INVESTIGATION AND EVALUATION OF MARINE ACCIDENTS IN TERMS OF GROUNDING AND CONTACTS/COLLISIONS IN THE ENGLISH CHANNEL UTILISING THE HFACS-PV APPROACH

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World shipping/maritime activities are handled largely in a complex and perilous environment. Marine accidents are often serious, leading to not only huge economic losses to shipping companies but also frequently casualties and ecological damage. Therefore, it is crucial to identify the relationship between the main factors and casualties of marine accidents for the purpose of mitigating such occurrences. In the study, grounding and collision/contact accidents in the English Channel were analyzed. Human Factor Analysis and Classification System (HFACS) was used as the analysis method in the study. The period for accident data gathering and analysis is from 2004 to 2020. 17 grounding and 10 collision/contact incidents have occurred in the study area in the stated time frame. The results have identified that Errors, (under Unsafe Acts) and Substandard Team Members (under Preconditions for Unsafe Acts) account for the majority of grounding and collision/contact accident causes in the Dover Strait.

Keywords: Human factor, HFACS-PV, Marine accident, Maritime safety, Accident analysis, English Channel.

1. Introduction

The occurrence of marine accidents, even in the current time of advanced and innovative technology, is still an ever-present concern. According to the UK shipping forecast, the English Channel is sub-divided into - Dover, Wight, Portland, and Plymouth. Several marine accidents have taken place in this channel, particularly in the Dover Strait. In order to reduce and mitigate these accidents, one needs to understand the trends, and root causes in different scenarios as well as the weather and climatic condition of the Strait. Similarly, the behaviour of vessel crews before, during, and after the accidents should also be considered, along with the impact of navigational aids, their availability and the operational knowledge of the crew including the Master (Zhang, et al., 2019).

1.1. Aim and Objectives

This research aims to investigate marine accidents in terms of grounding, collision and contacts in the English Channel using a Human Factor Analysis and Classification System (HFACS) approach. The English Channel has been the scene of a number of extensive shipping accidents with immediate and potential long-term impacts (Carter, et al., 2019). The goal is to ensure safe navigation within and around the English Channel. the focus of the research will be within the Dover Strait which is the busiest and most congested section of the English Channel. The aim shall be fulfilled through the following objectives.

i. To investigate causes of accidents in the Dover Strait regarding grounding, collision, and contacts.
ii. To identify the root causes of these accidents in the Dover Strait through the use of the HFACS approach.
iii. To evaluate these root causes and highlight trends.

2. Background and Literature Review

2.1. Dover Strait

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The Dover Strait has been named one of the busiest international sea routes in the world, regularly used by more than 400 vessels daily. (Garcia-Moreno, et al., 2019). The Dover Strait is the first International Maritime Organization (IMO) approved Traffic Separation Scheme (TSS) in the world as far back seventies and was first to come under full radar surveillance (Anon, 2015). The Channel is well equipped with several means such as Channel Navigation Information Services (CNIS), jointly operated by the French and UK administrations at CROSS Gres Nez and Dover Maritime Rescue Co-ordination Centre (MRCC), a compulsory reporting system for vessels over 300 gross tonnages (grt), Vessel Tracking Services (VTS), Automatic Identification System (AIS), Very High Frequency (VHF) radios for communication-exchange, Very High-Frequency Direction Finding (VHDF). Other systems include the Integrated Coastguard Communication System (ICCS), Information Management System (IMS), etc. aiming to provide safe navigation in the English Channel at all times. The UK part being manned by the Maritime and Coastguard Agency (MCA) and Her Majesty's (HM) coastguard to ensure that all vessels follow the International Regulations for Preventing Collisions at Sea 1972, (COLREGS) as amended (IMO, 1972; Glegg, et al., 2015; Garcia-Moreno, et al., 2019).

2.2. Marine Accident Contributing Factors

Accidents occur due to several factors which include but are not limited to those outlined as follows. However, these are considered key root causes of marine accidents.

- *Fatigue*: This comes as a result of overloading individuals with heavy work functions depriving them of their regular resting periods due to operational demands and or commercial pressures especially when the ship is under-manned, or improper schedules of operations or tasks (Anon, 2018; Apostol-Mates & Barbu 2019).

- *Distractions*: In this factor there are issues such as, paperwork, technological influence, human behaviour in relation to peripheral movement, personal devices, other crew members and external situations, to name a few (Maglić, et al., 2020). According to UK Marine Accident Investigation Branch (MAIB) investigation reports a collision between the cargo vessel Daroja and oil bunker barge Erin Wood, and the grounding of Attilio Ievoli were due to distractions (Othman, et al, 2015). Navigation is a highly demanding task that must be upheld in high esteem with undivided attention (Maglić, et al, 2016; Maglić, et al., 2020).

- *Reliance on Electronic Navigational Aids*: Electronic navigation equipment is used to assist the navigation officer to provide information that will aid his/ her decision-making. Over-reliance on the electronics will not make the decision for the officer-in-charge of the navigational watch nor will it perform the action meant for the Officer on Watch (OOW). Hence, the responsibility of managing the decision-making/taking appropriate actions as deemed safe and practicable for accident-avoidance rests on the OOW (Tsimplis, et al., 2019; Turna, et al., 2020).

- *External Influences*: This includes weather and sea conditions, as well as the behaviour of other vessels. All factors are outside of the control of the crew onboard. Records list cases of vessels colliding at berth, vessels drifting at anchorage, collisions during ship-to-ship operations, and loss to tsunami and surge waves, storms, and sudden heavy weather. In these instances, vessels may not break or breach navigational rules and regulations, but the potential for an accident is ever present (Tabri, et al., 2009; Silva, et al., 2019). An instance of this occurred in December 2018 when the Russia-registered bulk carrier Kuzma Minin grounded after dragging its anchor in Falmouth Bay, due to wind speeds in excess of 50 knots.

- *Teammate Influence and Task Deviation:* It is perceived that a consistently contributing factor throughout almost all maritime accidents is the human element (MCA-UK, 2016). The IMO has attempted to address the problem by adopting and amending maritime regulations to regulate the maritime industry. The majority of these regulations have been introduced by two instruments, namely the International Safety Management (ISM) code and the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) (IMO 2011; IMO 2022). Numerous maritime accident investigations have concluded that task deviations by seafarers contributed to many mishaps at sea, such as the grounding and listing of the vessel Hoegh Osaka (MAIB 2016). Research into investigating the difference between work as imagined and work as it is done in the marine industry is restricted (Praetorius, et al., 2015; Vries, 2017).

3. Methodology

3.1. Scope

Maritime shipping has been the headline of the leading modes of transportation and the most dominant in the world economy from history till now. The effectiveness and efficiency of maritime trade are closely interwoven with maritime safety. However, the presence of the human element has a complex socio-technical structure makes it difficult to fully analyse human factors in accidents (Uğurlu, et al., 2015). This is one of the severe challenges facing marine accidents. The HFACS approach structure allows for a comprehensible analysis of marine accidents. Based on the flexibility of the HFACS methodology, it gives one the leverage to carry out an effective qualitative analysis (Uğurlu, et al., 2018; Yildiz, et al., 2021). The HFACS combines active failures and latent conditions. Human factors play an important role in the maritime industry especially as regards accidents in the English Channel, affecting navigation safety, operational and maintenance efficiency, and safety. Fatalities and major accidents are not acceptable to the maritime and or shipping industry and the role of human factors can help with the goal of reducing/eliminating them (Uğurlu, et al., 2020; Yildiz, et al., 2021).

The greatest issue with the extraction and mapping of the Human and Organizational Factors (HOFs), in the HFACS structure, is the varying opinions and thoughts of the different researchers as stated in Olsen's (2011) study. A key reason for this is the different levels of the researchers' understanding of the HFACS structure. Improving and maintaining consistency regarding researchers' knowledge of both the individual HOFs and their specific definitions can greatly aid in solving and mitigating this problem. Within this study, the researchers are highly experienced and knowledgeable in both the HFACS structure and the definitions of its HOFs. In this HOF extraction and mapping process, the researchers individually coded and classified the HOFs, then the results were combined, and all coding was reviewed. It should be noted that all HOF codes were defined from accident reports. The process of discussing each individual HOF code was completed rigorously until a consensus was reached by all participants in the discussions. This methodology allows for considerable care to be taken to ensure that the codes are suitable and as accurate as possible.

3.2. HFACS-PV Approach

Uğurlu et al. (2018) used the standard HFACS method to analyse 70 collision-contact accidents that occurred on passenger vessels. However, they found that traditional HFACS structures are not suitable for the analysis of passenger vessel accidents. Therefore, they proposed a modified Human Factors Analysis and Classification System (HFACS-PV) structure for use in the analysis of the human factor in passenger collision-contact accidents (Fig. 1). The HFACS-PV structure includes 5 main levels: Operational Conditions, Unsafe Acts, Pre-conditions for Unsafe Acts, Unsafe Supervision and Organizational Influences. Unlike conventional HFACS, the main change in the structure is the environmental factors (operational conditions) added to the structure. Thus, the HFACS-PV structure is preferred here over the use of standard HFACS. It is also relevant as the analysis in this research includes passenger vessels (ferries).

Operational Conditions: This represents the last stage of the formation of a marine accident. Even if all the latent and active inconveniences required for the development of the accident come together, the accident will not occur unless the operational condition exists. For example, there is no possibility of a grounding accident unless the ship is navigating close to shallow waters. Operational conditions are divided into two categories: internal and external conditions. Internal conditions include vessel structural defects and non-conformities preventing ship motion. These are conditions that are partially controlled by operators. External conditions include non-ship factors that are not caused by human contribution or intervention. By using this classification, the effects of weather - sea conditions and local restrictions on marine accidents can be easily interpreted.

Unsafe Act: Similar to the traditional HFACS structure, it is divided into 2 sub-categories: errors and violations made by ship crew on board (Shappell & Wiegmann 2004). Errors are unintentional actions (IMO, 1999) and consist of decision-based errors, skill-based errors, and perception errors. Skill-based errors are errors made unconsciously due to lack of knowledge and experience. Decision errors are the result of choices and steps taken to reach a goal (Ergai et al., 2016). Perception errors are caused by visual, auditory, cognitive or attention problems.

Violations are behaviours where rules and regulations are intentionally ignored (IMO, 1999). Violations are divided into three sub-categories: rule violations, procedure violations, and abuse of authority (Uğurlu et al. 2018). Rule violations can be expressed as deliberate negligence or non-enforcement of legal

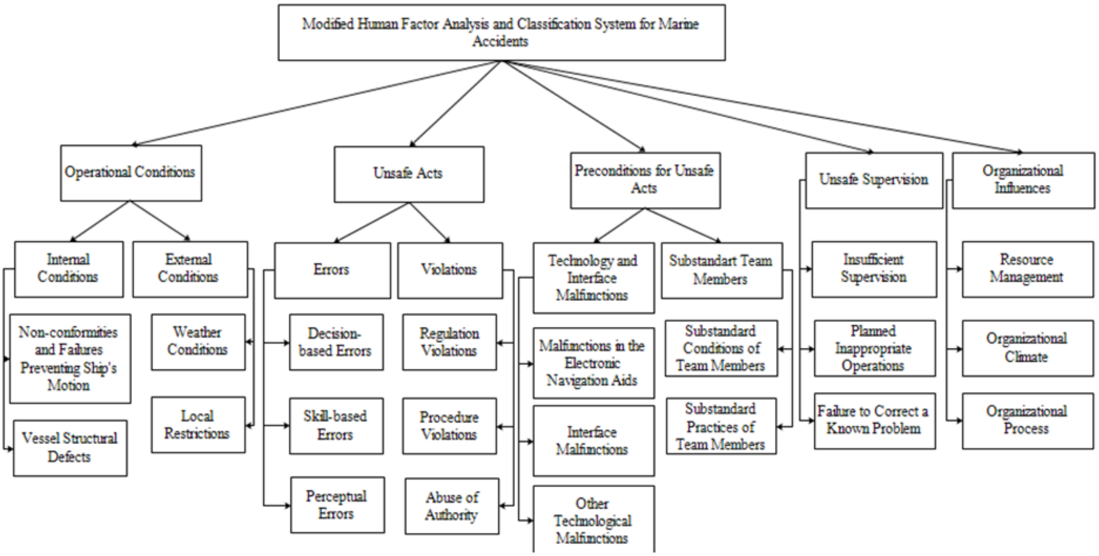

Fig. 1: HFACS-PV Framework

regulations issued by the IMO, flag states or competent authorities. An example of procedure violations is the violation of berthing and anchoring procedures. Abuses are violations made deliberately by authorized persons. It can be described as the arbitrary use of the authority that is inconsistent with the safety practices or legal regulations.

Pre-Conditions for Unsafe Act: It has been emphasized by many researchers (Chauvin et al, 2013), especially Shappell and Wiegmann (2000), that this level is important in accident formation. This level is divided into two sub-categories: sub-standard team members, and technology and interface malfunctions to ensure compliance with marine accidents (Celik & Cebi, 2009; Xi et al. 2009; Chen & Chou, 2012). Technology and interface malfunctions pave the way for the formation of decision errors and perceptual errors. In other words, when a technological breakdown occurs, the decision and perception mechanism of the officer on the bridge is directly affected from it. In addition, due to the fact that ship management is carried out as teamwork, "Operators" in the traditional structure are called "Team Members" in HFACS-PV.

Unsafe Supervision: This is examined under three subcategories: Insufficient supervision planned inappropriate operations and failure to correct the known problem. Non-conformities, such as deficiencies in tests and controls, delays in the operation of the planned maintenance system, planned inappropriate operations (e.g., voyage plan and the number of lookouts in the shift) are under the structure of unsafe supervision.

Organizational Influences: As in other HFACS structures in the literature (Xi et al. 2009; Xi et al. 2010; Chen & Chou, 2012; Chauvin et al, 2013), this level is divided into three sub-categories: Resource management, organizational climate, and organizational process. Non-conformities related to the personnel and equipment resources, resource management strategies of companies, ship operators, and ports are placed under the resource management sub-category. Human and Organizational Factors (HOFs) affecting the performance of the seafarers, such as deficiencies and non-conformities related to the organizational structure, policies, and corporate culture, are placed under the Organizational Climate sub-category (Chen & Chou, 2012; Wiegmann et al. 2005). The deficiencies and non-conformities in the operational management, such as safety assessments (working/resting hours, time pressure, motivation, shift patterns) and reviews (risk analysis, risk management, etc.) are included under the Organizational Process sub-category.

4. Analysis of Dover Strait Accidents using HFACS-PV

The HFACS-PV framework outlined in Fig. 1 was applied to 17 grounding accidents and 10 collision/contact accidents in the Dover Strait. These accidents occurred between 2004 and 2020. Sinking accidents have not been analysed in this study as there was only 1 sinking accident in the Dover Strait in this period. The information regarding the grounding and collision accidents was obtained from accident reports. These accident reports were sourced from a number of accident databases, such as the Global Integrated Shipping Information System (GISIS) and MAIB. Each accident report was meticulously scrutinised to determine the causes of the marine accidents using the HFACS-PV approach.

4.1. Grounding Accidents

17 grounding accidents were analysed using the HFACS-PV structure. in order to achieve this, the accident reports for each accident were carefully and coherently examined to apply the methodology to the accident. This allowed for root causes, in terms of human error to be identified. Furthermore, these results were collated to highlight the most significant categories in the HFACS-PV structure. Fig. 2 demonstrates the occurrence, by percentage per accident, of preconditions for grounding accidents.

It can be seen in Fig.2 that Unsafe Acts: Errors were observed in 28.6% of grounding accidents in the Dover Strait. This is followed by Substandard Team Members (19%), under Preconditions for Unsafe Acts. When the Errors category is examined, it can be seen that 68.8% of the errors that occurred were Decision Based Errors, followed by 62.5% for Perceptual Errors and 18.8% for Skill-Based errors. This shows that errors resulting from the skill level of the crew do not majorly contribute to grounding accident causes. However, it is clear that the perceptions and decisions made by the bridge team result in a grounding accident in more than 2/3 of grounding accidents. This is reinforced by the analysis of Preconditions for Unsafe Acts: Substandard Team Members (19%), where Substandard Condition of the Team Members is highlighted as a cause in 31.3% of grounding accidents in the Dover Strait, but Substandard Practices of Team Members occurs in 68.8%.

The top 3 causes of grounding accidents are thus found to be:

- Substandard Practices of Team Members – 68.8%
- Decision Based Errors – 68.8%
- Perceptual Errors – 62.5%

All of these accident causes are linked to the practices and the conduct of the bridge team in the preconditions for a grounding accident. Similarly, following the 3 preconditions listed above, the next highest cause for grounding accident was External Conditions: Weather Conditions with an occurrence of 56.3% of grounding accidents. In terms of Unsafe Acts: Errors, there is concurrence with the literature examined in Section 2, where *fatigue, distractions* and *external influence* are 3 of the main causes of grounding, sinking or collision/contact accidents. Similarly, when looking at Substandard Practices of Team Members, the literature also highlights *Teammate Influence and Task Deviation* as root causes of these marine accidents.

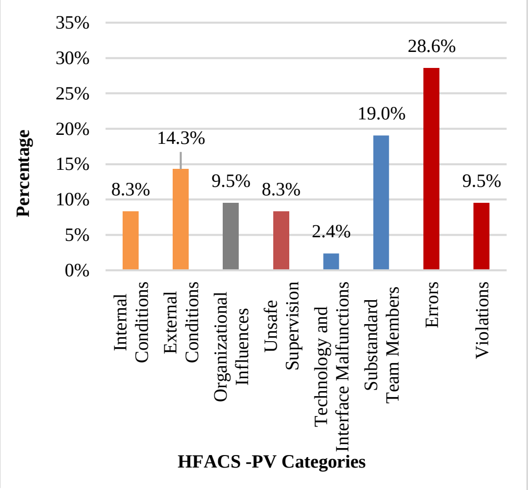

Fig. 2: The occurrence, by percentage per accident, of preconditions for grounding accidents.

4.2. Collision/Contact Accidents

Collision/contact accidents were analysed in the same manner as the grounding accidents in Section 4.1. Fig. 3 demonstrated the occurrence, by percentage per accident, of preconditions for collision/contact accidents.

It can be seen in Fig. 3 that Unsafe Acts: Errors (24.5%) again occur the most in terms of accident preconditions and causes, as with grounding accidents. However, the next most influential preconditions are; Substandard Team Members and Violations, both 13.2% occurrence respectively. These categories can be further examined to a more finite level as follows:

- Unsafe Acts: Errors (24.5%)
    - Decision Based Errors (37.5%)
    - Perceptual Errors (25%)
    - Skill-Based Errors (18.8%)
- Substandard Team Members (13.2%)
    - Conditions of Team Members (25%)
    - Practices of Team Members (18.8%)
- Violations (13.2%)
    - Procedure (18.8%)
    - Regulation (12.2%)
    - Abuse of Authority (12.5%)

As with grounding accidents it is the perceptions and decision making of the bridge crew that have led to collision/contact accidents. Similarly, the increase occurrence of violations, particularly procedural violations is in concurrence with collision accidents as the bridge crew must be able to identify a vessel in close proximity, make a decision on avoidance and carry out the correct procedure to ensure collision avoidance. All of these failures in multiple combinations are proven to result in collision accidents. Furthermore, what should be noted is that despite the other categories being consistent but low, there are a number of preconditions which exist that also play a role in collision/contact accidents. These are outlined as follows, along with their percentage occurrence per collision/contact accident:

- Internal Conditions (11.3%)
    - Non-Conformities and Failures to Prevent Ship Motion (31.3%)
- External Conditions (9.4%)
    - Weather Conditions (18.8%)
- Organizational Influences (11.3%)
    - Organisational Processes (18.8%)
- Technology and Interface Malfunctions (9.45)
    - Other Tech. Malfunctions (18.8%)

It can be seen that collision/contact accidents are more complicated in their accident formation. It has been found in this research and in other literature studies (Uğurlu, et al., 2018; Yildiz, et al., 2021) that a combination of events preconditions is required for a collision/contact to occur. One example is a combination of harsh weather conditions and technological problems (such as electronic navigation failure), or lack of awareness from the watch team and failure to follow procedure/incorrect company procedure.

5. Conclusions

This research has set out to investigate marine accidents in terms of grounding, collision and contact in the English Channel using the HFACS-PV approach. Three objectives were outlined to achieve this aim.

i. To investigate causes of accidents in the Dover Strait regarding grounding, collision, and contacts.

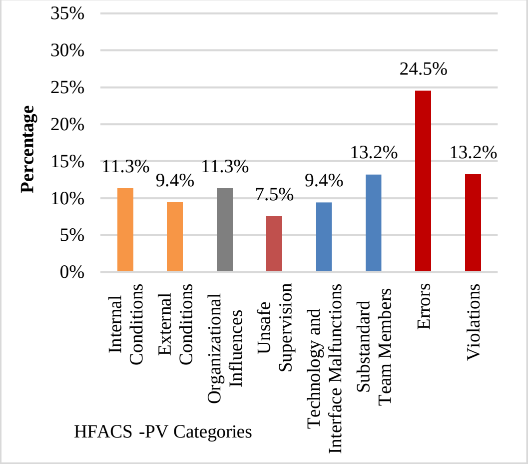

Fig. 3: The occurrence, by percentage per accident, of preconditions for collision/contact accidents.

This objective has been fulfilled as the grounding and collision/contact accidents have been evaluated from 2004 to 2020 in the Dover Strait. It was found that 27 accidents had occurred at this time in this area.

ii. To identify the root cause of these accidents in the Dover Strait through the use of the HFACS approach

The accidents that were identified were then scrutinised utilising the HFACS-PV approach where the preconditions and root causes of marine accidents were identified and categorised.

iii. To evaluate these root causes and highlight trends.

These preconditions and root causes were then analysed against the industry and literature trends. The results determined that the preconditions for grounding and collision/contact accidents were highly similar to other literature studies of different narrow waterways around the world.

It was concluded that the main causes of grounding accidents were the Substandard Practices of Team Member and Errors in terms of perception and decision-making. Similarly, the root causes of collision/contact accidents were found to be more intricate as a combination of preconditions must occur for a collision/contact to take place. These combinations have been found to mainly include: Errors in terms of perception and decision-making, Substandard Conditions of Team Members, Procedural Violations, Failures to Correct Ship Motion, Extreme Weather, Organisational influences (related to procedure) and Technological Malfunction.

Research work will continue to identify other potential accidents in the region and utilise the HFACS methodology to produce a dynamic risk assessment model that takes vessel, weather and operational parameters and conditions into more considerate detail. This goal here is to produce a predictive tool to assess the risks of grounding, sinking and collision/contact in narrow waterways.

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