for further detailed analysis. This is not an easy task and requires expertise to interpret the data.
- Suicides are not properly identified and reported.

CHIRP MARITIME (https://www.chirpmaritime.org/)

Details:

Derived from the aviation industry, CHIRP Maritime is a voluntary and confidential reporting system for all individuals employed in or associated with the maritime sector. The main aim is to enhance the safety of the maritime industry worldwide. Chip Maritime collects the information on the near misses, unsafe acts/unsafe conditions or incidents, then analyses the report with experts and provides the key outcomes through online publication in terms of underlying reasons and suggestions for improvement.

The second service that CHIRP Maritime provides is a reference library with accident and incident reports from major national maritime administrations with a link to the investigation report.

Advantages:

- All the collected near miss reports and analysis and suggestions are available to industry/the general public to enhance safety.
- Excellent platform is provided for lessons to be learned and safety enhancement.
- Reference database provides a very brief incident type, country and an easy link to the investigation report.

Gaps:

- All the reported near misses, analyses and solutions are not available in a database form (at least to the public). For further analyses, such a database would need to be generated by studying the reports using a comprehensive taxonomy.
- The reference library is excellent but could cover more countries.

MARS

Details:

MARS (The Mariners' Alerting and Reporting Scheme) is primarily a confidential reporting system run by the Nautical Institute to allow the full reporting of accidents (and near misses) without fear of identification or legal challenges. Provided free of charge and open access, MARS informs the industry in the form of alert reports derived from official industry sources, so that challenges resulting from recent incidents can be effectively communicated to the mariners on board ships and other relevant bodies. All the confidential reports submitted to the MARS platform since 1992 are available on the MARS website for public use.

Advantages:

- Provides a very useful database containing near misses, unsafe acts/conditions, and incidents which cannot be accessed via primary official data sources.
- Data collected over 25 years can be analysed in a time frame to identify the changes with the types of issues reported.

Gaps:

- All the reported near misses, incidents, and accidents are available for public access in the form of a short/narrative report. For further analyses, they need to be studied and utilised to generate a database. With the available information it may not be possible to capture all the underlying reasons.
- The form has certain sections where the reporter needs to provide textual description of the events. However, there is no taxonomy utilised to fill in the form.
- Out of 1,805 confidential reports, approximately 20% of them are related to occupational accidents and may need to be added to the other database to increase the number of records.

IMCA

Details:

The International Marine Contractors Association (IMCA) is a trade association representing the vast majority of contractors and the associated supply chain in the offshore marine construction industry worldwide. IMCA has been collecting critical safety matters and incidents through confidential reporting from members since 1997. IMCA processes and disseminates them to its members and wider public in the form of safety flashes on incidents and potential hazards, and the lessons learnt from them which can help prevent incidents occurring elsewhere in the industry.

Advantages:

- Provides a very useful database containing near misses, unsafe acts/conditions and incidents which cannot be accessed via primary official data sources
- Data collected over 23 years can be analysed in a time frame in order to identify the changes with the types of issues reported over the years

Gaps:

- All the reported near misses, incidents and accidents are available to the public in the form of short/narrative reports (safety flashes). However, for further analyses they need to be studied and utilised to generate a database. Members of IMCA can have access to the database and/or the safety statistics which IMCA publishes annually.

- The form has certain sections where the reporter needs to provide textual description of the events with some photographs, if available. However, there is no taxonomy utilised to fill in the form.
- Only a small percentage of confidential safety flashes are related to occupational accidents on merchant vessels.

NEARMISS.DK

Details:

Nearmiss.dk was established in a joint co-operation between Danish Shipowners' Association and Seahealth. It is a database which collects the near miss events from the ships owned by the Danish shipping companies. By reporting to the same database the industry draws experience from other companies in an effort to reduce the number of accidents on board merchant vessels.

Advantages:

- Very useful database containing near misses, unsafe acts/conditions, and incidents which cannot be accessed via primary official data sources.
- Public can register to access the database freely.
- Data collected over 19 years can be analysed in a time frame to identify the changes with the types of issues reported over the years
- Around 700 near misses/incidents are available for occupational hazards.

Gaps:

- All the reported near misses, incidents, and accidents are available to the public in the form of short/narrative report form (safety flashes). However, for further analyses they need to be studied and utilised to generate a database.
- The form has certain sections where the reporter needs to provide textual description of the events. However, there is no taxonomy utilised to fill in the form.
- Since 2013, there has been only a small number of entries in the system, and therefore this may not capture the status in the industry over the last seven years.

ACCIDENT DATABASES GENERATED AND HELD BY NATIONAL ADMINISTRATIONS

Details:

Most of the national administrations create and maintain a marine accident database covering all types of accidents including less serious (minor injures), serious injuries and very serious occupational accidents (fatalities).

Advantages:

- Most of the national administrations have a complete accident database which is suitable for in-depth analyses. Possibly the most comprehensive databases available.
- Continuously updated systems will provide the analyst with time-based statistics.
- They follow a certain taxonomy.

Gaps:

- Public access to the data is not available.
- In some circumstances an anonymous version of the database may be provided for non-commercial research studies subject to agreement.
- Suicides are not addressed separately, and therefore it is not easy to separate them from other injuries or fatalities.

- The database is created generally by studying the accident investigation reports and accident reporting forms using a certain taxonomy, which may change from one country to another. The database may suffer from the availability of accident details, particularly less serious accidents, which are not investigated. Therefore, the database may not be comprehensive enough to capture the root causes or underlying reasons.
- Creating an accident database for further analysis is a resource-intensive process and capturing the full details – particularly the underlying reasons or human/organisational factors – may not be possible.
- The database covers only their registered vessels or the vessels involved in marine accidents in their territorial waters. This may result in scarce data for some countries.
- Less serious occupational accidents may not have the necessary details for in-depth analysis.

COMMERCIAL MARITIME INTELLIGENCE DATA PROVIDERS

Details:
There are maritime business intelligence companies such as Lloyds List Intelligence and IHS Markit which provide data information services, including maritime casualties, through subscribed membership. Their main focus on maritime casualty intelligence is the ship-related casualties such as collision, grounding, fire etc.

Advantages:
- Wide range of data in ship operations is available from the same source.

Gaps:
- Occupational accidents are not included in their services.
- Only subscription-based access is available at commercial rates.

P&I CLUBS

Details:
Protection and Indemnity or P&I Clubs are non-governmental, non-profitable mutual or cooperative associations of marine insurance providers. They provide protection and indemnity insurance to their members, including ship owners, operators, charterers, and seafarers. Through the insurance claims, they gather marine casualty data from their clients who file claims for the marine incidents linked to their ships.

Advantages:
- Their data will be relevant for studying the occupational accidents.
- Suicides are covered under a separate heading provided such investigations are properly recorded onboard the ship.

Gaps:
- Their focus is on insurance claims, and data relevant to the detailed studies may not be collected by P&I Clubs.
- Their data is not readily available, except their annual reports which may provide very relevant but limited information about occupational accidents. They have provided their data for research purposes in the past.

APPENDIX E: EMSA EMCIP TAXONOMY

EMCIP Taxonomy

The European Marine Casualty Information Platform (EMCIP) is a database and a data distribution system operated by the European Maritime Safety Agency (EMSA), the European Commission and the EU/EEA Member States. EMCIP's main objective is to deliver a common data system for marine casualties for EU/EEA countries:

- to improve the information about marine casualties and incidents using common taxonomy;
- to widen and deepen the opportunities regarding the analysis of the results of casualty investigations;
- to enable general risk identification and profiling;
- to share lessons learned and safety issues detected in the course of safety investigations.

Notification of marine casualties and incidents, and reporting of data resulting from safety investigations in EMCIP, by using the EMCIP taxonomy, has been mandatory for member states since 17 June 2011. EMCIP provides a platform:

- to report and store data related to marine casualties and incidents involving all types of ships;
- to store occupational accidents related to ship operations, including causal factors;
- to enable the production of statistics and analysis of the technical, human, environmental and organisational factors involved in accidents at sea.

EMCIP is also connected to Global Integrated Shipping Information System (IMO-GISIS), managed by the International Maritime Organisation (IMO), to report marine casualties without any duplication of effort (EMSA). EMCIP taxonomy has been used by European Member and EEA states when they are reporting the accidents. While it follows IMO harmonised reporting rules, EMCIP developed a much more comprehensive taxonomy to enable the construction of a full risk model and to perform risk assessments. It covers both factual and contributory factors. With regard to occupational accidents, it provides taxonomies to capture different factors at different levels of detail. The MAIB occupational accident database is also based on the EMCIP taxonomy, which has the structure seen in the table below with regard to occupational accidents. Ship and environment-related information are also included in the taxonomy. Further details of Level 1 and Level 2 for some causal and injury-related taxonomy are given below, while full details can be accessed on the EMSA website (EMCIP Glossary, 2016).

DEVIATION LEVEL 1	MODE OF INJURY LEVEL 1	TYPE OF INJURY LEVEL 1	PART OF BODY INJURED LEVEL 1
Deviation Level 2	Mode of Injury Level 2	Type of Injury Level 2	Part of Body Injured Level 2
Deviation due to electrical problems, explosion, fire	Contact with electrical voltage, temperature, hazardous substances	Wounds and superficial injuries(MAIB*)	Head
Electrical problem due to equipment failure - leading to indirect contact	Indirect contact with a welding arc, spark, lightning (passive)	Superficial injuries	Head (Caput), brain and cranial nerves and vessels
Electrical problem - leading to direct contact	Direct contact with electricity, receipt of electrical charge in the body	Open wounds	Facial area
Electrical problem - leading to direct contact	Contact with naked flame or a hot or burning object or environment	Other types of wounds and superficial injuries	Eye(s)
Explosion (Explosion)	Contact with a cold or frozen object or environment	Bone fractures (MAIB*)	
Fire, flare up	Contact with hazardous substances - through nose, mouth via inhalation	Closed fractures	Ear(s)
Other	Contact with hazardous substances - on/through skin or eyes	Open fractures	Teeth
Deviation by overflow, overturn, leak, flow, vaporisation, emission	Contact with hazardous substances - through the digestive system by swallowing or eating	Other types of bone fractures	Head, multiple sites affected
Solid state - overflowing, overturning	Other group 10 type Contacts -Modes of Injury not listed above	Dislocations, sprains and strains(MAIB*)	Head, other parts not mentioned above
Liquid state - leaking, oozing, flowing, splashing, spraying	Drowned, buried, enveloped	Dislocations and subluxations	Neck, inclusive spine and vertebra in the neck
Gaseous state - vaporisation, aerosol formation, gas formation	Drowned in liquid	Sprains and strains	Neck, inclusive spine and vertebra in the neck
Pulverulent material - smoke generation, dust/particles in suspension/emission	Buried under solid	Other types of dislocations, sprains and strains	Neck, other parts not mentioned above
Other	Enveloped in, surrounded by gas or airborne particles	Traumatic amputations (Loss of body parts)(MAIB*)	Back, including spine and vertebra in the back
Breakage, bursting, splitting, slipping, fall, collapse of Material Agent	Other group 20 type Contacts	Concussion and internal injuries(MAIB*)	Back, including spine and vertebra in the back
Breakage of material - at joint, at seams	Horizontal or vertical impact with or against a stationary object (the victim is in motion)	Concussion and intracranial injuries	Back, other parts not mentioned above
Breakage, bursting - causing splinters (wood, glass, metal, stone, plastic, others)	Vertical motion, crash on or against (resulting from a fall)	Internal injuries	Torso and Organs
Slip, fall, collapse of Material Agent - from above (falling on the victim)	Horizontal motion, crash on or against	Other types of concussion and internal injuries	Rib cage, ribs including joints and shoulder blade
Slip, fall, collapse of Material Agent - from below (dragging the victim down)	Other group 30 type Contacts -Modes of Injury not listed above	Burns, scalds and frostbites	Chest area including organs
Slip, fall, collapse of Material Agent - on the same level (Slip, fall, collapse of Material Agent - on the same level)	Struck by object in motion, collision with	Burns and scalds (thermal)(MAIB*)	Pelvic and abdominal area including organs
other	Struck - by flying object	Chemical burns (corrosions)	Torso, multiple sites affected
Loss of control (total or partial) of machine, means of transport or handling equipment, handheld tool, object, animal	Struck - by falling object	Frostbites(MAIB*)	Torso, other parts not mentioned above
Loss of control (total or partial) - of machine (including unwanted start-up) or of the material being worked by the machine	Struck - by swinging object	Other types of burns, scalds and frostbites	Upper Extremities
Loss of control (total or partial) - of means of transport or handling equipment, (motorised or not)	Struck - by rotating, moving, transported object, including vehicles	Poisonings and infections(MAIB*)	Shoulder and shoulder joints
Loss of control (total or partial) - of hand-held tool (motorised or not) or of the material being worked by the tool	collision with a person (the victim is moving)	Acute poisonings	Arm, including elbow
Loss of control (total or partial) - of object (being carried, moved, handled, etc.)	Other group 40 type Contacts - Modes of Injury not listed above (	Acute infections	Hand
Loss of control (total or partial) - of animal	Contact with sharp, pointed, rough, coarse Material Agent	Other types of poisonings and infections	Finger(s)
Other	Contact with sharp Material Agent (knife, blade etc.)	Drowning and asphyxiation(MAIB*)	Wrist
Slipping - Stumbling and falling - Fall of persons	Contact with pointed Material Agent (nail, sharp tool etc.)	Asphyxiation	Upper extremities, multiple sites affected
Fall of person - to a lower level	Contact with hard or rough Material Agent	Drowning and non-fatal submersions	Upper extremities, other parts not mentioned above
Slipping - Stumbling and falling - Fall of person - on the same level	Other group 50 type Contacts -Modes of Injury not listed above	Other types of drowning and asphyxiation	Lower Extremities
Fall overboard of person	Trapped, crushed, etc	Effects of sound, vibration and pressure(MAIB*)	Hip and hip joint
Other	Trapped, crushed - in	Acute hearing losses	Leg, including knee
Body movement without any physical stress (generally leading to an external injury)	Trapped, crushed - under	Effects of pressure (barotrauma)	Ankle
Walking on a sharp object	Trapped, crushed - between	Other effects of sound, vibration and pressure	Foot
Kneeling on, sitting on, leaning against	Limb, hand or finger torn or cut off	Effects of temperature extremes, light and radiation(MAIB*)	Toe(s)
Being caught or carried away, by something or by momentum	Other group 60 type Contacts -Modes of Injury not listed above	Heat and sunstroke	Lower extremities, multiple sites affected
Uncoordinated movements, spurious or untimely actions	Physical or mental stress	Effects of radiation (non-thermal)	Lower Extremities, other parts not mentioned above
Other group 60 type Deviations not listed above	Physical stress - on the musculoskeletal system	Effects of reduced temperature	Whole body and multiple sites
Body movement under or with physical stress (generally leading to an internal injury)	Physical stress - due to radiation, noise, light or pressure	Other effects of temperature extremes, light and radiation	Whole body (Systemic effects)
Lifting, carrying, standing up	Mental stress or shock	Shock(MAIB*)	Multiple sites of the body affected
Pushing, pulling	Other group 70 type Contacts -Modes of Injury not listed above	Shocks after aggression and threats	Other Parts of body injured, not mentioned above
Putting down, bending down	Bite, kick, etc. (animal or human)	Traumatic shocks	Not specified
Twisting, turning	Bite	Other types of shocks	
Treading badly, twisting leg or ankle, slipping without falling	Sting from insect or fish	Multiple injuries(MAIB*)	
Other	Blow, kick, head butt, strangulation	Other specified injuries not included under other headings	
Shock, fright, violence, aggression, threat, presence	ther group 80 type Contacts -Modes of Injury not listed above	Other specified injuries not included under other headings	
Shock, fright	Other Contacts - Modes of Injury not listed in this classification	Unknown or unspecified(MAIB*)	
Violence, aggression, threat - between company employees subjected to the employer"s authority	No information (No information)		
Violence, aggression, threat - from people external to the company towards victims performing their duties (bank hold-up, bus drivers, etc.)			
Aggression, jostle - by animal (Aggression, jostle - by animal)			
Presence of the victim or of a third person in itself creating a danger for oneself and possibly others			

APPENDIX F: FIGURES FOR DATABASE ANALYSIS

F.1 Analysis of occupational accidents resulting in injuries – MAIB database

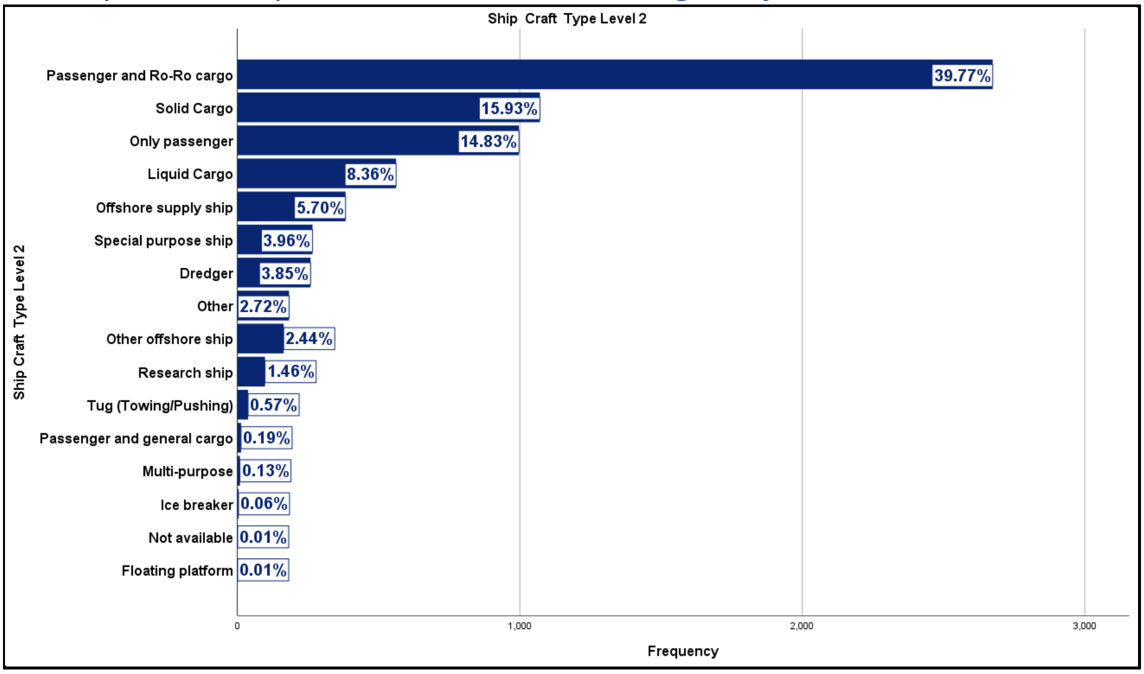

Figure F.1.1: Distribution of crew injuries on board different merchant vessels recorded in the UK MAIB database

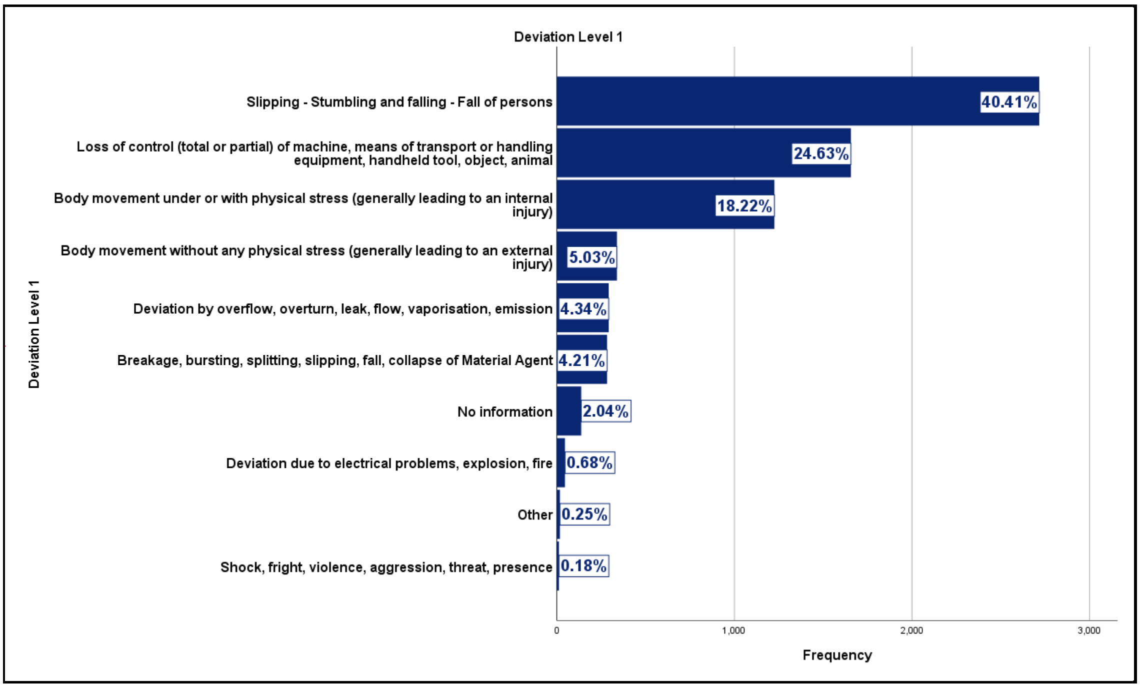

Figure F.1.2: Level 1 causal factors for crew injuries on board merchant vessels recorded in the UK MAIB database

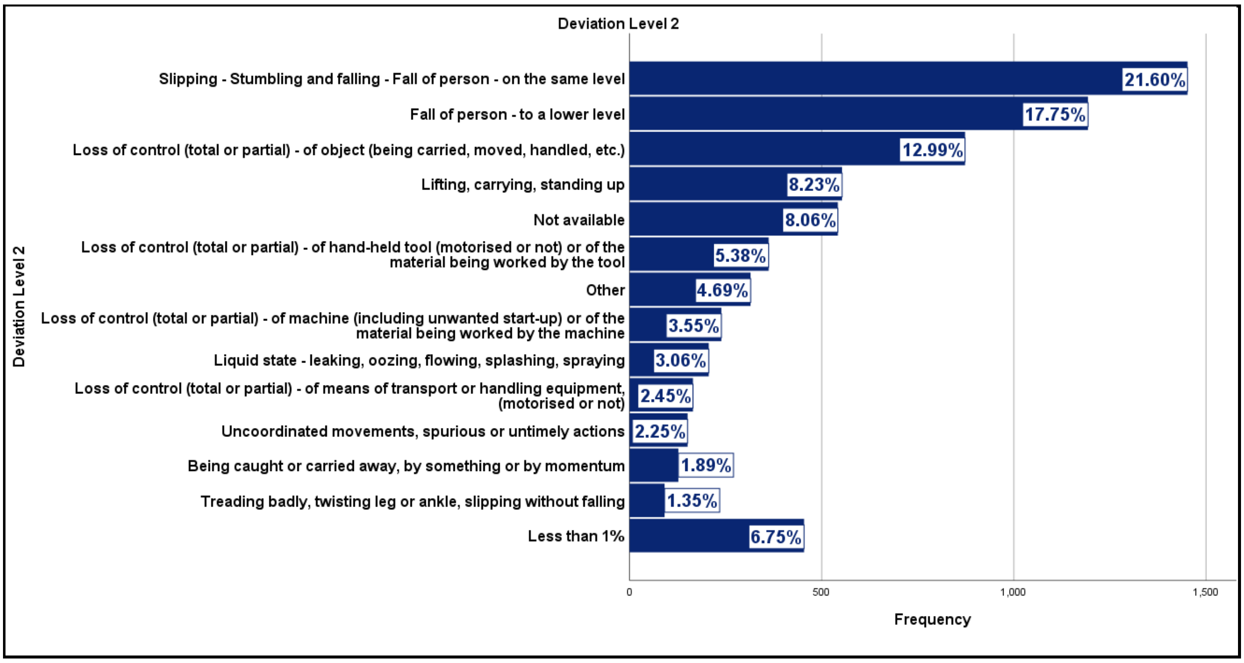

Figure F.1.3: Level 2 causal factors for crew injuries on board merchant vessels recorded in the UK MAIB database

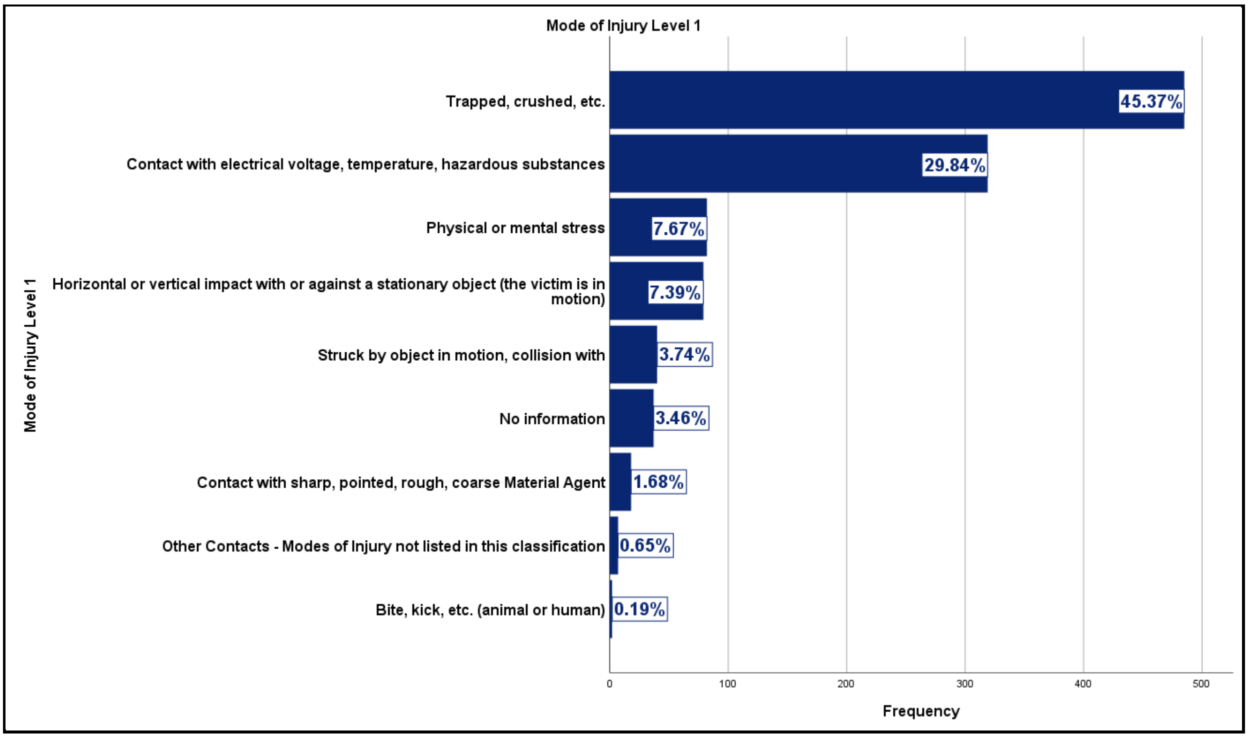

Figure F.1.4: Level 1 mode of injury on board merchant vessels recorded in the UK MAIB database

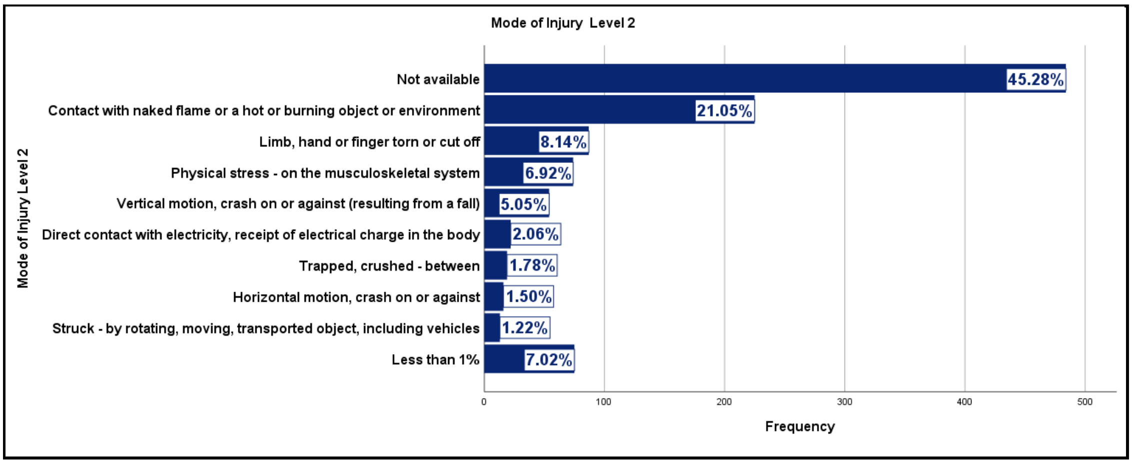

Figure F.1.5: Level 2 mode of injury on board merchant vessels recorded in the UK MAIB database

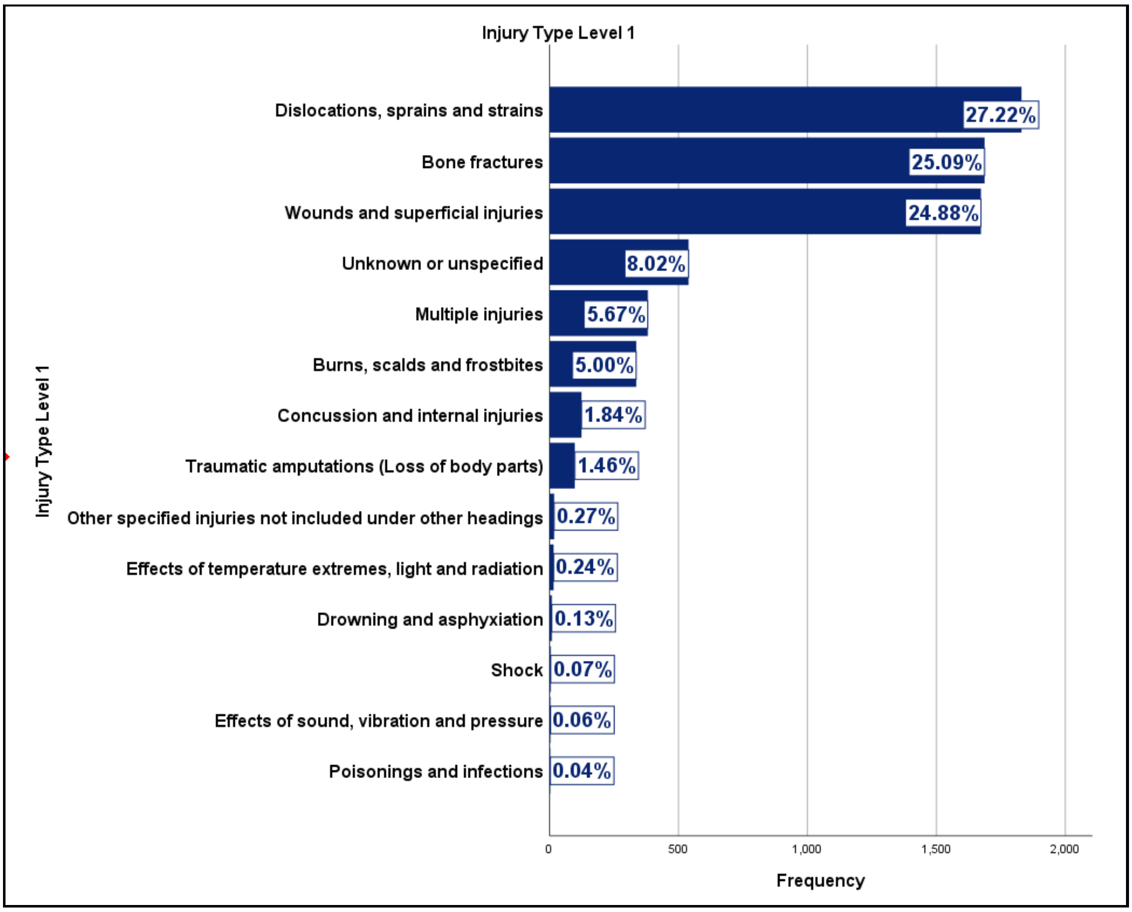

Figure F.1.6: Level 1 injury types which the crew sustained on board merchant vessels recorded in the UK MAIB database

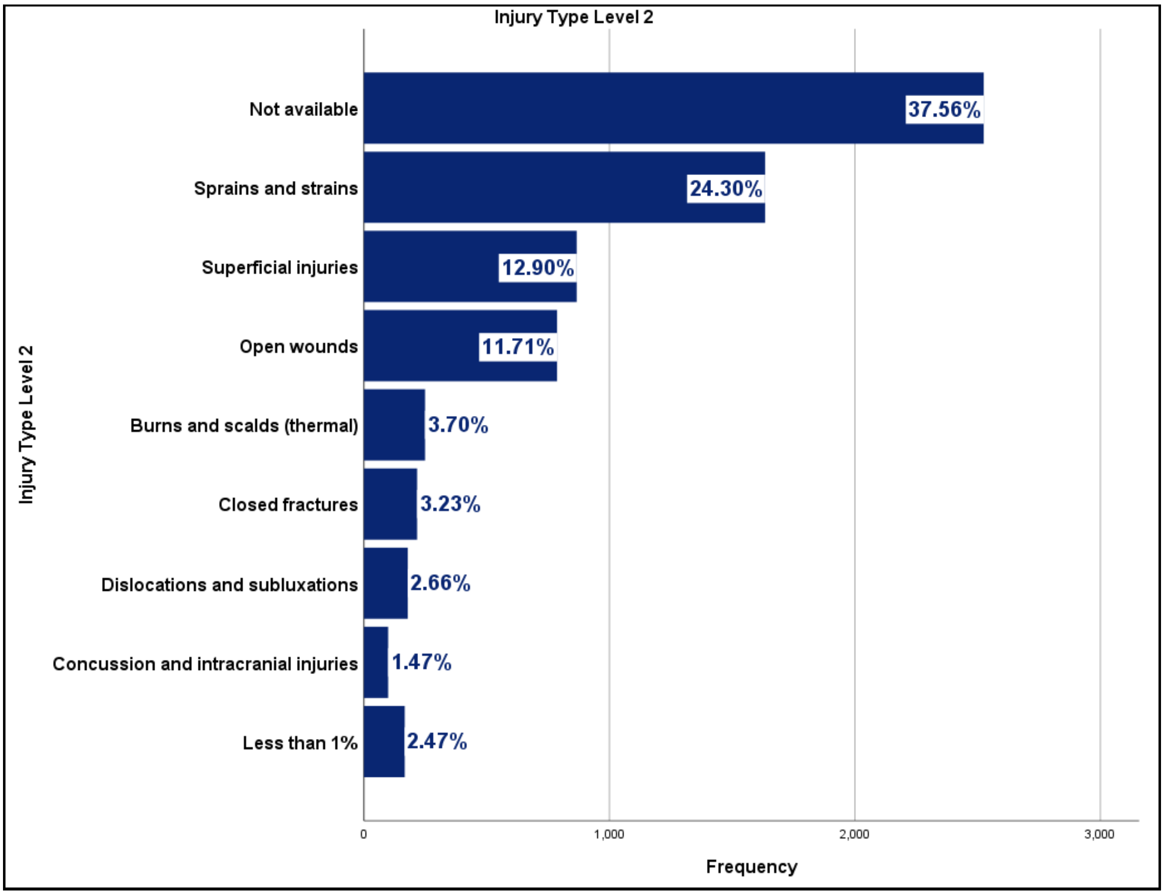

Figure F.1.7 Level 2 injury types sustained by the crew on board merchant vessels recorded in the UK MAIB database

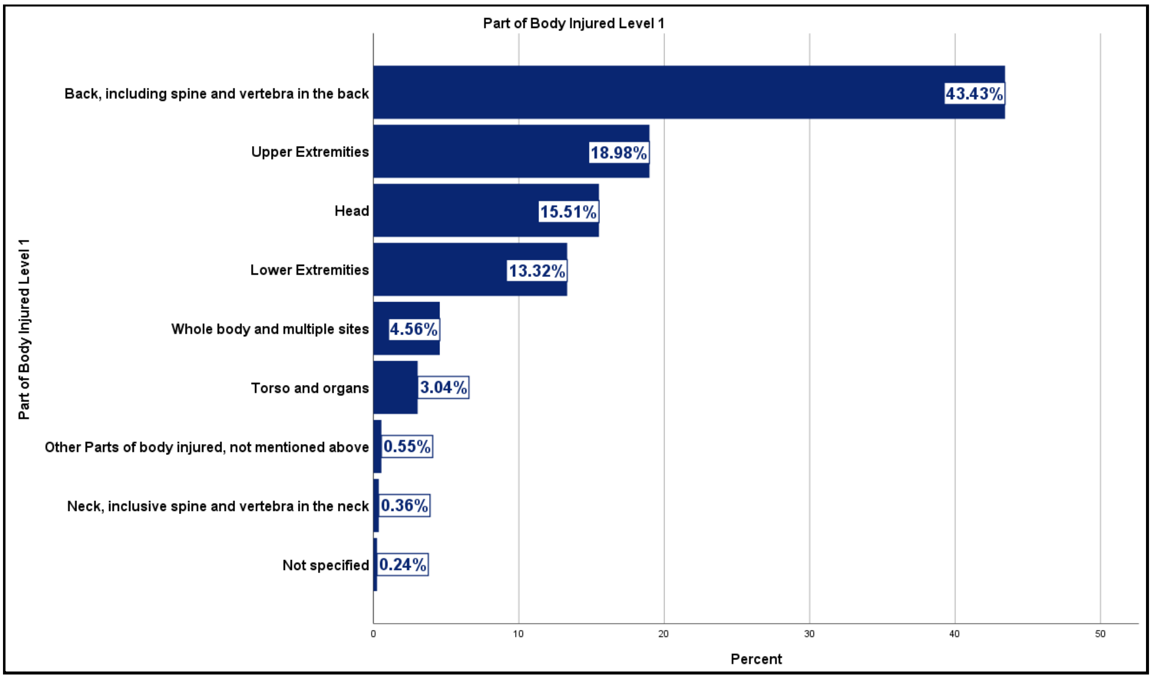

Figure F.1.8: Level 1 distribution of parts of body injured as recorded in the UK MAIB database (excluding the unavailable data from the distribution)

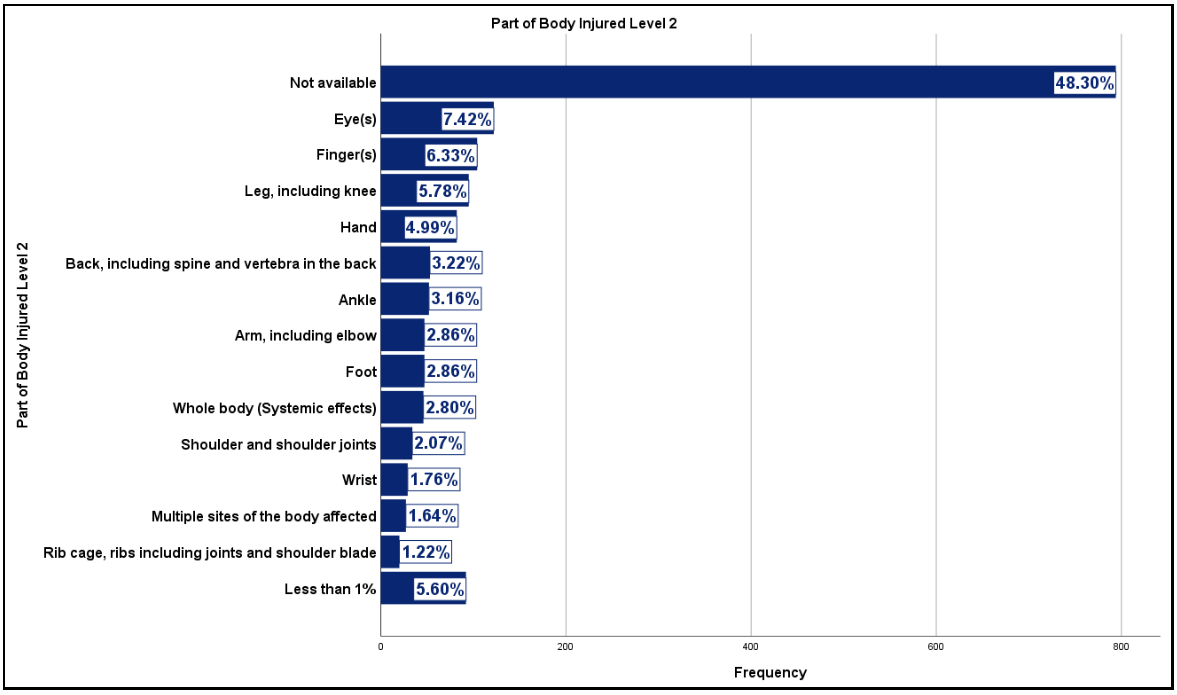

Figure F.1.9: Level 2 distribution of parts of body injured as recorded in the UK MAIB database

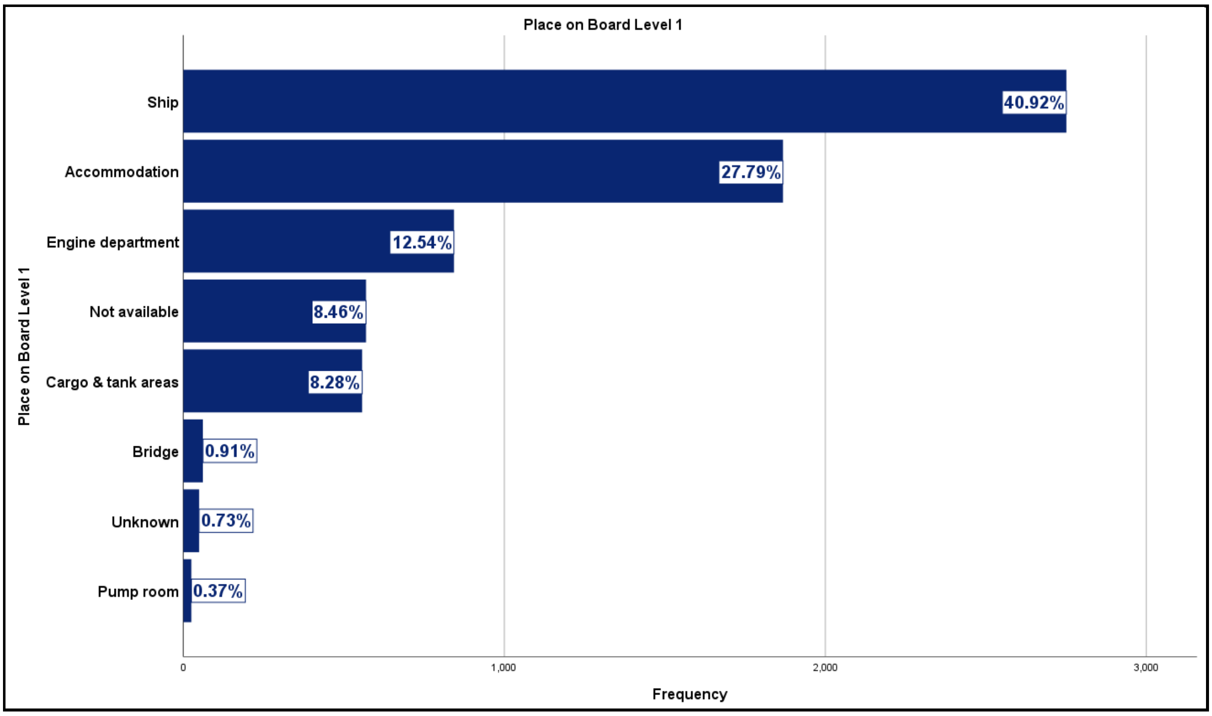

Figure F.1.10: Location (Level 1) of occupational accidents occurred onboard ship as recorded in the UK MAIB database

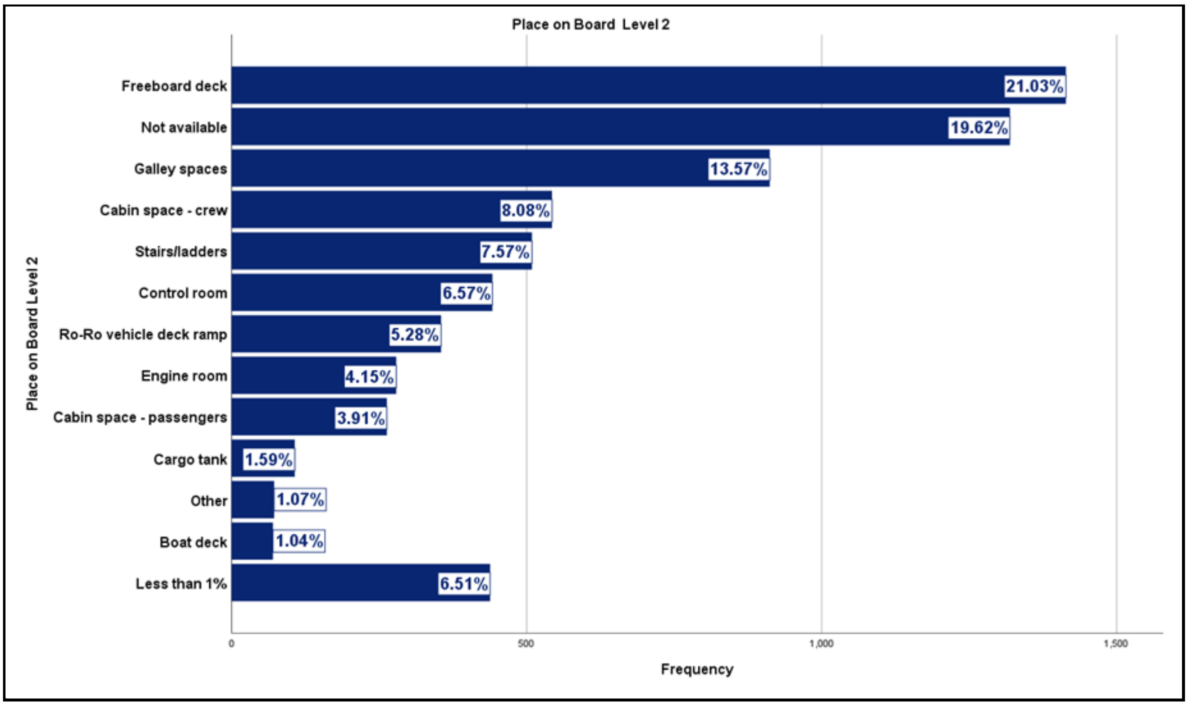

Figure F.1.11: Detailed (Level 2) location of occupational accidents on board ship as recorded in the UK MAIB database

F.2 Analysis of occupational accidents resulting in fatalities – MAIB database

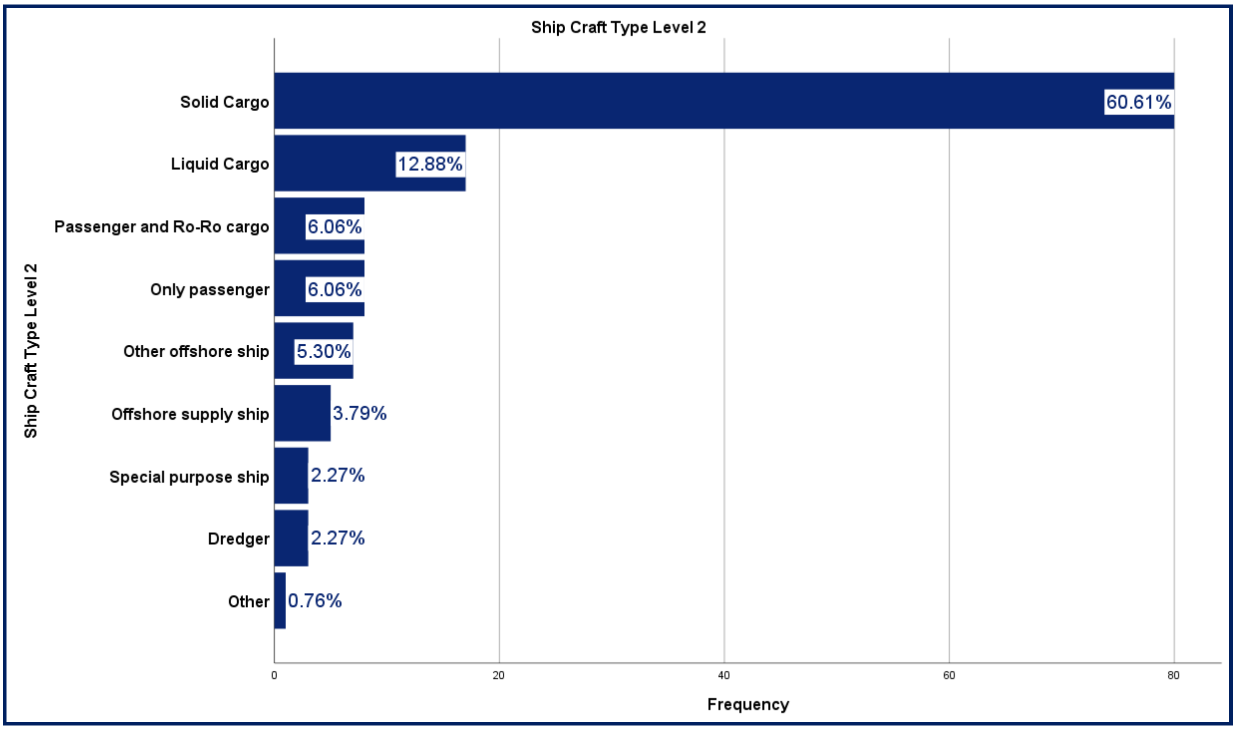

Figure F.2.1 Distribution of crew fatalities on board different merchant vessels recorded in the UK MAIB database

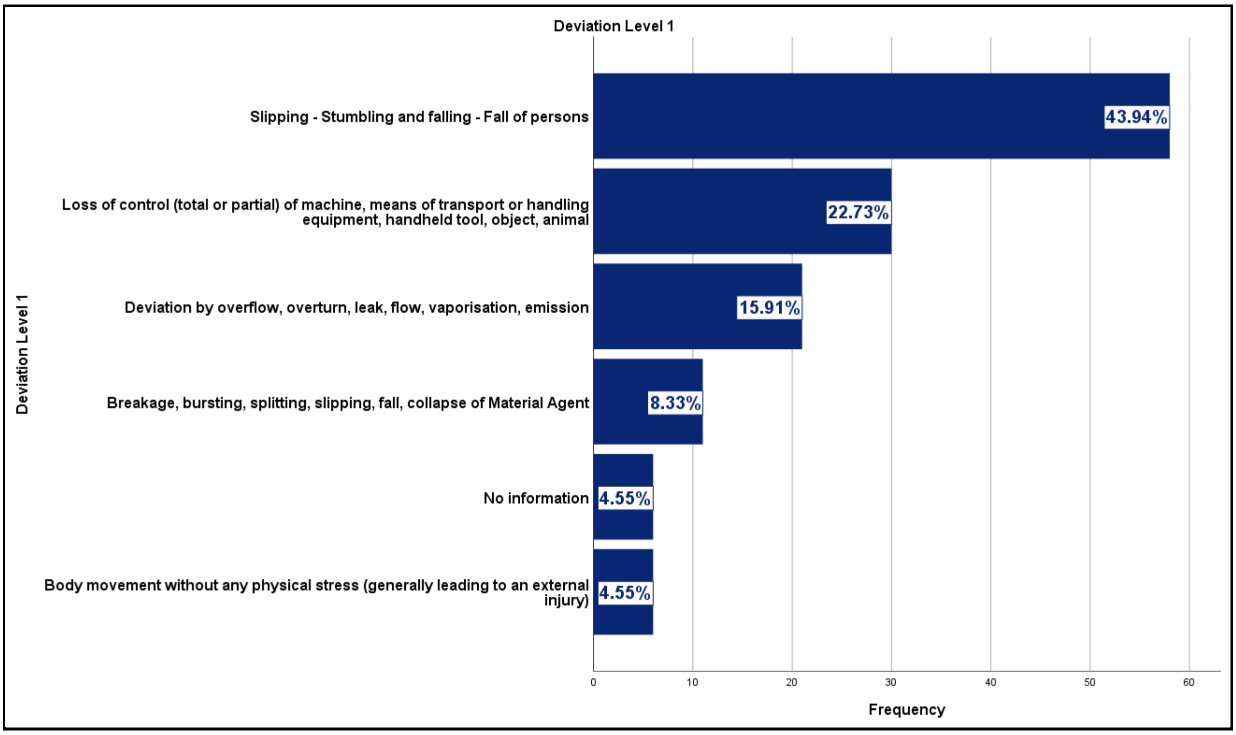

Figure F.2.3: Level 1 causal factors for crew fatalities on board merchant vessels recorded in the UK MAIB database

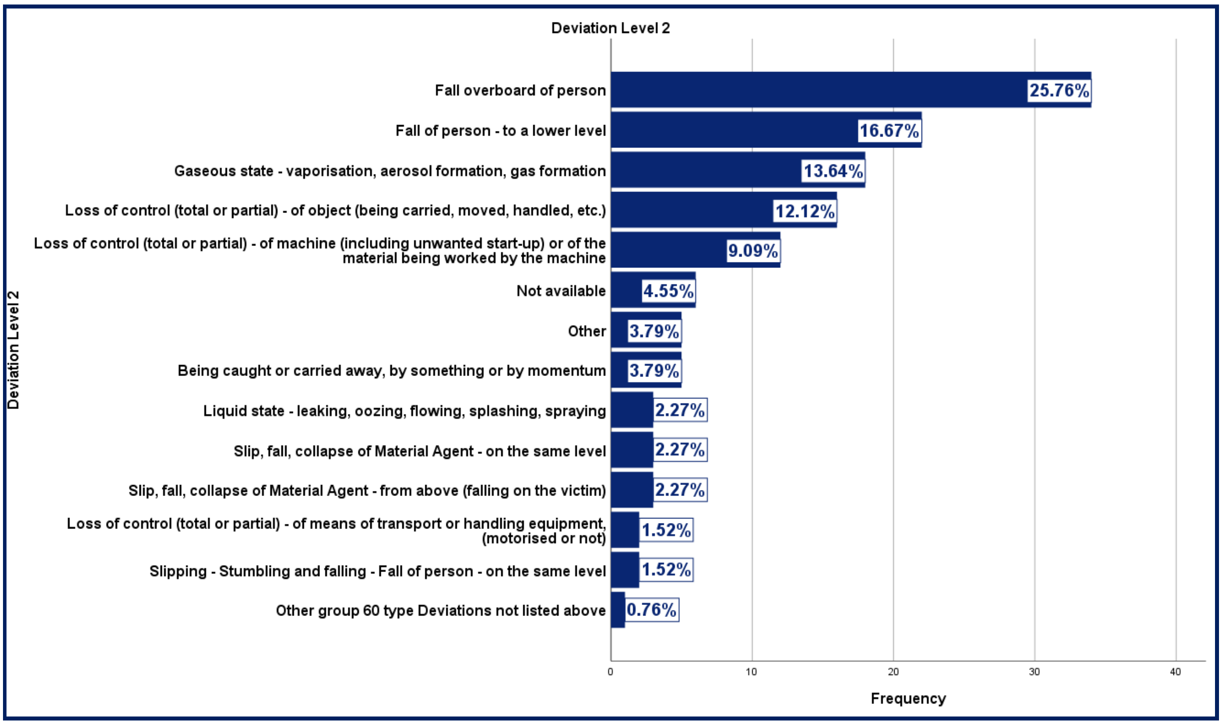

Figure F.2.4: Level 2 causal factors for crew fatalities on board merchant vessels recorded in the UK MAIB database

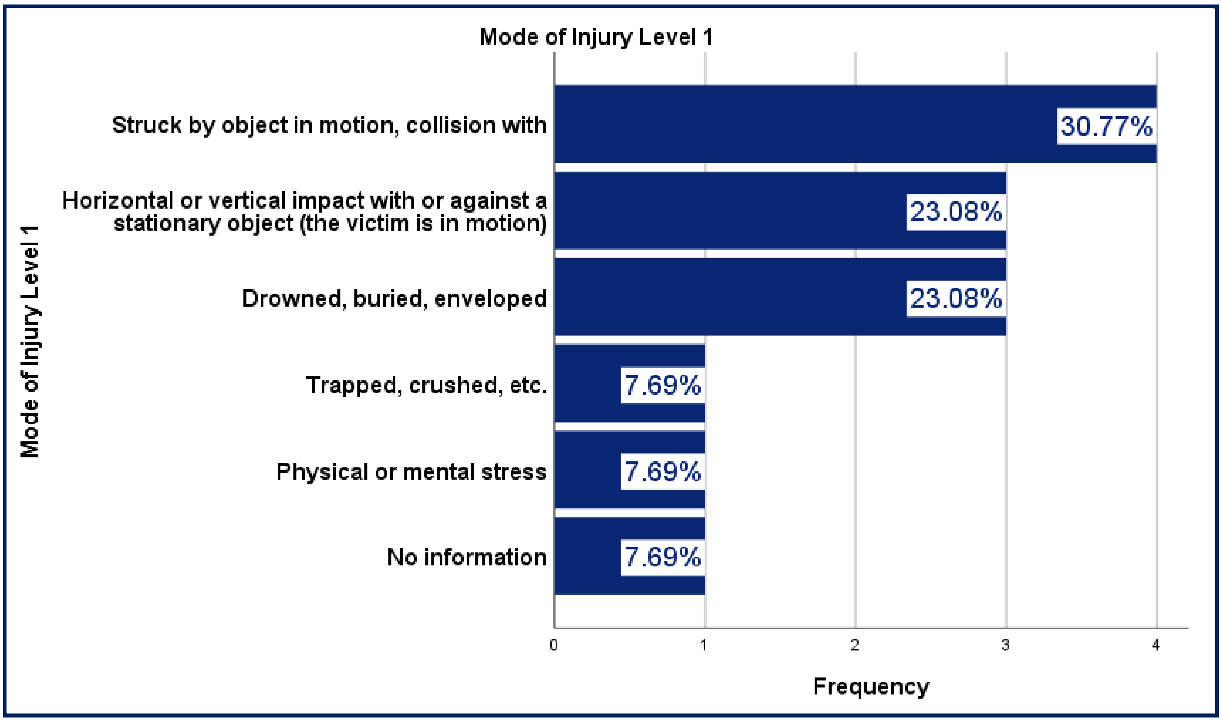

Figure F.2.5: Level 1 mode of fatal injuries on board merchant vessels recorded in the UK MAIB database

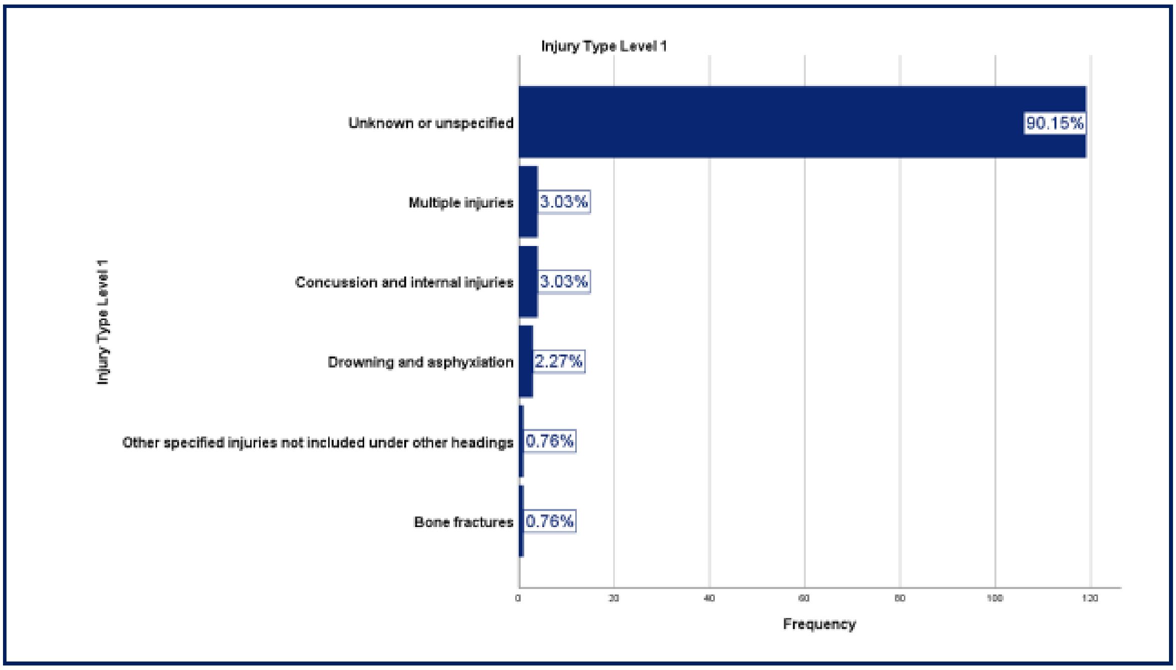

Figure F.2.6 Level 1 injury types which caused crew fatalities on board merchant vessels recorded in the UK MAIB database

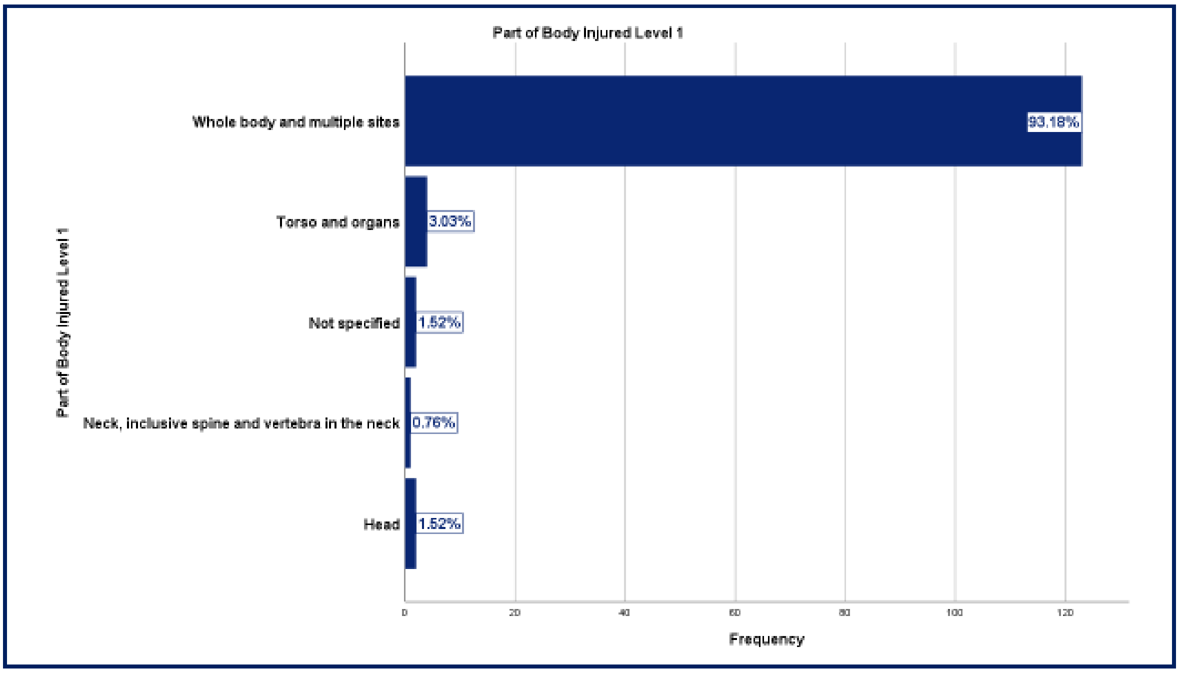

Figure F.2.7: Level 1 distribution of parts of body which were fatally injured as recorded in the UK MAIB database

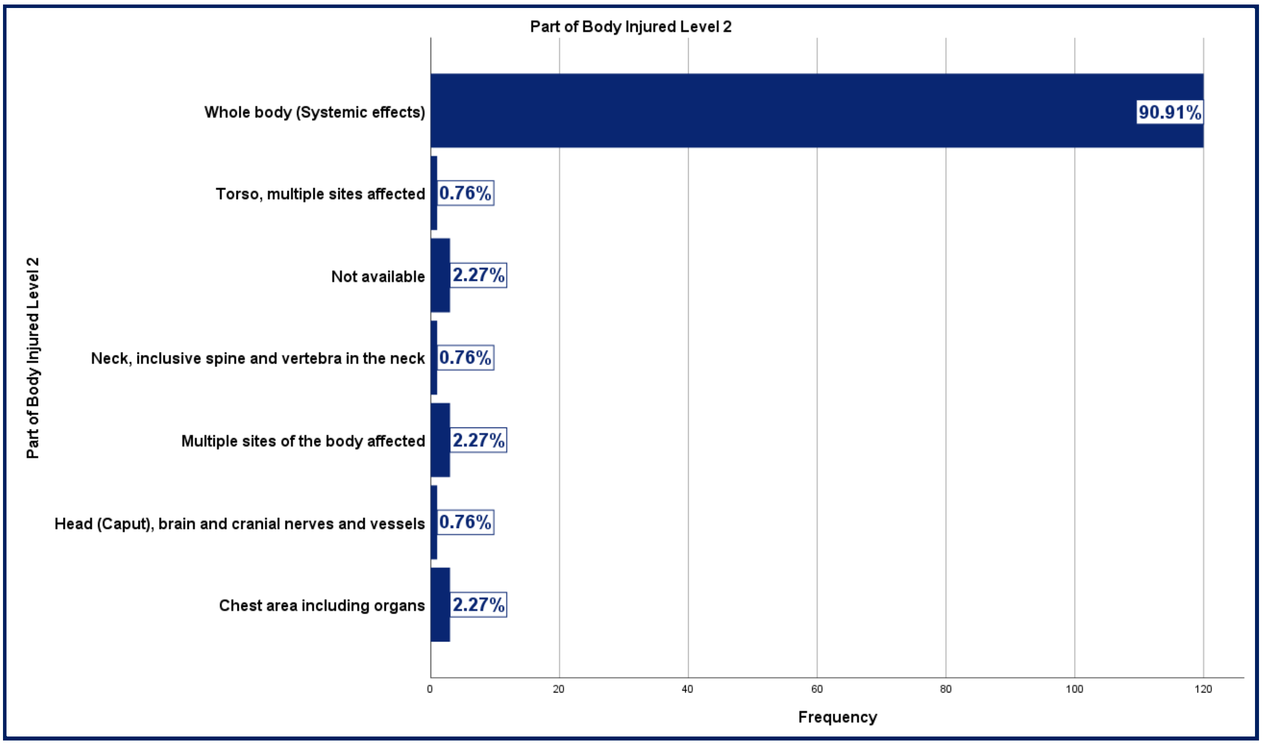

Figure F.2.8: Level 2 distribution of parts of body which were fatally injured as recorded in the UK MAIB database

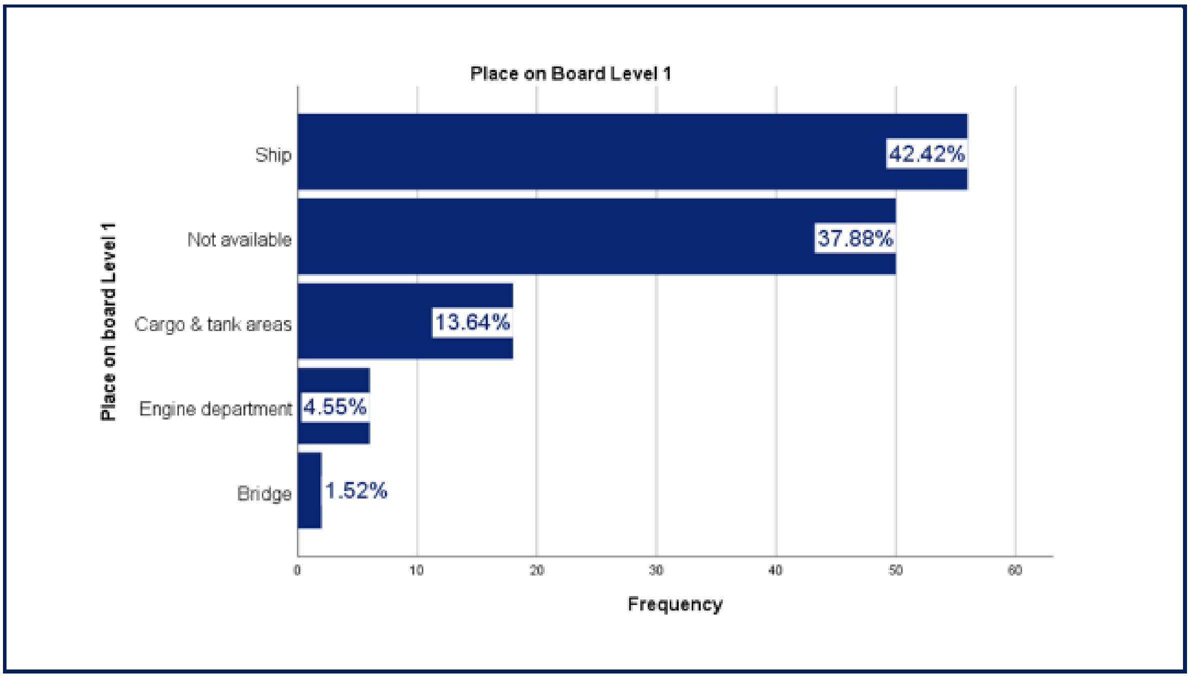

Figure F.2.9: Location (Level 1) of fatalities occurred on board ship as recorded in the UK MAIB database

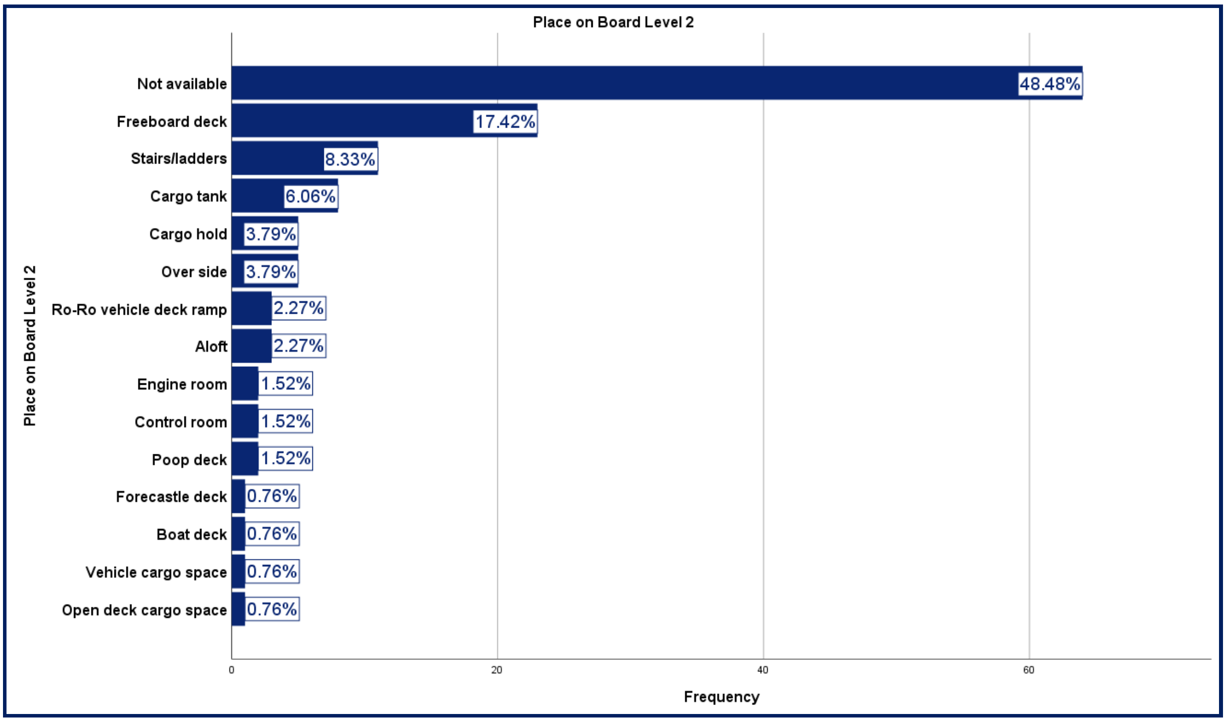

Figure F.2.10: Detailed (Level 2) location of fatalities occurred on board ship as recorded in the UK MAIB database

F.3 Comparison of causal factors obtained from database analysis and literature

The comparison of the top causal factors for occupational injuries and fatalities is made at two levels: Level 1, which provides the groupings of specific causes, and Level 2, which provides the more detailed causes.

- *Level 1 comparison for fatalities and injury categories*

The results presented in Table F.1.1 were categorised as Level 1 injuries and serious injuries and fatalities, as some sharp differences can be observed between these two categories. Top level causal factors identified by the MAIB fatality database were listed from largest to smallest and colour coded as dark red for the largest percentage and dark green for the smallest percentage. Corresponding percentages for the same causal factor from other data sources were provided on the same row.

Table F.1: comparison of top ten Level 1 causal factors for fatalities and injuries in world merchant shipping

	MAIB (fatality)	EMSA (fatality)	Worldwide (serious injury and fatality)	Çakir (serious injury and fatality)	MAIB (injury)	EMSA (injury)	Bailey, N	SWEDISH CLUB	AMERICAN CLUB	ABS/LEMAR
	data (1992-2017)	ref EMSA 2019 (2011-2018)	data (2000-2019)	ref Çakir 2019	data (1992-2017)	ref EMSA 2019	ref Bailey et al. 2010	ref Swedish Club 2016	ref ABS/LAMAR, 2019	ref ABS/LAMAR, 2019
Slipping – stumbling and falling – fall of persons	44.4%	51.0%	33.5%	46.2%	40.7%	37.8%	55.2%	44.8%	34.0%	29.0%
Loss of control (total or partial) of machine, means of transport or handling equipment, handheld tool, object, animal	22.6%	11.9%	12.8%	13.9%	24.5%	20.4%	8.5%	14.0%	8.0%	3.0%
Deviation by overflow, overturn, leak, flow, vaporisation, emission	15.8%	10.6%	11.4%	12.7%	4.2%	5.1%	11.4%	3.0%	2.0%	0.30%
Breakage, bursting, splitting, slipping, fall, collapse of material agent	8.3%	6.4%	9.5%	3.0%	4.1%	7.4%	7.7%	15.5%	9.5%*	18.5%*
Body movement without any physical stress (generally leading to an external injury)	4.5%	11.2%	13.8%	13.8%	5.1%	15.2%		6.5%	9.5%*	18.5%*
Others	4.5%	4.5%	1.0%		2.3%	5.6%			6.0%	13.0%
Deviation due to electrical problems, explosion, fire		2.9%	17.9%	10.2%	0.6%	1.4%	4.9%	6.3%	3.0%	5.0%
Body movement under or with physical stress (generally leading to an internal injury)		1.5%	0.17%		18.4%	7.4%	10.3%	8.1%	28.0%	13.0%
Shock, fright, violence, aggression, threat, presence					0.2%		1.2%	1.4%		

- *Level 2 comparison for injury category*

Table F.2: comparison of top ten Level 2 causal factors for fatalities and serious injuries in world merchant shipping

TOP TEN LEVEL 2 CAUSAL FACTORS Serious injury or fatality	MAIB Data (fatality)	Worldwide (serious injury and fatality)	Çakir 2019 (serious injury and fatality)
Fall overboard of person	25.75%	9.01%	42.6%
Fall of person – to a lower level	16.67%	22.96%	
Gaseous state – vaporisation, aerosol formation, gas formation	13.64%	8.84%	12.70%
Loss of control (total or partial) – of object (being carried, moved, handled, etc.)	12.12%		6.9%*
Loss of control (total or partial) – of machine (including unwanted start-up) or of the material being worked by the machine	9.09%		
Being caught or carried away, by something or by momentum	3.79%	13.78%	13.8%
Liquid state – leaking, oozing, flowing, splashing, spraying	2.27%	2.55%	
Slip, fall, collapse of material agent – from above (falling on the victim)	2.27%		3.00%
Slip, fall, collapse of material agent – on the same level	2.27%		
Loss of control (total or partial) – of means of transport or handling equipment, (motorised or not)	1.52%	7.14%	
Explosion		10.71%	4.53%
Breakage of material – at joint, at seams		5.44%	6.9%*
Fire, flare up		5.44%	4.23%
Slipping – stumbling and falling – fall of person – on the same level			3.60%
Slip, fall, collapse of material agent – from below (dragging the victim down)		2.55%	

Table F.3: comparison of top ten Level 2 causal factors for injuries in world merchant shipping

TOP TEN LEVEL 2 CAUSAL FACTORS injury	MAIB Data (injury)	Swedish Club	Bailey et al. 2010
Fall of person – on the same level	21.60%	44.55%	31.6%
Fall of person – to a lower level	17.75%		23.60%
Loss of control (total or partial) – of object (being carried, moved, handled, etc.)	12.99%		7.50%
Lifting, carrying, standing up	8.23%	4.95%	10.30%
Loss of control (total or partial) – of hand-held tool (motorised or not) or of the material being worked by the tool	5.38%	3.07%	
Loss of control (total or partial) – of machine (including unwanted start-up) or of the material being worked by the machine	3.55%	10.30%	
Liquid state – leaking, oozing, flowing, splashing, spraying	3.06%	1.39%	4.20%
Loss of control (total or partial) – of means of transport or handling equipment, (motorised or not)	2.45%		
Uncoordinated movements, spurious or untimely actions	2.25%		
Being caught or carried away, by something or by momentum	1.89%	6.53%	
Slip, fall, collapse of material agent – from above (falling on the victim)		15.45%	7.50%
Explosion		6.53%	
Fire, Flare Up			
Pulling, pushing		3.17%	
Gaseous state – vaporisation, aerosol formation, gas formation		0.79%	7.20%
Other			3.30%
Violence, aggression, threat – between company employees subjected to the employer's authority			1.20%
Electrical problem due to equipment failure – leading to indirect contact			0.80%

University of Strathclyde Glasgow

BESPOKE RESEARCH AND CONSULTANCY FROM HSE

Safety Challenges at Sea: Data and Evidence