POTENTIAL CAUSES OF COLLISIONS AT SEA THROUGH THE HTI PERSPECTIVE (TECHNOLOGY MANAGEMENT)

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ABSTRACT  
This paper discusses potential causes that can trigger collisions at sea from the perspective of Human Technology Interaction (HTI) on board merchant ships. The maritime transport industry (shipping) is accounted for more than 90% of the global trade. Studies have shown that ship collision has been the primary accident category for the past three decades with consequences involving loss of lives and environmental damages. Meanwhile, manoeuvring of ships utilises 90% of technological equipment by the officers on board. Hence, it is crucial to determine potential causes of collision from the Human Technology Interaction (HTI) perspective so that effective preventive measures can be developed based on the potential causes identified. Seven themes or categories of potential causes have emerged as a result of 41 interviews conducted with shipboard officers, shipping company personnel, shipbuilding personnel, trainers at the Maritime Education and Training (MET) institution and marine pilots. Ways to address these potential causes are also discussed.

Keywords: Collisions, Human Technology Interactions (HTI), merchant ships, technology management

INTRODUCTION  
Ship collision has been the primary accident category for the recent three decades (Christian & Kang, 2017). This global scenario emphasises the necessity for safety studies in ship collision occurrence (Calle et al., 2017) since collision also appears to be one of the three primary causes of “serious casualties” (Graham, 2012, as cited in Chauvin et al., 2013). In fact, ship-ship collision events constitute a major hazard for ship operations which can result in the loss of human lives and severe environmental damages (Zhang et al., 2017). Collisions happened due to many causes, which are mainly due to human interaction with technology. Allianz (2014) highlighted that over dependence on technology is seen as a key risk for merchant shipping.

LITERATURE REVIEW  
Human Factor Engineering (HFE) and Human - Machine Interaction (HMI) can be considered under the conceptual umbrella of Human – Technology Interaction (HTI) due to their common ground of how technology can be made useful and beneficial to human (Karvonen et al., 2010). Based on this definition, the researchers has adopted similar definition with regards to Human Computer Interaction (HCI) as well as it has similar ground as what have been discussed by Karvonen et al. (2010). Thus, the terms of HTI,
HFE, HCI and HMI in the following discussion will carry the same meaning of HTI. Sotiralis et al. (2016) concluded that factors such as navigation system detection and Human-Machine Interface (HMI) problems have considerable effects on the performance of the Officer on Watch (OOW) which can lead to collision. Merwe et al. (2016) commented that 67% of the analysed navigational accidents involved issues with the human machine interface. Theoretically, Bharadwaj (2013) argued that, when technology is used to replace human work, this is not necessarily a straight-forward and simple process, which often means that mariners have to work hard to construct a co-operational human machine system. As highlighted by Chauvin et al. (2013), studies dealing with collisions pointed out the role of several factors such as poor use of radar and lack of competency including in competency in handling technological equipment. Thus, the misuse of instrument or specifically, RADAR and ARPA is one of the cause that triggers collision. Besides that, Oltedal (2012) highlighted that among the main categories of causes of collisions between ships and platform can be identified as human deficiency to detect or interpret a technical state or error. The misuse and deficiency to detect or interpret technical state or error has indicated the incompetency in handling the technological equipment which indirectly has triggered collision. From the design of technological equipment point of view, there have been limited practice of more participatory and human-centred approaches, aside from what is required by regulatory bodies and authorities (Costa, 2016). This resistance has contributed to maritime casualties, including collision, associated with poor design (Earthly & Jones, 2010; CyClaDes, 2015; Kataria et al. (2015, cited in Costa et al., 2016). New technology may often create a false sense of confidence, and thereby lead to an increase in the acceptance of risks; there are also examples where the information given by electronic devices is trusted blindly and never questioned (Schröder-Hinrichs et al., 2012). The rise in the so called ‘radar-assisted’ collisions i.e collisions induced by the tendency for multiple vessels to expedite speed and perform sudden changes in direction while ignoring that other vessels could do the same because provided with the same technology (Rozzi and Amaldi, 2012). In addition, 80% of ship collision incidents were due to human errors which have indicated the failure in and inaccuracy of navigator assessments with respect to ship movement, collision avoidance timing, collision danger estimation and appropriate avoidance strategies (Tsou and Hsueh, 2010). Since 90% of navigational tasks on board are using technological equipment, the above 80% collision incidents indirectly has indicated the HTI issues discussed above. Technology on board merchant vessels includes Radio Detection and Ranging (RADAR), Automatic Radar Plotting Aids (ARPA), Electronic Chart Display and Information System (ECDIS) and Automatic Identification System (AIS).

THEORETICAL FRAMEWORK

Traditional HCI/HTI taught that interactive systems should be designed to be effective, efficient, engaging, error-tolerant, and easy to learn (Fallman, 2011). However, review from literature have proved that the objectives of the interactive system was not fully achieved. As such, the researchers would like to verify whether the same causes of collisions still occur on board the merchant vessels recently by assessing the usability measures of the interaction process. The researchers have adopted the Usability framework according to the ISO 9241-11, a standard consisting of specific metrics about how well a user fulfils specific goals (Georgsson and Staggers, 2016). The adoption of ISO 9241-11 in this study was because there was still very little research has been conducted with regards to collision of merchant shipping using the ISO related framework for solving problems related to HTI specifically on the usability framework. The Usability is related to HTI due to the common objectives of interactive system as discussed by Fallman (2011). Figure 1 below depicted the Usability framework which comprised of product and usability measures. According to the framework, the outcome of the interactions between human and technology are measured through efficiency, effectiveness and satisfaction. As such, a successful implementation of HTI on board merchant ships can also be assessed through these parameters.
METHODS
The study was conducted with the purpose of exploring the potential causes of collisions at sea from the perspective of Human Technology Interaction (HTI). Merchant ships can be considered as a sociotechnical system comprised of both human and technology governed by a set of policy and procedures. In the context of Usability framework in Figure 1, the users were represented by the officers performing navigational tasks. Example of navigational tasks includes the monitoring of technological equipment such as the Global Positioning System (GPS), Radio Detection and Ranging (RADAR) and Weather Monitoring, inputting data into the technological equipment such as Automatic Radar Plotting Aids (ARPA), Electronic Chart Display and Information System (ECDIS) besides the visual lookout. The environment on board ships were represented by the complex sociotechnical system comprised of multi-nationality and multi-cultural people interacting with various technological equipment in performing navigation, cargo operation and engineering operation throughout the voyage across the seven seas. As such, it was crucial to determine the outcomes of the interaction between human and technology in terms of its effectiveness, efficiency and user satisfaction. For this purpose, an exploratory study is a valuable means of finding out ‘what is happening; to seek new insights; to ask questions and to assess phenomena in a new light’ (Robson, 2002, cited in Saunders et al., 2009). It is particularly useful if we wish to clarify our own understanding of a problem, particularly in cases where we are unsure of the precise nature of the problem (Saunders et al., 2009). Identifying key issues and key variables forms the main objectives of an exploratory research. Thus, an exploratory study is suitable to answer the research questions.

Many research conducted on maritime accidents and incidents including collisions involved an analysis of quantitative data extracted from the accident and incident statistics (see Xi et al., 2010; Butt et al., 2012; Mazaheri et al., 2013; Weng & Yang, 2015). Thus, the researcher has taken a different approach by utilising the qualitative method in order to gain an in-depth understanding and a deeper insight of the unique sociotechnical system on the merchant ships focusing on the causes of collision. With this technique, the researcher hopes to find a new approach in addressing the collision accidents of merchant ships from the Human Technology Interaction (HTI) point of view. According to Saunders et al. (2009), literature search, interviewing ‘experts’ in the subject and conducting focus group interviews are the
suitable methods to address exploratory research. As such, purposive sampling was adopted in this study involving forty-one (41) participants as represented by Table 1.

Table 1. Participants’ demographic information

<table>
<thead>
<tr>
<th>No</th>
<th>Participants’ Group</th>
<th>No. of Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Front liners / Shipboard Officers</td>
<td>17</td>
</tr>
<tr>
<td>2</td>
<td>Shipping Company Personnel</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>Marine Pilot</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>Certificate of Competency (CoC) Trainers in MET</td>
<td>15</td>
</tr>
<tr>
<td>5</td>
<td>Shipbuilding Personnel</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>41</td>
</tr>
</tbody>
</table>

The participants were interviewed using a semi-structured interview mechanism. The questionnaire for the semi-structured interviews was developed using the Questionnaire Design Protocol (Yin, 2009). Table 2 depicts samples of the questions for the semi-structured interviews.

Table 2. Sample questions for the semi-structured interviews

<table>
<thead>
<tr>
<th>Question</th>
<th>What are the causes of collisions at sea?</th>
</tr>
</thead>
<tbody>
<tr>
<td>What</td>
<td>What are the common sources of errors in collision accidents?</td>
</tr>
<tr>
<td></td>
<td>What do you think are the causes of errors for the above?</td>
</tr>
<tr>
<td>Why</td>
<td>Why did the causes / root causes happen?</td>
</tr>
<tr>
<td></td>
<td>Why the root causes have not been eliminated yet?</td>
</tr>
</tbody>
</table>

The interview data were analysed using the Thematic Analysis (Clarke & Braun, 2014). Thematic Analysis (TA) is a method for identifying and interpreting patterns of meaning across qualitative data; it is not tied up to any theoretically framework; it is suitable for any type of data and can be used inductively, where the analysis is driven by the content of data, by the participants’ language and concepts (Clarke & Braun, 2014).

RESULTS
From the interviews, seven themes have been generated namely lack of familiarisation with technological equipment / automation, low level of understanding of the technological equipment / automation, overreliance and overconfidence, weak implementation of ergonomic designs, reliability issues inclusive of substandard equipment, distractions from technological equipment / automation, and complacency in handling technological equipment / automation.

Theme 1: Lack of familiarisation with technological equipment / automation
The scientific literature has highlighted that in general, there is lack of familiarisation on technological equipment on board ships. It is also related to the level of training they received, particularly during the
first week of joining the ships. As such, majority of the front liners agreed that lack of familiarisation with technological equipment is an issue, as represented by the following narratives:

“Every ship is different in terms of equipment. No training or time allocated like 1 week on board to familiarise with the equipment” [Front liner 10].

Furthermore, since there is no mechanism to measure the compatibility of training equipment in MET and the actual equipment on board, officers still need to get themselves familiarised with the use of the equipment on board even though they have already completed the training ashore. This is due to the different operations of the equipment. Even though every equipment has its own manual, due to time constraint and language that is not easy to understand, officers normally use or refer to the manual if problem arises and not due diligence [Front liner 16 & Front liner 17]. A notable remark made by Shipping Company Personnel 1 on the familiarisation of equipment on board is given below:

“(on advancement of Radio Detection and Ranging (RADAR) technology) actually the function is the same, the complexity is in the additional function” [Shipping Company Personnel 1].

Theme 2: Low Level of Understanding of Technological Equipment

Most feedbacks from Front liner 1, Front liner 5, Front liner 6 and Trainer 1 indicated the lack of understanding in operating the equipment. Among the stated reason are lack of or no practice, do not spend enough time to understand the equipment, users do not fully understand the functions of equipment resulting in using scanty information from automation to operate or make decision during navigation. Other than that, officers are not able to derive information from the equipment because they do not understand the instructions in the manual with language that is not easily to be understood. In addition, to read a manual written in a language that is difficult to understand requires time which the officers cannot afford to spend because of other daunting tasks that they need to do at the same time. Thus, they opt for trial and error, or referring to their seniors to resolve problems related to automation. A notable remark on utilisation of technology by the officers is as follows:

“You have been provided with all those technologies. Firstly, how much of that technology that you are able to use? Secondly, are you aware of the total features that you have there?” [Shipping Company Personnel 2].

Shipping Company Personnel 1 explained that since the level of absorption of training ashore was not measured, thus the two questions could not be answered at this point of time. Therefore, it can be concluded that there is no interaction between human and technology. Instead, it is the accommodation of human into the technological functions, which obviously leads to more risks. On the other hand, exposure to technological equipment should start in the earlier stage of the shipboard training so as to equip officers with the necessary knowledge and skills to perform navigational duty efficiently. However, it also depends on the leadership style on board for the cadets to have adequate exposure. This is clearly indicated in the following comment:

“There are Captains who do not want the cadets to touch the automation. So how the cadets want to learn on board?” [Trainer 3].

“(On understanding of automation) you still need to learn on how to use it and practice in using it. If not, there’s a danger if (it is) wrongly interpreted” [Front liner 12].

As for the Marine Pilot, they rely on the officers to give them information on equipment such as Radio Detection and Ranging (RADAR) and Electronic Chart Display and Information System (ECDIS) during the navigation because they are not familiar with the different types of equipment due to different manufacturers of the technological equipment. Besides, they do not have ample time to look at the equipment since they need to monitor the surrounding and communicate with the third parties such as Wharf Superintendent and Tug boat Masters as well while on duty.

Theme 3: Overreliance and Overconfidence

Overreliance to automation by the officers on board was reflected by the statements given by Front liner 5 and Front liner 7 indicating certain reason such as taking for granted that the equipment would do the job for you. Furthermore, Front liner 7 emphasised that:

“There was an accident where for 3 days the ship was off the course and everyone is following instrument (automation) that shows the passage plan A. On the 3rd day, the ship literally breached on an island and nobody realised it. People are taking it for granted that the instrument is 100% right, which is not true.
Nobody takes the sun sight, and then just rely on Global Positioning System (GPS). I am not saying this is not accurate equipment but all this must be taken with caution. You have to double check on it.” [Front liner 7]

Shipping company personnel also agreed that the “the officers are too dependent, overreliance with the navigation equipment. I can say that they trust 100% the equipment. Did not look outside the window and did not know what is happening. Just do the watch by sitting at the wheel house. That is the problem” [Shipping Company Personnel 3].

**Theme 4: Weak Implementation of Ergonomics Design**

The current practice of the shipping company does not include the front liners’ personal view during the initial design stage of the bridge, as represented in the excerpt below:

“(On feedback from the front liner) Yes, but only after everything is ready. Only people at the shipyard are the main decision makers to produce layout. Feedback (from the front liner) must be based on laws (Safety of Life at Sea (SOLAS), Marine Pollution (MARPOL) then it will be taken into consideration, if personal view, no” [Shipbuilding Personnel].

Furthermore, the shipping company personnel also agreed that the manufacturers have full control on the design of the technological equipment on the bridge of merchant ships.

On the same note, Front liner 5 has highlighted that, “(involvement during the design of the equipment) No. Sometimes, they put Electronic Chart Display and Information System (ECDIS) so far at the corner making it difficult to monitor.”

Meanwhile, ergonomics issues also have plagued the Marine Pilot when manoeuvring the largest vessel called the Triple E class (400m long) due to the absence of automation at the wing side of the ships. Thus, he has to go back and forth from the bridge, which is located at the centre of the ship, and the wing side in order to monitor the movement of the ships at the port.

**Theme 5: Reliability Issues including Substandard Equipment**

Some examples of the unreliability condition of automation are given by Trainer 2, Trainer 3, Front liner 10 and Shipping Company Personnel 2 in relation to the Global Positioning System (GPS) that could give a false reading depending on the area of the voyage, accuracy of equipment (Radio Detection and Ranging (RADAR) and Automatic RADAR Plotting Aids (ARPA)) that depend on weather conditions and service life and probability error of each equipment. Furthermore, detection of other ships depends on the material of the ships, as highlighted by Marine Pilot 4 below:

“Equipment can give you wrong information if wrongly interpret. If the ship is made of metal, or steel, it is easier to detect the radar pulse, but sometimes there are small wooden boats where you cannot detect. The radar is there to help you, but you cannot be 100% reliable on the radar.” [Marine Pilot 4]

The efficiency and reliability of automation will be undermined if it is not correctly set up, regularly monitored, or properly maintained; in fact, these are that tasks that, for the most part, have to be undertaken by the human element of any such system - that is, the seafarer.” (Nautical Institute, 2007).

**Theme 6: Distraction from Automation**

The number of alarms that need to be attended to is also another form of distractions, as clearly highlighted by Front liner 6 and Front liner 10. The statement is also supported by Shipping Company Personnel 1:

“You have so many alarms and then people tend to silent the alarm and they don’t really monitor.”

Automation can bring with it a plethora of alarms, which can be distracting, cause confusion and ignored by those who are not aware of their sources and implications (Nautical Institute, 2007). Due to the need to resolve the urgent matters, the alarms would be interpreted as noise at which they need to be switched off immediately. In addition, the ship owners should ensure that the seafarer is properly trained in the operation of each automated system and that he/she can recognise and respond to any alarm and take the appropriate corrective action in the event of a system failure.

**Theme 7: Complacency in Handling Technological Equipment**
Issues such as indolence and over expecting the automation to do more rather than anticipating the capability and limitation of automation are seen as the common scenario of the current generation in handling the navigational operation on board merchant ships. These statements were highlighted by a number of front liners, trainers and shipping company. Shipping Company Personnel 2 wrapped up the entire scenario with the following statement:

“So when you have a complexity of equipment, your mind was crowded with so many things, where is your priority now? Are you going to use the knob (auto pilot) or are you going to put it on manual and steer the vessel and also pay attention more to the visual lookout, it depends on who is on the bridge.” [Shipping Company Personnel 2]

Other than that, psychological issues and seafarers are becoming more relevant these days due to the increase in accidents and incidents related to human machine interface (Merwe et al., 2016). These psychological issues are reflected in the mind-set setting, which is subsequently reflected in the attitude of a person. It seems like the same approach and mechanism in handling human capability and development for the maritime industry, particularly in merchant shipping, has been adopted for a long time regardless of the advancement of technology.

DISCUSSION

Based on the review of literature, among the causes of collisions with regards to interaction with technology, errors include issues such as lack of familiarisation, overreliance, ergonomics, weaknesses and limitations that are rarely understood by the human operators, standardisation of equipment, and technology that does not support mental models. The themes generated from the findings has reflected the elements of the Usability measurement of the Usability framework of the ISO 9241-11 as depicted in Table 3.

<table>
<thead>
<tr>
<th>Findings of the interviews</th>
<th>Usability measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>i. Lack of familiarization</td>
<td>(In)Effectiveness</td>
</tr>
<tr>
<td>ii. Lack of understanding</td>
<td></td>
</tr>
<tr>
<td>iii. Overreliance and overconfidence</td>
<td></td>
</tr>
<tr>
<td>iv. Complacency</td>
<td></td>
</tr>
<tr>
<td>i. Lack of ergonomic design</td>
<td>(In)Efficiency</td>
</tr>
<tr>
<td>ii. Lack of reliability of technological equipment</td>
<td></td>
</tr>
<tr>
<td>i. Distraction from technological equipment</td>
<td>User (dis)Satisfaction</td>
</tr>
</tbody>
</table>

The root causes and ways to address these potential causes of collisions are further elaborated below.

ADDRESSING THE ROOT CAUSES OF POTENTIAL CAUSES OF COLLISION AT SEA

The root causes of the potential causes of collisions were identified from the content of the interviews as well as from the review of literatures. It was tabled in Table 4 below.

Issues of familiarisation and low level of understanding of technological equipment reflected the absence / lack of training on board ships for the new crew member, particularly with regards to technological equipment. Thus, a proper and systematic training should be provided on board the ships for new officers and the focus should be on familiarisation with the technological equipment. This can be done by having a dedicated training officer appointed by the company to conduct training on monthly basis. Cadets undergoing their shipboard training also can benefit from the dedicated training officer as they will be properly trained to use the actual equipment on board the ships.

Next, the common root causes for the weak implementation of ergonomic design, reliability issues and distractions from automation are the results of incompatibility of human with technology. Ships designers
rarely spend time on board the ships at sea and probably seldom have the opportunity to form a clear understanding of the real working conditions and demands of crew during ship operations (Chauvin et al., 2009; Mallam et al., 2015). This can be addressed by integrating human operators and technology better to avoid mismatches in the human-machine interface (Lützhöft & Dekker, 2002). It is therefore necessary to explore and develop complementary means to elicit, communicate, as well utilise and incorporate the seafarers’ knowledge and experiences into the early stages of design and development process of shipboard workspaces (Österman et al., 2016). In other words, the seafarers / shipboard officers should be involved from the very beginning of designing phase of the technological equipment for ships up to the arrangement of the equipment in the workspaces on board ships. Feedback of the seafarers should be accounted for throughout the process of shipbuilding, particularly on the bridge, where different types of technological equipment for manoeuvring the ship are placed.

Lastly, the root causes of overreliance, overconfidence and complacency while interacting with technological equipment are due to the negative mindset that manifests into negative attitude in handling the automation. As such, a fresh approach from the psychological point of view is needed to address the issue. One way to do this is by adopting the reflective learning of the Oil and Gas industries. Reflective learning is the process of internally examining and exploring an issue of concern, triggered by an experience, which creates and clarifies meaning in terms of self, and which results in a changed conceptual perspective (Boyd & Fales, 1983). By using reflective learning, a case study of collision accidents can be conducted among ship officers. The root causes and consequences of the collision can be discussed and related back to their actual practices in handling automation. Thus, officers will appreciate the value of the lesson learnt from the case study because they can relate it directly with their day-to-day practices, particularly in handling automation and/or technological equipment. Therefore, it is good to adopt this particular practice on board merchant ships and training at MET at both cadets’ and officers’ levels.

The entire elaborations of the above can be summarized as in Table 4 below.

<table>
<thead>
<tr>
<th>Potential causes of collisions</th>
<th>Root causes</th>
<th>Ways to address the root causes</th>
</tr>
</thead>
<tbody>
<tr>
<td>i. Lack of familiarization</td>
<td>Lack of systematic and proper training</td>
<td>Designated Training Officer to plan, develop and implement systematic training on board</td>
</tr>
<tr>
<td>ii. Lack of understanding</td>
<td>Negative mindset that manifests into negative attitude in handling the automation</td>
<td>Adopting ‘Reflective Learning’ to increase awareness and appreciation of the risk involved</td>
</tr>
<tr>
<td>iii. Overreliance and overconfidence</td>
<td>Incompatibility of human with technology</td>
<td>Shipboard officers should be involved in the entire process from the design phase up to the completion phase</td>
</tr>
<tr>
<td>iv. Complacency</td>
<td>User (dis)satisfaction</td>
<td>Shipboard officers should be involved in the entire process from the design phase up to the completion phase</td>
</tr>
</tbody>
</table>
CONCLUSION

Based on the findings, the study concludes seven themes / categories of potential causes that trigger collisions at sea from the perspective of Human Technology Interaction (HTI). These are lack of familiarisation with technological equipment, low level of understanding of technological equipment, overreliance and overconfidence, weak implementation of ergonomic designs, reliability issues inclusive of substandard equipment, distraction from automation in terms of number of alarms, and complacency in handling technological equipment. All these causes can trigger collisions, if they are not handled properly. Recommendations have been put forward to address each of the potential causes, respectively.

REFERENCES


