University College of Southeast Norway

E Navigation

GNSS, Resilient PNT and the perception of seafarers

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Abstract

The focus of this research is to explore the concept of e-navigation and the testbeds projects associated with it from the perspective of safety of navigation with a more specific focus on the GNSS systems currently used onboard ships and how sea personnel perceives and anticipate the developments in these areas.

The research problem is measuring the attitude of seafarers towards specific navigational safety systems by calculating the perceived ease of use of the current in use GPS system, and measuring the perceived usefulness of upgrading the GPS system to a resilient PNT system.

The research uses parametric methods to analyze responses from a sample of seafarers to reach results of attitude measurement which can be generalized on the population of seafarers.

The research concludes that seafarers perceive a high usefulness of the modernization of navigational safety systems, and that ease of use of the current GNSS systems onboard ships is evident.

Acknowledgement

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Introduction

The digital revolution

The digital revolution known as the third industrial revolution which started during the second half of the 20th century during which there was a change to a high reliability on digital computers in place of conventional mechanical and electronic methods has touched almost all aspects of the human development. Advancements in the digital technologies triggered a fast switch to computer controlled machines and appliances in all areas of economic activities which included the marine navigation as a field of development.

The shipping industry is different than other fields of activities in many ways and in particular in:

1- The shipping industry is an international industry linking trade between different nations but it does not fall under one nation's jurisdiction.

2- The risks associated with sea shipping cannot be managed by single entities and require international collaboration under the cover of an international entity to ensure safety of the personnel involved in the industry. In this case IMO has taken this role.

3- There is a need to harmonize the international standards used worldwide in the sea shipping industry, a platform that can be implemented internationally.

There was a need to collectively identify the areas of development within the sea shipping industry and to further manage the development projects through a standardized internationally-accepted platform. This is where the concept of e-navigation emerged.

History and facts

Traditionally sea shipping has been a catalyst of trade between nations. A tool of international trade dated to 3,000 B.C. when Phoenicians started using their ships to transport goods between the coastal cities of the Mediterranean Sea (*Stopford, M. 1988*). Over time the industry went through development phases and was growing in relation to the growth of international trade until seaborne trade has reached almost 10 billion metric tons of goods in 2014 (*UNCTAD, 2015*).

The size of the industry mandated that a big number of people work onboard ships to drive the industry forward – seafarers "someone who works or travels on a boat or ship on the sea" (*Merriam Webster online dictionary*). However, the scope of this study is limited only to people working onboard cargo carrying ships and not people using ships as a mean of transport as passengers, or people working onboard other types of ships like research ships, fishing ships, or military ships.

The seafarers face daily exposure to risks associated to the nature of the job. One of those risks is the risk of accident during navigation. The risk of accident does not only pose a risk of injury and loss of lives or property, but also a huge environmental impact.

This research aims at relating the new technological developments (part of E-Navigation) which touch the area of safety of navigation to the perception of seafarers, on how these developments might be useful in terms of improving certain areas of safety concerns as outlined in the research questions definition.

Research Questions

The research work is focused on measuring attitude of seafarers toward certain technologies being developed as part of E-navigation initiative. Based on these technologies the research questions are as follows:

Do seafarers believe that e-navigation initiative will have positive impact on the safety of navigation at sea on the long term (7 – 10 years)?

What is the level of perceived ease of use that seafarers currently have in the existing technology?

From seafarers' perspective, what is the level of perceived usefulness of the new technology?

E- Navigation

E-navigation is '*the collection, integration and display of maritime information aboard and ashore by electronic means to enhance berth-to-berth navigation and related services, safety and security at sea, and the protection of the marine environment*': definition from the International Association of Marine Aids to Navigation Lighthouse Authorities (IALA).

The main driving force behind the e-navigation concept is the lack of standardization within the marine transport environment. The technologies used in navigation have been developing rapidly with new equipment and communication systems being developed. However, without a regulatory party leading a collaborative effort toward the development and implementation of these developments, there is a risk that these efforts might not be reaching the expected targets and objectives.

IMO has adapted a policy which relies on user needs as the driving force behind the development of navigation and understands that a collaborative effort to develop, test and implement the new technologies and systems is optimum when developed within the field players in the maritime environment. The objective remains to improve safety and security in maritime transport through reducing the human and systems errors as much as possible.

IMO's maritime safety committee (MSC) approved the e-navigation strategy implementation plan during its 94th session 17-21 November 2014 (*IMO, 2014*)

IMO describes the e-navigation strategy implementation plan as: *a framework and a road map of tasks that would need to be implemented or conducted in the future to give effect to five prioritized e navigation solutions:*

• *improved, harmonized and user-friendly bridge design;*

• *means for standardized and automated reporting;*

• *improved reliability, resilience and integrity of bridge equipment and navigation information;*

• *integration and presentation of available information in graphical displays received via communication equipment; and*

• *improved communication of vessel traffic services (VTS) Service Portfolio (not limited to VTS stations).*

The 3rd point in the strategy implementation plan is addressing reliability of bridge equipment. One of the equipment mentioned by MSC is PNT (Position Navigation and Time) systems onboard ships.

E-Navigation testbeds

While it is established that sea transport has become safer over the course of time, the number of ships considered totally lost every year (ships with 500 GT or more) dropped from 225 in 1980, to 150 in 1996 and 55 in 2011 – *worldwide information published by The International Union of Marine Insurance (IUMI, 2012).*

This progress is a result of:

- Rules and regulations enforcing safety measures and equipment to be followed onboard ships as part of mandatory ship operation procedures. These rules are led by IMO as the main regulatory international body of sea transport. For example, SOLAS convention with the aim to increase safety of navigation by many means
- Technological advances allowing the use of sophisticated equipment increasing the level of overall navigational safety by reducing the risks of accidents. The introduction of modern navigational equipment like GPS, AIS, and ECDIS.

However, navigation remains inheriting risks of accidents due to many factors like human error, weather conditions, cargo deficiencies, etc.…E-Navigation testbeds are development projects aiming at providing technical solutions to certain e-navigation issues by incorporating user experiences on both sea side and shore side to introduce new solutions as part of e navigation concept lead by IMO.

E-Navigation concept is defined by IMO as being driven by user needs, which requires direct interaction with field users during all the phases including development, design, testing, control, and implementation. This mandates that the testbeds must take into consideration involvement of users during the design phase of any e-navigation technology.

In December 2013, the International Association of marine Aids to navigation and Lighthouse authorities (IALA) issued the IALA guidelines No. 1107 on the reporting of results of e-navigation testbeds. IALA assumed the role of issuing these guidelines based on the recommendation of IMO's sub-committee on safety of navigation during its 58th session and agreement of development of guidelines for the harmonization of e-navigation testbeds.

The e-navigation underway 2013 conference identified the need for a body to coordinate the harmonization process of testbeds results. The conference identified IALA to take over this role and to submit the results of the process to IMO.

"A testbed (also commonly spelled as 'test bed' in research publications) is a platform for trialing development projects. Testbeds generally involve rigorous, transparent and replicable testing of, for example, scientific theories, computational tools and new technologies". (IALA, 2013)

The above definition from IALA guidelines is incorporated within a framework which mandates that for testbeds results to be useful certain characteristics need to be existing. These factors include:

- Results should be objective
- Reproducible
- The data collected should be statistically accepted
- The results should be presented in a correct scientific format.

ACCSEAS e-navigation testbed

The ACCSEAS e-navigation test bed is a 3 years project completed in 2015 with a scope to improve navigational safety in the North Sea region. Since the European movement toward encouraging the transport of goods through short sea shipping as an alternative to road transport to avoid bottlenecks on highways and environmental impacts, efficient and safe marine transport is needed more than any time before.

The project identifies two main areas of concern (ACCSEAS, 2015):

1- Main areas of navigational congestion and limited access to ports
2- Prototyping and testing solutions to marine navigational safety improvements in the North Sea region

Resilient PNT

During the 94th session of the maritime safety committee of IMO in November 2014, the E-navigation strategy implementation plan (SIP) was approved. The SIP approaches the solutions to be implemented during the period 2015-2019. One of the solutions is: improved reliability, resilience and integrity of bridge equipment and navigation information including improved reliability and resilience of onboard positioning, navigation and timing (PNT) information by integration with and backup of by integration with external and internal systems. (*Rivkin, 2016*)

Linking the results of the studies on GNSS reliability and increased risk of deliberate jamming of GNSS signals with the inclusion of resilient PNT solution as part of E-navigation SIP leads to exploring the current projects addressing the problem and how secondary systems are being developed as a backup solution to the use of GNSS as a PNT tool of navigation.

The ACCSEAS developed a prototype of a resilient PNT system for further investigation into the feasibility of using e-Loran interchangeably with GPS to provide continuous PNT data to ship systems and deck crew.

Literature Review

Technological advances

The bridge equipment onboard ships have seen developments over time to match with the technological advances. One of these developments, for example, is the introduction of AIS (Automatic Identification System) onboard ships as mandatory equipment on vessels over 300 Gross Tonnage in 2000 by IMO as part of the SOLAS convention (*IMO, Regulation 19 of SOLAS Chapter V - Carriage requirements for shipborne navigational systems and equipment*). In a short description the AIS system is based on equipment onboard a ship which allows the ship to receive identifying information from surrounding ships and to broadcast identifying information to other ships and to vessel traffic service centers.

It was found, after the introduction of AIS as mandatory equipment onboard ships, that this new technology has significantly increased the safety of navigation at sea (*T. Stupak, 2014*).

However, the technology in the AIS system is part of an integrated navigational system that relies on exchange of information from different sources. The AIS transponder, for example, is connected to the ship's GNSS system to obtain the information related to PNT (Position, Navigation, and Timing). In this case the integrity of the data from the GNSS system represents an important factor of the overall AIS effectiveness.

GNSS

The word 'navigation' is derived from the Latin word "navigare" which means "to sail". The word "navigare" itself is originated from "navis", which means "ship", and "agree", which means 'to drive' (*Esmat, 2007*). Essentially navigation is a term used with operating and commanding the travel of a vessel in seawaters.

The advancement in micro-electronics and computer technology allowed the use of economically viable navigation solutions based on Global Navigation Satellite System (GNSS)

through the determination of the location of the vessel as well as its speed of travel. The most popular example is GPS. GPS is a constellation of satellites that transmit radio frequency signals. By trilateration, ground based receivers are able to calculate the position based on the travel time of the satellite's radio signals and information about the actual location, which is included in the transmitted signal. Determination of the receiver's latitude, longitude and altitude is possible when the distance from at least three satellites is known. GPS provides good reliable localization for outdoor navigation as long as there is good satellite coverage. However, it is usually not available in indoor environments. (*Noureldin et al., 2013*).

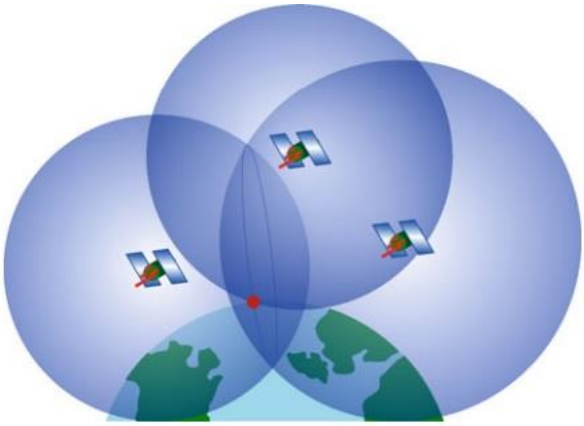

Figure 1 Localization of a vessel by constellation of satellites (Noureldin, et al.,2013)

While GPS system is the most popular system due to its inception since 1971, other initiatives have been established to incorporate more GNSS satellites in orbital positions around planet earth. It can be utilized for civilian uses as well as for military uses. Examples of the systems under development or partially completed include:

- GLONASS – Developed by the Russian aerospace defense forces and used as a substitute to GPS. Since 2012 GLONASS is widely used by GNSS receivers in addition to GPS for navigation (i.e. smart phones).
- GALILEO – Developed by the European Union and currently under development, this system is basically developed for high precision civilian use.

- BeiDou – being developed by China National Space Administration and expected to serve both military and civilian purposes.

The use of GNSS as mean for position, time, and navigation (PNT) has made a change in the way ships are being operated. It allowed integration and interface of GNSS with various systems onboard the ship used for safety of navigation. GNSS data are being integrated into the ship's ECDIS system, while AIS system uses the data from GNSS to broadcast to other ships in the vicinity and shore traffic services important information of the ship like speed and heading.

AIS uses VHF radio waves transmit and receive important information of a ship. AIS was introduced to ships sailing in international trade in 2004. This broadcast of information not only serves the ships in the vicinity, but also vessel traffic services centers are able to record and track marine traffic without any interaction with the passing ships. Subsequently ports have modernized their port management systems to incorporate the data from VTMS (vessel traffic management systems) to automatically record the events of a particular call (waypoints, services provided, event logging, etc.).

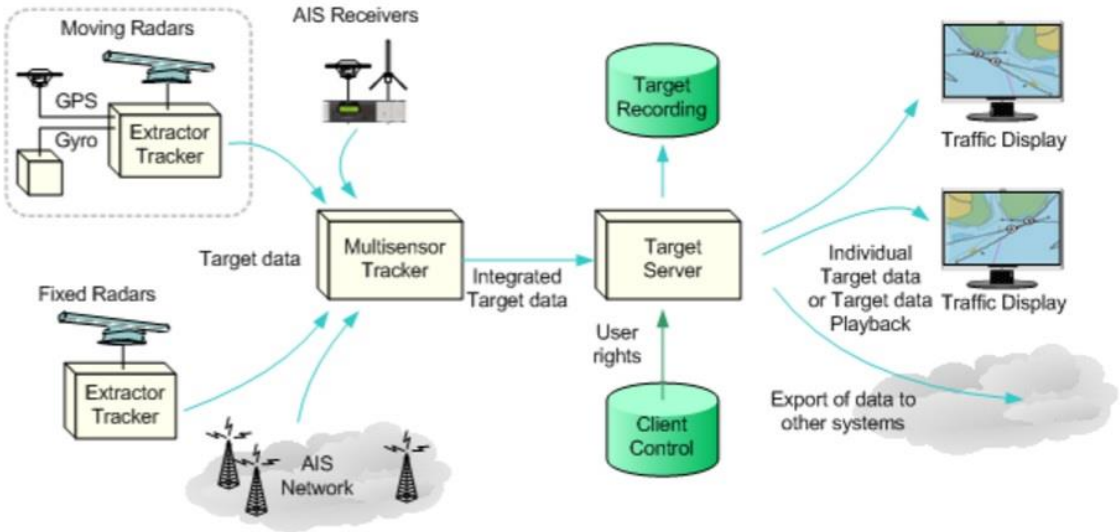

Figure 2. Layout of a modern VTMS system and interface with GPS data through AIS (Vissim, 2015)

GNSS drawbacks

Recent studies have shown that because GNSS signals are received at very low power levels. These signals are subject to interference which can disrupting or completely block the service leaving the ships in the affected area without a highly reliable navigation tool. This threat represents a serious risk to the safety of navigation. Studies have shown the countermeasure to this risk is based on detection and localization of the interference source which is made by the so-called personal privacy devices. (*Bartolucci et al, 2014*)

E-LORAN

The Loran system (short for Long Range Navigation) is an aid to navigation based on radio signal. It provides a way for locating a moving vessel at a given time and for navigation to a predetermined point or along a path of waypoints. E-Loran (enhanced Loran) is a major technology upgrade of Loran-C, but can be provided by the same sites and antenna technology used for Loran-C.

E-Loran conforms to a set of global standards and functions independently of GNSS systems like GPS, GLONASS, Galileo, or any other GNSS. Every e-Loran receiver will be possible to operate in all areas where e-Loran service is available. E-Loran receivers should function automatically with minimum or no user input.

The e-Loran system is made of modern control centers, transmitting centers and monitoring locations. E-Loran broadcast is synchronized to a fixed publicly-certified provider of Coordinated Universal Time (UTC) by a method different from GNSS. This makes the e-Loran Service supplier operate on a time scale that is matches the GNSS time system but operates independently.

The main difference between e-Loran and conventional Loran-C is adding a data channel on the broadcasted signal. This matches application corrections, warnings, and signal

status information to the user's device. The data channel allows e-Loran to match the demanding requirements of landing airplane using non-precision devices approaches and bringing vessels safely to ports in low-visibility due to fog or weather deterioration.(*The international Loran association, 2007*)

Linking to research problem

The focus of the research is approaching safety of navigation from the perspective of seafarers, to measure the attitude of seafarers toward specific technologies, are they aware of the existing challenges to these technologies? Are they aware of the ongoing experimental projects of e-navigation on the topic? measurement of perception or attitude might look as a simple task which can be easily measured and applied, however the complexity of human reactions and attitude make it a more complex task which require scientific approach.

Theory of reasoned action

An important part of introducing a new technology to a work field is to assess the value added by this technology to users and how far users are getting benefit from using it. The innovation process and the perceived value added by the party introducing the technology might not match with the perception of the users or with their abilities to implement the technology correctly to achieve the targeted value added.

In marine navigational safety domain an introduction of a new technology is affecting the safety of lives at sea. Before a change in navigational technologies or navigational tools is implemented the perceived value and the possibility to achieve that value is must be assessed.

The theory of reasoned action is a social psychological model concerned with the determination of behaviors. This theory assumes that the behavior of an individual is the result of a conscious intention based on expectations of the results of the said action.

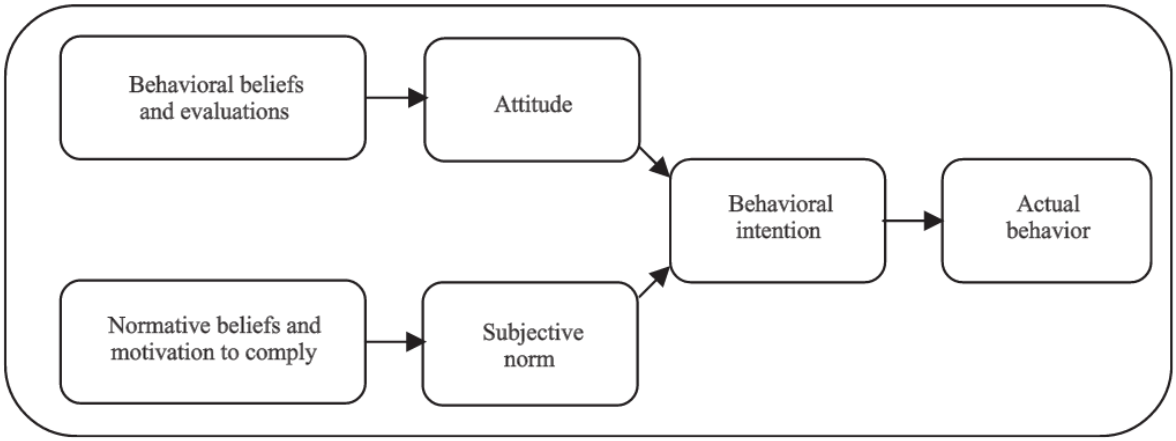

Figure 3. Theory of reasoned action (Fischbein & Ajzen, 1975).

The theory assumes that actual behavior is the direct result of the behavioral intention. However, intention is a result of various factors and can quickly change before the action. Therefore the theory imposes the following conditions to keep the relation between behavioral intention and actual behavior valid: (a) the measure of intention must correspond to the behavioral criterion in action, target, context, and time; and (b) intention does not change before the behavior is observed (*Ajzen & Fishbein, 1980*).

Theory of Planned Behavior

The theory of planned behavior is an extension to the theory of reasoned action. It deals with the limitations of the theory of reasoned action. The theory of planned behavior introduces one additional determinant of the individual behavior by adding control beliefs to the other two determinants previously described in the theory of reasoned action (behavioral beliefs and normative beliefs).

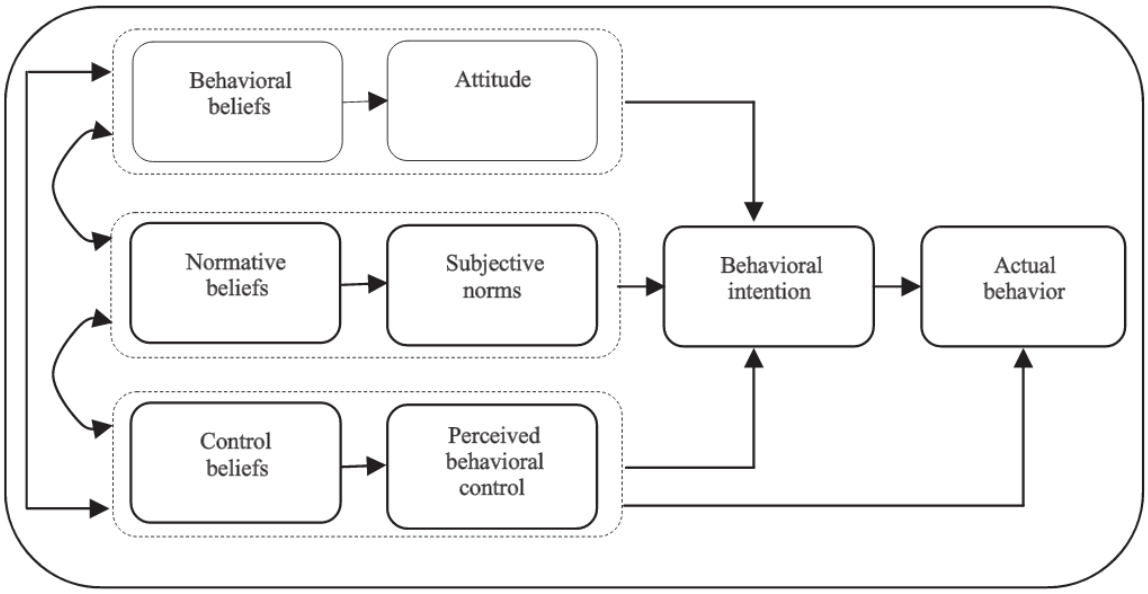

Figure 4. Theory of planned behavior (Ajzen, 1991).

The theory introduces the control beliefs which is the beliefs about the opportunities and resources possessed (or lacked) by the individual and also the anticipated barriers toward performing the behaviors (*Ajzen, 1991*).

Technology acceptance model

The theory of reasoned action and the theory of planned behavior are general models and do not apply to specific actions or domains, i.e. introduction of new technologies in performing a task.

The individual's level of usage and perception of a technology at the workplace differs highly from one individual to another and it remains a complex variable to measure. The technology acceptance model (*Davis, 1986*) introduces two main variables when it comes to the application of a certain technology used at workplace.

Perceived usefulness (PU):

the degree to which an individual believes that using a particular system will enhance his/her job performance and productivity (*Davis, 1986*).

Perceived Ease of Use (PEOU)

the degree to which an individual believes that using a particular system will be free of effort (*Davis, 1986*).

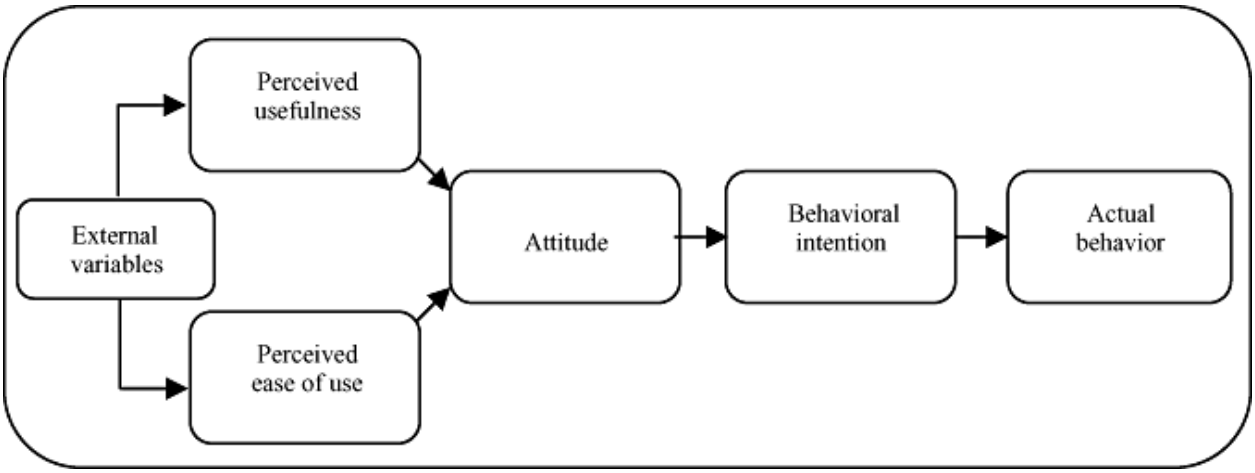

Figure 5. Technology acceptance model (Davis, 1989)

The technology acceptance model approaches the technology in focus differently. An individual behavior will be different with the change of external variables and then it will be affected by both factors of: Perceived usefulness and Perceived ease of use.

These two factors mentioned above will form the attitude of the individual toward a certain technology, the formed attitude will be translated into behavioral intention, the behavioral intention direction precedes the actual behavior which is the final result toward a certain technology.

The technology acceptance model (TAM) was originally developed during a study to test the acceptance of word processor technology (*Davis et al., 1989*) since then the TAM has been considered to be a generic tool to measure user attitude toward introduced technologies and changes to work processes, for example the use of e-mail and the use of the world wide web during the 1990s – a new technology at that time.

It has been proposed that the wide popularity of TAM is related to the following points: (a) it is parsimonious, IT-specific, and designed to provide an adequate explanation and prediction of a diverse user population's acceptance of a wide range of systems and technologies within varying organizational and cultural contexts and expertise levels; (b) it has a strong theoretical base and a well-researched and verified inventory of psychometric measurement scales, making its use operationally appealing; and (c) it has gained strong support for its overall explanatory power (*Mathieson, 1991; Szajna, 1996*).

TAM 2

In the year 2000, Venkatesh and Davis revisited the technology acceptance model to propose an extension to the model (*Venkatesh, et al., 2000*) to incorporate more social influence processes into the model. The three social processes are:

- Subjective norm
- Voluntariness and compliance with social influence
- Image and social influence

The model provided evidence that changes in social influence are possible with experience (*Venkatesh, et al., 2000*). TAM 2 assumes that the effect of subjective norm will be significant prior to implementation and during the early stages of implementation and user experience. However, by the time the system is experienced, trialed, and the user is learning and adapting to the advantages and usage of the system the subjective norm effect will subside as the strengths and weaknesses are further discovered.

This can be linked to a hypothesis that seafarers perceive GPS system as a simple and easy to use system onboard ships. The GPS system has been in use onboard ships since early 1990’s and it is normal that seafarers are being more and more accustomed to usage of GPS after the strengths of the system are experienced and proven.

TAM 2 has introduced “Job Relevance” as a key component which was defined as “an individual’s perception regarding the degree to which the target system is applicable to his or her job”. (*Venkatesh, et al. 2000*)

This can be linked to a hypothesis; that seafarers perceive the development of a resilient PNT system as useful to the safety of navigation. As a PNT system is an integral part of commanding a ship, a PNT system is not only used to fix location and speed of a ship, but it also acts as a main information feeding source to other essential systems onboard the ship which affects the safety of the ship and the crew onboard.

“Output Quality” has been introduced as a factor affecting the perceived usefulness of a system, the way a resilient PNT system will operate and the level of quality of information provided to the commanding crew and the interface with other ship systems (for example ECDIS and AIS) is critical with regards to safety of navigation at sea.

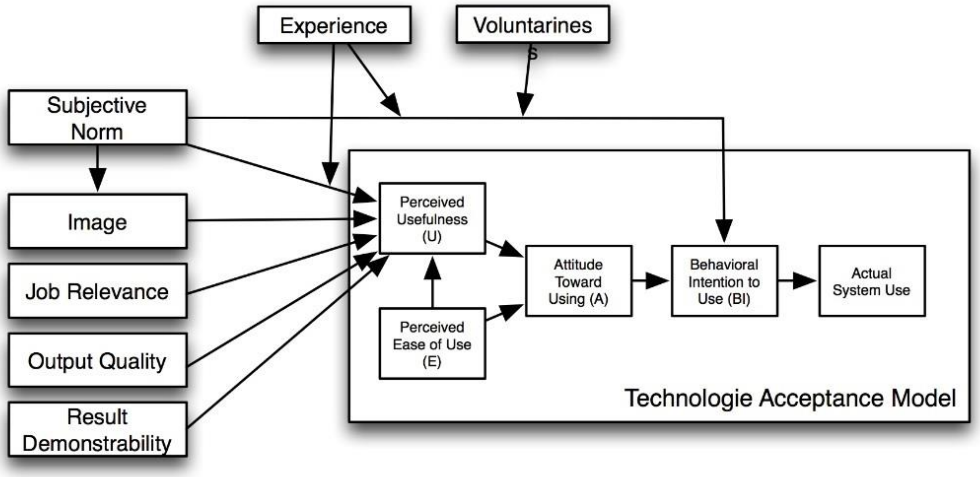

Figure 6. TAM 2 - (Venkatesh & Davis, 2000)

Methodology

The choice of deciding to proceed with a qualitative or a quantitative method is based on the researcher’s assumptions. This study is based on quantitative method and a questionnaire

is developed for the purpose of validating the aim of the study. It was decided to proceed with a quantitative method as it helps to provide a view of the trends in a population or a view of the relationships between the variables (*Creswell, 2011*).

A questionnaire design mated to quantitative analysis was developed in this study to examine the variables in the population. The developed questionnaire is based on the TAM 2 measurement scales and reliabilities to measure both of the variables (perceived ease of use PEOU and perceived usefulness PU) 1 set of questions composed of 4 points related to PEOU and 1 set of 4 questions related to PU. The questionnaire adapts the same model in TAM 2 with slight changes to accommodate the technologies in the scope. (*Davis et al., 2000*)

The questionnaire also includes questions on the demographic characteristics of the respondents to define the characteristics of the sample like gender, nationality, and age. A Likert Scale is applied for each question. The Likert scale is designed to measure how strongly respondents agree or disagree with statements on a five-point scale with the following levels:

(1) Strongly disagree, (2) Disagree, (3) Neutral, (4) Agree, (5) Strongly agree.

Cronbach's α (*Cronbach, 1951*) is a commonly used measure of reliability in the social sciences. Cronbach's alpha reliability defines the reliability of a sum of q measurements. The q measurements may represent q questionnaire / test points. Cronbach's alpha is referred to as a measure of "internal consistency" reliability to measure how the set of questions is consistent with the aim of the set. (*Bonett, et al., 2015*)

The TAM 2 questionnaire used has previously calculated Cronbach's α as follows (Venkatesh & Davis, 2000):

Set of questions	**Cronbach's α**
Perceived ease of use of current GPS system (Questions 2 to 5)	Ranged from 0.86 to 0.98
Perceived usefulness of a resilient PNT system (Questions 6 to 9)	Ranged from 0.87 to 0.98

The recorded Cronbach's α values represents good consistency within each set of question to measure the required variable.

The questionnaire was targeting the population of seafarers (current and previous). The researcher used a paper copy of the questionnaire by visiting ships at his workplace (the Port of Mesaieed, Qatar) and conducted brief interviews with the crew of some ships before letting them fil the questionnaire. Some of the questionnaire papers were handed over to ship agency clerics handling crew change, to be filled by the crew before their sign on – sign off to/from a ship. An electronic version of the questionnaire was created using the website www.surveymonkey.com. An electronically generated link could be extracted linking to the questionnaire and this link was shared through social media within the groups of faculty of technology and maritime sciences (Tekmar) of University College of south-east Norway and in other maritime / seafarers related groups.

Data collection

The questionnaire was distributed in two forms:

1- Online survey was created and it was distributed by the researcher to coworkers and university colleagues. In addition, it was circulated through social media to online groups of seafarers.

2- A paper copy of the questionnaire was given to working crew members onboard ships in my workplace (The port of Mesaieed, Qatar) for them to fill it and return. The majority of responses comes from seamen working onboard large bulk carriers (Supramax to Post-Panamax ships).

Total responses received to the questionnaire is 215 responses. 46 responses were eliminated from the research due to coming from a person who is not a seafarer (13 responses) or for submitting incomplete response (33 responses). The first 5 questions of the questionnaire served to define the characteristics of the sample in terms of (being a seafarer, age group, gender, nationality, and rank).

Demographics:

7 Female respondents were present in the sample representing 3.3% of total respondents, which is a reasonable representation in comparison with the percentage of women seafarers within the population which is estimated at 2% (*International transport workers federation (ITF), 2016*).

Age groups were represented as follows:

Age Group	Percent
<18	0.0%
18 – 29	24.1%
30 – 44	36.3%
45 – 59	29.2%
60+	10.4%

The sample consisted of 169 seafarers from 28 nationalities with 36 responses of Indian nationality and 20 responses of Filipino nationality as the top two nationalities of surveyed

seafarers. Below is representation of nationalities in the sample other nationalities include Romania, Indonesia, Canada, Italy, and Poland among others.

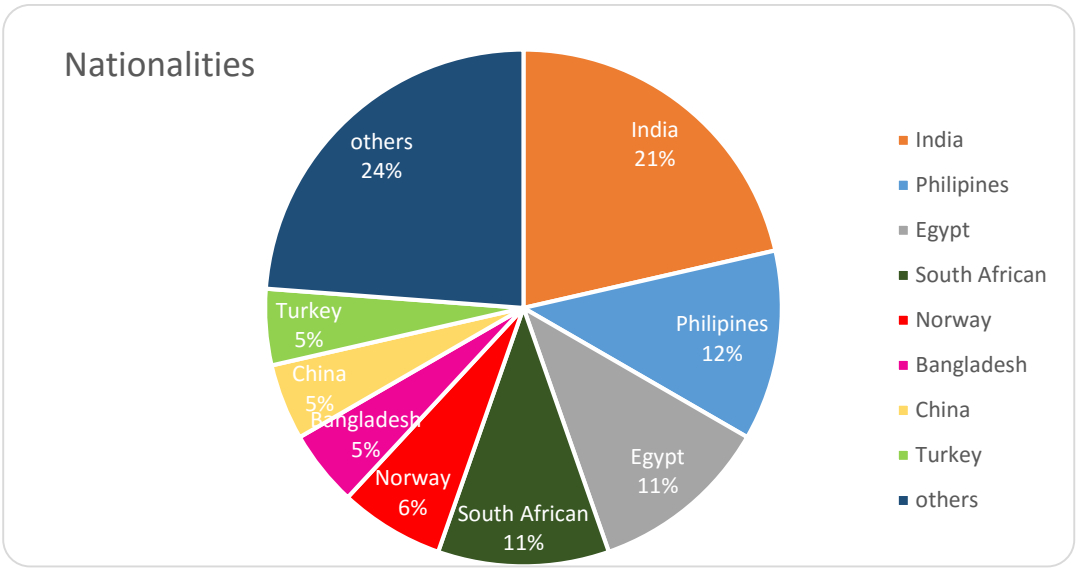

Figure 7. Nationalities distribution in sample

Data Analysis

Unit of analysis

The origin points of the data (*Wetcher-Hendricks, 2011*), in view of the research questions, the unit of analysis of this research is the current personnel holding job positions as seafarers onboard ships.

Variables

A variable is anything that changes (Wetcher-Hendricks, 2011). Each piece of data collected about a unit of analysis (a person) is considered a variable.

The main variables which are being measured in this study are two variables:

1- Perceived ease of use of GPS systems onboard ships
2- Perceived usefulness of a new resilient PNT system onboard ships

Surveys are made to collect data from respondents, usually data collected is classified as one of the following 4 types (Allen, I. E., & Seaman, 2007):

1- Nominal data:

   Data represented by categories without numerical representation

2- Ordinal data:

   Data represented by order or ranking of the response but no distance between the ranks is represented

3- Interval data:

   Data which is based on both order and distance measurement

4- Ratio data

   Data where measurement of order or rank, distance between ranks, and also fraction of variables is possible.

The following table summarizes the differences between the types of data (*Wetcher-Hendricks, 2011*):

Capability	**Nominal**	**Ordinal**	**Interval**	**Ratio**
Provides the ability to define variables' distinguishing factors	Yes	Yes	Yes	Yes
provides ranking of variables	No	Yes	Yes	Yes
provides understanding of differences between variables	No	No	Yes	Yes
Provides relation comparison between variables	No	No	No	Yes

The data is collected using a questionnaire based on Likert scale TAM 2 Questionnaire (*Venkatesh & Davis, 2000*). The Likert scale, which was developed in 1932, is a popular five-point bipolar response scale ranging from least to most, where people are requested to express

their opinion on a 5 points scale where the median point is neutral and expressed as “I don’t know” or “Neutral”.

Elaine Allen and Christopher A. Seaman (2007) described Likert scale data as descriptive statistics and explained that mean, standard deviation, and any other form of parametric analysis will be invalid to calculate the tendency of the data, while non-parametric tools based on the rank like the median or the range are appropriate measures to analyze the data.

Kuzon Jt., et al. (1996) assumed that likert scales data are not interval data and there is no description of the distance between the point of “Neutral” to “Agree” and the point of “Agree” to “Strongly Agree”, for example.

However, it has become a common practice to use parametric methods to analyze Likert scales data (*Blaikie N., 2003*). As a result of considering Likert scale data interval type data and not ordinal, parametric analysis methods will be correctly applied such as the mean, the variance, and analysis of variances “ANOVA”.

Statistical and methodological texts clearly define that measurement of central tendency of ordinal data is done by employing the median or mode, as the mean and standard deviation are not appropriate measures for ordinal data. (Jamieson, 2004). However, Boone H. & Boone D. (2012) mentioned that there is a difference between likert-type questions and likert-scale questions. They explained that Likert-scale questions are a set of four questions or more with internal consistency and relationship between them with the aim to measure the same phenomena. This can be addressed as a description of the TAM 2 questionnaire template employed by this research. The authors (Boone H. & Boone D., 2012) wrote that individual Likert-type data should be measured using non-parametric analysis methods (Median or Mode for central tendency, Frequencies for variabilities), while Likert-scale data should be measured

using parametric analysis tools (Mean for central tendency, and standard deviation for variability).

In response to the arguments about the feasibility of using parametric analysis tools to analyze ordinal data in the form of Likert scale data, Geoff Norman (2010) wrote about the robustness of results generated by using parametric methods to analyze Likert scale data. He concluded that parametric statistics can correctly be used with Likert data, small sample size, with unequal variances, and even with an assumption that the population is not normally distributed. It was stated that this conclusion is supported by empirical literature dating 80 years back.

After reviewing the controversy with regards to the analysis methods for handling the ordinal data, I have chosen to use parametric tools to analyze the data collected from the research questionnaire because I agree with the opinion that while ordinal data does not represent the distances between the points, the use of a Likert scale composed of four questions to measure one variable can be analyzed by combining the response data from the four questions through obtaining a mean of the means from each question as well as standard deviation to receive information which can be attributed to the population and therefore can be generalized to a certain extent. In addition, using parametric tools (for example mean and standard deviation) have been used in around 75% of research works assessing educational, health, and other social aspects effectively (*Norman 2010*). Therefore, the use of parametric tools has been proven relevant to measuring attitude.

After the data is collected and filtered, IBM SPSS 22 statistical analysis was used to process the parametric procedures.

Results

Age groups within the sample

Age

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	18-29	44	26.0	26.0	26.0
	29-44	62	36.7	36.7	62.7
	45-59	47	27.8	27.8	90.5
	>60	16	9.5	9.5	100.0
	Total	169	100.0	100.0	

Gender representation within the sample

Gender

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Female	5	3.0	3.0	3.0
	Male	164	97.0	97.0	100.0
	Total	169	100.0	100.0	

SPSS was used to test the reliability of the Likert scale sets (1 set of four questions measuring perceived ease of use, and 1 set of four questions measuring perceived usefulness) by calculating Cronbach's alpha.

PEOU

Reliability Statistics

Cronbach's Alpha	N of Items
0.838	4

PU

Reliability Statistics

Cronbach's Alpha	N of Items
.866	4

Question number one (aiming at measuring research question number one) responses were analyzed and below is the table of frequencies found as result:

Do you agree that E-navigation initiative will have a significant impact on the safety of navigation on the long term (7-10 years).

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly disagree	5	3.0	3.0	3.0
	Disagree	9	5.3	5.3	8.3
	Neutral	20	11.8	11.8	20.1
	Agree	59	34.9	34.9	55.0
	Strongly Agree	76	45.0	45.0	100.0
	Total	169	100.0	100.0	

Results were analyzed using the mean and standard deviation method:

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Do you agree that E-navigation* initiative will have a significant impact on the safety of navigation on the long term (7-10 years).	169	1.00	5.00	4.1361	1.01732
Valid N (listwise)	169				

The first set of questions, 4 questions aiming at measuring the level of perceived ease of use – Tables of frequencies:

Your interaction with the GPS system is clear and understandable.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly disagree	1	.6	.6	.6
	Disagree	4	2.4	2.4	3.0
	Neutral	13	7.7	7.7	10.7
	Agree	60	35.5	35.5	46.2
	Strongly Agree	91	53.8	53.8	100.0
	Total	169	100.0	100.0	

Interacting with the GPS system does not require a lot of your mental effort

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly disagree	4	2.4	2.4	2.4
	Disagree	11	6.5	6.5	8.9
	Neutral	19	11.2	11.2	20.1
	Agree	55	32.5	32.5	52.7
	Strongly Agree	80	47.3	47.3	100.0
	Total	169	100.0	100.0	

The GPS system is easy to use

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly disagree	1	.6	.6	.6
	Disagree	3	1.8	1.8	2.4
	Neutral	14	8.3	8.3	10.7
	Agree	57	33.7	33.7	44.4
	Strongly Agree	94	55.6	55.6	100.0
	Total	169	100.0	100.0	

It is easy to get the GPS system to do what you want it to do

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly disagree	3	1.8	1.8	1.8
	Disagree	5	3.0	3.0	4.7
	Neutral	17	10.1	10.1	14.8
	Agree	62	36.7	36.7	51.5
	Strongly Agree	82	48.5	48.5	100.0
	Total	169	100.0	100.0	

The mean value and the standard deviation is obtained for each question of the set:

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Your interaction with the GPS system** is clear and understandable.	169	1.00	5.00	4.3964	.78086
Interacting with the GPS system does not require a lot of your mental effort	169	1.00	5.00	4.1598	1.01971
The GPS system is easy to use	169	1.00	5.00	4.4201	.76831
It is easy to get the GPS system to do what you want it to do	169	1.00	5.00	4.2722	.89136
Valid N (listwise)	169				

The variable Perceived Ease of Use of GPS system (research question No. 2) is calculated based on the mean of the set of 4 scale question. Standard deviation is also calculated.

Descriptive Statistics

	N	Minimum	Maximum	Sum	Mean	Std. Deviation
PEOU GPS	169	1.00	5.00	728.75	4.3121	.71484
Valid N (listwise)	169					

The second set of scale questions – 4 questions (research question No. 3), table of frequencies:

A resilient PNT is useful onboard a ship

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly disagree	2	1.2	1.2	1.2
	Disagree	2	1.2	1.2	2.4
	Neutral	34	20.1	20.1	22.5
	Agree	53	31.4	31.4	53.8
	Strongly Agree	78	46.2	46.2	100.0
	Total	169	100.0	100.0	

A resilient PNT solution can improve the effectiveness of your work onboard the ship

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly disagree	2	1.2	1.2	1.2
	Disagree	9	5.3	5.3	6.5
	Neutral	36	21.3	21.3	27.8
	Agree	45	26.6	26.6	54.4
	Strongly Agree	77	45.6	45.6	100.0
	Total	169	100.0	100.0	

A resilient PNT solution can improve the safety of navigation.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly disagree	3	1.8	1.8	1.8
	Disagree	5	3.0	3.0	4.7
	Neutral	33	19.5	19.5	24.3
	Agree	43	25.4	25.4	49.7
	Strongly Agree	85	50.3	50.3	100.0
	Total	169	100.0	100.0	

The GPS system is reliable in terms of safety of navigation

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Strongly disagree	2	1.2	1.2	1.2
	Disagree	10	5.9	5.9	7.1
	Neutral	15	8.9	8.9	16.0
	Agree	61	36.1	36.1	52.1
	Strongly Agree	81	47.9	47.9	100.0
	Total	169	100.0	100.0	

Results were analyzed using the mean and standard deviation method:

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
A resilient PNT is useful onboard a ship	169	1.00	5.00	4.2012	.88358
A resilient PNT solution (a system designed to use GPS / eLoran interchangeably) can improve the effectiveness of your work onboard the ship	169	1.00	5.00	4.1006	.99190
A resilient PNT solution (a system designed to use GPS / eLoran interchangeably) can improve the safety of navigation.	169	1.00	5.00	4.1953	.97149
The GPS system is reliable in terms of safety of navigation	169	1.00	5.00	4.2367	.92753
Valid N (listwise)	169				

The variable Perceived Usefulness of a resilient PNT system (research question No. 3) is calculated based on the mean of the set of 4 scale questions, standard deviation is also calculated.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
PU_RPNT	169	2.00	5.00	4.1834	.79737
Valid N (listwise)	169				

Confidence interval of the means is calculated:

One-Sample Test

	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
E-navigation	52.854	168	.000	4.13609	3.9816	4.2906
PEOU GPS	78.420	168	.000	4.31213	4.2036	4.4207
PU_RPNT	68.205	168	.000	4.18343	4.0623	4.3045

One additional step is calculated to explore differences in perceived usefulness of resilient PNT system between the age group No. 3 (29-44) and age group No. 4 (45-59) by performing an independent sample t-test.

Independent Samples Test

		t-test for Equality of Means						
		t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
							Lower	Upper
PU_RPNT	Equal variances assumed	.543	107	.588	.07962	.14669	-.21118	.37041
	Equal variances not assumed	.541	97.702	.590	.07962	.14727	-.21264	.37188

Discussion

The research is centered on providing answers to the three research questions outlined in the introduction section of this document. The focus is on measuring attitude of seafarers on three specific subjects:

1- Perception of e-navigation initiative as a changing factor to safety of navigation

2- Perceived ease of use of the GPS system

3- Perceived usefulness of developing a resilient PNT system

The three hypotheses associated are:

Hypothesis a:

The mean of the responses from the Question No. 1 responses is equal to or greater than 3.

Hypothesis b:

The mean of the combined responses of the first set of questions (questions 2 to 5) is equal to or greater than 3.

Hypothesis c:

The mean of the combined responses of the second set of questions (questions 6 to 9) is equal to or greater than 3.

To evaluate the results of this research, I start by testing the reliability / consistency of the data collection tool (the questionnaire) which is built based on the TAM 2 questionnaire template (Venkatesh & Davis,2000). The reason a template questionnaire was used to base a new questionnaire is the established reliability of the sets used. The level of consistency is measured by calculating Cronbach's α of each set of question, and by comparing these values to the TAM 2 questionnaire Cronbach's α, the following is found:

Set of questions	**Cronbach's α TAM 2**	**Cronbach's α this research**
Perceived ease of use of current GPS system (Questions 2 to 5)	Ranged from 0.86 to 0.98	0.838
Perceived usefulness of a resilient PNT system (Questions 6 to 9)	Ranged from 0.87 to 0.98	0.866

Comparing the values predicts that the modified questionnaire maintained to a large degree the consistency of the original TAM 2 questionnaire and that each set of questions was internally consistent and consequently predicting good reliability.

Calculating the mean of the responses to Question No. 1 reveals a mean of 4.13 and standard deviation of 1.01. The standard deviation of 1.01 suggests that the sample is distributed close to the mean.

The confidence interval between 3.98 and 4.29 suggests that the true mean in the population is within this range. All data supports hypothesis a; that seafarers perceive the e-navigation initiative as having a positive effect on the safety of navigation.

The second variable of this research is the perceived ease of use of the GPS system, the research question tries to measure the attitude of seafarers toward the ease of use of the GPS technology which is not a new technology and have been in use on a large scale since the 1980s/early 1990s, the hypotheses assumes a high perceived ease of use value due to the system being used for long time by seafarers which by consequence assumes that the user experience with GPS system is favorable and not complicated.

In terms of numbers returned from the analysis of combined means of the Likert scale set of questions to measure this variable, the combined mean of the scale is 4.312 and standard deviation of 0.714. The low standard deviation gives an indication that the data is distributed close to the mean. The mean of 4.312 indicates that seafarers share a high perceived ease of use toward the GPS system. They don’t find it difficult to deal with and they can understand it correctly.

The confidence interval in the range 4.203 – 4.420 suggests that the distribution in the population is similar and that the results can be effectively generalized to describe the characteristics of the population of seafarers. Hypothesis b is supported.

The combined mean of the second set Likert scale questions to measure perceived usefulness of a resilient PNT system is found 4.183 with a standard deviation of 0.797, which indicates a high value of perceived usefulness. The data is distributed close to the mean indicated by the relatively low confidence interval. Hypothesis c is supported.

One additional step was performed during data analysis to explore the differences between two groups with regards to PU. The two groups selected are two age groups: group 3 (29-44) and group 4 (45-59).

The independent sample t-test results show that Levene's Test for Equality of Variances significance at 0.871 indicates that variabilities in the two groups responses are about the same. The t-test results show significance (2-tailed) of 0.588 indicates that the difference between the means of the age groups is likely to be due to chance and not due to a difference in the attitude based on age difference.

Limitations

The research work has some limitations affecting the generalizability of the results to the population which also implies possibilities of further research. First limitation is that several opinions in literature do not agree that parametric measures are appropriate to analyze ordinal data generated by Likert scale questions and that other measures should be applied like Mode instead of mean and standard deviation. This controversy affects the generalizability of results. More research might be useful if combining different methods parametric and non-parametric in measuring attitude and comparing results to strengthen the research results.

Another limitation is the fact that the sample was not representing seafarers working onboard different types of vessels as the majority of the responses comes from seafarers on one particular ship type, bulk carriers. This can be taken as a further area of research where

the ship type is selected and then differences in attitudes based on ship type experience is measured.

The focus of the research was the population of seafarers in general. Responses were collected based on the fact that the respondent is a seafarer without separating the sample based on rank categories or departments within a ship.

Conclusions

The focus of the research was measuring attitude of seafarers towards specific subjects in order to answer three research questions. The research concludes that while it is a complex process to measure attitude it remains possible to get reliable results about the attitude of the population of seafarers by applying standard attitude measuring techniques.

The research found that the efforts of the maritime community to introduce modern solutions to improve the safety of navigation at sea are perceived positively by seafarers. Seafarers perceive e-navigation as a positive initiative toward improvement of safety of navigation.

It was concluded that seafarers perceive the new systems of navigation more positively by the increase of time the technology has been used onboard ships. This is concluded through the high perceived ease of use of GPS system which is in use since 1980s.

In view of the current threads to GNSS effectiveness as a PNT tool onboard ships, seafarers believe that the introduction of a new resilient PNT system will have a positive effect on their work and it will effectively increase the level of navigational safety.

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Appendix 1: Questionnaire

Questionnaire on e-navigation, GNSS and resilient PNT

This questionnaire is intended to be filled by current or previous seagoing personnel.

Appendix A include some details and definitions aimed at clarifying some of the terms included in the questionnaire, it might be useful to read the appendix before filling the questionnaire.

Are you a seafarer? ☐Yes ☐No

Current or last rank: _____

Age: _____

Gender: ☐Male ☐Female

Nationality: _____

Please mark the answer that best describes your opinion:

1- E-navigation initiative will have a significant impact on the safety of navigation on the long term (7-10 years).

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Disagree I don't know Agree

2- Your interaction with the GPS system** Is clear and understandable.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Disagree I don't know Agree

3- Interacting with the GPS system does not require a lot of your mental effort.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Disagree I don't know Agree

4- The GPS system is easy to use.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Disagree I don't know Agree

5- It is easy to get the GPS system to do what you want it to do.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Disagree I don't know Agree

6- The GPS system is reliable in terms of safety of navigation.

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

Disagree	I don't know			Agree
7- A resilient PNT*** solution (a system designed to use GPS / eLoran interchangeably) can improve the safety of navigation.				
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Disagree	I don't know			Agree
8- A resilient PNT solution (a system designed to use GPS / eLoran**** interchangeably) can improve the effectiveness of your work onboard the ship.				
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Disagree	I don't know			Agree
9- A resilient PNT is useful onboard a ship				
☐ 1	☐ 2	☐ 3	☐ 4	☐ 5
Disagree	I don't know			Agree

***e-Navigation** is an International Maritime Organization (IMO) led concept based on the harmonization of marine navigation systems and supporting shore services driven by user needs.

*** GPS system uses communicating with satellites to determine the direction and speed of the ship, and this information is relayed on the screen. Marine GPS is often integrated with a chartplotter program so that the course of the ship can be plotted electronically and the GPS can be used to monitor how closely the ship is sticking to the plotted course, A basic marine GPS system may be handheld, designed to mount onto an instrument panel, or integrated directly into the instrument panel of the ship.

While the system serves as an important information feeding system to other navigation systems, the GPS system is not to be confused with ECDIS or AIS.

***A **resilient PNT** solutions aim to provide dependable navigation solutions at all times, even under GPS interference and jamming conditions, through the use of complementary backup navigation systems that are independent of GPS.

****Enhanced Loran (eLoran)** is an internationally-standardized positioning, navigation, and timing (PNT) service for use by many modes of transport and in other applications. It is the latest in the longstanding and proven series of low-frequency, LOng-RAnge Navigation (LORAN) systems.