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Research Article

Revisiting the HNoMS Helge Ingstad and Sola TS collision: Discussing the contribution of human factors

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Abstract

Human factors play pivotal roles in maritime accidents, incidents, and errors. In this paper, we discuss the attributes of human elements involved in the collision between frigate Helge Ingstad and tanker Sola TS. Although the warship Helge Ingstad was modern and well equipped, with requisite navigational aids, the availability of monitoring by VTS, and timely warnings made by the crew/pilot onboard Sola TS, the accident still occurred. It is not a mere coincidence that human factors of all three entities failed to avert such an accident. The officer of the watch perceived that Sola TS, a moving tanker, was a shore object. Also, he could not assimilate the indication from navaids and decision-making tools, including RADAR/APRA and AIS. The paper further discusses the significant human-related factors-"the deadly dozen"- caused by several contributing factors, including environmental, procedural, and competency issues, behavioral factors, sense-making, and fatigue. The paper concludes by suggesting ways to mitigate/control human errors.

1. Introduction

The maritime transport industry serves about 90 % of global trade and significantly contributes to global economic development (UNCTAD, 2021). Over the course of time, the size of the world fleet has steadily grown; conversely, the size of crew onboard modern ships has significantly reduced. It is indicative that ships in the 1970s had 40 - 50 seafarers onboard whereas, presently, the largest ships only have 15 - 25 seafarers (Murray, 2019). Although maritime transport today plays an important role in most countries' economic activities and logistics supply chains, it is also associated with certain externalities. One of the significant negative externalities is shipping accidents with consequences such as loss of lives, marine pollution, and loss of cargo and property, and this needs to be avoided (Hasanspahić et al., 2021). Currently, a paradigm shift is underway in automation and digitalization, often described as "shipping 4.0" (Ichimura et al., 2022; Singh, 2021). With futuristic concepts of artificial intelligence, e-navigation, and Internet of Things (IoT), the maritime industry may turn towards autonomous shipping for supposedly safer transportation (Porathe et al., 2018). Despite such claims, over-reliance on technology, and the ironies of automation, remain sources of accidents and, in some cases, drive human errors (Bainbridge, 1983; Baxter et al., 2012). Thus, the human-machine interface represents a critical safety link (Hasanspahić et al., 2021).

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According to a review of past studies (Bhattacharya, 2009), seafaring is ranked as the second most dangerous occupation, with fishing ranking first. Additionally, maritime workers have a higher occupational risk than other land activities. The fishing sector's occupational hazard is estimated to be 25 to 120 times more than other occupations (Jensen et al., 2014) and is higher in developing countries (FAO, 2018). According to the sources and categorization, it is estimated that human errors contribute to 89 - 96 % of ship collisions (Berg, 2013). Over the period 2011 - 2016, the European Maritime Safety Agency (EMSA) considers that "Human erroneous action represented 60 % of accidental events and 71 % of accidental events were linked to shipboard operations as a contributing factor" (EMSA, 2017). Overall, it is estimated that about 80 % of marine accidents are caused or influenced by human and organizational factors (Sánchez-Beaskoetxea et al., 2021).

The International Maritime Organization (IMO) considers the 'human element' crucial for enhancing maritime safety and security. In order to undertake safe and secure sea trade, a high level of seafarer's professionalism and competence is desirable. A deep analysis of shipping accidents over the years has produced an increasing awareness of the critical importance of the human element. As per the IMO, "the term human element is a complex multi-dimensional issue that affects maritime safety, security, and marine environmental protection" and covers a broad spectrum of human activities in the maritime sphere (IMO, 2004). The shipping industry's socio-technical system and scope of human element makes it a shared responsibility of the regulatory bodies (IMO and member states), companies, safety policies and safety culture, and seafarers who physically operate the ships (IMO, 2021). The *human element* issues were initially addressed by the IMO regulation on the Standards of Training, Certification and Watchkeeping of Seafarers Convention (STCW) in the 1980s, as revised in 1995 and again in 2010. The convention was a stepping-stone to ensure the effective competence of seafarers employed at sea. Another regulation is the International Safety Management (ISM) code, implemented through the International Convention for the Safety of Life at Sea, 1974 (SOLAS). Several human element issues are also covered in the International Labour Organization's (ILO), Maritime Labour Convention (MLC), regarded as the "fourth pillar" of maritime regulations (Barnett & Pekcan, 2017) Also, the progressive approach to appropriately address the human element in shipping was provoked in the mid-1990s, when the IMO adopted Resolution A.850(20) on human element vision, principles, and goals for the organization, and further updated it by implementing Resolution A.947(23).

Nonetheless, in marine accidents, society tends to judge very quickly in order to find a scapegoat (Çinarli, 2016). In many cases, the master and the crew are the target of criticism even before formal investigation, because finding a single cause for multifactorial casualties remains convenient. Although human factors are generally part of numerous cases, the crew is not always to blame (Nurcholis & Qurniawati, 2020; Sánchez-Beaskoetxea et al., 2021).

On 8 November 2018, at about 0401 hours, the Norwegian frigate KNM Helge Ingstad and the Maltese flag tanker Sola TS collided off Sture terminal in Hjelteford, Norway. The warship sustained significant damage in the collision and, in spite of frantic efforts to keep her afloat, the frigate slowly sank on a rocky, sloping seafloor close to the terminal. Soon after the accident, print and news media flooded with reports about human errors, violations of collision regulations, and poor command and watchkeeping standards onboard the warship. The Accident Investigation Board Norway (AIBN) and Defence Accident Investigation Board Norway (DAIBN) jointly conducted a preliminary and detailed investigation. In the accident investigation reports published by Norwegian authorities, 'Human Factors' were considered influential in the outcome (the accident). The concerned warship was modern, with seven sailors on duty, fitted with state-of-the-art navigation aids and communication suites, and was conducting operations in a relatively calm environment. Also, the traffic in the area was monitored by the Fedje Vessel Traffic Service (VTS) (Johnsen & Danielsen, 2021). The collision between the Norwegian warship "KNM Helge Ingstad" and "MV Sola TS" reiterated the human element's importance in maritime activities. The accident was considered a complex one. Indeed, it involved many individuals, including the bridge crew on both ships and the local VTS.

This paper deploys a qualitative approach. In order to fully comprehend the accident, the specifics of it are highlighted in subsequent paragraphs. Section 2 explains the relevant research methodology, and section 3 discusses the concept of the human element. Section 4 provides an overview of the collision between Helge Ingstad and TS Sola to set the associated background. Section 5 is focused on organizational impacts on human factors. Section 6 contains a discussion on personal factors which were found to be involved in the particular accident; the crucial issue of fatigue is addressed in section 7. Finally, the paper is concluded with a brief conclusion and recommendations.

2. Research methodology and understanding "Human Element" in the maritime system

2.1 Methodology

The discussion explores the 'attributes of the human element' in the accident between the tanker and the Norwegian warship. Accidents or incidents that occur in modern, complex, and technical systems need formalized and methodological investigative techniques to identify the core root cause and all related events that are otherwise difficult to identify using a traditional approach. The study of the causes of marine accidents is the basis of a large part of marine legislation (Murray, 2019; Schröder-Hinrichs et al., 2013). Therefore, the outcomes of investigations are essential documents to facilitate analysis. The research data is primarily based on official accident investigation reports (preliminary, part I and part II) and available literature to support the findings.

2.2Understanding "Human Element" in the maritime system

2.2.1 Human Element

The term *human element* can vary depending on the scientific background of the user. Barnett and Pekcan (2017) considers that the term 'Human Element' can be used as a synonym for "human factor", "human resources", or even "human error", and that these terms are generally used interchangeably in conversation. However, Squire (2005) considers it as a separate entity, which is often misinterpreted and used as cover for the human element, or even human error, and defines it as the "body of scientific knowledge relating about people and how they interact with their environment, especially when working" (p. 5). Johnsen and Danielsen (2021) define "human factor" as "the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and other methods to design in order to optimize human well-being and overall system performance" (p.4). Human error can also be viewed as a measure of human reliability. As far as the maritime system is considered, it is made of people where human error stands prominently in casualties (Hasanspahić et al., 2021). The frequency of major accidents and total loss in shipping are reducing, but human errors remain prominent in 80 to 85 percent of accidents (Sánchez-Beaskoetxea et al., 2021). Human performance can be the combined outcome of individual capacities, the interaction with the task, the impact of the work system (organization), and the work environment (Blackman et al., 2008). Despite unstable performance, humans remain the only element of the socio-technical system capable of adapting their behavior to change in a situation (Chauvin, 2011) and of finding solutions to save the day (Reason, 2008).

2.2.2 The deadly dozen

In large socio-technical systems, the human element continuously interacts with other persons (liveware), software, hardware, and the environment, and must constantly adapt to technical and operational changes. For example, the current maritime workforce systematically adapts to multinational and multicultural environments imposed by ship operators (Sampson, 2013). It is considered that there is a wide range of contributory factors that result in maritime accidents, incidents, and errors. Accidents often occur due to several, even many, different contributory factors, including technical failure and environmental, systemic, procedural, competence, and behavioral issues. In this respect, the UK Maritime and Coast Guard Agency (MCA) provides an interesting matrix to analyze the human element by emphasizing 12 significant factors ("the deadly dozen") that act as a catalyst for accidents in most cases (**Figure 1**). The twelve factors- "the deadly dozen"- may influence and act as pre-cursers to human errors, and lead to accidents (MCA, 2016). Some of the factors, such as situational awareness, are considered to be the most significant in the "deadly dozen" human factors in maritime safety, supported by the American Bureau of Shipping's (ABS) study findings (Lawson, 2018).

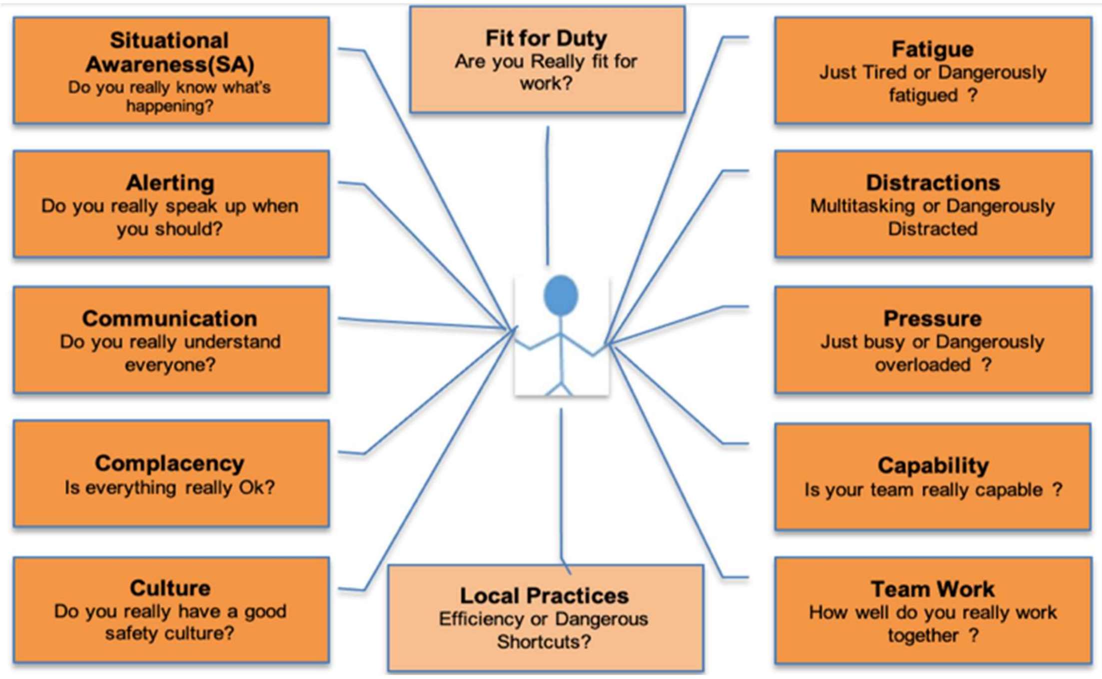

Figure 1 Twelve significant factors ("the deadly dozen"). Adopted by the authors, based on information from the MCA (2016).

2.2.3 The maritime system: People, technology, environment, and organizational factors

The maritime system is largely a people system, wherein human errors figure significantly in casualty situations (Han & Ding, 2013). Several studies have been undertaken on the aspects of the human element and how it plays an important role in determining safety standards. It is significant that the research community seems to view the topic of human involvement in accidents as being of great importance, perhaps in an effort to increase industrial safety by all necessary means (Wróbel, 2021). According to Han and Ding (2013), the study of the role of personnel in the safe and efficient operation of complex industrial systems is becoming recognized by the shipping and offshore community. It is vital to understand the nuances of "the maritime system", which is a people system. At times, people themselves act as weak links; however, more often, the weak link could be the ways in which technological, environmental, and organizational factors influence, the way people perform. People or humans[†] in the maritime industry closely interact with technology and the associated environment and are most commonly influenced by various organizational factors (Rothblum, 2000). The impact of these factors (**Figure 2**) on human performance is briefly elaborated on here:

[†]Including the ship's crew, pilots, dock workers, VTS operators, and others.

Technology: The design of technology may have a variable or big impact on how people perform. Every industry is driven by technology, and "industry 4.0" is particularly focused on the latest technology, however, concerns remain for how people perform with particular technology. A specific design may or may not suit two different people, who may respond differently. Modern ships are equipped with the latest technologies and automation, and individuals have varying abilities to comprehend these systems. For example, some people tend to use north up radar display, and some use head up orientation. Human performance may be altered depending on factors such as equipment layout, menus, perception and comprehension, maintenance, reach, strength, agility, and safety and performance.

Environment: The factors of the environment affect an individual's performance in taking actions that results in human error. The aspects of environmental conditions include physical work environment (lighting, noise, temperature), technology environment (artificial environmental constructions), and regulatory and economic climate. The physical work environment (extreme temperature, high sea state, high vibration, noise) directly affects the human ability to perform.

Organizational factors: Company policies and crew organization determines the overall safety culture in the maritime system. Crew size, hierarchical command structure, work schedule, etc., are various factors that can influence workload, teamwork, fatigue, risk-taking behavior and operational safety.

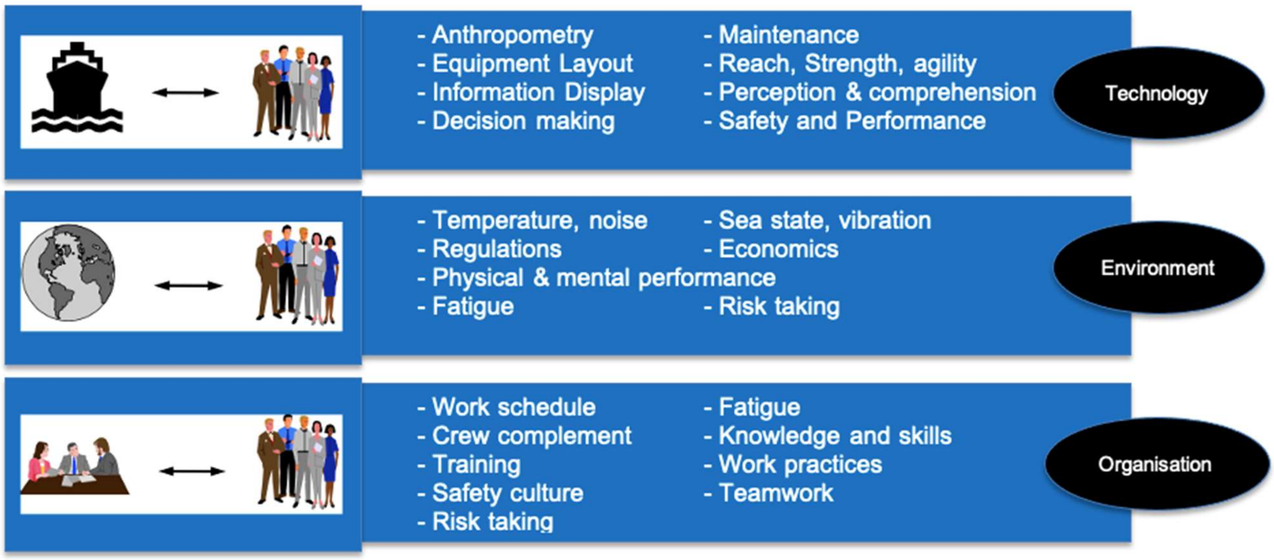

Figure 2 Effect of technology, environment, and organization on humans. Adopted by the authors, based on information from Rothblum (2000).

In any case, the human ability to deal effectively with complexity, pressures, and workload during an emergency and routine operations may differ (Rothblum, 2000). Galieriková (2019) considered that accidents could be reduced by adopting appropriate measures and establishing human-oriented design technologies, organizations, and work environments. Onboard Helge Ingstad, the VHF set was installed in a corner without a system task analysis‡. The consequences of this installation were poor visibility to Radar and Electronic Chart Display and Information System (ECDIS) while using the VHF. Just before the collision, the officer of the watch (OOW) was communicating with MV Sola TS (STS) and did not have easy access to the radar and ECDIS. With

‡An analysis that focuses on the inter-related job tasks required to keep work systems running effectively and efficiently.

many alarms, performing safety critical tasks such as navigation, along with training, made the environment in the bridge unfavorable towards effective sensemaking (Johnsen & Danielsen, 2021).

3. Overview of the collision between Helge Ingstad and tanker Sola TS

In this section, an overview of the collision between the Helge Ingstad and tanker Sola TS is highlighted through a narrative and timeline (VTS, tanker, and warship).

3.1 Narrative of the Accident

His/Her Norwegian Majesty's Ship (HnoMS) Helge Ingstad (HI) was a 135-meter-long and 16.8-meter-wide Norwegian frigate belonging to the "Fridtjof Nansen-class", whereas tanker Sola TS (STS) is a double-hull tanker (length overall 250 m and breadth of 44 m) registered in Malta. Upon completing a NATO exercise on 07 November 2018, HI had planned inshore transit for crew training whilst on passage to Dundee, Scotland. On 08 Nov 2018, at 02:38 a.m., the warship entered the Fedje VTS area, heading south. The ship notified Fedje VTS about the intended voyage and maintained a speed of 17 - 18 knots with AIS in passive mode. On the other hand, MV Sola TS (STS) departed from the Sture terminal with tugs and headed northerly for the next destination at maneuvering speed. The tanker sailed with the deck lights switched to allow seafarers to secure deck gears. The weather conditions in the area were good (dark night, clear sky, and good visibility). Before the collision, the pilot and crew onboard STS spotted the warship and attempted to avoid it by attracting its attention with an Aldis lamp and directing it on VHF, which the frigate's crew did not understand. The OOW and other crew onboard HI were unable to identify STS as an approaching vessel until the very last moment. Considering the conditions and high-tech equipment, the warship could have easily known of the existence of other vessels, including that of STS, by monitoring VTS and radar/AIS[§]. Also, as an integrated factor, the VTS operator's overall monitoring of the area was not optimal. Consequently, at about 04:01 a.m., both ships collided off Bergen (**Figure 3**). After suffering significant damage, the crew abandoned the frigate, which sank later very close to shore (Norway & Norway, 2019).

Figure 3 Planned route of warship, Fedje VTS area/point of impact during the collision (Norway & Norway, 2019).

3.2 Timeline of the Accident (VTS, STS, and HI)

A timeline, indicating how the events unfolded onboard HI, STS, and at VTS which finally led to collision between the two vessels, is tabulated below (**Table 1**).

[§]Sola TS AIS data was available.

Table 1 Timeline of the Accident. Adopted by the authors, based on information from Johnsen and Danielsen (2021).

Ser	Time hh:mm:ss	Event	Remarks
(i)	02:38:00	HI informed VTS about entering the Hjeltefjordarea	
(ii)	02:50:00	HI entered the area	• Ship was not transmitting on Automatic Information System (AIS)
(iii)	03:37:00	STS left the brightly lit Sture terminal	• Captain and the pilot at the bridge informed the VTS about their departure
(iv)	03:45:00	VTS acknowledged that STS departed	• Three ships going north and two ships including HI proceeding south • 03:45-03:53- onboard HI bridge-Briefing of new OOW, STS was identified as a shore object and part of Sture terminal
(v)	03:52:00	STS (bridge) noticed a ship (HI) coming towards STS	
(vi)	03:53:00	Previous OOW onboard HI handed over the watch to new OOW. STS was visually observed. The OOW perceived it as a shore object at Sture terminal. It was difficult to see STS	• Perception and understanding were not communicated or shared between the crew of bridge onboard HI • Verbal clues and information sharing was also a challenge due to high noise level • There was no common mental model amongst the crew on the bridge
(vii)	03:58:00	STS made enquiries with VTS about the approaching vessel (HI)	
(viii)	03:59:00	VTS discovered a possible collision between STS and HI	• VTS informed STS about HI
(ix)	03:59:56	STS tried to communicate with HI about the impending collision	• HI bridge continued to maintain the wrong perception about STS • STS could not manage to credibly communicate with HI
(x)	04:00:44	VTS told HI to take action; however, there was no direct command, no closed loop communication, and emergency keywords were not used	
(xi)	04:01:15	Collision occurred between HI and STS	• The process of sensemaking, including observing, orienting, and acting, were based on missing credible information • There was no closed-loop communication (did not manage to have a shared perception of the situation)

Undoubtedly, the collision between Helge Ingstad and Sola TS may be regarded as a complex case, involving several latent and active failures; all of these are summarized in **Table 2** (Wuori, 2020). Since the 1990s, casualty investigations strive to incorporate the latent conditions[**] (often organizational ones) and active failures[††](Rizzo et al., 1992) because, as it is reminded by Reason (1990), "future studies of human error will need to encompass organizational as well as individual fallibility" (p. 250).

Table 2 Identified Human Factors- Collision of Helge Ingstad and Sola TS. Adopted by the authors, based on information from Wuori (2020).

Organizational Human Factors		
Ser	**Factors**	**Type of Failure**
(a)	Safety Culture	Latent Failure
(b)	Bridge Resource Management	
Personal Human Factors		
(a)	Teamwork	
(b)	Situational Awareness	
(c)	Communication	
(d)	Complacency	**Active Failure**
(e)	Alerting	
(f)	Competence and Training	
(g)	Distraction	
(h)	Fatigue	

In addition to organizational and human factors, the study conducted by Johnsen and Danielsen (2021) revealed that the design of the environment and the bridge systems of HI were poor and obstructed effective sensemaking. A striking feature of the accident was the lack of evasive maneuvers taken by both ships to avoid the collision. Despite having state-of-the-art navigation and detection aids (ARPA and AIS), as well as the presence of VTS monitoring local traffic, all of the advanced technology equipment probably failed to support appropriate/efficient decision-making. It is true that, from one side, recent technological innovations have reduced casualties at sea. On the other hand, they can often be considered to be contributing factors to accidents, due to over-reliance on these systems (Graziano et al., 2016).

4. Some organizational factors leading to the accident

The following analysis focuses on safety culture and bridge resource management, since organizational culture is indispensable in strengthening the appropriate behaviors required on board (Barnett, 2005). Simultaneously, the term Bridge Resources Management (BRM) can be approached as an attempt to train crews on the various attributes of the human element. Thus, good management procedures, efficient training, and suitable capabilities and expertise can reduce human errors (Berg, 2013).

In addition, an organization's safety culture is the sum value of the individuals and groups and the attitudes, perceptions, competencies, and behavioral patterns. These factors further define management commitment to health and safety. A company with a positive safety culture provides

[**]*Latent conditions* are the inevitable "resident pathogens" in the system, and they are created from decisions made by the people whose tasks are removed in time and space from operational activities, including designers, decision-makers, and managers (Reason, 1990).

[††]*Active failures* are the unsafe acts performed by humans who are in direct contact with the system. Slips, lapses, fumbles, mistakes, and procedural violations are all examples (Reason, 1990).

greater impetus for safety. For the IMO, "A safety culture can be defined, as a culture in which there is a considerable informed endeavour to reduce risks to the individual, ships and the marine environment to a level that is 'as low as is reasonably practicable'. Specifically, for an organization making efforts to attain such a goal, economic and social benefits will be forthcoming, as a sound balance between safety and commerce will be maintained" (IMO, 2003).

The contribution of many scholars led to the proposition of a model with five steps in safety culture: pathological (denial of risk, errors are punished, new ideas are discouraged), reactive (after-effects), calculative (systematic management of risks), proactive (anticipation of risks), and generative (identifying weak signals, acceptance of fresh ideas). The working/safety culture of an organization is always determined by the management and affects a ship's design and operational conditions. In private companies, such as shipping companies, the management decisions often represent trade-offs between profitability (production function) and safety (protection function). For example, production pressure was a factor causing the 1967 Torrey Canyon foundering (Chauvin, 2011).

In particular, safety climate assessments are rare in the Navy (Russell et al., 2022). Considering the objectives and resources engaged in warships, they are expected to maintain high safety standards or, at least, have the capacity to do so on paper. However, the investigation considered that the organization and teamwork on HI's bridge were inexpedient, as shown in **Table 3**(Norway & Norway, 2019). It seems that conflicts supposedly restricted to shipping, such as safety vs cost, are now affecting navies. Indeed, to reduce operational costs, the manning onboard HI was characterized by a high-level strategy termed the LMC-Lean Manning concept. There was also a lack of workload assessment of navigation at night, with several alarms and impetus on training while performing the critical task of undertaking night navigation (Johnsen & Danielsen, 2021). The lax safety culture during transit may be attributed to several reasons. The ship was operating independently in its own waters, which gave overconfidence to the command and bridge team. Secondly, the ship was returning from a major NATO exercise, which probably made the overall organization, including the bridge team, less vigilant.

Table 3 Indicators of poor safety culture onboard two vessels. Adopted by the authors, based on information from Norway and Norway (2019).

Helge Ingstad	**Sola TS**
- Planned inshore passage and training activity through a narrow channel in night at relatively high speed	- Sailed with deck lights on, which disabled the warship to clearly identify tanker as a approach-ing vessel
- CIC not manned	- Poor response mechanism from crew
- Absence of experinced hands in bridge	- Over reliance on pilot
- Improper watch on VHF	- Ineffective watch on radar
- Lack of inputs from other crew to OOW	- Improper communication on VHF

Bridge (or Crew) Resource Management (BRM/CRM) intends to strengthen human performance in order to ensure safe bridge operations and training for officers in shipping and navies (O'Connor, 2011) In the case of Helge Ingstad, the limited training and experience of the crew led to a reduced overall capacity to address the traffic situation. While passing through such a narrow channel and executing a planned training schedule, no experienced officer[‡‡] was present on the bridge. In order to fulfil the operational requirement, officers were promoted before the minimum required period in the Norwegian Navy. The OOW of HI had limited experience and

[‡‡]Commanding officer or Executive officer

competence. The Officer of the watch Trainee (OOWT) practically had no experience or the competency to undertake independent watches. Without a doubt, it takes ample time to obtain sufficient acumen for correct watchkeeping. Mere qualifications would not adequately prepare someone to be aware of the risks of the working environment. An experienced OOW would have acted appropriately in identifying risk and taking prompt actions on the verge of risk, which would have led the bridge team properly. Wider experience and necessary training would have allowed the OOW to quickly process weak signals of potential danger.

As highlighted in the relevant investigation, the HI bridge team failed to assess the situation and considered the tanker a stationary "object". The collective failure of the HI bridge team is associated with poor shared mental models/SA of the bridge team (Norway & Norway, 2019). It shows an inadequate ability of the organization (the Navy) to understand the need for synergetic teams for safety and the vital role of experience in ship handling. Many collisions have shown that safety standards cannot be achieved by only using technology or by investing only in technical skills (TS). Therefore, nurturing non-technical skills (NTS) such as leadership, communication, decision-making, and situational awareness are equally important (Fjeld & Tvedt, 2020).

Another important hindrance was the authority gradient on both ships, limiting the effective circulation of information. Teamwork is about sharing a common goal and circulating information to the leader in order to maintain good situational awareness. The essence of teamwork lies in coordination and contribution to enhance team response (Clostermann, 2017). In a dynamic situation, good communication and interaction between team members enhance error detection and the probability of clearing up misconceptions. The HI personnel on the bridge noticed the closing in of the brightly lit object. However, no one shared their concerns with the OOW. Similarly, onboard the tanker, the master followed the pilot blindly, and other crew members on the bridge did not contribute as a team. In short, both ships failed to establish synergetic teams enabling them to potentially prevent the collision.

Also, due to social belief and power relationships, as well as the need for clarity in an emergency, ship organizations are mostly hierarchical(Berg, 2013) and can become autocratic, which does not facilitate the participation of other members of the bridge (Clostermann, 2017). A strict hierarchical structure (a mixture of experts and novices) and procedures also affected the teamwork onboard HI. The authority gradient cripples the ability to get accurate feedback from team members (Dzakpasu, 2019). Thus, no crew member could supplement the OOW with critical inputs. They followed orders assuming that the OOW controlled the situation.

Past incidents and research have shown inter-team failures on the bridge and the inability of the team to report or question leaders' errors or misrepresentations (USCG Marine Board of Investigation, 1979). Further, cultural factors may affect the capacity to work in a team. Some may interpret critical signals correctly, while others may not, and a few may completely ignore them (Barnett, 2005; Norway & Norway, 2019).

5. Personal factors

Personal factors contain two types of human failures: (a) Crew resource management (inadequate coordination, inadequate communication, lack of teamwork) and (b) Personal readiness (inadequate rest/sleep, lack of physical fitness, poor judgement), which are crew-oriented factors (Galieriková, 2019).

Graziano et al. (2016), in their studies, suggest that performance shaping factors (PSF),which may influence the performance of crew members, is a sum of all factors, including: (a) Personal Factors (cognitive fatigue, stress), (b) Aspect of communication/information (lack of information/situational awareness and no training), (c) Internal/external environment (weather, time of the day), (d) Organizational factors (manning, policies, culture), and (e) Training/competence (lack of training and experience). All humans construct the world according to their sense and data processing capacities. Each individual differs because of personal needs, self-concept, past experience, shared goals, and current practicalities that affect the representation of situations (MCA, 2010).

Inappropriate sense-making or inaccurate representation of a situation may trigger wrong decision-making and accidents(Johnsen & Danielsen, 2021). In the warship and tanker collision, automation/technology designed to assist watchkeepers in processing information did not prevent inappropriate representation of the situation and wrong decision-making. According to Baxter et al. (2012) and Bowo et al. (2021), automation and technology may sometimes impair an operator's ability to analyze and respond. Situational Awareness (SA) is the perception of environmental elements and events, comprehension of their meaning, and projection of their future status (Chauvin et al., 2013). In dynamic situations, decisions are based on SA.

Consequently, a bridge team must collect and exploit information to predict a course of action. It is a human tendency that, once crew have established SA, they tend to seek confirmation of their beliefs. In the case of HI, the watchkeepers were locked in the wrong appreciation of the situation. This shows that the mental construction of the situation hindered signals against such representation (e.g., Radar data or VTS). Psychologists have long established that overconfidence and confirmation bias generate an “illusion of validity” and inhibit the capacity to evaluate one’s views (Nickerson, 1998). The overconfidence of the HI bridge team in their SA created confirmation bias. It resulted in group thinking and being unable to accept alternative views. The initial error in identifying STS as a stationary object created a wrong perception/incorrect mental model. In addition, the tanker sailed with deck lights switched on, making it difficult for the warship crew to see STS navigation lights and identify it as a moving vessel. The perceptual blindness did not allow OOWs to appreciate the dangerous situation and risk of collision.

The pilot, onboard STS, also made assumptions on his intuitions (clear visibility, inputs from VTS, expecting the frigate’s response) and focused attention on the pilotage operation more than on the overall traffic situation. Information processing under cognitive stress and mental fatigue could be intuitive rather than analytical. The crew failed to identify a moving target due to attentional limitations and change blindness. People overlook special or unexpected events due to selective attention control, as their attention is focused on one task. Then, the overall picture or changes get skipped from updated SA. Significant and rapid changes are easier to identify, whereas small changes are difficult and are connected with change blindness.

Similarly, moving toward an object giving off light can make it challenging to identify the object’s movement. Thus, the relative change of the two ship’s positions with Sture terminal in the background did not allow the wrong perception to break, and the OOW could not identify the moving vessel. Similarly, the pilot’s inappropriate judgment/sense-making that the frigate could observe STS as approaching vessel deterred bold actions (MCA, 2010; Norway & Norway, 2019). The OOWs wrong perception did not allow him to alter to starboard despite the pilot’s instructions. Therefore, following the Observe-Orient-Decide-Act (OODA) loop (**Figure 4**) concept [§§] is essential to recalibrate the situation with a different perspective/mind frame. The OODA loop was its creator’s attempt to decipher how we develop mental perception, or ‘concept of meaning’, to understand and cope with our environment (Mednikarov & Lutzkanova, 2021).

Simultaneously effective communication is the backbone of sharing SA. However, human-to-human communication is complicated, and noise and misunderstanding can affect the transmission and reception of messages. Communication is exposed to varied interpretations by any person receiving the information.

[§§] The OODA loop was originally developed by Col. John Boyd, USAF, for making tactical decisions during air-air combat (Szeligowski, 2018). It is a four-step method for making sensible decisions in high-pressure scenarios. The procedure entails gathering relevant data, identifying potential preconceptions, making a decision, and acting before repeating the procedure with new information.

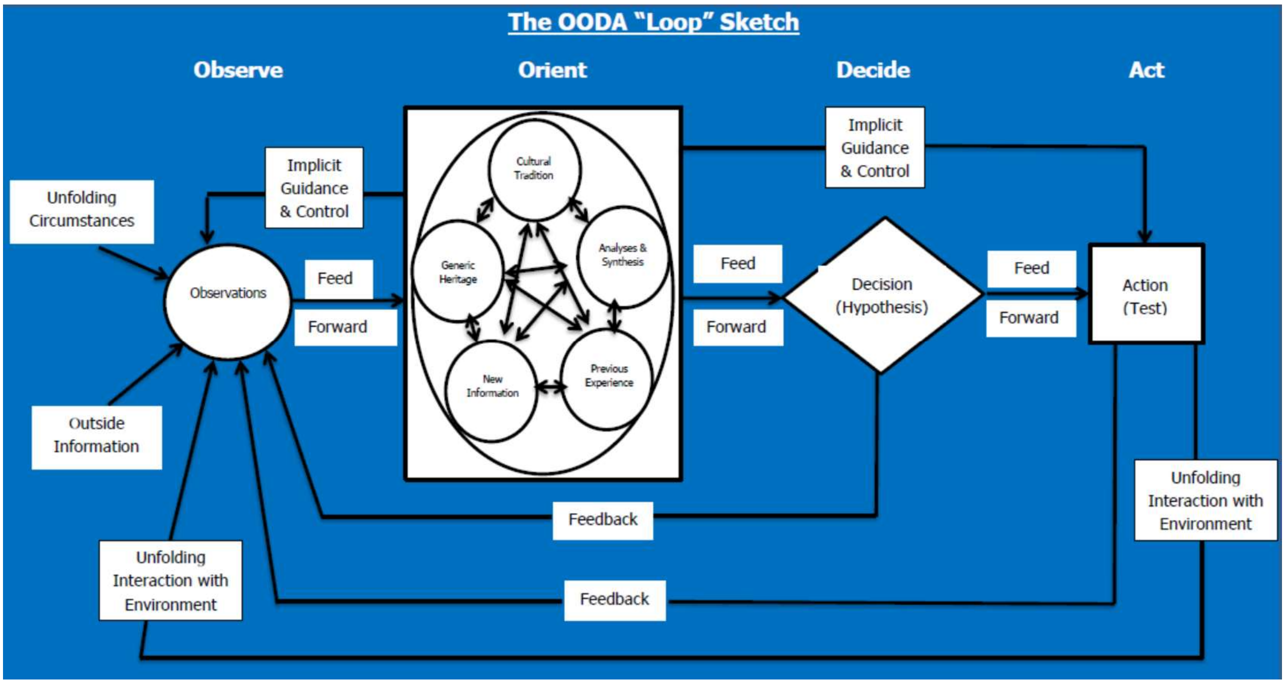

Figure 4 The OODA "Loop" Sketch (Mednikarov & Lutzkanova, 2021).

To make matters worse, during the VHF conversation with HI, the pilot did not use standard communication procedures, which affected the OOW onboard HI in identifying the approaching ship correctly. At the same time, the STS pilot was convinced that the frigate had already observed the moving tanker leaving the berth and understood the STS's VHF instruction. The pilot's use of the Norwegian language excluded the non-Norwegian members of the bridge team from understanding the situation. VTS contacted HI just prior to collision and directed him to take action. However, no information on STS was provided, as the OOW in HI still maintained the point of view to avoid shore objects (brightly lit contacts) on the starboard side.

In the maritime sector, people are from different nationalities and have differing mother tongues and varying language skills. In emergencies, a crew tends to revert to their native language or cannot communicate effectively. Thus, poor communication can lead a simple situation at sea or a task to catastrophe. The experiences/beliefs of the pilot/VTS operator about the use of the Norwegian language did not allow the tanker's crew to understand the situation, which, de facto, excluded them. Unambiguous communication from the pilot/VTS would have alerted the frigate in time (MCA, 2010; Norway & Norway, 2019) and awakened the members of the tankers if conducted in a common language.

Additionally, the UK MCA identified complacency as one of the significant human factors that can lead to maritime disasters. Complacency means self-confidence that everything is going well. One negative impact of complacency is the reduction in seeking additional information and analytical processing. At a team level, overconfidence also reduces open communication and limits the development of good SA. To negate complacency, a bridge team must exchange regular inputs, expecting to find problems, and get help if the situation is not understood.

The role of seafarers has undergone a significant transition, going from being the primary operator in charge of the system to a more or less passive observer. Since passive control activities do not require traditional knowledge and skills, it is possible that this knowledge and skills will be forgotten. One of the critical elements that may lead to complacent behavior is over reliance on modern technology. Operators lose focus and assume the system will not make a mistake, making it safe for them to turn their attention to other duties (engaging crew in training activity during watch onboard HI). This illusion of comfort emerges particularly when technology has been functioning well for a long time (Bielić et al., 2017).

The warship OOW neglected visual signs and did not properly check the radar, AIS[***] or visual bearing[†††]. Binoculars were not used effectively to identify the vessel. Similarly, the Sola TS crew were confident and focused on the unberthing operation. The navigation officer was not monitoring the traffic in the channel. Complacency seems common when the pilot is onboard. Instead, the crew must focus with increased awareness and vigilance.

Further, the VTS operator acknowledged STS's departure, but did not inform other vessels in the area. Consequently, the HI OOW and tanker pilot decision-making were blurred by overconfidence. The perceived control (everything is going well) about the situation did not allow OOWs to think differently (MCA, 2010; Norway & Norway, 2019). Moreover, distraction affected both bridge teams. A crew member is distracted from primary tasks by either a multiplicity of tasks or engagement in non-essential tasks (Sánchez-Beaskoetxea et al., 2021).

The cumulative factors that may generate higher distraction effects are fatigue, stress, poor health, and attention (Othman et al., 2016). These affect overall attention and mobilizes cognitive capacities for non-essential activities. The mental workload was high on the warship bridge, with numerous alarms, officers in training, handing over procedures, and radio communication through VHF (Very High Frequency). In other words, many distractions reduced the OOW's capacity to focus (Johnsen & Danielsen, 2021). Training activities divert attention from weak signals of danger, and the amplification of weak to strong signals requires a certain amount of attention and time (Norway & Norway, 2019)

It seems that the tanker crew were also distracted by the amount of tasks to perform, with a limited crew in a demanding post-cargo operation environment (cargo related-matter, paperwork, maneuvering and tugs, navigation, securing equipment). For both ships, it is important to recall that watchkeeping duties must remain the absolute priority, and other tasks must be subordinated. The inadequate response and decision-making may also be attributed to withdrawal symptoms or fatigue, which one can experience after a strenuous exercise (MCA, 2010; Norway & Norway, 2019).

6. The impact of fatigue

The reduction in manning levels in modern ships contributes to increased fatigue (Smith, 2007). Exposed to an irregular work schedule, including night duties, seafarers face increasing volumes of work, with the multiplication of regulations to implement without additional staff (Garb et al., 2011; Bhattacharya, 2012; Österman & Hult, 2016; Sampson et al., 2017). The situation in the Navy is not the same, because crew size is not an issue. However, there is a culture of undertaking drills to test crews, with limited consideration for the risk of fatigue. The Helge Ingstad, in this instance, was returning after an intensive NATO exercise, which demanded a high level of physical and mental endurance. The influence of fatigue on the HI and STS crews seems to be one of the critical factors in poor SA and teamwork. The reduced alertness and degraded performance made the Helge Ingstad OOW overlook the situation. It also impaired decision-making capabilities, which could be observed in ineffective communication and slow responses. The situation of the STS was undoubtedly not better, as the tanker had completed a long cargo operation which would have deeply affected the crew workload (Allen et al., 2008; WMU, 2020).

7. Conclusion and recommendations

The global maritime community has consistently worked to decrease maritime accidents, yet accidents caused by human error still occur. Understanding organizational and human factors on board ships is essential for reducing the number of maritime accidents (Bielić et al., 2017).

[***]Names of approaching vessels.
[†††]To determine if any risk of collision exists.

In this paper, the human factors (HF) that lead to a collision between HI and STS are examined. The latent conditions are introduced into a system during the design or building phase of the project or ship and in the modalities of operation determined ashore (e.g., lack of experienced OOW on the HI). Close scrutiny of the accident reports and literature review indicates that the human element failed on the bridge of HNoMS Helge Ingstad (Johnsen & Danielsen, 2021) and, to a certain extent, on the STS. The collision between HI and Sola TS indicates that, despite operational VTS, a local pilot onboard STS, and a large team onboard the warship bridge, accident prevention requires understanding of the complex situation by individuals. Poor SA, negligence, misconceptions, and limited experience and teamwork were significant contributory factors in the collision between the warship and STS (Norway & Norway, 2019).

Moreover, both organizational and personal human factors play a significant part in accident causation. Organizational factors, including design and of lacking the understanding of technology created error pathways, are few factors that lead to accidents. On the contrary, perception of technology as fully reliable may result in inadequate performance of crew members (Bielić et al., 2017).

Several steps must be taken in order to lower the likelihood of human error due to poor situational awareness, insufficient experience, and a lack of teamwork. It is paramount to conduct training in real like scenarios, and a favorable learning environment should be created. During such training, maintaining an offensive, exploratory role in ambiguous situations, with clearly defined responsibility for contributing to group SA, is essential. In training and real scenarios, human operators must use technological aid critically and obtain information from various sources, and all crew members should share safety-related information (Bielić et al., 2017). Team members must maintain a low threshold for sharing information and additional inputs that may be put to use in developing a correct appreciation of a situation. Communication procedures must be efficient, concise, and unambiguous. The right amount of experience, competence, preparation, and good teamwork is the key to avoiding incidents. Maintaining a balance between TS and NTS is also essential, and the training environment should replicate 'real world' characteristics (Cavaleiro et al., 2020). Studies have shown that class room based BRM training's effectiveness is low, as attitudes and NTS are not affected, and no performance improvement is gained during such sessions (Röttger et al., 2016). Therefore, individuals are to be put through rigorous and appropriate BRM training under varying scenarios to improve team building and decision-making so that inevitable human mistakes are captured and mitigated before they lead to casualties.

Another important aspect for watch stander at sea is to ensure strict observance of the Convention on the International Regulations for Preventing Collisions at Sea (COLREGs). The International Regulations for the Prevention of Collision at Sea (IRPCS) attempts to establish safe coordination in the movement of two vessels in a given close-quarters or collision encounter. It is crucial to implement the COLREGs in whole, and not simply some parts (Maza & Argüelles, 2022). A clear understanding of IRPCS and timely application can obviate risk of collision. The following may be considered as recommendations to evolve teamwork and enhance situational awareness and best practices:

- Culture of challenge and response (assertiveness)- Team members should be able to point out wrong decision-making. However, from an organizational perspective, encouraging and developing such a culture requires a lot of dedication and careful preparation.
- Team building- It is essential to move away from traditional systems of ship organization and think of the crew as a team, with the master serving as the team leader in order to build and maintain an effective safety culture (Bielić et al., 2017). The involvement of each team member is essential to create a sense of pride and belongingness (involve people, and people will understand). This improves individual performance, effective communication, and awareness of shared goals.
- The Observe-Orient-Decide-Act (OODA) loop- Situational awareness (state of mind) is the result of the process, i.e., situation analysis (**Figure 5**). Decision(s) need to be judiciously taken

and refined in any situation after weighing each input. Thus, developing a habit of check-recheck and double-check is important.

- Training and developing cognitive skills (both technical and non-technical) in individuals and teams.

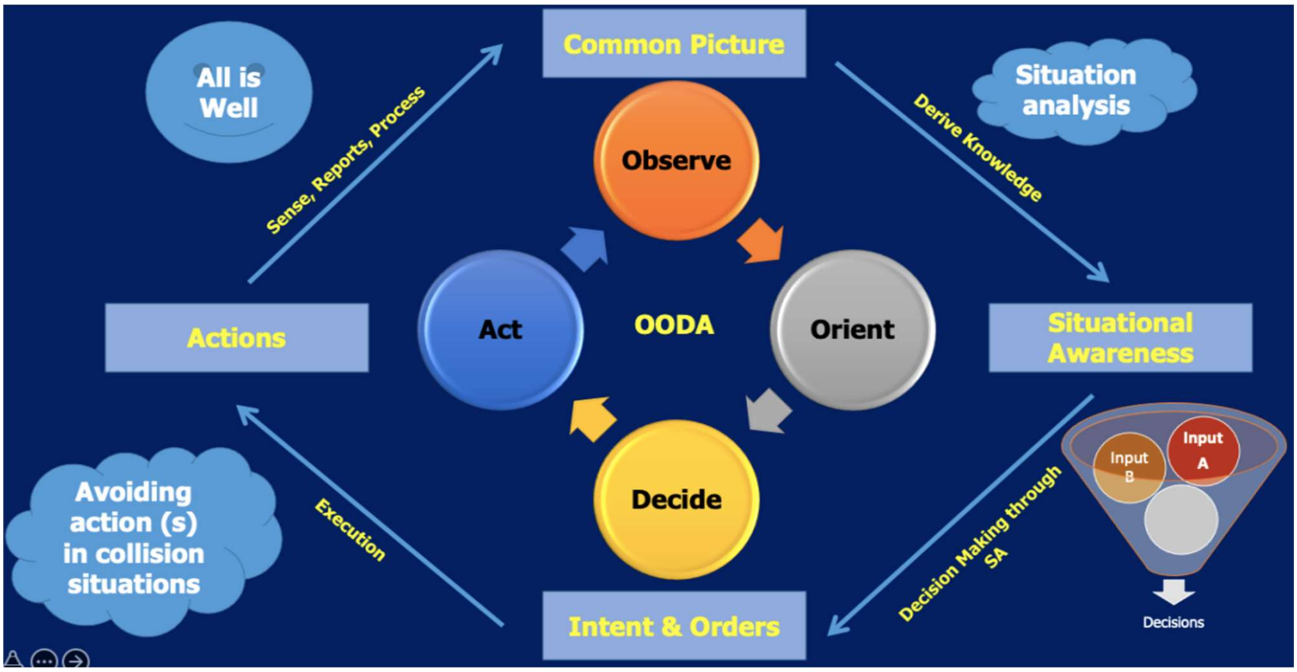

Figure 5 OODA Loop for situational awareness and decision-making. Adopted by the authors, based on information from Mednikarov and Lutzkanova (2021); Szeligowski (2018).

Technology and automation should be used to their best advantages. However, fundamentals must be followed while standing watch on a navigational bridge. The window in a navigational bridge is the most important screen onboard ship(s). Thus, an old-fashioned common sense of keeping an internal and external lookout is essential. It is important that the Pilot/OOW handling navigational watch take necessary and timely action(s), as per COLREGs, to avoid close quarters incidents or the risk of collisions.

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