

ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL

**A COMPREHENSIVE ANALYSIS OF MARITIME INCIDENTS FROM A
PERSONAL INJURY PERSPECTIVE**



M.Sc. THESIS

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Department of Maritime Transportation Engineering

Maritime Transportation Engineering Programme

JUNE 2024

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İSTANBUL TEKNİK ÜNİVERSİTESİ ★ LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ

**DENİZ OLAYLARININ KİŞİSEL YARALANMA PERSPEKTİFİNDEN
KAPSAMLI ANALİZİ**

YÜKSEK LİSANS TEZİ

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To all maritime casualties,



FOREWORD

First and foremost, I extend my heartfelt gratitude to my thesis advisor, Prof. Dr. Emre AKYUZ, whose guidance was pivotal throughout the development of this dissertation. His involvement has been both inspiring and instrumental. I also wish to express my appreciation to Prof. Dr. Yasin ARSLANOGLU and Asst. Prof. Dr. Tayfun UYANIK, esteemed members of the thesis' monitoring process, for their constructive comments and substantial contributions to the research content.

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This foreword would be incomplete without acknowledging the collective impact of all maritime casualties. The valuable lessons learned from their direct experiences have guided and inspired me throughout this journey. For this reason, this study is dedicated to all maritime casualties.

June 2024

Duygu YALÇIN



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ABBREVIATIONS

ABS	: American Bureau of Shipping
ANP	: Analytic Network Process
DNV	: Det Norske Veritas
EMSA	: European Maritime Safety Agency
ESAW	: European Statistics on Accidents at Work
FAC	: First Aid Case
FMEA	: Failure Modes and Effects Analysis
HAZOP	: Hazard and Operability Analysis
HFACS	: Human Factors Analysis and Classification System
ILO	: International Labor Organization
IMO	: International Maritime Organization
LL	: Load Line Convention
LWC	: Lost Workday Case
MAIB	: Maritime Accident Investigation Branch
MARPOL	: Marine Pollution Convention
MSC	: Maritime Safety Committee
MSCAT	: Marine Systematic Cause Analysis Technique
MTC	: Medical Treatment Case
PPD	: Permanent Partial Disability
PTD	: Permanent Total Disability
RWC	: Restricted Work Case
SOLAS	: Safety of Life at Sea
UNCLOS	: United Nations Convention on the Law of the Sea



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A COMPREHENSIVE ANALYSIS OF MARITIME INCIDENTS FROM A PERSONAL INJURY PERSPECTIVE

SUMMARY

Maritime accidents continue to be a significant concern all around the world. Although the public may mostly associate these incidents with vessels and assets, these incidents not only pose threats to significant financial losses but also have bigger consequences, like harm to the environment and potential risks to human life.

Accidents involving property loss, fatalities, injuries, or environmental damage are investigated to determine responsibility and root causes, enabling strategies to prevent future occurrences and enhance maritime safety. Reporting and investigating such incidents are vital and required by international laws and conventions. Organizations have integrated thorough accident reporting and analysis into their operations, resulting in comprehensive reports that help prevent future incidents. For instance, The European Maritime Safety Agency (EMSA) Annual Overview of Marine Casualties and Incidents 2023 report, covering 2014-2022. Average annual fatalities decreased from 114 in 2014 to 38 in 2022, and injuries from 999 in 2014 to 525 in 2022. Additionally, The Transportation Safety Board of Canada reported a similar decline in 2022, with marine fatalities dropping to seven from an average of fifteen. Similarly, The Maritime Accident Investigation Branch (MAIB) investigates UK maritime accidents and publishes annual reports. From 2013 to 2022, an average of 116 commercial ship crew members were injured annually. Despite these decreasing trends in the total number of casualties, a significant increase is observed in upper limb injuries, particularly hands, and fingers in the reports between 2020 to 2022.

This study aims to identify trends causing personal injuries and compare them with findings from MAIB. Such a comparison will help determine whether injury trends are consistent across different organizational environments or if they differ significantly. The ultimate goal is to obtain insights that will guide the development of more effective prevention strategies and safety measures tailored to the unique conditions of the ship's organizational structure.

The study examined five years of marine incident data involving approximately 35 MR-sized ships operated by a Turkish ship management company. A comprehensive analysis of variables and root causes of injuries was conducted using descriptive statistics. The company's incident management procedure was integrated with the Marine Systematic Cause Analysis Technique (MSCAT) for root cause analysis. Additionally, the European Statistics on Accidents at Work (ESAW) classification system was used to further explore numerous factors contributing to injuries.

The research analyzed 6,863 qualitative maritime incident reports collected from thirty-five different ships managed by the same company between 2018 and 2023. These reports, a primary qualitative data source, included detailed descriptions of the incident's outcome, severity, type of loss or potential loss, event sequences, and environmental conditions. The methodology employed a data-driven approach,

incorporating statistical analysis to interpret the semi-structured and unstructured narrative descriptions. This process began with the preparation of data according to the company's incident management procedures, involving the compilation, classification, and formatting of the data. Each report underwent manual screening to verify completeness. Subsequently, the data were organized and converted into quantitative variables for statistical analysis, while preserving the original text for content analysis.

The research focused on four main variables frequently used in maritime accident studies: accidents, near misses, unsafe acts, and conditions. Within this framework, near misses, unsafe acts, and conditions were treated as leading indicators, while accidents were considered lagging indicators. Incidents resulting in personal injuries were analyzed in terms of the severity and location of the injuries, the work processes involved, contributing materials and agents, modes of injury, affected body parts, and root causes. The analysis adhered to the company's incident management procedures, employing MSCAT mapping for detailed root cause analysis and the ESAW classification to further delineate the specifics of the injuries. This comprehensive methodological approach systematically identified and addressed factors contributing to injuries, enhancing the understanding of maritime safety dynamics.

The data and statistics used in this analysis do not include personal identifiers such as age, gender, or nationality. Furthermore, information regarding the ranks of individuals involved was not categorized. This decision was based on the understanding that errors are normal and can occur regardless of an individual's rank, gender, or nationality. This approach reflects a focus on systemic factors rather than personal attributes or hierarchical status in understanding incidents.

The analysis of data from this maritime company revealed that 37% of all incidents resulted in injuries ranging from minor to severe. Approximately 60% of these injuries were minor and treated with first aid, 27% required medical treatment, and 9.6% led to workday loss and sometimes urgent evacuation from the ship. The areas with the highest occurrence of personal injuries were the engine room (29%), the main deck (19%), and the provision storage areas and galley. The most common types of accidents were being struck by moving objects, slipping, tripping, falling, and bumping into objects. Slips and trips were notably prevalent in critical incidents, accounting for 41% of such cases. The study highlighted that hand and finger injuries were the most frequent, comprising 35% of injuries, consistent with MAIB annual reports. These injuries also accounted for 20% of critical injuries, underscoring their potential severity in maritime environments.

Immediate factors contributing to injuries included the improper use of personal protective equipment, failure to adhere to safety procedures, and inadequate securing and protection. In 51% of personal injury accidents, the primary cause was identified as a lack of competence, typically characterized by a lack of situational awareness and risk perception.

The study suggests that future research might employ statistical methods such as regression analysis and predictive modeling to identify patterns within datasets. Additionally, collecting more company-specific data and expanding the literature will provide a more comprehensive perspective on injury trends.

DENİZ OLAYLARININ KİŞİSEL YARALANMA PERSPEKTİFİNDEN KAPSAMLI ANALİZİ

ÖZET

Deniz kazaları dünya çapında önemli bir endişe kaynağı olmaya devam etmektedir. Kamuoyu bu olayları genellikle gemiler ve varlıklarla ilişkilendirirken, bu kazalar sadece maddi kayıplara yol açmakla kalmayıp, aynı zamanda çevreye verilen hasar ve insan hayatına yönelik riskler gibi daha büyük sonuçlar da doğurabilmektedir. Maddi kayıplar, personel yaralanmaları, ölümler veya çevresel hasarlarla sonuçlanan kazalar, sorumluluk ve temel nedenleri belirlemek amacıyla araştırılır; bu da gelecekteki olayların önlenmesi ve deniz güvenliğinin artırılması için stratejilerin geliştirilmesine yardımcı olur. Bu olayların raporlanması ve araştırılması uluslararası yasalar ve sözleşmeler tarafından zorunlu kılınmıştır. Bu doğrultuda, kuruluşlar kapsamlı raporlama ve analiz süreçlerini operasyonlarına entegre etmiş olup, bu raporlar kaza trendlerinin belirlenmesine ve önleyici tedbirlerin alınmasına yardımcı olmaktadır. Örneğin, Avrupa Deniz Emniyeti Ajansı'nın (EMSA) 2014-2022 dönemini kapsayan 2023 Deniz Kazaları Yıllık Genel Görünüm raporunda, yıllık ortalama ölümler 2014'teki 114'ten 2022'de 38'e, yaralanmalar ise 2014'teki 999'dan 2022'de 525'e düşmüştür. Ayrıca, Kanada Ulaştırma Güvenlik Kurulu, 2022 yılında ölümlü deniz kazalarının on beşten yediye düştüğünü bildirmiştir. Benzer şekilde, Birleşik Krallık Deniz Kazaları Araştırma Şubesi (MAIB), İngiltere'deki deniz kazalarını araştırmakta ve yıllık raporlar yayınlamaktadır. 2013-2023 yılları arası toplanan verilerde, yıllık ortalama 116 ticari gemi mürettebatı yaralanmış ve toplam kaza sayısındaki azalan trendlere rağmen, 2020 ile 2022 yılları arasındaki raporlarda üst ekstremite yaralanmalarında, özellikle el ve parmaklarda, önemli bir artış gözlenmiştir.

Bu çalışma, personel yaralanmalarına sebep olan trendleri belirlemeyi ve bunları MAIB bulgularıyla karşılaştırmayı amaçlamaktadır. Böyle bir karşılaştırma, yaralanma trendlerinin farklı kurumsal ortamlar arasında tutarlı olup olmadığını veya önemli ölçüde farklılık gösterip göstermediğini ortaya koymaya yardımcı olacaktır. Nihai hedef, gemi organizasyon yapısının benzersiz koşullarına özel olarak daha etkili önleme stratejileri ve güvenlik önlemlerinin geliştirilmesine rehberlik edecek bilgiler elde etmektir.

Çalışma, bir Türk denizcilik şirketi tarafından işletilen yaklaşık 35 MR boyutunda gemiyi içeren beş yıllık deniz olayı verilerini incelemiştir. Bu olaylar, kazalar, ramak kala olaylar, güvensiz davranışlar ve koşullar olarak kategorize edilmiştir. Yaralanmalara sebep olan kazaların değişkenleri ve kök nedenlerin kapsamlı bir analizi, tanımlayıcı istatistikler kullanılarak yapılmıştır. Şirketin olay yönetim prosedürü, kök neden analizi için Marine Systematic Cause Analysis Technique (MSCAT) ile entegre edilmiştir. Ayrıca, yaralanmalara katkıda bulunan çeşitli faktörleri daha ayrıntılı incelemek için Avrupa İş Kazaları İstatistikleri (ESAW) sınıflandırma sistemi kullanılmıştır.

Araştırma, 2018 ile 2023 yılları arasında aynı Denizcilik işletmesi tarafından yönetilen otuz beş farklı gemiden toplanan veritabanındaki 6.863 niteliksel deniz olayı raporunu analiz etmiştir. Bu raporlar, olayların sonucu, ciddiyeti, kayıp türü veya potansiyel kayıp türleri, olay dizileri ve çevresel koşullar gibi ayrıntılı açıklamaları içeren birincil niteliksel veri kaynağıdır. Metodoloji, yarı yapılandırılmış ve yapılandırılmamış olay açıklamalarını yorumlamak için istatistiksel analizi içeren veri odaklı bir yaklaşım kullanmıştır. Bu süreç, şirketin olay yönetim prosedürlerine göre verilerin hazırlanması, derlenmesi, sınıflandırılması ve biçimlendirilmesi ile başlamıştır. Her raporun eksiksizliğini doğrulamak için manuel tarama yapılmıştır. Ardından, veriler istatistiksel analiz için niceliksel değişkenlere dönüştürülmüş ve içerik analizi için orijinal metin korunmuştur.

Araştırma, deniz kazası çalışmalarında sıklıkla kullanılan dört ana değişkene odaklanmıştır: kazalar, ramak kala olaylar, güvensiz davranışlar ve koşullar. Bu çerçevede, ramak kala olaylar, güvensiz davranışlar ve koşullar öncü göstergeler olarak ele alınırken, kazalar gecikmiş göstergeler olarak kabul edilmiştir. Kişisel yaralanmalarla sonuçlanan olaylar, yaralanmaların ciddiyeti, yeri, ilgili iş süreçleri, katkıda bulunan materyaller ve etkenler, yaralanma şekilleri, etkilenen vücut bölgeleri ve temel nedenler incelenmiştir. Analiz, şirketin olay yönetim prosedürlerine uygun olarak, detaylı temel neden analizi için MSCAT haritalaması ve yaralanmaların özelliklerini daha da ayırt etmek için ESAW sınıflandırması kullanılarak gerçekleştirilmiştir. Bu kapsamlı metodolojik yaklaşım, yaralanmalara katkıda bulunan faktörleri sistematik olarak tanımlamaya ve ele almaya yardımcı olarak deniz güvenliği dinamiklerinin anlaşılmasını geliştirmiştir.

Bu analizde kullanılan veri ve istatistikler, yaş, cinsiyet veya milliyet gibi kişisel tanımlayıcı bilgileri içermemektedir. Ayrıca, ilgili kişilerin görevleri hakkında bilgi kategorize edilmemiştir. Bu karar, hataların normal olduğu ve bir bireyin görevi, cinsiyeti ya da milliyeti ne olursa olsun kazaların gerçekleşebileceği anlayışına dayanmaktadır. Bu yaklaşım, olayları anlamada kişisel nitelikler veya hiyerarşik durumlar yerine sistemik faktörlere odaklanmayı yansıtmaktadır.

Bahse konu Denizcilik işletmesine ait verilerinin analizi, tüm kazaların %37'sinin hafiften ağıra kadar değişen personel yaralanmalarıyla sonuçlandığını ortaya koymuştur. Bu yaralanmaların yaklaşık %60'ı hafif yaralanma olarak kaydedilmiş ve ilk yardım ile tedavi edilmiş iken, %27'si tıbbi tedavi gerektirmiş ve %9,6'sı iş kaybına ve bazen de yaralıların acil şekilde gemiden tahliye edilmesi gerektiren durumlara neden olmuş. Kişisel yaralanmaların en yüksek olduğu çalışma alanları makine dairesi (%29), ana güverte (%19) ve kumanya depolama alanları ve kuzine olarak sıralanmıştır.

En yaygın kaza türleri hareketli nesneler tarafından çarpılma, kayma, takılma düşme ve nesnelere çarpma olarak belirlenmiştir. Kayma ve takılmalar, kritik olaylarda belirgin bir şekilde yaygın olup, bu tür vakaların %41'ini oluşturmuştur. Çalışma, MAIB yıllık raporlarıyla tutarlı şekilde el ve parmak yaralanmalarının %35 ile en sık yaralanan bölge olarak ön plana çıkmıştır. Bu yaralanmalar, yaygın olmasının yanı sıra kritik yaralanmaların %20'sini oluşturarak potansiyel ciddiyetini ortaya koymuştur.

Yaralanmalara katkıda bulunan kritik faktörler arasında kişisel koruyucu ekipmanların yanlış kullanımı, güvenlik prosedürlerine uyulmaması ve yeterli sabitleme ve koruma uygulanmaması yer almıştır. Kişisel yaralanma kazalarının %51'inde temel neden olarak yetkinlik eksikliği, genellikle durumsal farkındalık, risk algısı ve yönetimi alt kategorisi ile karakterize edilmiştir.

Risk algısı ve yönetimi literatür incelemesi göstermiştir ki denizcilik güvenliği alanında da konu sıkça ele alınmış ve denizcilik ile açık deniz endüstrilerinde yürütülen çeşitli çalışmalarda, durumsal farkındalığın denizcilik operasyonlarının farklı yönlerinde kritik bir bileşen olduğu ve güvenlik ile karar verme süreçlerini önemli ölçüde etkilediği ortaya konmuştur.

Bu çalışma kapsamında ayrıca, güvenlik performansını değerlendirmek amacıyla Heinrich'in teorisiyle karşılaştırmalar yapılarak öncü ve gecikmeli göstergeleri arasındaki ilişki incelenmiş, ve raporlama sayıları incelenerek sistematik olarak karşılaştırılmıştır. Veri setindeki tüm kategoriler altındaki öncü ve gecikmeli gösterge rapor sayıları Heinrich teorisiyle karşılaştırıldığında, kaza sayısına göre öncü göstergelerin beklenenden düşük olduğu görülmüştür. Yalnızca yaralanma vakaları ele alınarak yapılan karşılaştırmada, kritik yaralanma, küçük yaralanma ve yaralanmasız olay rapor sayıları incelenmiş ve beklenenden önemli ölçüde daha düşük yaralanmasız olay raporlandığı görülmüştür. Aynı rakamlar el ve parmak yaralanmaları özelinde de incelenmiş olup, öncü göstergelerdeki raporlama sayısının eksikliği gözlemlenmiştir.

Küçük yaralanmalar ve yaralanmasız olayların sayısının büyük kazalara göre daha az olması, olay raporlamasında potansiyel eksiklikler veya daha az ciddi olayların tespiti ve yönetimi ile ilgili sorunları gösterebilir. Ayrıca, meydana gelen olayların daha ciddi sonuçlara doğru hızla ilerlediğini, önleyici tedbirlerdeki eksikliklere işaret edebilir. Bu alanların güçlendirilmesi, olayların ciddileşmeden önce erken uyarı işaretleri ve müdahale fırsatları sağlayabilir. Endüstri için önleyici eylemler, tüm olayların raporlanmasının önemine yönelik çalışan eğitimlerinin iyileştirilmesi, güvenlik kültürünün geliştirilmesi ve daha sıkı tehlike tespit süreçlerinin uygulanmasını içerir. Bu dengesizliği gidermek, kuruluşun güvenlik eğitim programlarını güçlendirmeyi, olay raporlama süreçlerini iyileştirmeyi ve riskleri etkili bir şekilde yönetmek ve azaltmak için daha sıkı güvenlik önlemlerini uygulamayı gerektirebilir. Bu proaktif yaklaşım, kuruluşun olay oranlarını beklenen güvenlik modellerine daha yakın hale getirebilir ve iş kazalarının sıklığını ve ciddiyetini azaltabilir.

Çalışma, gelecekteki araştırmaların regresyon analizi ve öngörüselleştirme gibi istatistiksel yöntemler kullanarak veri setlerindeki kalıpları belirlemesini önermektedir. Regresyon analizi, korelasyon katsayıları ve ileri düzey tahmin modellemesi gibi teknikler, gözle görülmeyen örüntüleri ve ilişkileri ortaya çıkarmaya yardımcı olduğu bilinmektedir.

Ayrıca denizcilik güvenlik eğitim modellerini detaylı olay raporlaması ve durumsal farkındalığı içerecek şekilde geliştirmenin önemli çalışma kapsamında vurgulanmış ve bu unsurların eğitim müfredatına dahil ederek, denizcilik personelinin riskleri daha iyi tanımlayıp azaltabileceğinin altı çizilmiştir.

Çalışma, ayrıca el, göz ve ayak koruyucu kişisel koruyucu ekipmanların tasarımında yenilik ve gelişim ihtiyacını da vurgulamaktadır. Gelecek araştırmalar, daha esnek, uyarlanabilir ve darbe dayanıklı el koruma ekipmanlarının tasarımına odaklanmalıdır. Bu, el ve parmak yaralanmalarının yüksek oranını etkili bir şekilde ele almak için önemlidir. Benzer şekilde, kayma ve düşme tehlikelerini yeterince ele almak için kaymaz ayakkabılar üzerinde tasarım iyileştirmeleri ve daha fazla araştırma gereklidir. Bu iyileştirmeler, yaralanmaları önlemek ve denizcilerin güvenliğini artırmak için kritik öneme sahiptir.



1. INTRODUCTION

Maritime accidents continue to be a significant concern all around the world. Although the general public may mostly associate these incidents with vessels and assets, these incidents not only pose threats to significant financial losses but also have bigger consequences, like harm to the environment and potential risks to human life.

Typically, accidents involving property loss, fatalities, injuries, or environmental damage undergo investigation, often aimed at determining responsibility and accountability. The primary objective of investigating these incidents is to understand the root causes, enabling the formulation of strategies to mitigate or prevent future occurrences. Through such investigations, it is possible to enhance maritime safety by identifying risk-reducing strategies and implementing necessary regulations (Abuelenin, 2017). Member states of the IMO prioritize the investigation of marine casualties and incidents to foster cooperation among nations and establish a unified approach to maritime accident investigations. This international interest has led to the development of various international maritime conventions, including the UNCLOS, SOLAS Convention, the MARPOL Convention, and the LL Convention. The reporting and investigation of safety-related incidents have become a mandatory requirement by various international law, convention, code, and regulations. In November 1997, the IMO MSC endorsed a marine accident investigation code through resolution A.849(20), demonstrating its commitment to standardizing investigative procedures in the maritime domain. This code was later amended and adopted as RESOLUTION MSC.255 (84) on 16 May 2008 which encompasses safety research, recommended practices, and international standards for investigating marine accidents and incidents. (Abuelenin, 2016).

Following adopting a systematic approach to improve safety, organizations have successfully integrated a culture of thorough accident reporting and analysis. This strategic initiative has embedded these practices within their operational frameworks. The direct result of such integration is the stabilizing the publication of comprehensive reports of maritime accidents, which provide insights into trends, causes, and potential

preventive measures. This process not only helps in understanding the specifics of each incident but also aids in developing strategies to prevent future accidents.

European Maritime Safety Agency Annual Overview of Marine Casualties and Incidents 2023 report provides 8 years of data between 2014 to 2022, including the analysis of 405 maritime incidents resulting in 604 fatalities, showing a downward trend. The average annual fatalities were sixty-seven, with the highest at 114 in 2014 and the lowest at 38 in 2022. During the same period, there were also 6,781 injuries reported. This also indicates a decreasing trend, averaging 753 injuries per year, peaking at 999 in 2014 and reducing to 525 in 2022. This data underscores a consistent decline in both fatalities and injuries over the analyzed period.

The latest report from the Transportation Safety Board of Canada Statistical Summary includes marine transportation occurrences providing a decade of maritime incident data and reaching similar statistics with EMSA. According to the report, marine fatalities in 2022 dropped to seven, down from eleven in 2021 and under the average of fifteen between 2012 and 2021. Specifically, two fatalities were linked to shipping accidents, and five occurred during separate incidents aboard ships. Additionally, the report noted a decrease in serious injuries to 40 in 2022 from 45 in 2021.

In addition to the above-mentioned organizations, the Maritime Accident Investigation Branch part of the United Kingdom Department for Transport is responsible for investigating all civil maritime accidents involving UK vessels worldwide and all vessels in British territorial waters. The findings from these investigations are published in the MAIB Annual report, aimed at disseminating safety lessons and informing the public and maritime industry about risks identified during investigations such as general information on trends in accidents, including types of incidents and outcomes. The latest report covering the period from 2013 to 2022 reveals that on average, 116 commercial ship crew members were injured each year. Like other reports, it is also observed that over the last five years, the number of injuries has consistently trended downwards and remained below the annual average. The MAIB's further analyses over the past three years have concentrated on injuries affecting specific body parts, revealing a significant trend of injuries. Despite these decreasing trends in the total number of casualties, a significant increase is observed in upper limb injuries, particularly hands, and fingers in the reports between 2020 to 2022. In 2020, there were twelve reported cases of hand and finger injuries, which increased to 15 in 2021 and then to 22 in 2022, indicating a growing

trend. The reports highlight that almost half of all injuries involve the upper limbs, emphasizing the substantial risks associated with hand-involved activities. The latest report from 2022, shows that fingers are the most frequently injured area, with fifteen instances during the year, underscoring their susceptibility due to constant use and exposure in various tasks. Moreover, there were seven reported injuries specifically to the hands (excluding fingers), pointing to the considerable dangers involved in tasks that require handling and grasping. These reports indicate the need for further research to thoroughly understand the common occurrence of hand and finger injuries among seafarers. This in-depth examination is aimed at identifying prevalent patterns and comparing them with findings from the MAIB. Such a comparison may show whether injury trends are consistent across different organizational environments or if they differ significantly. The ultimate objective is to derive insights that could guide the development of more effective prevention strategies and safety measures, specifically tailored to the unique conditions of the ship's organizational setting.

The study analyzed five years of marine incident data from 2018 to 2023 involving 35 MR-sized tankers typically between 25,000 and 55,000 deadweight tonnes from a Turkish tanker operator, which included accidents, near misses, unsafe acts, and conditions. A detailed examination of personal injury variables, such as the severity, location of injuries, the work processes involved, specific activities, materials agents contributing to injuries, modes of injuries, affected body parts, and root cause analysis was conducted by using descriptive statistics.

The study describes a comprehensive methodological approach for analyzing company-specific data related to marine injuries. The study utilized multiple methods, to investigate personal injury variables. The severity, mode of injury, and root causes were categorized according to the company's incident management procedures, which incorporated Marine Systematic Cause Analysis Technique mapping for conducting root cause analysis. The European Statistics on Accidents at Work classification was additionally implemented to examine the location of injuries, the work processes, specific activities, materials agents contributing to injuries, and affected body parts. Additionally, the research explored the relationship between leading and lagging indicators to assess safety performance, integrating comparisons with Heinrich's theory.



2. LITERATURE REVIEW

The scientific method of investigating accidents was initiated in England at the beginning of the 20th century with Vernon's extensive study on the causes of industrial accidents (Vernon, 1918). Vernon conducted a statistical analysis of fifty thousand industrial accidents collected from four different factories throughout the United Kingdom, focusing on the hourly variations across various categories of industrial accidents. This pioneering publication may have been the first to employ a systematic approach to identifying diverse causes of accidents. Vernon initially categorized the factors into two principal groups: (i) factors of personal origin and (ii) factors of external origin. Despite a century having passed, many industries continue to face accidents, systematically recording all incidents, from minor to severe, to analyze and understand these occurrences. (Awal and Hasegawa, 2017).

Across all industries, departments must conduct root cause analyses effectively for corrective and preventive activities related to the failures as required by national and international requirements. The goal is to resolve problems by identifying root causes and preventing their recurrence. Various techniques are used for root cause analysis related to accidents. Due to the unique nature of ship operations existing techniques for root cause analysis are sometimes complicated. The following section reviews the common root cause analysis techniques, and tools utilized in the maritime industry.

Within the maritime domain, a range of methodologies are employed to analyze incidents. One such approach, endorsed by the IMO for examining maritime incidents through a human factor perspective, is the SHELL model (Chen and Chou, 2012). Named after the initial letters of software, hardware, environment, and liveware. This model situates humans at the core of the system prone to accidents. It aims to assess human interactions across all facets implicated in accident causation.

Additionally, the Human Factors Analysis and Classification System for Maritime Accidents represents a prototype framework aligned with IMO guidelines, offering extensive insights into maritime incidents. Initially developed by the U.S. Navy to improve aviation safety, it has since been adapted for use in various domains, including

healthcare, mining, and the maritime industry. By systematically classifying human error, HFACS provides a structured method for identifying and rectifying systemic issues that contribute to accidents, enhancing safety protocols, and preventing future occurrences (Wiegmann and Shappell, 2003).

Another method called Hazard and Operability Analysis can be considered another main technique that is very similar to Failure Modes and Effects Analysis in terms of application. It is used to identify errors through brainstorming. In literature, the HAZOP technique is frequently mentioned as being utilized during the risk analysis phase. For instance, it has been applied in the risk assessment of the main engine of a container ship (Zhan et al, 2012). HAZOP method is defined as structured and systematic technique for identifying potential hazards and operability problems in industrial processes. It is primarily used to assess complex systems where significant hazards exist. The HAZOP process involves a multidisciplinary team that systematically reviews process diagrams and uses guide words to probe for deviations from the design intent that could lead to hazards or operability issues. The ultimate goal of HAZOP is to enhance the safety and efficiency of the process by identifying vulnerabilities and suggesting mitigations (Crawley and Tyler, 2015).

Another method, the Analytic Network Process, developed by Saaty in 1996, is a significant tool in the field of Multi-Criteria Decision Making, a sub-discipline of operational research that focuses on structuring and solving decision-making problems involving multiple criteria (Saaty, 1996). The ANP is specifically designed to identify and account for the dependencies and feedback relationships both within and between clusters and elements involved in decision-making scenarios. The primary goal of ANP is to equip users with a sophisticated tool that helps in selecting alternatives by considering not only the attributes and criteria but also the potential consequences of each choice. By doing this, ANP facilitates a thorough understanding of both the internal dependencies among the elements and the external connections between different elements (Akyuz, 2015).

In addition to these methods, the literature includes studies that adopt a hybrid maritime accident analysis approach by combining two techniques. For instance, The HFACS method offers a schematic conceptual framework for analyzing and categorizing human error in maritime accidents, while the ANP technique quantifies accident causes by identifying correlations among them. This combination allows for

a numerical investigation and analysis of the most significant causes of maritime accidents. Furthermore, the proposed model includes a maritime accident prevention plan aimed at proactively addressing similar incidents. This approach is illustrated with a real-life case study involving a serious liquefied petroleum gas leakage from a gas carrier vessel (Akyuz, 2017).

Additionally, commercial software tools are also available for analyzing maritime accidents, complementing the techniques previously mentioned. One example is the American Bureau of Shipping MaRCAT, which employs a complex and predefined fault tree to identify root causes without providing numerical results. Similarly, the Det Norske Veritas MSCAT, is another commercial tool (Keçeci and Arslan, 2015). MSCAT is a checklist-based tool used for incident investigation. This technique maps out incident root causes by linking event types to immediate causes, which are then connected to fundamental causes, and finally to predefined corrective action areas. However, assessing the validity of MSCAT is challenging due to the lack of publicly available scientific references (Pranger, 2009). Another significant limitation of MSCAT is its nonquantitative approach, which limits its ability to provide detailed analytical results (Keçeci and Arslan, 2017). Another study highlighted that the method outlined is effective and can be utilized by well-trained supervisors, enabling each incident or near-miss to be evaluated in a uniform, risk-based manner. This approach effectively connects each assessment back to the facility's risk assessment, highlighting risk pathways that may be overly optimistic (i.e., risks that are greater than initially anticipated). Such discrepancies could stem from initial over-optimism or the deterioration of safety barriers, whether human or mechanical (Pitblado et al, 2015).

As introduced in the first chapter, the dataset for this study leveraged the MSCAT mapping system to conduct a comprehensive root cause analysis of all incidents. This system was applied to both leading and lagging indicators, enabling detailed examinations of all personal injury cases, with a particular focus on hand and finger injuries.

MSCAT developed by DNV, is a structured methodology used in the maritime industry for analyzing the root causes of safety incidents. This technique is part of broader safety management efforts and is designed to help identify the underlying factors contributing to accidents and near-misses on marine vessels. The approach

involves systematically examining incident reports to pinpoint what went wrong and why, focusing on both direct causes and deeper systemic issues. It employs a combination of diagrammatic and tabular methods to map out sequences of events and their interrelationships, facilitating a comprehensive understanding of the incident dynamics. MSCAT is often used by shipping companies, safety officers, and regulatory bodies to enhance safety protocols and implement preventative measures. By using this method, stakeholders can better understand the patterns and trends in safety incidents, leading to more effective risk management strategies in the maritime sector.

The literature review reveals that the Systematic Cause Analysis Technique is a structured methodology used for root cause analysis, which helps identify the fundamental reasons for faults or problems. This technique is highly valued for its systematic approach to diagnosing incidents by identifying both direct and underlying causes of issues. An example of the application of SCAT is presented in the study where they discuss enhancing traditional root cause analysis with the 3 × 5 Why's technique. This method extends the typical inquiry to cover occurrence, human, and systemic issues, providing a deeper understanding of the problem and ensuring that corrective actions address all contributing factors (Gangidi, 2019).

DNV recently shared an overview of the Root Cause Analysis method SCAT, which is based on DNV's loss causation model. SCAT operates on the principle that all accidents stem from similar fundamental causes, primarily linked to deficiencies within management systems. The DNV Loss Causation Model depicted outlines a progression from Lack of Control through Basic Causes and Immediate Causes, leading to an Incident and resulting in Loss, which is characterized as unintended harm or damage. This model emphasizes the necessity to control and address these causes at multiple stages to prevent accidents, with each step involving inadequate system standards, personal factors, or substandard conditions and practices contributing to the eventual adverse outcomes. The overview outlines four critical stages in utilizing the SCAT for organizational learning and improvement:

Analyze: This stage emphasizes the need to assess events with a high potential for loss through root cause analysis to ensure corrective actions are identified and such events are not repeated.

Learn: It provides simple guidance on extracting lessons from events through incident reporting, investigation, and analysis, which is crucial for continuous improvement.

Test: This involves evaluating your knowledge of learning from events, through some form of quiz or assessment tool, which could include earning achievement badges as a form of recognition and motivation.

Chart: This allows users to download the SCAT Chart in multiple languages, enabling them to print these resources as posters for reference and to facilitate the explanation of root cause analysis to others, enhancing understanding and application across the organization.

Each step is designed to build upon the previous one, creating a comprehensive framework for preventing future incidents by learning from past mistakes and ensuring that this knowledge is effectively communicated and understood organization wide. (DNV., 2022).

As introduced in the first chapter, ESAW classification was additionally employed to further explore the varied factors contributing to injuries including location, the work processes, specific activities, materials agents contributing to injuries, and affected body parts. The additional implementation of classification applies to 239 personal injury accidents allowing for a detailed examination of numerous factors. This comprehensive approach facilitates a deeper understanding of the contexts and causes of workplace injuries, aiding in the development of targeted preventive measures to enhance seafarer's safety (Eurostat, 2001).

The ESAW classification system is utilized in numerous studies to analyze workplace injuries within specific industries, including the maritime industry. These studies indicate the ESAW classification system's adaptability and utility in analyzing workplace injuries and developing targeted interventions within the maritime industry, providing a structured approach to understanding and preventing workplace accidents. Such studies utilize this methodology to incorporate ESAW classifications to assess occupational risks in shipbuilding, enhancing the identification of accident causal pathways and safety barriers. The research applied this method to a shipyard in Portugal, demonstrating its effectiveness in pinpointing risks and developing preventive strategies (Jacinto and Silva, 2010).

Another study utilized ESAW variables to investigate the origins and patterns of head injuries across various economic sectors, from 2010 to 2017. This comprehensive analysis spanned twenty industry sectors, including maritime, to uncover distinct injury patterns. The data, drawn from a national statutory insurance and reporting system, offered a refined understanding of how head injuries occur and vary across different fields. In sectors like construction and manufacturing, head injuries were linked to routine activities involving the use of hand-held tools. The research highlighted the necessity for enhanced safety protocols concerning tools and machinery, along with the development of superior protective equipment to mitigate these risks. Other sectors exhibited unique injury profiles, particularly healthcare, where head injuries are often associated with violence and threats. This variation underscores the importance of developing targeted safety measures that address the specific nature of each sector. By analyzing the specific conditions and mechanisms of injuries, the study provided valuable insights into effective prevention strategies tailored to the unique needs of each sector, promoting a safer work environment across the board (Heimonen et al., 2021).

Additionally, the injuries were assessed according to their criticality from the severity point of view, specifically focusing on cases classified under LWC (Lost Workday Cases) and PPT (Permanent Partial Disabilities) along with PDC (Permanent Disabilities Cases) as critical. During this evaluation, an analysis was conducted to identify which variables led to more severe outcomes. This approach helped in understanding the impact of varied factors on the severity of the injuries sustained in these incidents.

As discussed in the opening chapter, the research investigated the relationship between leading and lagging indicators to evaluate safety performance. This included integrating comparisons with Heinrich's theory to provide a comprehensive understanding of the dynamics influencing safety outcomes.

The analysis examined the correlation across 6,863 incident cases, initially reviewing the distribution of incident records by various categories such as accidents, near misses, unsafe acts, and unsafe conditions, and comparing these findings with Heinrich's severity ratios. Additionally, the study delved into 2,103 personal injury incident records, analyzing, and comparing their distribution across the same categories. The focus then narrowed to 357 cases of hand/finger injuries, which found

the most frequently affected body area, analyzing their distribution by the same categories to understand patterns and trends in the light of the theory.

Heinrich's theory, as proposed in the 1930s, has been extensively studied and discussed in the field of occupational safety. The theory highlights a causal relationship between near-misses, minor injuries, and major accidents. Heinrich's original severity ratios (1:29:300) suggested that for every major accident, there are 29 minor injuries and 300 no-injury incidents (Majumdar et al, 2021). This highlights the continued relevance and application of Heinrich's ratios in understanding and analyzing safety and accident prevention strategies across different industries. Heinrich's pyramid illustrates the frequency distribution of incidents and emphasizes the importance of addressing less severe incidents to prevent more serious accidents. By understanding and applying this model, organizations can prioritize preventative measures that tackle the root causes of unsafe conditions and actions, thereby significantly reducing the occurrence of more severe outcomes. By addressing the foundational elements highlighted in the pyramid, organizations can effectively lower the probability of severe accidents, thereby protecting workers and resources sustainably and effectively (Marshall et al, 2018). Furthermore, focusing on proactive measures, such as improving workplace conditions, training employees to perform tasks safely, and rigorously investigating and learning from near misses, can significantly reduce the likelihood of accidents. This proactive approach aligns with modern interpretations of Heinrich's theory, which stresses continuous improvement and organizational learning as key factors in achieving safety excellence (Yorio and Moore, 2018). These references highlight both the application and the critiques of Heinrich's theory in various modern contexts, suggesting that while the model has been foundational in safety management, its application may require adaptation to fit specific industry realities. However, certain studies have raised concerns about the predictive validity of Heinrich's ratios. One such study critically analyzed these ratios using data from General Aviation accidents and found no significant correlation between the total number of accidents and fatalities, thus casting doubt on the pyramid's predictive validity. This research, utilizing NTSB data, further questioned the statistical validity of Heinrich's pyramid in the context of General Aviation accidents (Onwuka, 2020).

While conducting the analyses mentioned above, descriptive statistics methods were utilized to systematically summarize and interpret the data. Descriptive statistics are a crucial part of data analysis in research, providing simple summaries of the samples and measures used in a study. They include measures of central tendency (like mean, median, and mode) and measures of dispersion (like range, variance, and standard deviation), which help to describe the distribution of the data. One of the key functions of descriptive statistics is to lay the groundwork for further statistical analysis by summarizing the data in a way that is digestible and informative for both researchers and stakeholders. This simplification of data allows for a clearer understanding of the data's structure before applying more complex inferential statistics, which aim to make predictions or infer patterns based on the sample data.

Numerous studies offer a comprehensive overview of the method's implementation. Some of these studies serve as the initial steps in a series designed to educate radiographers on basic statistical concepts, enabling them to interpret existing research and conduct their studies. This paper is foundational, providing a guide to descriptive statistics that underpins more advanced analytical techniques. (Marshall and Jonker, 2010).

3. METHODOLOGY

The universe of this study encompasses maritime incidents, with a particular focus on incidents resulting in personal injuries among seafarers. However, due to the sensitive nature of accident data and the confidentiality policies maintained by maritime companies, access to comprehensive accident records is restricted. Although agencies like the MAIB and the EMSA provide regional reports, these documents often lack the granularity needed for a focused study on personal injuries. Moreover, even when such data is available, not all companies share their incident reports with lower consequences or leading indicators unless mandated by regulation. Therefore, a full representation of the universe through these channels is unattainable. Given these constraints, this study employs a convenience sampling strategy, focusing on available data from the Turkish Tanker Operator's internal records offering a practical source of data, albeit limited to one organization's experiences. This sampling method was chosen because of the impracticality of accessing a broader dataset due to the reasons mentioned earlier.

The research analyzed 6,863 qualitative maritime incident reports collected from a tanker operator's database for the years 2018 to 2023 from thirty-five different ships under the same management. These reports, a primary qualitative data source, included detailed descriptions of the incident's consequence, severity, type of losses, or potential type of losses for the leading indicators, event sequences, and environmental conditions. The methodology utilized a data-driven approach, incorporating statistical analysis to interpret the semi-structured and unstructured narrative descriptions. This process began with the preparation of data according to the company's incident management procedure, which involved compiling, classifying, and formatting the data. Each report underwent a manual screening to verify completeness. Subsequently, the data was organized and converted into quantitative variables for statistical analysis, while also preserving the original text for content analysis.

The research focused on four primary variables frequently used in maritime accident studies: accidents, near misses, unsafe acts, and conditions. Within this framework,

near misses, unsafe acts, and conditions were treated as leading indicators, while accidents were considered lagging indicators. The incidents resulting in personal injuries were analyzed, which explored the severity, location of the injuries, the work processes involved, contributing materials and agents, modes of injury, affected body parts, and the root causes. The analysis adhered to the company's incident management procedures, employing MSCAT mapping for detailed root cause analysis and the ESAW classification to further delineate the specifics of the injuries.

Additionally, the research investigated the correlation between leading and lagging safety indicators, employing comparisons to Heinrich's theory to assess safety performance. This comprehensive methodological approach helped systematically identify and address factors contributing to injuries, enhancing the understanding of maritime safety dynamics.

It is essential to recognize that these statistics are based solely on the provided data from the same company, and the actual level of criticality may vary in different environments, depending on the safety measures in place or the approach to safety culture.

The data and statistics used in this analysis do not include any personal identifiers such as age, gender, nationality, or other details. Furthermore, information regarding the rank of individuals involved was not categorized. This decision was based on the understanding that errors are a normal occurrence and can happen regardless of an individual's level of experience or rank. The approach reflects a focus on systemic factors over personal attributes or hierarchical status in understanding incidents.

4. ANALYSIS OF MARITIME INCIDENTS

The subsequent section offers a detailed analysis of data collected between 2018 and 2022, organized primarily by incident type and the corresponding number of cases for each category. The data, sourced from accident reports, is further broken down into subcategories such as type, severity, location, process involved, activity, agent responsible, injury mode, and injury type and location. Each subcategory undergoes a frequency analysis to examine the prevalence of each incident type, with a particular focus on the criticality of incidents based on their severity. The findings are presented alongside potential interpretations to provide a comprehensive understanding of the data's implications on maritime safety. These interpretations draw on existing literature and are corroborated by the correlational data within some categories. Additionally, this section includes two case studies that highlight the most severe incidents recorded in the database over a five-year period, illustrating critical outcomes and their impact on maritime safety protocols.

4.1. Analysis of Accident Records by Type of Losses

This chapter is structured based on the classifications defined in the Company's Incident Management Procedure. Below are the detailed definitions of each category of accidents:

Personal Injury: Any sign or symptom of physical damage or impairment to any part of the body directly resulting from an incident, regardless of the length of time between the incident and the appearance of the injury. Categories include First Aid Case, Restricted Work Case, Medical Treatment Case, Lost Workday Case, Permanent Total Disability, Permanent Partial Disability, and Fatality.

Critical Personal Injury: Includes severe categories such as LWC, PTD, PPD, and Fatality. Further details of these categories will be available in the following chapter (4.2. Analysis of Personal Injury Accident Records by Severity)

Fire & Explosion: Any type of fire event including battery explosions, scavenge fires, boiler fires, etc.

Navigational-Type: Encompasses maritime incidents such as collisions, allisions, groundings, and bottom touches.

Flooding: Includes incidents resulting from hull breaches or valve failures.

Mooring: Includes scenarios like anchor damage/loss, failure of mooring equipment, ropes, etc.

Oil Spill / Pollution: This encompasses spills of liquids (cargo, bunkers, hydraulic oil, lubricating oil, stern tube oil, etc.) and garbage, along with noise pollution, air pollution, etc.

Machinery Failure: Includes loss of power, blackout, failure of cargo equipment, all E/Room equipment, bow thruster, communication equipment, navigation equipment, and all critical equipment, etc. (Company IMS, 2022)

This chapter will delve into the intricate details of various accident types by analyzing 674 accident reports from the company-specific data set, categorized based on the type of loss sustained. Through this comprehensive analysis, the chapter will explore their impacts on safety protocols, operational efficiency, and the broader implications for industry standards.

Personal Injury (239 cases): This category, representing the largest share of accidents, highlights significant risks to personal safety aboard ships. It underscores the need for rigorous behavior-based safety improvement to mitigate accidents that lead directly to physical injuries. Twenty-four of these personal injury cases have been reported as critical, where individuals were lost workdays and, or repatriated from the ship.

Property Damage (152 cases): Covering a range of damages including equipment failures and weather-related accidents, this category calls for enhanced protective measures for both the ship's property and cargo.

Oil Spill/Pollution (84 cases): This type of incident refers to environmental hazards associated with maritime activities. Implementing stricter protocols for handling and transferring hazardous materials, along with rapid response strategies for containment and mitigation, are critical to reducing the occurrence of these accidents and their effect on nature.

Mooring (53 cases): Mooring accidents, including anchor and equipment failures, suggest the necessity for regular inspections and maintenance of mooring equipment, along with proper training in handling such equipment under varying conditions.

Machinery Failure (32 cases): The breakdown of essential machinery can lead to severe operational disruptions. Preventive maintenance and real-time monitoring systems are found pivotal in anticipating failures before they lead to larger issues.

Ballast/Cargo Transfer Related (16 cases): Contamination during transfer processes illustrates the need for more rigorous control and monitoring systems, to ensure the safety of the crew and the integrity of cargo and ballast during handling.

Navigational (14 cases): These accidents often result from errors in navigation or collisions. Emphasizing the use of advanced navigation systems, ongoing crew training in collision avoidance, and strict adherence to maritime traffic regulations.

Fire & Explosion (11 cases): Although relatively low in frequency, the potential severity of these accidents mandates stringent control measures. These measures include regular maintenance and checks of electrical and fuel-handling systems, and enhanced training on fire safety to prevent such hazardous events.

Bunker Transfer Related (6 cases): Similar to ballast and cargo, these accidents focus on the need for careful management of fuel and lubricant transfers, which should include comprehensive training and adherence to protocols to prevent spills and contamination.

Piracy/Security (2 cases): Although the least frequent, the elevated risk associated with piracy and security breaches requires constant vigilance and the implementation of security protocols.

Other (37 cases): This miscellaneous category highlights less common or unique accidents, suggesting a need for a flexible and adaptive approach to incident management that can handle unexpected situations effectively.

The analysis indicates that while some types of accidents occur less frequently, their potential impact on safety, environment, and operations is significant. Each category of accident demands targeted strategies that include training, equipment maintenance, procedural adherence, and environmental protection measures. Enhanced focus on

these areas can lead to a significant reduction in maritime incidents, thereby improving safety and operational efficiency for the crew, vessels, and operators.

The high percentage of personal injuries established a framework for the study, prompting further investigation into numerous factors contributing to these injuries (Figure 3.1).

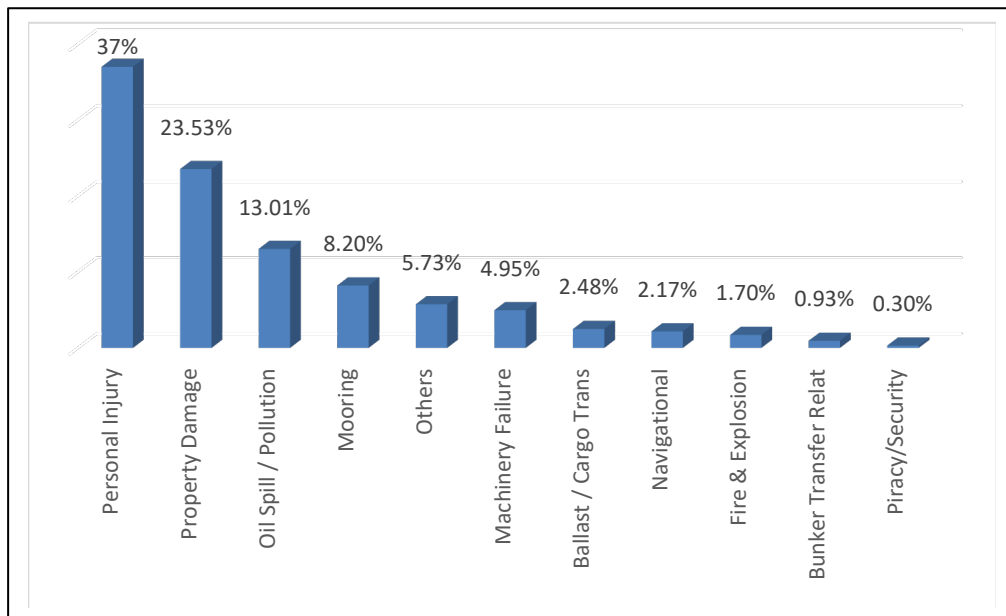


Figure 3.1: Distribution of accident records by type of loss.

4.2. Analysis of Injury Records by Severity

This chapter is structured based on the classifications defined in the Company's Incident Management Procedure. Below are the detailed definitions of each category of personal injury accidents:

First Aid Case : Any one-time treatment and subsequent observation or minor injuries such as bruises, scratches, cuts, burns, splinters, etc. The first aid may or may not be administered by a physician or registered professional. FACs include Follow-up visits to a physician or nurse for observation only, or for routine dressing changes; negative X-ray results; cleaning abrasions/wounds with antiseptic and applying dressing; irrigation of the eye and removal of non-embedded foreign objects using a cotton swab; one-time administration of oxygen after exposure to a toxic atmosphere and resumption of normal (but not restricted) work the following day; soaking, application of hot-cold compress, and use of an elastic bandage on sprains and strains immediately

after injury; applying a one-off cold compress or limited soaking of a bruise; use of non-prescription medicines; use of elastic bandages; treatment of first-degree burns.

Medical Treatment Case : Any work-related loss of consciousness (unless due to ill health), injury, or illness requiring more than first aid treatment by a physician, dentist, surgeon, or registered medical personnel e.g. a nurse or paramedic under the standing orders of a physician, under the specific order of a physician, or if at sea with no physician onboard could be considered as being in the province of a physician. MTCs include injuries resulting in loss of consciousness, even if the individual resumes work after regaining consciousness (this does not cover loss of consciousness due to ill health); sutures for non-cosmetic purposes; use of casts, splints, or other means of immobilization; any general surgical treatment; removal of embedded objects from the eye by surgical means; use of other than non-prescriptive drugs or medications; use of a series of compresses for treatments of bruises, sprains or strains; MTCs exclude the hospitalization for observation without treatment; a one-off tetanus injection; consultative visit to, or examination by, a physician or registered professional for a confirmatory check.

Restricted Work Case: Injuries result in an individual being unable to perform all normally assigned work functions during a scheduled work shift or being assigned to another job on a temporary or permanent basis on the day following the injury. In addition, less than normal assigned work functions fall under the category as well including performing all duties or normal assigned work functions but at a capacity less than a full-time schedule or performing limited duties at normally assigned jobs on a full-time schedule; and transferring to other duties.

Lost Workday Case: Injuries result in an individual being unable to carry out any of their duties or unable to return to work on a scheduled work shift on the day following the injury unless caused by delays in getting medical treatment ashore. An injury is classified as an LWC if the individual is discharged from the ship for medical treatment.

Permanent Partial Disability: Any work injury that results in the complete loss or permanent loss of use of any member or part of the body, or any pre-existing disability of the injured member or impaired body function, that partially restricts or limits an

employee's ability to work permanently at sea. Such an individual could be employed ashore but not at sea in line with industry guidelines.

Permanent Total Disability: Any work injury that incapacitates an employee permanently and results in termination of employment on medical grounds (e.g., loss of limb(s), permanent brain damage, loss of sight) and precludes the individual from working either at sea or ashore.

Fatality: A death directly resulting from a work injury regardless of the length of time between the injury and death. (Company IMS, 2022)

This chapter will explore the complexities of diverse types of injuries by examining 239 reports from a company-specific dataset, organized according to the severity.

First Aid Case (145 cases): The majority of cases involved minor injuries that were treated with first aid measures. The primary body parts affected were the hands/fingers and eyes. The most common types of injuries observed were wounds and superficial injuries, accounting for nearly 70% of the cases, followed by burns, corrosion, scalds, and frostbite.

Medical Treatment Case (65 cases): These cases necessitated medical treatment beyond onboard first aid and telemedical advice, with individuals promptly arranged for doctor visits at the earliest opportunity. The primary body parts affected in these medical treatment cases similarly include hands/fingers, eyes, and followed by the lumbar region. The most frequent types of injuries observed were superficial injuries, followed by dislocations, sprains, and strains. The top specific activities leading to these injuries were noted as handling objects, carrying by hand, and movement.

Lost Workday Case (23 cases): These injuries resulted in individuals being unable to carry out their duties or returning to work the day after the injury. Some cases even necessitated immediate discharge from the ship for medical treatment and early repatriation of the seafarers. The top types of injuries observed included dislocations, sprains, strains, concussions, internal injuries, and fractures. The primary material agents associated with these incidents included buildings, structures, and ground-level surfaces, where floor conditions led to slips, trips, and falls among the victims.

Restricted Work Case (5 cases): Injuries in this category led to reduced work capacity, including part-time schedules, limited duties, or job transfers. Similarly, the primary body parts injured were the lumbar region and hands/fingers.

Permanent Partial Disability (1 case): A particular case involved a critical injury leading to the permanent loss of two fingers, affecting the employee’s long-term ability to work. The accident details have been featured as a case study found in the section titled “Traumatic Amputations” under chapter 3.8.

Permanent Total Disability (0 cases): No PTD cases were reported.

Fatality (0 cases): No fatality cases were reported. (Figure 3.2).

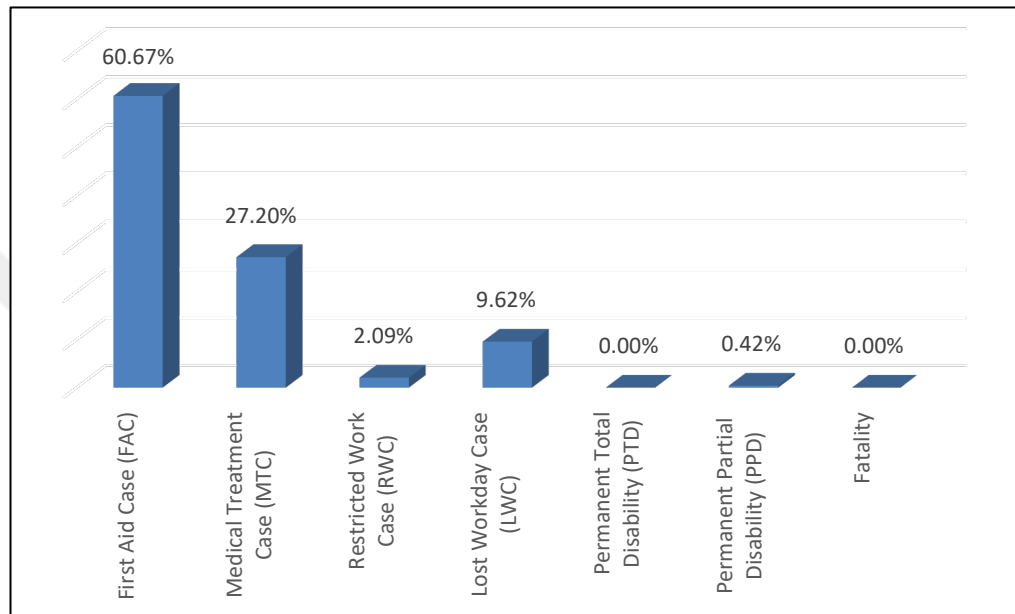


Figure 3.2: Distribution of injury records by severity.

4.3. Analysis of Injury Records by Location

This chapter is structured around the classifications defined in the ILO Occupational Injuries statistics. One key aspect detailed is the Location of the Accident, which specifies the site where the accident occurred. The location category refers to the specific area where the incident occurred, and where the individual was situated or engaged in work at the time of the accident. The location involved could be the regular workplace of the injured person, or any other area within the facility. Additionally, it might encompass spaces outside the regular workplace (Taswell and Digby, 2008). Within the study, the accident location data that was analyzed was based on two categories defined in the ESAW Guidelines: Workstations and Working Environment.

4.3.1. Analysis of injury records by workstations

This chapter begins with an exploration of the concept of a Workstation as defined by ESAW. A workstation is understood as the usual, or alternatively, occasional nature of the job or post that the victim held at the time of the accident. (Eurostat, 2001).

In line with ESAW Annex I: Classifications for workstations, every incident recorded in this dataset can be classified as occurring within Code 2: Occasional or mobile workstation or during a journey on behalf of the employer. Nonetheless, ships represent a specialized working environment that necessitates finer categorization. Consequently, the primary areas identified for the occurrence of accidents on ships are the deck, engine room, bridge, accommodation, and pier.

This chapter will investigate the primary sites of injuries by analyzing 239 reports from a specific company dataset. The focus will be on identifying the most hazardous areas to target for further safety interventions.

Deck (85 cases): As the focal point for a multitude of maritime operations, the deck incorporates the main deck, cargo area, mooring station, pilot boarding station, paint room, and bunkering station. The increased severity is due to the complex and dynamic nature of deck operations, which often involve heavy lifting, maintenance activities, and exposure to environmental elements that cause slip-and-fall injuries.

Engine (81 cases): The engine compartment serves as the heart of the ship's propulsion and stability, encompassing the steering gear room, engine room, and store/workshop. The technical and hands-on nature of work here, often involving heavy machinery, accounts for a substantial number of incidents. However, the critical incident rate is comparatively modest at 6.17%, which may be a testament to the specialized nature of the tasks and the complex, yet controlled interaction with hazardous machinery.

Accommodation (61 cases): The accommodation area is the center of crew life and operations onboard, including the provision store/galley, cabins, mess rooms, ship's office, garbage room, upper decks, and gym. This segment of the ship, although not directly linked to maritime operations, still reports a consistent stream of injuries, likely due to everyday activities and the use of various onboard equipment. With a critical incident rate of 6.56%, these living and operational spaces, though seemingly benign, prove that regular activities and equipment interactions have the potential to result in significant safety incidents.

Bridge (9 cases): As the pivotal area for navigation and vessel control, the bridge has fewer reported injuries, reflecting the less physically demanding nature of tasks and the rigorous enforcement of safety measures. Despite a smaller number of overall incidents, the bridge has an 11.11% critical incident rate, suggesting that while accidents are less frequent, they can be severe, underscoring the gravity of the bridge's functions.

Pier (3 cases): The pier, being the stage for embarkation and disembarkation, records the lowest injury counts, hinting at the potential effectiveness of safety protocols in these transitional spaces. With zero critical incidents reported, the pier appears to be a lower-risk area, likely due to the shorter time spent at the pier compared to the ship.

Various work processes were ongoing within the identified workstations at the time of the incidents, including production, storing, public service, intellectual work, office tasks, commercial activities, setup and maintenance, cleaning, waste management, monitoring, and movement or artistic activities. The data suggests a correlation between the nature of shipboard tasks and the frequency of injury accidents. Areas involving physical labor and interaction with machinery, show higher incident rates. Conversely, spaces like the bridge and pier, where intellectual and less physically demanding tasks predominate, reflect lower figures. This disparity underscores the necessity for stringent safety measures and comprehensive training to mitigate risks, particularly in high-activity areas (Figure 3.3).

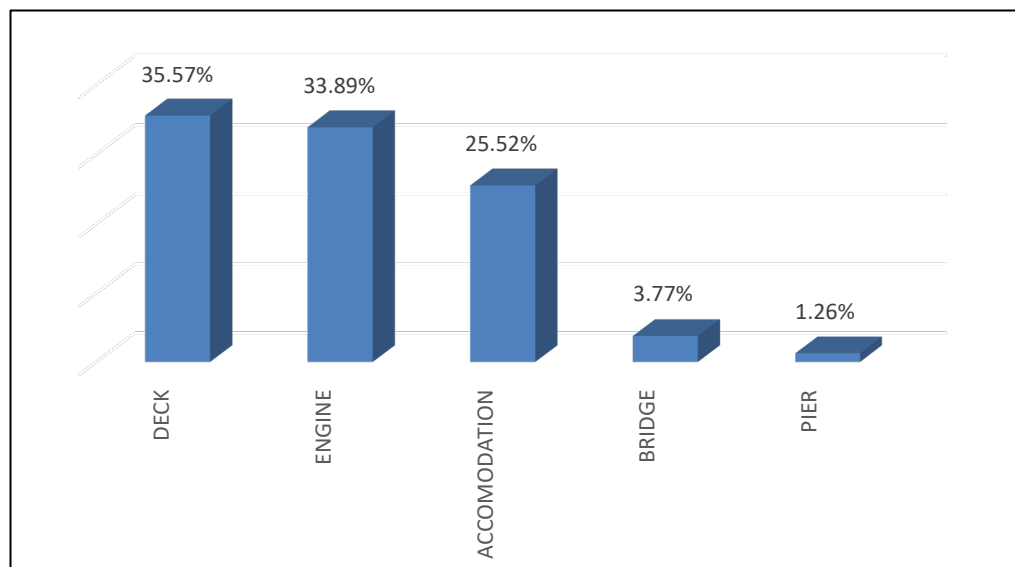


Figure 3.3: Distribution of injury records by workstation.

A detailed analysis of maritime accidents classified as critical reveals a slight contrast compared to more general personal injury accidents. This in-depth examination, covering twenty-four critical accidents, highlights a heightened risk associated with activities at the deck workstation. This data insightfully points out the disparities in accident severity across different shipboard environments, with the deck particularly highlighted as a concern for critical injuries (Figure 3.4).

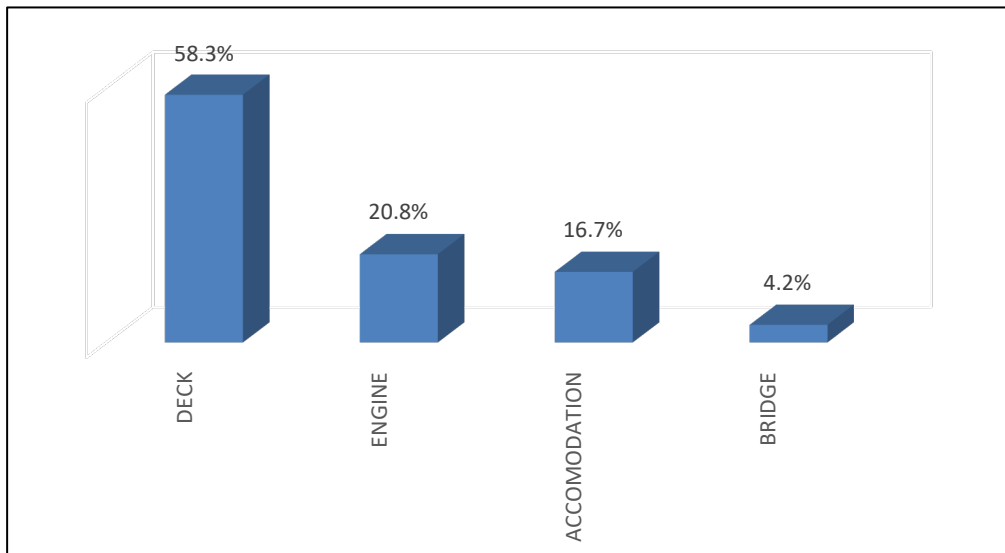


Figure 3.4: Distribution of critical injury records by workstation.

4.3.2. Analysis of injury records by working environment

This chapter begins with an exploration of the concept of the Working environment as defined by ESAW as the workplace, work premises, or general environment where the accident happened.

In line with ESAW Annex I: Classifications for the working environment, every incident recorded in this dataset can be classified as occurring within Code 111 Sea or ocean - aboard all types of vessels, platforms, ships, boats, and barges. Given the unique attributes of the ship environment, a more granular examination was found to be necessary. Therefore, attention is focused on the primary shipboard areas where accidents have been identified. Within the engine department, spaces such as the store/workshop, engine room, and steering gear room are designated for engine-related tasks. The deck encompasses crucial zones including the mooring station, main deck, stores/workshops, bunkering station, pilot boarding station, cargo area, and paint room, each serving distinct purposes related to deck operations. Accommodation

zones address the essential needs of crew members, providing facilities like provision stores/galleys, garbage rooms, upper decks, cabins, changing rooms, gyms, messrooms, and the ship's office. Work locations such as the bridge and pier remain unchanged under the working environment category.

This chapter will investigate the specific sites of injuries by analyzing 239 reports from a specific company dataset. This work environment data provides a focused analysis of personal injury accidents aboard ships, offering a detailed count of occurrences within specified areas, thereby enabling a targeted approach to understanding risk within these micro-environments.

Engine Room (70 cases): Standing out with the highest frequency of incidents, the engine room is an area synonymous with high-risk exposure due to the operational engagement with complex machinery and the intrinsic hazards of engine maintenance. Despite the relatively low critical incident rate stands at 5.71%, the most severe injury within this period resulted in the amputation of fingers recorded under this category.

Main Deck (45 cases): The main deck follows with a substantial number of cases, likely due to its centrality in ship operations, including cargo handling, and external maintenance tasks which are prone to accidents. With a 13.33% critical incident rate, it is marked by a particular susceptibility to accidents, underscoring the necessity for robust safety measures. The majority of these serious incidents arise from falls, including slips, trips, and falls on the same level, as well as injuries sustained from overloading during manual handling.

Provision Store/Galley (23 cases): The provision store/galley is a significant location for injuries, potentially due to the interaction with kitchen equipment and the handling of provisions which can lead to a variety of risks. The critical incident rate of 8.70% is indicative of significant risks stemming from the interaction with hazardous kitchen operation.

Store/Workshop (20 cases): The store/workshop, which serves as a central hub for storage and maintenance tasks including hazardous operations like fabrication, machining, and welding, records a substantial number of accidents. With a notable 10% critical incident rate, this highlights the significant risks associated with storage and repair activities. Furthermore, within each deck and engine department, there is typically at least one location designated as a store and workshop where such incidents

occur. The statistical breakdown shows these occurrences are distinct within the deck and machinery spaces.

Cargo Area (18 cases): As a site of intensive manual labor and machinery use, the cargo area's representation in the statistics is indicative of the occupational hazards present in cargo operations. This category presents a significant 11.11% critical incident rate, reflective of the occupational hazards tied to machinery use and the physical demands of cargo handling.

Mooring Station (16 cases): The mooring station emerges as another high-risk area, with a critical incident rate of 25%, which is substantial. The physical nature of securing the ship, often under variable and challenging weather conditions, contributes to the injury count, with accidents commonly involving falls, being struck by moving objects, and entanglement with equipment. This calls for a critical review and upgrade of safety practices, especially targeted at the unique operational challenges of mooring.

Cargo Area (18 cases): As a site of intensive manual labor and machinery use, the cargo area's representation in the statistics is indicative of the occupational hazards present in cargo operations. This category presents a significant 11.11% critical incident rate, reflective of the occupational hazards tied to various cargo operations on tanker ships.

Mooring Station (16 cases): The mooring station emerges as another high-risk area, with a critical incident rate of 25%, which is substantial. The physical nature of securing the ship, often under variable and challenging weather conditions, contributes to the injury count, with accidents commonly involving falls, being struck by moving objects, and entanglement with equipment. This calls for a critical review and upgrade of safety practices, especially targeted at the unique operational challenges of mooring.

Other Areas (47 cases): In examining the broader scope of shipboard environments, various locations that reported personal injury accidents are observed. These include the cabin with nine cases, bridge with nine, upper decks with seven, messroom with four, garbage room with four, paint room with three, pier with three, steering gear room with two, pilot boarding station with two, gym with two, ship's office with one, and bunkering station with one case. Looking at the incidents from a critical injury standpoint, the data shows that even areas with fewer overall incidents have

experienced severe accidents. Critical injuries were recorded in garbage room with one, paint room with one, and bunkering station with one case.

Furthermore, the data suggests a relationship between the nature of the onboard tasks and the probability of accidents, necessitating a holistic and location-specific approach to safety management within maritime operations (Figure 3.5).

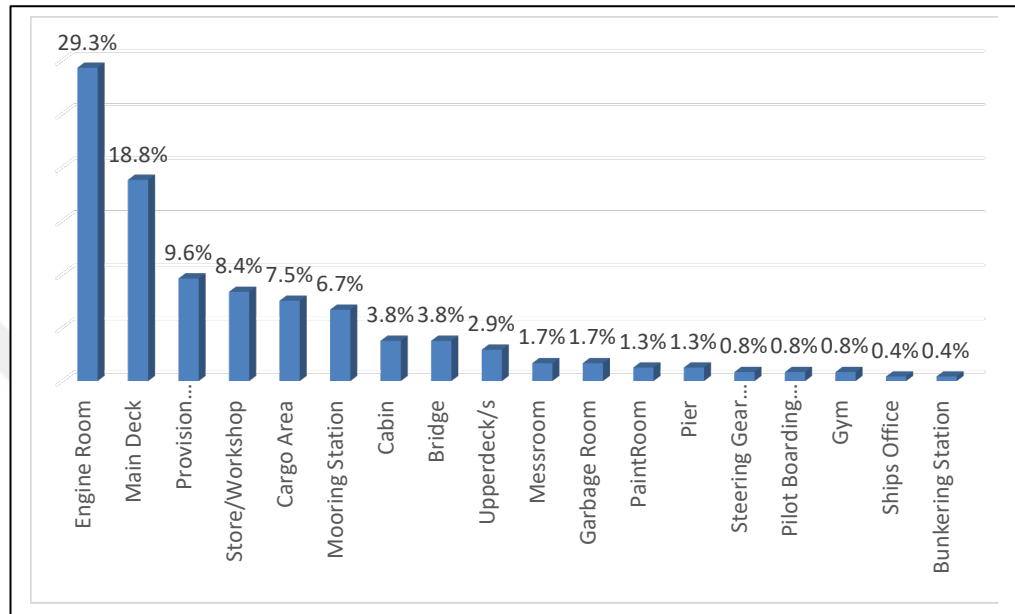


Figure 3.5: Distribution of injury records by the working environment.

Expanding upon the previous analysis of maritime accidents, the supplementary statistics of 24 critical injury case confirms the significance of the main deck as a focal point for severe maritime accidents. However, they also unveil substantial risks across various shipboard areas, including those linked to operational functions such as mooring, unmooring, and anchoring operations at the mooring station (Figure 3.6).

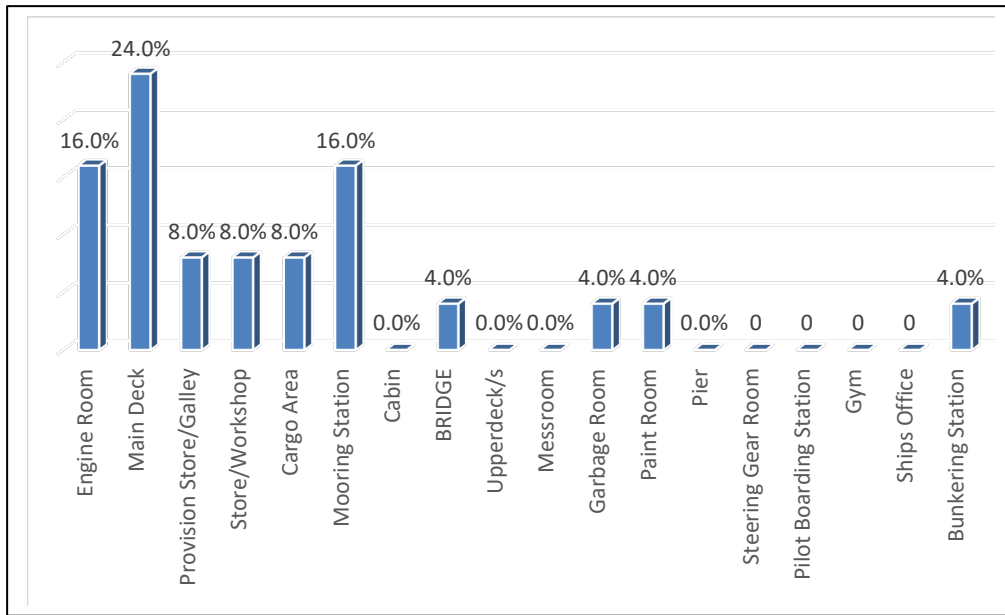


Figure 3.6: Distribution of critical injury records by working environment.

4.4. Analysis of Injury Records by Working Process

This chapter begins with an exploration of the concept of a Working process as defined by ESAW. The category is understood as the main type or kind of work that the worker was carrying out at the time of the accident. It is not the occupation of the worker or the economic activity (industry) in which he or she works, which are broader concepts. It is a description of the type of activity or work being performed during the period of time ending at the instant of the accident, i.e., a subset of the tasks covered by the occupation of the victim. Examples of work processes are maintenance, repair, tuning, and adjusting of machines and equipment; fishing, services, care, and other assistance to human beings; buying and selling and associated commercial activities; and sporting and artistic activities (Eurostat, 2001).

The analysis of 239 reports from the company-specific dataset was categorized according to the working process of injuries, in alignment with ESAW Annex I: Classifications. This provides a detailed examination of personal injury incidents on ships, offering statistical insights into the intricate relationship between occupational tasks and the frequency of injuries.

Maintenance, Repair, Tuning, Adjustment (79 cases): The majority of these incidents, including fifty-six cases in the engine room and twenty-one on deck, involved the use

of hand tools and machinery. This category, which constitutes a sizable portion of all injuries, has a critical incident rate of 11.39%. The high-risk nature of these tasks, essential to ship operation, emphasizes their potential for severe outcomes.

Monitoring, Inspection (39 cases): Predominantly occurring during the movement of seafarers on board the ship with 75% of accidents involving falls on the same level, this category has a critical incident rate of 12.82%.

Setup and Preparation (34 cases): This category primarily encompasses various essential maritime operations, during which there is a notable risk of critical incidents such as mooring, unmooring, anchoring, and bunkering, with a critical incident rate of 15%. Additionally, a significant risk identified in this category is the setup of piracy prevention equipment, which frequently involves handling razor wire results with hand finger injuries.

Commercial Activity (19 cases): Injuries in this category often occur during cargo handling, marking the intrinsic risks associated with commercial maritime operations. Despite its broader representation in overall injury statistics, the critical incident rate here is relatively lower at 5.26%.

Storing (17 cases): Half of the storage operation injuries, split between provision store and workshops, involve overload injuries. The critical incident rate is considered high at 11%, indicating a need for ergonomic improvements and better load management techniques.

Production, Manufacturing, Processing (16 cases): Occurrences recorded mostly during food preparation, with a critical incident rate of 6.25%. Even routine tasks like cooking can pose substantial risks, often due to interactions with kitchen machinery or hot substances in shipboard environments.

Movement, Sport, Artistic Activity (13 cases): Over half of these incidents stem from the distinctive difficulties of the maritime environment, including the unpredictable rolling and pitching of the ship. These conditions can make even a simple task like walking inside your cabin risky, potentially leading to injuries.

Cleaning of Working Areas and Machines (12 cases): Although typically resulting in minor injuries, the absence of critical incidents in this category still highlights substantial risks, particularly regarding eye injuries from using air-pressurized hand equipment.

Intellectual Work (5 cases): All incidents in this category were minor and treated with first aid, reflecting the comparatively safer conditions of administrative tasks aboard ships, with no critical incidents reported.

Waste Management, Disposal (5 cases): This category features a single critical injury caused a severe injury and the early repatriation of the seafarer. Injury caused by pulling a defective handle on a garbage container while transporting it (Figure 3.7).

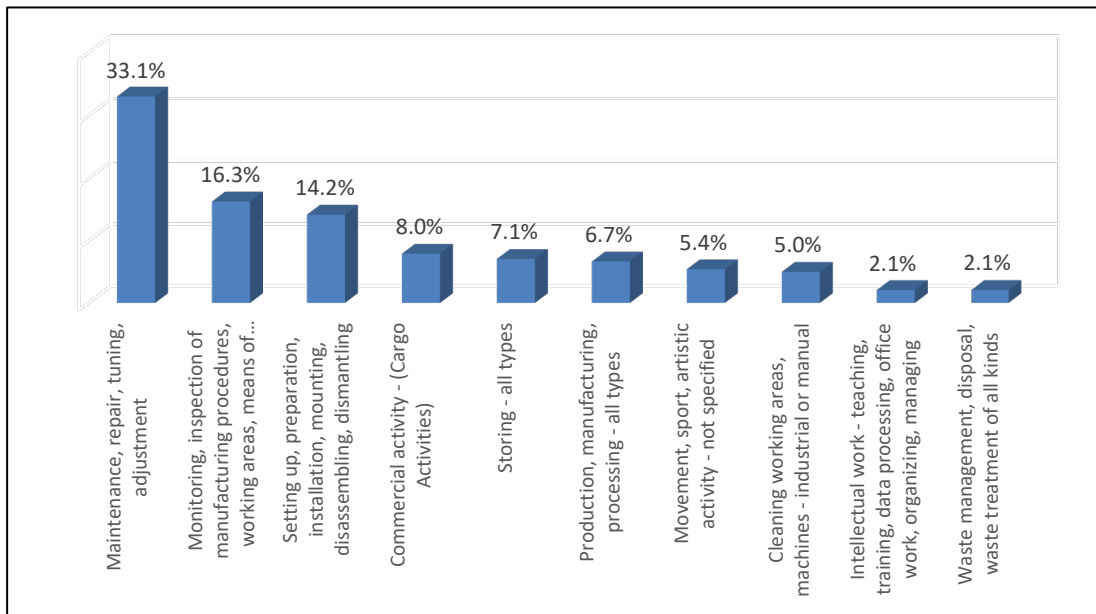


Figure 3.7: Distribution of injury records by working process.

The additional review encapsulates twenty-four critical accidents categorized by working process, enabling a comparative analysis of the overall injuries. The distribution of critical accidents across various work processes onboard ships reveals a consistent trend with the broader data, where maintenance, repair, and preparation tasks pose the most significant risks for severe injuries (Figure 3.8).

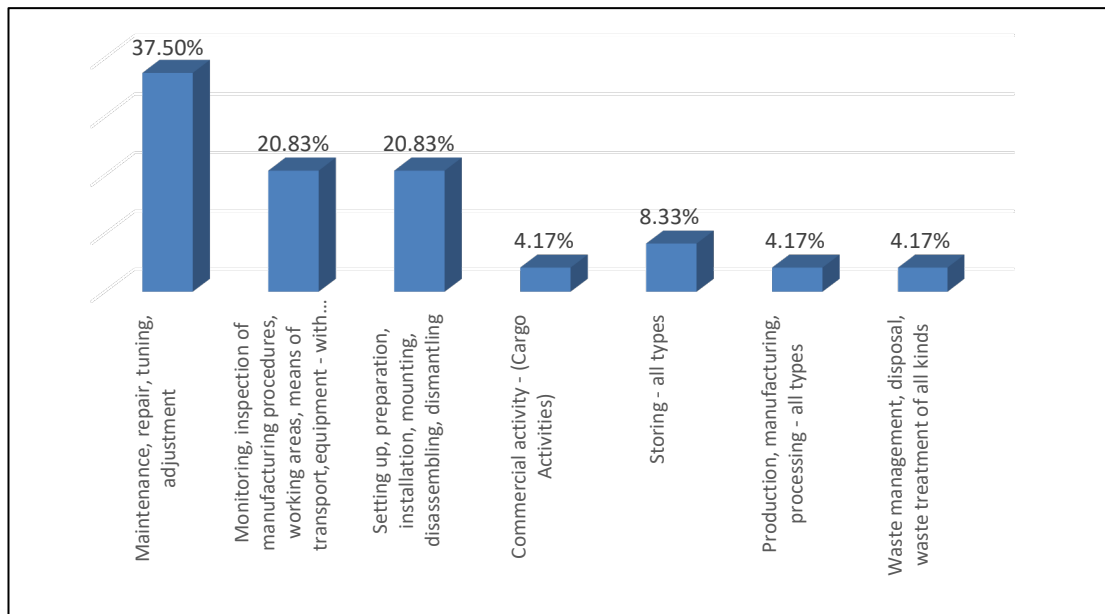


Figure 3.8: Distribution of critical injury records by working process.

4.5. Analysis of Injury Records by Specific Physical Activity

This chapter begins with an exploration of the concept of a Specific Physical Activity as defined by ESAW. The category is understood as the activity being carried out by the worker when the accident occurred. It may be an activity that is carried out for just a short time or one that takes a long period. It is one of the tasks that forms part of the work process. Examples of specific activities are starting a machine, operating a machine, driving a vehicle, using a hand tool, carrying a load, filling a container, digging the ground, painting an object, ironing, opening a package, climbing a ladder, walking, and standing in a queue. As can be seen in the conceptual framework, the victim may be using an item, material, or object (material agency) when the accident occurs, but not always. (Eurostat, 2001).

The analysis of 239 injury reports from the company-specific dataset was categorized according to the specific physical activities of injuries, in alignment with ESAW Annex I: Classifications. This offers a concentrated examination of personal injury incidents on ships, providing statistical insights while the Working Process variable delineates a task that unfolds over an extended duration, and the Specific Physical Activity variable is significantly more precise and can be delineated from the sequence of events culminating in the accident.

Handling of Objects (72 cases): This category involves interactions with objects such as grasping, placing, tying, fastening, and manipulating containers. Despite the high number of incidents, the critical rate of 4.2% indicates that while object-handling incidents are frequent, they seldom result in severe injuries.

Movement (66 cases): Movement-related activities, including walking, running, and climbing, account for a considerable number of workplace injuries in shipboard environments, with a 10.6% critical rate. 85% of the critical cases involved trips and falls at ground level.

Working with Hand-Held Tools (36 cases): This category covers the use of both manual and motorized tools. With a critical incident rate of 5.6%, the relatively low occurrence of severe injuries suggests that safety measures are generally successful in reducing the severity of injuries from tool use.

Carrying by Hand (36 cases): Carrying objects by hand, whether moving them vertically or horizontally, poses a substantial risk, evidenced by a 13.9% critical rate. All serious incidents involved musculoskeletal injuries, emphasizing the importance of proper body posture, technique and ergonomic practices in preventing significant harm.

Operating Machine (15 cases): Operating machinery, which involves tasks such as starting, stopping, and monitoring, shows the highest proportion of critical injuries at 26.7%. Most of these severe cases occurred in the engine room during maintenance activities.

Driving/Being on Board a Means of Transport or Handling Equipment (11 cases): Involvement with both motorized and non-motorized transport resulted in a critical incident rate of 27.3%, indicating significant dangers associated with these activities.

Presence (3 cases): This category, characterized by a low incidence rate and no critical cases, involves injuries that occur simply by being in a specific location. Most of the time, the ship's rolling and pitching are noted as contributing factors to these injuries.

From this data, we can conclude that handling objects and movement are the most common activities leading to personal injuries (Figure 3.9).

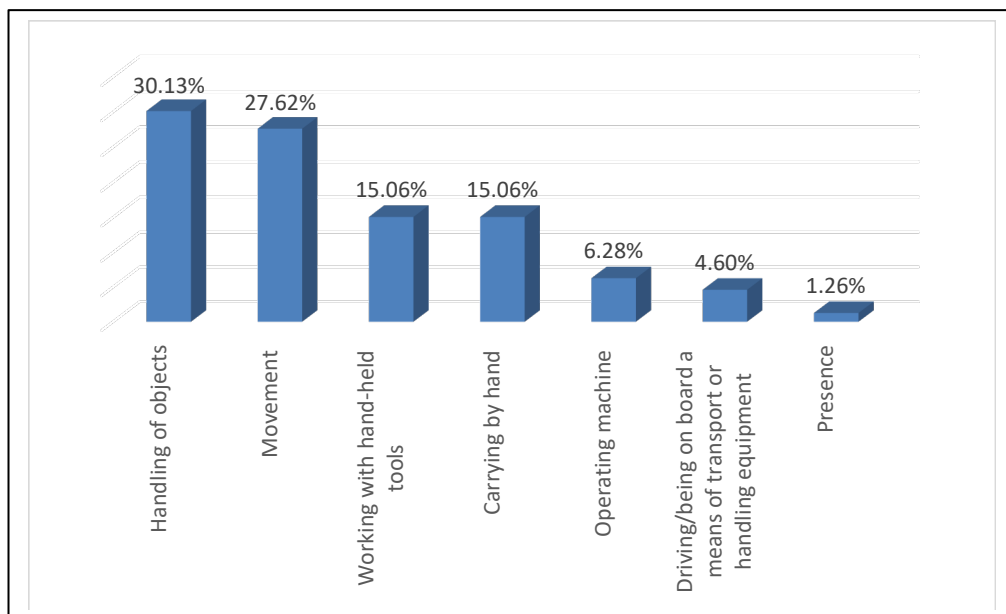


Figure 3.9: Distribution of injury records by specific physical activity.

An additional review of twenty-four critical accidents categorized by specific activity was conducted, enabling a comparative analysis of the overall injuries. According to this analysis, the largest criticality rates are seen in activities involving movement, carrying by hand, and operating machinery. These findings imply that targeted safety actions specially directed towards each activity may be necessary (Figure 3.10).

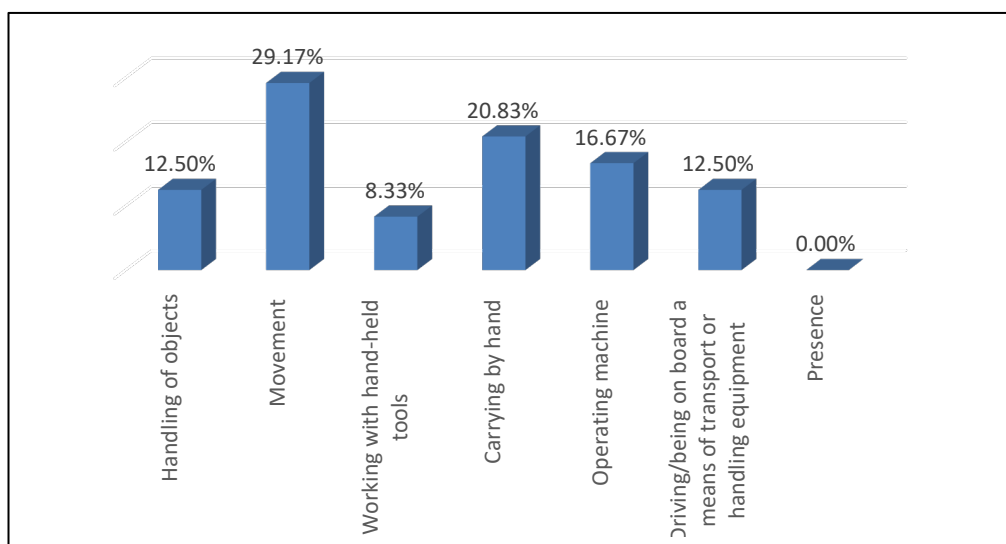


Figure 3.10: Distribution of critical injury records by specific physical activity.

4.6. Analysis of Injury Records by Material Agent

This chapter begins with an exploration of the concept of the Material Agent as defined by ESAW. The category is understood as the item, agent, object, material, or product with which the victim came into contact during the accident, and which caused the injury or the psychological phenomenon. It may be the same as the material agency associated with the specific activity of the victim at the time of the accident, or the material agency linked to the deviation from the normal which led to the accident, but this is not always the case. As has been seen earlier, the material agency can take many forms, including buildings, working areas, ladders, pipes, motors, hand tools, machines, containers, vehicles, safety devices, chemicals, sports equipment, animals, other human beings, plants, waste material and natural phenomena such as noise, radiation, floods, ice and so on. Here, also, it is useful, in some cases, to know whether the material agency was stationary or moving when it caused the injury. (Eurostat, 2001).

The analysis of 239 reports from the company-specific dataset was categorized according to the specific physical activities of injuries, in alignment with ESAW Annex I: Classifications.

The analysis initially concentrates on broad categories, but future studies could delve into more specific material agents, or possibly select multiple agents from those listed in the annex. This approach is particularly relevant given that Code 20 Physical phenomena and natural elements can be considered permanent role in maritime injuries. Thus, a detailed examination of different material agents could enhance our comprehension of the contributing factors.

Buildings, Structures, Surfaces - At Ground Level (34 cases): These injuries often involve interactions with both fixed and mobile elements like doors, rigid surface structures, as well as hazardous floor conditions. Effective preventive measures include installing non-slip surfaces, clear hazard signage on the walkways are the most common barriers reduce the frequency of these injuries. Nearly the quarter (26.5%) of the injuries under the category recorded as critical with the majority occurring around the main deck working environment.

Physical Phenomena and Natural Elements (28 cases): The recorded cases often involve severe weather conditions that can cause accidents even during passive

activities, due to ship movements. This highlights the unpredictability and broad scope of potential accidents on ships. The category also covers accidents caused by other physical phenomena such as noise, pressure changes, and natural radiation, which may not typically be considered in standard safety protocols but can lead to significant risks in specific environments. Out of twenty-eight incidents tied to physical phenomena and natural elements, two were critical (7.1%). These incidents frequently take place under severe weather conditions, affecting both active and passive activities on board, highlighting the importance of adhering to strict no-exit protocols during adverse sea and weather conditions. Considering that ships are essentially floating platforms, timing considerations—whether at sea, in port, or at anchor—and weather assessments are crucial due to the inherent risks associated with water and unstable conditions.

Machines and Equipment - Portable or Mobile (27 cases): This category highlights the critical need for specialized training for machine and equipment operators of distinct types of machinery utilized on ships. Notably, 30% of the injuries in this category were recorded as eye injuries, followed by 25% involving hand and finger injuries. Additionally, a significant 75% of the cases were due to being struck by moving objects, underscoring the elevated risk of impact-related injuries with mobile equipment and mitigating risks from moving machinery. The critical cases accounted for 11.1% of the incidents, with a significant percentage of eye and hand/finger injuries similarly stressing the importance of protective gear.

Materials, Objects, Products (22 cases): This category encompasses a wide range of materials and components of diverse sizes, including machine and system parts, cooking materials, as well as particles, dust, and debris. Notably, 35% of the incidents occurred during the food preparation process including carrying and lifting provisions. The remaining cases take place in workshops. The predominant root causes identified in these incidents were the improper use of personal protective equipment and improper lifting techniques. The critical cases accounted for 4.5 % of the incidents.

Safety Devices and Equipment (21 cases): The data highlights that the most frequent types of accidents in this specific category involved injuries to hands and fingers caused primarily by interactions with razor wire and self-closing door mechanisms. Razor wire, often used as piracy prevention measure for ships, poses a significant risk of cuts or lacerations due to its sharp edges. Self-closing doors, on the other hand, can lead to pinching or crushing injuries if hands or fingers are inadvertently placed near

the closing mechanism or caught between the door and its frame. Despite the occurrence of injuries involving safety devices and equipment, only one resulted in a critical injury with a rate of 4.8%. However, this data emphasizes the necessity for enhancements in evaluating the design of self-closing door mechanisms and security prevention materials. Specifically, it calls for a focus on technological evaluation to mitigate hand and finger injuries.

Systems for the Supply and Distribution of Materials (18 cases): This category includes both fixed and mobile networks for transporting gas, air, and liquids hot and cold. The majority of incidents involved contact with extreme temperatures, resulting in burns, highlighting the need for protective measures against leaking or splashing liquids in temperature extremes. Of the cases associated with material supply and distribution systems, two were severe with a rate of 11.1%. Burns from contact with extreme temperatures were the primary concern for the critical injuries as well.

Conveying, Transport, and Storage Systems (16 cases): This category covers a wide range of equipment, from conveyors and cranes to storage containers. Most injuries occurred during manual handling, with a significant percentage resulting from overstress or overexertion related to ergonomic factors, leading to lumbar injuries. Similarly, manual handling was the main reason for the single critical case under this category, with a rate of 6.25%.

Office, Personal Equipment and Domestic Appliances (15 cases): Half of the incidents in this category occurred during food preparation, with injuries mainly consisting of burns and superficial strains. A sizable proportion of injuries involved hands or fingers.

Chemicals and Hazardous Substances (11 cases): This category includes a variety of hazardous substances that lead to injuries, with 60% of cases resulting in eye injuries. The data underscores the critical need for eye protection and safe handling practices for hazardous materials.

Hand Tools, Not Powered (11 cases): These tools accounted for a high percentage of hand injuries, with many occurring during maintenance, repair, or adjustments. The prevalent mode of injury was being struck by moving objects, emphasizing the need for caution and proper safety measures when using hand tools.

Motors, Systems for Energy Transmission and Storage (10 cases): Injuries reported under the category are indicating a notable risk associated with energy transmission

and storage systems, particularly those involving rotating components like fan blades or flywheels. Among these incidents, three were critical, resulting in a criticality rate of 30%. All critical incidents under this category involves machinery operation and took place in the engine room.

Machines and Equipment - Fixed (9 cases): Injuries sustained under this category predominantly occurred while maintaining fixed deck machinery and equipment, such as mooring winches followed by the utilization of heavy-duty lathe machines in workshops. Among these, a single case reported as critical, involving the misalignment of the starboard anchor chain during adjustment led to serious finger injury, representing 11.1% of incidents within this category.

Below-Ground-Level Structures and Surfaces (6 cases): Injuries reported within this category, encompassing falls from an open manhole on the deck, and enclosed space entries such as inspections in the scavenging area, bilge wells and tanks. Single critical injury counted as 16.7% involved entering an enclosed space resulting in a fall through an escape route opening while inspecting the tank surface preparation for painting, ultimately leading to a dislocated shoulder.

Hand-held or Hand-guided Tools, Mechanical (2 cases): This category involves activities like activities such as sawing, cutting, separating, carving, slotting, chiseling, trimming, clipping, and shearing, as well as scraping, polishing, and buffing, including the use of disc cutters. Two minor incidents were reported under this category with no result in critical outcomes.

This detailed analysis of each category provides insights into specific risks associated with different material agencies and environments on ships, offering a basis for tailored safety strategies and interventions (Figure 3.11).

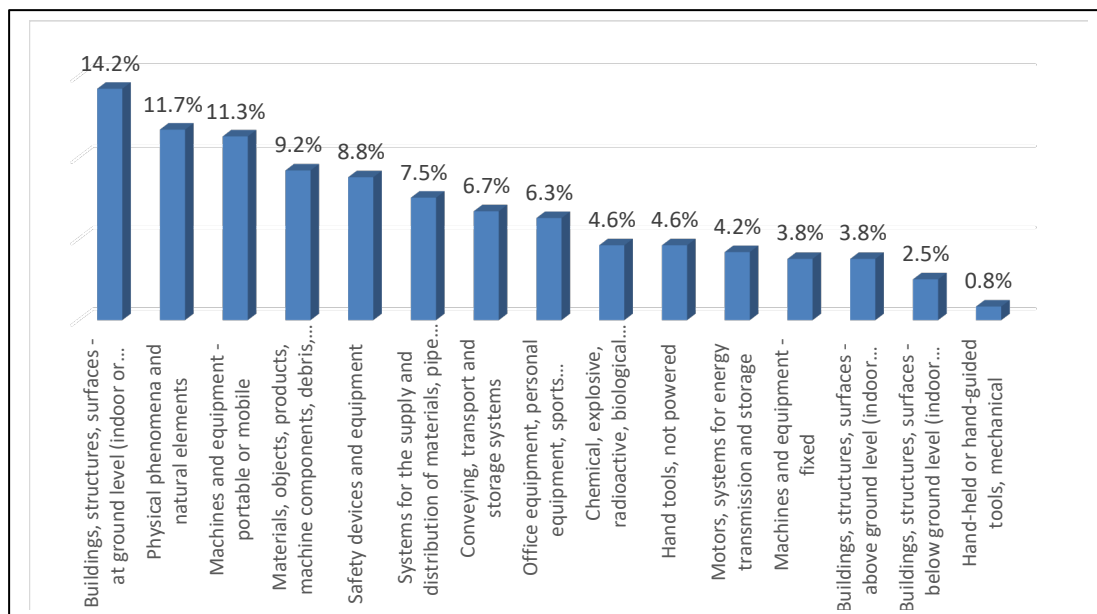


Figure 3.11: Distribution of injury records by material agent.

Further review of the data has identified twenty-four critical accidents categorized by material agent, facilitating a comparative analysis with previously discussed overall personal injury incidents. This analysis reveals that activities with the highest critical rates were operations involving buildings, structures, and surfaces at ground level followed by motors, systems for energy transmission and storage, and buildings, structures, and surfaces below ground level (Figure 3.12).

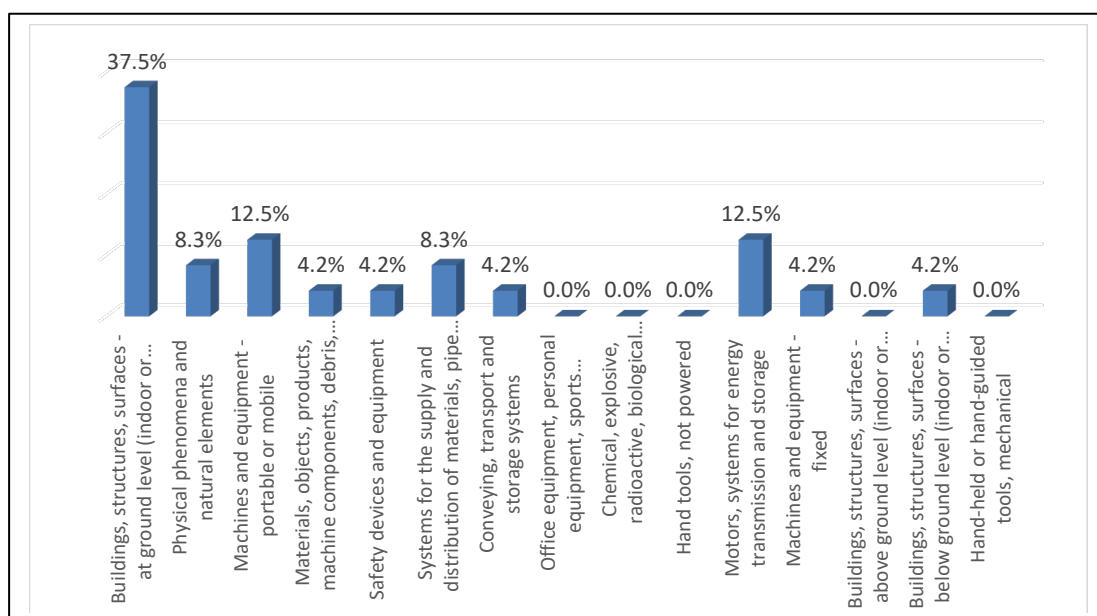


Figure 3.12: Distribution of critical injury records by material agent.

4.7. Analysis of Injury Records by Mode of Injury

This chapter begins with an exploration of the concept of the Mode of Injury which defined by MSCAT as the Type of Event where the categories slightly differ from ESAW Mode of Injury classifications. The category is understood as the action that leads to the injury and categories are designed to describe how the victim was injured and how he or she came into contact with the object that caused the injury. (Eurostat, 2001).

The analysis of 239 reports from the company-specific dataset was categorized according to the mode of injury, in alignment with MSCAT Type of Event section. Categories includes Fall from Elevation (person, equipment, material), Fall from/on Same Level (slip, fall, trip over), Struck Against (bump into, run into), Struck By (hit by moving object), Caught in (on, between or under), Contact with Temperature Extremes (heat/cold), Contact with Electricity, Contact with Noise, Contact with Vibration, Contact with Radiation, Contact with Hazardous Substance/Dose (toxic/corrosive/carcinogenic/biological/viral), Overstress by overexertion, Overload, Ergonomic factors

Struck By (Hit by Moving Object) (59 Cases): This category is employed for injuries where an object is in motion and collides with the victim, whether due solely to the object's movement or involving both the object and the victim in motion during the impact. Injuries in this category typically stem from moving machinery parts, falling objects, or particles in motion. About 44% of these incidents occurred while working with hand-held tools, with machines and equipment serving as the predominant material agency. Additionally, approximately half of the incidents happened during maintenance, repair, tuning, or adjustment tasks. Of these injuries, 35% resulted in eye injuries and 30% resulted in hand injuries. The critical rate accounted as 6.78% appears that while such incidents are frequent, the likelihood of them being critical is not as high as in some other categories. One of the critical injuries in this category occurred when a fixed drill's head made contact with the victim's foot after accidentally touching the equipment's starter button. Another incident involved a mooring rope suddenly losing tension, causing it to snap from a lower fender toward deck level, violently vibrating and striking two team members at the mooring station.

Fall From/On Same Level (Slip and Fall/Trip Over) (44 Cases): This refers to injuries that occur when a person loses balance and slips, trips, or falls due to hazards like wet floors, loose cables, obstacles, uneven surfaces, or poor lighting conditions. Out of all, ten injuries reported as critical, leading to the highest critical rate of 22.73% of the category. This highlights the need for stringent measures to address walking surface integrity and hazard identification. The critical injuries comprised dislocations, sprains, strains, and concussions resulting from hard impacts to the head, along with a singular case of a fracture. The fracture case was the Chief Cook who tripped over a door sill, causing him to fall and injure his arm while carrying a plate in his left hand, unable to grab onto anything during the fall. Four other critical cases involved slipping while walking between frames, and tripping while stepping on a frame on the main deck. Additionally, another case under the category occurred due to the rolling and pitching motion of the ship.

In addition to company-specific data, the European Maritime Safety Agency The annual overview of marine casualties and incidents 2023 report mentions that a total of 5,785 injuries were reported from various incidents involving maritime casualties, with "Slipping - stumbling and falling - fall of person" being the leading cause, accounting for 1,776 injuries or 30.7% of all reported cases between 2014 and 2022. This statistic aligns with company-specific analyses indicating that slips, stumbles, and falls are the most common hazards in these settings. It underscores the need for targeted safety enhancements and further design development for footwear technology to effectively address the hazard.

Struck Against (Bump Into/Run Into) (40 Cases): This category encompasses injuries resulting from accidental bumps into or runs into a fixed object or structure or contact with hard, sharp, or rough objects. Examples include cuts from sharp items like knives or razors, being pricked by pointed objects such as nails or punches and experiencing scratching or grazing from rough surfaces like graters, sandpaper, or rough wood. Notably, a "hard agent refers to a material lacking flexibility due to its mass or density, thus not cushioning or absorbing impact. Under the category, no critical injuries reported, and the majority of all injuries were superficial in nature. This suggests that while such incidents are common, they tend to be less severe.

Caught In, On, Between, or Under (27 Cases): This category represents injuries where individuals are caught, trapped, or compressed by various objects, machinery, or in

confined spaces. A massive portion of these injuries (90%) involve the hands, which is understandable given the nature of manual labor and the use of machinery in various workplace inside the ship. Of the total incidents, four were critical, resulting in a critical rate of 14.81%. Notably, half of the critical injuries were almost identical, caused by fingers being caught in rotating fan blades. In the first critical case, the individual gripped the cover on the impeller level inadvertently. This action resulted in his left hand's middle fingertip being deeply cut after getting caught in the propeller blade. In the second critical case, the Chief Engineer's fingers accidentally came into contact with the fan blades despite the presence of a protective guard. The details of the significant injury have been featured as a case study can be found in the section titled Traumatic Amputations within Chapter 3.8 Analysis of Personal Injury Accident Records by Type of Injury. This specific information points to a recurring danger with rotating machinery suggests that particular attention is needed for rotating parts to safeguard against such risks.

Contact with Temperature Extremes (Heat/Cold) (26 Cases): This type of event involves a person coming into contact with extreme temperatures, either hot or cold. Each of these injuries falls under the category described as burn, corrosion, scald, or frostbite. A significant majority, approximately 62%, of these incidents occurred during maintenance, repair, tuning, and adjustment activities within the engine room. The primary culprits for these injuries were systems involved in the supply and distribution of materials, such as pipe networks, which often lead to accidents like hot water splashes or fuel/water leakages. Particularly, maintenance jobs related to boilers were spotlighted as common area for such injuries. Additionally, around 27% of these temperature-related injuries were associated with the working process in production, manufacturing, or processing. This percentage predominantly corresponds to cooking-related activities, which can involve hazards leading to burns or scalds. Within the context of temperature-related incidents, although the critical rate was relatively low at 3.85%, the severity of the incidents was significant. The details of the significant injury have been featured as a case study can be found in the section titled Burns, Scalds, and Frostbites within Chapter 3.8 Analysis of Personal Injury Accident Records by Type of Injury.

Overstress by Overexertion, Overload, Ergonomic Factors (22 Cases): This category involves the individuals suffered physical injuries due to excessive force,

overwhelming workload, or poor ergonomic practices. In dataset, the events typically arose during activities that require manual labor, repetitive actions, or extended physical activity. The majority of these incidents (77%) were lumbar injuries, and nearly all were characterized by dislocations, sprains, or strains. The predominant root cause identified was improper lifting techniques. Within this group, there was a critical injury rate of 13.64%. The first critical case involved an individual who experienced sudden back pain while lifting a hose during deck washing, implying an incorrect posture and sudden movement led to the injury. The second critical incident involved a crew member who injured his neck while chipping on deck in a bent position, leading to a week off work. This suggests that ergonomic considerations were insufficient for the task. Another critical injury occurred in dry dock process, where the victim was assisting in securing a tank manhole cover, adopted an incorrect lifting posture and subsequently experienced severe lower back pain, another clear instance where ergonomic principles were not adhered to. The critical injuries, although fewer in number, underscore the importance of proper lifting techniques, ergonomic task design, and the need for workplace ergonomics training to prevent such injuries.

Fall From Elevation (Person/Equipment/Material) (11 Cases): The category encompasses incidents where either a person, equipment, or materials plummet from a height, which can happen in various scenarios such as when engaging in high-altitude tasks, using ladders, or operating on raised platforms. All instances of falls were presenting unique circumstances. Examples of the low severity incidents involved victims using portable ladders that slid out from under them. Another individual fell onto the deck as they failed to notice an open manhole while carrying a box. Another case involved a person losing their balance and falling on a wet staircase during rainy weather. Another fall occurred where an aluminum ladder bent and slid, leading to a fall, and in a more severe case, an individual fell into the sea while attempting to inspect a potential cargo hose leakage on the shoreside, not realizing they were on the edge of the terminal. Luckily, the victim was retrieved from the sea without experiencing any potential adverse outcomes. Additionally, among these injuries, two were deemed critical, contributing to a critical rate of 18.2%. These injuries collectively underscore the high risks inherent in working at heights and the imperative for rigorous fall protection measures. This includes ensuring the stability and security of ladders, clear signage, and securing of open hatches.

Contact With Hazardous Substance (10 Cases): This category of injury pertains to encounters with hazardous chemicals or toxic substances, which can precipitate a range of health complications. Events in this category often transpire during activities like cargo handling, maintenance tasks, or as a result of accidental leaks or spills. Out of ten injuries, a notable 70% affected the eyes, and more than half of these injuries occurred within the engine room environment. The majority of these cases arose during the use of air-pressurized systems for cleaning, leading to particles coming into contact with the eyes. In addition to the previously mentioned hazards, some eye injuries also occurred in situations where individuals inadvertently touched their eyes with contaminated hands. These injuries typically happen in post-work processes when workers, attempting to wipe their sweat or adjust to discomforts like itching, accidentally transfer harmful substances to their eyes. Such incidents underscore the importance of maintaining strict hygiene protocols, particularly in environments where workers are exposed to hazardous chemicals or particles. It highlights the need for awareness that emphasizes the risks of contaminated hands. Despite the occurrence of these ten injuries, none reached a critical level. However, this may not accurately reflect possible long-term outcomes following exposure to hazardous substances.

This thorough examination of each category offers valuable insights into the distinct risks linked with various injury modes and ship environments. These findings serve as a foundation for implementing customized safety measures and interventions (Figure 3.13).

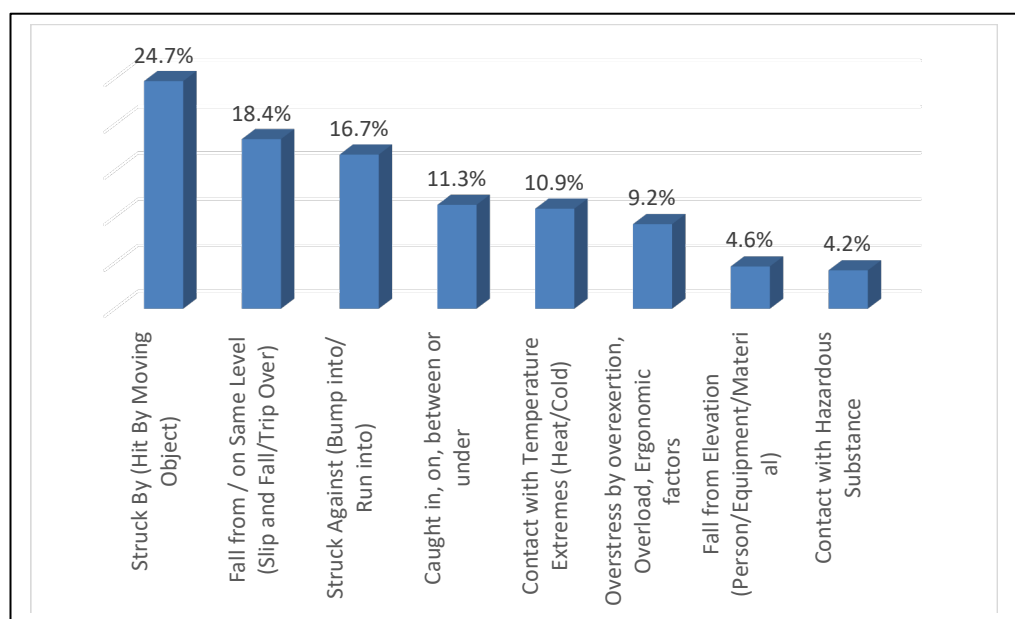


Figure 3.13: Distribution of injury records by mode of injury.

Further analysis has identified twenty-four critical accidents categorized by mode of injury which may be comparatively studied regarding overall injuries. This analysis reveals that the most critical area for intervention is in preventing falls from the same level with 22.7% of such incidents resulting in critical injuries where the victim experienced lost workdays or required repatriation. This underscores the importance of prioritizing safety improvements related to slips, trips, and falls. While the category of struck by objects presents the highest number of incidents, these do not commonly result in critical injuries. The modes involving temperature extremes, despite their lower critical rates, should not be neglected due to the potential for severe long-term health effects. Falls from elevation, although less frequent, carry a considerable risk of severe injury, necessitating strict safety protocols (Figure 3.14).

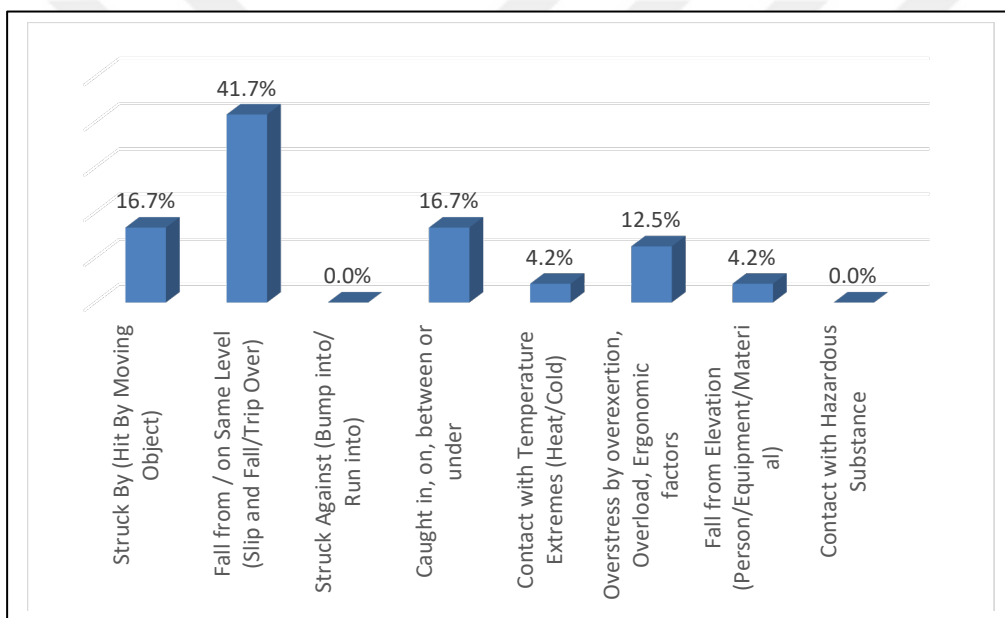


Figure 3.14: Distribution of critical injury records by mode of injury.

4.8. Analysis of Injury Records by Type of Injury

This chapter begins with an exploration of the concept of the Type of Injury as defined by ESAW. The category is understood as the type of injury sustained by the victim. A person may receive several injuries in an accident, but for statistical purposes, it is the most serious injury received that is used for analysis. They can range from minor superficial wounds such as scratches or bruises to more serious injuries including fractures, sprains, amputations, concussions, other internal injuries, burns, frostbite,

poisoning, infection, asphyxiation, or the effects of physical or psychological phenomena, such as radiation, heat, cold, abuse, noise and so on. (Eurostat, 2001).

The analysis of 239 reports from the company-specific dataset was categorized according to the type of injuries sustained, in alignment with ESAW Annex I: Classifications. This dataset on type of injuries offers an overview analysis from the broad categories. Additionally, the category encompasses two case studies related to the specific types of injuries involved.

Wounds and Superficial Injuries (152 cases): The category of wounds and superficial injuries, covers a wide array of injuries. They range from minor contusions, bruises, and blisters to more significant lacerations, open wounds, and deep cuts that can damage muscles, tendons, and nerves. This includes injuries from non-venomous insect bites, and foreign objects that penetrate the eyes or ears, as well as scalp wounds. Within this category, 41% are hand and finger injuries, underscoring the vulnerability of these body parts. Eye injuries also represent a sizable portion at 17%. Additionally, the data indicates that 35% of injuries are due to being struck by moving objects, while another 26% result from collisions with objects. Routine activities such as maintenance, repair, tuning, and adjustment are implicated in 35% of the cases, followed by monitoring and inspection of manufacturing procedures, which account for 20%. In environments such as the deck and engine room, both areas are equally represented at 35% in the data. Assessment of the superficial injuries category under the main deck and engine room working environment predominantly reveals hand injuries in the engine room, followed by eye injuries. Meanwhile, on the main deck, an equal number of hand and eye injuries are observed. For hand injuries on the main deck, it is noted that 30% of accidents are attributed to failure to use personal protective equipment properly, while in the engine room, this figure stands at 32%. In summary, the high frequency of hand injuries observed in both the main deck and engine room work settings can be attributed to the difficulties encountered when using safety gloves. Further evaluation and assessment of the effectiveness of these protective hand gloves for fine adjustments of small components or operations requiring similar delicate hand functions, deserves to be the main focus of a separate study.

Dislocations, Sprains, and Strains (47 cases): The category includes injuries like subluxations and dislocations that affect the joints, as well as muscle, tendon, and ligament damage resulting from overexertion. This often leads to ruptures, tears, and

hernias. This type of injury is significantly influenced by overstress due to overexertion, overload, and ergonomic factors, with 45% of the cases related to these causes, particularly affecting the lumbar region of the body. Following closely, 42% of injuries occur due to falls from or on the same level, such as slips, trips, and falls. These incidents are equally prevalent in situations involving movement and the manual carrying of items in specific activity categories. Out of these injuries, fourteen cases are marked as critical. Notably, the mode of injury linked to falling from or on the same level demonstrates the highest rate of critical incidents, indicating a serious risk factor that warrants attention for preventive measures.

Burns, Scalds, and Frostbites (28 cases): This category includes thermal burns and scalds from hot objects or open fire, chemical burns (corrosions), and frostbites. The injuries can range from burns with open wounds, radiation burns, sunburns, effects of lightning, and electric current burns to the effects of reduced temperature leading to frostbite with dead tissue (necrosis). These cases related to burn injuries in our data set show exposure risks are notably high in the engine room work environment and within systems that involve the supply and distribution of materials, such as pipe networks. This underscores the necessity of preventive measures, particularly the proper insulation of hot surface isolation arrangements to mitigate such risks. Despite the diverse range of burn and cold exposure injuries, only one case is marked as critical, which equates to approximately 3.6% of injuries in this category. Although few in number, due to the serious long-term effects, the details of the single critical injury in this category are presented as a case study here below.

Case Study 1

In a notable injury to the 4th Engineer, the incident started with an alert by the Oiler regarding a fuel spray near the pump while the victim was engaged in administrative tasks inside the engine control room. Reacting promptly, the 4th Engineer proceeded to investigate the situation and subsequently informed the 2nd Engineer. During the investigation, the victim required assistance from the Oiler to open a strong valve for further investigation. As the valve opening process commenced, hot fuel oil splashed from the filter casing, resulting in burns to the lower extremity of the victim.

The initial root cause analysis identified the failure to use PPE properly as the primary factor. The victim went to the ECR for administrative tasks at night and was not

wearing the proper PPE to conduct a round in the engine room. The victim was dressed in daily clothes instead of the required overalls. Then, Lack of Situational Awareness and Risk Perception was found to be a secondary contributing factor to the injury. Earlier in the day, the pump had been operating with closed valves inadvertently by the victim, causing the fuel oil inside the line to warm up and create pressure between the transfer pump's inlet and outlet valves. This pressure led to a fuel spray mark on the engine room valve, indicating a leak due to the pressured fuel oil inside the line. The potential risk of burns from the line containing hot fuel oil was not considered, victim decided to proceed to the site without appropriate PPE to address an immediate issue. This split-second decision resulted in an injury that required at least six months for recovery.

Lessons learned from this case underscore the crucial role of maintaining effective situational awareness onboard. In addition, this case highlights the necessity of meticulous preparation when managing pressurized transfer lines and their components, emphasizing that even minor oversights can lead to significant accidents. It also demonstrates the importance of implementing proper use of PPE and adherence to safety protocols that could have prevented the injury, illustrating that safety measures are only effective when consistently and correctly applied. This case serves as another reminder of the need for PPE vigilance to ensure that we are prepared to handle emergencies safely.

Concussion and Internal Injuries (6 cases): This group consists of concussions and intracranial injuries, as well as internal injuries without fractures. These include internal contusions, hemorrhages, lacerations, and ruptures to the brain and internal organs, such as injuries to intra-thoracic, intra-abdominal, and pelvic organs. In the dataset, most of the injuries occurred at the deck working station, and the half of them taking place at the mooring station. Out of these injuries, four case recorded as critical, translating to a remarkably high critical rate of approximately 66.7% for this category.

Bone Fractures (4 cases): The bone fractures category includes both open and closed fractures. Simple fractures, fractures with dislocations, and fractures with internal or nerve injuries are encompassed here, along with compound fractures which involve injuries to soft parts of the body. Out of all fracture cases, three are designated as critical, accounting for a significant 75% of this type of injury. Meanwhile, the remaining case, which was initially considered to be a fracture, resulted in a negative

diagnosis after a medical examination. However, it was still recorded as a restricted workday incident. An example of such an injury occurred while the 2nd Engineer was aligning the LT Main Cooling SW line; the individual's left-hand little finger was trapped between the line and an electric motor box, due to hand slipping.

Multiple Injuries (1 case): This category is specific to instances where the victim has sustained two or more equally serious types of injuries. The particular case reported is critical, resulting in a 100% critical rate for this type. The critical incident occurred during bunker post-operation, as the bunkering hose was being detached from the bunker manifold, the Fitter, despite being explicitly cautioned by the 3rd Engineer that the hose was not yet secured and to stand by, proceeded to loosen the last bolt and nut due to a misunderstanding. This caused the hose to become unfastened and strike the 3rd Engineer, leading to a loss of balance and a subsequent fall from the drip tray to the deck level, which is classified as a fall from elevation incident.

Traumatic Amputations (1 case): This includes severe injuries such as amputations and crushing injuries, as well as enucleations, which refer to the complete removal of an organ, particularly the eye, or traumatic avulsion of the eye and loss of an ear. The particular case of amputation is also critical, leading to a 100% critical rate.

Case Study 2

A vessel was transitioning from dry dock to berth for routine operations. During this shift, the emergency diesel generator was operational to supply power. The Chief Engineer, responsible for overseeing the generator's function, went to perform a routine check. While conducting a visual inspection of the emergency diesel generator, the Chief Engineer leaned over the radiator and inadvertently placed his hand on the fan protection guard. Tragically, his two fingers were caught by the rotating fan blades. Despite immediate medical attention and transportation to the hospital, the injury resulted in the amputation of the two affected fingers following an urgent surgical procedure. The accident investigation revealed that although the generator was equipped with a protective grating, the incident exposed a critical design flaw. The grating had a side gap wide enough to allow fingers to slip through and contact with the fan blades. Despite the Chief Engineer's experience and the presence of warning labels on the generator highlighting the risk of hand injuries, the Chief Engineer's attention during the inspection was compromised. This lapse in focus and situational

awareness directly contributed to the accident with a severe outcome. Lessons learned from these incidents underscore the critical importance of heightened awareness among workers, particularly when operating near machinery with rotating components like fans. Additionally, effective hazard identification and implementation of mitigation measures, such as enhancing protective coverings on machinery, are essential for preventing accidents. Furthermore, strict adherence to safety protocols, including lockout-tagout procedures, is vital to ensure that machinery is safely de-energized during maintenance or inspection, thus minimizing the risk of accidental operation and enhancing overall workplace safety. Enhancements in machine guarding and a reinforced culture of safety can significantly mitigate such risks.

Overall, this data suggests a broad spectrum of injury types in the surveyed environment, with varying degrees of frequency and severity. The majority of these involve wounds and superficial injuries, suggesting that these are the most common but potentially the least severe type of accidents. Dislocations, sprains, and strains also make up a considerable number indicating common physical activity-related injuries. The frequency of these incidents and the root cause statistics highlight the urgent need for innovative technologies and dedicated research and development efforts. These efforts should focus on enhancing the current designs of personal protective equipment by incorporating modern technologies to make them more flexible, adaptable, and impact-resistant which is essential for effectively preventing injuries (Figure 3.15).

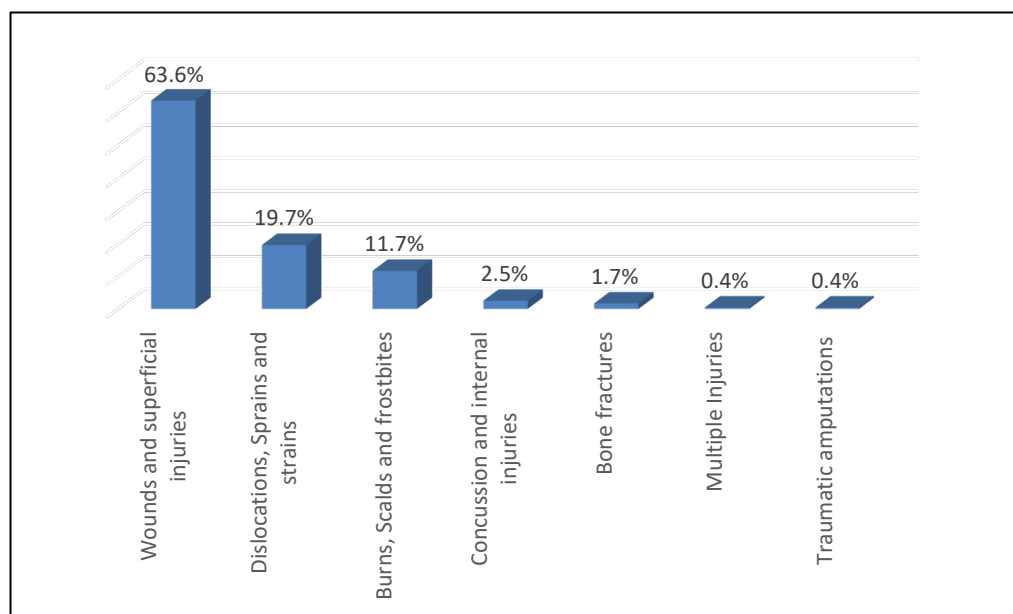


Figure 3.15: Distribution of injury records by type of injury.

Further analysis of the twenty-four critical accidents categorized by type of injury presents a comprehensive spectrum, each varying in severity and criticality. Wounds and superficial injuries are the most common yet have the lowest rate of critical outcomes. Conversely, the less frequent occurrences of concussions, internal injuries, fractures, multiple injuries, and amputations carry a higher risk of being critical, reflecting their potentially life-threatening nature (Figure 3.16).

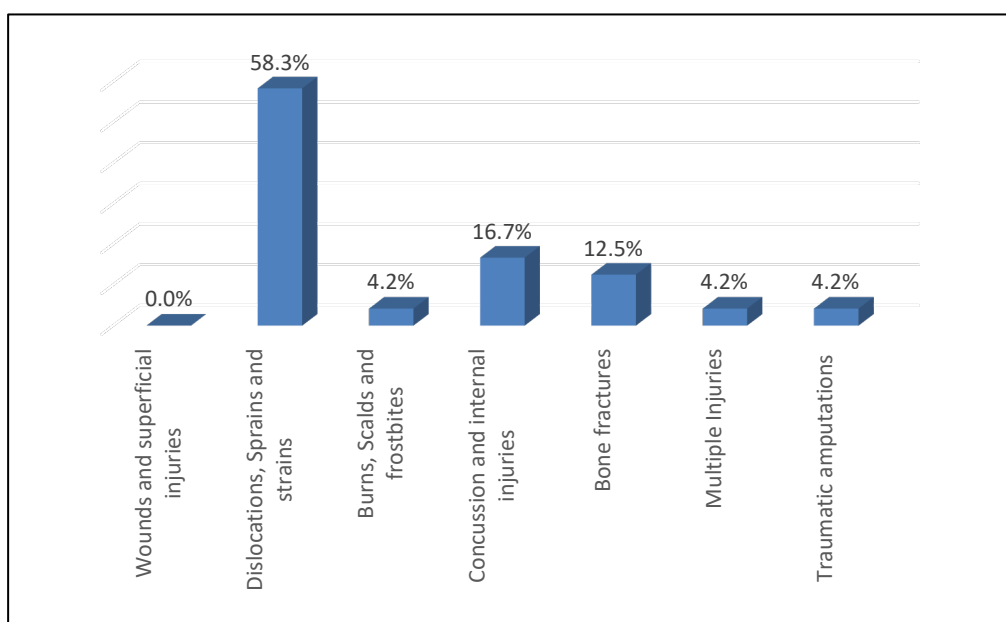


Figure 3.16: Distribution of critical injury records by type of injury.

4.9. Analysis of Injury Records by Part of Body

This chapter begins with an exploration of the concept of the Part of Body as defined by ESAW. The category is understood as the part of the body that was injured. If several injuries were received, for statistical purposes it should refer to the part of the body sustaining the most serious injury. It may also be useful to indicate the side of the body that was injured. Only in cases where there were several injuries to different parts of the body and no injury was more severe than the others should a grouping of locations be used, such as multiple locations (Eurostat, 2001).

The analysis of 239 personal injury accident reports from a company-specific dataset was categorized according to the part of body injured, in alignment with ESAW Annex I: Classifications. This analysis of the body parts injured will be conducted in two

stages. The initial stage of the analysis will focus on general parts of the body, while the second stage will delve into detailed examinations of the injuries.

Upper Extremities (108 cases): Injuries to the upper extremities, comprising the shoulder area, arms, and hands including fingers and wrists, account for 108 cases with an 8.3% critical incident rate. The critical cases are not isolated to a specific area, indicating a uniform risk across all tasks and regions within this category.

Head (48 cases): There were forty-eight cases of head injuries, impacting areas from the brain to the teeth, with a 4.2% critical rate. Critical cases often involve interaction with material agents such as buildings or structures and typically occur during falls from or on the same level, frequently associated with deck workstations.

Lower Extremities (43 cases): This category refers to injuries to the lower part of the body, including hips, legs, and feet, with an 11.6% critical incident rate. The critical cases predominantly involve dislocations, sprains, strains, and in one instance, a burn due to hot fuel leakage.

Back (18 cases): Injuries to the back, specifically the spine and vertebrae, were found to have an 11.1% critical rate. Critical injuries in this group are often related to overexertion, overload, or ergonomic issues, frequently resulting from improper lifting during manual carrying activities on the deck.

Torso and Internal Organs (11 cases): The torso and internal organs, including the rib cage and chest area, account for eleven cases with a notably high critical rate of 27.3%. Critical injuries here are diverse, occurring in accommodation areas and the deck during various work processes, such as setup, waste management, and storage.

Whole Body or Multiple Sites (8 cases): This group includes cases where systemic effects or multiple body parts are affected, totaling eight cases with two critical, marking a 25% critical rate. The critical injuries are linked to the working environment, particularly the bunkering station and engine room.

Neck (3 cases): Neck injuries involving the spine and vertebrae in the neck region, with one being critical, resulted in a 33.3% critical incident rate. The reported critical case involves prolonged bending of the neck during a chipping task on the deck, leading to significant injury and a week off work.

The data indicates that 45% of accidents in this section involve injuries to the upper extremities, making them the most commonly affected body parts. This trend is consistent with the MAIB annual reports, which reveal that over the past 3 years, approximately 43% of all reported accidents resulted in upper limb injuries. The alignment between these statistics and the company-specific results underscores a persistent and widespread issue. This high incidence rate highlights the critical need for targeted interventions, such as improving the design and functionality of personal protective equipment focused on upper extremity protection (Figure 3.17).

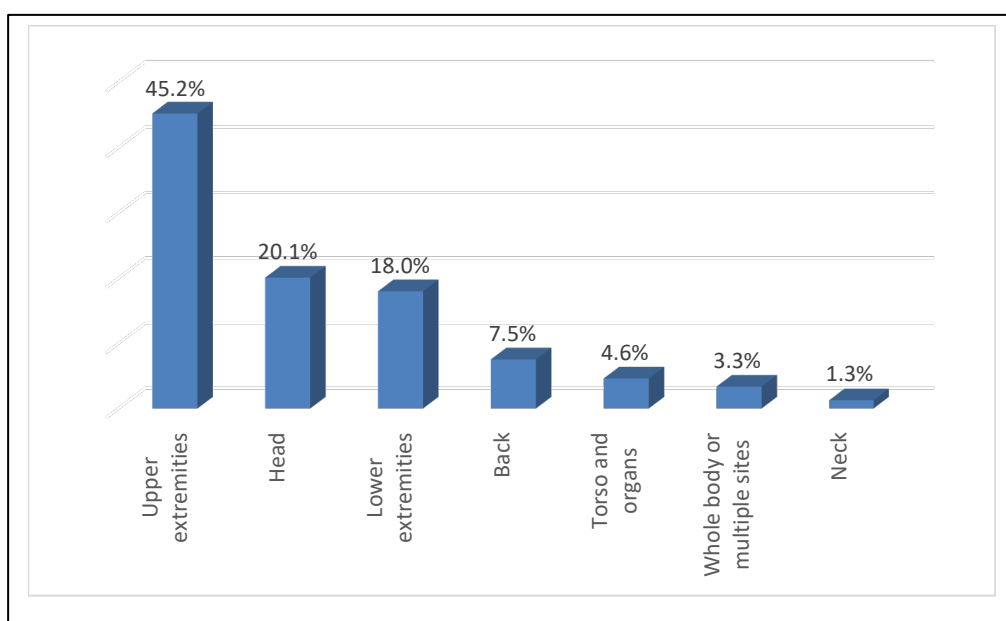


Figure 3.17: Distribution of injury records by part of the body.

A further analysis uncovers twenty-four critical incidents out of the total, segmented by the affected body part illustrating a diverse range of injury severity and urgency. Similarly, upper extremity injuries are not only the most frequent but also result in the most severe outcomes. Followed by the lower extremities, torso, and internal organs show the greatest proportion of critical rates, despite their lower occurrence. Likewise, injuries to the neck and those affecting the entire body or multiple sites are comparatively rare but tend to be more severe when they do happen (Figure 3.18).

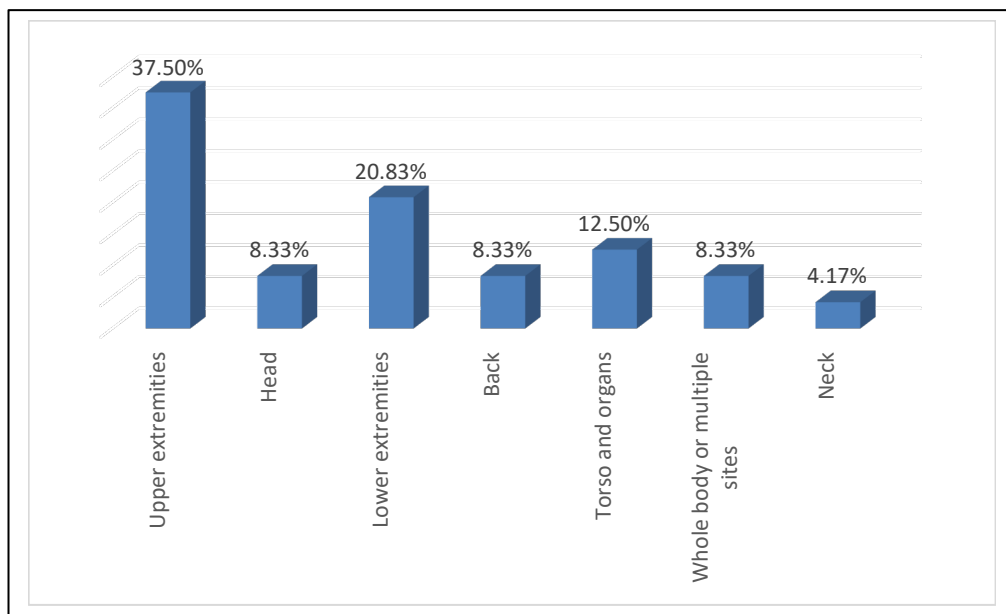


Figure 3.18: Distribution of critical injury records by part of the body.

In addition to the previously mentioned body parts, this study has chosen to further analyze specific areas of injury within the body part category, guided by its fundamental purpose. Special attention is given to specific body parts injured, including the hand/fingers, eye, lumbar region, arm, leg, ankle, face, and foot, as well as injuries involving the whole body or multiple sites, skull, wrist, chest, waist, neck, knee, abdomen, elbow, buttock, mouth, and thigh.

Hand/Fingers (84 cases): These injuries include a range of traumas from minor cuts to severe fractures. For the category of hand and finger injuries, there is a discernible pattern in their occurrence across various locations and activities. For instance, the engine room emerges as the most common site for such injuries, accounting for 30% of the incidents, suggesting a high-risk environment possibly due to machinery operation or maintenance tasks. Following this, the provision store and galley are noted for 15% of the hand and finger injuries, possibly due to the use of cutting tools or handling provisions. The main deck is the third most frequent location for these injuries at 11%, likely related to manual handling or deck operations. It is observed that the handling of objects specific activity leading to these hand/finger injuries made up 47% of the cases. There is a 17% incident rate associated with failing to use personal protective equipment properly, which points to a considerable possibility for injury prevention through better PPE compliance. Lack of situational awareness, risk

perception, or risk awareness accounts for 53% of hand and finger injuries. This substantial proportion suggests that many injuries could be preventable with improved safety awareness programs. Representing a diverse range of injuries, hand and finger traumas had a 5.95% critical incident rate, highlighting that a notable fraction of these injuries could lead to significant functional impairment.

Eye (27 cases): Eye incidents are commonly linked to interactions with hazardous substances that lead to contamination in the eye. Additionally, these incidents frequently occur during tasks that involve the use of pressurized cleaning tools or de-rusting equipment, activities that heighten the risk of foreign particles entering the eye. The absence of critical incidents among the total cases could be attributed to immediate and efficient first aid treatment on board, which appears to have effectively mitigated the potential severity of these injuries.

Lumbar (18 cases): Injuries to the lumbar region, crucial for mobility and support, can significantly impair individuals. With a critical incident rate of 11.11%, these injuries underscore the potential for severe consequences.

Arm (17 cases): Arm injuries, encompassing damage to bones, muscles, and nerves, can critically impact function. The arm's 17.65% critical incident rate indicates the potential for significant complications and extensive medical treatment.

Leg (15 cases): Leg injuries, ranging from muscle strains to complex fractures, can severely affect mobility. Despite a critical incident rate of 6.67%, these injuries occasionally lead to serious conditions requiring substantial care.

Ankle (13 cases): Ankle injuries, although common, can cause serious mobility issues. The 15.38% critical incident rate highlights the possibility of severe disruption to walking or weight-bearing abilities.

Face (11 cases): Facial injuries, involving soft tissue or bone, may require surgical intervention or pose recovery challenges. With a 9.09% critical incident rate, some of these injuries involves complex fractures on the teethes impacting both function and aesthetics.

Foot (10 cases): Foot injuries, ranging from minor to severe, are common due to bearing the body's weight. The foot's 10% critical incident rate suggests the potential for serious fractures or tendon damage.

Skull (9 cases): Skull injuries are serious due to brain involvement. With an 11.11% critical incident rate, these injuries occasionally lead to grave outcomes such as brain injury.

Whole Body or Multiple Sites (8 cases): Injuries affecting multiple body parts, or the entire body often result from major accidents. The 25% critical incident rate reflects the seriousness of such trauma and its comprehensive impact.

Wrist (5 cases): Wrist injuries, though less frequent, can significantly affect hand function. The 20% critical incident rate indicates the need for intensive treatment.

Chest (5 cases): Chest injuries, while generally manageable, serve essential functions with no critical incidents reported.

Waist (4 cases): Waist injuries, with a 50% critical incident rate, often involve serious complications such as spinal damage or significant soft tissue trauma.

Neck (3 cases): Neck injuries pose serious risks, with a 33.33% critical incident rate indicating potential outcomes like nerve damage or vascular compromise.

Abdomen (2 cases): Abdominal injuries, with a 50% critical incident rate, can rapidly become life-threatening due to housing vital organs.

Thigh (1 case): The critical incident rate shows %100 from a particular case, thigh injuries, although rare, can lead to severe issues requiring immediate medical attention.

Others (7 Cases): The category includes knee (3 cases), elbow (2 cases), buttock (1 case), and mouth (1 case) injuries, while potentially restrictive, do not typically result in critical complications.

The data reveals a range of affected areas, with hand and finger injuries being the most prevalent. This suggests a pressing need for heightened safety measures and protective equipment in activities where these extremities are at risk, particularly in areas like the engine room and during tasks involving object handling. The substantial percentage of hand/finger injuries linked to PPE non-compliance and lack of awareness underscores the critical necessity for improved safety protocols and training to mitigate such injuries. While eye injuries are not as common, they emphasize the importance of protective eyewear, especially in environments prone to chemical and dust exposure. Injuries to the lumbar region, arms, and legs also indicate significant occurrences,

potentially stemming from overexertion or accidents involving movement, leading to slips, trips, and falls (Figure 3.19).

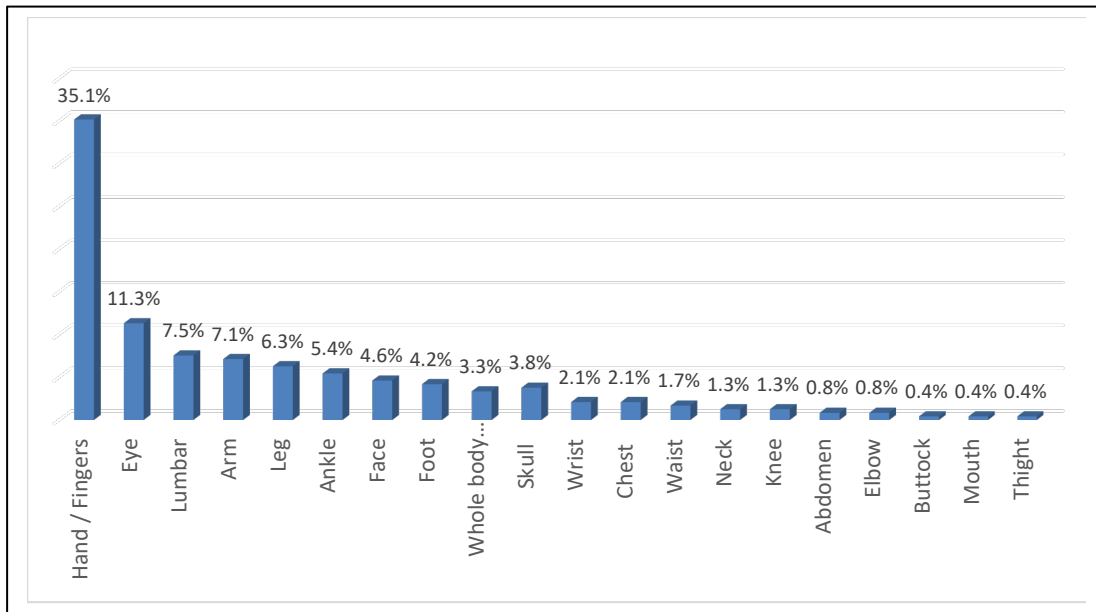


Figure 3.19: Distribution of injury records by specific parts of the body.

Out of the total cases, twenty-four critical incidents were identified and categorized by the affected body part. This analysis revealed that hands and fingers are not only the most frequently injured body parts but also have significantly higher critical incident rates. Consequently, this trend extends to the upper extremities, which show similarly high counts and severity of injuries (Figure 3.20).

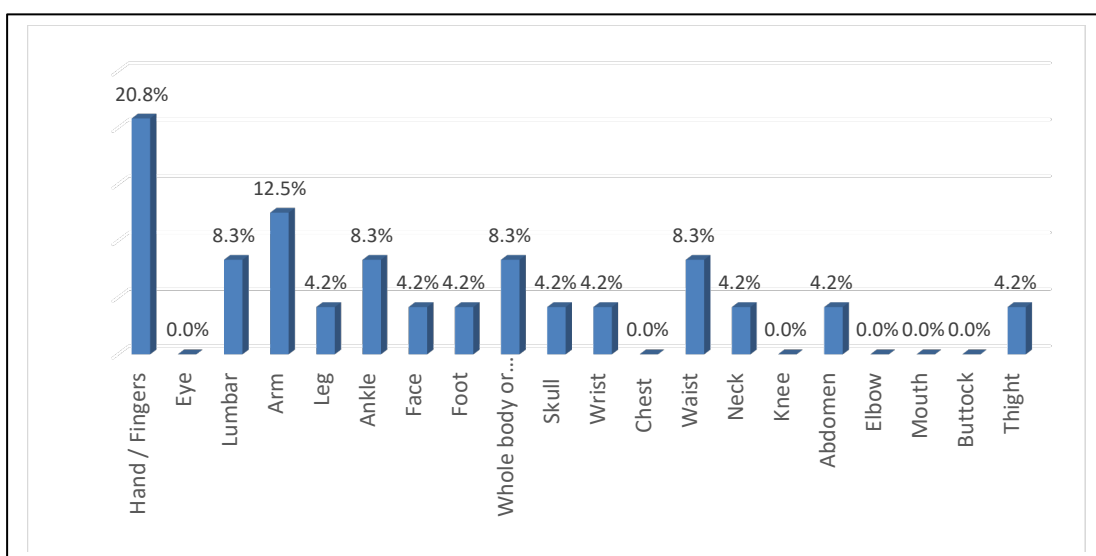


Figure 3.20: Distribution of critical injury records by specific parts of the body.

4.10. Analysis of Injury Records by Root Causes

This chapter begins with an exploration of the concept of the Root Causes as defined by MSCAT Immediate and Basic Causes, as required by the Company's Incident Management Procedure.

The category is also referenced in ILO and ESAW resources under Deviation from the Normal title where it is defined as the deviation from the normal way of working or the normal process, i.e., what went wrong. It is the event leading to the accident, but it does not assign responsibility for the accident to any person and does not constitute the cause. There may be a series of several interlinked or successive events preceding the accident, but the deviation that is used in the statistics is the last one before the person was injured. A deviation may take the form of something breaking or bursting, losing control of a machine, tripping over something, inappropriately lifting something, aggression by another person, being attacked by an animal, falling, and so on. Sometimes there is an item, tool, material, or object that is linked to the abnormal occurrence or abnormality of the process, known as the material agency. (Eurostat, 2001).

This analysis encompasses a two-stage process that includes identifying both the immediate and basic causes of each incident. The concept of immediate cause in the initial stage is integral in understanding the specific event or action that directly results in an incident. This is the closest cause in time to the outcome. However, this immediate cause might be influenced by broader factors, such as external conditions, work processes, and human factors which require more in-depth examination to fully understand the incident. Expanding further, the second stage of the analysis, basic causes delve into the systemic issues that underpin incidents, particularly in workplace settings. This deeper investigation aims to uncover the underlying factors that contribute to the occurrence of incidents. Basic causes often relate to broader organizational, environmental, or procedural issues that are not immediately apparent. These causes are often not visible in the immediate aftermath of an incident and require a thorough investigation to uncover.

In the analysis framework, immediate causes are categorized into Substandard Acts and Substandard Conditions while basic causes are categorized into Personal Factors and Job/System Factors. By categorizing causes in this manner, the analysis aims to

provide a structured approach to identifying and addressing both the direct and underlying reasons behind incidents, thereby facilitating more effective strategies for prevention and improvement in safety standards.

Understanding both immediate and basic causes is crucial for effective risk management and prevention strategies. By addressing the immediate causes, short-term safety improvements can be implemented quickly. However, to achieve long-term safety, it is essential to identify and rectify the basic causes, ensuring that both human behaviors and environmental conditions are conducive to safety (Company IMS, 2022)

4.10.1. MSCAT Immediate cause

In the analysis framework, immediate causes are categorized into Substandard Acts and Substandard Conditions.

Substandard Acts: These are unsafe actions performed by individuals, which could include violations of procedures, misuse of equipment, or disregard for established safety measures. Examples could involve an employee operating machinery without proper training or bypassing safety checks to speed up a process.

Substandard Conditions: These refer to environmental or physical states that contribute to incidents, often resulting from inadequate workplace management or maintenance. This could encompass scenarios like poor lighting that leads to accidents, slippery floors that are not promptly addressed, or outdated machinery that fails during use.

The analysis of 239 reports from a company-specific dataset was categorized according to the immediate causes of the injuries, in alignment with MSCAT.

Failing to Use Personal Protective Equipment Properly (36 Cases): The highest number of personal injury incidents stems from improper use or lacking personal protective equipment. Even though this category holds the highest number of cases, the absence of critical incidents suggests that the resulting injuries may be less severe or that PPE, even when used incorrectly or partially, provides a degree of protection against critical injuries.

Failure to Follow Procedure/Instruction (34 Cases): A considerable number of injuries are due to personnel not following established procedures or instructions, suggesting that reinforcing training and understanding of standard operating procedures could be beneficial. Non-compliance with procedures is a close second and carrying an 11.8% critical incident rate. The cases here point to a significant issue with adherence to safety protocols. A notable percentage of these non-compliance cases lead to severe injuries, which could imply that these protocols if followed, are crucial in preventing serious accidents.

Improper Securing (28 Cases): Failures in securing equipment or loads have led to numerous injuries, pointing to a need for rigorous checks and enhanced attention is needed to thoroughly consider securing techniques and available technologies suitable for an unstable environment like ships. Improper securing processes are identified in twenty-eight cases, with a 14.3% critical incident rate, indicative of the high risks associated with securing tasks. Injuries in this category tend to be more severe, suggesting that they often occur during high-risk activities, such as working at heights or with heavy machinery. In these scenarios, failure to secure properly is easily leading to serious consequences.

Improper Lifting (23 Cases): A considerable number of incidents involve improper lifting methods. This category suggests a need for enhanced manual handling techniques and possibly the introduction of mechanical aids to reduce the physical strain on workers. The critical incident rate of 13%, illustrate the dangers of manual tasks when not executed correctly. Given that a considerable number of injuries from improper lifting are critical, it is clear that there is a risk of significant injury from what might be considered routine manual tasks.

Inadequate Guards or Barriers (14 Cases): This shows a considerable number of injuries might be prevented by proper guards or barriers. The category carries a 28.6% critical incident rate, which reflects the high impact on the severity of injuries when safety barriers are insufficient, which may reflect the critical role that physical safeguards play in protecting workers from hazards in their work environment.

Extreme Adverse Sea/Weather Conditions (14 Cases): Identical in case number to the previous category, this indicates that environmental factors play a significant role in safety, particularly in maritime settings. The presence of critical injuries here with a

28.6% rate suggests that environmental factors can pose serious threats to safety, likely due to their unpredictable nature and potential to significantly amplify risks in the workplace.

Improper Position for Task (13 Cases): Slightly fewer in number but still significant, injuries due to improper positioning suggest a need for ergonomic training and task design to minimize risk. The 23% critical incident rate shows a higher rate of severe injuries highlighting the importance of ergonomics and proper technique in tasks.

Improper Operation of Tool/Equipment/Machinery/Device (9 Cases): These injuries point towards a potential lack of proper training or maintenance, indicating room for improvement in equipment handling protocols. Tool or equipment mishandling accounts for 11% of critical incident rate.

Inadequate Condition of Floor/Surface (8 Cases): This category suggests that regular maintenance and safety checks of work environments could reduce the incidence of injuries. A 12.5% critical incident rate draws attention to the impact of the work environment on safety where even small improvements might prevent serious injuries.

Exposure to High Temperature (6 Cases): The presence of these cases highlights the need for adequate thermal regulation and protective measures in environments where hot temperatures are a risk. The category carries a 16.7% critical incident rate, and the need for preventative safety measures is clear.

Failure to Inform/Warn (6 Cases): Effective communication is key in preventing injuries, as evidenced by the injuries where a failure to inform or warn resulted in harm. Failure to inform or warn led to a 16.7% critical injury rate underscoring the importance of clear communication and relevant communication equipment in use in the workplace.

Incorrect Navigation or Ship Handling (1 Case): While only reported once, any case in this category can have serious implications, pointing to the critical nature of navigation and ship handling skills in maritime safety. This single critical incident suggests that navigation or ship handling errors, while not common, can lead to severe consequences, underlining the need for strict safety protocols.

Various Other Causes (47 Cases): This category aggregates various causes of personal injury accidents with less frequent immediate causes of personal injury. For instance, issues with personal protective equipment appear in seven cases, highlighting areas

where better oversight could be beneficial. Operating at improper speed emerges in five cases, improper placement in four, and both operating equipment without authority and the use of incorrect materials in three cases each. These suggest specific operational procedures that may require tightening of safety protocols. Similarly, inadequate, or excessive illumination, poor housekeeping/order, use of defective machinery, actions by external parties, restricted space, and inadequate warning systems are noted, albeit less frequently, but still point to potential risk factors. Single instances involving exposure to chemicals and inadequate ventilation indicate unique but critical areas to address for preventing such accidents.

It is important to analyze these incidents further to determine the basic root causes and implement targeted interventions for each category (Figure 3.21).

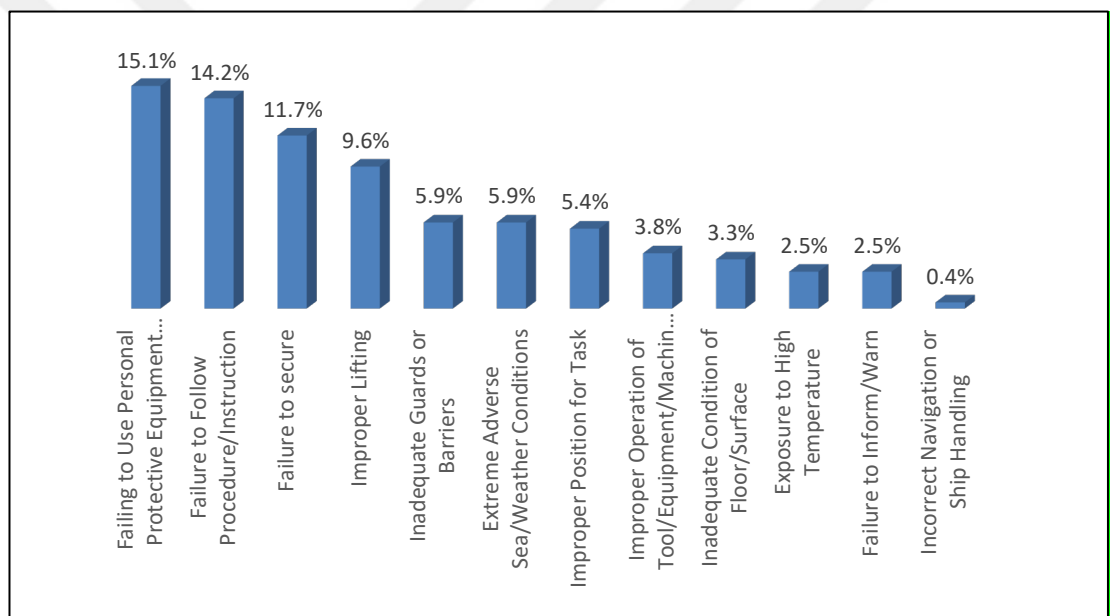


Figure 3.21: Distribution of injury records by immediate cause.

A further analysis uncovers twenty-four critical incidents out of the total injury cases, segmented by the immediate causes highlighting several key insights. First, the most common incidents involve the misuse of personal protective equipment, but these tend not to result in critical injuries, suggesting that PPE, even when misused, provides a baseline level of protection. Second, procedural non-compliance, securing failures, and inadequate barriers or guards are associated with a higher severity of injury, indicating these as critical areas for intervention. These categories point toward the need for rigorous safety protocols, thorough training, and physical safeguards. Lastly,

even single incidents in categories like navigation errors can have severe outcomes, emphasizing the importance of safety in all aspects of workplace operations (Figure 3.22).

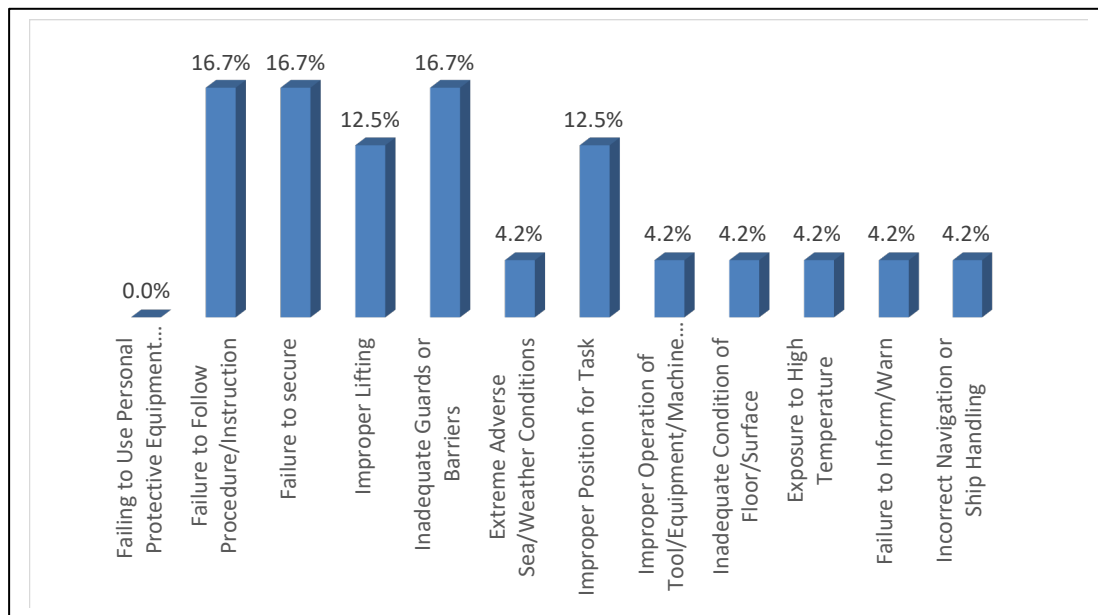


Figure 3.22: Distribution of critical injury records by immediate cause.

4.10.2. MSCAT Basic cause

In the analysis framework, basic causes are categorized into Personal Factors and Job/System Factors.

Personal Factors: These involve individual attributes such as lack of knowledge, skills deficiencies, or personal neglect, which influence behavior and can lead to unsafe acts or conditions. Personal factors might include an employee's resistance to following safety protocols due to a lack of understanding of their importance.

Job/System Factors: These are related to organizational and procedural aspects of a job that can lead to unsafe acts or conditions. This could include insufficient training programs, poorly designed equipment, lack of safety incentives, or inadequate safety policies.

The analysis of 239 reports from the company-specific dataset was categorized according to the basic causes of the injuries, in alignment with MSCAT. This dataset on basic causes offers an overview analysis from the broad categories. A more detailed

analysis of the major category will be provided in the following chapter (4.10.3. MSCAT/Basic cause/Category “Lack of competence”)

Lack of Competence (123 cases): This category represents the highest number of cases, indicating that a considerable number of accidents were attributed to a deficiency in the human factor. It encompasses a substantial portion of personal injury accidents, suggesting that employees may lack the necessary skills, knowledge, or qualifications to perform tasks safely. This lack of competence could result from numerous factors, including insufficient familiarity, orientation, induction, and training, as well as misunderstood instructions or information, a deficiency in situational awareness/risk perception/risk awareness, inadequate initial instruction/skill training, practice, performance, coaching, and review instructions. To address these issues, organizations typically implement enhancements to their training programs and safety cultures. This involves developing comprehensive training modules tailored to specific job roles and associated risks, encompassing both initial and ongoing training to maintain up-to-date skills. Competency assessments are also crucial, regularly evaluating employees' competencies to ensure they meet the required standards for their roles. Furthermore, strengthening onboarding processes is essential, ensuring that new employees receive thorough inductions into the company's safety culture and understand the importance of safety in their daily tasks. Investing in continued education opportunities allows employees to further their education and qualifications related to their job functions. Implementing safety mentorship programs pairs less experienced workers with mentors who can provide on-the-job guidance and support, reinforcing best practices. Establishing feedback mechanisms enables employees to provide input on best management practices and suggestions for improvement. Incorporating safety and competence into performance evaluations reinforces their importance within the organization. Promoting a culture of safety, where safety is a shared responsibility and competence is valued and rewarded, is crucial. Organizations typically focus on these areas to address preventive measures, guided by maritime industry national and international regulators and authorities.

The highest number of personal injuries was due to lack of competence, which also constitutes a sizable proportion of the critical cases. Over 11% of accidents in this category were critical, emphasizing the urgent need for further analysis. It is imperative that data from similar industries and companies is benchmarked. However,

the European Maritime Safety Agency The annual overview of marine casualties and incidents 2023 report mentions a similar conclusion on this point with the company-specific data. For the period between 2014 and 2022, the average contribution of human factors to the analyzed incidents was 80.7%.

Inadequate Tool/Equipment/Machinery/Device (19 cases): Injuries falls under this category point to issues with the tools and equipment used on-site. Regular inspections, maintenance, and ensuring the suitability of the equipment for the task at hand could mitigate these risks. Although this category accounts for fewer accidents, the presence of a single critical case suggests that even a single failure or mishap with equipment can have severe consequences.

Improper Motivation (15 cases): These cases might reflect an organizational culture issue where employees are not adequately encouraged to follow safety procedures or may take shortcuts. Motivational strategies and recognition programs for safe behavior could be beneficial. While improper motivation led to several injuries, none were critical, indicating these might be more minor in nature or that safety systems are mitigating the severity.

Inadequate Physical/Physiological Capability (14 cases): This category suggests that physical or health limitations of staff may lead to accidents. This could be addressed by proper job matching, health assessments, and ergonomic interventions. This category has a relatively high critical rate of 14.3%. This highlights the importance of matching tasks to an employee's physical capabilities.

Inadequate Communication/Information (14 cases): Here, the accidents are due to failures in communication, signaling the need for better information dissemination and communication channels within the work environment. Miscommunication can lead to critical accidents, as shown by the critical rate of 7.1%. This underscores the need for clear and effective communication in preventing serious injuries.

Inadequate Work/Production Standards (9 cases): This implies that there may be a lack of poorly enforced standards for work and production, highlighting the importance of standard operating procedures and their strict implementation.

Physical/Physiological Stress (8 cases): Stress-induced accidents indicate that the work environment may be physically demanding, requiring measures to manage workload and improve working conditions. In our specific data set, this category is

primarily related to seafarer fatigue. No critical injuries have been recorded, but this does not imply that fatigue is being adequately managed. Literature reviews indicate that fatigue might significantly contribute to a lack of situational awareness among seafarers. As literature reviews reveal, the potential for fatigue at sea is high due to seafarers' exposure to numerous operational and technical risk factors. The combined effect of these risk factors is strongly associated with fatigue and its consequences for human error, which can lead to marine accidents. Given the challenges in measuring human fatigue and establishing it as a root cause of accidents, it is crucial to develop methods to detect and quantify fatigue and its mental symptoms accurately. (Bal Beşikçi, E. et al 2015).

Inadequate Leadership (8 cases): Leadership plays a crucial role in safety, and these cases show a gap that could be filled by proper leadership and development focused on safety. A quarter of the cases in this category were critical (%25), indicating a strong impact of leadership on serious injuries.

Inadequate Supervision/Coaching (8 cases): It is understood that injuries reported in this category could be prevented through better supervision and coaching, ensuring that all safety protocols are followed diligently. The 25% critical rate is as significant as that for leadership, highlighting the importance of proper job supervision and coaching in maintaining a safe work environment.

Inadequate Product/Service Design (5 cases): These injuries suggest design flaws in products or services that may pose risks to safety, pointing to the need for design reviews focused on user safety. Even though the Traumatic Amputations Case Study, shows the primary immediate cause as insufficient guards or barriers, a secondary immediate cause falls under this category, as the victim sustained a finger amputation due to the inadequate design of protective covers on the emergency diesel generator's ventilation fan. This highlights the critical need for improved safety measures and design enhancements to prevent such incidents. Ensuring that protective covers and barriers are adequately designed and implemented is essential to reducing the risk of severe injuries.

Inadequate Mental/Psychological Capability (5 cases): Injuries under this heading suggest the mental or psychological state of employees can impact safety, indicating a need for support systems such as counseling and mental health programs. The critical

rate of 20% is notable, suggesting that when mental or psychological capability issues lead to accidents, they have a high likelihood of being serious.

Inadequate Maintenance/Inspection (5 cases): The necessity of regular and thorough maintenance and inspection is underscored by these cases to prevent malfunctions that could lead to injuries. Similar to mental/psychological capability, the critical incident rate of 20% points to the potential severity of accidents that occur due to maintenance issues.

Inadequate Supply Chain Management (3 cases): These few cases still highlight the ripple effect that supply chain issues can have on safety, suggesting a need for robust supply chain risk assessments.

Excessive Wear/Tear (3 cases): A smaller number of accidents are attributed to wear and tear, which can be managed with proactive replacement and refurbishment schedules.

Each category brings to light specific aspects that require attention to minimize the risk of personal injury accidents in the workplace. The significant occurrence of accidents attributed to “Lack of Competence” is particularly striking, underscoring the requirement for deeper analysis (Figure 3.23).

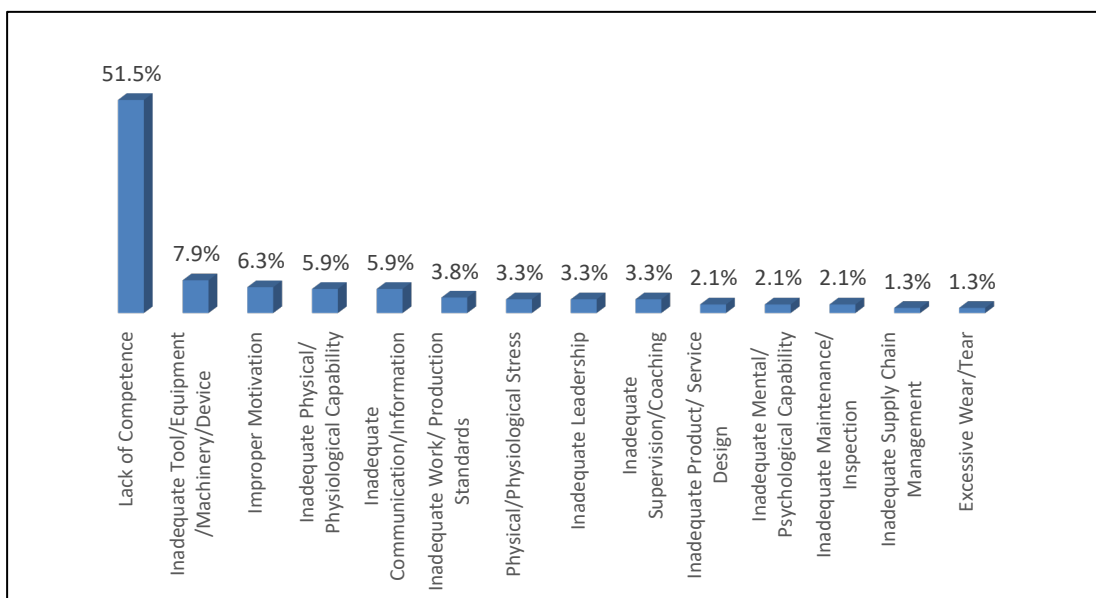


Figure 3.23: Distribution of injury records by basic cause.

A further analysis uncovers twenty-four critical incidents out of the total injury cases revealing a heterogeneous distribution of critical incidents across various basic causes,

with Lack of Competence accounting for the highest number of overall and critical cases. The critical incident rates notably suggest that accidents due to inadequate leadership and inadequate supervision/coaching have the second highest likelihood of being serious, with 25% of incidents being critical for each (Figure 3.24).

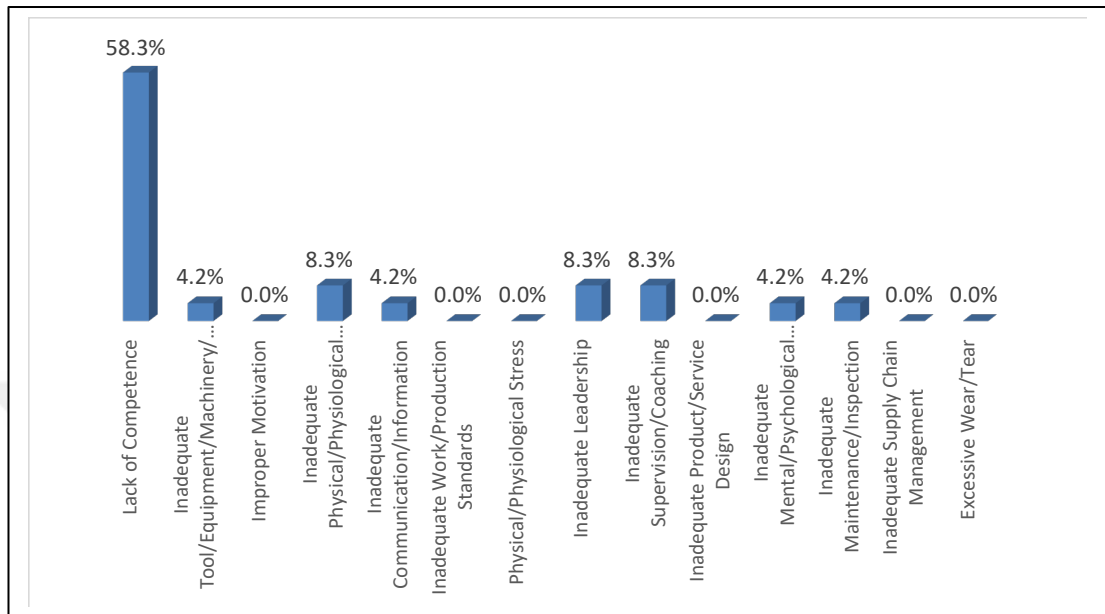


Figure 3.24: Distribution of critical injury records by basic cause.

4.10.3. MSCAT Basic cause; lack of competence

The category of Lack of Competence refers to human factors including training proficiency or supervision. This category includes factors such as lack of situational awareness, risk perception, inadequate experience, and insufficient initial training within our dataset. Furthermore, the MSCAT map identifies additional potential root causes falling under Lack of Competence, which is not applicable to the dataset of this study. These include inadequate orientation/induction, pinpointing deficiencies in introducing new employees to their roles, and safety protocols. Similarly, inadequate initial training highlights the inadequacy of foundational training for new employees, emphasizing the need for enhanced comprehensive programs covering all safety aspects and job-specific risks. Inadequate update/refreshers training suggests a lack of regular training updates, resulting in outdated skills. Misunderstood instruction/information refers to communication issues, including language barriers. Inadequate performance indicates a lack of proficiency due to infrequent task performance, while inadequate coaching suggests insufficient guidance or mentorship.

support for less experienced workers. Lastly, inadequate review instruction underscores the importance of regular reviews to ensure instructions and procedures remain relevant to current practices.

The analysis of 123 reports from a company-specific dataset recorded under the basic cause of Lack of Competence main basic cause for the injuries sustained, in alignment with MSCAT.

Lack of Situational Awareness/Risk Perception/Risk Awareness (107 Cases): The absence of situational awareness, risk perception, and risk awareness refers to an individual's capacity to recognize elements in their surroundings, interpret their significance, and anticipate their future conditions. This category, which accounts for 87% of all injuries recorded under Lack of competence category and 92% of them recorded as critical which highlights a significant lack of awareness regarding the inherent risks in the work environment. It is noteworthy that even top-severity events that required medical evacuation, prolonged hospital stays, and recovery periods defined their root causes as lack of situational awareness/risk perception/risk awareness.

To delve deeper into the topic of situational awareness, numerous academic studies have highlighted the increasing importance and growing need to focus on further enhancing techniques tailored for maritime workplace setup and safety. Thus far, situational awareness has been explored from various aspects; however, within the literature review, no specific approach concerning occupational workplace injuries in the maritime environment was observed. However, the studies cited below have undertaken thorough research on the subject, uncovering significant findings.

The literature review includes an approach and examination from the standpoint and perspective of risk-based situational awareness. The study revealed a multifaceted concept that is applied in various high-risk environments to enhance decision-making and safety. A conceptual model developed by Naderpour et al (2011) integrates data fusion and risk assessment to create a robust framework for situational awareness in dynamic settings. This model is critical in environments where decisions carry significant risks, such as military operations and emergency response. Another study focused on the domain of process safety, where situational risk awareness plays a crucial role in reducing hardware failures and human errors. The study also stresses

the significance of gathering evidence and evaluating situations, which is vital for upholding operational safety in industries characterized by complex dynamics, such as chemical processing and oil refineries (Naderpour et al, 2014). Another perspective stems from a distinct field, focusing on the role of situational awareness in driving safety, particularly among motorcyclists. This highlights the influence of experience on risk perception and hazard detection. Another research discovered that more experienced riders demonstrate greater proficiency in detecting hazards and evaluating the seriousness of situations. This implies that training and experience play pivotal roles in enhancing situational awareness among drivers (Bellet and Banet, 2012). Another viewpoint emerges from a separate domain: healthcare. Situational awareness holds paramount importance in guaranteeing patient safety, especially within high-risk environments like operating theaters and intensive care units where the significance of comprehending present conditions and predicting future scenarios to avert safety incidents, thus emphasizing the critical role of situational awareness in medical settings highlighted (Stomski et al, 2018). Overall, these studies highlight the critical role of situational awareness across various domains, demonstrating its importance in enhancing safety and improving outcomes in high-risk environments.

In the realm of maritime safety, a comparable emphasis on situational awareness has emerged as crucial for ensuring the safe operation of ships and averting accidents. This importance is underscored by several studies conducted within the maritime and offshore industries, each examining various approaches and aspects of the issue. A pivotal study in the literature reveals that situational awareness is a crucial component across various aspects of maritime operations, significantly impacting safety and decision-making. The study emphasizes that within the maritime domain, proficient situation analysis is pivotal for making informed decisions that enhance safety measures and prevent accidents (Melnik et al, 2022). Another study discusses the challenges faced by maritime safety and security organizations in managing large datasets and vessel movements. The paper suggests that maritime safety systems need to provide comprehensive alerts and support for maintaining data quality to ensure effective situational awareness and efficient incident response (Glandrup, 2013). Another definition of situational awareness as a crucial safety factor, especially for the Officer of the Watch, is presented in the study. This research examines both the historical significance and modern technological advancements that contribute to

enhancing situational awareness in maritime operations (Jaram et al, 2021). Another perspective delves into the specific information requirements essential for navigators, highlighting the array of data relied on during the pilotage phase. This study underscores the significance of grasping this information needed to bolster effective situational awareness (Sharma et al, 2019). Another research scrutinizes the role of situational awareness in averting unsafe actions and enhancing risk assessments among offshore vessel crews. Their research also delves into how leadership influences situational awareness and safety outcomes (Sætrevik and Hystad, 2017). Addressing cybersecurity concerns, another study emphasizes the emerging cyber risk challenges in maritime transportation. It highlights vulnerabilities in surveillance systems like the Automatic Identification System (AIS) and advocates for integrating cybersecurity into maritime situational awareness to safeguard operations (Simola and Pöyhönen, 2022). Lastly, another study identifies the levels at which situational awareness errors occur among offshore drilling personnel and discusses how isolation, fatigue, and stress impact their situational awareness (Sneddon et al, 2006). Collectively, these studies underscore the pivotal role of situational awareness in maritime safety, emphasizing its necessity in navigating the complex and rapidly evolving challenges within the maritime sector.

In addition to the dominant category of Lack of Situational Awareness/Risk Perception/Risk Awareness, other fundamental causes were identified as the root cause for the remaining personal injury accidents.

Inadequate Experience (9 Cases): Accidents in this category suggest that employees participated in tasks for which they lacked sufficient practical experience. Addressing this could involve aligning task assignments with an employee's experience level and enhancing on-the-job training. This category includes a single critical accident, underscoring the potential severity of mismatched experience levels.

Inadequate Practice (4 Cases): The absence of adequate practice prevented employees from effectively applying their knowledge. Implementing opportunities for simulated practice or supervised toolbox meeting sessions could enhance the necessary skills before independent task performance begins.

Inadequate Initial Instruction/Skill Training (3 Cases): This category focuses more on the practical skills required for specific job functions. Enhancing skill-based training, coupled with assessments to measure proficiency, could bridge this gap (Figure 3.25).

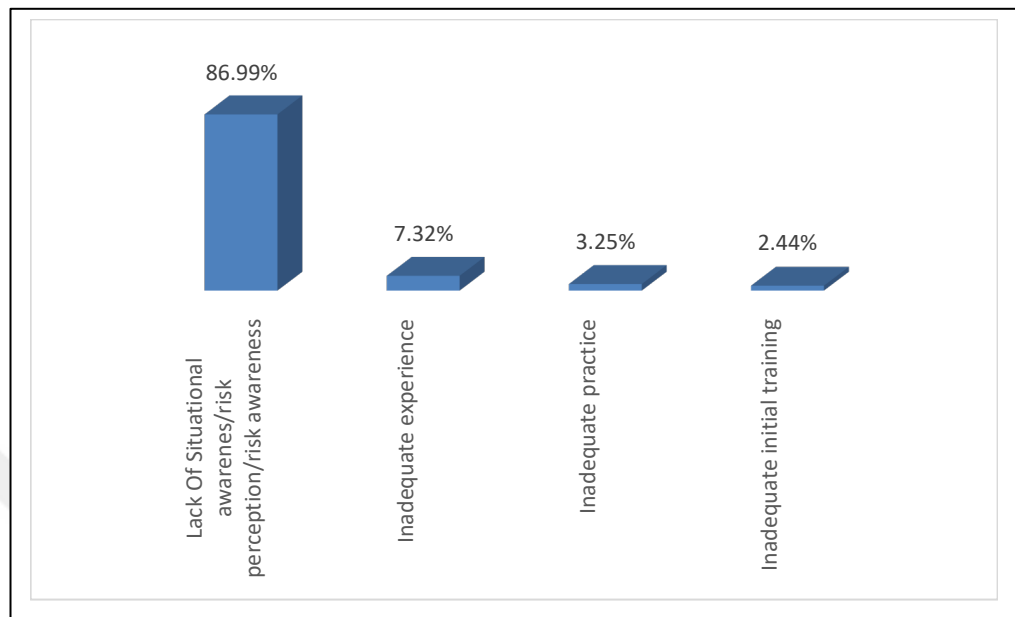


Figure 3.25: Distribution of injury records by basic cause: Lack of competence.

Further analysis of fourteen critical incidents attributed to the basic cause reported as Lack of Competence reveals that Lack of Situational Awareness/Risk Perception/Risk Awareness not only accounts for the highest number of accidents but also demonstrates similar rates of critical incidents (Figure 3.26).

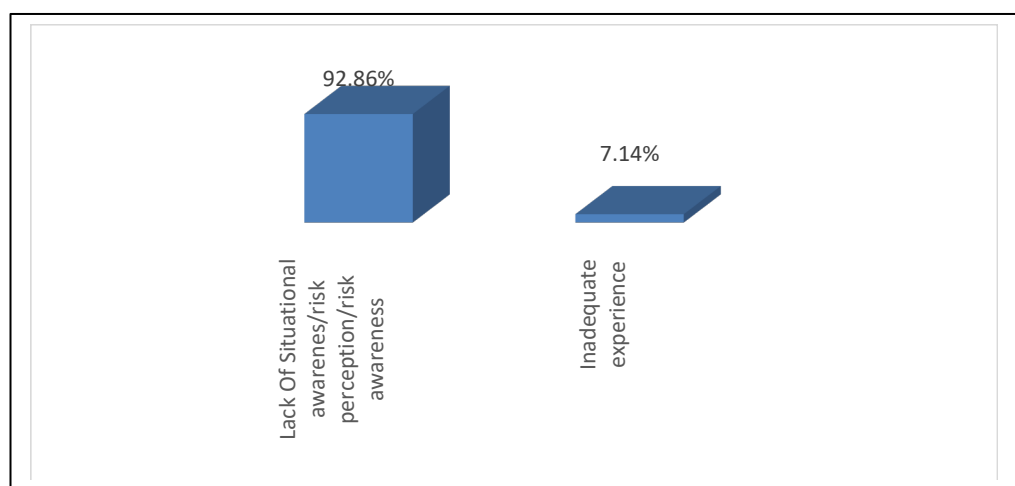


Figure 3.26: Distribution of critical injury records by basic cause: Lack of competence.

4.11. Heinrich's Theory

The research aims to explore the relationship between leading and lagging safety indicators, using comparisons with Heinrich's theory to evaluate safety performance. This thorough methodological approach has systematically pinpointed and addressed factors that contribute to injuries, thus improving our understanding of safety dynamics in the maritime sector.

Within this framework, 6863 incidents are analyzed according to the categories defined by the company's incident management procedure as follows:

Incident: A dangerous occurrence that leads to or may lead to any kind of loss. The company categorizes the incidents into four categories which are Accidents, Near Misses, Unsafe Acts, and Unsafe Conditions.

Accident: Any incident, which has inadvertently caused a loss or hazard to life, property, and environment, is called an accident, however, some incidents caused a loss with an intention (i.e., piracy, security breaches) will be named as Accident in this, and collateral procedure and documents.

Near Miss: An event that you have seen or heard about that under slightly different circumstances could have resulted in injury, property damage, environment, or process loss. Near misses are more frequently encountered every day and at any stage of shipboard operations.

Unsafe Act: An undesirable behavior that could have caused the accident, e.g., operating a hand tool without guards or PPE.

Unsafe Conditions: Any condition at an area or workplace that could have caused an accident, e.g., missing handrails, damaged working platform, slippery floor, or environment. (Company IMS, 2022)

Initially, the distribution of all incident records will be examined. This will be followed by an analysis of accident records specifically related to injuries, categorized similarly. Finally, there will be a focused review of the distribution of incident records of hand and finger injuries.

4.11.1. Analysis of incident records by the category

The analysis involved 6863 incident records from a company-specific dataset, categorized as required by the Company's Incident Management Procedure.

This data provides a comprehensive overview of safety incidents within the observed environment, indicating a considerable number of precursor incidents that could potentially escalate into more severe accidents. The breakdown of these incidents into various categories highlights the layered complexity of workplace safety and the importance of addressing each layer to mitigate risks.

When we examine these data from the perspective of Heinrich's theory, we gain significant insights into workplace safety. Heinrich's model suggests that behind every major accident, there are numerous less serious injuries and even more non-injury incidents (near misses and unsafe conditions). This model asserts that accidents are not just random and isolated events, but rather the result of more frequently occurring less serious events. Analyzing the distribution of 6864 incidents includes:

Accident Reports (646 cases): This is at the top of Heinrich's pyramid and represents the most serious incidents. Each major accident is associated with a series of less serious incidents and underlying root causes.

Near Misses (1675 cases): These are incidents that could have resulted in a serious accident but did not lead to one, although they had the potential to do so. According to Heinrich's model, such incidents should be carefully analyzed and viewed as learning opportunities because they often signal potential serious accidents.

Unsafe Acts (1030 cases): This includes situations where employees do not adhere to safety standards. Such actions can directly lead to accidents, and, in Heinrich's model, these incidents are emphasized as risk factors that need to be addressed to prevent accidents.

Unsafe Conditions (3512 case): This refers to unsafe conditions in the work environment. It forms the broadest part of the pyramid and is the most common type of incident. Unsafe conditions can lead to near misses and ultimately accidents (Figure 3.27).

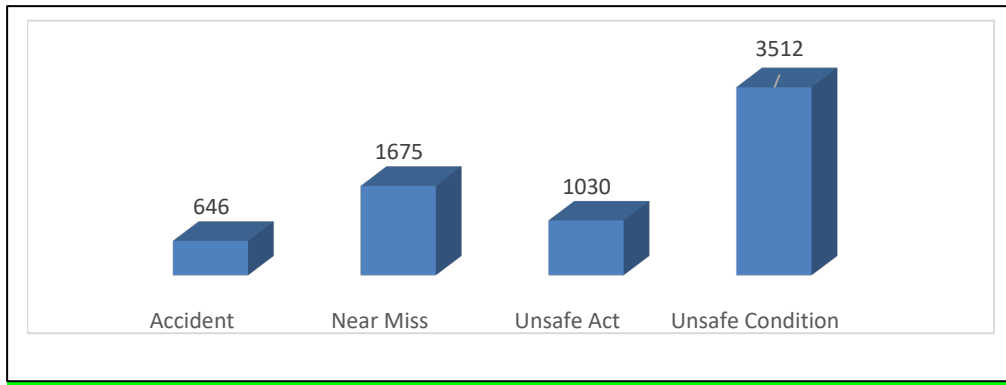


Figure 3.27: Distribution of incident records by the category.

In the dataset of this study, the provided ratio lacks a specific breakdown into major and minor accidents, but it indicates 646 accidents (severity unspecified) 1676 near misses, and 4544 unsafe acts/conditions. Despite this lack of detail, it offers a distinct perspective when compared to Heinrich's traditional safety model, which advocates for a ratio of one major accident to twenty-nine minor accidents or near misses and three hundred no-injury incidents (1/29/300).

The ratio shows a much lower ratio of near misses to accidents than expected if Heinrich's model were applied by the implementation, a higher number of unsafe acts/conditions, but still not proportionally as high as Heinrich's model would suggest. The relatively high number of accidents compared to near misses could indicate that many incidents that could potentially be controlled or avoided escalate to actual accidents. The lower-than-expected number of near misses relative to accidents suggests potential underreporting or lack of detection. The count of unsafe acts/conditions being lower than expected might point to a need for more rigorous safety inspections, better training, and a more proactive safety culture that encourages reporting and correcting unsafe conditions before they lead to accidents.

As a result, the ratio of 646/1675/4542 for the current study, considering Heinrich's model, suggests potential areas for improvement such as enhancing the ease of the process for incident reporting is crucial. Also, organizations may benefit from adopting more stringent preventive measures, improving training programs to foster a culture of safety, and implementing more comprehensive hazard identification processes. This approach would not only align more closely with Heinrich's preventative framework

but also likely reduce the number of accidents by addressing and rectifying contributing factors at earlier stages.

4.11.2. Analysis of injury incident records by the category

The analysis involved 2103 personal injury incident records from a company-specific dataset, categorized as required by the Company's Incident Management Procedure. This provides a detailed analysis that explores the distribution of incident records within the personal injury category, guided by Heinrich's theory, by including accident severity and examination of the interactions among several types of incidents that result in personal injuries.

Critical accidents (24 cases): According to Heinrich's pyramid, these cases are at the top and result in severe outcomes but are least frequent by the number. These include LWC and PPD severity cases that resulted in injuries.

Accidents (215 cases): These cases are positioned at the second level of Heinrich's pyramid, representing minor and medium consequences. This suggests that while more frequent than critical accidents, these incidents are less severe but still significant enough to warrant attention and corrective actions. These include FAC, MTC, and RWC severity cases that resulted in injuries.

Non-injury incidents (1864 cases): This category includes Near Misses (818 cases), Unsafe Acts (443 cases), and Unsafe Conditions (603 cases), which are situated at the bottom of the pyramid. These are incidents that narrowly avoided causing injuries, serve as crucial warnings and learning opportunities. They highlight situations where accidents were narrowly averted, making up the extensive base of the pyramid and being the most prevalent. This number of non-injury incidents indicates that there are many opportunities to identify and mitigate risks before they result in actual harm. According to Heinrich, the majority of personal injury cases can be attributed to these fundamental issues, suggesting that addressing these non-injury incidents can significantly reduce the likelihood of more severe accidents (Figure 3.28).

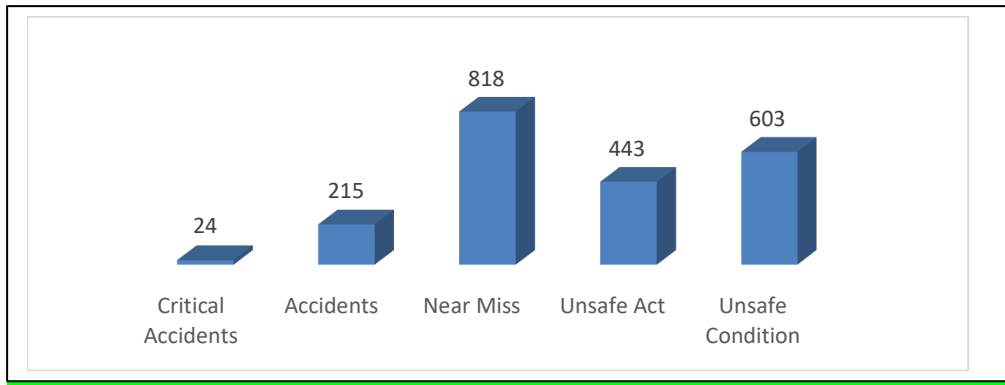


Figure 3.28: Distribution of injury incident records by the category.

Comparing it to Heinrich's original ratio, the proportion of major accidents to minor injuries and no-injury incidents in this dataset is much higher in terms of no-injury incidents and lower in terms of minor injuries relative to major accidents. This suggests a different distribution and possibly different underlying causes or safety practices within the context this data was collected. Analyzing the ratio of 24/215/1864 in the context of Heinrich's safety model, which traditionally posits a ratio of 1/29/300, reveals interesting deviations and potential insights into an organization's safety practices. Heinrich's model suggests that for every major accident, there are expected to be twenty-nine minor injuries and three hundred no-injury incidents. In the ratio of this dataset - 24 major accidents, 215 minor injuries, and 1864 no-injury incidents - we see a significant variation from Heinrich's model. If we scale Heinrich's ratios to match the twenty-four major accidents, we expect approximately 696 minor injuries and 7200 no-injury incidents, based on the original 1/29/300 proportion. This comparison reveals that the data shows a lower-than-expected number of minor injuries and significantly fewer no-injury incidents. The lower number of both minor injuries and no-injury incidents relative to the number of major accidents could indicate potential gaps in incident reporting or issues with the detection and management of less severe incidents. It might also suggest that incidents that do occur are more likely to escalate to more serious outcomes, pointing to possible deficiencies in preventive measures. Enhancing these areas could provide earlier warning signs and opportunities for intervention before incidents become severe.

Preventive actions for the industry are led by an increased focus on better training for employees on the importance of reporting all incidents, improving safety culture, and possibly employing more rigorous hazard identification processes. Addressing this

imbalance could involve strengthening the organization's safety training programs, enhancing incident reporting processes, and applying more stringent safety measures to manage and mitigate risks effectively. This proactive approach could help realign the organization's incident ratios closer to expected safety models and reduce the frequency and severity of workplace accidents (Figure 3.29).

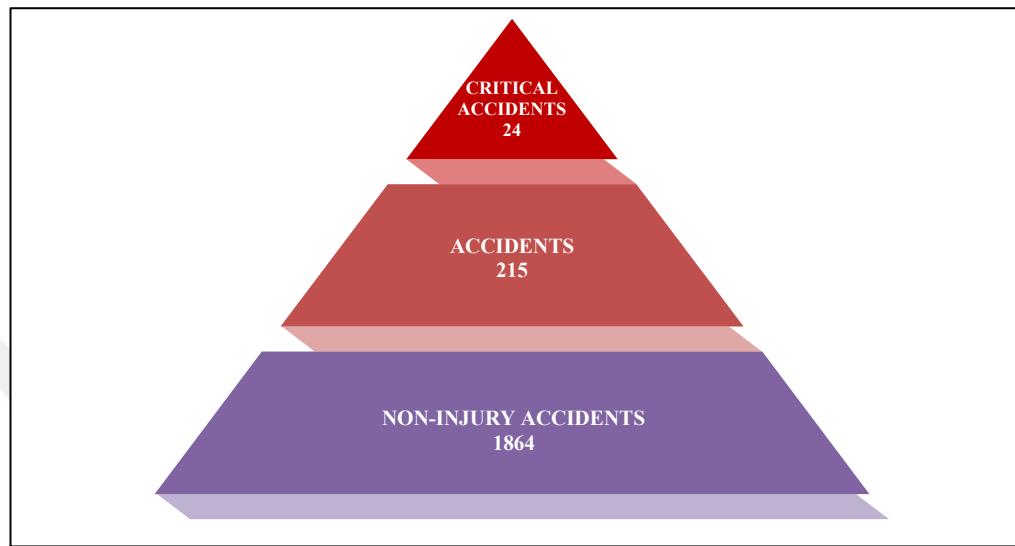


Figure 3.29: Distribution of injury incident records.

4.11.3. Analysis of hand and finger injury incident records by the category

The analysis involved 357 hand, finger injury incident records from a company-specific dataset, categorized as required by the Company's Incident Management Procedure. This sets the stage for a more detailed analysis focusing on the number of cases that resulted in or could potentially result in hand and finger injuries.

Critical Accidents (5 cases): These represent the smallest number, but the most severe injuries to hand and fingers have occurred. Category includes LWC and PPD severity cases that resulted in hand and finger injuries.

Accidents (79 cases): These represents the worst cases leading to medical observation and restricted work capacity without any long-term interruption. Category includes FAC, MTC, and RWC severity cases that resulted in hand and finger injuries.

Non-injury incidents (273 cases): The category includes Near Misses (135 cases), Unsafe Acts, and Unsafe Conditions (138 cases) representing the leading indicators where Heinrich's theory posits that a high number of non-injury incidents can indicate

systemic safety issues and that reducing these can prevent more serious accidents. The idea is that by addressing unsafe acts and conditions and reducing the number of near misses, one could effectively reduce the number of more serious accidents and injuries.

The ratio of 5/79/273, when evaluated based on Heinrich's traditional safety model of 1/29/300, highlights several critical insights and potential areas for improvement in occupational safety management. Heinrich's model originally emphasized that for every major accident, there would typically be twenty-nine minor injuries and three hundred no-injury incidents, suggesting a focus on addressing less severe incidents to prevent more serious accidents. In contrast, the obtained ratio indicates a disproportionately higher number of major accidents (5 major accidents compared to the expected 1 when scaled) and fewer minor injuries and no-injury incidents than Heinrich's model would predict (79 minor injuries and 273 no-injury incidents vs. the scaled expectations of 145 and 1500, respectively). This discrepancy suggests a higher severity index, where incidents that do occur are more likely to result in significant harm. The reduced number of minor and no-injury incidents relative to major accidents might indicate possible underreporting or deficiencies in safety measures that fail to control the escalation of incidents. Addressing these gaps could involve enhancing preventive safety measures to better control the progression from minor injuries to major accidents, improving incident reporting processes, and boosting safety awareness programs to ensure all incidents are reported and analyzed. Strengthening these areas could help mitigate risks more effectively and align the organization's safety outcomes closer to expected theoretical models like Heinrich's pyramid (Figure 3.30).

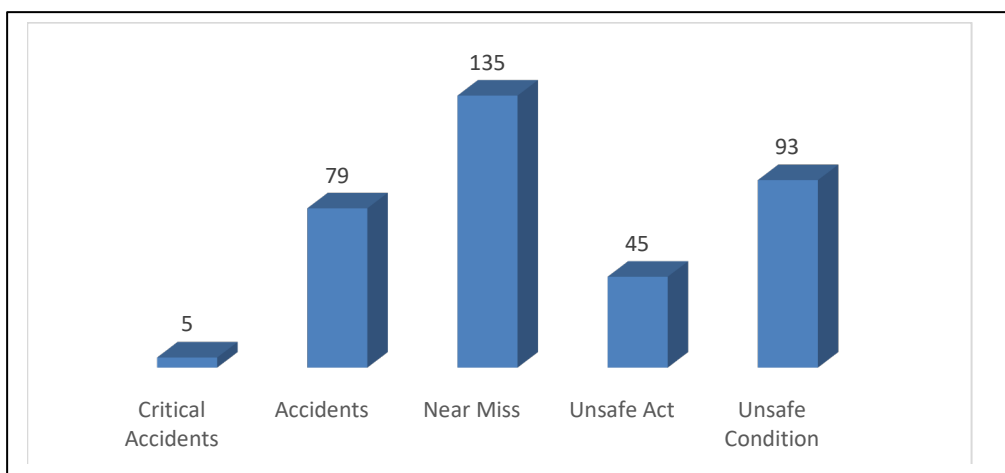


Figure 3.30: Distribution of hand & finger injury records by the category.

5. CONCLUSION

The study of maritime incidents is essential for enhancing safety measures to prevent serious injuries to seafarers, representing a critical area of focus. For effective examination, a comprehensive incident analysis procedure is required to investigate the root causes of these incidents. International regulations discussed in the literature review emphasize the importance of reporting and analyzing specific events. Employing the appropriate techniques during the analysis will enable the accurate identification of accidents and the determination of corresponding corrective/preventive actions. This thesis underscores the need for robust maritime safety protocols and contributes to the broader understanding of accident prevention through methodical investigation and adherence to international standards.

Incident investigation is essential for high-hazard facilities to learn from incidents and prevent their recurrence. While many existing methods focus on identifying management system root causes or use barrier-based approaches, they often fail to integrate closely with facility risk assessments and can be complex to implement. This can lead to missed lessons, particularly for major accidents. (Pitblado et al, 2015).

A five-year study of company-specific marine accident analysis showed that 37% resulted in injuries ranging from minor to major. The bulk of these injuries (60%) were minor enough to be treated with first aid, while 27% required medical treatment and 9.6% led to loss of work and even early repatriation from the ship.

In terms of working locations on ships, the deck and engine were the most frequent places for injuries, each accounting for around 30%. Critical injuries, however, occurred predominantly on the deck (58%) and in the engine (20%). In the working environment category, the engine room saw the highest percentage of personal injury accidents (29%), followed by the main deck (19%). The provision store/galley was the third most common area for such incidents. Critical accidents primarily took place on the main deck (24%), followed equally by the engine room and mooring station (16% each).

As for the work activities linked to injuries, maintenance, repair, tuning, and adjustment were responsible for 33% of personal injury accidents, a figure that was closely similar to critical injuries.

Handling objects and movement categories were found top-rated specific activities leading to injuries, each accounting for 30%. Critical incidents represented by movement and carrying by hand categories and resulted frequently from improper lifting or slips, trips, and falls.

The main material agents involved in the injuries were Buildings, structures, and surfaces - at ground level (indoor or outdoor, fixed, or mobile, temporary, or not) followed by Physical phenomena and natural elements which we know as rolling and pitching on board the ships.

The most frequent types of accidents involved being struck by moving objects, slipping, or tripping on the same level, and bumping into objects. Slips and trips were especially prevalent in critical incidents, making up 41% of such cases.

When it came to types of injuries, wounds and superficial injuries were most common, comprising 63% of cases. However, dislocations, sprains, and strains, while making up only 20% of injuries, accounted for 58% of severe cases.

The study highlights that hand and finger injuries are the most commonly occurring injuries in the company-specific dataset of marine incidents, a finding supported by data from the Marine Accident Investigation Branch (MAIB) annual reports. These types of injuries are not only frequent but also play a significant role in severe or critical injuries (20%), indicating their potential seriousness in marine environments. This consistency with MAIB reports suggests that hand and finger injuries are a persistent safety issue in the maritime industry and the seafarers, underscoring the need for targeted safety measures together with their underlying causes.

The study identified several crucial factors contributing to injuries on ships, with significant emphasis on the improper use of personal protective equipment and failures in adhering to established safety procedures or maintaining secure environments for movement. These factors were highlighted as particularly significant basic contributors to injuries including the critical ones.

At a more foundational level, a lack of competence was pinpointed as the primary basic cause of 51% of personal injury accidents. Further analysis using the MSCAT

map revealed that this incompetence is typically marked by the lack of situational awareness, risk perception, and risk management, which were evident in 87% of these cases. The impact of these deficiencies becomes starkly more apparent in severe incidents, where the category selected as the main basic cause in 92% of the cases. This data underscores the need for more rigorous training and safety protocol enforcement to mitigate these risks and enhance safety on ships by improving the human factor approach.

Furthermore, when comparing the dataset with Heinrich's theory, a foundational model in safety management, the analysis highlights potential opportunities for improving safety protocols. Traditionally, Heinrich's model posits a ratio of one accident to twenty-nine minor injuries or near misses and three hundred no-injury incidents (1/29/300). However, this study found a markedly different ratio of 646 accidents (severity non-specified), 1675 near misses, and 4542 no-injury incidents including unsafe acts and conditions, indicating a much lower ratio of near misses to accidents.

The data indicates that for each accident reported, there are an average of 2.6 minor injuries or near misses and seven incidents where no injuries occurred. This discrepancy suggests that many incidents that could potentially be managed or mitigated escalate into actual accidents.

Further analysis of the dataset, which categorizes only the personal injury incidents, reveals similar deviations from Heinrich's traditional safety model. Heinrich's model, which posits a ratio of one major accident to twenty-nine minor injuries and three hundred no-injury incidents (1/29/300), compared with the dataset presents a ratio of twenty-four major injuries to 215 minor injuries and 1864 no-injury incidents including near misses, unsafe acts, and conditions, deviating from the expected proportions.

When scaling Heinrich's model to align with the twenty-four major accidents recorded in this dataset, the expected figures would be approximately 696 minor injuries and 7200 no-injury incidents, far exceeding the observed data. This substantial variation highlights a lower-than-anticipated number of both minor injuries and no-injury incidents relative to major accidents, suggesting potential deficiencies in incident reporting, detection, and management of less severe incidents.

Finally, the study includes the analysis of 357 hand and finger injury incident records from a company-specific dataset to shed light on occupational safety concerning hand and finger injuries. When evaluated against Heinrich's traditional safety model of one major accident to twenty-nine minor injuries and three hundred no-injury incidents, the recorded ratio of five major injuries, seventy-nine minor injuries, and 273 no-injury incidents similarly diverge from expected values. According to Heinrich's model, the expected numbers would be one major accident, 145 minor injuries, and 1500 no-injury incidents compared to the five major accidents reported. This discrepancy highlights a higher severity index in the recorded incidents, with a propensity for more serious outcomes.

In conclusion, this thesis suggests that addressing these discrepancies involves enhancing the organization's safety training, promoting a culture that prioritizes thorough incident reporting, and employing stringent hazard identification processes. Strengthening these aspects of the organization's safety protocols could align its performance closer to Heinrich's model, ultimately reducing both the frequency and severity of workplace accidents. This proactive approach would not only improve safety outcomes but also foster a more aware and responsive safety culture, potentially preventing serious injuries and promoting a safer work environment.

6. SUGGESTIONS

Analyzing company-specific data to identify risk factors that lead to personal injuries can yield significant insights into improving safety in the workplace. To enhance the effectiveness and relevance of this study on workplace injuries, particularly in the maritime industry, several recommendations are proposed based on the analysis conducted. These suggestions aim to deepen our understanding of injury mechanisms and contribute to the development of more effective safety measures.

Future studies should employ statistical and mathematical methods to analyze relationships within the data. Techniques such as regression analysis, correlation coefficients, and advanced predictive modeling could be invaluable in uncovering non-obvious patterns and correlations. This analytical approach will provide empirical support for recommendations, helping develop targeted interventions that are statistically proven to reduce workplace injuries.

Enhancing maritime safety training models to include detailed incident reporting and situational awareness is crucial. By adapting these elements into training curricula, maritime personnel can be better prepared to recognize and mitigate risks, leading to a reduction in incident occurrences.

Expanding the literature dataset and incorporating more company-specific data on injury-related accidents will enrich the findings. Analyzing a broader array of datasets will offer a more comprehensive overview of injury trends across different organizational settings. This expansion will not only enhance the robustness of the conclusions but also provide a richer base for benchmarking safety practices across the industry.

Additionally, future studies could concentrate on examining specific material agents and the interaction between multiple agents involved in injuries, as detailed in section 3.6. By exploring the roles of multiple material agents, such as physical phenomena and natural elements in maritime accidents, we can greatly improve our understanding of the factors that contribute to these incidents.

Furthermore, the study clearly highlights the need for further innovation and development in the design of protective personal protective equipment for hands, eyes, and feet. Future research and development efforts should concentrate on designing hand protection equipment that is more flexible, adaptable, and impact-resistant. This is crucial to effectively address the high incidence of hand and finger injuries. Similarly, design improvements and further research are also found necessary for anti-slip footwear to adequately address slip and fall hazards. These improvements are crucial for effectively preventing injuries and enhancing the safety of seafarers.

By addressing these areas, future developments might significantly contribute to the advancement of safety measures in the maritime industry, aligning with both theoretical safety models and practical needs. These efforts will not only mitigate risks but also foster a safer working environment through improved training, better equipment, and enhanced incident reporting processes.

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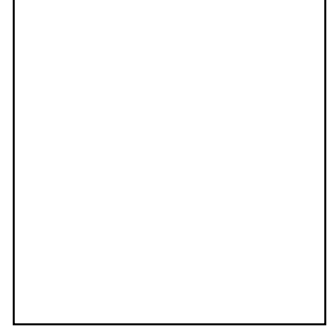
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