Int Marit Health
2024; 75, 2: 79–88
10.5603/imh.99407
www.intmarhealth.pl

ISSN 1641-9251
eISSN 2081-3252

VIA MEDICA

ORIGINAL ARTICLE

Maritime accidents in the estuary of the River Seine from 2009–2019

Jean-Claude Chatard[1], Michel Quioc[2]

[1]Faculty of Medicine Jacques Lisfranc, University Lyon-Saint-Etienne, France
[2]French Maritime Academy, Le Havre, France

ABSTRACT

Background: *In confined waters, ships run a high risk of groundings, contact, sinkings and near misses. In such waters the maritime traffic is dense, the waterway is narrow, the depth is limited, and tides and currents are constantly changing.*

Materials and methods: *From 2009–2019, 75 accidents were investigated in the estuary of the Seine. Weather conditions and perceived fatigue were studied. From May to June 2020, 114 seafarers, 34 pilots and 80 captains, responded to a questionnaire focusing on the use of Pilot Portable Units (PPU) and Electronic Chart Display Information Systems (ECDIS).*

Results: *The 75 accidents corresponded to an average of 6.8 ± 3.2 accidents per year. Groundings were the most frequent accidents (35%, n = 26) followed by contact accidents with the quayside (25%, n = 19), between ships or tugs while manoeuvring (8%, n = 6) or while sailing (1%, n = 1). There was no loss of vessels nor fatalities of crew members. In poor weather conditions, there were 76% more accidents than in normal conditions (4.4 ± 2.5 accidents/10,000 movements versus 2.5 ± 1.9 accidents/10,000 movements, p < 0.03). Almost all the accidents (96%) were related to human errors of judgment (81%), or negligence (53%), or both (39). Perceived fatigue was probably in cause in 6 accidents. Only 3 accidents were related to mechanical causes. Through the questionnaires, 69% of the pilots complained of difficulties in mastering the devices and software. They felt distracted by alarms which affected their attention while navigating. They requested training on a simulator. Concerning ship captains, 83% felt comfortable with ECDIS devices yet only 20% were able to configure the ECDIS correctly.*

Conclusions: *In the Seine estuary, 75 accidents occurred within the 11 year-study. Risk factors were poor weather conditions and human error. PPU and ECDIS were considered as useful tools in the prevention of accidents. However, pilots and captains requested more thorough training in their use.*

(Int Marit Health 2024; 75, 2: 79–88)

Keywords: confined waters, collision, grounding, Pilot Portable Unit, Electronic Chart Display Information System, ECDIS

INTRODUCTION

In confined waters, the risk of maritime incidents is significant and about 90% of all marine accidents happen in such waters [1]. Indeed, the maritime traffic is dense, the shipping lanes are narrow, the depth of water is limited, and the tides and currents are constantly changing [2, 3]. Large vessels have reduced manoeuvrability when changing course [2] which also presents an increased risk of accidents in dense traffic [4]. Excess speed and poor weather conditions like reduced visibility due to fog [5], strong winds [6], heavy rain and storms [7], ice or snow [3] are also important risk factors. During the hours of darkness,

Jean-Claude CHATARD, Faculty of Medicine Jacques Lisfranc, University Lyon-Saint-Etienne, France, e-mail: chatard@univ-st-etienne.fr

Received: 16.02.2024 Accepted: 28.02.2024

the number of incidents may be twice as high than during the day [2, 4, 8].

Incidents are mainly represented by collisions and contact when the shipping is dense [4, 7, 9, 10], groundings and standings [2, 3], sinking in bad weather conditions, fire or explosions [2, 7] and near misses.

Pilotage is one of the accepted means of minimizing shipping [9] accidents in confined waters [2, 6]. Local pilots with expert knowledge help captains in the navigation of their vessels. They have a high degree of local knowledge and converse in the local language. They can communicate effectively with the tugboats and the ports [11]. Therefore, they play a critical role in ensuring maritime safety in challenging waterways.

Since 2016, Pilot Portable Units, PPUs, have been used by pilots for guiding ships while Electronic Chart Display Information Systems, ECDIS, are used by captains for the ship's positioning and safety [5, 12]. ECDIS has been compulsory since 2018 to visualize in real time the position of the ship on electronic charts.

Despite the help of PPU and ECDIS, shipping accidents occur regularly, and human error remains the major cause ranging from 56% [2, 3], to 95% [2, 13]. Negligence errors like inadequate watchkeeping or poor use of radar [14] are the more frequent followed by errors of judgment like misunderstanding or misinterpretation between two officers [15] or both. In the case of human error, fatigue and stress play a major role [16, 17]. It can be combined with equipment failure, bad weather conditions, lack of shipping experience [7] or lack of adequate knowledge about the region [2]. An inadequate understanding of safety criteria between the master and the crew is also a precondition for unsafe actions, as well as resource management issues, inadequate software in written procedures from the company and administrative deficiencies [18].

The risk of maritime accidents has been studied in many confined waterways worldwide as presented in Table 1 grouping 26 studies. However, there is no study concerning the estuary of the Seine.

Table 1. Studies concerning some restricted water locations

Restricted water location	Study characteristics	References
Bosphorus strait	1953–2002, one of the most congested traffic in the world 2,500 crossing per day, 700,000 passengers/year, > 30 large tankers/day, 461 accidents, 57% grounding and stranding	[2]
Barcelona port	1972–2004, 669 accidents, 40 commercial accidents compared to 41 high speed accidents. Human error was the key factor in the chain of failure	[25]
Istanbul strait	1953–2002, 461 accidents, 57% collisions due to loss of manoeuvrability in currents, darkness, sharp turn and dense traffic	[4]
Norwegian waters	2000–2017, grounding and collision depends on inadequate watch, ship type, size, poor visibility and flag of convenience	[30]
Taiwan strait	1999–2014, 220 ship collision conflicts/day were used for measuring maritime traffic safety and predict collision risk	[10]
Venice Lagoon	2017, severe atmospheric conditions are often present, e-navigation strategy was developed to reduce navigational accidents	[5]
Ningbo-Zhoushan, China	2013–2021, 3,500 ships cross the port/day, 28 studied legs, > 1.5 Singapore strait, enormous ship collision risk. From 2010, traffic separation scheme and mandatory ship reporting system	[31]
Inshore coast of Norway	1990–2005, 35 accidents, cruising speed above 25 kt, 60% grounding, 23% technical malfunction, 16% reduced visibility, 60% dark, performance-shaping factors are investigated	[1]
Beicao channel of Shanghai	2022, safety of ship pilotage analysis, use of radar and Automatic Identification System (AIS), human and organizational factors, targeted risk control strategy	[32]
Singapore strait	2013, 105-km long and 16-km wide waterway. Traffic density and speed were studied to calculate theoretical capacity of the main strait and 15 legs taking into account 43 million pieces of AIS data	[33]
Inshore coast of Finland and Denmark	1997–2006, 210 accidents mainly grounding and collisions due to human failures and the rapid increase in traffic between Russia and Finland, night/day and weather conditions not in cause	[3]
Arctic	1993–2011, root cause analysis is proposed to clarify and prevent incidents from happening	[23]
Western Shenzhen port	2007–2017, adjacent to Hong Kong, 500,000 ships/year. Risk factors are traffic, speed, heading variance, 93 accidents, 50% collisions	[34]

→

Table 1 cont. Studies concerning some restricted water locations

Chinese coastal waters	2013–2020, Analysis of maritime accidents in different water area using an advanced machine learning approach	[20]
Mediterranean ports	1967–2021, 634 accidents compared to 2,799 worldwide port accidents. 37% collisions, 25% contact, 5% human life loss, 2% loss of cargo. Risk factors are gross tonnage between 500–5,000 GT and heavy weather conditions	[35]
Rotterdam port	June–July 2007, focus on traffic separation scheme, AIS, to avoid collisions. Ship size and speed are studied	[36]
Busan Korean waterway	2012, accident risk assessment, ship type and size, position, speed, distance between ships, time of the day	[37]
Korean ports	2004–2013, 767 accidents, 6.1% due to pilot negligence, fatigue and age	[28]
Surabaya west channel, Indonesia	2019, dense traffic of 28,112 ships, 17 great metropolitan ports are deserved (17 ports checked). Waterway system, ship, human factors are studied. Recommendations for decision making width revitalization and speed limit are given	[38]
Kerch strait, Black sea	1999–2019, in grounding and sinking the risk factors are dense traffic, inland and old ships they are different to those of collisions	[39]
Taiwan strait	2014–2019, 583 accidents, 33% collisions, increase with the ship tonnage	[40]
Southeast Texas waterways	2012, 779 tugs/cargoes/tankers/monthly, 2–4 accidents/month, Inland water transportation of hazardous materials. Studied risk are traffic, ship design, size, speed, equipment failure, human error, bad weather, AIS data	[41]
Xiazhimen waterway	12-km long and 1-km wide channel, largest port in the world in cargo throughput. An empirical ship domain was formulated and validated to predict the navigation risk taking into account the speed fluctuations and the safe distance between ships	[42]
Yangtze river	2009–2018, 6,300km river long, three Georges Reservoir 681 km long + 42 km intersection, 173 accidents reported. Accidents declined with the years, constant traffic 80–95,000/year, 66% grounding, 13% collisions, 7% sinking, 38 dead/missing. Human error ship condition and traffic investigated	[21]
Tianjin port of China	2008–2013, 552,907 ships activities, 65% of the accidents are collisions, 193 collisions involved 342 ships, risk factors depend on area, time of day, wind, ship model and small length < 100 m. Without pilotage the risk increased by 9. Poor visibility was not a risk factor	[6]
Malacca Strait	2011–2020, 900 km long, 2007, 84,000 ships/year,126,000 movements, one of the most important shipping short cut in the world between Pacific and Indian oceans. How enhance the safety of ship, littoral state action against criminal activities, piracy, illegal fishing, human trafficking, unresolved maritime boundaries ? Huge decrease in accident 63 in 2001 versus 23 in 2017	[43]

The main goal of the present study was to analyse 75 accidents on the Seine between the ports of Rouen and Le Havre, from 2009 to 2019. A second aim was to analyse the main causes of accidents that include weather conditions, size of vessel, the level of fatigue and experience of the pilots. The third aim was to determine the efficiency of the PPU and ECDIS for pilots and captains in preventing maritime incidents.

MATERIALS AND METHODS

ANALYSIS OF ACCIDENTS

A total of 75 accidents were recorded in the Seine estuary, a 70-NM long and 120-180-meter-wide waterway between Rouen and the Atlantic Ocean at Le Havre (Fig. 1). Incidents were investigated by the local pilots themselves. They followed the recommendations of the National Federation of Maritime Pilots according to ISO 9001 standards. They concerned groundings and contact when manoeuvring at the dock, or when sailing, near miss incidents and dangerous close situations.

For all the accidents, factors affecting navigation were analysed: density of maritime traffic, unfavourable weather, poor visibility < 500 m by fog, that occurs on average 69 days/year in the estuary, strong winds, night navigation, length of vessels, perceived fatigue, yearly amount of workload represented by the number of ships per pilot and experience of pilots.

Human errors (HE) responsible for accidents were also studied and classified into 4 types following the recommendations of [19]: Type 1 HE corresponded to errors of judgment, such as the assessment of a trajectory. Type 2 EH corresponded to negligence such as not listening to an alarm. Type 3 HE corresponded to type 1 and 2 HE. The absence of HE corresponded to type 0 HE, such as engine damage or rudder damage.

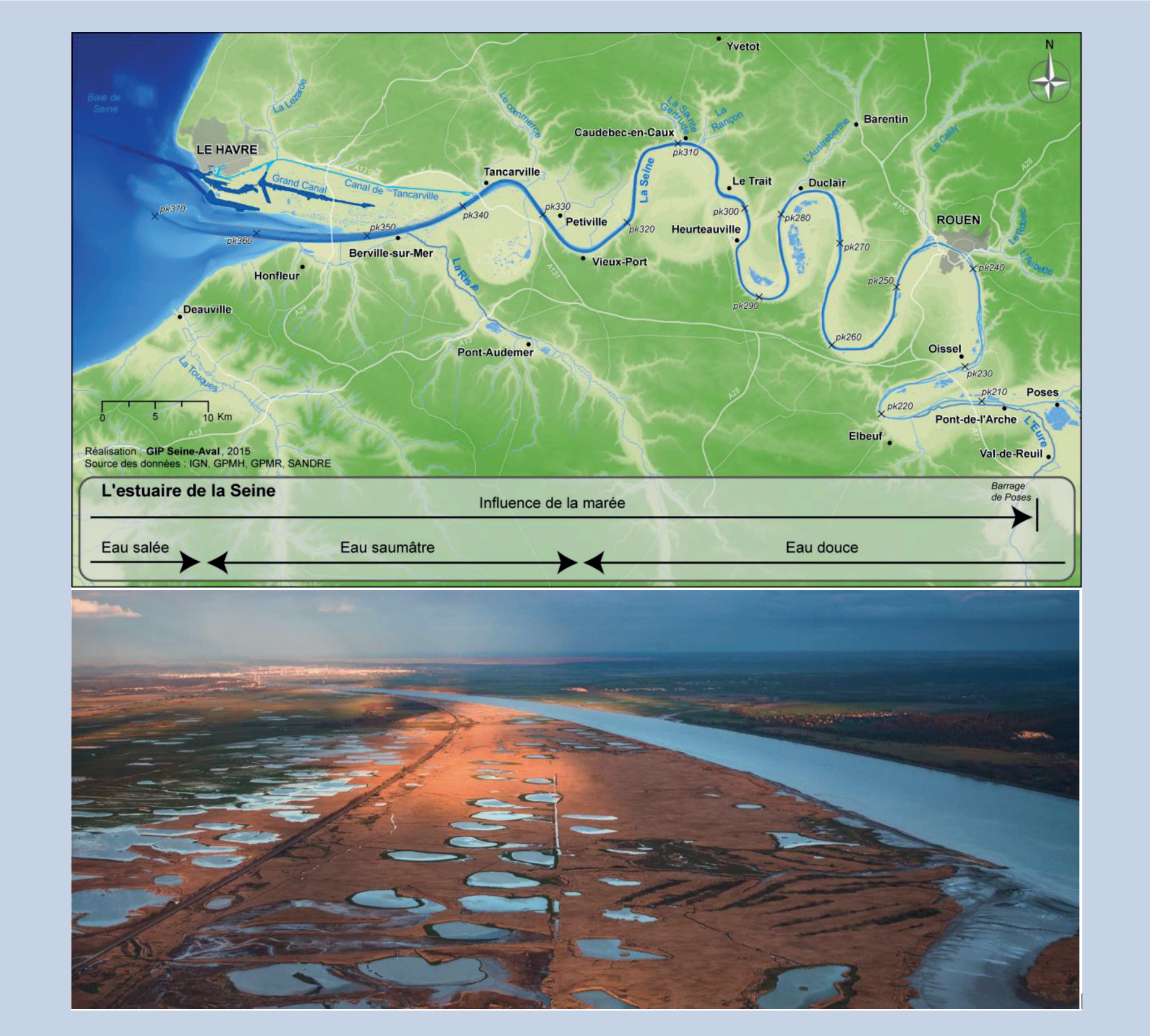

Figure 1. Map of the estuary of the River Seine, a 70 NM long and 120 180 m wide waterway from Rouen to Le Havre source: French IGN maps)

PPU AND ECDIS QUESTIONNAIRE

From May to June 2020, 150 seafarers, working in the estuary, 51 pilots and 99 captains, were contacted by (MQ) to respond to Microsoft Form® online questionnaires. In total, 114 (34 pilots and 80 captains) responded and their responses to the questionnaires were analysed.

For pilots the questionnaires focused on the use of PPU type navigation aids. For captains, it focused on the understanding and use of ECDIS type navigation aids. The goal was to determine if these two tools were used correctly and if they provided added security.

STATISTICAL ANALYSIS

One-way ANOVA analysis and correlation coefficients were carried out between the yearly number of accidents and the weather conditions, fog, navigation at night, fatigue at work, ship length, maritime traffic, age and experience of pilots and captains. A *p* value of *0.05* was chosen as the level of statistical significance. The Stata 11 program was used for the statistical analysis.

RESULTS

ACCIDENTS

From 2009 to 2019, 75 accidents were recorded, corresponding to an average of 6.8 ± 3.2 accidents per year. The number of accidents varied greatly from one year to the next with a minimum of 2 in 2019 and a maximum of 12 accidents in 2011 (Fig. 2).

Groundings were the most frequent accidents (35%, n = 26) followed by contact accidents with the quayside

Figure 2. Number of maritime accidents and annual ship traffic on the estuary of the Seine between Rouen and Le Havre

(25%, n = 19), contact accidents between ships or tugs while manoeuvring (8%, n = 6) or while sailing (1%, n = 1). Near misses represented 23 cases (30%). There were no vessel losses nor fatalities of crew members.

Over the 11-year period studied, maritime traffic decreased regularly by –18%, (r = 0.76, *p < 0.01*). However, the number of accidents decreased by only 8%, statistically not significant, when compared to a constant annual traffic of 10,000 movements (5.8%/10,000 movements in 2019 versus 6.3%/10,000 movements in 2009, *p : NS*).

In 2017 and 2018, a 16% increase in accidents, although not significant, was observed compared to the previous 8 years (7.6 ± 0.5 vs 6.4 ± 2.8 accidents/10,000 movements, *p : NS*).

RISK FACTORS

Degraded navigational conditions

The number of accidents in poor weather conditions (n = 55) was 76% higher than in normal conditions (4.4 ± 2.5 accidents/10,000 movements versus 2.5 ± 1.9 accidents/10,000 movements, *p < 0.03*). Poor conditions were reduced visibility due to fog (n = 10), strong winds (n = 4) and night navigation (n = 41). The large size of the ships (r = –0.20, *p = NS*) was not an aggravating factor.

Human error

Almost all accidents (96%, n = 72/75) were related to human error. Accidents due to error of judgment were the most frequent (81%, n = 61) followed by accidents due to negligence (53%, n = 40). The combination of two human errors, error of judgment and negligence, represented 39%, n = 29 of accidents. Only 3 accidents were linked to mechanical causes, engine, or rudder malfunction.

Age and experience of the pilots

At the time of the accidents, the average age of the 75 pilots was 46.5 ± 6.3 years with an average experience of 14.0 ± 6.8 years. Only 9% of pilots were considered inexperienced with less than a 5 year-experience.

The relative inexperience of the pilots (r = –0.10, *p = NS*) and a high pilot workload was not an aggravating factor with even a trend, but not significant, towards a reduction in accidents above 240 ships/pilot/year (5.4 ± 3.1 vs 6.8 ± 2.4 accidents/10,000 movements, *p = NS*). Out of the 75 accidents, only 6 were due or accentuated by fatigue.

PPU QUESTIONNAIRE FOR PILOTS

The average age of the 34 pilots who responded to the questionnaire was 50.1 ± 6.3 and the average experience was 16.6 ± 6.3 years.

Since 2016, 80% of pilots have regularly used a PPU with shared antennas and a personal software license. The PPU has changed the way they navigate for 68% of them. In 67% of cases, the pilots configured it with mirror settings identical to the radar. The PPU was primarily used to calculate the rate of turn and lateral placement of the vessel in the channel.

Although very useful, 69% of pilots complained of difficulties in mastering the device and mastering the software. They felt bothered by the alarms which distracted their attention while navigating. They requested training or retraining sessions in small groups on a simulator. They thought they knew little about ECDIS regulations, with 79% of pilots having had no training at all on these devices. Furthermore, 70% of them were unaware of errors in systems connected to the AIS (smoothing or incorrect TE declaration), 70% of them were also unaware that the alarms were configurable, 68% did not know the accuracy of a Catzog ENC and 42% were unaware that ECDIS has been mandatory since 2018.

ECDIS QUESTIONNAIRE FOR CAPTAINS

The average age of the 80 captains who responded to the questionnaire was 48.6 ± 8.7 years. For 74% of the captains, the average experience as captain exceeded 5 years. Only 22% of the captains were novices, meaning they had just made their first trip on the Seine.

Their ships were representative of the traffic of the port of Rouen with a majority of oil/gas tankers (39%) and bulk carriers (29%). Three quarters of captains had worked for the same company for more than 5 years and had been sailing on the same ship for more than 6 months.

Among the 80 captains, 83% felt comfortable with ECDIS devices, including 61% perfectly comfortable. For them, the familiarization time was on average 1 to 2 months. On the other hand, 17% of captains did not feel comfortable, including 11% who did not feel comfortable at all. They regretted that companies frequently changed the brand of device.

In total, 11 different types of ECDIS devices, among 35 available on the market, were used with as many different presentations and interfaces.

Almost all the captains interviewed (98%) had received training on ECDIS devices more than a year ago and since this training 65% of them had worked on the same ECDIS.

The legal obligation to check plotted routes was respected by 81% of captains.

However, it could be shown that this verification sometimes contained errors. In fact, only 19% of captains were able to identify certain inconsistencies between the official navigation charts and the sounding data, such as from the Pont de Tancarville, a quarter of the way along the route, where the official charts no longer provide any sounding data.

Device alarms were deactivated by 44% of captains because they were considered too numerous (> 30/hour) and therefore disruptive to navigational operations. Almost half of captains (46%) were not interested in the accuracy of hydrographic data, and 48% in the appropriate setting of alarms such as lateral course deviation.

Only 29% systematically took into account the quality of the satellite signal. Only 21% correctly set the Safety Frame to < 3 min, and only 19% set the Safety Contour to the 5 m isobath.

Finally, only 20% of captains set the ECDIS devices correctly. On the other hand, 74% of captains were very satisfied with the explanations given by pilots.

COMPARISONS BETWEEN PILOTS AND CAPTAINS

Table 2 compares pilots' and captains' responses on the use of PPU and ECDIS. For 2/3 of pilots, theoretical and practical ECDIS training was not sufficient. In all, 44% of pilots feel they have not mastered ECDIS. The majority of captains consider PPU and ECDIS as complementary. Untimely alarms from both types of equipment are limiting factors in their use, especially among captains.

DISCUSSION

ACCIDENTS

One of the most important points of this study was to indicate that the number of accidents was almost constant over a 11 year-period. An explanation was that although

Table 2. Comparison between training and use of digital devices by pilots and captains

	Pilots (n = 34) %	Captains (n = 80) %	p
ECDIS **40h** theoretical training	21	100	< 0.05
ECDIS specific training	36	100	< 0.05
Good knowledge and attitude toward the electronic devices	44	83	< 0.05
Systematic check of the whole waterway	NA	19	NA
Audible alarms in use	17	53	< 0.05
Annoyance and distraction caused by alarms	29	53	< 0.05
Officers appreciating the on-board pilot equipped with a PPU	NA	71	NA
Officers noting that the pilot does not share information from his PPU	NA	66	NA

the traffic decreased on the Seine by 18% over 11 years, the vessel size increased for economic reasons. Large ships have a limited manoeuvrability in sharp turns > 70° [2] and/or in degraded navigational conditions [20], fog [5] and strong winds [6]. Darkness [4, 8] may double the number of incidents when compared to daylight. Associated with currents, they are the two dominant factors causing 50% of the collisions in the Bosphorus strait [2].

However, Gould et al. [1] studying navigational accidents in the Royal Norwegian Navy did not find that either adverse weather or reduced visibility were common at the time of 35 accidents. It was concluded that seafarers modify their behaviour according to the level of risk.

Liu et al. [20] found that large and low speed cargoes of 10–20 years of age cause most of the groundings. On the contrary, the majority of the collisions were due to small ships < 100 m, < 10 years of age, because of their larger number and higher speed [20] [1, 21]. Surprisingly, in the present study, the size of the ships was not an aggravating factor. Nor was the high workload of the pilot. Akten et al. [2] concluded that safe navigation relies mainly on the levels of seamen's knowledge rather than on the sophistication of the ship's equipment and its condition. In the present study, there were no foundering, ship losses or fatalities amongst seamen confirming that there have been few losses of life in Europe over recent decades [22]. Ship design, number of lifeboats, maritime radiocommunication, aids to navigation, radar, ECDIS and weather forecasting have contributed to improvements in safety [2].

In the UK, out of 90 fatal accidents over a century, fog was particularly related to collisions as well as wrecks close to shore and standings while storms or gales were commonly linked to foundering [22]. The estuary of the Seine is close to the UK. In the present study, fog with a visibility < 500 m, was present in 10 of the 75 accidents.

In the Arctic, poor weather conditions, cold water, charting, lack of communication and navigational aids and its remoteness are some of the challenges for the crew members [23].

In the Three Gorges Reservoir Region, China, between 2009 and 2018, 173 accidents were reported with a 66% incidence of grounding. During that period, the number of accidents declined regularly from 4.5 accidents/10,000 movements to 1/10,000 movements within 10 years. They resulted in 38 casualties (dead/missing), 28 shipwrecks and huge economic losses [21] contrasting with the present study. Cargo vessels were the most involved in the accidents. The influence of traffic density was not obvious. Indeed, it was almost constant over the 10 years ranging from 80,000 to 95,000/year (Table 1). Vessels in poor condition, lack of maintenance, environmental factors and human error were the main causes of those accidents reported. In collision accidents, all the fishing ships sunk while all the accidents involving tankers were groundings.

HUMAN ERROR

One of the key findings of the study was that almost all accidents (96%) were due to human errors of judgment (81%), negligence (53%) or both (39%). Only 3 accidents were mechanically independent of human error.

These data are close to those of the literature, which give an average of 80–90% human error in maritime accidents, whether in confined navigational areas or in the open sea [24]. Accidents are a result of a highly complex set of coincidences leading to a chain of failures [25].

Although errors of judgment or negligence are clearly the fault of individuals, they are often not apparent, remaining in the background in the accidents [11].

Adumene et al. [26] have shown that a high number of other factors can contribute to these errors, such as ignorance of a procedure, the complexity of the links between machine and man, and the organization of companies, or even the body of legislation governing navigation. They analysed marine operations from the Bayesian Network modelling approach in 5 levels (i) external factors (ii) organizational influences (iii) unsafe supervision (iv) preconditions (v) unsafe acts. Each level considers 2 to 6 causal categories for a total of 21.

Using this classification, Hasanspahic et al. [18] studied 135 marine accidents. They found that 2 factors out 21 were the leading cause of the accidents explaining more than 88% of the variability. The first factor was the organizational climate, the second was the software. A reduction in 10% of these contributory factors could reduce the number of maritime accidents by 13%. The authors concluded that maritime industry stakeholders should create an adequate safety climate between master and crew. On the one hand, companies should ensure that masters have adequate leadership knowledge and capability in software work procedures. On another hand, crew members should report inadequate or inapplicable checklists. Their company management should replace obsolete manuals and implement corrective actions and new policies.

In navigational accidents in the Royal Norwegian Navy, [1] found that the most frequently occurring human factors were related to the task-demand imbalance. It included navigator expectations, perceptual demands, attention demand and anticipatory requirements. Performance-shaping factors, which influence the likelihood of an error occurring, contributed to 43% of shipping accidents.

Xue et al. [21] categorized human errors into operational errors, like negligence, management errors, disregard of regulations, fatigue, poor state of health and pilot-related incidents. Failures in the operation of equipment, poor decision making and deficiencies in the operation of the vessel were also described. The 173 reported accidents were principally attributed to negligence and operating errors which were mainly caused by lack of emergency procedures and disregard for applying safe distance and speed regulations.

For Hetherington et al. [16], stress and fatigue in terms of poor health and diminished performance have been a catastrophic contributing factor in groundings. In 1989, the watchkeeper of the Exxon Valdez had had only 5–6 h of sleep. Nowadays, there are shorter sea passages, increased levels of traffic, long discharging operations, reduced manning and rapid turnaround that increase the number of hours on duty. Seamen may work up to 12 h or more with a 6h rest period.

PILOTS

Pilotage is one of the accepted means of minimizing shipping accidents in restricted waters [2, 6]. Safety is the basic task of pilotage. In 2013, only 1/4 of the ships entering or leaving Tianjin port were piloted. Indeed, pilotage is costly and there are often not enough pilots for all ships. The collision probability of vessels without a pilot was found to be about 9 times higher than those with a pilot [27].

On another hand, Park et al. [28] studying 767 Korean port accidents from 2004 to 2013, found that 47 accidents, 6.1% of the accidents, were caused by pilots either noticing an inappropriate command or by the crew failing to execute the appropriate command of the pilots. Fatigue, size of the ship and age of pilots were a matter of concern especially in ships of poor condition and in large ships with improved navigational technology.

From 2002–2016, Acejo et al. [7] studied 693 maritime accidents. Pilot error or mishandling was the 4th cause of immediate collision representing 12.9%. In grounding, pilot error was the 8th cause, representing 6.8% of the accidents.

From 1987–1992, the Canadian Transportation and Safety board reviewed 273 incidents with ships in Canadian pilotage waters on their approach to a port [16]. Of the incidents, 42% involved miscommunication or lack of communication between pilot, captain or the officer on watch. When asked whether bridge officers were reluctant to question a pilot's decision, 92% of the masters said sometimes. These communication issues can often result in errors or accidents.

From 2004 to 2014 in Sweden, Chambers University of Technology showed that the most common causes of the 94 pilotage marine accidents were machinery damage following contact with fixed or floating objects. Significant weather factors contributing to marine accidents were identified as wind and visibility.

In the straits of Istanbul, the primary factors of accident were ships proceeding without a pilot, dense traffic, changes in strong currents, sharp changes in direction and darkness [2]. Factors of secondary importance were a low level of alertness and lack of adequate knowledge of the waterway. The IMO recommends that all ships should use the pilotage services to comply with the requirements of safe navigation.

PPU AND ECDIS

The majority of pilots and captains consider PPU and ECDIS as complementary and useful. Indeed, automation reduces workload and plays a major role in monitoring in real time the collision risk in restricted water. It has changed the role of crew members [16]. Indeed, it controls the relative motion, flow and distance between ships and calculates the rate of turn and lateral placement of the vessel in the channel. However, in the present study, questionnaires revealed that for 2/3 of pilots, theoretical and practical ECDIS training were not considered as sufficient. Pilots requested training or retraining sessions in small groups on simulators.

Pilots and captains complained that GPS, ECDIS, radar or VHF reduce their capacity to concentrate and when installed, reduce their efficiency to such a degree they are unable to cope at times of critical decision making. Lee in 2000, [29] concluded that electronic navigation would reduce workload but at the same time introduce weaknesses that could reduce safety.

The International Maritime Organization, IMO created proactive regulatory frameworks that include (i) SOLAS 1974/78/88 for the safety of life at sea (ii) MARPOL 1973/78 for the prevention of marine pollution (iii) STCW 1978-2010 for the standards of training, certification and watchkeeping for seafarers (iv) COLREG 1972, international regulations for preventing collisions at sea.

However, the adoption and compliance with these regulations is still to be completely adopted. Indeed, the questionnaires have demonstrated that these rules also complicate the interaction between humans and machines placing demands on costly training, risk management and operations. It creates new human weaknesses and amplifies existing ones. For example, in the present study, pilots often limit noisy alarms as they reduce their concentration.

It has been shown that automation was a partial cause of accidents mainly to the over reliance on these systems. It is thus suggested that before navigation, pilots and captains should be encouraged to check that navigational devices like GPS are working properly without any errors. During navigation, they should be encouraged to double check the system with their radar. They should also control that all transmitted information has been displayed and that their system is up to date [5].

In the present study, it was difficult to make conclusions about the impact of the new safety procedures set in 2016, ISO quality, using PPU and ECDIS. Indeed, the study stopped in 2019, and only 3 years were recorded. Worse, the number of accidents increased in 2017 and 2018.

LIMITATIONS OF THE STUDY

The investigation reports did not make it possible to accurately assess the links between the use of navigation aids and all the accidents.

Reports were not standardized and tended to be heterogeneous. All the accident were registered. However, it was estimated that only 30–50% of the near missed incidents and dangerous close situations were probably registered.

Investigators were often highly competent in navigation but not in human factors resulting in competence bias.

In pilots, the perceived fatigue was estimated. It was not clearly quantified nor the amount of rest and sleep. Indeed, sleep was compulsory per 6-hour period. However, when the traffic was dense sleep could have been reduced.

Human errors were not always fully detailed in the accident reports.

Organizational responsibilities were not reported and analysed.

CONCLUSIONS

In the estuary of the Seine, 75 accidents occurred within 11 years of follow up. Groundings were the most frequent accidents (35%, n = 26) followed by contact accidents with the quayside (25%, n = 19), between ships or tugs while manoeuvring (8%, n = 6) or while sailing (1%, n = 1). In poor weather conditions, fog, strong winds and navigation at night, the accident risk increases by 76%. Almost all the accidents (96%) were related to human errors of judgment (81%), or negligence (53%), or both (39). Only 3 accidents were related to mechanical causes.

PPU and ECDIS were considered as useful devices for the prevention of accidents. However, pilots and captains complained about difficulties in mastering the device and software and requested training on simulators. They both felt distracted by the alarms which disrupted their attention while navigating. It must be emphasized that only 20% of the ECDIS were set correctly by captains. Training should be considered of major importance. On the other hand, 74% of the captains were very satisfied with the explanations given by the pilots.

ARTICLE INFORMATION AND DECLARATIONS

Data availability statement: The original contributions presented in the study are included in the article. Further inquiries can be directed to the corresponding author.

Ethics statement: The present work meets the publisher ethical requirement and does not involve studies with animal and humans.

Author contributions: Jean-Claude Chatard: writing text tables and figures, original draft, data curation, statistical analysis, references collection and analysis. Michel Quioc: conceptualization, methodology, questionnaire conception, investigation, data acquisition, direct contact with the pilots and captains, statistical analysis, review, supervision.

Funding: None.

Acknowledgments: The authors thank James Pryce, English native, expert in scientific translation, for reviewing the English manuscript.

Conflict of interest: None declared.

Supplementary material: None.

REFERENCES

1. Gould K, Røed B, Koefoed V, et al. Performance-Shaping factors associated with navigation accidents in the Royal Norwegian Navy. Military Psychology. 2009; 18(sup1): S111–S129, doi: 10.1207/s15327876mp1803s_9.
2. Akten N. Analysis of shipping casualties in the Bosphorus. Journal of Navigation. 2004; 57(3): 345–356, doi: 10.1017/s0373463304002826.
3. Kujala P, Hänninen M, Arola T, et al. Analysis of the marine traffic safety in the Gulf of Finland. Reliability Engineering & System Safety. 2009; 94(8): 1349–1357, doi: 10.1016/j.ress.2009.02.028.
4. Aydogdu Y, Yurtoren C, Park JS, et al. A study on local traffic management to improve marine traffic safety in the Istanbul Strait. J Navig. 2011; 65(1): 99–112, doi: 10.1017/s0373463311000555.
5. Di Ciaccio F, Menegazzo P, Troisi S. Optimization of the maritime signaling system in the Lagoon of Venice. Sensors (Basel). 2019; 19(5), doi: 10.3390/s19051216, indexed in Pubmed: 30857359.
6. Zhang J, Teixeira Â, Soares CG, et al. Quantitative assessment of collision risk influence factors in the Tianjin port. Safety Science. 2018; 110: 363–371, doi: 10.1016/j.ssci.2018.05.002.
7. Acejo IL, Sampson H, Turgo NN, et al. The causes of maritime accidents in the period 2002-2016. 2018.
8. Weng J, Yang D, Weng J, et al. Investigation of shipping accident injury severity and mortality. Accid Anal Prev. 2015; 76: 92–101, doi: 10.1016/j.aap.2015.01.002, indexed in Pubmed: 25617776.
9. Chen P, Huang Y, Mou J, et al. Ship collision candidate detection method: A velocity obstacle approach. Ocean Engineering. 2018; 170: 186–198, doi: 10.1016/j.oceaneng.2018.10.023.
10. Chai T, Xue H, Chai T, et al. A study on ship collision conflict prediction in the Taiwan Strait using the EMD-based LSSVM method. PLoS One. 2021; 16(5): e0250948, doi: 10.1371/journal.pone.0250948, indexed in Pubmed: 33970943.
11. Aydin M, Uğurlu Ö, Boran M, et al. Assessment of human error contribution to maritime pilot transfer operation under HFACS-PV and SLIM approach. Ocean Engineering. 2022; 266: 112830, doi: 10.1016/j.oceaneng.2022.112830.
12. Liu Z, Wu Z, Zheng Z, et al. A novel framework for regional collision risk identification based on AIS data. Applied Ocean Research. 2019; 89: 261–272, doi: 10.1016/j.apor.2019.05.020.
13. Wang Y, Fu S, Wang Y, et al. Framework for process analysis of maritime accidents caused by the unsafe acts of seafarers: a case study of ship collision. J Mar Sci Eng. 2022; 10(11): 1793, doi: 10.3390/jmse10111793.
14. Chauvin C, Lardjane S, Morel G, et al. Human and organisational factors in maritime accidents: analysis of collisions at sea using the HFACS. Accid Anal Prev. 2013; 59: 26–37, doi: 10.1016/j.aap.2013.05.006, indexed in Pubmed: 23764875.

15. Weng J, Liao S, Li G. Bayesian regression model for estimating economic loss resulting from two-ship collisions. Transportation Research Record: Journal of the Transportation Research Board. 2019; 2673(1): 164–172, doi: 10.1177/0361198118821599.
16. Hetherington C, Flin R, Mearns K. Safety in shipping: the human element. J Safety Res. 2006; 37(4): 401–411, doi: 10.1016/j.jsr.2006.04.007, indexed in Pubmed: 17046789.
17. Akhtar M, Utne I. Human fatigue's effect on the risk of maritime groundings – A Bayesian Network modeling approach. Safety Science. 2014; 62: 427–440, doi: 10.1016/j.ssci.2013.10.002.
18. Hasanspahić N, Vujičić S, Frančić V, et al. The role of the human factor in marine accidents. J Mar Sci Eng. 2021; 9(3): 261, doi: 10.3390/jmse9030261.
19. Weng J, Yang D, Chai T, et al. Investigation of occurrence likelihood of human errors in shipping operations. Ocean Engineering. 2019; 182: 28–37, doi: 10.1016/j.oceaneng.2019.04.083.
20. Liu K, Yu Q, Yuan Z, et al. A systematic analysis for maritime accidents causation in Chinese coastal waters using machine learning approaches. Ocean & Coastal Management. 2021; 213: 105859, doi: 10.1016/j.ocecoaman.2021.105859.
21. Xue J, Papadimitriou E, Reniers G, et al. A comprehensive statistical investigation framework for characteristics and causes analysis of ship accidents: A case study in the fluctuating backwater area of Three Gorges Reservoir region. Ocean Engineering. 2021; 229: 108981, doi: 10.1016/j.oceaneng.2021.108981.
22. Carter T, Williams JG, Roberts SE. Crew and passenger deaths from vessel accidents in United Kingdom passenger ships since 1900. Int Marit Health. 2019; 70(1): 1–10, doi: 10.5603/IMH.2019.0001, indexed in Pubmed: 30931511.
23. Kum S, Sahin B. A root cause analysis for Arctic Marine accidents from 1993 to 2011. Safety Science. 2015; 74: 206–220, doi: 10.1016/j.ssci.2014.12.010.
24. Soares C, Teixeira AP. Risk assessment in maritime transportation. Reliability Engineering & System Safety. 2001; 74(3): 299–309, doi: 10.1016/s0951-8320(01)00104-1.
25. Antão P, Soares CG. Causal factors in accidents of high-speed craft and conventional ocean-going vessels. Reliability Engineering & System Safety. 2008; 93(9): 1292–1304, doi: 10.1016/j.ress.2007.07.010.
26. Adumene S, Afenyo M, Salehi V, et al. An adaptive model for human factors assessment in maritime operations. International Journal of Industrial Ergonomics. 2022; 89: 103293, doi: 10.1016/j.ergon.2022.103293.
27. Zhang L, Wang H, Meng Q, et al. Ship accident consequences and contributing factors analyses using ship accident investigation reports. Proceedings of the Institution of Mechanical Engineers, Part O: Journal of Risk and Reliability. 2019; 233(1): 35–47, doi: 10.1177/1748006x18768917.
28. Park Y, Yip T, Park H. An analysis of pilotage marine accidents in Korea. The Asian Journal of Shipping and Logistics. 2019; 35(1): 49–54, doi: 10.1016/j.ajsl.2019.03.007.
29. Lee JD, Sanquist TF. Augmenting the operator function model with cognitive operations: assessing the cognitive demands of technological innovation in ship navigation. IEEE Transactions on Systems, Man, and Cybernetics - Part A: Systems and Humans. 2000; 30(3): 273–285, doi: 10.1109/3468.844353.
30. Bye R, Aalberg A. Maritime navigation accidents and risk indicators: An exploratory statistical analysis using AIS data and accident reports. Reliability Engineering & System Safety. 2018; 176: 174–186, doi: 10.1016/j.ress.2018.03.033.
31. Feng H, Grifoll M, Yang Z, et al. Collision risk assessment for ships' routeing waters: An information entropy approach with Automatic Identification System (AIS) data. Ocean & Coastal Management. 2022; 224: 106184, doi: 10.1016/j.ocecoaman.2022.106184.
32. Guo Y, Jin Y, Hu S, et al. Risk evolution analysis of ship pilotage operation by an integrated model of FRAM and DBN. Reliability Engineering & System Safety. 2023; 229: 108850, doi: 10.1016/j.ress.2022.108850.
33. Kang L, Meng Q, Liu Q. Fundamental diagram of ship traffic in the Singapore Strait. Ocean Engineering. 2018; 147: 340–354, doi: 10.1016/j.oceaneng.2017.10.051.
34. Li M, Mou J, Liu R, et al. Relational model of accidents and vessel traffic using AIS data and GIS: a case study of the western port of Shenzhen city. Journal of Marine Science and Engineering. 2019; 7(6): 163, doi: 10.3390/jmse7060163.
35. Marino M, Cavallaro L, Castro E, et al. Analysis on a database of ship accidents in port areas. Data Brief. 2023; 48: 109127, doi: 10.1016/j.dib.2023.109127, indexed in Pubmed: 37139115.
36. Mou J, Tak C, Ligteringen H. Study on collision avoidance in busy waterways by using AIS data. Ocean Engineering. 2010; 37(5-6): 483–490, doi: 10.1016/j.oceaneng.2010.01.012.
37. Ng T, Park YS, Smith M, et al. A comparison of ES and PARK maritime traffic risk assessment models in a Korean waterway. Journal of the Korean Society of Marine Environment and safety. 2015; 21(3): 246–252, doi: 10.7837/kosomes.2015.21.3.246.
38. Purba PH, Dinariyana A, Handani DW, et al. Application of formal safety assessment for ship collision risk analysis in Surabaya west access channel. IOP Conference Series: Earth and Environmental Science. 2020; 557(1): 012034, doi: 10.1088/1755-1315/557/1/012034.
39. Ugurlu H, Cicek I. Analysis and assessment of ship collision accidents using Fault Tree and Multiple Correspondence Analysis. Ocean Engineering. 2022; 245: 110514, doi: 10.1016/j.oceaneng.2021.110514.
40. Ung ST. Navigation risk estimation using a modified Bayesian network modeling-a case study in Taiwan. Reliability Engineering & System Safety. 2021; 213: 107777, doi: 10.1016/j.ress.2021.107777.
41. Wu X, Mehta A, Zaloom V, et al. Analysis of waterway transportation in Southeast Texas waterway based on AIS data. Ocean Engineering. 2016; 121: 196–209, doi: 10.1016/j.oceaneng.2016.05.012.
42. Xin X, Liu K, Yang X, et al. A simulation model for ship navigation in the "Xiazhimen" waterway based on statistical analysis of AIS data. Ocean Engineering. 2019; 180: 279–289, doi: 10.1016/j.oceaneng.2019.03.052.
43. Zulkifli, N, RI Raja Ibrahim, Fahmi, A Azlan, and A Yasid, Maritime Cooperation in the Straits of Malacca (2016-2020): Challenges and Recommend For a New Framework. Asian Journal of Research in Education and Social Sciences, 2020; 2: 10–32.