ROOT CAUSES OF COLLISION AT SEA DUE TO ‘HUMAN TECHNOLOGY INTERACTION’ (HTI) FROM THE ‘TECHNOLOGY ACCEPTANCE MODEL’ (TAM) PERSPECTIVE

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ABSTRACT
This paper discusses the root causes of collision at sea due to Human Technology Interaction (HTI) from the Technology Acceptance Model (TAM) perspective. The purpose was to assess the level of acceptance of technology as aids to navigation on board merchant ships. Shipboard officers, shipping company personnel, shipbuilding personnel, trainers at the Maritime Education and Training (MET) institution and marine pilots were interviewed to assess their perceptions on the root causes of collisions due to interactions with technology. The findings comprised of three distinctive categories namely ‘competency level of officers in handling technological equipment’, ‘ergonomic aspects of the technological equipment’ and the ‘attitude and mindset of the officers in handling the technological equipment’. From TAM perspective, the ‘competency level’ can be associated to the Perceived Ease of Use (PEOU) and Perceived Usefulness (PU). The ‘ergonomic aspects of the technological equipment’ can be associated with the PEOU and the ‘attitude and mindset of officers’ can be associated with the ‘attitude and behavioural intention of the users’. Overall, the level of acceptance of technology by officers on board ships are low in all categories. Based on the weaknesses identified, proper recommendations can be made to the regulatory bodies and shipowners and ships manufacturers to strengthen collaborations in improving the design of the technological equipment, and subsequently, improve the quality of HTI on board ships. Furthermore, future studies can use the same model proposed in this study to assess the level of acceptance of technology for different level of officers or different types of bridge layout on board ships.

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

1. INTRODUCTION

According to Christian and Kang (2017), ship collision has been the primary accident category for the recent three decades. Calle et al. (2017) highlighted that this global scenario emphasises the necessity for safety studies in ship collision occurrence. Collision also appears to be one of the three primary causes of “serious casualties” (Graham, 2012, as cited in Chauvin et al., 2013). Zhang et al. (2017) further emphasized that, ship-ship collision events constitute a major hazard for ship operations which can result in the loss of human lives and severe environmental damages. Collisions happened due to many causes, which are mainly due to human interaction with technology. However, most studies also have pointed out that the root causes of accident other than collisions also revolve around the human interaction with technology. Allianz (2014) highlighted that over dependence on technology is seen as a key risk for merchant shipping.

Merwe et al. (2016) commented that 67% of the analysed navigational accidents involved issues with the human machine interface. 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. Theoretically, Bhardwaj (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-operative 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). Schröeder-Hinrichs et al. (2012) argued that new technology may often create a false sense of confidence, and thereby lead to an increase in the acceptance of risks; there was an example where the information given by electronic devices is trusted blindly and never questioned. 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 have 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). These technological equipment (also known as automation) are installed on the bridge or command centre of the ship in which the navigation operation is performed by the OOW.

As a conclusion, this study is significant since there was no similar study conducted previously to assess the level of acceptance of technology on board ships prior the installation of the technological equipment on the bridge of the ships. The findings will contribute to the improvement of the current level of interaction between human and technology on board merchant ships.

2. THEORETICAL FRAMEWORK OF THE STUDY

Treeratanapon (2012) described the Technology Acceptance Model or TAM as an information system theory that models how users come to accept and use a technology. In terms of shipping, TAM is relevant in assessing the acceptance level of technology by mariners since 90% of navigational tasks on board ships involve technology as an aid to navigation. Marangunić & Granić (2015) claimed that TAM has evolved to become a key model in understanding predictors of human behaviour toward potential acceptance or rejection of the technology. TAM is depicted in Figure 1 below.
The Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) of TAM are considered as the most important determinants of actual system use (Surendran, 2012). Based on the elaboration, the authors have adopted TAM model to assess whether there is a correlation between TAM and the root causes of collision at sea due to human interaction with technology. Since the earlier stage of design of technological equipment and the layout of the bridge (in which the technological equipment is installed), it does not include the opinion from the operators, thus the level of acceptance of the technology was not known until the accident happened. In addition, from the review of literature, there was no similar study has been conducted on finding the relationship between TAM and root causes of collision at sea. It is important to see the correlation since TAM is an established method of measuring the user acceptance of technology.

Table 1 Components of TAM (Surendran, 2012)

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<th>No.</th>
<th>TAM components</th>
<th>Definition/Description</th>
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<tr>
<td>1.</td>
<td>External Variables</td>
<td>Comprised of social, cultural and political factors</td>
</tr>
<tr>
<td>2.</td>
<td>Perceived Usefulness (PU)</td>
<td>User’s believe that using a system will enhance job performance</td>
</tr>
<tr>
<td>3.</td>
<td>Perceived Ease of Use (PEOU)</td>
<td>User’s believe that using a system will be free of effort</td>
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<tr>
<td>4.</td>
<td>Attitude Towards Using</td>
<td>User’s evaluation on desirability of using a particular technology / system</td>
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<tr>
<td>5.</td>
<td>Behavioural Intention to Use</td>
<td>Measure of the likelihood of a user to use the technology / system</td>
</tr>
<tr>
<td>6.</td>
<td>Actual System Use</td>
<td>The targeted system</td>
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From the review of literature above, the most common root causes of collision were blindly trust the technological equipment, misunderstand the information provided thus lead to wrong decision making, deficiency to detect or interpret a technical state or error and failure to incorporate the feedback from the main user during the earlier stage of design of technological equipment. In addition, other root causes lead to navigational accident, particularly collision were inaccuracy of navigator assessments with respect to ship movement, collision avoidance timing, collision danger estimation and appropriate
avoidance strategies. These root causes can be categorised as ‘lack of competency in handling technological equipment’, ‘negative attitude in handling technological equipment’ and ‘weak implementation of ergonomic design’. Hypothetically, the three categories of root causes above can be mapped with TAM under the Actual System Use since the accident and incident happened after the technology has been used in real situation. Figure 2 shows the relationship between TAM and root causes of errors as explained above.

![Figure 2 Research Model – Mapping of Root Causes of Collision with the Technology Acceptance Model (TAM)](image)

3. METHODOLOGY

The purpose of the study was to explore whether any relationship exists between the Technology Acceptance Model (TAM) to the actual root causes of collision at sea due to Human Technology Interaction (HTI). So far, no such study has been conducted to assess the level of acceptance of technology on board even though 90% of navigational tasks involved technology as a tool to assist safe navigation. The sampling method adopted was Purposive Sampling since the subject must be addressed to the navigation operation of merchant ships. As such, seven groups of people ranging from the operators of navigation operation, the shipping company’s personnel that designed and implemented the procedures as well as involved in the shipbuilding, Regulators, Marine Pilots and Trainers that taught the navigational subjects at the Maritime Education and Training Institution (MET). A total of 43 respondents have took part in the study. Since many research conducted on maritime incident and accident including collision involved an analysis of quantitative data extracted from accident and incident statistics as represented by Xi et al. (2010), Mazaheri et al. (2013) and Weng & Yang (2015). Thus the authors have taken a different approach by utilizing qualitative method in order to gain in-depth understanding and insight of the unique sociotechnical system on the merchant ships focusing on the navigation operation. Semi-structured interview is seen as the most appropriate approach when the questions are either complex or open ended and where the order and logic of the questioning may need to be varied. The development of the questionnaire was discussed below.

3.1. Development of questions for the semi-structured interview

From the review of literatures and leveraging on the experience of the respondents, the questionnaire was designed comprised of 4W (What, Why, Who, Where) and 1H (How). Practically, the questions were made as an open ended questions to ensure as many answers can be provided to the authors. A list of questions was depicted in Table 2 below.

![Table 2 List of questions and associated components of TAM](image)
3.2.1. Data analysis approach and mechanism

The interview data were processed using Thematic Analysis (Clarke and Braun, 2014). Thematic analysis (TA) is a method for identifying and interpreting patterns of meaning across qualitative data; not tied up to any theoretically framework; suitable for any type of data and it can be used inductively, where the analysis is driven by the content of the data, by the participants’ language and concepts (Clarke and Braun, 2014). Braun and Clarke (2006) and Vaismoradi et al. (2013) have agreed that an independent qualitative descriptive approach mainly described as “a method for identifying, analysing and reporting patterns (themes) within data”. Sandelowski and Leeman (2012) explained that a theme is defined as a coherent integration of the disparate pieces of data that constitute the findings. It captures important data in relation to the question, and represents some level of response pattern or meaning within the data set (Braun and Clarke, 2006). Five steps of thematic analysis comprised of familiarisation with data and identifying items of potential interest, generating initial codes, searching for themes, reviewing potential themes and lastly, defining and naming themes. Figure 3 below depicted the flow of the thematic analysis explained above.

After completion of the five steps of TA, the authors make sense of the themes by triangulating it with the relevant theory and secondary data wherever applicable.

The focus of this mechanism is to achieve conclusions at the end of the analysis of each objective of the study. In the context of own research, the outcomes of the study can be utilised to improve the current practices of designing technological equipment on board ships.

<table>
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<tr>
<th>No.</th>
<th>Questions</th>
<th>TAM components</th>
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<tbody>
<tr>
<td>1.</td>
<td>How competent are officers in utilizing technology to assist them in navigation operation?</td>
<td>Perceived Usefulness (PU); Perceived Ease of Use (PEOU)</td>
</tr>
<tr>
<td>2.</td>
<td>What do you think of the ergonomics aspect of the technological equipment on board?</td>
<td>Perceived Ease of Use (PEOU)</td>
</tr>
<tr>
<td>3.</td>
<td>How well officers handle the multiple automation during navigating at congested areas?</td>
<td>Attitude towards Using Behavioural Intention to Use</td>
</tr>
<tr>
<td>4.</td>
<td>How does technology gives impact to the execution of tasks during navigation operation?</td>
<td>Attitude towards Using and Behavioural Intention to Use</td>
</tr>
<tr>
<td>5.</td>
<td>What can be improved in terms of the interface between human and technology on the bridge of merchant ships?</td>
<td>Perceived Usefulness (PU); Perceived Ease of Use (PEOU)</td>
</tr>
<tr>
<td>6.</td>
<td>How effective is the current design of technological equipment to assist safe navigation?</td>
<td>Perceived Ease of Use (PEOU)</td>
</tr>
<tr>
<td>7.</td>
<td>How important is the feedback from the operators of technological equipment during the design stage of the technological equipment?</td>
<td>Perceived Usefulness (PU); Perceived Ease of Use (PEOU)</td>
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4. ANALYSIS AND FINDING

4.1. Demographic profile analysis

Purposive sampling was adopted in determining the target group for the study. All respondents chosen have seafaring background as the baseline but differ in their roles and responsibilities at the organisations. Table 3 shows the list of each group of respondent. From Table 2, it can be seen that only one Regulatory Body personnel and one Shipbuilding Personnel were successfully interviewed by the researcher. Time constraint and unavailability of the personnel during the actual date and time of the interviews were the reasons as to why only one participant from each group was available during the interview sessions. However, these two respondents were able to answer the interview questions since they have years of relevant experience.

<table>
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<th>No</th>
<th>Interviewee’s Group</th>
<th>No. of Respondent</th>
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<tr>
<td>1</td>
<td>Front liners</td>
<td>17</td>
</tr>
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Figure 3 Coding steps using thematic analysis

Table 3 Demographic data of the group of respondents
The Regulatory Body personnel has about 5 years of experience as the Director of Safety of Navigation and before that was an experienced seafarer of more than 20 years sailing in the international water. As for the Shipbuilding Personnel, he has about 7 years of experience working in the Shipbuilding division of a shipping company. Furthermore, all 43 respondents have participated in the interviews. All interviews were audiotaped and later transcribed.

4.2. Results and findings

Upon completion of the data collection phase, an inductive thematic analysis (Braun and Clarke, 2006) was performed on the interview transcriptions (Underwood and Waterson, 2013). The findings from the 43 interviews are represented in the form of themes and discussed below for answering the interview questions earlier. The seven questions in Table 1 above can be clustered into three distinctive categories namely competency level, ergonomic aspects and handling of multiple technological equipment and multitasking during navigation operation. The explanation below will consist of the direct interpretation of the root causes and the mapping of the result with the respective TAM components.

4.2.1. Competency level of officers in utilizing technology to assist them in navigation operation

Two themes have been generated addressing the competency level of officers in handling technological equipment namely, lack of familiarization with technological equipment and not fully understand the functions and limitations of the technological equipment. Detailed explanation is given below:

1. Lack of familiarization with technological equipment (automation)

The scientific literature has highlighted that in general, there is lack of familiarization 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. Lack of familiarization with technological equipment is an issue among front liners as represented by the narratives below:

“Every ship is different in terms of equipment. No training or time allocated like 1 week on board to familiarize with the equipment,” said 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 familiarize themselves with the equipment on board even though they have already completed the training ashore. This is due to the operation of the equipment are different. Even though every equipment has its own manual, due to time constraint and the language which is not easy to understand, officers normally open the manual if there is trouble and not for due diligence (Front liner 16 and Front liner 17). A notable remark made by Shipping Company Personnel 1 on the familiarization of equipment on board: “(on advancement of RADAR technology)
actually the function is the same, the complexity is in the additional function,” commented Shipping Company Personnel 1.

A supporting remark from the industry namely the Nautical Institute (2013) has highlighted that today’s seafarers need to be trained on the new technology and equipment; they should not be expected to pick it up after they have joined the vessel, or to undergo familiarisation by other staff on board, who themselves have no formal training or qualifications in the use of such equipment.

4.2.1.2. Low level of understanding of the technological equipment (automation)

Maritime Safety Committee (2006) as cited in Pleskacz (2011) argued that human operators rarely understand all characteristics of automatic system and these systems’ weaknesses and limitations were found to be the main causes of accident or skill errors. For example, due to inadequate skills and insufficient experience, officers used ARPA carelessly, thus creating errors (Tsou and Hsueh, 2010).

Most feedbacks from Front liner 1, 5 and 6, MET Trainer 1 and Regulatory Body are indicating the lack of understanding in operating the equipment. Reason being, lack of or no practice, do not spend enough time to understand the equipment, functions of the equipment are not well understood by the users resulting in using scanty information from automation to operate or to 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 with language that is not easily to be understood requires time which the officers cannot afford to spend because of other daunting tasks that need to be done as well. Thus, they opt for trial and error, or listening to the seniors in resolving the problem related to automation. A notable remark on utilization of technology by the officers:

“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?” commented Shipping Company Personnel 2. Shipping Company Personnel 2 further clarified that there was more value added functions in each of the technological equipment rather than the necessary functions for safe navigation.

Shipping Company Personnel 1 mentioned that since the level of absorption of training ashore is not measured, thus the two questions cannot 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 invite 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 knowledge and skills required to perform navigational duty efficiently. However, it also depends on the leadership style on board for the cadets to have adequate exposure as the comment below:

“There are Captains who do not want the cadets to touch the automation. So how the cadets want to learn on board?” said 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 wrongly interpreted” said Front liner 12.

On the other hand, Marine Pilot 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 navigation because they are not familiar with the equipment on different types of ships. Besides, they do not have time to look at the equipment since they need to monitor the surrounding and communicate with the third parties as well. From the industry point of view, Asyali (2014) emphasized that most of the human errors tend to occur as a result of technologies, work environments, and organizational factors which do not sufficiently consider the abilities and limitations of the people who must interact with them.
4.2.2. Ergonomics aspect of the technological equipment

Three themes have been generated under the ergonomics aspect namely weak ergonomic design, reliability issue and distraction from automation / technological equipment. Elaborations of each theme are as below.

4.2.2.1. Weak implementation of ergonomics design

Poorly designed automation can decrease and subsequently, loss of situation awareness and in extreme circumstances, lead to accidents (Miller and Parasuraman, 2007). On the same note, Bhardwaj (2013) argued that the operating procedures are rarely considered at the design stage, resulting in badly designed interfaces that encourage mistakes at which no amount of training or management intervention can mitigate. The author further emphasized that the voice of the seafarer who is at the sharp end of working with technology must be heard. For instance, his objections to paperwork must be taken seriously, and not rejecting them as mere ignorance, conservatism, or indolence. Thus, it is important to know the requirement of the operators on the bridge in order to perform efficiently during the watch keeping duty. However, the current practice of the shipping company does not include the personal view of the front liners during the initial design stage of the bridge as represented 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 also agreed that manufacturers have full control on the design of the technological equipment.

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

From the industry point of view, Squire (2013) emphasized that the front liners expectations of a ship that is fit for purpose in every respect, but he may not always find that this is the case, because neither he nor any of his predecessors was involved in the design process. SIGGTO (1990) as cited in Asyali (2014) has highlighted that evidence suggested that over 60% of automation errors are committed during the specification / requirements and design phases and the remainder during the software coding.

As a conclusion, it can be seen that the perception of the shipping company is contrasted with the other parties (scientific literatures, front liners, marine pilots and industry) with regards to the ergonomics issues on the bridge of merchant ships.

2. Reliability issues inclusive of substandard equipment

The Automatic Identification System (AIS) has reliability issues as highlighted by Harati – Mokhtari et al. (2011) because of its poor performance and transmission of erroneous information. Thus, it is not reliable to be used as equipment for anti-collision operations. McBride et al. (2014) emphasized that human must involve in error management by detecting, understanding and correcting errors when automation errs due to its unreliability. Examples of the unreliability conditions of automation as examples given by Trainer 2, Trainer 3, Front liner 10 and Shipping Company 2 are, the Global Positioning System (GPS) was giving false reading depending on the area of the voyage, accuracy of equipment (RADAR and ARPA) depends on the weather conditions and service life and probability error of each equipment. Furthermore, detection of other ships depended on the material of the ships as highlighted by the 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”

Nautical Institute (2005) and Nautical Institute (2007) emphasized that the efficiency and reliability of automation will be undermined if they are not correctly set up, regularly monitored or properly maintained in which, these are tasks that, for the most part, have to be undertaken by the human element of any such system - that is, the seafarer.

As such, it can be concluded that the front liners, trainers, shipping company and marine pilots have the same view with the academic researchers and industry with regards to the reliability of the technological equipment (automation). In the context of TAM, low level of Perceived Ease of Use was identified for this theme.

4.2.2.3 Distractions from the automation

An example of distraction from technological equipment or automation can be in the form of information overload especially during critical conditions. Too often there is data or information overload, which overwhelms and confuses the watch officer when he or she is making a necessary decision (Gill, 2011). Other than that, the numbers of alarms that need to be attended to are also another form of distractions as clearly highlighted by Frontliner 6 and Front liner 10. The statement is also supported by the Shipping Company Personnel 1:

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

Nautical Institute (2007) highlighted that automation can bring with it a plethora of alarms, which can be distracting, can cause confusion and can be ignored by those who are not aware of their sources and implications. 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 article further highlighted that, 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.

Taking into consideration the review of literatures, the feedback from shipping company and the industry, the gap seems to be in the form of lack of training in proper usage of automation either on board ships or in Maritime Education and Training (MET).

3. Attitude and mindset in handling of multiple technological equipment and multitasking during navigation

Two themes have been generated namely overreliance and overconfidence and complacency.

4.2.3.1 Overreliance and Overconfidence

An overly complex system design can lead to rejection of the system and humans do not have to really understand software/system operation to develop confidence and trust in system (Madni, 2011). Overconfidence is another problem where too much reliance on automation even when it malfunctions (Miller and Parasuraman, 2007). When there is too much reliance on the automation, it will lead to lack of cross checking of data where officers blindly trust the automation to give them the correct information.

Despite the advantages of precise measurement, calculation and navigation, automation also render flawed judgment and decision processes due to complacency, overreliance, misuse and blind compliance (Mosier and Fischer, 2010). The same scenario of too much reliance given by the officers on board as mentioned by Front liner 5 and Front liner 7 with reasons of taking for granted that the equipment will do the job for you. Furthermore, Front liner 7 emphasized that:
“There was an accident where for 3 days the ship was off 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 realized it. People are taking it for granted that instrument is 100% right, which is not true. Nobody takes the sun sight, and then just rely on 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.”

In addition to modern techniques such as radar overlay of the electronic chart, the traditional track monitoring methods such as parallel index and visual bearings should be included at the control stage as emphasized by the UK P&I Club (2011).

Pleskacz (2011) argued that one of the shortcomings of having the technology on the bridge is the recurring practice of watch keepers assessing a situation solely by looking into console screens instead of looking out the wheelhouse windows. On the same note, shipping company 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,” commented Shipping Company Personnel 3.

In several casualty investigations, automation has resulted in the navigator developing an ‘operational bias’ relying on the automated systems rather than the salient cues provided visually through the bridge window as proved by UK P&I Club (2011). Three years later, over dependence on technology has still been identified as one of the key risks for the future safety of merchant shipping (Allianz, 2014).

It can be seen that overreliance and overconfident are significant root causes since it can lead to accident and incident at sea.

4.2.3.2 Complacency

Complacency as defined by Parasuraman and Manzey (2010) is that operators purportedly did not conduct sufficient checks of system state and assumed “all was well” when in fact a dangerous condition was developing that led to the accident. Wherever possible, individuals are inclined to avoid acting at the more challenging knowledge – based performance level (Gill, 2011). It means that, it is a human nature to do what they perceive as an easier task (or what they know best and have the previous experience) rather than higher level task that requires an integration of knowledge, skills and experience that they have. 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 as well. Shipping Company Personnel 2 has wrapped up the entire scenario with the following statement:

“So when you have a complexity of equipment, your mind-set has now crowded with so many things, where is your priority now? Are you going to use the knob 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”

Psychological issues and seafarers are becoming more relevant these days due to the increase in accident and incident related to human machine interface as cited in Merwe et al. (2016). These psychological issues are reflected in the mind-set setting, subsequently in the attitude of a person. It seems like the same approach and mechanism in handling human capability and development for maritime industry and particularly in merchant shipping is being adopted for so long. Thus, a fresh approach in psychological aspect is needed to address the negative mind-set; hence, becoming a negative attitude that is reflected in the form of overreliance, overconfidence and complacency while interacting with technological equipment.

5. DISCUSSION AND IMPLICATIONS
The findings of the study have indicated that the mapping of the root causes of collision at sea due to interaction of human and technology have resulted in low level of technology acceptance existed in two out of three categories of themes generated above.

Firstly, the competency issues in utilizing technology have reflected issues such as lack of familiarization and lack of understanding in handling automation. Industry and academic researchers have the same views that the inadequate attention given to the abilities and limitations of human has resulted in seafarers’ lack of understanding in automation which sometimes has resulted in accident at sea. From TAM perspective, the lack of competency in utilising technology has indicated that there is a low level / absence of the Perceived Ease of Use (PEOU) as well as the Perceived Usefulness (PU). In terms of PEOU, users have highlighted that familiarization and understanding of the features and limitations of the technological equipment is crucial in order to perform the job as expected. Thus, effort is needed to make themselves comfortable and competent with the system so that they can operate it confidently. On the other hand, there are too many features / functions of technological equipment not utilized since those are the value added functions rather than crucial functions for navigation. It has served as distraction rather than useful functions to enhance the efficiency of navigation, thus reflecting the low level of Perceived Usefulness (PU).

Secondly, the ergonomic aspect of the technological equipment has reflected the weak implementation of ergonomic design, reliability issues and the distractions for automation / technological equipment. Since the opinion / feedback from the users were not taken into consideration during the design stage of the system/technology, users encountered problems such as distractions from number of alarms, overwhelming of information and erroneous data generated by the technological equipment. In the context of TAM, there is a low level of PEOU since a lot of effort is needed for the officers to adapt to the location of the technological equipment since their feedback was not considered during the design of the technological equipment as well as the bridge layout. Distraction from the technological equipment in the form of number of alarms also indicated that the system will not enhance the job performance, instead, degrade it due to the risks involved. Other than that, the risk of misinterpreting data especially during critical condition and reliability issue of the technological equipment reflects that the system cannot enhance the job performance as well.

Thirdly, the attitude and mindset in handling of multiple automation / technological equipment has been represented by the overreliance, overconfidence and complacency. In the context of TAM, the issues of overreliance, overconfidence and complacency are relevant to the high level of negative attitude towards using the technology / system and the behavioural intention to use technology. However, this is not a good impact since overreliance, overconfidence and complacency in handling the technological equipment have been proved to be the root causes of many accident and incident at sea particularly collision.

6. CONSTRAINTS AND FUTURE STUDIES

Constraints observed during the conduct of the study are the scope of the study only for the merchant ships. Other types of ships with different types of technological equipment and bridge layout were not considered. Next, the absence of similar study of mapping the root causes of accident and TAM have restricted the authors to make comparisons to increase reliability of the study. In the future, the method in assessing the relationship between TAM and root causes of collision can be extended to assess the level of acceptance of technology for different types of ships, since different layout of bridge existed. In addition, the method can also be adopted based on the rank of officers to assess the difference in level of acceptance of technology among different rank of officers.

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