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Journal of The Arab Institute of Navigation

Semi Annual Scientific Journal
Issue 46 (volume 2) July 2023
pISSN (2090-8202) - eISSN (2974-4768)
https://doi.org/10.59660/46772
INDEXED IN (EBSCO)

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Impact of Risk Assessment of ECDIS on Its Situational Awareness for Marine Officers

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DOI NO. https://doi.org/10.59660/46737
Received 08 November 2022, Revised 12 January 2023, Acceptance 25 February 2023, Available online and Published 01 July 2023

المستخلص

لتخطيط الرحلة البحريه، يعد نظام عرض الخرائط الإلكترونية والمعلومات (ECDIS) أداة تشغيلية حيوية معترف بها على أنها متوافقة مع المخططات الورقية الحالية. نظرًا لأن الملاحة الإلكترونية أصبحت ذات أهمية متزايدة من خلال الجمع بين التقنيات الحالية والجديدة لزيادة سلامة الملاحة والكفاءة التجارية والأمن، فقد تم إدخال تطوير أدوات الملاحة الإلكترونية. ومن الأمثلة على هذه الأجهزة (AIS) ، (ARPA) ، و (NAVTEX) ، بالإضافة إلى برامج Tide and Sailing Direction. على الرغم من أن ECDIS أداة ملاحية ممتازة للسلامة البحرية، إلا أنها لا تزال تواجه العديد من التحديات مع سيناريوهات مختلفة على متن السفينة، والتي تهدد السلامة البحرية وتمنع اتخاذ القرار الأفضل في وجود ECDIS على متن السفينة، سواء كانت أساسية أو مساعدة للملاحة. تهدف هذه الدراسة إلى تحسين وعي الضباط للملاحة الذكية من خلال معالجة قصور نظام عرض الخرائط الالكترونية والوصول إلى مستوى كافٍ من أداء ECDIS. في هذا البحث، تم إجراء نهج مختلط (مقابلة، استجواب) لاستكشاف عوامل تقييم المخاطر التي يمكن أن تعزز الوعي للضابط باستخدام برامج ((SPSS) / (AMOs) / (NVivo)) . استخدم المسح أداة الاستجواب كطريقة لجمع البيانات، وتم استخدام تقنيات تحليل البيانات المختلفة لتلبية أهداف البحث. تهدف الدراسة إلى اكتشاف ما إذا كان ECDIS متصلاً بأجهزة مساعدة ملاحية إضافية من خلال ٣ أبعاد لتقييم المخاطر (تفادى التصادم، الظروف الجوية والتحذيرات والتنبؤات المتعلقة بالملاحة) سيعزز الوعي للضباط. خلصت الدراسة إلى أن الأجهزة مثل (AIS و RADAR و ARPA و NAVTEX) بالإضافة إلى برنامج TIDE مهمة وستكون مفيدة للغاية إذا كانت مرتبطة بـ ECDIS وتعزز الوعي للضباط.

الكلمات المفتاحية: نظام عرض الخرائط الالكترونية ، الملاحة الإلكترونية، تقييم المخاطر، والوعي ، تفادى التصادم، الظروف الجوية.

ABSTRACT

For passage planning, Electronic Chart Display and Information System (ECDIS) is a vital operational tool that is acknowledged as being compatible with current paper charts. As e-navigation becomes increasingly significant by combining existing and new technologies to increase navigation safety, commercial efficiency, and security, the creation of e-navigational tools has been launched. Automatic Identification System (AIS), Automatic Radar Plotting Aid (ARPA), and Navigational Telex (NAVTEX), as well as the Tide and Sailing Direction programs, are examples of these devices. Although ECDIS as an excellent navigational tool for maritime safety, it is still facing several challenges with different onboard scenarios, which threaten marine safety and prevent having the best decision in the presence of ECDIS onboard, whether primary or aid to navigation. This study aims to discuss the officers' situational awareness for smart navigation by addressing ECDIS issues and reaching a sufficient level of ECDIS performance. In this research a mixed approach (Interview and Questionnaires) conducted to explore risk assessment factors that could enhance officer's situational awareness by using ((NVivo)/ analysis of a moment structures (AMOs) / Statistical Package for the Social Sciences (SPSS) programs. The survey used a Questioners as a data collection method, various data analysis techniques are employed to meet research objectives. This study aims to discover if ECDIS is connected to additional Navigational Aid devices through 3 Risk Assessment dimensions (collision avoidance, under keel clearance, weather and navigation warning) will be enhance officers' situational awareness. Study concluded that devices such as (AIS, RADAR, ARPA and NAVTEX) in addition to TIDE program are important and will be very useful if they are linked with ECDIS and enhance officers' situational awareness.

Keywords: ECDIS, E-Navigation, Risk Assessment, Situational Awareness.

1. INTRODUCTION

The development of electronic navigational tools has been introduced in recent times, as it has become very important for safe navigation, by integrating new and old technologies together to improve security and safety of navigation. International Maritime organization (IMO) has been interested in developing ECDIS as one of the basic electronic navigational tools, as a device that assists in electronic marine navigation, beside the other navigational tools such as; the Gyro Compass, Global Positioning System (GPS), Radio Detecting and Ranging (Radar), Automatic Radar Plotting Aid (ARPA), Automatic Identification System (AIS). ECDIS is a very sophisticated and complex system that, in addition to performing navigational tasks, also incorporates computer-based information system components that provide a real-time representation of the navigator's own vessel position (Weintrit and Neumann, 2015). For many years, risk assessment has been used to improve the safety precautions in various aspects of vessel operation. It hasn't yet been directly extended to ECDIS and all of its features. The marine industry has been slow to adopt ECDIS despite the clear benefits of electronic charts over paper charts (Hanson et al., 2017).

The following are some examples of collisions that have already been investigated and found to be ECDIS related as, Ovit (MAIB, 2014), Commodore Clipper (MAIB, 2015) and MV Muros

(MAIB, 2017). The conclusions in all of these cases are nearly identical. The ECDIS system had no technical issues and performed flawlessly in all situations. All of the events were caused by ineffective use of the equipment or poor performance by the bridge crew. As a result, the term "ECDIS-assisted accidents" isn't entirely accurate (Cho et al., 2019).

Accordingly, this research aims to enhance marine officer's situational awareness through providing the better mode of navigation in a way of minimizing collisions and achieving safe distance, speed and course without causing confusion to officers with much information present on the device. Therefore, this research explores areas for better maritime navigation to improve marine officers' situational awareness, which is achieved through accomplishing an adequate level of ECDIS performance.

2. PROBLEM STATEMENT

Despite the fact of having ECDIS as a good navigational tool for maritime safety, it is still facing several challenges with different onboard scenarios which decrease the level of marine safety and prevent from having the best decision in the presence of ECDIS onboard, whether primary or aid to navigation.

A gap is still present between the situational awareness according to the current status of what ECDIS actually provides as a navigational tool and what ECDIS could provide according to IMO plans, as solutions to the problems currently present and what is really needed by marine officers to avoid such challenges in different scenarios and having better decision making.

3. LITERATURE REVIEW

These researches investigated the relationship between risk assessment and situational awareness of ECDIS, it also illustrates some specific ship risk assessments.

3.1 Assessing Ship Risks: ECDIS Security

The proponents of ECDIS are true in their assertion that, when properly understood, its usage improves navigational safety. Its detractors argue that it is a sophisticated instrument that, when used incorrectly, can potentially raise hazards (Vieira et al., 2017).

- **Collision Avoidance**

A collision avoidance system is a safety feature that warns, alerts, or assists in avoiding crashes and lowering the chance of an accident. Radar, lasers, cameras, GPS, and artificial intelligence are among the technology and sensors used by collision avoidance systems. Some collision avoidance systems warn or alert, while others take control and help in avoiding crashes and reducing risk (Lee et al., 2013).

- **Under Keel Clearance**

Under keel clearance (UKC) became a key component in safe and efficient navigation. Many ports set rules for minimum UKC in their navigation channels because improper calculation of UKC can have major safety and/or economic ramifications. Particular rules effectively serve as a safety net based on their best estimates of current capabilities for determining UKC. They can be based on factors like how recently surveyed depths have been updated, or how much the wind might cause the water level to be lower than the projected tide (Ryu et al., 2021).

- **Weather and Navigation Warning**

Weather information should be included in ECDIS for two convincing reasons. For improved navigation, one is to assist with route optimization. The second is to make navigation more secure by avoiding bad weather regions. ECDIS should have knowledge of the wind, waves, swell, tidal and surface currents in order to calculate the ship's speed loss. Nautical charts and weather alerts from the GMDSS (Global Maritime Distress and Safety System) should be incorporated to ECDIS as a dynamic database (Jincan and Maoyan, 2015).

4. ECDIS SIMULATION SCENARIOS

Simulation scenarios carried out to discover how (AIS, RADAR, ARPA) in addition to TIDE program could be useful if being connected to ECDIS system.

First scenario, Passage plans as represented in the red dashed line. as shown in Figure 1 the officer did a maneuver in the passage plan according to the information collected from both AIS and ARPA and become off course. This is due to the two targets had been identified by using the two connected sensors of AIS and ARPA. Therefore, the officer carried out safe maneuver and early action to be able to avoid collision with the two identified targets and make safe passage plan.

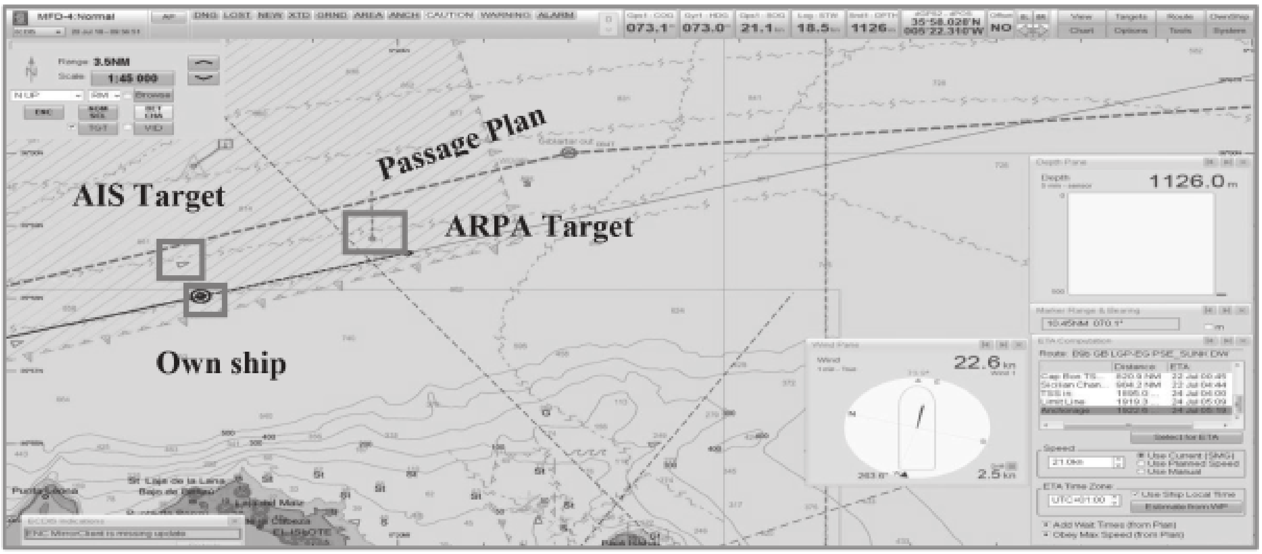

Figure 1: ECDIS interface integrated with ARPA & AIS
Source: AASTMT ECDIS Simulator

The second scenario, that demonstrates the high importance of integrating Tide as a water level measuring software with ECDIS is the example shown in Figure 2. It could be observed that the ship in the figure is passing under bridge with a certain maneuver. Here, there are two issues that should be carefully handled; first, the actual depth so as to have a good room to pass under bridge without any collisions with the bridge. This is done and obtained by connecting the Tide so as to be able to have the information of the actual depth. The one shown in the figure is the charted depth of 30m but not the actual depth of the ship illustrated in the figure. This means that the officer would only be able to pass under bridge through manually computing the actual depth via tide table and tidal stream publications.

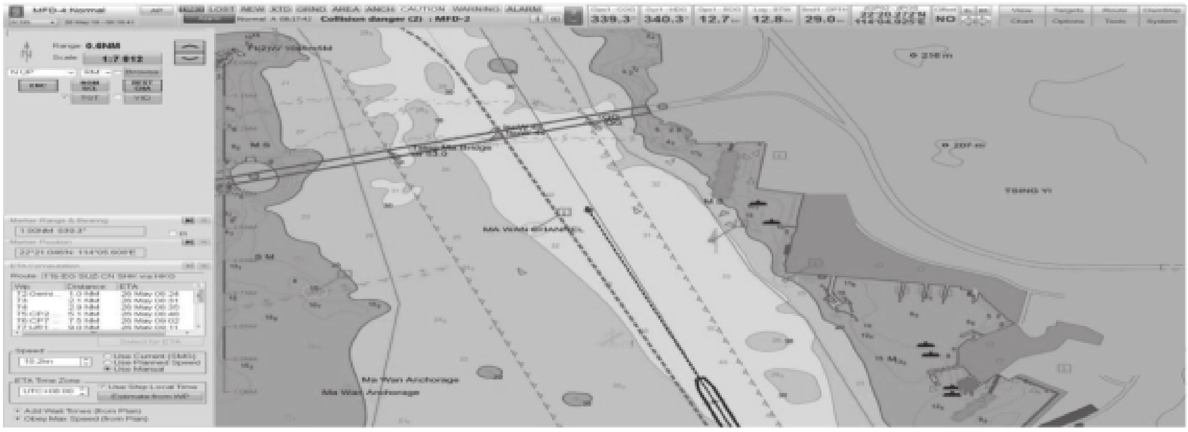

Figure 2: ECDIS interface while passing under Bridge
Source: AASTMT ECDIS Simulator

5. METHODOLOGY

According to what was mentioned in this paper, the realism philosophy was chosen for this research. A mixed approach and quantitative and qualitative analysis were chosen because situational awareness and risk assessment are broad concepts that, with the aid of the deductive and inductive research approaches, were synchronized and described in a more systematic manner. Moreover, the interview was developed for collecting data from experts who have more than 15 years of experience using ECIDS, and the questionnaire was developed as a data collection method for marine officers. A questionnaire is collected from marine officers who use ECDIS; according to Singh and Masuku (2014), to achieve a 95% confidence level, the sample size needed was 400. Therefore, 600 marine officers were targeted, out of which only 473 were received. In addition, 31 expert ECDIS users with 15 years or more experience was interviewed. The semi-structured interview's goal is to investigate ECDIS system difficulties, and the questionnaire's goal is to assess the effects of those challenges and suggest ideas for resolving them. Quantitative data has included two main phases: testing research hypotheses using ECDIS standalone and testing research hypotheses using ECDIS integrated. The interviews Have been analyzed using objective analysis using NVivo12 program, while the questionnaires Have been analyzed using validity, reliability, descriptive analysis, and inferential analysis, which is carried out utilizing correlation and structural equation modeling (SEM) to test the study hypotheses, and normality testing for the study variables. Using SPSS and AMOS programs.

The research hypotheses could be stated as follows:

H_1: There is a significant relationship between Risk Assessment Parameters and Situational Awareness.

H_{1a}: There is a significant relationship between Collision Avoidance and Situational Awareness.

H_{1b}: There is a significant relationship between Under Keel Clearance and Situational Awareness.

H_{1c}: There is a significant relationship between Navigational Warning and Situational Awareness.

Figure 3 illustrates the research framework, where the independent variable is the risk assessment, and the dependent variable is the situational awareness.

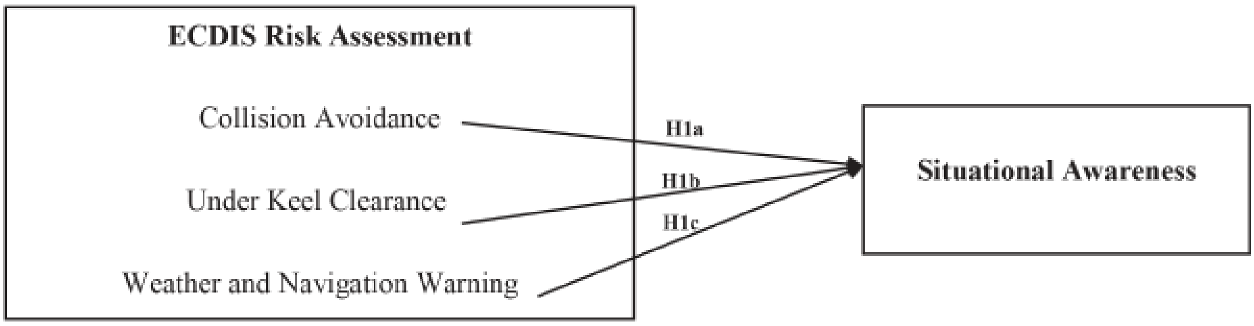

Figure 3: Proposed Research Framework

6. FINDING AND RESULTS

6.1 Qualitative Analysis

Through interviews, the researcher tries to know different views, opinions and perspectives of the participant that depends on their prior experience and knowledge. The participants are asked about their opinion about ECDIS, its challenges and how it could be developed to reach safer navigation. Qualitative analysis Data is analyzed using NVivo 12 program The themes extracted from interviews are shown as follows:

6.1.1 Collision Avoidance Theme

The collision avoidance theme is the first theme compiled from the codes that appeared in the interviews, where codes such as ship status, ship name, call sign, bearing (BRG), course, speed (SPD), time to closest point of approach (TCPA), and closest point of approach (CPA) are integrated. Figure 4 shows the codes for the collision avoidance theme.

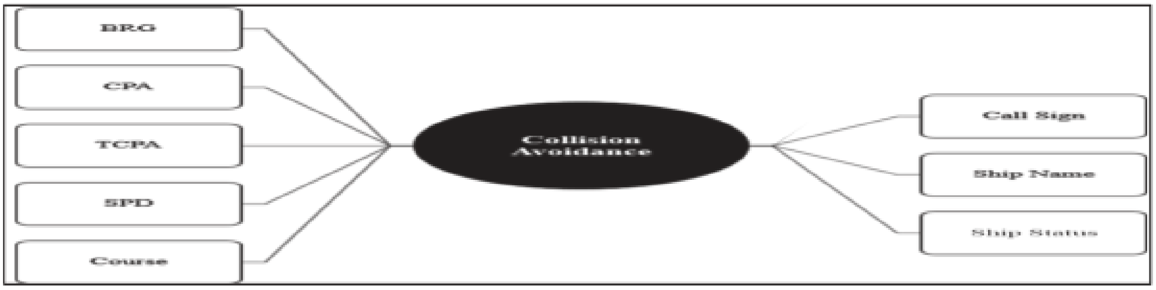

Figure 4: Codes Related to Collision Avoidance Theme

6.1.2 Weather and Navigation Warning Theme

The weather and navigation warning theme are the second theme compiled from the codes that appeared in the interviews, where codes such as "temporary" and "preliminary" (T&P) corrections, navigational warning, weather conditions, shortest distance, and recommended route are integrated. Figure 5 shows the codes for the Weather and Navigation Warning Theme.

Figure 5: Codes Related to Weather and Navigation Warning Theme

6.1.3 Under Keel Clearance Theme

Under keel clearance theme is the third theme compiled from the codes that appeared in the interviews, where codes such as actual depth, tidal stream, and tide are integrated. Figure 6 shows the codes for the under keel clearance theme.

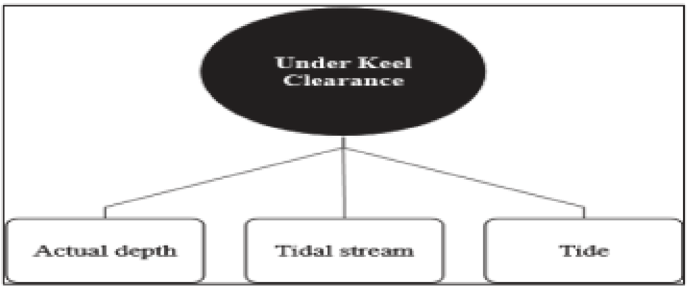

Figure 6: Codes Related to Under Keel Clearance Theme

6.2 Quantitative Analysis

The main conclusions of the data analysis are presented in this section, which also presents the empirical investigation.

6.2.1 Testing Research Hypothesis ECDIS Stand Alone

In the next sub sections, the result of the analysis ECDIS standalone.

6.2.1.1 Normality Testing for the Research Variables

To evaluate whether a data set is normal, one of the presumptions must be confirmed. After that an informal test is performed to determine the approximate normalcy because the formal test reveals that the values are not normally distributed. Some of the skewness and kurtosis values are near the acceptable threshold of ±1, which denotes that the study's data are roughly normal. In order to describe the correlations between the research variables, parametric tests are performed.

6.2.1.2 Testing Research Hypothesis

The correlation and path analyses of the structural equation modeling are used in this part to test the study's hypotheses. Since the study's data are demonstrated to be regularly distributed, the Pearson correlation is utilized. Table 1 shows the correlation matrix for the relationship between all research variables of the study.

Table 1: Correlation Matrix for the Research Variables

		1.	2.	3.	4.
1. Collision Avoidance	Pearson Correlation	1			
	Sig. (2-tailed)				
	N	473			
2. Under keel clearance	Pearson Correlation	.699**	1		
	Sig. (2-tailed)	.000			
	N	473	473		
3. Weather and Navigation Warning	Pearson Correlation	.548**	.532**	1	
	Sig. (2-tailed)	.000	.000		
	N	473	473	473	
4. Situational Awareness	Pearson Correlation	.520**	.508**	.615**	1
	Sig. (2-tailed)	.000	.000	.000	
	N	473	473	473	473
**. Correlation is significant at the 0.01 level (2-tailed).					

- There is a significant direct correlation between the Collision Avoidance and Situational Awareness, as the correlation coefficient is 0.520.
- There is a significant direct correlation between the Under-keel clearance and Situational Awareness, as the correlation coefficient is 0.508.
- There is a significant direct correlation between the Weather and Navigation Warning and Situational Awareness, as the correlation coefficient is 0.615.
- All variables are statistically significant at a level of 0.01.

Table 2: SEM Analysis for the Research Variables

		Estimate	P	R^2
Situational Awareness	Collision Avoidance	.177	.001	.504
Situational Awareness	Under keel clearance	.113	.009	
Situational Awareness	Weather and Navigation Warning	.421	.000	

- The first hypothesis "There is a significant relationship between Risk Assessment and Situational Awareness." consist of three sub hypotheses and the results are as follow,

- For the first sub hypothesis of the first hypothesis, it is supported as there is a significant positive effect of Collision Avoidance on Situational Awareness, as the P-value is less than 0.05, and the estimate is 0.177.

- For the second sub hypothesis of the first hypothesis, it is supported as there is a significant positive effect of Under keel clearance on Situational Awareness, as the P-value is less than 0.05, and the estimate is 0.113.

- For the third sub hypothesis of the first hypothesis, it is supported as there is a significant positive effect of Weather and Navigation Warning on Situational Awareness, as the P-value is less than 0.05, and the estimate is 0.421. Moreover, the R square is 0.504 which means 50.4% of the variation of the Situational Awareness can be explained by the independent variables together. Based on the previous results the research hypothesis according to before connecting ECDIS responses is fully supported.

6.2.2 Testing Research Hypothesis ECDIS Integrated

In the next sub sections, the result of the analysis after connecting sensors to ECDIS.

6.2.2.1 Normality Testing for the Research Variables

It assumes that the data is normally distributed if the P-value is greater than 0.05. It is called the formal test of normality. Then an informal test is performed to determine the approximate normalcy because the formal test reveals that the values are not normally distributed. It can be seen that some of the skewness and kurtosis values are near the acceptable threshold of ±1, which denotes that the study's data are roughly normal. In order to describe the correlations between the research variables, parametric tests are performed.

6.2.2.2 Testing Research Hypothesis

Table 3 shows the correlation matrix for the relationship between all research variables of the study.

Table 3: Correlation Matrix for the Research Variables

		1.	2.	3.	4.
1. Collision Avoidance	Pearson Correlation	1			
	Sig. (2-tailed)				
	N	473			
2. Under keel clearance	Pearson Correlation	.405**	1		
	Sig. (2-tailed)	.000			
	N	473	473		
3. Weather and Navigation Warning	Pearson Correlation	.303**	.591**	1	
	Sig. (2-tailed)	.000	.000		
	N	473	473	473	
4. Situational Awareness	Pearson Correlation	.354**	.597**	.698**	1
	Sig. (2-tailed)	.000	.000	.000	
	N	473	473	473	473
**. Correlation is significant at the 0.01 level (2-tailed).					

- There is a significant direct correlation between the Collision Avoidance and Situational Awareness, as the correlation coefficient is 0.354, and statistically significant at a level of 0.01.
- There is a significant direct correlation between the Under-keel clearance and Situational Awareness, as the correlation coefficient is 0.597, and statistically significant at a level of 0.01.
- There is a significant direct correlation between the Weather and Navigation Warning and Situational Awareness, as the correlation coefficient is 0.698, and statistically significant at a level of 0.01.

Table 4 shows the SEM analysis for the impact of the research variables. It could be observed that:

Table 4: SEM Analysis for the Research Variables

			Estimate	P	R^2
Situational Awareness	<---	Collision Avoidance	.440	.000	.703
Situational Awareness	<---	Under keel clearance	.183	.000	
Situational Awareness	<---	Weather and Navigation Warning	.272	.000	

- The first hypothesis "There is a significant relationship between Risk Assessment and Situational Awareness" consist of three sub hypotheses and the results are as follow,

- For the first sub hypothesis of the first hypothesis is supported, as there is a significant positive effect of Collision Avoidance on Situational Awareness, as the P-value is less than 0.05, and the estimate is 0.440.

- For the second sub hypothesis of the first hypothesis is supported, as there is a significant positive effect of Under keel clearance on Situational Awareness, as the P-value is less than 0.05, and the estimate is 0.183.
- For the third sub hypothesis of the first hypothesis is supported, as there is a significant positive effect of Weather and Navigation Warning on Situational Awareness, as the P-value is less than 0.05, and the estimate is 0.272. Therefore, the third sub hypothesis of the first hypothesis. Moreover, the R square is 0.703 which means 70.3% of the variation of the Situational Awareness can be explained by the independent variables together. Based on the previous results the research hypothesis according to after connecting ECDIS responses is fully supported.

6.2.3 Comparing Means using Testing Difference

Table 5 shows the T-test for the difference between ECDIS Integration. It shows that there is a significant difference of Collision Avoidance, Under-keel clearance, and Situational Awareness, as the corresponding P-values are less than 0.05, while, there is an insignificant difference of Weather and Navigation Warning as the P-value is more than 0.05.

Table 5: T-test analysis for ECDIS Integration

	ECDIS Integration	Mean	P-value
Collision Avoidance	Before	3.2304	0.000
	After	3.8288	
Under keel clearance	Before	3.4926	0.000
	After	3.8816	
Weather and Navigation Warning	Before	3.5645	0.399
	After	3.6808	
Situational Awareness	Before	3.5539	0.000
	After	3.8288	

7. Conclusions

The ship is viewed as a very sophisticated, massive man-machine system. The level of involvement between the operator and the system affects how well it performs. The task's performance effectiveness may go up or down as a result. The ship's display system has to be built to give the operator precise information as soon as feasible. In order to do this, this research looked at the benefits and drawbacks of ECDIS hardware and software, as well as how ECDIS performed when combined with collision avoidance, under keel clearance, and weather and navigation warning hardware and software.

Based on the results of qualitative and quantitative data analysis, it is clear that the use of AIS, RADAR and ARPA helps the ship to determine the coordinates and condition of the ships surrounding it, and this is to ensure the safety of navigation and collision avoidance. As well as the use of the NAVTEX device, which in turn also helps to provide Weather and Navigation Warning, and it can also be combined with the Sailing Direction program, and this is to determine the best ways for safe navigation to reach the desired destinations. The Tide program also helps to know the water levels in confined waters due to the difference in level and depth with the tides.

According to the study results, the following recommendations are provided:

- Based on the qualitative data analysis, it can be said that devices such as AIS, RADAR and ARPA are important and will be very useful if they are linked with ECDIS and this is to avoid Collision.
- The TCPA, and PAD information required for collision avoidance is created from the real-time ship information in the AIS, ARPA preventing delays in the target ships' information processing.
- Additionally, information obtained from Tide could be helpful in passing under bridges and confined waters safely, which in turn helps in avoiding collisions.

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