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Contents

Challenges facing modern modifications of dual-fuel engines

The shipping industry faces many challenges regarding greenhouse emissions from ship fuels. For carbon removal to be sufficiently in line with the Paris Agreement's target of limiting global warming to 1.5°C, green emissions force the shipping industry to assess ship emissions in a comprehensive manner. Notably, with a number of innovations being applied to the 1,500-2,000 new two-stroke and 750 new four-stroke vessels launched annually. The greatest challenge in order to achieve marine GHG reductions is the current commercial fleet, which consists of approximately 55,000 ship with two-stroke engines and 30,000 ships with four-stroke engines.

Modifying these existing vessels to be able to run on alternative fuels such as ammonia and methanol is one option for the marine industry to achieve the desired reductions in emissions. However, the path to retrofitting is uncertain. “Aside from the efficiency improvements and biofuel utilization, retrofitting is another option for the existing fleet to achieve decarbonisation targets,” says Christos Chrysakis, Director of Business Development at DNV.

Nonetheless, there are no requirements for retrofitting, so the future timeline for achieving this is unclear. Currently, the most direct way to reduce emissions on the existing fleet is to run single-fuel engines on sustainable biofuels. Many biofuels, such as FAME and HVO, have properties where they can be blended with existing fossil fuels. This is an attractive option for ship owners because it provides them with a flexible way to achieve decarbonization without having to make a large capital investment.

Since biofuels are not currently scalable, converting large ships to dual-fuel engines is increasingly seen as one way the shipping industry can achieve its decarbonization goals. Retrofitting a mono-fuel engine to bi-fuel allows the ship's engine to run on a second sustainable fuel, as long as this is accompanied by pilot injection of conventional fuel. While this conventional fuel will be primarily a conventional fossil fuel, sustainable biofuels or synthetic fuels can also be used.

Although many countries are pushing the IMO to be more ambitious and aim for zero emissions by 2050, some of the organization's regulations stand in the way of the rapid and large-scale retrofitting of the global fleet's dual fuels. Of greatest concern to retrofit advocates, IMO is now requiring that original engine testing be carried out for the exact same type of electronically controlled engine of dual fuel conversion to be NOx-compliant. However, relatively new engine technologies such as methanol and ammonia are not available for all sizes, which means that the original test engine is often not available for some of the modifications required for bi-fuel engines.

It will take time and cooperation from a variety of parties to successfully address all of these concerns and any unforeseen ones that may arise. The task of dual-fuel conversion is difficult and complex. However, if the marine industry is serious about attaining its decarbonization ambitions, all stakeholders now concur that achieving this goal successfully is essential.

Editorial Board

Numerical analysis of the buoy design to extract the effective kinetic wave energy.

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المستخلص

في العديد من البلدان، أصبحت طاقة أمواج البحر معترف بها على نطاق واسع كمورد هام ومفعم بالأمل. الهدف من هذا البحث هو تقييم تأثير التعديلات في شكل العوامة على فعالية نموذج الموجة من خلال استخدام ديناميكيات السوائل الحاسوبية (CFD) لتقييم التعديلات في السلوك الديناميكي للعوامة. يتم محاكاة سلوك العوامة باستخدام برنامج ANSYS Fluent، وقياس حجم اقتراب السوائل ، ووحدة تدفق خلال سير السوائل، وتطبيق نماذج موجة Stokes من الدرجة الخامسة. لمزيد من التحقيق في حساسية الموجة في الظروف الصعبة، تم تطبيق موجات ستوكس في المجال الضحل عند انحدار الموجة العالية .تتكون عملية التحقق من تحليل مقارن بين النتائج العملية والرياضية. تمت مقارنة نتائج الحساب الديناميكي للسائل العددي، وتم تعديل الملاحظات المختبرية. للتكوينات المختلفة للطفو تحت الماء، تم تحليل خصائص السحب والرفع للنتائج العددية. الهدف من هذه الدراسة هو التعرف على الشكل الأمثل للعوامات. استند اختيار هذا الشكل إلى عدة عوامل، كان أهمها أقل إنتروبيا، بالإضافة إلى الحد الأقصى لمعامل الرفع والسحب. تم تحديد الشكل المثالي ليكون كروي الشكل (الشكل ب).

1. Abstract

In many countries, sea wave energy is becoming more widely recognized as a significant and hopeful resource. The objective of this research is to evaluate the impact of alterations in buoy shape on the efficacy of the wave model by utilizing Computational Fluid Dynamics (CFD) to assess modifications in the buoy's dynamic behavior. The buoy's behavior is simulated using ANSYS Fluent, the volume of fluid approach, the open channel flow module, and 5th order Stokes wave models. To further investigate the wave sensitivity in challenging circumstances, Stokes waves were applied in the shallow domain at high wave steepness. The validation process consisted of a comparative analysis between the practical and mathematical results. The outcomes of a numerical fluid dynamical computation were compared, and laboratory observations were modified. For various configurations of underwater buoyancy, the drag and lift characteristics of numerical results were analyzed. The aim of this study was to identify the optimum buoy shape. The selection of this shape was based on several factors, of which the most significant were the least entropy, as well as the maximum lift and drag coefficient. Ideal shape was determined to be a spherical shape (shape B).

2. Introduction

The energy crisis and environmental degradation have gotten worse recently as a result of traditional energy sources' unreliability and detrimental effects on our daily life. Due to their sustainability and environmental friendliness, renewable energies like solar, wind, and ocean energy have thus been employed as an alternative to conventional energy (Jacobson, 2015). Studies have shown that ocean waves are denser than the sun and wind (Falnes, 2007). Around 2-terawatt worth of wave energy is commercially viable, which is sufficient to provide the entire world's energy needs in 2008(Gunn, 2012). GIRARDS created the first wave energy device in 1799 (Falcão, 2010). Three categories of wave energy converters—point absorbers, attenuators, and terminator—can be distinguished (Drew, 2016). One of the finest choices for ocean devices in the wave energy sectors is the floating point absorber (B. Lei, 2017). The majority of the time, forces between two bodies act to extract wave energy from wave energy converters (Viet,2016). Flexible polyvinylidene fluoride (PVDF) was used by Taylor et al. to (2001) develop an eel-like device that transforms mechanical energy from flowing river or ocean water. By leaving a predictable path of travelling vortices, the device stresses the piezoelectric components for the generation of electrical power (George, 2001). Optimisation should lower manufacturing costs for the majority of wave energy converter (WEC) systems currently in the precommercial stage. The progress and responsiveness of the launch mechanism, particularly the travel of the buoy across a predetermined route, have an impact on the WEC's efficiency (Aderinto, 2019). According to Viet, (2016) for the converters to successfully absorb energy, absorber floats are required. The buoy's size, shape, and wave incidence features affect how it moves in waves. In a separate experiment, Pastor (2014) looked at the behavior of different buoys during the same wave excitations to maximize the energy. Although their masses varied, the identical twin boys had the same radius. In their study, Amiri and Radfar examined how well four buoy versions with various radii and the same mass absorbed wave energy (Amiri, 2016). De Backer (2010) used a separate method to determine the mass of the buoys. According to its mass, the amount of water it is in, the gravitational force it is subjected to, and its hydrodynamic properties, the floating body moves according to the motion equations of the drifting body. Due to the variations in the ambient conditions, wave height characteristics, and buoy sizes, it is difficult to compare the researcher's results. Giorgi (2016) discovered that cylindrical buoys had significantly higher simulation forces than spherical buoys (Giorgi, 2016). The buoys were the same size and depth. Lopez (2017) study buoys in both periodic and erratic waves. The forms of the floating component were cylindrical, reversed conical, and had slightly bent ends. In order to increase productivity, it had a spherical underwater body. Mahdi (2019) investigated several diameters and droughts for the region of Rio de Janeiro. By relating experimental findings to RAWs based on simulation and the energy intake of a cylindrical-hemispherical buoy (Mahdi ,2019). Hulme (1981) created the swinging instrument using his knowledge of how water molecules move in waves. The device's capture width ratio was raised by improving the pendulum WEC. Wave energy is made up of kinetic and potential energy. The buoy's hydrodynamic efficiency will be improved if its heaving and pitching motions are used effectively (Hulme, 1981). Models must be evaluated to fully understand the fluid/structure relationship that affects the offshore construction. Unavoidably, testing will take place in a small scale in the lab before being done in real seawater. However, the development of simulation programs has made it easier to do quick research. That is, if the mathematical model utilized accurately simulates the actual environment. (Finnegan, 2012). Numerical wave tanks (NWTs) are the names given to the numerical models that imitate wave tanks. Numerous numerical techniques are used to build NWTs. A wave is created in a NWT at the input border and is dampened close to the output limit. Kim et al., (2001) mathematically simulated 3-D nonlinear waves with several directions that use the fixed-difference approach. Using a numerical wave maker, the waves were produced by setting the speed of water molecules to the wave maker limits (Kim et al, 2001) To investigate the impact of an irregular waveform, Koo and Kim (2004) enhanced the procedure to incorporate fluid structure interactions (Koo and Kim, 2004) .Sun and Faltinsen (2006) modeled a two-dimensional simulated bowl to model the effects of buoy on an open surface (Sun and Faltinsen, 2006) .An irregular wave bowl was modeled using complex equations by (Ning et al,2007). YOU and LIU (2011) modeled irregular wave behavior. As an example of wave-body interaction, they looked at fluid motion inside a sphere (YOU and LIU ,2011). Wu and Hu (2004) simulated the unsteady relationship among water and buoys mathematically (Wu and Hu, 2004). Angeliki (2023) has studied that the buoy's dynamic behavior, ability to absorb energy, and capacity to convert wave kinetic energy into direct and indirect electrical energy depend gently on the shape and the material selection (Angeliki, 2023). Jessice's (2022) investigation includes an analysis of wave energy's current state development, methods and technology for utilizing it, effects on the environment and benefits and drawbacks of using it (Jessice's,2022). Studies comparing forces on the fixed structure to the measurement of the free surface height are likewise limited, particularly in the shallows. When constructed to the costly experimental setup, the CFD would be a more realistic output. To further explore the effect of wave shape on wave energy devices, ANSYS Fluent was used in this article to perform CFD analysis. This analysis allowed researchers to investigate how waves interact with structures and how arrays of different types of devices are affected by the waves. The study compared numerical findings to experiments and reviewed the validation method used for accuracy. The results of this research were applied to various underwater buoys to determine the effectiveness of different wave energy devices. Additionally, this research has opened up the possibility for further development in wave energy technologies, as well as other potential applications for CFD analysis.

3. Methodology

The creation of numerical models and running of simulations were done using ANSYS Fluent. By contrasting the numerical results with those from the trials by obtaining the free surface level at two locations in the wave tank with the same parameters as Bhinder's (2009) simulation of the wave tank was approved before modelling the point absorber. After validation, altering buoy's shape signaled the beginning of the wave simulation of the point absorber. The dimensions were utilized to calculate the lift and drag coefficients in the second stage of the simulation. Conical, spherical, and other buoy shapes are considered. Pressure, velocity magnitude, entropy and lift and drag coefficients were computed. To get the most energy and experience the fewest losses, the optimum design was chosen.

3.1 Validation

The validation process was separated to 3 phases:

(1) The geometry, which dictated the model's actual size.

(2) The mesh configuration, which was created and refined to measure the free surface height.

(3) The physical setup, which determined the evaluation, region configuration, water depth, and other fluids interaction characteristics.

3.1.1 Geometry Setup

The wave tank that was used for the experimental study was 35 m, 2.5 m, and 1.5 m. The tank was equipped with multi-element regular 2D wave generation equipment. The tank was designed considering the wave-damping zone to minimize the reflection. The tank was filled was one fluid, its properties are shown in Table (1).

Table 1: properties of fluid

K (W/m. K)	0.597
ρ (kg/m3)	1000
T (°C)	20
Q (J/kg. K)	4182
μ (kg/m. s)	0.001

Waves can be formed in diverse ways resulting in waves with different characteristics, different heights, lengths, and periods Fig (1). These variables must be determined in for the complicated sea state to be characterized by the energy spectrum. The wave characteristics are shown in Table (2)

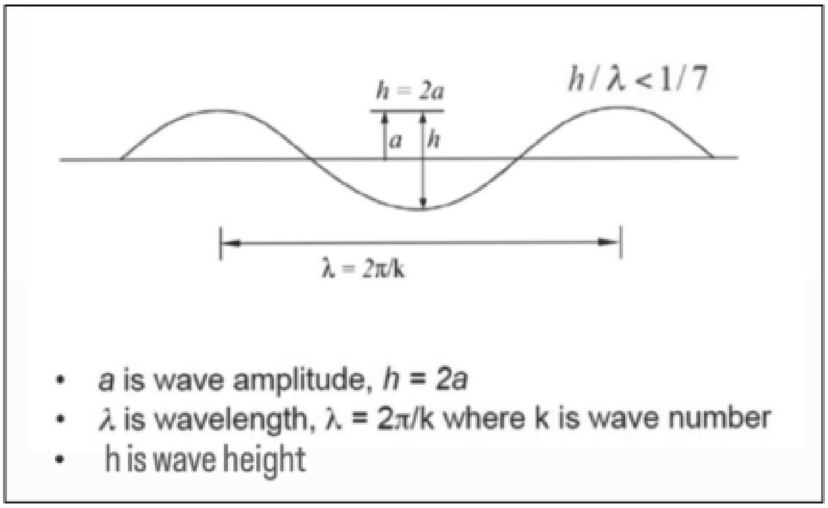

Fig (1) Wave Characteristics

Table 2: wave value

Wave height	0.3m
Period Time	4.2s
Water Depth	1.5m

3.1.2 Mesh Setup

Mesh generation is a critical component of computational fluid dynamic modeling. The domain is shown in Fig (2). The mesh structure was modified to reduce the problem time significantly. Different mesh configurations were tested and the optimum mesh was selected (Bhinder et al., 2009). The size of mesh was 600000 and the size function was selected to be curvature as illustrated in Fig (3).

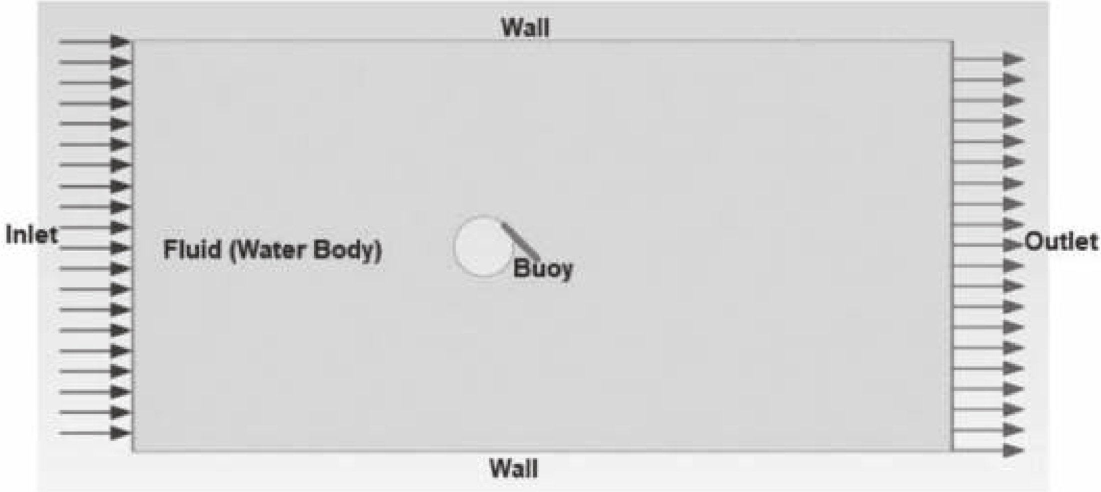

Fig (2) Fluid Domain

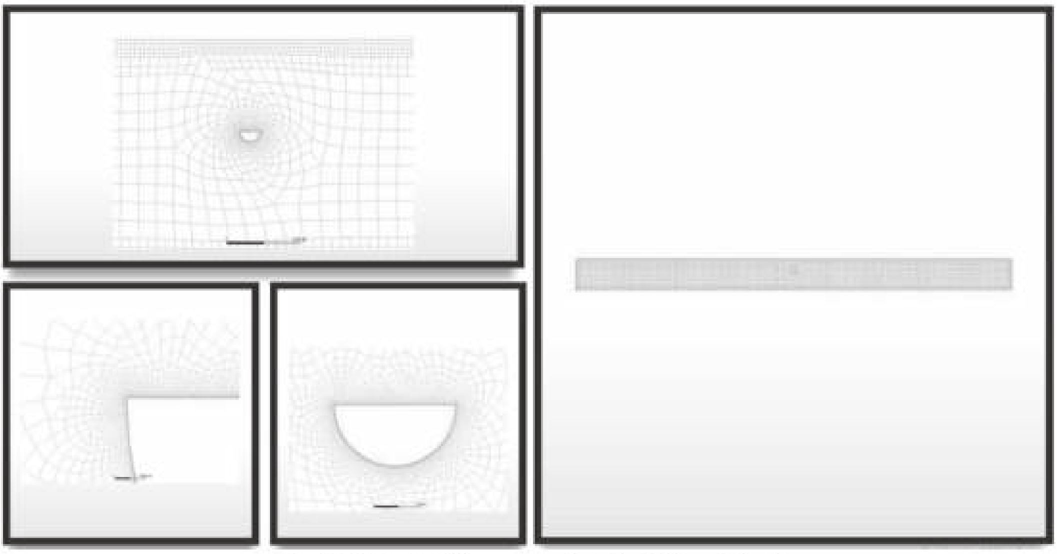

Fig (3) Mesh Structure in the Wave Tank

3.1.3 Physics Setup

The finite volume technique is the strategy used in ANSYS Fluent to solve the problem. The target region is divided into smaller regions by using this technique. The simulation was carried out while second-order monotonicity-preserving momentum and continuity equations were iteratively solved across each sub-region. As a result, an approximate value for each variable is obtained at various places within the domain (Malalasekera et al., 2007).

One of the equations that can be simulated by ANSYS is represented as,

$$\frac{\partial p}{\partial t} + \frac{\partial pu_1}{\partial x} + \frac{\partial pu_2}{\partial y} = 0. \quad (1)$$

And Navier-stokes equations, which are given as,

$$p(\frac{\partial u_1}{\partial t} + u\frac{\partial u_1}{\partial x} + v\frac{\partial u_1}{\partial y} = -\frac{\partial p}{\partial x} + 2\mu\frac{\partial^2 u_1}{\partial x^2} + \frac{\partial}{\partial y}\left(\mu\left(\frac{\partial u_1}{\partial y} + \frac{\partial u_2}{\partial x}\right)\right) + F_1 \quad (2)$$

$$p(\frac{\partial u_2}{\partial t} + u\frac{\partial u_2}{\partial x} + v\frac{\partial u_2}{\partial y} = -\frac{\partial p}{\partial y} + 2\mu\frac{\partial^2 u_2}{\partial y^2} + \frac{\partial}{\partial x}\left(\mu\left(\frac{\partial u_1}{\partial y} + \frac{\partial u_2}{\partial x}\right)\right) - pg + F_2 \quad (3)$$

Where,

p	*Pressure*	t	*Time*	x	*Horizontal Distance*
u_1	*Horizontal Flow Velocity*	u_2	*Vertical Flow Velocity*	y	Vertical Height
F_1	*Horizontal Force*	F_2	*Vertical Force*	μ	*Viscosity*

Since the RNG turbulence model was extremely precise and dependable provided by the software, it was used for all simulations. Swirling's impact on turbulence in the RNG model, clarity in whirling flows.

$$\frac{\partial}{\partial t}(pk) + \frac{\partial k}{\partial x_i}(pku_i) = \frac{\partial}{\partial x_j}\left[\left(\alpha_k u_{\varepsilon ff}\right)\frac{\partial k}{\partial x_i}\right] + G_k - \rho\varepsilon \quad (4)$$

$$\frac{\partial}{\partial t}(p\varepsilon) + \frac{\partial k}{\partial x_i}(p\varepsilon u_i) = \frac{\partial}{\partial x_j}\left[\left(\alpha_\varepsilon u_{\varepsilon ff}\right)\frac{\partial \varepsilon}{\partial x_i}\right] + G_{l\varepsilon}\frac{\varepsilon}{k}G_k - G^* G^*_{2\varepsilon\rho}\frac{\varepsilon^2}{k} \quad (5)$$

$$G^*_{2\varepsilon} = G_{2\varepsilon} + \frac{C\mu\rho\eta^3(1-\frac{\eta}{\eta_O})}{1+\beta\eta^3} \quad (6)$$

$$\eta = \frac{sk}{\varepsilon} \quad (7)$$

Where,

G_k	*Kinetic Energy Generation*
$G_{21}\ G_{2\varepsilon}$	*Model Constants*
k	*Turbulence Kinetic Energy*
ε	*Rate Of Dissipation.*

An explicit solution differed from an implicit solution in that an explicit solution was solved gradually by stepping through time at each computing cell, but the time step in an implicit solution was confined to fulfil requirement for stability. However, using information from a previous time step, an implicit solution was solved in each timestep, which calls for more intricate iterations without imposing time step restrictions.

The Split Lagrangian approach was utilized in the Numeric tab's volume of fluids (VOF) addictive section because it produced lower cumulative volute error than other methods provided by ANSYS Fluent.

The boundary conditions are illustrated in Fig (4). The model was developed using fifth-order Stokes wave theory (Bhinder et al., 2009) based on the specifications of the simulated wave.

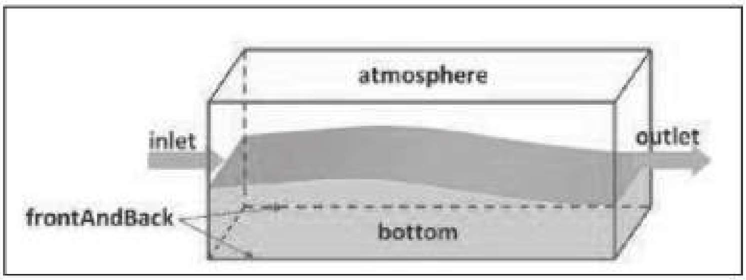

Fig (4) Boundary Conditions

The Fluent segregated solver was applied in these computations. It takes several rounds of solution loops before convergence is attained because the governing equations are nonlinear. The schemes were referred to as the pressure-based segregated algorithm as PISO was recommended for transient calculations.

3.2 Buoy Modelling

This study recommends creating a similar setting in to compare the behaviors of several buoys in waves. There are four different types of buoy shapes considered; conical and spherical, and odd buoys. Fig (5). To understand The results of these adjustments on the effectiveness of the wave energy model, the CFD is used to assess changes in the buoy's hydrodynamic characteristics brought on by changes in buoy shape. The radius chosen in this study, 0.1 m was simulated to determine the drag and lift coefficients.

$$F_X = \frac{1}{2}\rho C_{DX} D u \sqrt{(u^2 + w^2)} + \rho C_{MX} A u^{\cdot} \quad (8)$$

$$F_y = \frac{1}{2}\rho C_{DY} B w \sqrt{(u^2 + w^2)} + \rho C_{MY} A w^{\cdot} \quad (9)$$

Where,

F_X	Horizontal Force	C_{DX}	Horizontal Drag Coefficient
D	Depth	u	Horizontal Velocity
ρ	Denisty	C_{MX}	Horizontal Inertia Coefficient
A	Area	$u^{\cdot}$	Horizontal Acceleration
F_y	Vertical Force	C_{DY}	Vertical Drag Coefficient
B	Width	w	Vertical Velocity
C_{MY}	Vertical Inertia Coefficient	$w^{\cdot}$	Vertical Acceleration

Entropy minimization is the primary branch in the design of energy systems. It is the most efficient method of calculating missing energy and work destruction. As a result, much attention has been focused on the topic of entropy development due to heat and mass transmission. Strain-originated breakdown and thermal loss, which represent the creastion of viscous and thermal entropy, respectively, are the two factors in fluid flow (Iandoli, 2005). The creation of entropy can be represented as (Shehata, 2016).

$$S_{gen} = S_V + S_{th} \tag{10}$$

The local viscous irreversibiliities is expressed as,

$$S_V = \frac{\mu}{T_o} \emptyset \tag{11}$$

∅ -- the viscous dissipation term that can be written as,

$$\emptyset = [(\frac{\partial u}{\partial x})^2 + (\frac{\partial v}{\partial y})^2] + (\frac{\partial u}{\partial y} + \frac{\partial v}{\partial x})^2 \tag{12}$$

So the entropy generation can be expressed as:

$$S_G = \iint S_V dydx \tag{13}$$

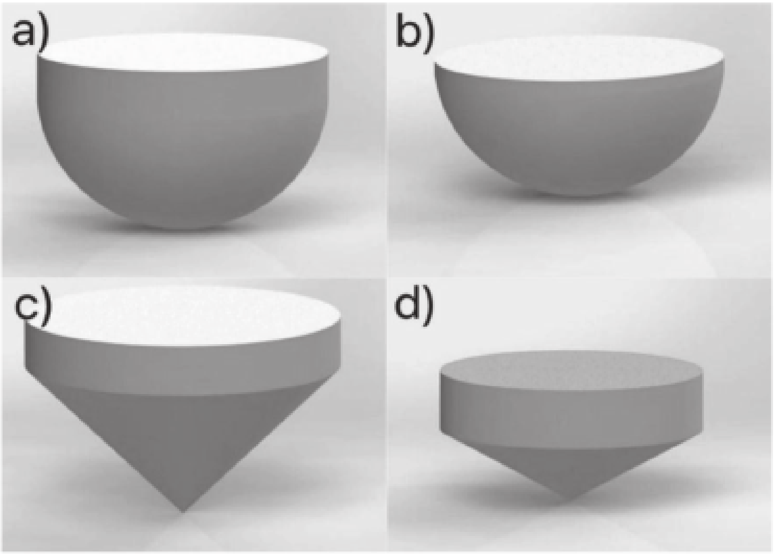

Fig (5) Buoy Shapes

4. Results and discussion

For Euler equations as well as additional scalars like turbulence, the integral equations were fluidly solved. Using a computational grid and a control volume-based approach, the domain was split into discrete volume controlled. The governing equations were included into the structure to produce mathematical formulation for small variables.

4.1 Validation

A linear wave was modeled using the same parameters as Bhinders et al., (2009) study to produce a relation between free surface height and the number of seconds, which the three highest peak values from each case were compared, it was discovered that the difference was less than 10 %, Table (3). This small discrepancy results from other settings which were not mentioned clearly in the study.

Table (3) difference of results for surface elevations bet model & simulation

Distance (m)	Highest `peak	Free surface elevation from the baseline model	Free surface elevation from simulation results
2.1	First Peak	0.18	0.17
	Second Peak	0.19	0.18
	Third Peak	0.185	0.175
6.5	First Peak	0.155	0.155
	Second Peak	0.155	0.145
	Third Peak	0.145	0.14

4.2 Buoy Results

The lift and drag coefficients of the various buoy forms were calculated using a CFD software program (Fluent). Fluid estimates the computer simulation's fluid dynamic properties. Fluid dynamic software was used to create a mesh around the geometrical model of the buoy and start the calculations. After many rounds of iterations, the simulation achieved its conclusion. The result of the simulation depends on the starting boundary conditions, the size of the grid, and the flow conditions estimated at each node in the mesh.

4.2.1 Pressure

The pressure was the first variable studied by fixing the radius and mass of the four buoys. It can be observed that the flow from the inlet moves toward the outlet of the tank. Contours were obtained at each buoy shape and compared to other shapes. A graph was also created to show how pressure changed in the axial direction. The resulting profile is shown in Fig (6), while Fig (7) illustrates the pressure distribution over the distance.

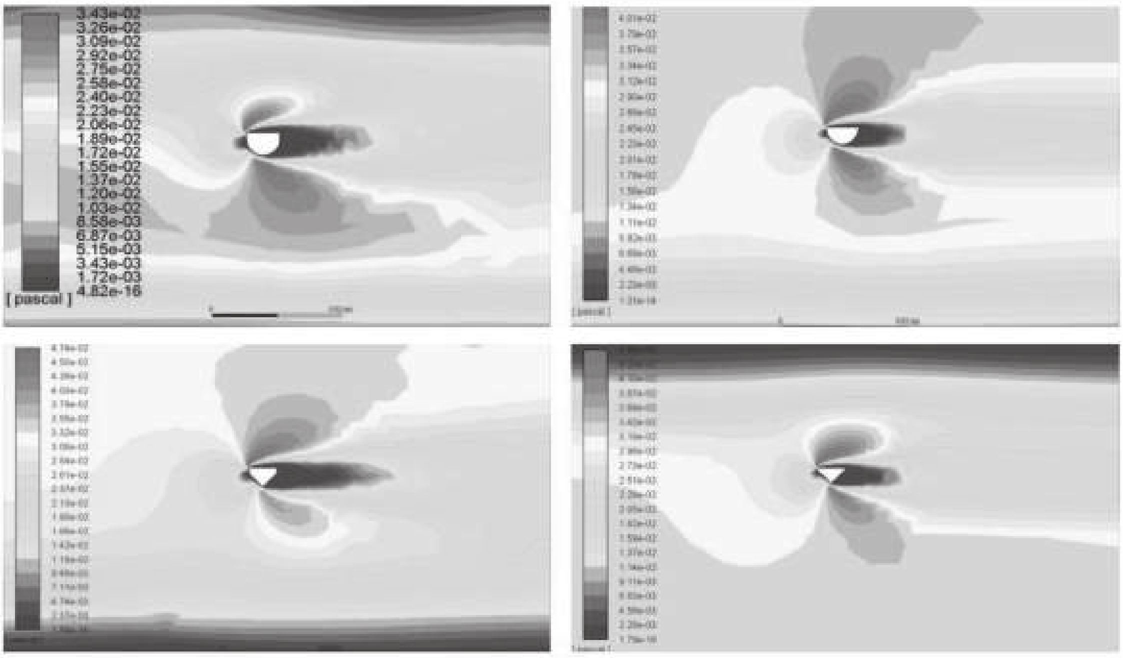

Fig (6) Static Pressure Contour

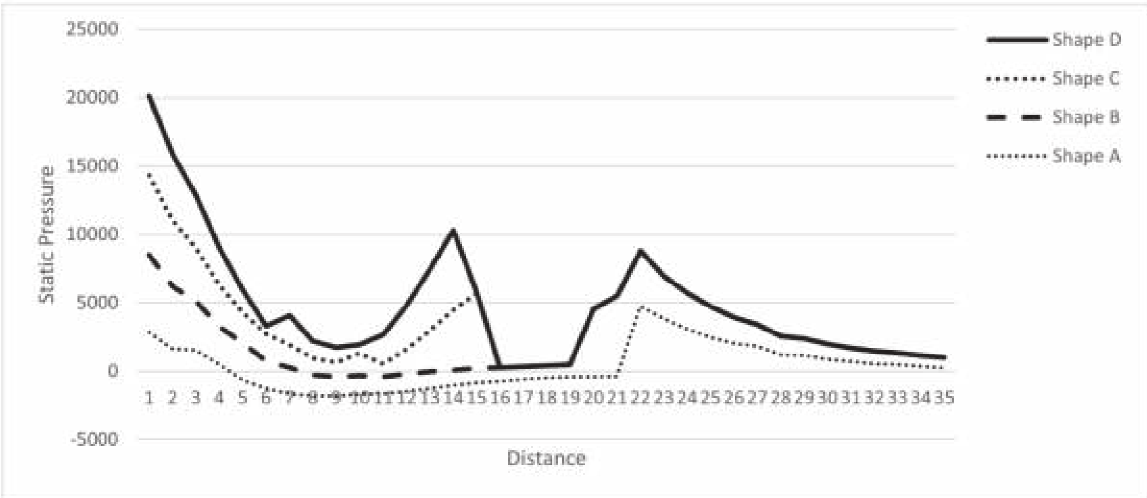

Fig (7) Pressure Distribution

4.2.2 Velocity Magnitude

By keeping the buoy's size and weight constant, the contours illustrate how the buoy's shape affects its average velocity. The average velocity was selected based on the environmental conditions as Bhinder et al., (2009) mentioned. The initialization was computed from the inlet and traveled toward the tank's outlet. It was useful to view the vector and contour plots individually. While the vector plots provided a better indication of the fluid's flow direction as shown in Fig (8), the contours provided a better representation of the velocity magnitude for each buoy shape as shown in Fig (9).

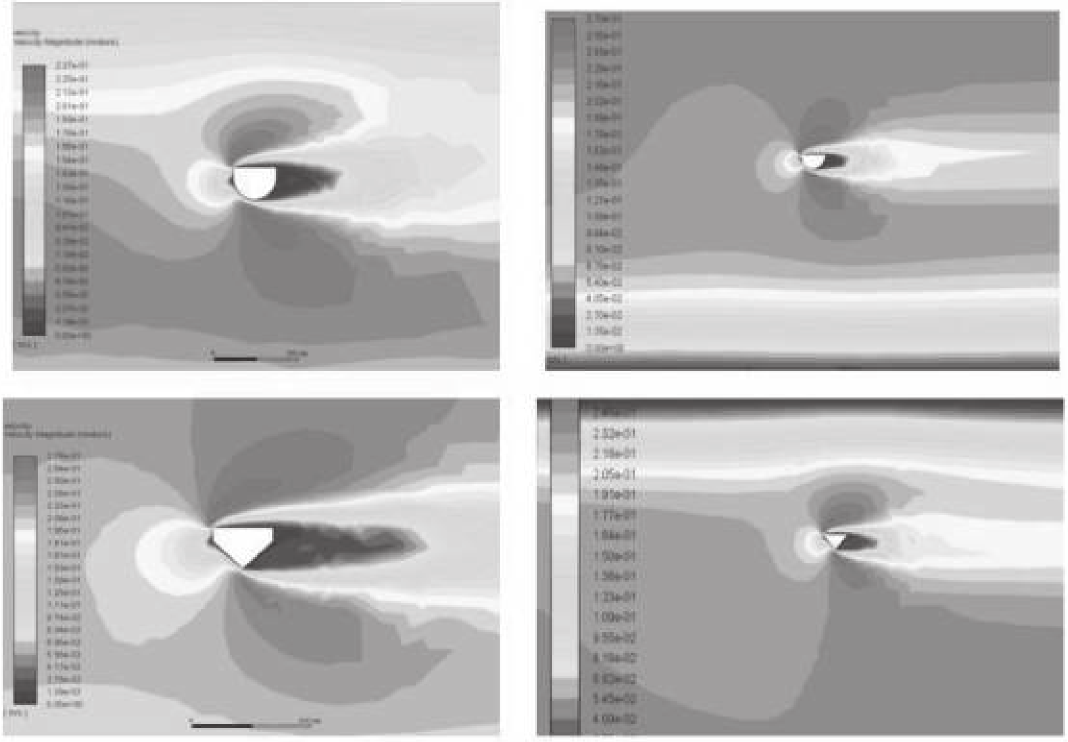

Fig (8) Velocity Contour

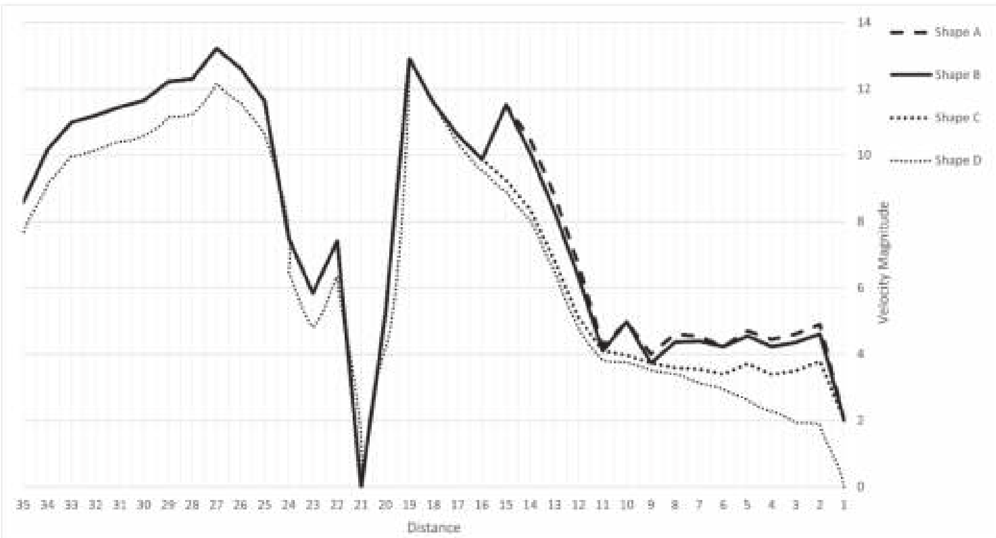

Fig (9) Velocity Distribution

4.2.3 Entropy

Entropy can potentially affect buoys in several ways, depending on the context and specific factors involved like wave action, corrosion, and thermal expansion. Wave action can affect buoys as the movement of water is a manifestation of energy, and the more chaotic the motion, the higher the entropy. Therefore, in areas with high wave energy, buoys may experience more wear and tear due to the increased forces acting on them. Buoys are typically exposed to seawater and atmospheric conditions, which can lead to corrosion of the buoy's metal components. Corrosion is a naturally occurring process that involves the breaking down of metals into their constituent ions, and it is driven by thermodynamic principles, including entropy. Specifically, corrosion tends to occur in environments where there is a high degree of disorder and randomness, which is reflected in the higher entropy of the system. Moreover, buoy materials are often subject to thermal expansion due to changing temperatures. Thermal expansion is a manifestation of increased molecular activity that occurs at higher temperatures, resulting in an increase in entropy. As a result of this thermal expansion process, buoys can experience changes in shape or size which may have a direct effect on their performance or longevity. Additionally, these changes may cause metal fatigue or other structural stresses that can reduce a buoy's resistance to wave motion or corrosion over time. Overall, entropy can have a range of effects on buoys depending on the specific circumstances and mechanisms involved. However, it is important to note that buoys are designed and engineered to withstand the harsh conditions of the marine environment; factors such as corrosion and thermal expansion are generally considered in their design and maintenance to ensure their longevity and performance over time. Fig (10) shows the evaluation of entropy distribution in the fluid flow direction for the four shapes.

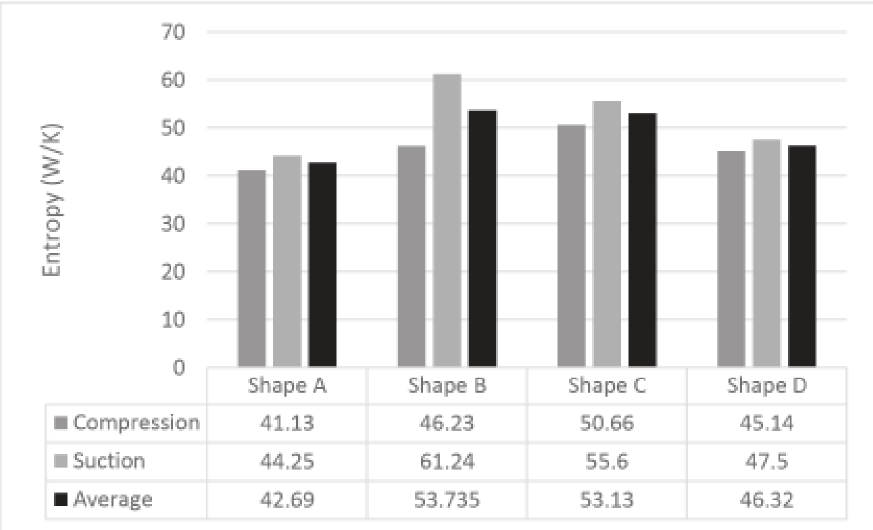

Fig (10) Entropy Distribution

4.2.4 Lift Coefficient

The lift force coefficient is affected by the Reynolds number, the amplitude ratio, and the amplitude ratio, and the lowered velocity. The lift coefficient is the factor that engineers use to represent all the complicated dependencies of shape, inclination, and other conditions. The lift coefficient results from the heave and pitch oscillations are presented in Fig (11).

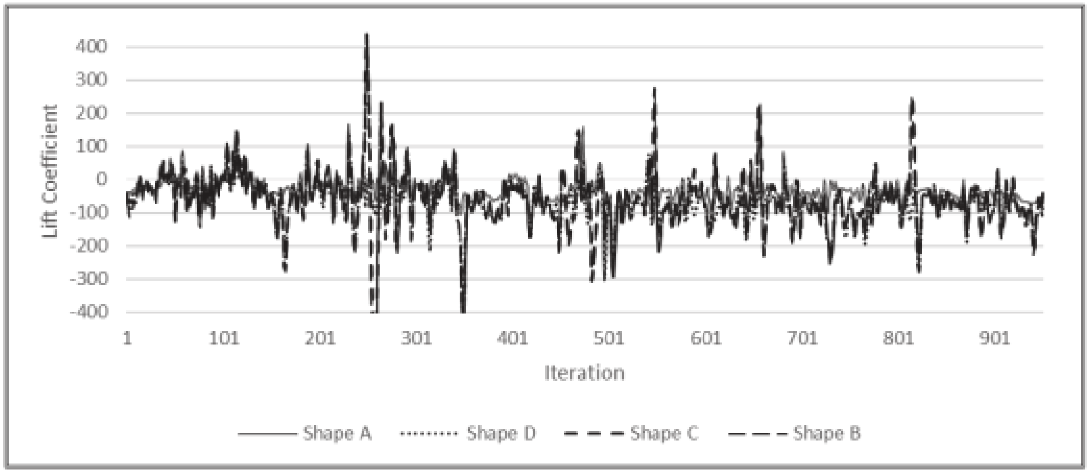

Fig (11) Lift Coefficient

4.2.5 Drag Coefficient

The buoy's shape, the flow's Reynolds number, and the surface's roughness are only a few of the variables that affect the drag coefficient. Along with intricate buoy dependencies, the drag coefficient also takes fluid viscosity and compressibility into account. Figure (12) displays the drag coefficient for four different forms.

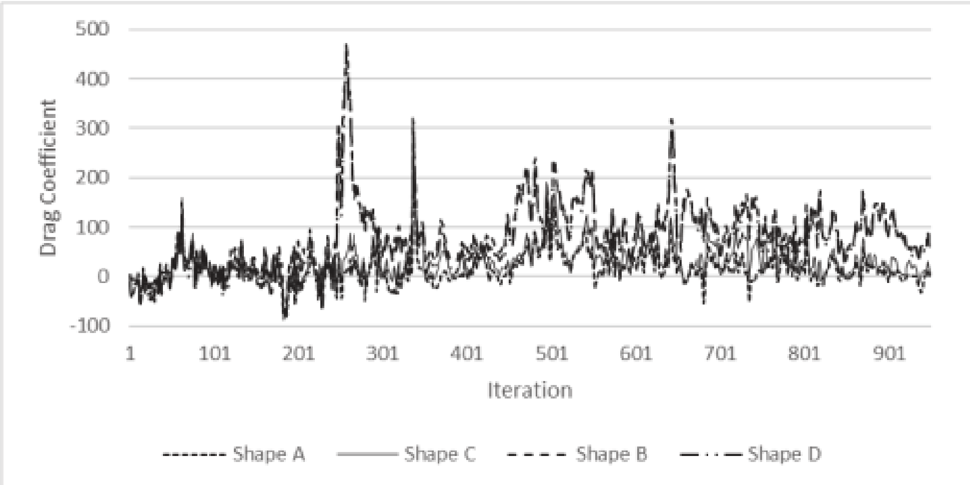

Fig (12) Drag Coefficient

5. Conclusion

In conclusion, the ANSYS Fluent simulation findings had been effectively validated by comparison to the study conducted by Bhinder et al. (2009) It was determined that there was a less than 10% variation in the findings between the simulation and validation source, which is suitable.

This study suggested creating comparable settings to compare the ways in which different buoys behave in waves. Conical, spherical, and odd buoy shapes are taken into consideration. The buoy's motion in the wave is influenced by its size, shape, and wave characteristics. This study investigated how different buoy shapes with constant radius and mass behaved in waves. Contours showed the velocity and pressure around the four buoys. The drag and lift coefficients were intended. The selection of the optimum buoy shape was a complex process that involved several factors. The primary factors considered in the selection process were the least entropy, maximum lift coefficient and drag coefficient. After careful consideration of the various options, it was determined that the optimum buoy shape was a spherical shape (shape B). This shape was determined to be the best option due to its ability to provide maximum lift and drag coefficients while still maintaining a low entropy value. The results of this study are beneficial in helping to identify optimal buoy shapes for various applications. The lift and drag coefficients are key considerations in determining the buoyancy of an object in a fluid environment such as water. Additionally, the entropy factor is important as it releases how much energy is missing by moving the buoy. By selecting shape B, it was possible to maximize the energy waste and ensure that the buoy would provide an optimal performance.

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A Decade of ECDIS:
Analytical Review of the ECDIS Effect towards the Safety of Maritime Shipping

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المستخلص

يعد نظام الخرائط الإلكترونية على متن السفن أحد أحدث التعديلات التي نصت عليها المنظمة البحرية الدولية (IMO) في عام ٢٠٠٨ وقد طبق على نطاق واسع بحلول عام ٢٠١٢، وكان الغرض الرئيسي من استخدام الخرائط الإلكترونية هو الاستفادة من التكنولوجيا الحديثة للمساعدة في عملية تشغيل السفن للحصول على وردية ملاحية آمنة وخط سير آمن ورسو امن في الموانئ. بالإضافة إلى ذلك، فإن الخريطة الإلكترونية تسهل عملية التخطيط الملاحي للرحلة البحرية.

وبعد مرور عشر سنوات (٢٠١٢-٢٠٢٢). فان السؤال يطرح نفسه، هل يعتبر استخدام الخرائط الإلكترونية اضافة إيجابية نحو تشغيل أكثر اماناً للسفن، أم هو على العكس من ذلك، وانه قد أدى إلى زيادة الحوادث البحرية؟

بدأ الباحثون الدراسة بافتراض أن الخرائط الإلكترونية قد تكون سببًا لزيادة للحوادث البحرية وليس التقليل منها كما كان مرجو، ووجد الباحثون أن الإحصائيات الموجودة في أيدي الباحثين لم تكن مؤشرا على رأي قاطع. لذلك، استخدم الباحثون معيار الاستبيان كوسيلة للإحصاء الكمي كأداة بحثية للتعرف على رأي ورؤية ضباط الممشى لاستخدام الخرائط الإلكترونية خلال عقد من الزمن، ولتحديد ما إذا كان هناك حاجة إلى أي تطوير سواء في الإطار التشغيلي أو التعليمي.

كانت المنهجية المستخدمة في هذا البحث هي أسلوب التحليل النوعي للبيانات من خلال استبيان لمستخدمي الخرائط الإلكترونية المختلفين وقد أشار إلى أن المعدة محل البحث كان لها تأثير إيجابي غير مسبوق على سلامة الملاحة. اعتمد الاستبيان على ١٠ أسئلة مختلفة، ومع ذلك، اتفق جزء كبير على أن هناك مجالًا كبيراً للتطور في مجالات البرمجة والأجهزة وأجهزة الاستشعار الخارجية للمساهمة بفعالية في نظام الممشى المتكامل الفعال.

Abstract

The Electronic Charts Display Information System (ECDIS) on board ships is one of the latest amendments that have been stipulated by the International Maritime Organization (IMO) since 2008 and had been widely spread in 2012, and the main purpose of implementing the use of ECDIS was to use modern technology to help in operating ships to obtain a safe navigational watch and a safe approach and mooring in ports. Additionally, it facilitates voyage planning as an easy-to-use tool.

Hence, ten years passed (2012-2022). The question arose, was the use of ECDIS considered an improvement to the safe operation of ships, or, on the contrary, it led to an increase in marine accidents?
The authors initiated the study after the hypothesis that the ECDIS could be a major cause of marine accidents, and the authors found that the statistics in the hands of the researchers were not indicative of a conclusive opinion. Therefore, the researcher used the criterion of questionnaire as a means of quantitative statistics as a research tool to identify the opinion and vision of bridge seafarers for the use of ECDIS in a decade and to identify if any development is needed either in operational or educational sight.
The methodology used in this research was the qualitative analysis data method through a questionnaire for different ECDIS users and indicated that the equipment carried an unprecedented positive effect on the safety of navigation. The questionnaire was based on 10 different questions. Yet, a great fraction agreed that there is a massive room for improvement in the areas of software, hardware, and external sensors to effectively contribute to an efficient Integrated Bridge System.

1 Introduction

A decade ago, the primary and obligatory means of navigation were paper charts, which the navigator could rely on to plan her/his voyage, monitor route, and plot positions. Those duties required significant effort and professionalism from the navigator, especially during long voyages. On the other hand, Electronic Chart Systems (ECS) and ECDIS existed as navigational aids and were not yet obligatory used as primary navigation tools.
In 2008, the IMO began to implement the application of ECDIS on high-speed crafts, the real spread of the newly added equipment was in 2012 when newly built cargo ships were obligated to carry ECDIS on board. Accordingly, the compulsory implementation of ECDIS was specified according to the type and tonnage of each vessel where ECDIS should be used as the primary method of navigation in addition to an approved backup system depending upon the flag state preference, to be either a paper chart or to install another separate ECDIS and transform the vessel to a "paperless" ship. This change illuminated the privilege to have the ECDIS connected to all the navigational devices in the bridge as an integrated system to facilitate monitoring the data originating from all connected equipment.
In addition, to implement the installation of ECDIS on board almost all the existing vessels in addition to the newly built ones, the need presented itself for all operators to have undergone training, this training became compulsory according to the International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers (STCW/78), so that they can deal with ECDIS correctly and safely (IMO, 2017).
Finally, concerns developed after a decade (2012-2022) about the ECDIS and its effectiveness as a reliable device used to play an effective crucial role to achieve safe navigation and the sufficiency of its development, and if ECDIS is good enough to rely on or if the ECDIS might need more development.

2 Historical background

In 1986 the North Sea Hydrographic Commission (NSHC) completed a study on the benefits and consequences of the development of ECDIS for Hydrographic Offices (HOs) (IHO, 2014). Following that study, and because of its impact, several manufacturers showed interest in being involved in the development of ECDIS. Meanwhile, the industry reached a point where it became essential for all related parties, Hydrographic Offices, mariners, National Shipping Authorities, and manufacturers, to have at least the first draft of the IHO and/or IMO guidance for both the Electronic Navigation Chart (ENC) and its display systems (IHO, 2014).

Consequently, ECDIS specifications' first draft was presented to IHO Member State Hydrographers at Monaco in May 1987 at the 13th International Hydrographic Conference, and it was distributed in an enormous figure to many other parties including National Shipping Authorities, Mariner Associations, and Marine Equipment Manufacturers, to receive their feedback regarding the draft (IHO,2014).

A year later, in November 1988, the Committee on ECDIS (COE) recognized the need for the presence of a common standard for Colors & Symbols. With the support of the Colors and Symbols Maintenance Working Group (CSMWG) specifications and guidelines for both chart symbols and colors were developed (IHO, 2014).

After three months, in January 1989, the IMO Safety of Navigation sub-committee integrated a common task with the Maritime Safety Committee (MSC) resulting in a recommendation recognizing the need to unify the symbols and colors for all navigational charts. Accordingly, they invited the Comité International Radio-Maritime (CIRM) and assigned the IHO to make a detailed technical proposal (IHO, 2014).

Simultaneously, the IMO/IHO Harmonizing group for ECDIS developed the Provisional Performance Standards (PPS), which was published in May 1989 by the IMO. Furthermore, a modified version of the PPS was prepared for industry convenience and was adopted in 1995 resulting in the production of IMO resolution Performance Standards for Electronic Chart Display and Information Systems (ECDIS) A.817 (19) (IHO, 2014).

Since this resolution had integrated many elements of the original IHO Specification. Therefore, for the time being, “Standard-52” (S-52) was considered the only standard that provides details of the hydrographic requirements for ECDIS PS (IHO, 2014).

In 2008, the Committee on Hydrographic Requirements for Information Systems (CHRIS) in its 20th meeting redesigned the S-52 to contain the modified IMO ECDIS PS, MSC.232 (82) with the correlated new International Electrotechnical Commission (IEC) 61174 Specification for ECDIS hardware test aiming towards the verification of compliance for ECDIS type approval. Finally, Edition 6 of S-52 was published, and the IMO PS ended up having only one standard which is the current resolution MSC.232 (82) (IHO, 2014).

Finally, to ensure that chart data provided by the chart suppliers to the end users maintained a high degree of security and to avoid the presence of any criminal activity that might affect the safe navigation of the vessel and thus affected the harmony in the operation of ECDIS, the IHO specified publication S-63 to ensure a secured ECDIS. This publication was updated in 2020 by the IHO and nominated as the IHO Data Protection scheme Edition 1.2.1 (IHO, 2020).

3 ECDIS International Standards

Three main parties participated in the regulations of ECDIS, namely the IMO, IHO, and IEC. All three organizations have established standards and publications for ECDIS to be an internationally approved maritime device, covering all three areas of software, hardware, and chart data.

The International regulative standards could be summarized as follows:

- **IMO standards:**
  - IMO Resolution A.817(19) Performance Standards for Electronic Chart Display and Information Systems (ECDIS), as amended.
  - IMO Resolution Msc.232(82) Adoption of The Revised Performance Standards for Electronic Chart Display and Information Systems (ECDIS).

- **IHO standards:**
  - S-52 (Specifications for Chart Content and Display Aspects of ECDIS).
  - S-57 (IHO Transfer Standard for Digital Hydrographic Data).
  - S-61 (Product Specification for Raster Navigational Charts (RNC)).
  - S-63 (IHO Data Protection Scheme).
  - S-64 (IHO Test Data Sets for ECDIS).

- **IEC standards:**
  - IEC 61174, ECDIS operational and performance requirements, methods of testing, and required test results.

The relationships among the International Organizations and working groups that have madeimportant contributions to the development of ECDIS are shown schematically in Figure 1.

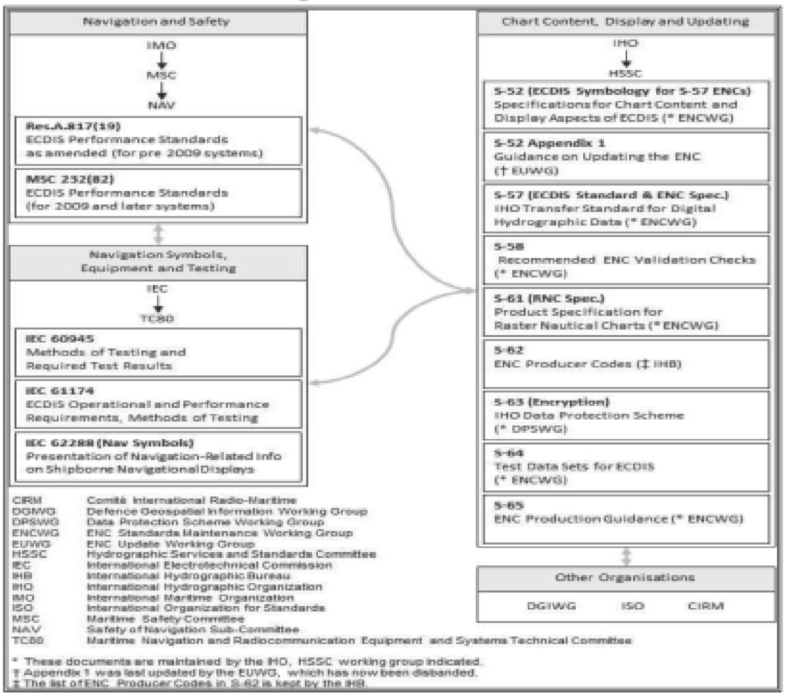

Figure 1: International Organizations involved in ECDIS Standardization. Source :(IHO, 2014).

As shown in figure 1, the efforts involved in producing a safe operating system for ECDIS was the fruitful performance for 14 working bodies to reach the end to the device seafarers were able to use smoothly on board their vessels (IHO, 2014).

4 Safety of Life at Sea Convention (SOLAS) Requirements for the Carriage of ECDIS

To add any new requirement in an IMO convention, a process of procedural steps should be made for these amendments to take effect, and a predefined percentage of ratifying member States should sign in favor of that new amendment. Starting from that point, SOLAS chapter five *"Safety of Navigation"* stipulated the new requirements for the carriage of ECDIS in regulation 19/2.1.4 to all ships as follows:

"All ships, irrespective of size, shall have nautical charts and nautical publications to plan and display the ship's route for the intended voyage and to plot and monitor positions throughout the voyage. An electronic chart display and information system (ECDIS) is also accepted as meeting the chart carriage requirements' (IMO, 2020).

Consequently, SOLAS classified vessels into two categories, a new ship, and an existing ship. Furthermore, the vessels were classified into three types according to their line of work: Passenger Ships, Tanker Ships, and Cargo Ships. Each type was limited for implementation by their Gross Tonnage (GT) Capacity, as shown in figure 2.

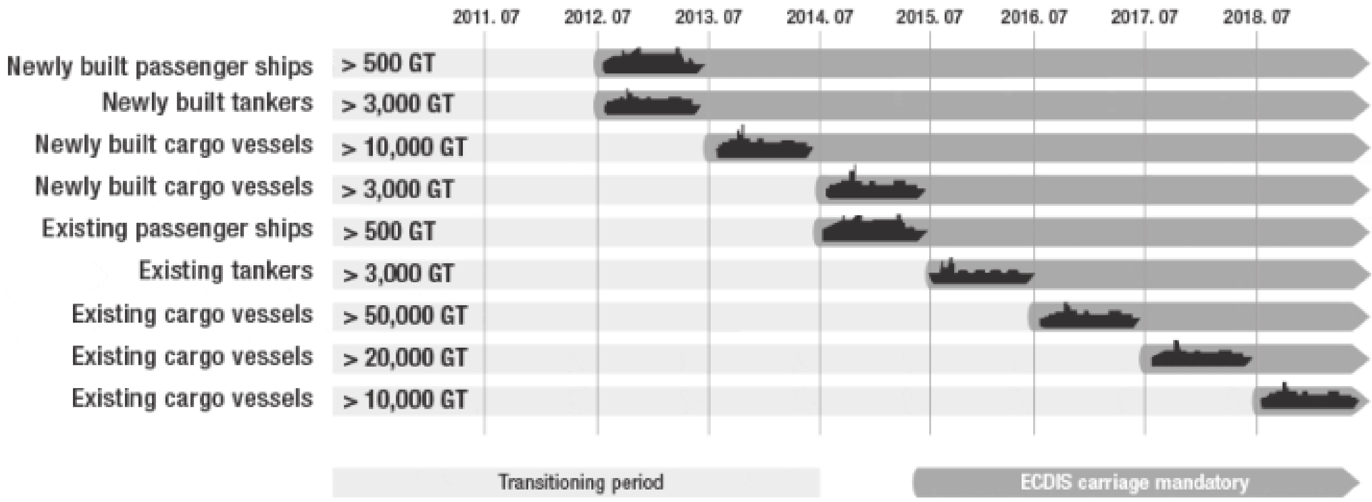

Figure 2: SOLAS Requirements for the Carriage of ECDIS. Source: (Furuno Electric Co., LTD, 2014).

As shown in figure 2; the existing ship is the vessel where her keel in the shipyard was laid before the assigned date and the newly built vessel is the vessel where its keel was laid after the assigned date.

5 Development of ECDIS

Corresponding to the implementation process for an Integrated Bridge System (IBS) to operate ECDIS, the global organizations related to the maritime industry gathered their forces and developed their requirements in various standards to develop the ECDIS.

Electronic Navigation or E-Navigation is a new hypothesis in marine navigation defined as the harmonized collection, integration, exchange, presentation, and analysis of marine information on board and ashore by electronic means to enhance berth-to-berth navigation and related services for safety and security at sea and protection of the marine environment (IMO, 2009).

Since ECDIS is the only system that could be considered as a central system for presenting different information capable of satisfying the end user needs and fulfilling the requirements for E-navigation through the integration between all such navigational equipment (Bistrovića & Komorčec, 2014). Therefore, ECDIS should be made compatible with E-navigation by inserting changes in all related operational standards for targeted equipment. Also, it may include developing some functions to achieve the concept of IBS to produce sharable information between ships and shore (Bistrovića & Komorčec, 2014).

Additionally, IHO had the S-100 (Universal Hydrographic data model) which should eventually replace the established IHO Transfer Standard for Digital Hydrographic Data S-57, allowing the usage of chart images, for instance; classification of the seabed, high-density bathymetry, 3D data, dynamical ECDIS and online updates (IHO, 2010).

Moreover, the maritime Industry may use S-100 as the new E-Navigation tool used for exchanging data between own vessel, other vessels, and ashore, not to mention the capability for analyzing and facilitating the decision-making process. Furthermore, the international standard format for route exchange from IMO facilities the ability to share routes between ship and shore at route planning and execution phases to enhance the safety of navigation at sea. (CIRM, 2020).

Although all ECDIS can operate using ENC on both modes of S-57 and S-100 and should run smoothly for the entire operation. Unfortunately, till now it is not mandatory on-board ships (IHO, 2018).

Figure 3 explains the latest technology available for reaching a smooth data exchange between ship and shore following the E-Navigation mode including the participation between satellite systems for positioning and cloud storage with VTS stations and remote control stations on land supported by the AIS data from all surrounding vessels to each at the end to the integrated navigational system performing with the optimum use of all on board and in the sea and on land resources (Sushchinskii & Rodionov, 2022).

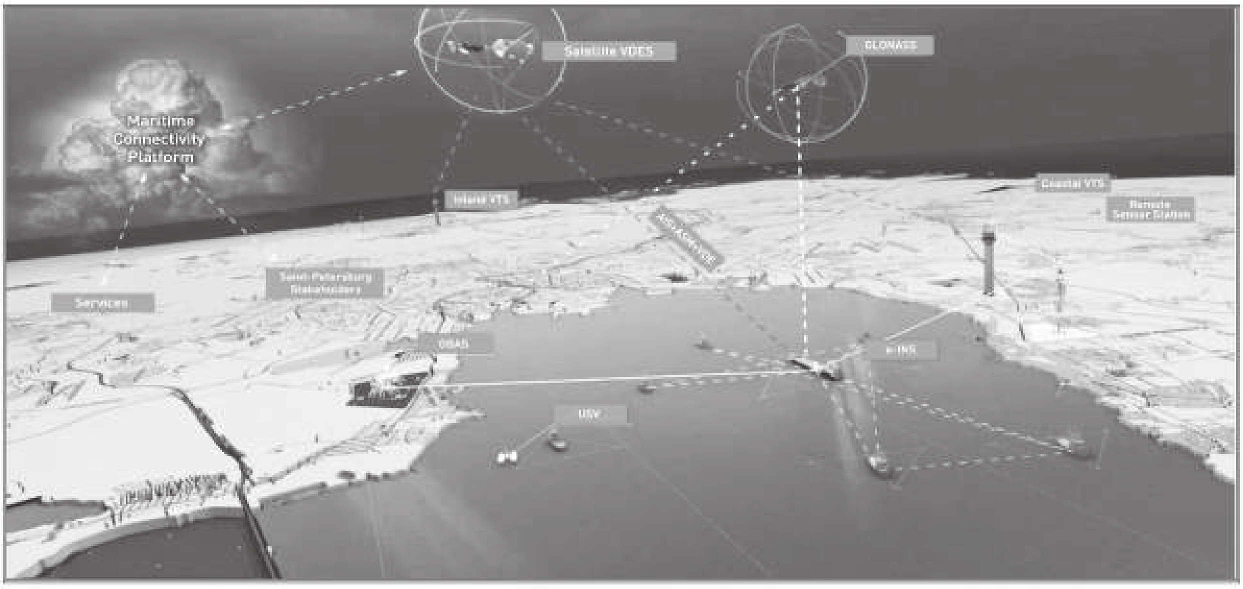

Figure 3: exchange information between ships and shore using E-navigation. Source: (Sushchinskii & Rodionov, 2022).

It is worth mentioning that there are serious intentions for the standardization of the interface of all types of ECDIS (S-Mode Display) allowing operators to easily familiarize themselves with different ECDIS models when changing between ships during different contracts/companies without the need for type-specific training (Patraiko, 2017).

Finally, with all this mutation in the technology related to E-navigation, the maritime industry needed to adapt especially from the human factor perspective by applying a new method of training to cope with the industry development (IAMU, 2019). On the other hand, E-Navigation should support the implementation of the first three degrees identified by the IMO for the Marine Autonomous Surface Ship (MASS).

6 Training for ECDIS

ECDIS operators should complete the mandatory courses according to the STCW/78 convention as amended to be competent in maintaining a safe navigational watch during the use of ECDIS functions (IMO, 2017).

There are two types of training according to the level of operators. The first type is the operational level STCW training competency according to table A-II/1 as shown and covered in figures 5 and 6. The second type is the management level training as per STCW table A-II/2 as shown in figure 4.

However, all of these courses are focusing on the minimum international requirements for ECDIS functions but still, type-specific training is not obligatory for ECDIS to issue a certificate of competency (COC) which demonstrates the reality of the presence of different types of ECDIS in the industry (IMO, 2017).

The second type is the operational level training as per STCW table A-II/2 as shown in figures 5 and continued in figure 6 which includes the same functions but with different level of operation.

Table A-II/2 *(continued)*

Function: Navigation at the management level *(continued)*

Column 1	Column 2	Column 3	Column 4
Competence	**Knowledge, understanding and proficiency**	**Methods for demonstrating competence**	**Criteria for evaluating competence**
Maintain safe navigation through the use of information from navigation equipment and systems to assist command decision making **Note:** Training and assessment in the use of ARPA is not required for those who serve exclusively on ships not fitted with ARPA. This limitation shall be reflected in the endorsement issued to the seafarer concerned	An appreciation of system errors and thorough understanding of the operational aspects of navigational systems Blind pilotage planning Evaluation of navigational information derived from all sources, including radar and ARPA, in order to make and implement command decisions for collision avoidance and for directing the safe navigation of the ship The interrelationship and optimum use of all navigational data available for conducting navigation	Examination and assessment of evidence obtained from approved ARPA simulator and one or more of the following: .1 approved in-service experience .2 approved simulator training, where appropriate .3 approved laboratory equipment training	Information obtained from navigation equipment and systems is correctly interpreted and analysed, taking into account the limitations of the equipment and prevailing circumstances and conditions Action taken to avoid a close encounter or collision with another vessel is in accordance with the International Regulations for Preventing Collisions at Sea, 1972, as amended
Maintain the safety of navigation through the use of ECDIS and associated navigation systems to assist command decision making **Note:** Training and assessment in the use of ECDIS is not required for those who serve exclusively on ships not fitted with ECDIS. This limitation shall be reflected in the endorsement issued to the seafarer concerned	Management of operational procedures, system files and data, including: .1 manage procurement, licensing and updating of chart data and system software to conform to established procedures .2 system and information updating, including the ability to update ECDIS system version in accordance with vendor's product development .3 create and maintain system configuration and backup files .4 create and maintain log files in accordance with established procedures .5 create and maintain route plan files in accordance with established procedures .6 use ECDIS log-book and track history functions for inspection of system functions, alarm settings and user responses Use ECDIS playback functionality for passage review, route planning and review of system functions	Assessment of evidence obtained from one of the following: .1 approved in-service experience .2 approved training ship experience .3 approved ECDIS simulator training	Operational procedures for using ECDIS are established, applied and monitored Actions taken to minimize risk to safety of navigation

Figure 4: STCW ECDIS training tables A-II/2 management levels. Source: (IMO,2017)

Table A-II/1 *(continued)*

Function: Navigation at the operational level *(continued)*

Column 1	Column 2	Column 3	Column 4
Competence	**Knowledge, understanding and proficiency**	**Methods for demonstrating competence**	**Criteria for evaluating competence**
Use of ECDIS to maintain the safety of navigation **Note:** Training and assessment in the use of ECDIS is not required for those who serve exclusively on ships not fitted with ECDIS. This limitation shall be reflected in the endorsement issued to the seafarer concerned	Navigation using ECDIS Knowledge of the capability and limitations of ECDIS operations, including: .1 a thorough understanding of Electronic Navigational Chart (ENC) data, data accuracy, presentation rules, display options and other chart data formats .2 the dangers of over-reliance .3 familiarity with the functions of ECDIS required by performance standards in force Proficiency in operation, interpretation, and analysis of information obtained from ECDIS, including: .1 use of functions that are integrated with other navigation systems in various installations, including proper functioning and adjustment to desired settings .2 safe monitoring and adjustment of information, including own position, sea area display, mode and orientation, chart data displayed, route monitoring, user-created information layers, contacts (when interfaced with AIS and/or radar tracking) and radar overlay functions (when interfaced) .3 confirmation of vessel position by alternative means .4 efficient use of settings to ensure conformance to operational procedures, including alarm parameters for anti-grounding, proximity to contacts and special areas, completeness of chart data and chart update status, and backup arrangements .5 adjustment of settings and values to suit the present conditions	Examination and assessment of evidence obtained from one or more of the following: .1 approved training ship experience .2 approved ECDIS simulator training	Monitors information on ECDIS in a manner that contributes to safe navigation Information obtained from ECDIS (including radar overlay and/or radar tracking functions, when fitted) is correctly interpreted and analysed, taking into account the limitations of the equipment, all connected sensors (including radar and AIS where interfaced), and prevailing circumstances and conditions Safety of navigation is maintained through adjustments made to the ship's course and speed through ECDIS-controlled track-keeping functions (when fitted) Communication is clear, concise and acknowledged at all times in a seamanlike manner

Table A-II/1 *(continued)*

Function: Navigation at the operational level *(continued)*

Column 1	Column 2	Column 3	Column 4
Competence	**Knowledge, understanding and proficiency**	**Methods for demonstrating competence**	**Criteria for evaluating competence**
Use of ECDIS to maintain the safety of navigation *(continued)*	.6 situational awareness while using ECDIS including safe water and proximity of hazards, set and drift, chart data and scale selection, suitability of route, contact detection and management, and integrity of sensors		

Figures 5&6: STCW ECDIS training tables A-II/1 operational level. Source: (IMO,2017)

Consequently, operators should require extra training to be familiar with the type or model of ECDIS available on board their vessel, to achieve that, numerous methods could be established, for

example, the companies might draft a bilateral agreement with the onboard ECDIS manufacturer to deliver onboard training, or by sending the officers to training centers equipped with the required ECIDS Model. However, sending officers for type-specific training can be harder for fleets that have a wide range of ECDIS models, and officers will still require a brief period of onboard familiarisation when dealing with ship-specific installations (Chhabra, 2014).
Companies' accountability to ensure the proper delivery of the type-specific training was based on the responsibility assigned to them according to the International Safety Management (ISM) Code (Section 6) to ensure their bridge officer's familiarity with the onboard ECDIS. This responsibility was delegated also to the Master on board representing his company to ensure familiarity for all ECDIS users on board. The most understandable process of familiarisation with onboard ECDIS functions is to read the onboard user manual with evidence of proof by a signature on the management system to ensure that the ECDIS users had read the manual and are familiar with the ECDIS in question (Chhabra, 2014).

7 Accidents related to ECDIS

In this section, the authors checked the probability of having ECDIS as the primary cause of a ship's accident, the statistical data used in this study are based on the grounding accidents investigation reports published by the following bodies:

- Marine Accident Investigation Branch (MAIB),
- The Federal Bureau of Maritime Casualty Investigation (BSU).
- The Marine Safety Investigation Unit (MSIU).
- The Dutch Safety Board (DSB).

There was a record of a total of 80 grounding accidents in the period from 2008 to 2018; after analyzing the recorded accidents it was noticed that in 22 cases the probability of finding more than one reason for the accident related to ECDIS and ENC has been spotted and illustrated in Figure 7. The Y-axis represents the number of cases, and the X-axis represents the years. Additionally, we categorized the incidents/accidents into three types: Less Serious – Serious - Very Serious (Turna & Ozturk, 2019).
For further explanation, "very serious" are marine casualties resulting in the complete loss of the vessel or big harm to the environment or loss of life. Where "Serious" refers to marine incidents to vessels not big enough to be "very serious" and includes for instance fire, collision, grounding, heavy weather damage, and suspected hull defect, affecting the ship's performance and leading to an unseaworthy vessel. In addition to the consequences of pollution or inappropriate towage. Lastly, "less serious" are marine incidents that do not qualify to be "very serious" or "serious" (Turna & Ozturk, 2019).
Following that reason, a total of 22 grounding cases have been classified as follows (Ships and Offshore Structures, 2019).

- 2 very serious accidents
- 18 serious accidents
- 2 less serious accidents

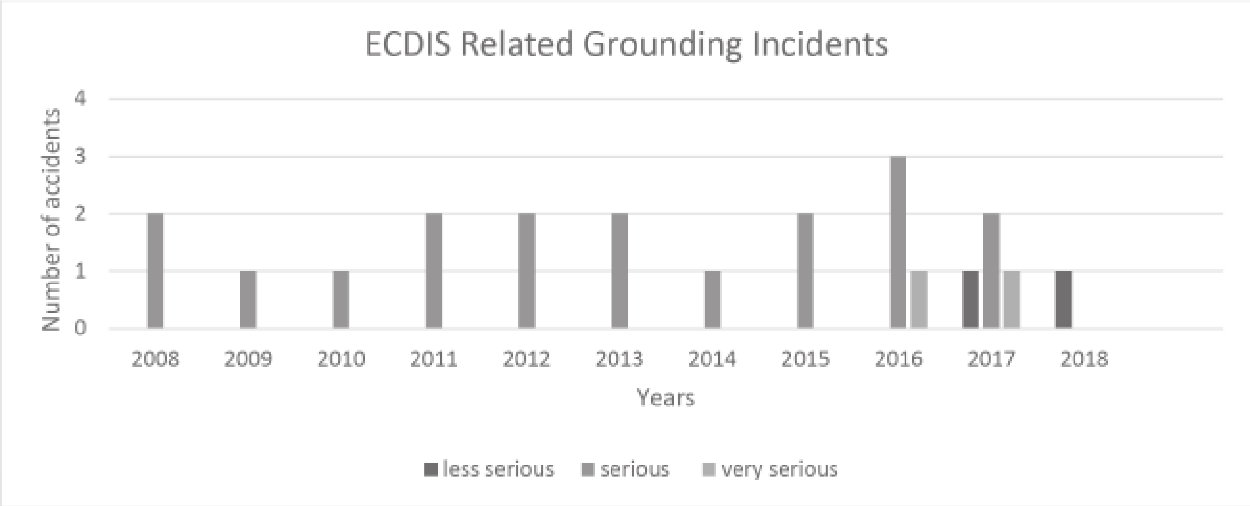

Figure 7: Statistics for grounding accidents related to ECDIS from 2008 to 2018.
Source: (Turna & Ozturk, 2019).

Forthcoming from the fact shown in figure 5 that the indicators to the records for the three measuring elements, the author identified the discrepancies in all of them over the years which leads the authors to follow the track of a quantitative questionnaire as a survey involving a random sample of bridge competencies as a mean for measuring the hypotheses involving the implementation of the ECDIS and its link to be considered as a major cause for accidents. (Turna & Ozturk, 2019).

8 Questionnaire

A questionnaire is a research instrument that consists of a set of questions or other types of prompts that aims to collect information from a respondent. A research questionnaire is typically a mix of close-ended questions and open-ended questions. Such questions offer the respondent the ability to elaborate on their thoughts. Research questionnaires were developed in 1838 by the Statistical Society of London. The data collected from a data collection questionnaire can be both qualitative as well as quantitative in nature. A questionnaire may or may not be delivered in the form of a survey, but a survey always consists of a questionnaire. (QuestionPro, 2022)

The questionnaire related to our research was distributed to people in direct and frequent involvement with ECDIS, whether onboard ships or ashore (companies, training centers, equipment distributors). The questionnaire contained the following questions: -

Q1. Do you think the presence of ECDIS reduced the number of accidents?

The authors set this question to measure the effect of using ECDIS concerning the number of accidents from the operator's point of view.

Q2. Do you think the presence of ECDIS facilitates the job of the bridge before and during sailing?

The purpose is to clarify if the ECDIS is considered a useful navigation tool on the bridge and if it is helpful more than the paper chart for bridge operations at all stages.

Q.3 Do think the ECDIS requires more options to be added?
The authors set this question to analyze if the ECDIS functions/options are sufficient/reliable to achieve safe navigation or need more options.

Q.4 Do you prefer to use the ECDIS or the paper chart?
The authors set this question to verify if the ECDIS existence as a navigation tool is better than the paper chart or if the paper chart is still the most comfortable tool for use by the operators.

Q.5 Do you prefer to have another ECDIS as a backup or the paper chart?
The authors asked this question to identify the preferred backup system because while using ECDIS as a primary navigation tool and according to the requirements; it is compulsory to have a backup arrangement then the question opened the area for volunteers to identify their tendencies either towards paper chart or secondary ECDIS.

Q.6 Do you think that using ECDIS in S-Mode will be more "user-friendly" than using different models of ECDIS?
The authors set this question to clarify when manufacturers of ECDIS make standardization for the interface of ECDIS display, does it make it easier for operators to transfer from one model to another without needing time for type-specific training or familiarization or not?

Q.7 Do you think that the mandatory sensors connected to ECDIS (Satellite Positioning Fixing System, Speed & Distance Measuring Device, & Gyro Compass) are sufficient to achieve safe navigation, or do other sensors needed to be added mandatory?
The authors set this question to estimate the minimum requirements for the number and function of sensors that should be connected to the ECDIS and if current requirements are sufficient to depend on for ECDIS use in navigation or if ECDIS needs more sensors.

Q.8 To the best of your knowledge, are there any administrations/companies that do not apply ECDIS carriage requirements?
The authors set this question to identify the deficiencies of administrations or companies in the application of international carriage requirements.

Q.9 to the best of your knowledge, does the vector charts library (ENC) cover all sailing areas globally?
We set this question to track the sailing areas which are not covered by vector charts, and whether we still need Raster charts or paper charts for the uncovered areas.

Q.10 Do you think that ECDIS training requirements in its current status are sufficient for safely operating the equipment?

We set this question to know what additional requirements need to be added to STCW compulsory training courses to raise the level of safety to operate the equipment.

The sample used in this survey was a total of (92) volunteers divided into bridge officers with various positions from second mates, chief mates, and Masters, with different ranges of ages and work on board diverse types of vessels or involved in the management of several types of ships but with a previous career for work at sea as navigating officers.
The results of that survey could be summarized that 92.4 % (64.1 % agree and 28.3 % strongly disagree) believed that ECDIS reduced the number of accidents. Also, 97.8 % (54.9 % agree and 42.9 % strongly agree) believed that ECDIS facilitates the job of the bridge team before and during sailing. Where 46.2 % (27.5 % agree and 18.7 % strongly agree) asked for more options to be added as suggested in Table I with a total of 4 suggestions.

Table 1: ECIDS options to be added as extracted from the questionnaire

Item	Suggestion
1	Search and rescue patterns
2	Target prediction
3	Navigation warnings and forecast
4	Secure online updating

Source: (Author)

Additionally, 98.9 % preferred to use the ECDIS over the paper chart and 45.7 % preferred a secondary ECDIS as a backup, and 42.4 % preferred a secondary ECDIS as a backup with paper charts. At the same time, 85.7 % (67 % agree and 18.7 % strongly agree) preferred to use the S-Mode and 59.4 % (39.6 % agree and 19.8 % strongly agree) requested more sensors to be connected to the ECDIS as suggested in Table II below with a total of 3 suggestions.

Table II: ECDIS added sensors as extracted from the questionnaire

Item	Suggestion
1	AIS
2	Anemometer
3	Echo Sounder

Finally, according to the implementation requirements for the ECDIS, it was logged that 33.8 % (25 % agree and 8.8 % strongly agree) were in favor that the vector charts were covering all navigable sea areas, according to their vessel's coverage and operating areas. In addition, 78.3 % (53.3 % agree and 25 % strongly agree) requested extra training requirements for ECDIS.

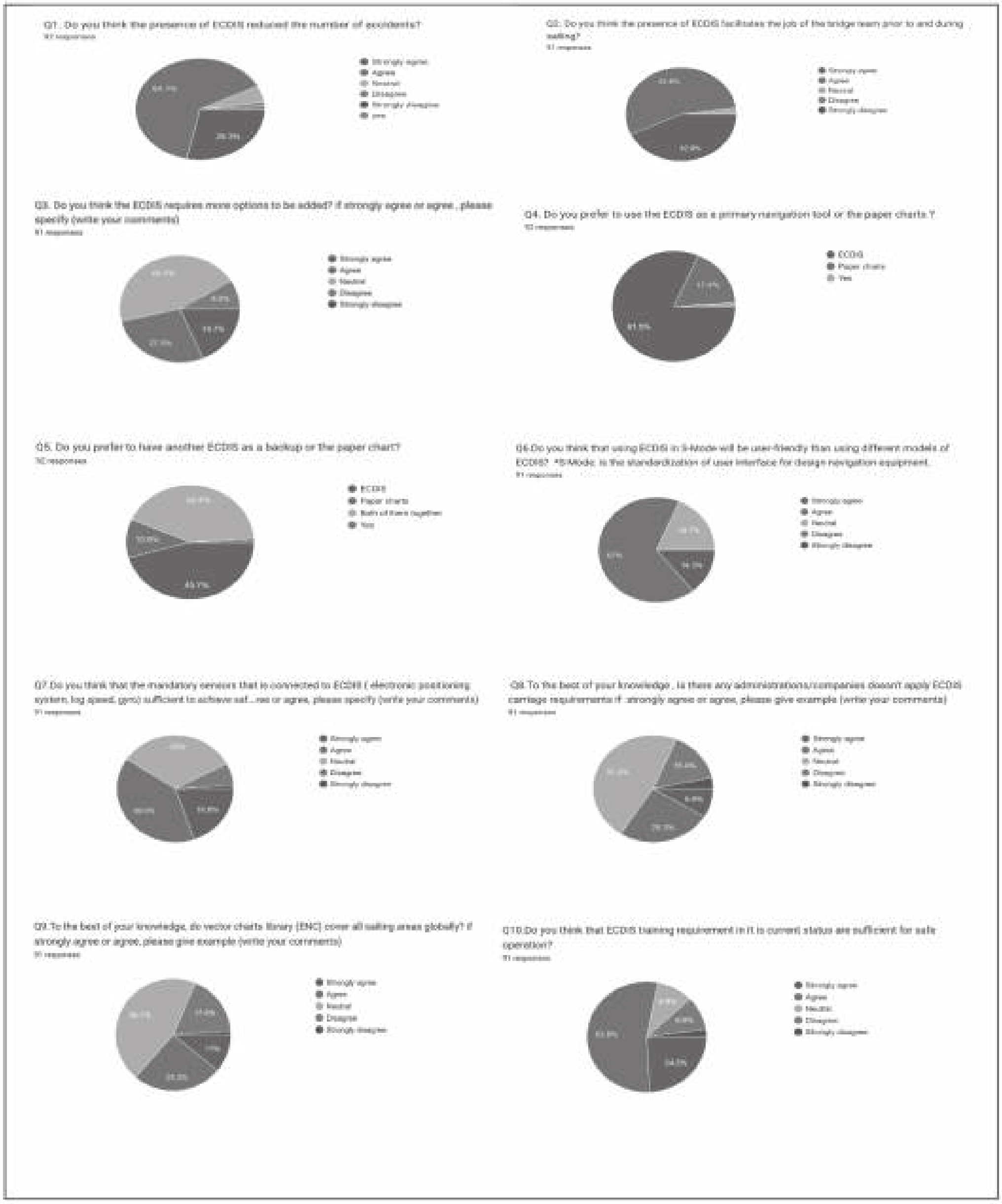

Figure:8 Questionaire Statistics
Source: (Author)

Referring to figure 8, it identifiess the results of the questionnaire in the form of ten statistical pie charts with different variables colored to indicate the results of the survey.

9 Discussion

Discussing the results from the survey was that the majority of results agreed that ECDIS reduced the number of accidents and facilitates the job of the bridge team before and during sailing. The ECDIS preferred to be used over the paper charts. Additionally, the ECDIS vector charts covered most of the navigable sea areas. However, the presence of ECDIS was satisfactory for most of the

volunteers in that survey, but more options were preferred to be applied and implemented for the ECDIS such as the programmed search and rescue patterns.
In addition, the S-Mode was identified as a beneficial approach to unify the cognitive and technical skills of end users with recommendations for extra training requirements for ECDIS due to different manufacturers with different software in the market.

10 Conclusion

It has been evident that any new addition to the Maritime Industry suffers a period of uncertainty in its purpose and a lot of miss-haps in its application before the Maritime community gains its benefits, ECDIS is no exception. ECDIS had been used onboard ships and training centers since its outbreak in 2012, allowing 10 years of building up exposure experience, highlighting errors, and thus developing as a result.
The questionnaire carried out by the authors of this review reflected the opinions of a sample of direct users of ECDIS, with a majority convinced that the equipment carried an unprecedented positive effect on the safety of navigation. Yet, a great fraction agreed that there is a massive room for improvement in the areas of software, hardware, and external sensors to effectively contribute to an efficient Integrated Bridge System.
This review captured the attention of Academia to the importance of constant review of newly added navigation equipment, especially those of direct effect on the safety of Shipping. The topic still in need of further studies using data may not be out for publication yet but surely will benefit the regulators to best develop ECDIS in the future.

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Experimental Investigation to the Effect of Heavy Load on the Performance of Different Grades of Lubricating Oil for Slow Speed Marine Diesel Engine

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المستلخص

من المعروف أن الحمولات الثقيلة هي من بين أكثر العوامل التشغيلية الحرجة المؤثرة علي آداء طبقة زيت التزليق داخل المحامل الانزلاقية الخاصة بمحركات الديزل البحرية بطيئة السرعات. وفي ضوء تلك الحقيقة تم تنفيذ بحث شامل لفحص آداء المحامل الانزلاقية عند الأحمال الزائدة والناتجة عن أقصي ضغط داخل غرفة الاحتراق لمحرك الديزل. علاوة علي ذلك قد امتد نطاق إجراءات التجارب المعملية ليشمل أكثر من مدي سرعة وهي ٤٠ – ٨٥ – ١٠٥ لفة في الدقيقة بما يتوافق مع أحمال المحرك (٤٠% - ٨٥% - ١٠٠%) علي التوالي وبالجمع أيضا مع اختبار أنواع مختلفة من زيوت التزليق تشمل 0W30 – 5W40 – 20W50. واستخدمت منصة تجارب المحامل الانزلاقية متعددة الأغراض لإجراء التجارب المعملية بسبب قدرتها علي استيعاب مختلف التغييرات في العوامل التشغيلية الرئيسية. ولقد أوضحت التجارب المعملية المنبنية أساسا على تتبع التغيرات الطارئة على ملف توزيع ضغط طبقة زيت التزليق وكذا قيم أقصى ضغط لطبقة زيت التزليق - أوضحت تأثير الأحمال الزائدة علي المحامل الانزلاقية لمحرك الديزل البحري. وبناء على كل ما تم اجراؤه من تجارب معملية في ظروف حمولات مثالية وزائدة اتضح قدرة زيت التزليق من درجة 5W40 على خلق أفضل ظروف تشغيلية عند مختلف السرعات المطبقة. وأيضا وفي ضوء مخططات التحميل التي تم الحصول عليها من خلال التجارب بات من الواضح أنه عند السرعة ١٠٥ لفة في الدقيقة والتي تمثل ١٠٠% من الحمل في حالة الحمولات الزائدة - اتضح أنه كلما زادت درجة لزوجة زيت التزليق كلما قلل ذلك من قدرة زيت التزليق على تحمل حمولات قسوى. وبالتالي لضمان الحصول على تشغيل آمن في كلا الحالتين من الحمولات المثالية والزائدة لابد من الانتقاء الصحيح لزيت التزليق الذي يوفر اللزوجة الكافية المثالية المطلوبة.

Abstract

Heavy loads are known to be among the most critical operational factors affecting the behavior of the lubricating oil film within journal bearing related to marine slow speed diesel engines. In light of the fact, a comprehensive investigation was carried out to examine the performance of journal bearing under heavy loads resulting from increased maximum pressure within the combustion chamber. Further, the research test trial procedures have been extended to cover the different speed ranges of 40 rpm, 85 rpm and 105 rpm, as corresponding to the engine loads (40 %, 85% and 100 % respectively), together with the different oil grades of 20W50, 5W40 and 0W30. Universal Journal Bearing Test Rig (UJBTR) was utilized for conducting the experimental test trials due to its capability to contain versatile variations regarding the key operational factors. Experimental test trials basically based on tracing the changes in the oil film pressure distribution and the maximum oil film pressure values, have given insight into the behavior of heavy-loaded journal bearing of diesel engine related to ships. Based all the experimental test trials under optimal and heavy load conditions, oil grade 5W40 was concluded to provide the most optimal operating conditions for all tested speed ranges.

Keywords: Hydrodynamic Lubrication, Pressure Distribution, heavy loads, Slow Speeds, Oil Grades.

1. Introduction

Hydrodynamic lubrication within main journal bearing of marine diesel engines is of foremost importance, as it prevents metal-to-metal contact between journal shaft and journal bearing. In this way, the failure of the journal bearing due to applied loads could be prevented. The oil film lubrication within main journal bearing is liable to complete failure in case heavy loads which result from early injection. Early injection (VIT) leads to the increase of the maximum pressure of the combustion gases. This, in turn, negatively affects the lubricating oil film within journal bearing. In such a condition, the propulsion system suffers complete failure, due to the misalignment of the crank shaft with the intermediate shaft and the propeller shaft. The serious impacts of this condition lead to unsafe navigation and big losses, represented in unnecessary delays and high maintenance costs. This ultimately leads the ship to become off hire.

Several research studies have been focused on the performance of journal bearing related to diesel engines. Most of them have especially investigated the different factors that could contribute to the failure of the main bearing. Forces resulting from diesel engine combustion, wear friction, misalignment, overloads and critical operational factors were probably the most prominent research areas among them. For enhancing journal bearing performance in real operating conditions Estupinan and Santos [1] evaluated the various strategies for applying controllable radial oil injection to main crank shaft journal bearing, observing the operational factors of minimum film thickness, maximum film pressure, friction losses and maximum vibration levels. Based on the conducted study, it was found out that the lubrication performance of main engine bearing could be enhanced via combining conventional hydrodynamic lubrication with controllable radial oil injection. Thomsen and Klit [2] proposed a flexure journal bearing design for enhancing operational behavior and hydrodynamic performance was evaluated based on oil film thickness, pressure as well as temperature. The operating conditions involved a rotational speed of 1500 rpm, and a load of 225 kN and the lubricant oil grade viscosity VG 32. Considering the predicted minimum film thickness, the proposed flexure journal bearing was also found to be able to operate at three times the misalignment compared to the stiff bearing. Liu et al. [3] investigated the lubricating properties of diesel engine main bearings at a speed of 2100 rpm via different applied loads. The derived outcomes ascertained that single cylinder misfire exerted a greater impact on the two adjacent main bearing loads and the axis orbits related to the two adjacent main bearings. Sander et al. [4] analyzed the behavior of automotive journal bearings under severe loading conditions. The research considered elastic deformation of the components under high pressure and at high shear rate. The operational shaft speed ranged from 1000 rpm up to 7000 rpm, whereas the applied load was from 40 kN up to 80 kN. Zadorozhnaya et al. [5] utilized the calculation of hydro-mechanical characteristics to trace the impact of the transient regime of the internal combustion engine on the resource of crank shaft bearing at different operating conditions. The study has made it possible to predict resource (wear) the bearings of the crankshaft of the internal combustion engine at different operating conditions. Xianbin and Jundong [6] obtained the elastohydrodynamic lubrication of the main bearing depending on the maximum dynamic pressure, the oil film thickness and friction power. The study established the dynamic model of marine four-stroke diesel engine body. The parameters of the main bearing comprised a journal speed of 900 rpm and the oil grade SAE 15W40. The research efforts could introduce a reference regarding the optimization design of the main bearing of 6-stroke diesel engine. Marey et al. carried out a series of research programs for investigating and enhancing the oil film lubrication within journal bearing in marine application. Marey et al. [7] involved the design and setup of a journal bearing test rig (JBTR). The study made it possible to trace the oil film pressure distribution at different speeds and constant load. Marey et al. [8] conducted a numerical study to investigate the oil film pressure profile within journal bearing. A new Computational Fluid Dynamic (CFD) model has been built for coupling future experimental test trials with computerized ones. Marey. [9] Utilized different oil grades for experimentally investigating the pressure behaviour of different lubricants within the hydrodynamic journal bearing, at different speeds ranging from 50 to 400 RPM at constant load. Marey et al. [10] enlarged the capabilities of journal bearing to contain much more sophisticated experimental test trials, via comprehensive and continuous modifications. The modifications involved adding a hydraulic loading system and full monitoring process via Supervisory Control and Data Acquisition (SCADA) system. The integrated systems have turned the structure into a Universal Journal Bearing Test Rig (UJBTR) that allowed for more extensive experiments for enhancing the performance of journal bearing and testing the most critical operational factors. Uncertainty and validation measurement analysis of UJBTR Marey et al. [11] has been carried out for ensuring the accuracy of the obtained outcomes. Li et al. [12] utilized the V8 engine model to study the lubrication performance of different poly-condensation of main bearing and concluded that oil film pressure, average filling rate of oil and misalignment of main bearing were the most important factors affecting the lubrication performance of bearings. Wan et al. [13] introduced a new method for monitoring the lubrication conditions of journal bearings in a diesel engine based on contact potential. It was concluded that asperity contact could be accurately monitored utilizing the contact potential. Additionally, monitoring the lubrication condition of a bearing utilizing contact potential was verified. Garcia et al. [14] have developed a numerical model to investigate the impact of wear and misalignment on the bearings of a stationary diesel engine at a shaft speed of 2000 rpm via changing the surface roughness as well as the bearing load. Increasing the load by 25 % was found to double the hydrodynamic pressure in the bearing. Nataraj [15] worked on enhancing the evaluation method of journal bearing performance in heavy-duty diesel engines at different engine speeds ranging from 800 rpm up till 2400 rpm under different applied load conditions. The study recommended the inclusion of multiple surface patches for changing the distribution and magnitude of bearing performance parameters such as pressure, friction losses and clearance height. Apresai et al. [16] utilized model equations to investigate diesel engine bearing wear at different engine speeds ranging from 720 rpm up to 1000 rpm and varying loads from 2000 N up to 10000 N. The main bearing was assured to ease the rotations of the crankshaft and to hold the forces created on the piston via the combustion of the mixture of compressed air and fuel in the combustion chamber.

Based on the above survey of previous research efforts, it is obvious that the operational conditions of lubricating oil film within journal bearing, and regarding marine slow speed diesel engines under overloads, were not given sufficient investigations.

2. Crank Shaft Main Bearing Assembly Forces

Circumferential Grooved Bearings (CGB) have been ascertained to provide the optimal solution in regard to marine modern large slow speed diesel engines. The reasons why such bearing type represents the best alternative involve firstly its ability to absorb strong shock-like loads arising from combustion gases and weight parts. This fact may be attributed to the lubricant oil film between the grooved bearing and journal shaft which represents a highly loadable bearing. Additionally, grooved bearings have proved their suitability regarding slow speeds and they are also characterized by their long operating life that often lasts an engine's entire life span.

The rotation of crank shaft related to slow speed diesel engine is driven by the forces resulting from the combustion gases. These gases are distributed on the area of the piston crown. The forces move to the piston rod, then they are transferred to cross head and finally they work on the connecting rod of each cylinder. The analysis of the forces on the main journal bearing is involved in Rui et al. [17]. The crank shaft is mainly subjected to forces from the big end of the connecting rod and the main bearings. These two types of forces ensure the balance of the forces working on the shaft. The forces working on the main journal bearing could exceed the required limits in case of heavy loads that result from incorrect injection timing.

3. Effects of Heavy Loads on Main Journal Bearing

Crank shaft of main journal bearing in marine diesel engine often suffers failure due to heavy loads resulting from the problems of poor Heavy Fuel Oil (HFO). The use of HFO leads to incomplete combustion of fuel oil. The problem of early injection leads to increasing the maximum pressure of combustion gases. All of the previously mentioned problems negatively affect the lubricating oil film in the crank shaft main journal bearing as outlined in Figure 1. The main risk occurs when oil lubrication moves from the hydrodynamic region to the boundary region, incurring the wear. The resultant wear leads to a very high risk resulting from the misalignment between crank shaft, intermediate shaft and propeller shaft. It can also incur the failure of the main bearing with the result of increased friction losses and hence the mechanical efficiency of the engine will decrease. The negative consequences of such a condition involve increased levels of emissions resulting from the increase in fuel consumption leading ultimately to decreasing the ship energy efficiency.

All these consequences are so much detrimental regarding the shafting system responsible for the safe navigation of the ship. Based on the previous facts, the work at hand is focused on the investigation of the effect of heavy loads on the performance of main journal bearing at different speeds, representing the loading program main engine on board ships.

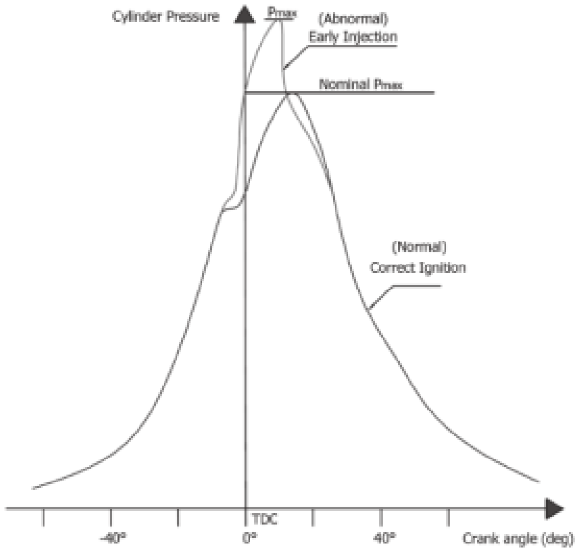

Figure 1: Typical faults shown on marine diesel engine draw card.

4. UJBTR Arrangement

UJBTR Marey et al. [10] utilized to accomplish the experimental tests, has involved four intrinsic systems, ensuring the efficient operation and accurate outcomes Figure 2. The shafting system consists of the drive motor and the drive shaft connected by the flexible coupling. Mounted on the stand, the shafting system is provided with two foundations for the supporting journal bearings and one thrust bearing. The main lubricating oil system comprises the lubricating oil pump unit, the filters and the lubricating oil cooler. All of the regulator valves, pressure gauges and sensors are included in the system. In addition, it is provided with the necessary thermocouples and oil hoses. The hydraulic oil system, in its turn, contains the hydraulic power pack unit, the filters as well as two hydraulic pistons. It also integrates the necessary hydraulic oil hoses, the proximity sensors, the pressure gauges and sensors. White metal is the material from which Circumferential Grooved Bearing (CGB) of UJBTR is made. The nominal diameter, width and wall thickness are 116 mm, 105 mm, 58 mm and 5.5 mm respectively. The main bearing clearance is 0.1 mm, whereas L/D ratio of Circumferential grooved bearing is 0.55. CGB is horizontally mounted on main journal bearing and contains pressure sensors (14No's) and thermocouples (14No's) Figure 3, for measuring the oil film pressure and temperature distribution within journal bearing. The determination of the distribution of the pressure sensors and thermocouples is based on a sensitivity study and in accordance with design criteria requirements. The flexible coupling connects journal shaft and drive shaft, and journal shaft is driven by AC motor with a maximum speed of 1450 rpm. Also, VFD controls shaft speed and rotation direction. For preventing misalignment and vibration of the shaft, the shafting system contains two supporting journal bearings. The lubricating oil system is operated to supply the main journal bearing and the supporting journal bearings with the lubricating oil. Further, the inlet port of the oil supply pressure is located on the upper part of journal bearings and the required pressure is determined according to the shaft weight and the applied lateral loads. Moreover, the lubricating oil system is regularly checked for ensuring proper operation and for avoiding any leakage, abnormal noise or vibration. Oil supply temperature is kept constant throughout the experimental test trials. The set point of the oil supply temperature is set to 40 °C on the SCADA system. The cooling system is then operated automatically via the closed loop system using the PID controller. The oil heater is turned on and the Thermocouple (TC) on the oil sump tank sends a feedback signal to the PLC. Here, the PLC sends a signal to the Zelio Controller to determine the cooling fan speed, whether it is low, medium or high. The cooling fan speed is controlled by the VFD in order to keep the oil temperature constant at 40 °C. In addition, the PID controller helps reduce the overshoot resulting from turning the oil heater on and off and also from turning the cooling fan on and off. The dead band width is also reduced to ± 1 °C via the cooling fan display page to keep the oil temperature between 39 °C and 41 °C, as neither the cooling fan nor the oil heater works in this range.

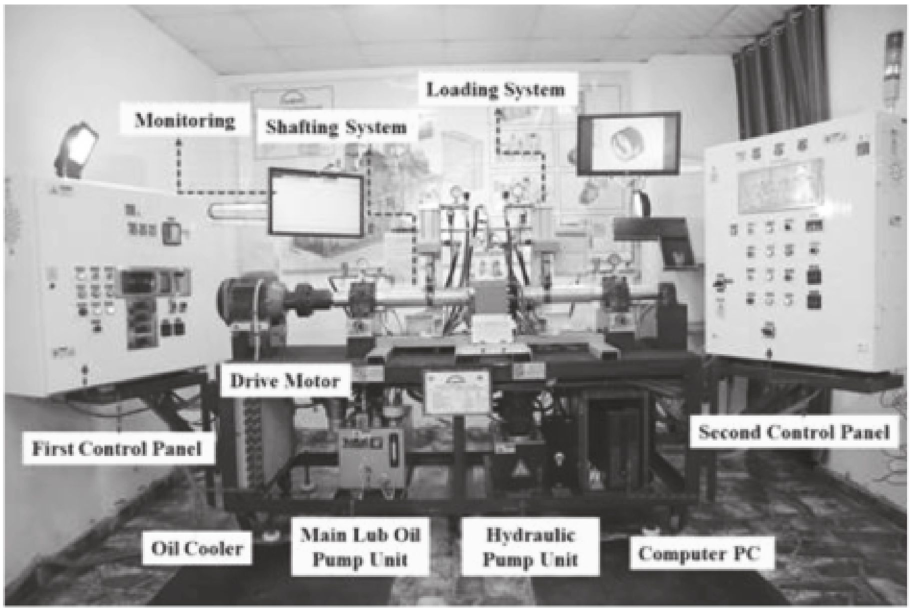

Figure 2: A schematic of UJBTR with operating systems [10].

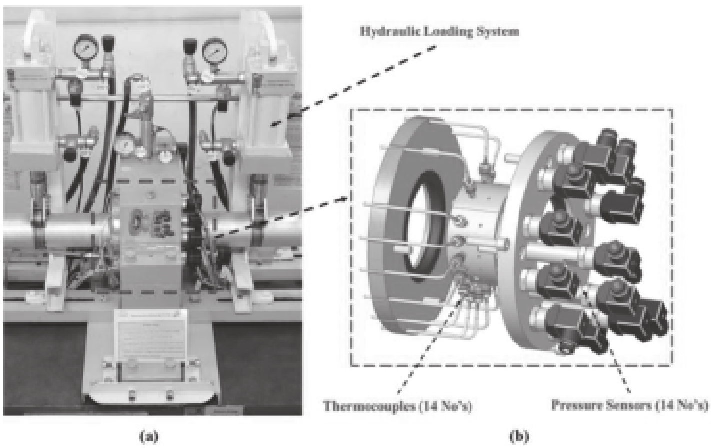

Figure 3: (a) UJBTR main journal bearing and (b) Pressure sensors and thermocouples distributed on grooved bearing circumference [10].

Finally, for ensuring the accurate performance of the whole UJBTR structure and its related systems, it is provided with a fully control system. It is operated via the advanced and highly precise SCADA control system for ensuring all procedures and experiments are accurately and efficiently manipulated and free of errors. Figure 4 shows an overview of UJBTR instrumentation and data acquisition system represented in the SCADA system integrated into UJBTR.

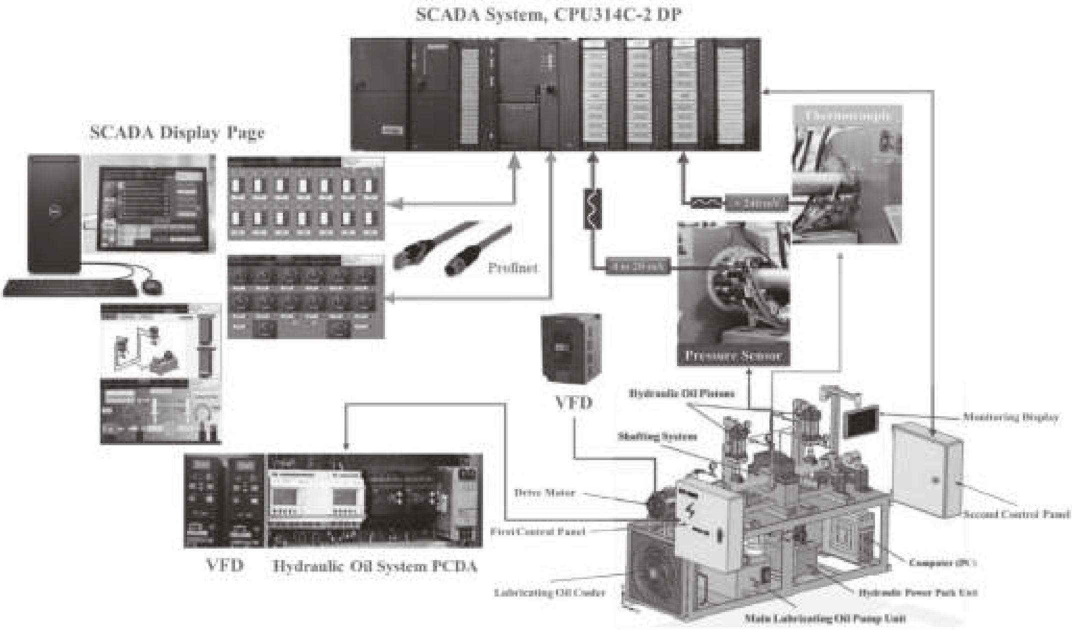

Figure 4: UJBTR Supervisory Control and Data Acquisition (SCADA) system (adapted from Marey et al. [10]).

5. Experimental Test Trials on Main Journal Bearing

Journal shaft of UJBTR has been utilized as a scale model (scale 3:16), of a marine slow speed main engine crank shaft type (SHD-MAN B&W 6S50MC) [18], to simulate heavy loads working on the main journal bearing crankshaft and resulting from the combustion gases of the combustion chamber. Further, the forces produced from the combustion gases have been represented by the simulated hydraulic loading system related to the UJBTR. Heavy load test trials have been carried out in accordance with the loading program related to the marine slow speed diesel engine. The test trials were conducted at different speed limits including 40 rpm, 85 rpm and 105 rpm, representing part load, Normal Continuous Rate (NCR) and Maximum Continuous Rate (MCR) respectively. At each of the previously mentioned speed ranges, the performance of the oil film pressure profile has been examined without load as well as under both optimal loads and heavy loads. Technical data and operational parameters of UJBTR are provided in Table 1. Further, specifications and properties related to the different oil grades 20W-50, 5W-40 and 0W-30 are shown in Table 2.

Table 1 Technical data and operational parameters for UJBTR.

Parameters	Value
L, Bearing Length	58 mm
D, Inner Diameter For Grooved Bearing	105.05 mm
Φs Shaft Diameter	104.97 mm
r, Radius for Journal Shaft	52.425 mm
C_0, Total Clearance	0.104 mm
C, Radial Clearance	0.052 mm
L/D ratio	0.55 mm
Eccentricity	0.032 mm : 0.015 mm
Operating Speeds	40, 85 and 105 rpm
W, Applied Loads	491 N : 6377 N

Table 2 Parameters and specifications for the different oil grades.

Parameters	Oil Grade Properties		
	20W50	**5W40**	**0W30**
Density at 15 ℃	0.88 g/ml	0.85 g/ml	0.838 g/ml
Kinematic Viscosity at 100 °C	19 mm^2/s	14 mm^2/s	11.8 mm^2/s
Kinematic Viscosity at 40 °C	161 mm^2/s	84.7 mm^2/s	61 mm^2/s
Viscosity Index	136	171	193
Flash Point	260 ℃	236 ℃	217 ℃
Pour Point	-24 ℃	-36 ℃	-42 ℃

5.1. Test trial procedures

UJBTR is operated under full control of SCADA system, and the lubricating oil system is checked to ensure all journal bearings were properly fed with the lubricating oil with no leakage. The inlet port of oil supply pressure is located on the upper part of journal bearings, where the pressure is adjusted based on applied lateral loads. Oil supply temperature is kept constant during test trials. The following procedures illustrate the use of the cooling system for keeping oil temperature and for preventing fluctuations during experimentation. The temperature of the oil supply pressure is set to 40 ℃ on the SCADA system. The cooling system is then operated automatically via the closed loop system using PID controller. On turning the oil heater on, a feedback signal is sent by the Thermocouple (TC) on the oil sump tank to PLC. After that, a signal is sent by the PLC to the Zelio Controller to determine the cooling fan speed, whether it is low, medium or high. The cooling fan speed is controlled by the VFD, so that the oil temperature could be kept stable at 40 °C. As for the determination of the oil supply pressure, it depends on the lateral loads applied on the journal shaft. That is, oil supply pressure is continuously adjusted so that it can be consistent with the applied loads at the different speed ranges related to the experimental trials. Noteworthy that the test trials have been conducted repeatedly for each individual oil grade and the related readings were obtained via SCADA system.

6. Results and Discussion

In this paper, a comprehensive analysis of hydrodynamic performance of heavily loaded journal bearings and utilizing UJBTR was experimentally carried out. It comprised versatile operational conditions comprising different grade oils, where test trials were conducted according to the loading programs of marine slow speed diesel engines. The effect of such critical operational factors on the oil film pressure distribution profile within journal bearing will be discussed.

6.1. Experimental results with oil grade 20W50

Figures 5, 6 and 7 illustrate a number of outcomes that were derived based on conducting test trials utilizing oil grade 20W50. The pressure values obtained without load at journal shaft speeds of 40 rpm, 85 rpm and 105 rpm were observed to be very low, where they recorded 0.06 bar at the angles of 108° and 126°. In this region, the cavitation occurs due to the decreased oil pressure values, which negatively affects the journal bearing performance. However, when test trials were conducted under optimal loads, the pressure values obtained at the same angles were noted to rise due to the increased oil supply pressure. Consequently, the cavitation phenomenon disappears due to the increased pressure which obtained the value of 0.46 bar under the optimal loads 2943 N and 3336 N at both journal shaft speeds of 40 rpm and 85 rpm respectively, whereas at a speed of 105 rpm it assumed the value of 0.58 bar under 4817 N. Additionally, the recorded values of the maximum oil film pressure P_{Max} under optimal load and at an angle of 198° were 4.16 bar, 5.12 bar and 9.46 bar at speeds of 40 rpm, 85 rpm and 105 rpm respectively. While the obtained values of P_{Max} were 2.73 bar, 4.04 bar and 9.2 bar at the same previously mentioned angles and speed ranges but under heavy loads of 3993 N, 4170 N and 5592 N respectively. Hence, based on the conducted test trials it is noted that the differences in the values of P_{Max} under the impact of the heavy loads at the angle and speeds outlined before were 1.43 bar (34.8%), 1.08 bar (21.1%) and 0.26 bar (2.75%) respectively. Based on the previously mentioned outcomes, it is clear that operating at the slow speed of 40 rpm under a heavy load for long periods, represents a risk on journal bearing resulting from the lubrication moving from the hydrodynamic region to the boundary region. Consequently, the performance of journal bearing in marine diesel engines is negatively affected under heavy loads at part load operating conditions.

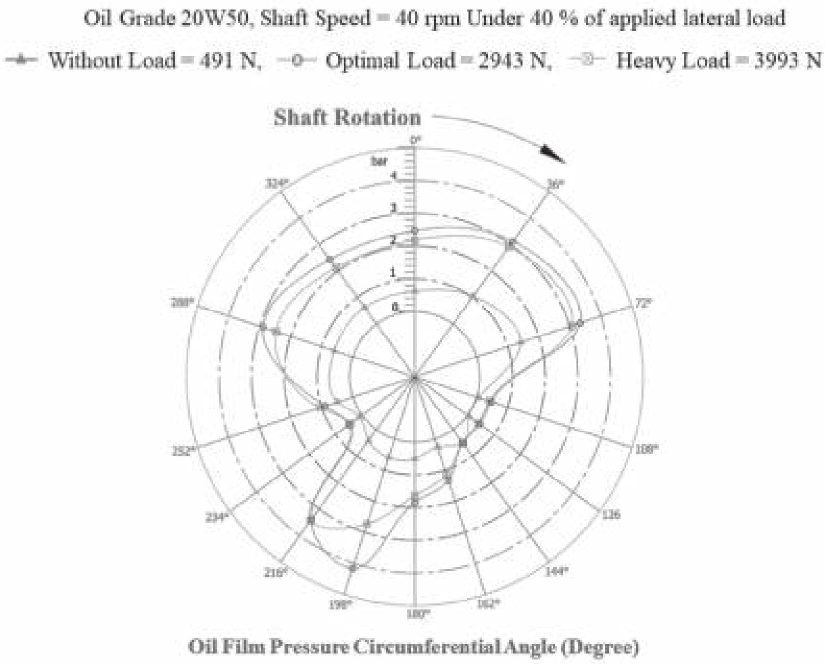

Figure 5: Variation of oil film pressure along the circumference of CGB.

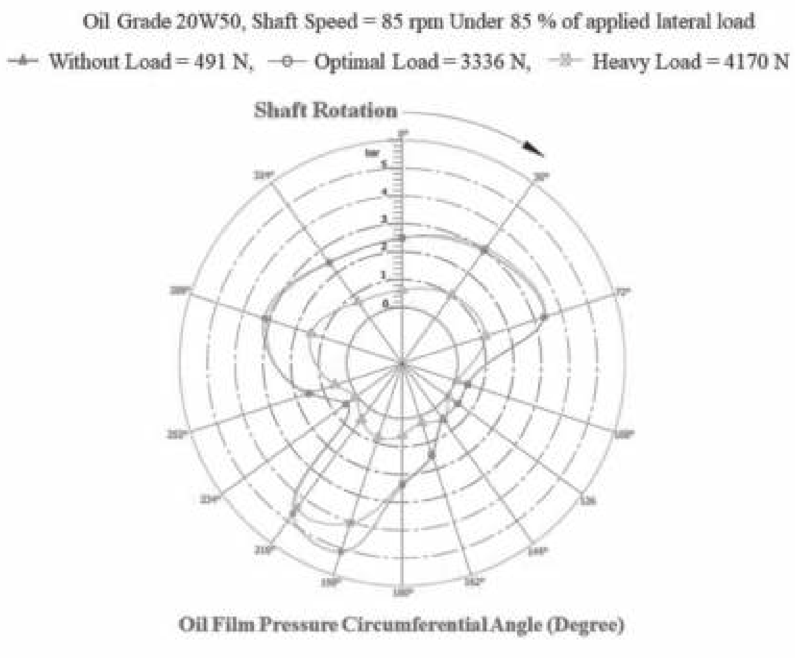

Figure 6: Variation of oil film pressure along the circumference of CGB.

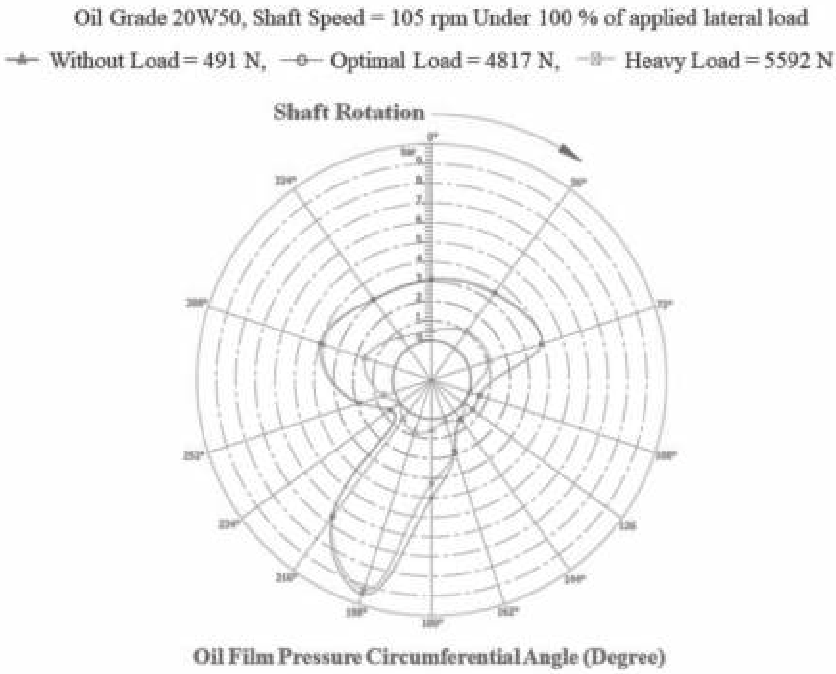

Figure 7: Variation of oil film pressure along the circumference of CGB.

6.2. Experimental results with oil grade 5W40

Another group of test trials on journal bearing were carried out also under heavy loads but utilizing the oil grade 5W40. Figures 8-10 show the impacts of heavy loads at different shaft speeds on the performance of the lubricating oil film within journal bearing in such a case. The cavitation phenomenon still exists at the shaft speed ranges of 40 rpm, 85 rpm and 105 rpm under the low oil pressure of 0.06 at the angles of 108° and 126°.

6.2.1. Performance of oil grade 5W40 Vs oil grade 20W50

The differences in the values of the P_{Max} in case of 20W50 grade oil and those recorded at an angle of 198° when 5W40 oil grade was utilized under the optimal load were -0.53 bar, 1.57 bar and -1.56 bar. In comparison, those differences in case of applying heavy load were 0.5 bar, 2.23 bar and -2.38 bar. The differences in the values of P_{Max} can be attributed to the variance in the degree of oil viscosity, which was 0.161 Pa.s for oil grade 20W50 whereas it was 0.0847 Pa.s for 5W40. The second reason for such difference is the different applied loads in case of oil grade 5W40, which were 4905 N, 5592 N and 5837 N respectively under heavy loads. Thus, the viscosity of oil grade 5W40 has the capability of tolerating higher loads than that of oil grade 20W50, but the value of the P_{Max} at the speed of 105 rpm under heavy load is lower by 26%.

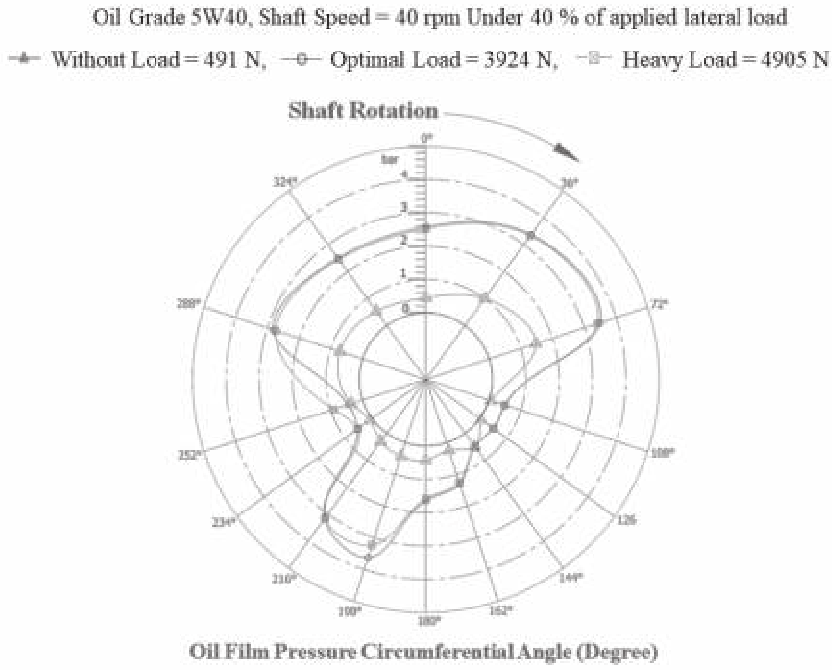

Figure 8: Variation of oil film pressure along the circumference of CGB.

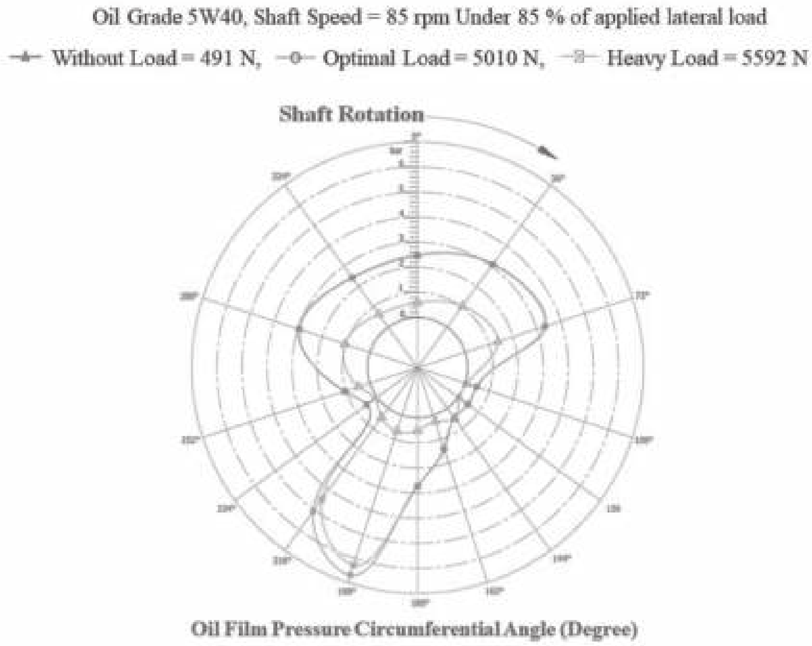

Figure 9: Variation of oil film pressure along the circumference of CGB.

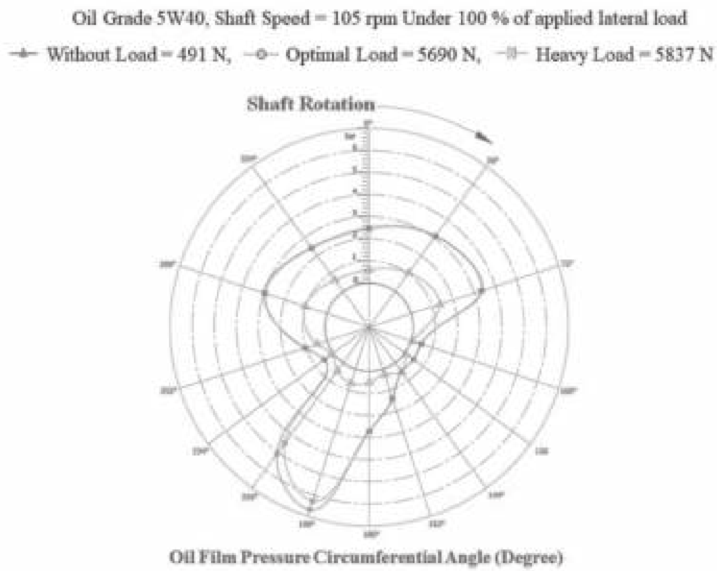

Figure 10: Variation of oil film pressure along the circumference of CGB.

6.3. Experimental Results with Oil Grade 0W30

In comparison with the results obtained with 20W50 and 5W40, experimenting with oil grade 0W30 shown in Figures 11-13 has yielded additional significant outcomes in regard to the impact of heavy loads on the behavior of the lubricating oil film within journal bearing. Again, the cavitation phenomenon which appeared while testing with the previously mentioned oil grades continues to exist with oil grade 0W30 at the same shaft speeds and angles, where the oil film pressure was 0.05 bar.

6.3.1. Derived observations with oil grade 0W30 Vs oil grades 5W40 and 20W50

As for the P_{Max} at the angle of 198° and the optimal load at 40 rpm, it is observed that both have obtained the values of 3.01 bar and 2747 N respectively. Those are lower values than those acquired when experimenting with 20W50 and 5W40. In relation to those values when obtained under heavy load, they have assumed the values of 2.7 bar and 4022 N, which are both lower values if compared with their peers obtained with oil grade 5W40. Therefore, it turned out at the slow speed of 40 rpm which represents the part load in marine diesel engine, oil grade 0W30 whose viscosity is 0.061 Pa. s will not the optimal option for operation under both optimal and heavy loads. The reason is that such oil grade will not tolerate the applied loads effectively and thus will represent a risk on the performance of journal bearing. It is also noted that at shaft speed of 85 rpm which represents NCR, the values of the optimal and heavy loads (5396 N and 6082 N) were higher with oil grade 0W30 than those obtained with oil grades 20W50 and 5W40. Also, with oil grade 0W30, the value of the P_{Max} at the angle of 198° was lowest in case of both optimal and heavy loads than it was with oil grade 5W40, assuming the values of 5.86 bar and 5.6 bar respectively. Additionally, at shaft speed of 105 rpm, it is observed that the value of heavy load was higher with oil grade 0W30 where it was 6377 N than it was with oil grades 20W50 and 5W40. Whereas the value of the P_{Max} recorded under heavy load was less than its counterparts obtained with oil grades 20W50 and 5W40, where it was 6.6 bar.

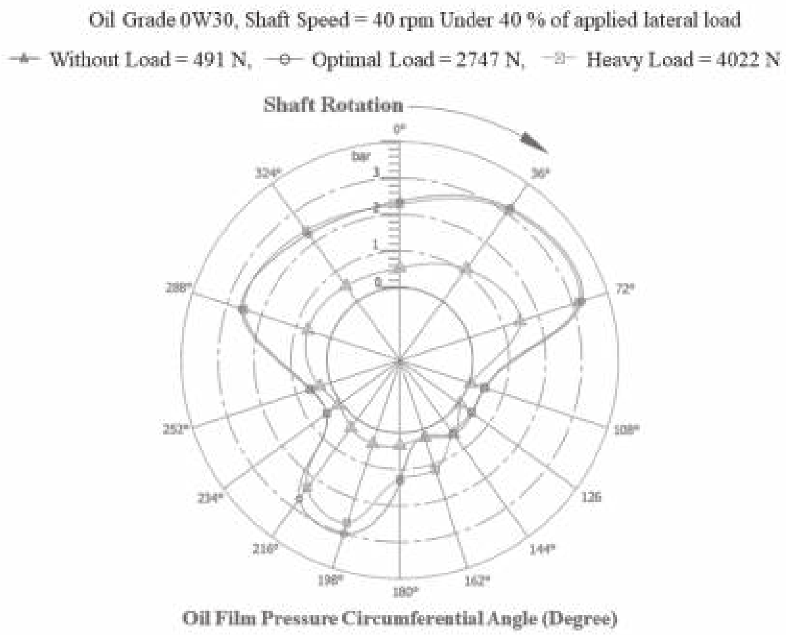

Figure 11: Variation of oil film pressure along the circumference of CGB.

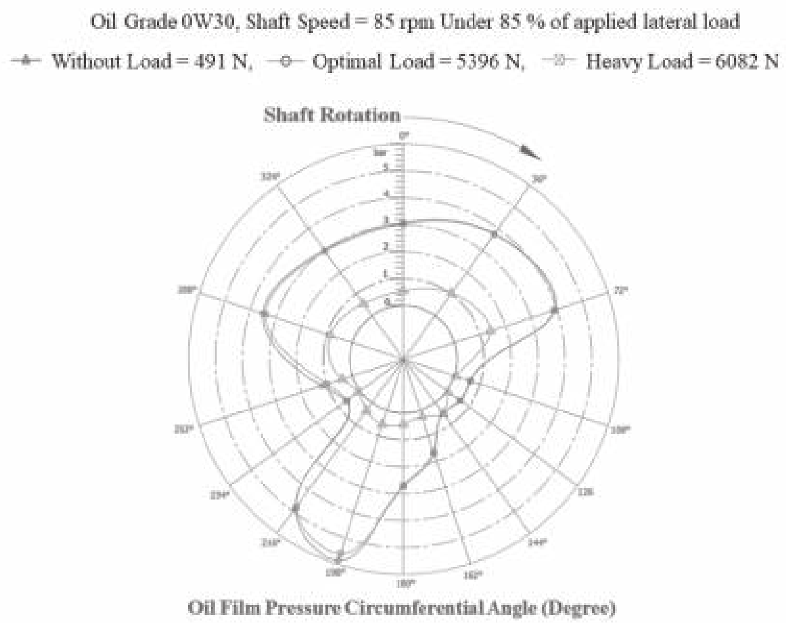

Figure 12: Variation of oil film pressure along the circumference of CGB.

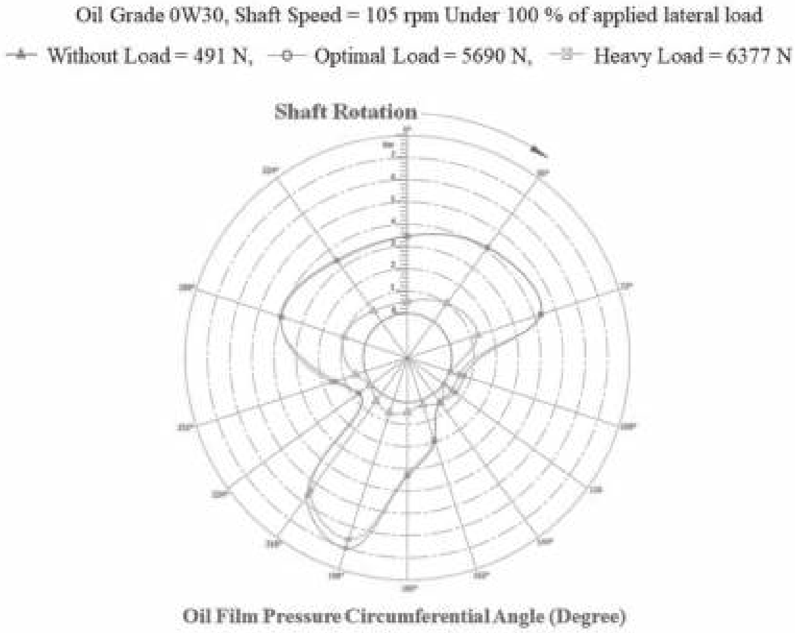

Figure 13: Variation of oil film pressure along the circumference of CGB.

The load diagrams Figure 14 illustrate the relation between shaft load and shaft speed in case of optimal load and heavy load. While Figure 15 shows the relation between shaft power and shaft speed at the same loading conditions. From the outlined loading diagrams, it is obvious that there is a positive relation those two operational factors throughout the course of the conducted experimental test trials utilizing the different oil grades previously mentioned.

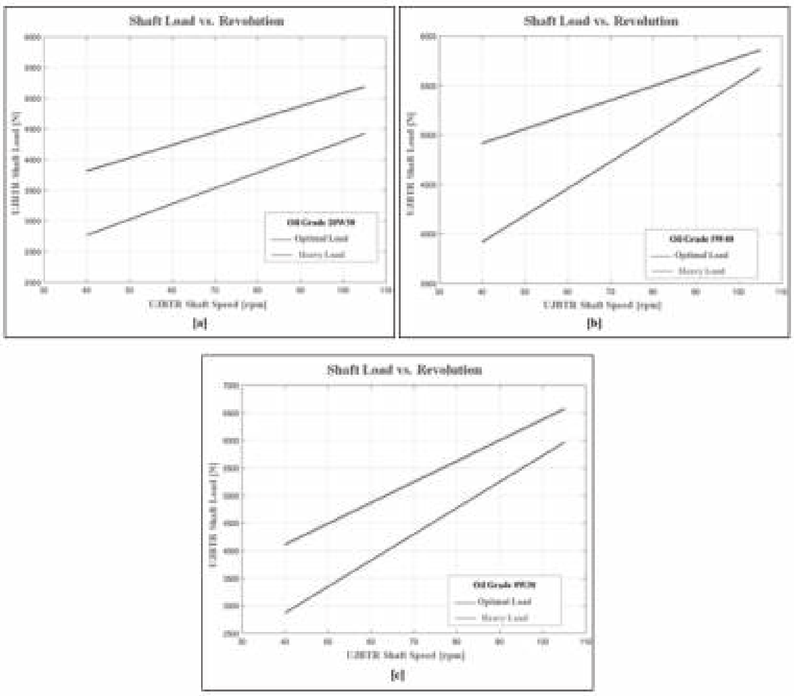

Figure 14: Load diagrams of UJBTR (Shaft Load vs. Revolution) for oil grades. (a) 20W50 (b) 5W40 (c) 0W30.

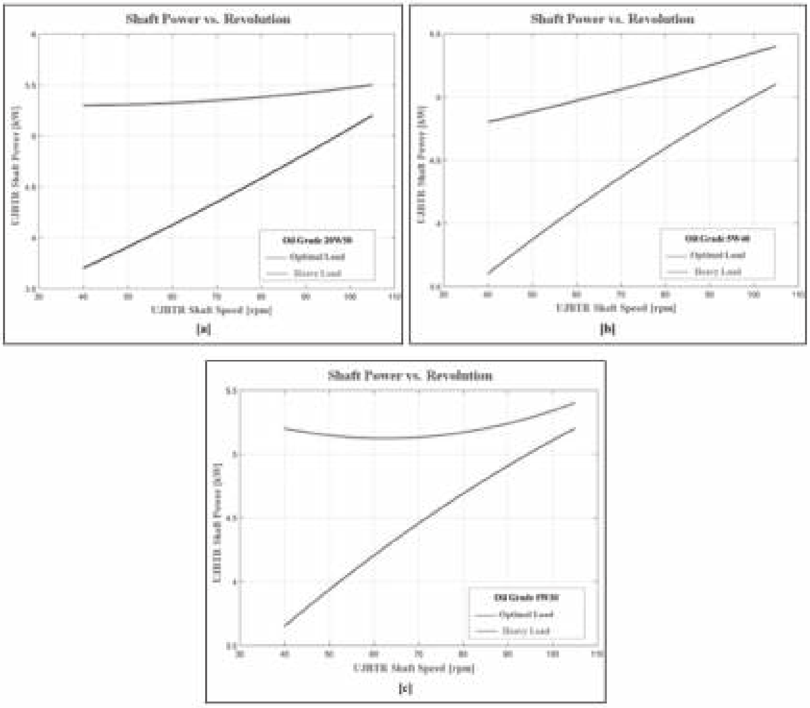

Figure 15: Load diagrams of UJBTR (Shaft Power vs. Revolution) for oil grades. (a) 20W50 (b) 5W40 (c) 0W30.

Conclusion

To realize the most possible optimal operating conditions regarding journal bearing in marine applications, the present work investigates the impact of heavy loads on the performance of journal bearing at different speeds, which represent the loading program for slow speed marine diesel engine. Further, the scope of research has extended to cover the influence of different oil grades (20W50, 5W40 and 0W30) in such operating conditions. Based on the obtained research outcomes and comparative studies of the registered characteristics, the following conclusions can be drawn:

- Throughout test trials conducted without load at all speed variations and different oil grades, the cavitation phenomenon occurred at both angles of 108° and 126°. This is due to the low values obtained in regard to the oil pressure profile at this specific region.
- With the increase of shaft speed and applied loads, the oil supply pressure increases with the result of drifting from the cavitation region.
- At increased shaft speeds the lubricating oil film within journal bearing is capable of tolerating the lateral applied loads.
- While oil grade 0W30 of lower viscosity 0.061 Pa. s at the slow speed of 40 rpm is not efficient regarding tolerating the applied loads, it has the capability to stand the exerted loads at increased speed ranges of 85 rpm and 105 rpm.
- Under heavy load condition, oil grade 20W50 has obtained the least ability in regard to tolerating the applied loads at all experimental test trial speed ranges. The high viscosity properties characterizing this oil grade results in high friction between the oil molecules, leading in turn to increased friction losses and the inability to apply further lateral loads.

- Throughout all conducted experimentation for optimal and heavy loads, oil grade 5W40 was concluded to be the most efficient oil grade in operational conditions. It has offered the optimal alternative among all tested oil grades as it provided the least loss in the P_{Max} value when moving from the optimal load to the heavy load test trials at all shaft speeds.
- According to the previously outlined load diagrams, at 105 rpm for 100 % of load in case of heavy load, it is concluded that the higher the viscosity grade of the lubricating oil, the less the capability of the lubricant to tolerate extreme loads and the higher gets the power of the shaft. Accordingly, selecting the oil grade with adequate viscosity will ensure safe operation in both cases of optimal load and heavy load.

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Nomenclature

C_0	total clearance	mm	PLC	programmable logic controller
C	radial clearance	mm	Profinet	process field net
D	inner diameter for grooved bearing	mm	PS	power supply
L	bearing length	mm	PT	pressure transmitter
L/D	bearing length/inner diameter for grooved bearing		SCADA	supervisory control and data acquisition
N	shaft speed	rpm	SM	signal module
P	motor power	kW	TC	thermocouple
P_{max}	maximum oil film pressure	bar	UJBTR	universal journal bearing test rig
P_0	nominal bearing pressure	bar	VFD	variable frequency drive
r	Radius for Journal Shaft	mm		
T	temperature	℃		
W	applied load	N		
Φ_s	shaft diameter	mm		

Dimensionless Group

P_0/P_{max}	maximum film pressure ratio

Greek Letters

μ	dynamic oil viscosity	Pa.s
ρ	lubricant Density	kg/m^3

Abbreviations

CGB	circumferential grooved bearing
CP	communication processor

The Effect of Safety Philosophical Factors on Risk Management

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المستخلص:
نظرا لأن الغاز الطبيعي المسال يعتبر أحد أنظف أنواع الوقود الأحفوري، فإن الهدف الأساسي من هذه الدراسة هو جمع البيانات المتعلقة بتزويد الغاز الطبيعي المسال كوقود في الصناعة البحرية. الغرض من البحث الحالي هو النظر في العوامل الفلسفية للسلامة وكيف يمكن أن تؤثر على إدارة المخاطر. للتحقيق في هذه العلاقة، يتم جمع البيانات الكمية من الاستبيانات التي يتم توزيعها على ٢٠٠ بحار. وأخيرا، أظهرت نتائج تحليل الارتباط وجود علاقة مهمة بين العوامل الفلسفية للسلامة وإدارة المخاطر، بينما أظهر تحليل الانحدار تأثيرا إيجابيا كبيرا لعوامل السلامة الفلسفية على إدارة المخاطر.

Abstract
Since Liquefied Natural Gas (LNG) is regarded as one of the cleanest fossil fuels, the primary goal of this study is to collect data concerning the bunkering of LNG in Maritime Industry. The purpose of the current research is to look into Safety Philosophical Factors and how it could affect risk management. To investigate this relationship, quantitative data are collected from questionnaires that are distributed among 200 seafarers. Finally, the findings of correlation analysis showed a significant relationship between safety philosophical factors and risk management, while the regression analysis showed a positive significant impact of safety philosophical factors on risk management.

Keywords: Liquefied Natural Gas, Safety Philosophical Factors, Risk Management

1. Introduction

The condition of being protected from danger, harm, or injury is commonly defined as safety. Safety is a necessary daily resource for individuals and communities to achieve their goals. There are numerous definitions of safety depending on the context, and the field in which it occurs. The importance of safety has changed dramatically in the last few decades of the 20th century, as the idea of safety has changed with time. Because of developments in marine commerce and the global environment at the end of the twentieth century, much emphasis was placed on the perception of maritime and navigational safety (Formela et al., 2019).

Functional safety is a notion that applies to all industries. It is essential for the deployment of complex technologies employed in safety-related systems. It ensures that the safety-related systems will provide the essential risk reduction to assure the equipment's safety. But first, consider the concept of security: Freedom from an unreasonably high risk of bodily harm or health damage as a result of property or environmental degradation, either directly or indirectly (International Electrotechnical Commission, 2000). Safety at sea is related to navigational safety, emission reduction, people's safety in emergency circumstances, and ship technological and operational safety (Formela et al., 2019).

On modern, technologically advanced ships, the safety of the sailors is crucial. Operating in fast changing operational, economic, social, political, and international situations are the shipping industry as a whole and the maritime sector. Because of the increased operational complexity, sailors must have the necessary skills and training to handle challenges. Also, because of the complexity, decision-makers are concentrating more on training safety (Markopoulos et al., 2020).

The current study puts its main focus on testing the relationship between Safety Philosophical Factors and Risk Management in Maritime Field. Although LNG starts to be significantly adopted in Maritime industry, LNG has number of challenges and dangers that could occur. LNG is a cryogenic liquid that is held at close to atmospheric pressure. When released, there is a risk of fire, Boiling Liquid Expanding Vapor Explosion (BLEVE), cryogenic burns, metallic part shattering, and asphyxiation. In severe situations, in addition to the direct harmful consequences of exposure to those nearby, fire or structural failure could result in the destruction of the vessel, with major loss of life to those nearby. If the vessel is alongside at the time, this may include those on shore (Stokes et al., 2013).

Therefore, it is important to provide suitable trainings that help seafarers to know how to deal with LNG bunkering and avoid its challenges in order to succeed in manage the risks that could happen as a result of using LNG. Accordingly, this paper is divided into six sections, which are; introduction, aim and objectives, literature review, methodology, analysis and findings, conclusion and recommendations.

2. Research Aim and Objectives

The current research purposes examining the relationship between Safety Philosophical Factors and Risk Management while bunkering Liquefied Natural Gas inside the field of maritime. Accordingly, one main objective is developed, which is;

- To identify Safety Philosophical Factors achieving Risk Management in Liquefied Natural Gas bunkering in maritime industry.

3. Literature Review

This section consists of two sub-sections, where it discusses previous literature that had investigated the same topic.

3.1 Safety Factors and Risk Management

Many sorts of safety have been the genesis for early civilizations (Egypt, Greece, and China) to exist, so these civilizations did not create the concept by themselves as it was formed naturally from their daily lives. Nevertheless, there may be more to the relationship between risk and safety than a simple linguistic change. Thus, safety can be viewed as a component of overall risk management. Although the security risk management may be perceived as an expense against the operation, it also represents a substantial threat if not handled carefully (Mokhtari et al., 2021).

Maritime transportation is characterized by its higher danger level than air transportation, but it is close to rail transportation's level of safety and far greater than road transportation's level of safety. Accident risk and, more specifically, the involvement of the human component in these risks are critical considerations in this scenario. Indeed, human error appears to be the major cause of maritime catastrophes. Accordingly, the risks come initially from human factors that could be represented in; (Berg, 2013)

- Elements that reduce performance (tired, stress, and health issues)
- Organizational features (safety training, team management and safety culture)
- Insufficient technical and cognitive capacities
- Insufficient interpersonal competencies (problems in understanding a shared language and communication challenges)

It is important to refer that, safety culture and training are still suffering from some gaps in Maritime industry. Therefore, the marine industry's safety culture and training need to be given more attention and growth. The importance of safety training, safety culture, and competency evaluation must be increased (Berg, 2013). Frequent training, continuing awareness of cultural change, and an ongoing process of continuous development are all necessary for maintaining safety culture (Goldberg 2013).

As can be seen from the above, risk is mostly dependent on human errors; as a result, risk management could be enhanced by focusing on people (seafarers, masters and officers) through applying safety training and safety procedures. The IMO, like other regulatory authorities, distinguishes between safety and security. In this sense, safety refers to protection against the danger of injury caused by unintentional events such as accidents, whereas security refers to protection from purposeful occurrences (Joseph and Dalaklis, 2021). The International Atomic Energy Agency (IAEA) contends that handling safety and security frequently occurs concurrently. Regardless of intent, businesses will deal with the ramifications of an occurrence in the same way. For example, if there is a power outage on board, regardless of the source, the crew will respond in the same way by ensuring that the situation does not threaten the ship's safety or security (for example; drift into the path of another ship) (Hopcraft, 2021).

Because seafarers' activities directly affect the safety and security of a ship's systems, they must be provided with the necessary digital competences to make educated decisions concerning such systems. IMO has long stressed the link between the human factor and maritime safety and security. IMO explicitly recognized the link between training and ship safety in 1993. Taking this a step further, the IMO contends that safety and security are dependent on a plethora of complicated interacting elements, such as training, talent, and experience (Hopcraft, 2021).

As previously said, safety and security frequently have conflicting priorities; nonetheless, as businesses attempt to improve one, they accidentally advance the other. Both the IAEA and the IMO have called for the concurrent development of a safety and security culture that promotes holistic risk management. The IMO contends that a safety culture is an essential component of a company's safety management system (SMS) (Hopcraft, 2021). According to the IMO, this should also entail the establishment of a just culture in which organizations acknowledge that accidents can occur and that these provide a chance to learn what improvements are required to fix flaws in the current safety management system (Hopcraft et al., 2023). The creation of an organizational culture that considers both safety and security enables a company to assess the risks it faces and determine the actions needed to mitigate that risk (Hopcraft, 2021).

In terms of risk management, the IMO specifically highlighted the importance of improving operations of marine safety following many high-profile safety-related accidents. The IMO approved a number of regulations demanding stricter safety management systems aboard ships to that end (IMO, 1988).

The Safety of Life at Sea (SOLAS) convention emerged and incorporated the ISM Code as a requirement. The ISM Code was developed to make sure that all governments and businesses apply risk management strategies that increase the safety of mariners. Together with these guidelines, industry participants began to create risk management frameworks. These aided individuals in understanding, visualizing, and meeting new safety criteria in day-to-day operations (Hopcraft et al., 2023).

One risk management strategy that focuses on adding many layers of mitigations is Reason's Swiss Cheese Model (Reason, 2016). These safeguards can take the shape of hardware, software, or rules and processes. These layers contain defects (holes). A successful SMS will prevent those holes from aligning. Due to its ease of understanding, this risk perspective has been widely used since it was first introduced. As a consequence, the researchers utilize this model to illustrate a shortcoming in current risk management practices. Figure 1 shows this Model (Hopcraft et al., 2023).

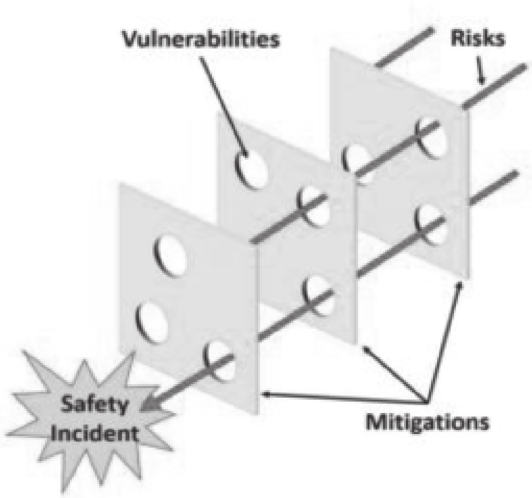

Figure 1: Reason's Swiss Cheese Model
Source: Hopcraft et al., (2023)

Yet, like with loss-of-life incidents, operational safety is dependent on human-machine interactions, which is referred to as a socio-technical system. A system's performance is determined by the optimization of both technical and social elements. Yet, dangers might arise inside the system as a result of poorly ordered or poorly managed interactions between various pieces. Accordingly, safety must also be ensured within the devices themselves. The Swiss Cheese Model is illustrated in Figure 2 to represent essential features used in the safety of socio-technical systems (ships). Four layers are included; the governance layer, which represents the laws and regulations that must be followed. The management layer is the internal practices that direct the company's core risk profile. The technical layer consists of technological and, in many cases, digital safety management and mitigation tools. The human element is the fourth layer, and it is responsible for operating within the safety boundaries (Hopcraft et al., 2023).

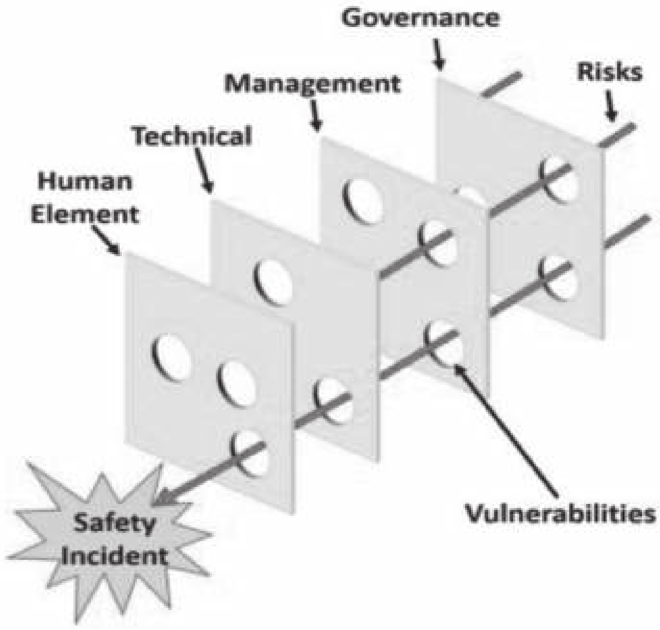

Figure 2: Swiss Cheese Model utilizes in the safety of ships
Source: Hopcraft et al., (2023)

The purpose of this current study is to examine the connection between risk management and safety philosophical factor. Because of environmental protection legislation regarding emission limitations and LNG's cost-effectiveness, the LNG usage as a fuel in marine operations is expanding. IMO is concerned about LNG usage and other low-flashpoint fuels as gaseous fuels on ships. The Maritime Safety Committee approved modifications to the 1978 International Convention on Standards of Training, Certification, and Watchkeeping (STCW) for Seafarers regarding the necessary minimum standards for masters, officers, and other crew members on ships within light of the IGF, and the Gases or Other Low-Flashpoint Fuels (IGF) safety code was put into effect. The STCW revisions include requirements for crew members working on ships subject to the International Code of Safety for Ship Using Gases or Other Low-flashpoint Fuels to complete basic and advanced training (Zincir and Dere, 2015).

Several research are being conducted to reduce shipboard emissions as emission limitations and energy efficiency rules become more stringent. These investigations could be the main engine following treatment procedures, such as filtering and cleaning equipment, that aim to eliminate dangerous combustion products. Prevention studies prior to the combustion process, on the other hand, can be another sort of emission abatement study. Alternative fuel use at ship main engine and diesel generators is one of the prevention studies before the combustion process (Calleya et al., 2011).

Current technological developments and international maritime legislation highlight the importance of training engine officers and ratings who will work on LNG-fueled ships. Training methods for STCW involve simulator training, training programs, in-service training, and training on ships as per STCW 2010. In addition to theoretical training and aboard experience, simulator training aids learning and provides learners with practical experience (Zincir and Dere, 2015).

3.2 Challenges in Maritime Industry while using Liquefied Natural Gas

LNG is a developed natural gas transportation technique that is used to transport it across oceans over great distances. LNG is the finest option for transporting natural gas across long distances, particularly those more than 2000 kilometres. LNG is created by cooling natural gas to 162 degrees Celsius at atmospheric pressure. Because one cubic metre of LNG includes around 625 cubic metres of natural gas, LNG has a substantially higher energy density than natural gas. Furthermore, because LNG is colourless, non-toxic, odourless, and noncorrosive, it is widely used in a variety of sectors. Because methane is the most abundant component of LNG, it emits extremely few greenhouse gases and nitrogen oxides, and nearly no sulphur oxides when evaporated and burned (He et al., 2019). Therefore, LNG is one of the cleanest resources of energy (Lowell et al., 2013).

When LNG spills on the ground or in water, it instantly vaporises and leaves no traces. If LNG spills over water, it has no negative impact on waterways (Dodge, 2014). Although LNG has all these advantages, it is only used by 668 LNG-fueled ships in operation, and construction on 76 additional buildings is ongoing (Zincir and Dere, 2015).

Previous studies have investigated the adoption of LNG and linking it to risk management in the maritime industry. Stokes et al. (2013) sought to establish the needs for maximizing safety in LNG bunkering operations, as well as to comprehend how to assess the skill gap between crew and port staff in order to eliminate human factor risks in LNG. It was concluded that changes in technology, procedures, and processes will necessitate a review of the abilities required to operate the new LNG operations concurrently safely and efficiently. It is worth noting some of the additional advantages of ensuring worker capabilities in this manner. It can considerably reduce the risk of human mistakes, offering additional protection to the LNG bunkering systems on board and on shore, as well as the vessel as a whole, lowering the likelihood of a serious event. Additionally, wider benefits may be realised as skilled employees are less likely incur workplace health and safety risks originating from human error.

A statistical method for determining the safe exclusion zone surrounding LNG bunkering facilities was provided by Jeong et al. (2017) using a specially developed computer programme and quantitative risk assessment. The conclusion demonstrates that, for a variety of reasons, IMO member states have not yet developed their own clear standards for safety exclusion zones in LNG bunkering.

In their 2018 study, Ovidi et al. focused on LNG safety as they approached a bunkering terminal through port channels in an industrial region. The risk level associated with the ship approaching the harbour was measured using a risk matrix technique. A case study of industrial relevance was used to demonstrate the tool's capability for assisting risk-based decision making. The findings of the investigation showed that LNG carrier access creates a significant risk level for industrial and civic installations near the channel.

With a focus on LNG technology, Iannaccone et al. (2018) examined the safety of onshore bunkering options for systems of maritime fuel. The results show that traditional IFO bunkering is fundamentally safer than LNG and enable the accurate determination of crucial process units and operations. In order to ensure the long-term growth of the LNG supply chain for marine applications, safety concerns must be weighed against environmental advantages.

Hongjun et al. (2018) proposed that LNG leaks could occur during pontoon bunkering operations in China. It is decided that the pontoon equipped with IMO Type C tanks, as well as suitable berthing/unberthing and safety systems, has been demonstrated safe and reliable by practices. It is also estimated that about 30 such upgraded LNG bunkering pontoons with a fuelling capacity of 500 m^3 will be required on the Yangtze and Pearl Rivers by 2025. Ultimately, practices have validated the pontoon's safety and dependability, and its fourth version has been developed.

Jeong et al. (2018) was carried out to evaluate potential dangers connected with LNG bunkering. In the LNG bunkering process, a unique method for developing practical safety exclusion zones was provided. The investigation disproved the presumption that current probabilistic risk assessment practice focused entirely on population independent analysis because the size of safety exclusion zones appeared to be set up in an unfeasibly wide manner. Instead, it was shown that the suggested method—which included both population-dependent and independent assessments—was effective at more accurately identifying the zones.

Aneziris et al. (2020) gave an in-depth literature study on LNG port safety and risk assessment. 23 articles in English were collected and analyzed, where they included the period between 2008-2018. The evaluation showed gaps in science and harmonisation, while safety and hazard zones required greater research and analysis.

3.3 Research Gap

According to the above literature review, it is noticed that previous studies focuses on LNG and tries to identify the challenges related to LNG and how can risk management control and avoid these challenges. On the other hand, previous studies did not focus on factors that may affect risk management related to LNG bunkering. Therefore, the current study aims to overcome this gap through examining the impact of safety philosophical factors on risk management.

4. Research Methodology

Research methodology is a process a researcher uses to conduct his research in a methodical way, gathering a variety of ideas, thoughts, theories, and concepts to apply to a certain study topic (Matthews, 2014). Research methodology's main objective is to produce accurate and trustworthy data on the subject area with regard to future-looking procedures (Ørngreen and Levinsen 2017). The current study applied positivism philosophy and deductive approach aiming to reach the study aim. Qualitative data are collected through questionnaires, where a non-random technique of convenience sampling is used, and the final data consisted of 200 seafarers who are working at the energy sector companies.

As, the current study aims to examine the effect of Safety Philosophical Factors on the Risk Management while using LNG, the research framework could be shown as follows;

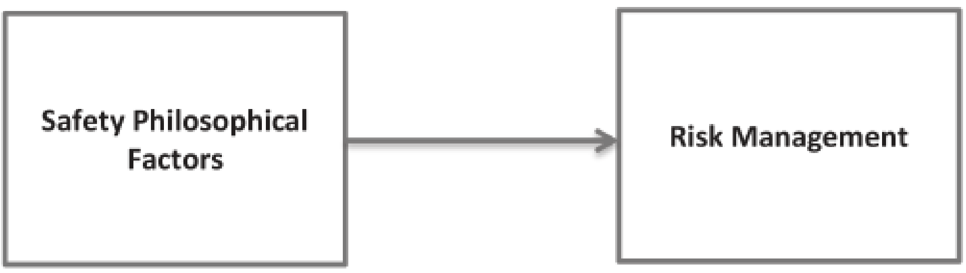

Figure 3: Research Framework

From the framework, the hypothesis of the research is developed, which indicated that;

H: There is a significant relationship between safety philosophical factors and risk management

The research hypothesis is analyzed through using correlation and regression analysis, where data are collected from questionnaires. Table (1) shows the statements used in the questionnaires.

Table 1: Research Variables Measurement

Variables	Measurement	References
Safety Philosophical Factors	The organization's safety policy is established, and its principles are shared by all members.	Fan et al. (2022)
	Safety duties and responsibilities are well defined.	
	Errors are reported with no consequences or punishments.	
	Vertical/horizontal communications on safety are emphasized. (Vertical is between levels of an organizational hierarchy. Horizontal is between individuals or units at the same hierarchy.)	
	Management is dedicated to safe procedures.	
	The safety management system's audits are adequately executed.	
	The organization's risk assessment is effective.	
	The organization has a well-developed safety checklist for simultaneous LNG bunkering activities.	
	The organization's emergency procedures and policies are adequately designed.	
	Clear mission statements are extensively shown at work.	
	As part of the training program, specialized training and education are delivered on a regular basis.	
	Near misses and incident/accident reports teach employees valuable lessons.	
	Employees are well educated on the company's safety policies.	
	Staff training includes learning and improving contentious safety.	

Variables	Measurement	References
	Safety training and education are provided based on the degree of personnel.	
Risk Management	Uncertainty is seen as a significant challenge in our organization.	Ndubisi and Agarwal (2014) Szambelan and Jiang (2019)
	Our team promotes opportunity for success rather than possibilities for failure	
	Our team has a strong preference towards high-risk ventures with a high probability of success.	
	Because of the environment nature, our team feels that bold, broad-reaching actions are required to fulfil our organization's goals.	
	Our organization often takes a strong, proactive stance to increase the likelihood of capitalizing on prospective opportunities, when there is uncertainty.	

5. Research Analysis and Discussion

The empirical analysis is shown in this section, where it includes five sub-sections;

5.1 Data Testing using Validity and Reliability for the Research Variables

Validity analysis implies the degree to which an instrument assesses what is supposed to quantify efficiently and properly. The extracted average variance (AVE) represents the average community for the hidden factor (should be ≥50%). Furthermore, the size of the factor loadings (FL) of the measures on their respective constructs (which should be ≥0.4), can be used to assess item reliability (Bell et al., 2018). Likert Scale 5 has been used for the questionnaire (1 – strongly disagree, 2 – disagree, 3 – not sure, 4 – agree, 5 – strongly agree), Reliability analysis relates to the amount of consistency of the scale used to assess the stated construct. Cronbach's Alpha was chosen as the most often used trial measure of reliability (should be 0.7) (Fuentes-Huerta et al., 2018).

This section tests the validity and reliability of the research variables. It was found that from the analysis results at Table (2) that all the fifteen statements of the safety philosophical factors are valid, as the factor loadings of the 15 statements are greater than 0.4. In addition, the result of AVE was 63.315%. Regarding the reliability test, it is observed that the Cronbach Alpha of the statements is 0.958, which means that the statements are reliable to form this construct.

Regarding the validity and reliability of the dependent variable, Table (2) shows that the factor loading of the five statements are 0.741, 0.625, 0.587, 0.626 and 0.672 respectively. In addition, the result of AVE was 65.013%, therefore, all the five statements of the risk management are valid. It could also be noticed that the Cronbach Alpha is 0.861, which means that the assigned statements are reliable to form this construct.

Table 2 Validity and Reliability of the Variables

Items	FL	AVE	Cronbach's Alpha
SP1	.614	63.315%	.958
SP2	.604		
SP3	.591		
SP4	.603		
SP5	.715		
SP6	.641		
SP7	.621		
SP8	.625		
SP9	.627		
SP10	.693		
SP11	.563		
SP12	.683		
SP13	.671		
SP14	.638		
SP15	.608		
R1	.741	65.013%	.861
R2	.625		
R3	.587		
R4	.626		
R5	.672		

5.2 Descriptive Analysis for the Research Variable

The descriptive analysis shows that the mean values of the safety philosophical factors and risk management equal 4.9050 and 4.8950 with a standard deviation of 0.29395 and 0.30732, while the minimum andmaximum values are 4.00 and 5.00. and 4.00 and 5.00 respectively.

Table 3 Descriptive Analysis

	N	Minimum	Maximum	Mean	Std. Deviation
Safety Philosophical Factors	200	4.00	5.00	4.9050	.29395
Risk Management	200	4.00	5.00	4.8950	.30732

5.3 Normality Test

Normality is one of the assumptions that must be checked in order to evaluate whether or not a data collection is normal. Table 4 shows the formal testing using the Kolmogorov-Smirnov test. As the related P-values are less than 0.05, it is clear that the research variables are not regularly distributed.

Table 4: Formal Testing of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	P-value	Statistic	df	P-value
Safety Philosophical Factors	.532	200	.000	.332	200	.000
Risk Management	.529	200	.000	.352	200	.000

5.4 Testing Regression Assumptions

Regressions assumptions are tested through autocorrelation and heteroscedasticity.

Autocorrelation: It is another important assumption of the ordinary least squares' method in which means that the errors present in the model have relationship between each other. A Durbin-Watson (D-W) test is used because it is one of the statistical tests used to compare the null hypothesis (there is no autocorrelation to others that are autocorrelated). The results indicated that the model test equals 2.130, which shows that the no autocorrelation is supported.

Durbin-Watson Value = 2.130

Heteroscedasticity Assumption: It is the problem of having inconstant variance in the model assigned. The scatter plot of the standardized residuals against the unstandardized predicted values is used, where the results show heteroscedastic relationships between the variables.

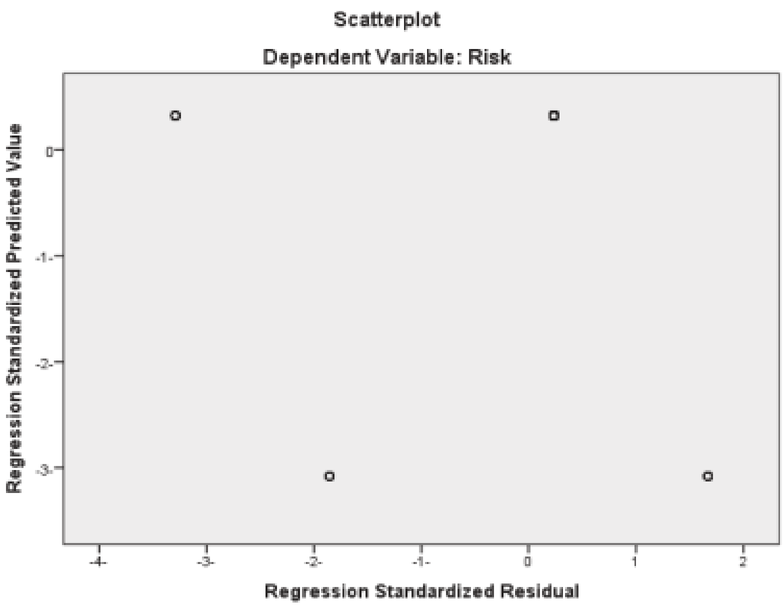

Figure 4: Scatter Plot for Heteroscedasticity

5.5 Testing the Research Hypotheses

This section introduces the correlation and regression analysis, where the non-parametric test of Spearman correlation is applied. The correlation matrix shows that Safety Philosophical Factors has a positive significant relationship withRisk Management as P-Value= 0.000 and r= 0.390.

Table 6 Correlation Matrix between Safety Philosophical Factors and Risk Management

			Safety Philosophical Factors	Risk Management
Spearman's rho	Safety Philosophical Factors	Coefficient	1.000	.
		2-tailed Sig.	.	.
		N	200	200
	Risk Management	Coefficient	.390	1.000
		2-tailed	.000	.
		N	200	200

The regression model in Table (7) illustrates that there is a positive significant influence of Safety Philosophical Factors and Risk Management, as the coefficient =0.407 with a significance= 0.000. Furthermore, the R square is 0.152, indicating that the model can explain 15.2% of the variation in Risk Management, which means that safety philosophical factors affects risk management by only 15.2%, by that there are independents factors that may affect risk management other than the current independent such as; digital transformation, and supply chain management.

Table 7 Regression Model for Safety Philosophical Factors on Risk Management

Model		Unstandardized Coefficients		Std. Coefficients	t	Significance	R Square	P Value
		B	Std. Error	Beta				
1	(Constant)	2.897	.336		8.615	.000	0.152	0.000
	Safety Philosophica l Factors	.407	.068	.390	5.954	.000		

6. <u>Results</u>

From the above analysis, the correlation and regression analysis proved that safety philosophical factors have positive significant influence on risk management regarding LNG bunkering. The concluded results are expected as safety factors are expected to enhance the risk management in maritime industry.

7. <u>Conclusions, Recommendation and Limitation</u>

In the context of maritime transport, the current study focusing on investigating the impact of the safety philosophical factors on the Risk Management for the ships that use Liquefied Natural Gas. Accordingly, one main hypothesis is developed and the analysis shows a positive significant impact of safety political factors on risk management. The current study proved that the safety factors and procedures that the seafarers follow represents main factors that reduce risks related to LNG usage.

Decision-makers can be advised based on the findings to ensure the existence of all safety measures and address any issues found to prevent any accidents related to the use of LNG. Additionally, it is suggested that seafarers receive regular training on how to cope with LNG.

Finally, it is important to refer that the current research has some limitations. These limitations are related to the time period, the used population and the used sample. According to these limitations, the research suggests making future research that included a longer period of time and wider sample. Another limitation is related to the research variables, the current study recommends testing other independent variables that may affect the risk management.

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The Digitization Technology for the Deaf on Cruise Passenger ships "The Problems and the Solutions"

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المستخلص
الصم كيان موجود في جميع المجتمعات والبلدان. المشكلة هي أن الصم وضعاف السمع (DHH) يواجهون صعوبات كبيرة أثناء النقل بجميع أنواعه ، وخاصة البحرية منها. توضح هذه الدراسة تلك التحديات والمشكلات وتلفت انتباه الحكومات والمنظمات والجمعيات الدولية إلى ضرورة تحسين مجال النقل البحري. تم تطوير استبيان للصم لتحديد المشاكل التي تواجه الصم وكيفية إيجاد حلول لهذه المشاكل (شارك فيها حوالي ٣٨٠ شخص أصم).
تم تطوير استبيان آخر للبحارة في مجال الرحلات البحرية ونقل الركاب البحري ، من أجل التعرف على المشاكل ، كما أن هناك العديد من المقابلات مع العمال أثناء اتصالهم بالصم ومشاركتهم في تقديم الحلول ، وشارك فيها حوالي ٦٠ شخصًا.
تكشف النتائج أن مجتمع الصم لا يتمتع بجميع الحقوق في استخدام وسائل النقل. البحث له العديد من القيود ، فمن الصعب للغاية الحصول على عينة من المشاركين المختارين من DHH في الدول العربية ، كما أنه من الصعب جدًا التواصل معهم. بالإضافة إلى قلة الأبحاث والمراجع والدراسات حول هذا الشأن.

Abstract
Deaf people are an entity that exists in all societies and countries. The problem is deaf and hard-of-hearing (DHH) face major difficulties during transportation of all kinds, especially marine ones. This Study clarifies those challenges, problems and draws the attention of governments, international organizations, and associations to the requirement for improving the field of maritime transport. A questionnaire was developed for the deaf to identify the problems facing the deaf and how to find solutions to these problems (about 380 deaf people participated in).
Another questionnaire was developed for seafarers in the field of cruise and marine passenger transport, in order to recognize the problems, also there are many interviews with workers during their contacts with the deaf and their participation in providing solutions, and approximately 60 people participated in.
The results reveal that the deaf community does not enjoy all rights in transportation. The research has many limitations, it is so difficult to gain a sample of participants chosen from the DHH in the Arab countries, and also very difficult to communicate with them. In addition to, the lack of research, references, and studies on this concern.

Keywords: DHHs – Passenger ships – transportation – Deaf rights – A smartphone application

1- Introduction

It is certainly very difficult for the deaf to deal with societies that are not aware that the deaf has special treatment. It is convinced that the challenges they face are difficult and unique. Therefore, these challenges or problems facing the (DHH) are very great and the deaf cannot comprehend or solve them on their own.

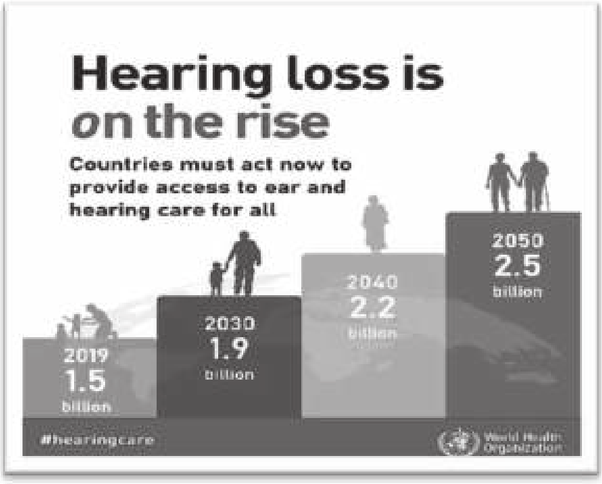

Figure (1): The number of deaf people worldwide
Source: WHO, (2019)

Deaf people are a part of society that cannot be neglected or ignored, as the number of DHH worldwide in 2019 exceeded 1.5 billion people and this number is expected to reach 2.5 billion people by 2050 according to statistics and studies from the World Health Organization (WHO) as showed in Figure (1). The number of deaf and hearing loss around the world in each region is increasing as shown in Figure (2), unfortunately in most countries, especially Developing Countries, do not offer the hearing-impaired or deaf person the least means to help he/she to pass life easily and simply.

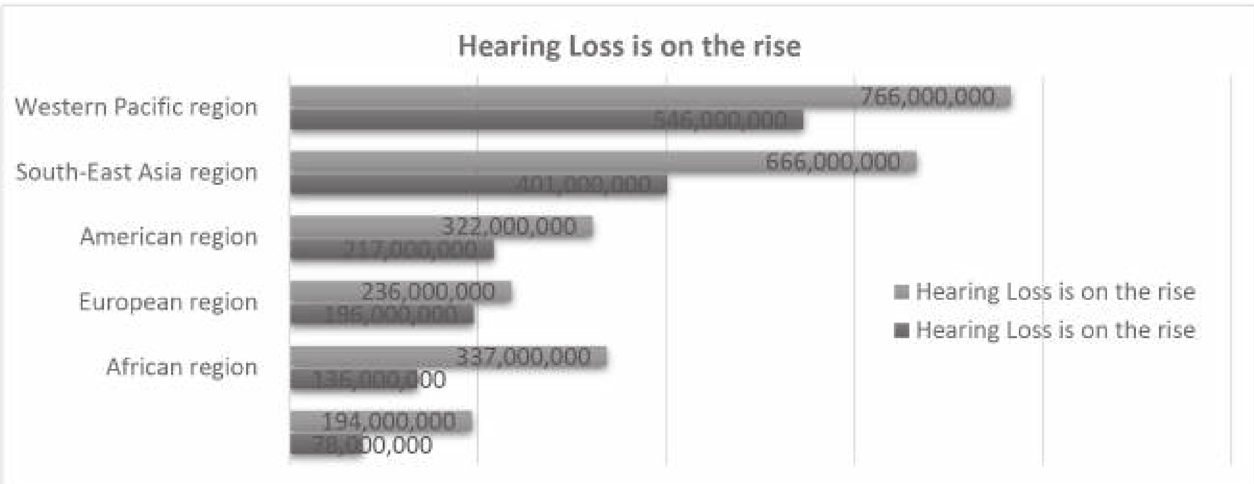

Figure (2): Number of Deaf & Hearing loss around the world regions
Source: WHO (2019)

There are immense problems that deaf people face daily in all areas, the most important of which is the field of transportation, especially daily transportation, for example, the train, bus, metro, and during plane travel, but all of the above means of transportation do not exceed hours in the life of the DHH. But for a journey on passenger ships, the matter goes beyond days not hours like other modes of transportation, which increases the challenges and problems expected to occur during cruises on passenger ships, especially in emergency situations or disasters that occur during cruises.

As stated in the World Report on Hearing (WRH), (2021).

> *"World Hearing Day is an annual global advocacy event and the largest awareness campaign that calls for action to address hearing loss and related issues. It is celebrated on the 3rd of March to raise awareness regarding hearing loss and to promote ear and hearing care at community and national levels across the world. Every year, this day addresses a specific theme, and to reflect this, activities are carried out by WHO and its partners".*

Society considers the DHH to be one of the sick or disabled people and they need specific medical treatment, but the DHH community does not consider themselves disabled or sick. However, they are societies and entities that have different associations, clubs, and languages, and other societies and entities must recognize them and fulfill their needs from all stages of education, health, and appropriate job opportunities that allow the deaf to work in most fields and to be able to earn the sums that allow them to live in a good and dignified manner.

Unfortunately, in most developing countries, a very large percentage of deaf people occupy temporary jobs and do not learn how to read or write, due to the high cost of their education which the weak budgets of developing countries cannot afford. On the other side, in some developed countries such as the USA or European countries, caring for the DHH is a priority for their attention, and large budgets are allocated to them, and there are schools, universities, and clubs dedicated to the deaf, and as a result, the DHH can read and write as well as enroll in universities, they can enroll in a very good job just like engineers, doctors, journalists, and teachers.

This paper addresses the problems and challenges that face the deaf during cruises on passenger ships, especially in emergencies, recognize the difficulties facing DHH in different modes of transportation, and deliberate the parameters that affect the DHH during emergencies designing and implementing a specialized prototype software system on a mobile smartphone or tab that allows the deaf to deal with the critical situation or emergencies on a passenger ship.

Background

Ana et al (2021) aimed to focus on the rights of persons with disabilities to transportation in Brazil. The researchers conducted a descriptive analysis of the mobility practices of people with disabilities. Researchers have found that a higher level of immobility compared to people without disabilities seriously affects their access to urban goods and services.

Forough (2019), and Gary and Timothy (1989) presented detailed and important studies on the problems that DHH suffer from and their short-term and long-term solutions or designing models. Forough (2019) discussed the nature of the problems faced by the deaf during their use of transportation at airports. Based on the survey and personal interviews, a prototype was designed and implemented to help the deaf to move and navigate at airports.

Gary and Timothy (1989) pointed out the problem of loss of communication that deaf people face with oral communication when using transportation modes and the increased risk in emergencies. The research introduced a short-term and long-term plans to solve those problems.

Elmar and Christian (2012) provided insights into the barriers faced by hearing and visually impaired passengers when using public transportation services. Through personal interviews and general surveys, the researchers found a variety of different problems experienced by disabled passengers. In addition, multiple solutions were presented.

2- Methodology

This study is classified as deductive quantitative research. Creswell, (2012) stated that there are several key characteristics of the quantitative approach. First, describe the research problem by needing an explanation of the relationship between the variables. Second, present specific, measurable, and observable research questions and hypotheses. Third, digital data collection through personal interviews or questionnaires. Fourth: Analyzing the results, taking into account the variables and hypotheses, using statistical analysis. Fifth: design and implement an application that helps DHH through emergencies on passenger ships.

The research required conducting a preliminary survey of the conditions of the DHH and the visually impaired in all fields, which produced preliminary lines for the research plan.

The Proposed Model

Clarification of the scientific research model for the relationship between hypotheses, variables, and the research goal, which is the Deaf satisfaction with transportation modes as shown in Figure(3) this model had been created by the researcher according to the previous studies. In addition, an initial plan for the research was clarified in terms of data collection, sample participants, and methods for analyzing the results, then a simplified explanation of the number and contents of the research and the expected implementation period.

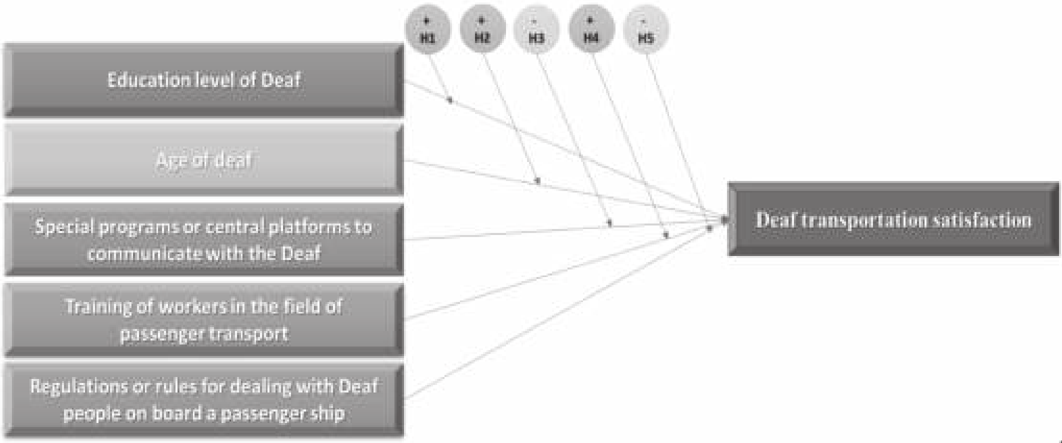

Figure (3) The research model

3- Data Collection and Questionnaire

3-1 Creating Questionnaires

One of the most important stages of the research is designing a questionnaire for DHH and another for those involved in marine tourism. A website specialized in creating questionnaire forms called QuestionPro was used. The Uniform Resource Locator (URL) address of the two questionnaires has been published on the Internet and social networking sites Facebook and Messenger, and most of the associations and institutions that support and help the deaf have been contacted, and some companies that have passenger ships have been contacted on their official websites, emails, and sometimes via WhatsApp to all Arab countries from the East to West and from north to south.

3-2 Data Analysis.

Data were collected for the first and second questionnaires from the electronic platform and all answers were converted into Microsoft Excel tables and had been analyzed by Structural Equation Modeling (SEM). The data were analyzed according to an advanced scientific method.

4- Analysis Results

4-1 Assessing the Structural Model, I

The SEM Examed the structural model including path coefficients, collinearity diagnostics, coefficient of determination (R^2), effect size (f^2), predictive relevance (Q^2), and goodness of fit criteria GoF.

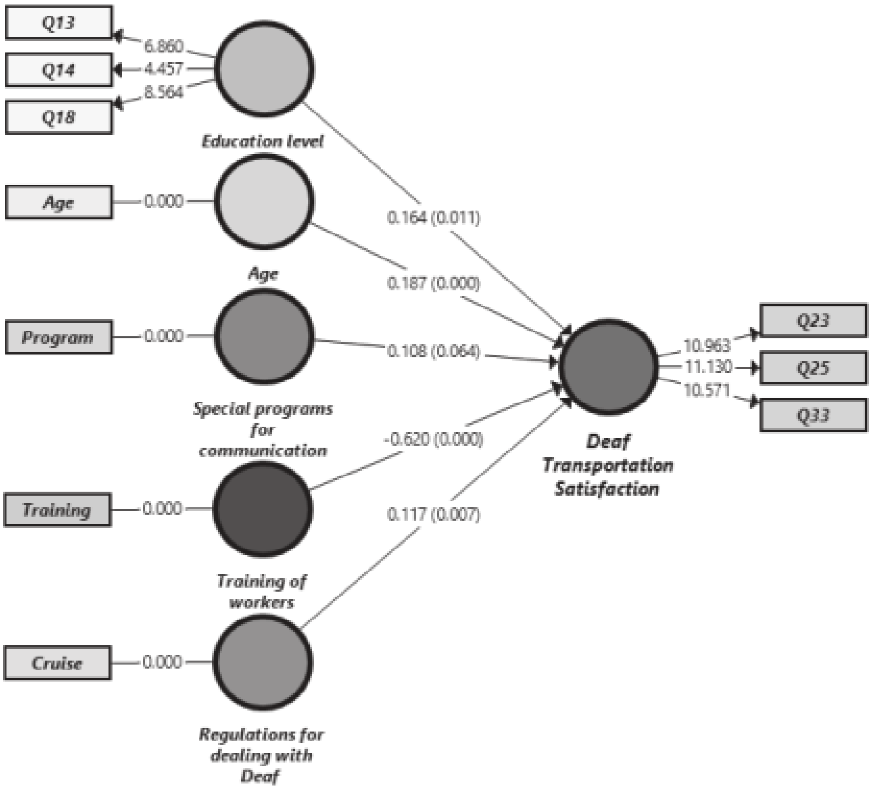

Figure (4): Model I Hypotheses Testing

Before analyzing the structural model, the collinearity between constructs was examined using Variance Inflation Factors (VIF) and found that all values were less than the threshold of 5 (Hair et al., 2017).

Table (1): Structural model I assessment

Path	β	t-value	P-value	Remark	*F* Square ≥0.02	VIF <5
H1: Age -> Deaf Transportation Satisfaction	0.187	3.535	***	Supported	0.063	1.039
H2: Education level -> Deaf Transportation Satisfaction	0.164	2.552	0.011*	Supported	0.043	1.196
H3: Regulations for dealing with Deaf -> Deaf Transportation Satisfaction	0.117	2.684	0.007**	Supported	0.024	1.085
H4: Special programs for communication -> Deaf Transportation Satisfaction	0.108	1.855	0.064†	Supported	0.02	1.216
H5: Training of Seafarers -> Deaf Transportation Satisfaction	-0.62	12.273	***	Supported	0.639	1.131
Overall Model Fit: R Square (>0.1)=0.465, Q Square (>0)=0.171, GoF (>0.1)=0.621						

***P < 0.001; **P < 0.01; *P < 0.05; †*P < 0.1. Cut-off values reference Chin (1998), Cohen (1988), Hair et al. (2017), and Wetzels et al. (2009).

The results of the first hypothesis in Table (1) showed that; Age has a statistically significant positive effect on Deaf Transportation Satisfaction since ($\beta = 0.187, t = 3.535, P < 0.001$), this suggests DHH will be more satisfied if he gets older, so that the first hypothesis is accepted. The results also showed that Education level has statistically significant positive effect on Deaf Transportation Satisfaction since ($\beta = 0.164, t = 2.552, P < 0.05$), this suggests DHH will be more satisfied if he is well educated, so that the second hypothesis is accepted. Moreover, Regulations for dealing with the Deaf has statistically significant positive effect on Deaf Transportation Satisfaction since ($\beta = 0.117, t = 2.684, P < 0.01$).

This means as there exist more regulations for dealing with the Deaf, this suggests they will be more satisfied, so that the third hypothesis is accepted. Furthermore, Special programs for communication has a statistically significant positive effect on Deaf Transportation Satisfaction since ($\beta = 0.108, t = 1.855, P < 0.1$), this means there exist more special programs for communication, which suggests they will be more satisfied, so that the fourth hypothesis is accepted. Finally, the training of Seafarers have statistically significant effect on Deaf Transportation Satisfaction since ($\beta = -0.62, t = 12.273, P < 0.001$), and so the fifth hypothesis is accepted.

4-2 Coefficient of Determination (R^2)

The coefficient of determination (R^2) refers to the effect of independent variables on the dependent latent variables, which is one of the quality measures of the structural model (Hair, Sarstedt, Hopkins, & Kuppelwieser, 2014). R^2 estimates vary from 0 to 1, in which 0 means low explained variance and 1 means high explained variance. Researchers have used a different cut-off of R^2 value. In our case R^2 equals to 0.465 which is a medium explained variance.

4-3 Effect Size (f^2)

The f^2 effect size is the measure of how much impact the endogenous construct will have if an exogenous construct was removed from the model. A construct is considered to have a small effect if its f^2 value is between 0.02 and 0.14, while it is considered to have a medium effect if its f^2 value is between 0.15 and 0.34, and a large effect if its f^2 value ≥ 0.35.

A construct with an f^2 value < 0.02 means it does not affect the endogenous construct (Hair et al., 2017). The Results in Table (1) indicate that which mean R^2 = 0.465 of the variation in Deaf Transportation Satisfaction is explained by the variation in the independent variables with a small Cohen's effect size for age (f^2 =0.063), an Education level (f^2 =0.043), Regulations for dealing with Deaf (f^2 =0.024), Special programs for communication (f^2 =0.02), and high Cohen's effect size Training of Seafarers (f^2 =0.639).

4-4 Predictive Relevance (Q^2)

Q^2 value indicates the model's out-of-sample predictive power. When a model is said to have predictive power or predictive relevance, it means that it can accurately predict data not used in the model estimation. The analysis evaluated predictive relevance by assessing Stone-Geisser's Q^2 Blindfolding a sample reuse technique that can be used to calculate Q^2 values for latent variables. Executed the blindfolding procedure and calculated the Q^2 values for *Deaf Transportation Satisfaction* (Q^2 =0.171) which is greater than zero, thus indicating predictive relevance for endogenous latent variables in our PLS path model (Hair et al. 2017).

4-5 The Goodness of Fit of the Model

Tenenhaus et al. (2005), proposed the Goodness of Fit (GoF) as a global fit indicator; it is the geometric mean of the average R^2 the average variance extracted from the endogenous variables. The aim of GoF's is to take into consideration the research model at all stages, i.e., the measurement model and the structural model, with an emphasis on the overall model performance (Henseler & Sarstedt, 2013). The GoF value (0.621) is above 0.36, suggesting a high fit, hence it can be safely concluded that the GoF model has a higher level of fit to be considered a sufficient valid global PLS model.

The GoF was introduced by Tenenhaus et al. (2005) as a global fit metric. The GoF criterion for determining if GoF values are too little, too moderate, or too high to be considered a globally adequate PLS model.

4-6 Assessing the Structural Model II

Examining the structural model includes path coefficients, collinearity diagnostics, coefficient of determination (R^2), effect size (f^2), predictive relevance (Q^2), and goodness of fit criteria. Before analyzing the structural model, the collinearity between constructs was examined using (VIF), and found that all values were less than the threshold of 5 (Hair et al., 2017).

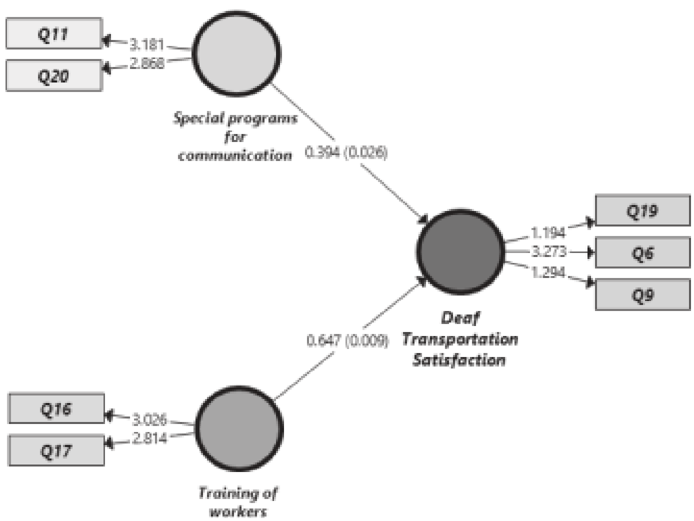

Figure (5): Model II Hypotheses Testing

The results of the first hypothesis in Table (2) showed that; Special programs for communication have a statistically significant positive effect on Deaf Transportation Satisfaction since ($\beta = 0.394, t = 2.233, P < 0.05$), this means as there exist more special programs for communication, this suggests they will be more satisfied, so that the first hypothesis is accepted. Finally, Training of Seafarers has a statistically significant positive effect on Deaf Transportation Satisfaction since ($\beta = 0.647, t = 2.6, P < 0.01$), this means there exists more Training of Seafarers, this suggests they will be more satisfied so that the second hypothesis is accepted. The Results in Table (2) indicate that about 51.3% of the variation in Deaf Transportation Satisfaction is explained by the variation in the independent variables with moderate Cohen's effect size for Special programs for communication (f^2 =0.301), and high Cohen's effect size Training of Seafarers (f^2 =0.812).

Table (2): Structural model II assessment

Path	β	t-value	P-value	Remark	*F* Square	VIF
					≥0.02	<5
H1: Special programs for communication -> Deaf Transportation Satisfaction	0.394	2.233	0.026*	Supported	0.301	1.004
H2: Training of Seafarers -> Deaf Transportation Satisfaction	0.647	2.6	0.009**	Supported	0.812	1.004
Overall Model Fit: R Square (>0.1)= 0.513, Q Square (>0)= 0.032, GoF (>0.1)= 0.590						

***P < 0.001; **P < 0.01; *P < 0.05; ††P < 0.1. Cut-off values reference Chin (1998), Cohen (1988), Hair et al. (2017), Wetzels et al. (2009).

Then, the analysis evaluated predictive relevance by assessing Stone-Geisser's Q^2 Blindfolding a sample reuse technique that can be used to calculate Q^2 values for latent variables. We executed the blindfolding procedure and calculated the Q^2 values for Deaf Transportation Satisfaction (Q^2 =0.032) which is greater than zero, thus indicating predictive relevance for endogenous latent variables in our PLS path model (Hair et al. 2017). The GoF value (0.590) is above 0.36, suggesting a high fit, hence it can be safely concluded that the GoF model has a higher level of fit to be considered a sufficient valid global PLS model.

5- Conclusion

This study included five components that are considered the main drivers of research, which are age, education, smartphone applications, training of workers in the field of passenger maritime transport, and safety laws on passenger ships for the deaf. The results were consistent with most of the hypotheses. Entering the deaf community had a positive impact on getting an idea of how to deal with deaf people, designing a questionnaire, and designing a prototype for an application that helps deaf people during emergencies on board passenger ships.

Personal interviews played a major role in involving deaf people in answering the questionnaire. The results of the questionnaire analysis for DHH were reasonable and acceptable. 387 DHH respondents participated in answering the questionnaire, but only 291 completed the questionnaire as a result of the inability of some deaf people to read or embarrassment from the social standard of living. Hearing-impaired people often lack oral communication when using transportation, resulting in a loss of communication and increased risk in an emergency situation, which only exacerbates the problem.

As for the second questionnaire about seafarers working on passenger ships and the way they deal with the disabled, especially the deaf, more than 60 participants from seafarers working on passenger ships have never met a person with a disability. None of them are trained to deal with the deaf, as well is no evidence of handling or steps to follow during the risks DHH is exposed.

Based on the results of the two questionnaires, personal interviews, and previous studies, it was found that all individuals are correct and compatible with the message model and that the relationships between the independent variables and the dependent variable are correct, reliable, and reliable, as indicated by the statistical results of the questionnaire questions. Accordingly, the research continued its natural course after the results of the statistical analysis of the questionnaire, where it was found that a method must be devised for the deaf to help them act during emergencies while they are on passenger ships.

Accordingly, communication was made with one of the leading companies in the transportation of passengers, and sign language translation was included in the special video safety instructions on passenger ships during cruises. The research continued its course by devising another way to direct the DHH to the meeting points on ships in case of emergency, and a model application was made to guide the deaf to go from different places such as the restaurant, café, and bedrooms to the assembly point to board the lifeboat, and all the steps were translated in Arabic sign language. Accordingly, the results of the questionnaire led the study to most of the needs required to complete the study in full.

Deaf people should not be seen as perpetual victims of circumstances whose only desire is to connect with the hearing world, but rather promise a tomorrow of an ethic in which deaf individuals are embraced as normal people looking for ways to make life simpler and more enjoyable.

6- Recommendations

According to this study, the most basic aspects of a deaf person's life emphasize the need to take care of this entity. Also many external factors affect the interaction of the deaf with others or vice versa while using all kinds of transportation

6-1 In the Field of Education and Training:

Educational and governmental institutions must provide an appropriate number of schools based on healthy and developed educational foundations to improve the educational level of the deaf and ensure the competence of teachers and educators. Universities specializing in the field of languages, media, and communication should include an educational curriculum for sign language and how to deal with deaf communities, in a way that helps spread environmental awareness through dialogue between deaf people and others.

6-2 In the Field of Passenger Maritime Transport:

It was found that most tourism companies and passenger transport companies have a clear interest in quiet tourists (deaf) to improve the level of navigational tourism for the disabled. Maritime institutions and academies should add an intensive program for students in maritime transport and graduates while renewing nautical certificates and declarations.

International organizations and international institutions concerned with human rights and the rights of the deaf must include paragraphs in all legal manuscripts by forcing companies specialized in passenger transport or tourism companies to allocate rooms equipped with all modern equipment that allows deaf people to remain calm and safe from risks, accidents, and disasters. It was found from the prototype on the smartphone that was designed that the rooms for the disabled and the deaf should be chosen near the meeting points in case of emergency so that the deaf would not find it difficult to board the lifeboats.

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Impact of Dry Port on Seaport Competitiveness

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المستخلص

تلعب الموانئ دورًا مهمًا في ربط الأفراد المحتاجين للخدمات اللوجستية بالمنظمات التي تقدم الخدمات اللوجستية. بدلاً من أن تكون مجرد محاور لإعادة الشحن. تطورت الموانئ مؤخرًا إلى مراكز لوجستية متكاملة مع سلسلة نقل مستمرة، حيث تعتمد هذه التطورات بشكل أساسي على أنظمة سلسلة التوريد لمشغلي الموانئ الرئيسيين .على الرغم من أن التغييرات تؤثر على حركة التعامل مع المحطة الطرفية، إلا أن الكميات المتزايدة أدت إلى زيادة ضغط العمل، فضلاً عن مستويات الازدحام وفترات الانتظار في المناطق الطرفية. يعتمد نموذج الميناء الجاف على ميناء بحري متصل مباشرة بالمحطات الداخلية متعددة الوسائط، حيث يمكن تدوير الشحن على الفور إلى الميناء البحري في وحدات تحميل متعددة الوسائط. يبحث هذا البحث في تأثير نمو السفن على تنافسية الموانئ، ويبحث في التكامل بين الموانئ البحرية والموانئ الجافة لمواجهة الزيادة الهائلة في حجم السفن في الموانئ البحرية .ولتحقيق هذا الهدف تم إجراء مسح لقياس العلاقة بين الموانئ الجافة والموانئ البحرية. توضح هذه الورقة أيضًا كيف يرتبط توسع السفينة بانخفاض الكفاءة التشغيلية، والازدحام، والقدرة المحدودة ودعم البنية التحتية، والمبادئ التوجيهية القديمة لتطوير الموانئ الحالية، والحاجة الملحة إلى استثمارات إضافية في التنمية المكانية، وتنمية الموارد البشرية.

Abstract

Ports play an important role in connecting individuals in need of logistics services with organizations that provide logistics services. Rather of being merely transshipment hubs. Ports have recently evolved into integrated logistics centers with a continuous transport chain, with these developments primarily relying on the supply chain systems of major port operators. Though changes impact terminal handling traffic, rising quantities have increased job pressure, as well as congestion levels and dwell periods in terminal areas. The dry port model relies on a seaport which is directly connected to inland intermodal stations, where freight may be rotated immediately to the seaport in intermodal loading units.

This research investigates the influence of vessel growth on port competitiveness and investigates integration between seaports and dry ports to counteract the huge increase in ship size at seaports. To achieve this goal, a survey was conducted to measure the relationship between dry ports and seaports. This paper also illustrates how the vessel expansion is associated with reduced operational efficiency, congestion, limited capacity and infrastructure support, outdated guidelines for existing port development, and the urgent need for additional investment in spatial development, and human resource development.

Keywords: Dry Ports – Competitiveness – Seaports – Vessel size

1. Introduction

The maritime industry plays an indispensable role in global trade and economic development, all commercial and maritime sectors depend on the services and capabilities provided by the shipping sector to facilitate the supply chain cycle from door to door. Therefore, the efficiency of maritime sector services is a major focus in the competitiveness of any economy and its ability to achieve economic growth, and attract foreign investment to the country. As the number of seaports and port efficiency, as well as the quantity of foreign trade exports and imports, have become crucial indices for measuring the country's success, sea ports play a vital role in economic growth and enhance national income.

Technological progress, changes in institutional functions, substantial participation of major ports in regional and international competition, dramatic spatial development, improvements in seaport services, and broader implications of changes in the business environment each had an impact on seaport profitability, often changes. Furthermore, the changing competitiveness of seaports is intimately tied to the character of the marine business, which is significantly influenced by changing investor activity.

A major obstacle for seaports trying to accommodate these megaships is their draft, i.e. not having deep or wide channels. For example, safe passage through a canal requires a separation safe zone between the ships, in addition to the coupling beams of the two ships. This can be a major issue for two huge ships. One-way channels must be developed to accommodate most large ships, causing delays in waits for smaller ships (Yan, 2021).

Dry ports play an important role in reducing transport time and cost. As well as, the function of dry ports in enabling the national economy's international trade and cargo handling. In order to facilitate the establishment of a free trade area between States, dry ports are one of Egypt's interfaces with international trade activities, the flow of imports and exports of commodities and the facilitation of trucking with many countries. Planning and management of these ports, operationalizing container activities at the regional and international levels, and coordinating action among the parties involved in them to ensure smooth functioning and good service delivery in order to relieve pressure on seaports.

In addition, terminal operators and seaport authorities are under pressure to invest heavily in equipment and voyage access to reduce or eliminate the potential economies of scale of such large entities at ports. Additionally, ports should work with inland terminals to enhance flexibility by restoring inland navigate. It should be noted that incorporating dry ports into maritime transportation networks can have a substantial influence on seaport profitability. Based on these talks, this paper addresses the challenges that ports face as a result of vessel expansion and the role that dry ports play in assisting ports in resolving these problems. What role may dry ports play in ensuring ports stay competitive?

2. Seaport Competitiveness

Technological progress, changes in institutional functions, substantial participation of seaports in regional and global competition, dramatic spatial development, improvements in seaport services, and significant effects of changes in the business environment have all had an impact on seaport competitiveness. Furthermore, the changing competitiveness of seaports is intimately tied to the character of the marine business, which is significantly influenced by producer and investor activity. Frequent and productive effort and change have a strong influence upon it (Munim, 2019).

Competitiveness was first used to examine the strategic behavior of enterprises, but it was later expanded to apply to rivalry between nations and economic ecosystems. A seaport as defined a network in which the success of each firm is intrinsically linked to the competitiveness of the system as a whole. Port (terminal) operating efficiency, port cargo handling prices, dependability, shipper and carrier and port selection preferences, the depth of the navigation channel, adaptation to changing market situations, landside accessibility, and product distinctiveness are all major determinants. These components differ from those that emphasize efficiency, accessibility to main liners and shippers, network extension, and hinterland growth (Saeed, 2019).

3. The Effect of Ship Size on Seaport Competitiveness.

A major obstacle for seaports in accommodating megaships is their draft, i.e. not having deep and wide channels. For example, safe passage through a canal requires a separation safe zone between the ships, in addition to the coupling beams of the two ships. This may be a critical challenge for huge ships. One-way channels must be developed to accommodate most large ships, causing delays in waits for smaller ships (Nguyen, 2021).

Ports handling feeder vessels are therefore more attractive to shipping companies. In addition, selected mega hub ports will require quayside cranes, enabling faster handling with shorter turnaround times. Significant investments are required to prove the mega ship's capacity and equipment suitability to ensure smooth cargo flow to and from the vessel. Terminal operators and seaport authorities are under pressure to invest heavily in equipment and nautical access to reduce or eliminate the potential economies of scale of such large units in ports (Tran, 2021).

This is important for improving vessel efficiency (shorter turnaround times) and port efficiency (faster transshipment processes). Ports and terminals are urged to undertake significant and quick infrastructure expenditures in order to handle larger vessel sizes and compete with other ports. In terms of port competitiveness, this has a significant impact on ship-port relationships. This is because operational bottlenecks and port inefficiencies lead to inadequate port infrastructure and superstructures.

Terminals, port stevedores, shippers, and logistics and transportation corporations can improve efficiency by making full use of information technology (IT) solutions. To ensure the essential capabilities to manage a VLCS, a single IT platform for all parties participating in the port procedure for logistics may be required. Significant increases in ship size have forced gateway ports to be highly synchronized with their hinterland through dedicated rapid transit corridors served by barges or rail, often including dry ports (Jiang, 2014).

Move a large amount of containers quickly from vessel to hinterlands and conversely to reduce freight, that has a negative influence on port attractiveness. To shorten container stay time, the inland transportation infrastructure must be adequately connected to and from ports. Ports are becoming overcrowded as a result of growing external and domestic traffic, and these congestions can have an indirect impact. Delays caused by congestion, for example, might cause lay time to expire, causing arrival at the next port of call to be delayed (Li, 2014).

The advent of megaships increases the need to expand Storage capacity to allow for the addition of extra containers. Container intermediate parking, reroute yard areas, and freight container plug-ins, and storage areas are therefore essential for smooth handling .Improving port productivity will require the incorporation of large amounts of skilled personnel, equipment and self-driving vehicles. Accordingly, seaports must have new Expansions suitable to accommodate mega-fleet (Nur, 2019).

4. The role of Dry Ports

By using multimodal transport, dry ports play an important role in reducing transport time and cost. In addition, the function of dry ports in enabling the national economy's international trade and cargo handling. In order to facilitate the establishment of a free trade area between States, dry ports are one of Egypt's interfaces with international trade activities, the flow of imports and exports of commodities and the facilitation of trucking with many countries. Planning and management of these ports, operationalizing container activities at the regional and international levels, and coordinating action among the parties involved in them to ensure smooth functioning and good service delivery in order to relieve pressure on seaports.

Follow-up on technological changes in this area, identify a traffic plan for car traffic and heavy transportation within the port, to provide indicative signals, lighting, various means of communication, and identify the required for storage and transportation. The importance of a dry port is to eliminate the problem of cargo accumulated at seaports and to maximize the port's complementary role in reviving international trade and transit traffic and linking seaports to neighboring cities. The customs procedures on the cargo are carried out entirely within the dry port, relieving the pressure on the seaport and the speed of circulation (Abdul Rasoul, 2022).

5. The Role of Dry Ports in Seaport Competitiveness

Dry ports are a critical part of port production as containers move in and out of ports with high-performance means for effective supply chain solutions across the transport chain as well as in the hinterland. Advances in the supply chain have increased pressure on port operations and inland cargo flows, making inland access a key factor in determining port competitiveness (Sangkyun, 2015).

Increased container flows into and out of ports have caused terminal overcrowding and increased container wait times, reducing ports' overall competitiveness. The emergence of dry ports connecting various actors. As container volumes have increased, access to port hinterlands has become critical to competitive advantage. The establishment of dry ports has had an influence on port competition, specifically through enhancing port performance and expanding the range of services available to port customers. (Hyuksoo, 2015).

Improve port and hinterland connections, as well as port volume of trade and capacities. This demonstrates the importance of installing modern intermodal terminals. Dry ports' capacity to regulate and optimize substantial segments of the container transportation chain will aid in the development of inland seaport capabilities.

The addition of sea ports to the dry ports system will boost capacity, improve access to the port, increase container handling efficiency and reliability, operate as a decongestion sector in the port, and improve productivity. This will boost the port's competitiveness.

Increasing the port's competitiveness by providing storage spaces to increase the number and volume of cargo and containers handled. Keeping pace with global trends to facilitate cross-border trade through border ports, such as the Salloum port on the western borders of the Arab Republic of Egypt, Qustol and Arkin on the southern borders of the Arab Republic of Egypt and achieving competitive advantages for investors, by reducing the rates of time taken to complete customs release and export procedures.

Hence the need to discuss the work and description of dry ports, so that they can examine their operational relationship with seaports, because the dry port depends on a directly connected seaport. Close to consumption places, raw materials places and industrial areas to serve trade in transit traffic to increase competitive advantage.

Ensuring the ability to operate the 2017 VLCS requires a unified IT platform for everyone involved in the port logistics process. Inevitably poor “information structure” (e.g. Port Community Systems). Freight forwarders, shippers, terminal operators and shipping companies believe dry ports can reduce supply chain disruptions and save money and time in container handling (Thai, 2021).

6. Development of Questionnaire

Surveys are one of the best known and most commonly used analytical methods. It offers a convenient method to collect information from specific population groups. A questionnaire is defined as "a tool for gathering information to describe, compare, or explain knowledge, attitudes, behavior, and/or socio demographic characteristics". This approach is extremely adaptable for measuring many sorts of data (subjective, objective, qualitative and quantitative). Generally speaking, there are several sorts of surveys that may be used in study. Mail survey, cluster monitoring survey, household admission and interviews.

However, respondents who take surveys often want to limit their responses, which can render the survey pointless. However, researchers can overcome this problem to some extent by providing sufficient space for comments. From another side, response rates for hand written questionnaires are low, especially postal surveys, are the most common problem and can significantly reduce the reliability of survey results. Naturally, postal surveys may not yield responses from data subjects, further negatively impacting survey results. The following equation was used to calculate the sample size.

$$n = \frac{X^2 \times N \times P \times (1-P)}{(ME^2 \times (N-1) \div (X^2 \times P \times (1-P))}$$

Where:

n = sample size.

X^2 = Chi-square for the specified confidence level at 1 degree of freedom.

N = Population Size.

P = population proportion (.50)

ME = desired Margin of Error (expressed as a proportion)

An opinion poll was conducted for workers in maritime sector, by taking a sample of workers at the middle and senior management level. 350 copies of the questionnaire were distributed through Google Forms. 320 were answered, 20 were excluded, and 300 were statistically analyzed by SPSS.

6.1 Descriptive analysis for the statement of the questionnaire

1- Dry port have a positive effect on productivity of seaport.

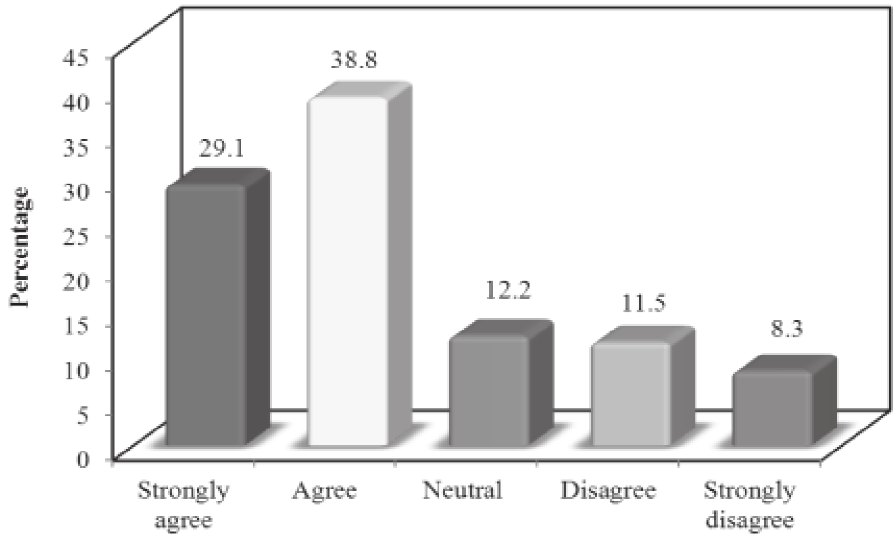

Figure (1): Dry port have a positive effect on productivity of seaport.

67.9% agree that dry port have a positive effect on productivity of seaport, 19.8% do not agree and 12.2% are neutral, and therefore this will positively affect the performance of seaport.

2- Dry port has a positive effect on vessels size.

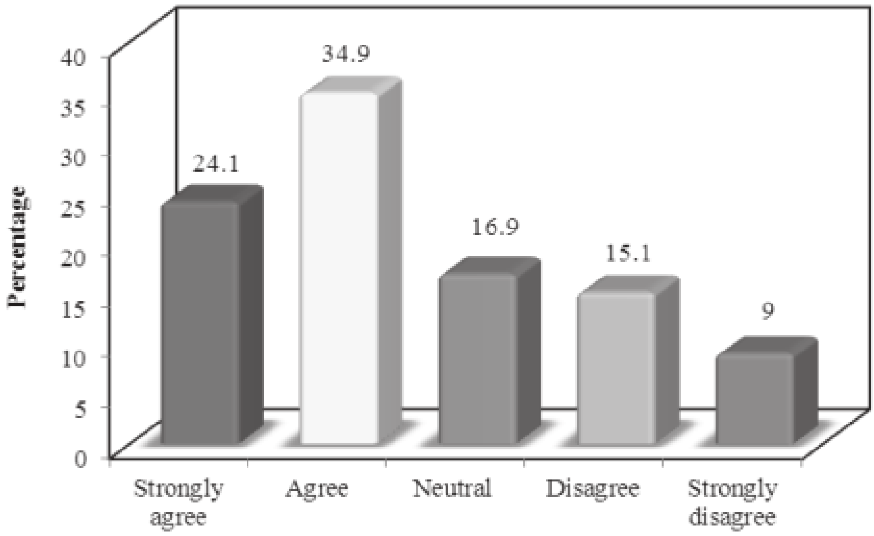

Figure (2) Dry port have a positive effect on vessels size.

59% agree that dry port have a positive impact on productivity of seaport, 24.1% do not agree and 16.9% are neutral, and therefore this will positively affect the solution to the problem of seaport overcrowding and the vessels size and speed handling in seaport.

3- Dry port has a positive impact on competitiveness of seaport.

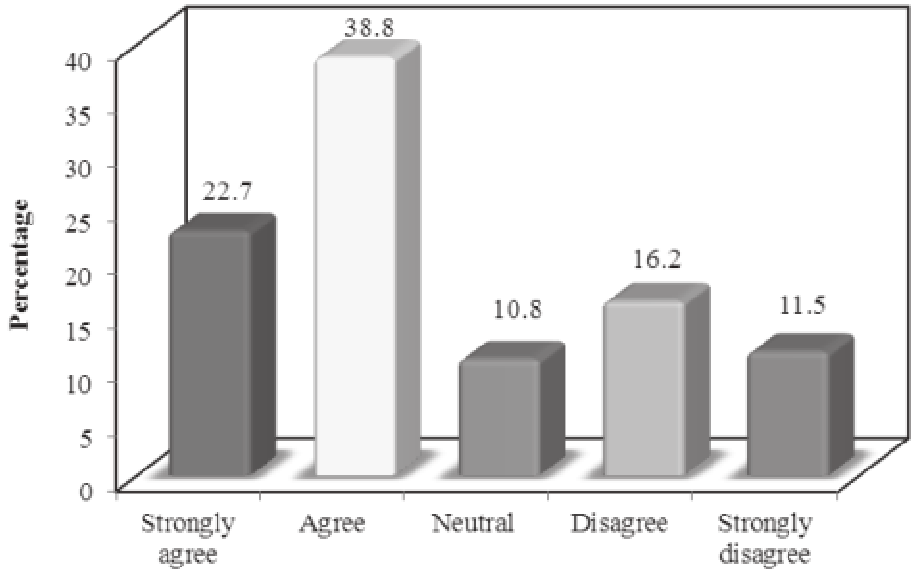

Figure (3) Dry port has a positive effect on competitiveness of seaport.

61.5% agree that dry port have a positive effect on productivity of seaport, 27.7% do not agree and 10.8% are neutral, and therefore this will positively affect the competitiveness of Egyptian seaport.

Through the descriptive analysis of the survey questions, dry ports have a positive impact on the productivity of sea ports, the size of ships, and on increasing the competitiveness of sea ports. From the above, found that dry ports will affect the increase in the competitiveness of sea ports.

6.2 Hypothesis Test

This paper tests the research hypotheses between one dependent variable and three independent variables, and after conducting multivariate linear regression, it was found that the dry port will positively affect the competitiveness of seaports.

Table (1): Multivariate Linear regression for Dry port

	B	SE	Beta	t	p
(Constant)	0.137	0.112		1.225	0.222
Competitiveness	0.660	0.105	0.557	6.296*	<0.001*
Vessel size	0.372	0.073	0.342	5.074*	<0.001*
Productivity	-0.058	0.084	-0.052	-0.684	0.494
R^2=0.675, adjusted R^2=0.671, SE=0.75, F=189.524*, p<0.001*					

F, p: f and p values for the model

R^2: Coefficient of determination

B: Unstandardized Coefficients

SE: Estimates Standard error

Beta: Standardized Coefficients

t: t-test of significance

*: Statistically significant at $p \leq 0.05$

Table (1) shows the multiple regression analysis for the impact of the three variables under study together on Dry ports. It was found out that competitiveness has the most significant positive impact on Dry ports followed by vessel size in the presence of other variables (P-value< 0.05) While productivity has insignificant positive impact on Dry port. Thus, it will have an effect on the competition of seaports.

7. Discussion

The influence of dry ports on seaports as ship sizes vary remains unknown. As a result, this study has proven dry port may benefit these seaport in a variety of ways, and as a consequence, seaport accessibility, infrastructure, service quality, efficiency, and capacity are likely to improve. Furthermore, the availability of dry port reduces total stay time, limits waiting time for large boats, enhances seaport operations efficiency, reduces internal traffic, allows for proper information interchange, allows for faster turnaround time, and boosts container yard profitability.

The increasing involvement of large ships in seaports could lead to a number of issues, including decreased operational efficiency, congestion, and restricted capacity. Although larger vessels are not now frequent in seaports, their presence in the future may have substantial financial effects. To preserve a competitive edge, seaports must adapt to this transformation. To guarantee that these seaports are ready to accommodate larger vessels, a seaport infrastructure comprised of seaports, inland terminals, transportation networks, and freight routes must be established, in addition to concentrating on collaboration between seaports and dry ports. This is essential for enhancing idle port capacity and competitiveness.

8. Conclusion

Essentially, the presence of huge ships in a harbor raises certain concerns about seaport efficiency. Congestion, capacity, and infrastructural support limits, out-of-date standards for the development of existing ports, extra funding needs for urban expansion, as well as the requirement for personnel training are all factors to consider. As a result, the paper advocated the creation of a dry port to mitigate the harmful impact of large boats on the network of seaports. Because of general changes in marine logistics services, such as enhanced port performance and increasing variance in port services, dry ports have an impact on container port systems, and reduced proximity to ports. Remote areas, increasing trade volume and port storage capacity, productivity, and up to global performance indicators.

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ANALYSIS FOR PHYSICAL ERGONOMIC FACTORS IN OIL TANKER CASE STUDY

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المستخلص

من المتوقع أن يزدهر النقل البحري على مدى السنوات الخمس القادمة بمعدل زيادة سنوية يبلغ ٣.٤٪ وبالرغم من ذلك تستمر الحوادث البحرية في الزيادة مما يهدد السلامة والتكلفة. ورغم ذلك تحدث الحوادث البحرية لأسباب متنوعة منها الموائمة وهي دراسة عن كيفية تفاعل الأفراد مع المكونات الأخرى للنظام من خلال استخدام النظريات والمفاهيم والبيانات والنهج لتحسين رفاهية الإنسان والاداء الكلي للنظام. تهدف هذه الورقة إلى تقييم عناصر الموائمة الفيزيائية وعرض الدراسات السابقة المترابطة بالمجال البحري؛ بالإضافة الي اختيار مجموعة متنوعة من عوامل الموائمة الفيزيائية لتقييمها في سفينة بترول كدراسة حالة واستخدام الدراسة الإحصائية لتقييم تلك العوامل في السفن التجارية الأخرى وتحليلها ومقارنتها بنتائج دراسة الحالة لمعرفة مستوى التشابه، تم اكتشاف أن غالبية عوامل الموائمة الفيزيائية كانت غير مرضية بما في ذلك العواقب الوخيمة نتيجة لسوء تصميم مكان العمل مثل الإضاءة غير الكافية ودرجة الحرارة الشديدة والضوضاء.

Abstract

Over the next five years, shipping industry is predicted to grow at a 3.4% annual rate. However, marine accidents are on the rise, threatening both safety and expenses. Marine accidents happen for a variety of causes, including ergonomic issues, ergonomics is the study of how individuals interact with other components of a system, and it employs theory, concepts, data, and approaches to optimize human well-being and overall system performance. This paper aimed to assess physical ergonomic elements and reviewed the previous studies related to ergonomic factors, particularly those related to the marine industry; furthermore, a variety of physical ergonomic factors were selected to be evaluated in a tanker ship as case study. Using statistical analysis to assess physical ergonomic elements in other merchant ships and to compare the results to case study result for finding out the level of similarity, it was discovered that the majority of physical ergonomic factors were unsatisfactory, including severe consequences as a result of poor workplace design such as inadequate lighting, extreme temperature and noise.

KEYWORDS: Maritime transport, Marine accidents, Physical ergonomic factors, Lighting, Noise, Inclined ladder, Spare parts control.

Introduction

Shipping, which is responsible for transporting the largest proportion of the total volume of world trade, is truly the lifeblood of the global economy. Around 80 percent of the volume of international trade in goods is carried by sea, and the percentage is even higher for most developing countries (United Nations Conference on Trade and Development, 2021), Between the range of 1990 and 2015 sea transport expanded by 151.5% compared with an 87.1% increase in worldwide gross domestic product (Profillidis & Botzoris, 2018).

Even though, Ship's crews suffer injuries in a range of work-related accidents every year, including falls from great heights and repetitive stress injuries and could finally lead knee injuries, head injuries, burns, toxic exposure, broken bones, tendon and muscle strains, neck and back injuries, fear and anxiety, nightmares and trouble sleeping, Maritime accidents effect on ships and could lead to Fire, grounding, sinking, flooding or capsizing of a vessel.

The majority of marine incidents between the years of 2002 and 2016 were caused by a variety of factors such as human and non-human (Acejo, 2018). The majority of them were examined, and it was shown that ergonomic factors contributed for the majority of them.

As a result of the annual reports of maritime organizations, which show the increasing number of marine accidents and the accompanying death or physical or psychological marine injuries to some crew members of the ship, damage to the hull of ships or pollution to the environment and the consequent economic problems, the investigators in marine accidents confirmed that they are the result of reasons related to physical, cognitive and organizational ergonomics factors, The problem of the study stems from the study and analysis of some physical inside an oil tanker ship and statistical study to reduce the increasing number of marine accidents which agree with study show Human factors have accounted for over 80% of maritime industry accidents (Wróbel, 2021).

Background

Ergonomic is the scientific study of people and their working conditions, especially done in order to improve effectiveness (Cambridge, 2022), According to (Middleworth, 2017) there are three broad domains of ergonomics: physical, cognitive, and organizational.

There have been many previous studies that have evaluated physical ergonomic factors such as study of Casado, et al., (2012) which examined the impact of awkward postures on workers to prevent work-related musculoskeletal disorders of Spanish Fishermen and the result was work areas aboard a fishing vessel present typical examples of a work environments that pose risks to workers also the study found a new simulating for the workplace and work postures to be an effective tool for assessing the workplace and preventing musculoskeletal disorders aboard fishing vessels. Longo, et al., (2022) studied unsuitable postures for operators who are responsible in Lashing and de-lashing operations of containers cargo on board container ships, The results of the analyses indicated that there are several activities that are categorized as critical for the working postures (interventions to modify the working postures are required immediately or as soon as possible) and some of the body muscles undergo an excessive strain.

Case study

Some aspects of physical ergonomic factors were selected to be examined in oil tanker such as lightening factor, temperature extreme factors, Noise factor, forceful exertions factor and engine room design factor for spare parts store and gauges

Information was collected through a set of tools such as interview, survey and personal judgment

- The interview allowed the researcher to learn more about the study by asking the ship's crew questions and receiving their responses.
- Personal judgement and inspection, which allow the researcher to gather data for the study.

1.1 Lightening factor

- Regarding lighting factor in oil tanker and By using Lux light meter which is one of the programs to measure illuminations of lighting it show defects were shown in table 1 :-

Table 1 Actual and standard illuminations lighting level in Engine room

Location	Actual illumination	Standard illumination
Electrical room	200: 287 lux	200:500 lux
Spare parts room	0: 40 lux	50:200 lux
Mechanical workshop	110: 184 lux	300:750 lux

Source (Archtoolbox, 2021)

Table 1 indicate that there is lack in illuminations lighting level in Electrical room, Spare parts room and mechanical workshop which lead to complains from Engine room crew about lack of lighting illumination while maintenance and while searching for spare parts in store also eye flicker for some of crew.

1.2 Temperature extreme factor

- Regarding extreme temperature factor in oil tanker and By using temperature sensor inside purifier room deficiency shown in table 2 :-

Table 2 Actual and standard Temperature in workplace

Location	Actual temperature	Ideal temperature
Temperature in purifier room	37 Celsius	20° Celsius

Source: (Olli Seppänen, 2006)

Table 2 indicate extreme temperature in purifier room which lead to oiler from engine room crew lose consciousness in purifier room after sweating large amount of water during maintenance.

1.3 Noise factor

Regarding noise factor in oil tanker and By using sound meter decibel tool deficiency was found as shown in table 3:-

Table 3 Actual and standard Noise level in ships

Location	Actual Noise	Standard Noise
Crew accommodation B floor	97 decibels	60 decibel

Source: (ABS, 2018)

Table 3 indicate that noise level is high in surrounding crew cabins which lead to complains signed from crew due to noise of air handling unit which prevent quiet sleep after working.

1.4 Forceful exertions factor for inclined ladder

- Regarding the inclined ladder in engine room of oil tanker and by using Clinometer bubble level to measure angle of inclination for engine room ladder deficiency was as shown in table 4 :-

Table 4 Actual angle of inclination for engine room ladder and standard angle of inclination

Location	Actual degree	Standard degree
Inclination degree for engine room ladder	65 degree	45 to 60 degree

Source: (ABS, 2018).

Table 4 show that the angle of the inclination ladder is more than the maximum limit of standard angle which lead to many complains about pain in knees from repeatedly climbing the inclined ladder in engine room of that oil tanker and more than six oilers and engineers for that ship crew were exposed to tear in inner meniscus in their leg knee that could be mainly due to many reasons one of them was the degree of inclined ladder in engine room.

1.5 Engine room Spare parts control

Regarding spare parts control in oil tanker as shown in figure 1 defects were:

- No effective system on the ship for inventorying spare parts.
- Mainly new spare parts are purchasing from local store and aren't original.
- No minimum ROP (reorder point) for spare parts for each equipment which is the minimum number of units that a business needs to have in stock to prevent stock outs and ensure order fulfillment.
- Used Spare parts stored with new spare parts.
- Used Spare parts aren't updated in inventory.
- No system to differentiate between new received spare parts original or not

Which lead to

- New spare parts could be lost as it stored with used spare parts
- Damage could happen to equipment due to using local spare parts
- In case of emergency situations for any equipment it could lead to stock out as No ROP which could lead to ship off hire

Figure 1 spare parts store in engine room

1.6 Safe limit indicator for gauges

Regarding design and layout engine room in oil tanker it was found that all parameters for operation of all machines and equipment's is without color shape ranges to indicate safe limit of working operation as shown in Figure 2

Figure 2 analog gauges fixed beside generators in engine room

Which lead to

- Complain from engine room crew about taking too much time to be familiar with system and equipment's safe parameters limit which lead to be bad effect in watch keeping objectives
- ❖ Guidance notes on the application of ergonomics to marine systems (ABS, 2018) it shows that operating values fall within a range, the ranges may be identified by a color applied to the face of the display as red for danger and green for normal.

Analyzation of Physical Ergonomic Factors

The statistical study was carried out in order to analyze physical ergonomic factors and organizational ergonomic in other commercial ships and to compare the results to the case study result to find out the level of similarity. In this section 15 ergonomic elements are selected for further study on statistical research to represent organizational ergonomic factors and physical factors and 13 of those ergonomic elements where previously studied in case study , the questionnaire contained 34 questions represented those 15 ergonomic elements and distributed to 50 marine engineer with different ranks and different years of experience then the result of this questionnaire is computed by Statistical Package for the Social Sciences (SPSS) twentieth edition to analyze the study and the result obtained from SPSS where analyzed.

1.7 Questionnaire final form

➢ The questionnaire contained two main parts:

- The first part: is preliminary information about the study sample (Name, years of experience, current job rank, and current company).
- The second part: includes a set of (34) questions distributed on two dimensions as follows
  - The first dimension, which expresses the challenging organizational ergonomic factors in merchant ships and it consists of 23 questions
  - The second dimension, which expresses the challenging physical ergonomic factors in merchant ships and it consists of 11 questions.

1.8 Study sample

The researcher used purposive sampling in the statistical study and the characteristics of the study sample individuals were described through the following basic data (functional grade, number of years of experience) by calculating the repetitions and percentages as Figure 3 and table 5 :-

Table 5 Sample distribution according to job rank qualification percentage

Educational qualification	N=50	٪
Third engineer	12	24.0
Second engineer	24	48.0
Chief engineer	14	28.0
Total	50	100.0

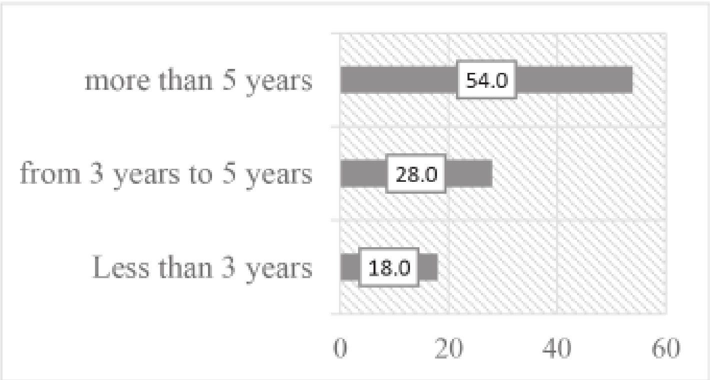

Figure 3: Sample distribution according to years of experience

1.9 Reliability of the Questionnaire

As shown in table 6 the values of Cronbach's alpha coefficients for the questionnaire of the elements of compatibility in the maritime field on some personnel working on ships range between (0.702-0.808), which are acceptable values and are a strong indicator of the stability of the questionnaire and its validity for application.

Table 6 Cronbach's alpha coefficient for every statement

Question No	Cronbach's coefficient	Question No	Cronbach's coefficient	Question No	Cronbach's coefficient
1	0.765	13	0.734	25	0.803
2	0.748	14	0.712	26	0.676
3	0.766	15	0.703	27	0.808
4	0.769	16	0.710	28	0.781
5	0.708	17	0.722	29	0.788
6	0.769	18	0.712	30	0.765
7	0.725	19	0.702	31	0.790
8	0.738	20	0.707	32	0.767
9	0.702	21	0.704	33	0.791
10	0.754	22	0.791	34	0.773
11	0.705	23	0.773	Total ergonomic factors	0.852
12	0.722	24	0.799		

According to (Saidi & siew, 2019) provided acceptable lower limits for Cronbach's alpha as acceptable limits range from 0.7 to 1 and regarding table 6 show that the value of Cronbach's alpha coefficient for the questionnaire of the analyzing ergonomic factors in the maritime field is (0.852), which is an acceptable value and is a strong indicator of the stability of the questionnaire.

1.10 Validation

The Pearson correlation coefficient between each score of the questionnaire questions and the total score of the questionnaire as shown in table 7

Table 7 Correlation coefficients between the statement score and the total score of the questionnaire

Question No	Correlation coefficients	Question No	Correlation coefficients	Question No	Correlation coefficients	Question No	Correlation coefficients
1	0.310 *	10	-0.314 *	19	-0.378 **	28	- 0.563 ***
2	- 0.569 ***	11	0.593 ***	20	0.575 ***	29	-0.592 ***
3	0.572 ***	12	0.352 *	21	0.356 *	30	0,434 **
4	-0.565 ***	13	0.521 ***	22	0,570 ***	31	-0.527 ***
5	- 0.503 ***	14	0.319 *	23	-0.372 **	32	0.356 *
6	0.351 *	15	0.431 **	24	0.537 ***	33	0.482 ***
7	0.393 **	16	0.571 ***	25	-0.592 ***	34	0.505 ***
8	0.578 ***	17	0.519 ***	26	0.360 *		
9	0.510 ***	18	0.522 ***	27	0.392 **		

* A function at a significance level of 0.05 ** A function at a significance level of 0.01

*** A function at a significance level of 0.001

Table 7 show that all questions of the questionnaire of the ergonomic factors in the maritime field on some of the personnel working on the ships were associated with statistically significant correlation coefficients at the levels of significance (0.05, 0.01, 0.001) which indicates the validity of the internal consistency and its validity for application.

- According to (Toresano, 2016) value of Correlation coefficients ranged from -1 to +1

While 0 mean indicate no relation.

1.11 <u>Statistical treatments used in the study</u>

1. Mean value is the average value of the dataset and it's calculated through

$$\bar{X} = (\sum Y)*3) + (\sum N)*1) / (R*3)$$

Where

R=Number of all respondents

$\bar{X}$ = Mean value ∑Y= Sum of all answer yes ∑N= Sum of all answer No

2. Relative weight is a way to measure relative importance for every variable in questionnaire and it's calculated by:-

$$(W) = \sum(Y)*(3) / (R *(3))$$

Where

W=relative weight Y =Number of yes answers R=Number of all respondents

<u>Discussion</u>

- Related to the problems related to physical ergonomic factors in merchant ships analysis of physical questions are:-

Question No.23 which stated does the noise caused by the operation of any equipment in the ship sometimes affect your sleep?

- The majority of respondents to this question, which is a poor factor, answered "yes," with a relative weight of 70% and a mean value of 2.40, placing it as the eighth most important factor. This high percentage was obtained from 65.7% of engineers with senior ranks, such as chief engineer and second engineer, which is strong proof of a poor factor. Factor is widespread, and the result corresponds to the flaws mentioned in the case study, further demonstrating the suffering factor.

- According to national library of medicine (Huang, 2021) which study the relation between sleep and injury it was noted that there is a significant evidence that noise effect on sleep as represented in question No.23.
- This result agree with (Cui, Wang, Yang, & Liu, 2022) who studied the impact of marine engine noise exposure on seafarer they found sleep efficiency decreased with the growing engine noise levels and the higher number of engine noise events.

- Regarding noise factor in question No.23 and also case study it was obvious that noise factor effect badly on most of seafarers

Question No.24 which stated do you sometimes feel a little pain in your knees as a result of frequent boarding of the stairs of the ship's machine room??

- This is a poor factor, and some respondents answered “yes”, placing it at number 14 with a relative weight of 48% and a mean value of 1.96. This high percentage was gathered from 75% of engineers with senior ranks, such as chief engineer and second engineer, and it is clear evidence of this. Additionally, the case study's defects are matched with the factor, which is more proof that the factor is poor.
- Researcher believe that reasons is Poor design of ladders with high inclination degree.
- ❖ This result agree with (Coulter & Bawab, 2017) that there is effects of Navy ship ladder descent on the knee internal joint reaction forces.
- ❖ Regarding inclination degree for ladders in engine room as mentioned in question No.24 and also case study it was obvious inclination degree for ladders in engine room effect badly on seafarers

Question No.25 which stated Are there places in the ship where lighting is insufficient and affects your job in engine room?

- This question signifies a negative characteristic and most of the respondents determined yes with relative weight 40% with mean value 1.80 which ranked this factor as number 17 and this high percentage is been collected from 50 % of engineers with years of experience over 5 years which is evidence of poor factor besides Factor is common and Result is matched with defects mentioned in case study which is an additional evidence of suffering factor.
- Researcher considered all negative answers because bad design of engine room lighting and Ship owner want to save money instead of lighting costs

- ❖ This result agree with (Newsham & Tosco, 2005) that lighting effects on office worker satisfaction and performance, and energy efficiency.

- Regarding lighting factor in question No.25 and also case study it was obvious lighting factor is poor

Question No.29 which stated does high temperature in purifier room affect you on your job?

- This refers to an adverse perspective, and some respondents answered “yes”, placing it 17th overall with a relative weight of 40% and a mean value of 1.80. Additionally, 60% of engineers with senior ranks, such as chief engineer and second engineer, contributed to this high percentage, which is reflective of a bad factor. Factor is common, and the results indicated that 40% of engineers have flaws similar to those discussed in the case study.
- Researcher assumed that the following are the main reasons are bad design of engine room workshop and bad design of purifier room

- ❖ These results agree with (Manuputty, Andarini, & Riniwati, 2020) that the performance variable is influenced by work environment such as temperature, behavior and health variables by 52.10%.
- Regarding work place design factor mentioned in question No.29 and also case study it was obvious work place design factor is poor for most of engineers.

Conclusion

The majority of physical ergonomic factors were found to be unsatisfactory, physical ergonomic factors with extreme consequences such as bad work place design particularly high inclination degree for engine room stairs, poor lighting, high noise surrounding ship's crew cabin, all of the above ergonomic factors have a direct impact on human causing knee problems, sleep disruption, and circadian changes, which could eventually lead to an increase in the number of injuries and deaths, as well as a decrease in human performance, resulting in the project's objectives not being met.

Recommendations

- For shipping industry in order to achieve ideal ergonomic factors for seafarers and economic objectives the following aspects related to ergonomic elements are recommended
  - It was necessary to have an optimum inclination degree for ladders, Optimum design for the purifier room, optimum design for air handling units and Take prompt corrective actions to correct all ship ergonomic factors related to physical.
- Related to research the following items need further and deeply research
  - The rest of the factors related to organizational and cognitive ergonomic which haven't studied deeply in this study and modeling for ergonomic factor and apply in marine industry.

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

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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.

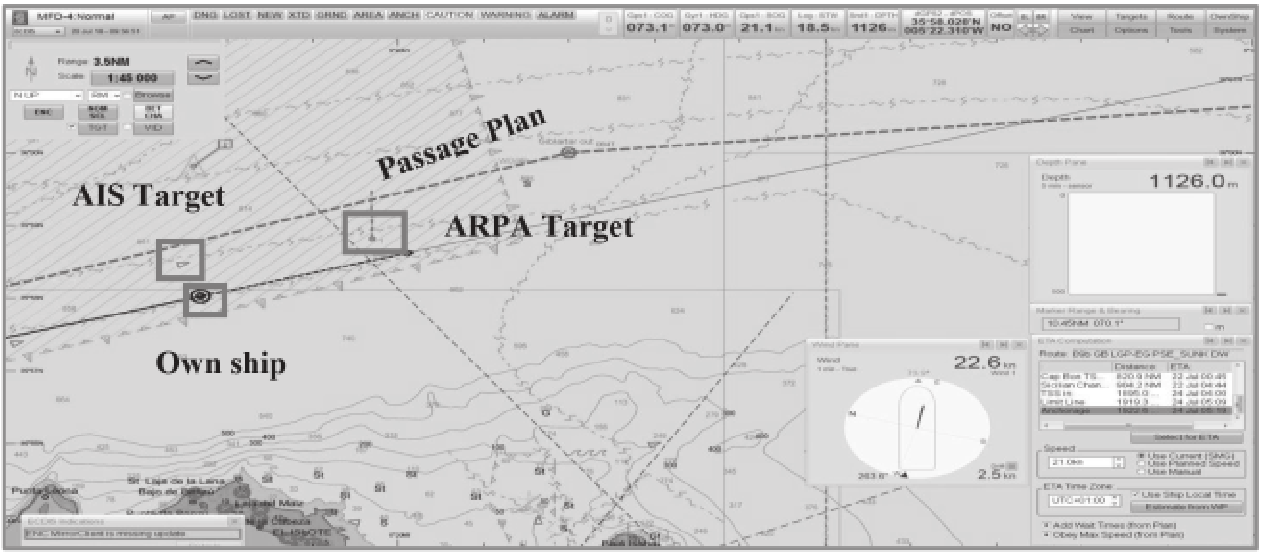

Figure 1: ECDIS interface integrated with ARPA & AIS
Source: AASTMT ECDIS Simulator

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.

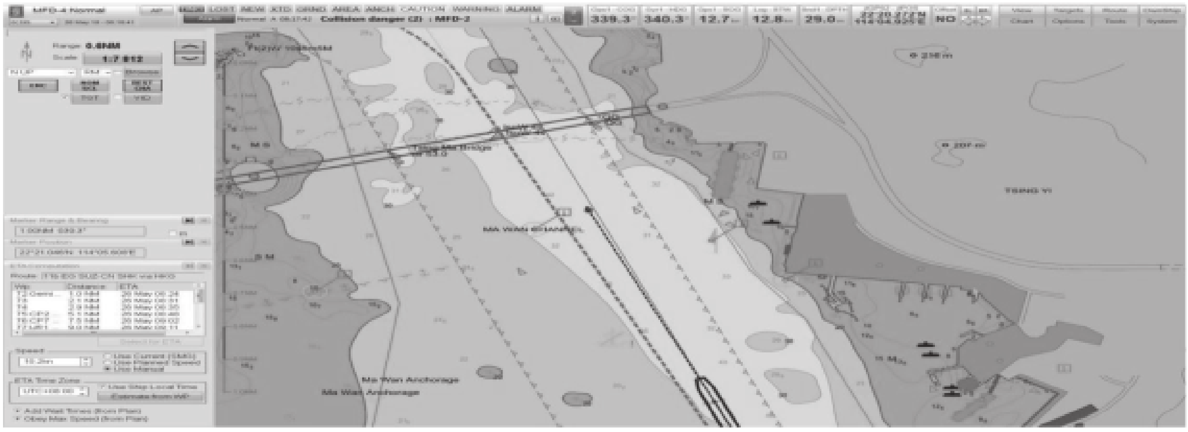

Figure 2: ECDIS interface while passing under Bridge
Source: AASTMT ECDIS Simulator

5. <u>METHODOLOGY</u>

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.

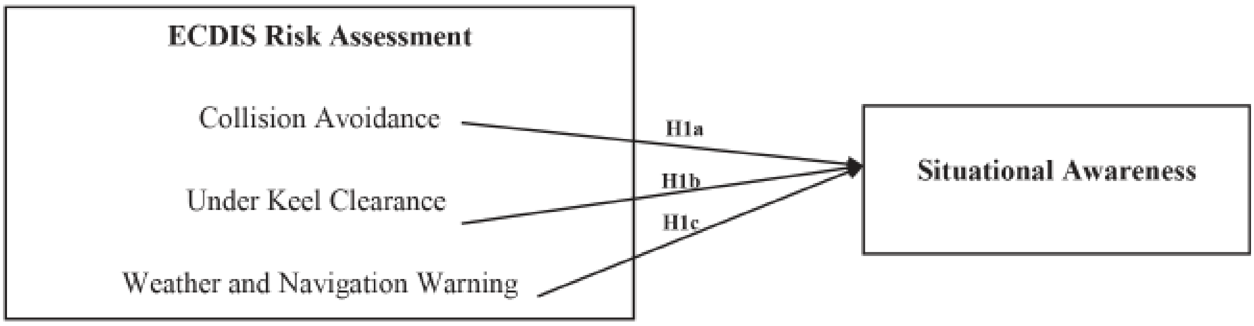

Figure 3: Proposed Research Framework

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.

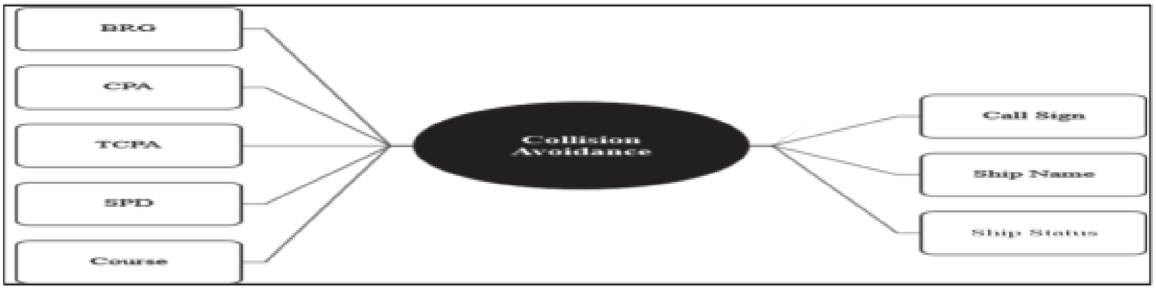

Figure 4: Codes Related to Collision Avoidance Theme

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.

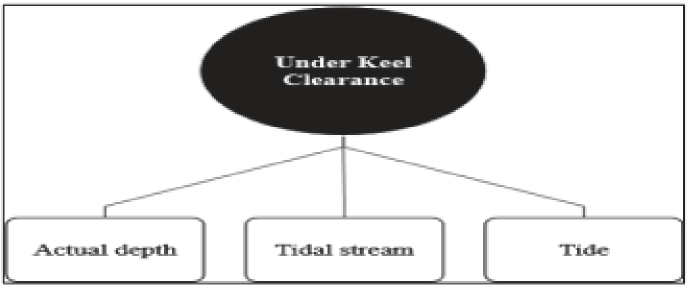

Figure 6: Codes Related to Under Keel Clearance Theme

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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Technological Innovations in the Maritime Sector: A Comprehensive Analysis of Intelligence Knowledge and Industry Dynamics for Graduates Adaptation

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المستخلص

تُكمل المهارات الشخصية المُكتسبة من قبل الخريجيين، مثل التوعية بالظروف المحيطة، وإتخاذ القرارات، إدارة عبء العمل والتواصل، مُتطلبات الأتفاقية الدولية (STCW) لعام ١٩٧٨، بصيغتها المعدلة. حيث يُساعد أيضاً تطبيق (GMP-BoK) في تصنيف هذه المهارات، بما في ذلك المهارات القيادية، والتي يُمكن تطويرها من خلال النمو المعرفي والسمات المؤثرة (Fjeld et al., 2018).

هناك دراسات قليلة عن الذكاء الاصطناعي (AI) في التعليم البحري، مما أدى إلى وجود فجوة بين صناعات النقل البحري والتعليم (Yang et al. 2019; Mirovi and Milievi et al. 2018).
ومع ذلك، أستنتج Zhang and Lam (2019) أن أبرز العقبات التي تواجه التنمية المتوازنة في قطاع النقل البحري هي قلة الدعم التنفيذي ونقص الخبرة.

تتناول الورقة البحثية أهمية تطوير التعليم والتدريب البحري (MET)، وتقديم حُلول للتعامل مع الفجوة بين التقدم التكنولوجي وإستعداد المعاهد البحرية لتغيير مهارات وقُدرات الخريجيين والعاملين على متن السفن الحديثة. يتم ذلك من خلال إستعراض أساليب مختلفة يُمكن إستخدامها لتطوير التعليم والتدريب البحري، مثل تقنيات الذكاء الاصطناعي (AI) والواقع الافتراضي (VR). وبالإضافة الي ذلك، تم إستخدام تقنية التحليل الإحصائي (SPSS) للحصول على النتائج. كَشفت الدراسة أن الخريجيين الجُدد يعانون من قلق أكبر من الخريجيين الذين لديهم خبرة من أحتمالية إستبعادهم من سوق العمل، حيث يعتقدون أن خبراتهم الحالية تجاه مهارات الذكاء الإصطناعي والتفكير الحاسوبي لن تُسهل توظيفهم في مجالات متنوعة في صناعة النقل البحري. تم تطبيق المنهج الوصفي كمنهجية مُختارة لإستيعاب فهم شامل لإمكانيات الإبتكارات التكنولوجية الحديثة.

Abstract

Interpersonal skills used by mates, such as situational awareness, decision-making, workload management, communication, and leadership, complement the requirements of the International Convention on Standards of Training, Certification, and Watch keeping for Seafarers (STCW) 1978, as amended. The GMP taxonomy helps categorize these skills, including leadership, which can be developed through cognitive growth and emotional attributes (Fjeld et al., 2018).

There have been few studies on Artificial Intelligence (AI) in maritime education, resulting in a gap between the maritime industries and education (Yang et al. 2019; Mirovi and Milievi et al. 2018). However, Zhang and Lam (2019) discovered that the primary impediments to enharmonic development in the marine sector are a lack of executive sponsorship and a lack of expertise.

This paper demonstrates the importance of developing maritime education, bridging the gap between technological progress and the readiness of maritime institutes to change the honor and capabilities of crew and staff on board modern ships, by reviewing the various methods that can be used to change education and training, such as an AI and Virtual Reality techniques (VR). Moreover, it employed the Statistical Package for the Social Sciences (SPSS) technique to acquire the outcomes. Revealed that graduates exhibit greater unease than professionals regarding potential expulsion from the workforce, believing that their acquired expertise and computational thinking skills will not facilitate employment in diverse sectors of the maritime industry. A descriptive approach was employed as the chosen methodology for capturing a comprehensive understanding of the efficiency of the new technology.

Keywords: Virtual Reality / Augmented Reality Techniques, Innovation Intelligence, Autonomous.

1. Introduction

At present, the global shipping industry employs approximately 1.6 million seafarers and is responsible for transporting over 90% of the world's cargo, according to UNCTAD's 2019 report. Despite the significant role of humans in maritime operations, there is a prevalent belief that removing direct human involvement can enhance safety and efficiency in the industry (Wróbel et al. 2017; Hoem et al. 2019; Oksavik et al. 2020). Consequently, ocean-going merchant vessels that are maritime autonomous surface ships, also referred to as MASSs will sail across the ocean either completely autonomously or under the supervision of a remote onshore control center (SCC) (IMO MSC 2018; Strkersen 2021; Ramos et al. 2019).

The level of direct human involvement in maritime operations is decreasing as automation increases, from manual control to remote monitoring (Komianos, 2018). MASSs, or ocean-going merchant ships, can operate autonomously or under remote supervision (IMO MSC, 2018; Kobyliski, 2018; Fan et al., 2020). Maritime Education and Training Institutions (MET) provide practical onboard training as well as theoretical instruction to seafarers, which is critical for their professional education. Apprentices are young people and potential seafarers who provide valuable insights into upcoming changes in the shipping industry and should be actively involved in shaping its future (Glen, 2008). Their viewpoints are critical in the development of international policies concerning marine automation, educational models, and employment.

The present study's purpose is to analyze future maritime institute graduates' perspectives towards autonomous shipping, as well as its consequences for the labor market and its ability to adapt to change. The concerns listed below must be addressed:

- Evaluating the preparedness of METs to address the challenges posed by autonomous shipping.
- Investigating the extent of concerns among cadets regarding potential job displacement in the maritime industry resulting from the rise of autonomous control systems.
- Assessing if graduates are concerned that their talents may become outdated in an increasingly automated marine business.

Furthermore, the study's objective is to gather data on the effectiveness of MET curricula in equipping graduates and seafarers with innovation intelligence knowledge and computational thinking skills for working with emerging technologies. A survey was conducted among recent graduates, seafarers, and industry employees to assess these skills and their perception of the adequacy of their education and training in these areas.

This research paper is structured in the following manner: Initially, the methods and materials, which include the assumptions and demographic information of the participants, are introduced. Subsequently, the results of the survey are presented and discussed.

Literature Reviews

Sharma et al. (2019) conducted expert research to validate the significance of seafarer competency criteria to MASS. Fan et al. (2020) asserted that training and education are variables influencing MASS operational hazards. Janßen et al. (2021) proposed that future remote operators' experience, as well as their training, should be explored. Ultimately, Nautilus Federation (2018) found in its expert-based research that training and reskilling are among the most significant barriers to MASS adoption, however, were considered significantly less important than the dependability of communication linkages or legal difficulties.

The existence of a gap between the current and future industry structure, as well as the methods of training individuals to meet future expectations, has been identified (Pie trzykowski and Hajduk 2019; Hogg and Ghosh 2016). Publishers have expressed opinions on this gap, highlighting the need for educational and professional readiness to keep pace with technological development. These opinions can be summed up as follows:

1. Technological advancements such as the Internet of Things (IoT), big data, AI, cloud computing, VR, simulation, improved connectivity, and e-learning have transformed the

learning process, encompassing emerging technologies, changing ship and port operations, evolving trade patterns, and the need for updated regulations (Kaizer, A. et al. 2021).

2. With the marine industry's increasing globalization, the focus of education and training has shifted from subject matter expertise and competency to developing essential interpersonal skills and attitudes for international work environments. This includes fostering teamwork, leadership, project management, and cultural awareness.
3. The recognition of educational demands and collaborative potential has led to the development of innovative educational techniques aimed at effectively addressing these challenges. e.g., to effectively address these challenges;
    - The ongoing advancements in technology and the increasing importance of developing interpersonal skills and attitudes require a continuous and prolonged learning process, thereby leading MET institutions to expand beyond conventional educational approaches
    - In the new STCW regime, new instructional techniques must blend theory and practice.

2. GMP Project Enhances MET for Innovation

The Nippon Foundation has collaborated with International Association of Maritime Universities (IAMU) members to create the GMP project in response to the rapid changes in the global maritime industry caused by shifting markets, goods, and social norms (IAMU, 2019). The framework of the GMP project is to classify intended learning outcomes into a taxonomy of cognitive, affective, and psychomotor domains to assist educators in designing curriculum, with the objective of defining psychomotor outcomes (Bolmsten, J., Manuel, M.E., Kaizer, A. et al. 2021).

The GMP project aims to provide a foundation for curriculum development, learning activities, and evaluation in 66 maritime institutions. Its objectives, as outlined in the 2019 Body of Knowledge (BoK), are to be specific in the following areas:

a) Meeting the educational requirement for innovation management among aspiring maritime professionals.
b) Meeting the demand for innovation education among new entrants to the labor force.
c) Developing critical thinking, creativity, and innovation skills in order to succeed in the maritime industry.

3. Revitalizing MET for Automation Challenges

Raising awareness of job opportunities necessitates familiarizing future students and employees with emerging technologies such as MASS through curriculum changes and industry partnerships. Consideration should be given to the potential impact of autonomous merchant ships on the maritime job market (Haralambides 2017).

Moreover, broadening the curriculum requires its redesign to incorporate a diverse range of skills, including soft skills, alongside technical subjects. This comprehensive approach aims to enhance the readiness of future students and employees in navigating the changing job market influenced by automation (Baller et al., 2016).

4. Methods

The questionnaire was developed to enable the participation of graduates from diverse backgrounds, such as numerous streams, institutes, and regions, as well as varied degrees of understanding regarding autonomous ships, GMP, and intelligent shipping. The most notable groups were those who were studying to become future navigators or future engineers in the engine department.

In this study, information is provided about the participants who completed the questionnaire in terms of gender, age, country of graduation from the MET, years of sea service, current occupation, and highest educational level received. Out of the 400 participants who returned and properly filled in questionnaires, 357 identified as male and 43 as female, representing 89.25% and 10.75%, respectively. The majority of participants (68.25%) fell into the age range of less than 35 years. The highest number of participants graduated from Egypt (26%), followed by Jordan (17.5%) and Saudi Arabia (12.5%). In terms of years of sea service, 67.25% of participants had less than 5 years of experience, while 32.75% had more than 5 years. The majority of participants identified as O.O.W (42%), followed by Certificate of Competence (CoC) holders (36.5%), while the smallest group was represented by instructors (5.25%). The highest level of education received was a CoC (36.5%), followed by a Bachelor's Degree (26.5%) and basic studies (24.25%). Only a small percentage of participants held a Master's degree (7.25%) or Doctorate (1.75%).

4.1 Questionnaire Panel: The study employed descriptive statistics research methods to collect data and assess the respondent’s effectiveness in their current MET curricula. As explained by Payne and Payne (2004), these methods aim to identify patterns in human experiences by breaking down the social world into elements. The questionnaire contains 5 sections targeting different aspects. The five sections were as below:

1. Socio-demographic Data:

This section of the respondents, including age, gender, education, years of experience, occupation, and nationalities, were collected through six questions in this section to better understand the characteristics of the sample.

2. Innovation Intelligence Knowledge and Computational Thinking Skills:

This section is to assess respondents' knowledge of Innovation Intelligence and Computational Thinking Skills, specifically their readiness to handle the most recent technological advancements used in the maritime industry.

3. Practical Applications / Simulator-Based Training and Industry Collaboration:
This section is to assess and measure the respondents' simulator-based training experience with new technological innovations, their perception of the pace of technological change in the industry, and their opportunities to collaborate with industry professionals.

4. STCW on Technological Innovation (MET Curricula):
This section seeks responses on the effectiveness of the IMO and STCW in dealing with the impact of technological innovation on the maritime industry.

5. Emerging the New Technological Innovation and GMPs into MET Curricula:
This section is to assess the value of interpersonal skills, attitudes, leadership, teamwork, project management, and cultural awareness for graduates and seafarers in an international context. The section also seeks to evaluate the role of formal technical education and on-the-job training in the development of diverse skills and knowledge for individuals to become GMPs capable of adapting to new technologies and innovations to remain competitive in the maritime industry.

As shown in Table (1) A questionnaire was given to participants, asking them to indicate their level of agreement with various statements. According to Pimentel (2010), the Likert scale, classified as an interval scale, is used, and the mean value is important for interpreting the responses.

Table (1) Likert Scale Value Interpretation

Level	Scale	Lower Limit	Upper Limit	Interval
Strongly Disagree	1	1.00	1.80	1.00 : 1.80
Disagree	2	1.81	2.60	1.81 : 2.60
Neither agree nor disagree	3	2.61	3.40	2.61 : 3.40
Agree	4	3.41	4.20	3.41 : 4.20
Strongly Agree	5	4.21	5.00	4.21 : 5.00

A Google form with 14 carefully designed questions was distributed in 4 sections in addition to the section on the demographic data to a diverse group of graduates and seafarers to collect data on their perspectives. The research sample was randomly selected and representative. Within two weeks, a response rate of over 400 participants, with 220 responses in the first week, was achieved. To extract meaningful insights, the collected data underwent rigorous statistical analysis using SPSS. The analysis included examining frequency, percentage, and Chi-Square measures within the research sample.

A sample of 15 responses was used for pilot testing conducted for the reliability test (Cronbach's Alpha), In the final stage a total of 400 responses were collected, with half coming from recent graduates with short sea services and half from current seafarers with long sea services, all of them are graduated from different METs institutes.

Table (2) Reliability Analysis (Cronbach's Alpha)

Case Processing Summary			
		N	%
Cases	Valid	15	100.0
	Excluded	0	.0
	Total	15	100.0
a. Listwise deletion based on all studied categories in the procedure.			

Reliability Statistics		
Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.882	.882	14

As shown in Table (2) the analysis included 14 questions across 5 sections, covering socio-demographic data. A total of 15 responses were used for pilot testing, and no cases were excluded based on the specified criteria. The scale used in the analysis showed high internal consistency, with a Cronbach's alpha coefficient of .882, as a value of .7 or higher is generally considered to be acceptable. This indicates that the items in the scale measure the same construct reliably. Standardizing the items did not significantly improve reliability. These findings validate the scale's internal consistency and support the validity of the study's results.

Table (3) Frequencies Statistics - Section (1)

Socio demographics data	**Frequency (N=400)**	**Percent**
Sec.1_Q1_What is your gender identity?		
• Male	357	89.25%
• Female	43	10.75%
Sec.1_Q2_What age range do you fall into?		
• Less than 35 years	273	68.25%
• More than 35 years	127	31.75%
Sec.1_Q3_In which country did you graduate from the maritime education and training institute (MET)?		
• Egypt	104	26.0%
• Jordan	70	17.5%
• Saudi Arabia	50	12.5%
• Syria	40	10.0%
• Lebanon	36	9.0%
• Algeria	34	8.5%
• Oman	26	6.5%
• Bahrain	15	3.75%
• Morocco	10	2.5%
• United Arab Emirates	6	1.5%
• Others	9	2.25
Sec.1_Q4_How many years of sea service do you have?		

• Less than 5 years • More than 5 years	269 131	67.25% 32.75%
Sec.1_Q5_What is your current occupation?		
• Cadets • O.O.W • Master • Chief Engineer • Instructor • Others	97 168 53 48 21 13	24.25% 42.0% 13.25% 12.0% 5.25% 3.25%
Sec.1_Q6_What is the highest educational level you have received after graduation?		
• Basic Studies • Bachelor's Degree • CoC • Master's Degree • Doctorate • Professional • Others	97 106 146 29 7 4 11	24.25% 26.5% 36.5% 7.25% 1.75% 1.0% 2.75%

5. Result

The survey collected opinions on the impact of technological innovation in the maritime industry. As shown in Table (4) In Section 2, a majority (65.55%) disagreed or strongly disagreed with their knowledge and readiness for recent technological advancements, while (16.7%) agreed or strongly agreed. In Section 3, a majority (57.78%) disagreed or strongly disagreed with simulator-based training, perception of technological change, and collaboration opportunities, while (33.26%) agreed or strongly agreed.

In Section 4, (54.75%) disagreed or strongly disagreed with the effectiveness of IMO and STCW, while (32.2%) agreed or strongly agreed. In Section 5, a significant majority (63.63%) expressed agreement on the importance of interpersonal skills, leadership, teamwork, and cultural awareness, as well as the significance of formal technical education and on-the-job training for adapting to new technologies and remaining competitive. However, (19.43%) strongly disagreed or disagreed with these views.

Table (4) Distribution of the studied sample according to Items (n = 400)

Q	Items	Strongly Disagree		Disagree		Neutral		Agree		Strongly Agree		Mean	SD.
		No.	%	No.	%	No.	%	No.	%	No.	%		
1	Section 2	185	46.3	110	27.5	65	16.3	29	7.3	11	2.8	1.93	1.08
2		124	31.0	105	26.3	78	19.5	63	15.8	30	7.5	2.43	1.28
1	Section 3	110	27.5	135	33.8	85	21.3	55	13.8	15	3.8	2.33	1.13
2		92	23.0	124	31.0	78	19.5	64	16.0	42	10.5	2.60	1.29
3		102	25.5	134	33.5	73	18.3	44	11.0	47	11.8	2.50	1.30
4		117	29.3	110	27.5	78	19.5	54	13.5	41	10.3	2.48	1.31
1	Section 4	150	37.5	120	30.0	50	12.5	45	11.3	35	8.8	2.24	1.30
2		75	18.8	105	26.3	85	21.3	80	20.0	55	13.8	2.84	1.32
3		101	25.3	126	31.5	67	16.8	51	12.8	55	13.8	2.58	1.35
4		83	20.8	115	28.8	73	18.3	63	15.8	66	16.5	2.79	1.38
1	Section 5	54	13.5	62	15.5	43	10.8	141	35.3	100	25.0	3.43	1.37
2		28	7.0	33	8.3	85	21.3	137	34.3	117	29.3	3.71	1.18
3		28	7.0	33	8.3	70	17.5	147	36.8	122	30.5	3.76	1.18
4		33	8.3	39	9.8	75	18.8	152	38.0	101	25.3	3.62	1.20

SD: **Standard deviation**

As shown in Table (5), In Section 2, respondents' understanding of Innovation Intelligence and Computational Thinking Skills showed room for improvement, with an average score of 2.18 out of 5.0. The variability in scores was highlighted by a standard deviation of 0.81, indicating differences in individual performance. Similarly, Section 3 revealed opportunities for enhancement in simulator-based training and industry collaboration, with an average score of 2.48 out of 4.25 and a moderate standard deviation of 0.63. Promoting these areas can better prepare respondents for technological advancements in the maritime industry.

Moving on to Section 4, respondents demonstrated a partial understanding of the impact of technological innovation in relation to the IMO and STCW, with an average score of 2.61 out of

4.50. The standard deviation of 0.68 indicated variability in individual scores, necessitating further examination of the effectiveness of these organizations in addressing technological challenges.

Finally, in Section 5, respondents showcased a good level of interpersonal skills, leadership, teamwork, and cultural awareness, with an average score of 3.63 out of 4.75. The low standard deviation of 0.61 suggested consistent performance in these areas, highlighting the value of formal technical education and on-the-job training for developing versatile maritime professionals capable of adapting to new technologies and innovations.

Table (5) Descriptive analysis of the studied sample according to score (n = 400)

	Total Score	Average Score	% Score
Section 2	**(2 – 10)**		
Min. – Max.	2.0 – 10.0	1.0 – 5.0	0.0 – 100.0
Mean ± SD.	4.35 ± 1.62	2.18 ± 0.81	29.41 ± 20.23
Median	4.0	2.0	25.0
Section 3	**(4 – 20)**		
Min. – Max.	5.0 – 17.0	1.25 – 4.25	6.25 – 81.25
Mean ± SD.	9.91 ± 2.53	2.48 ± 0.63	36.91 ± 15.83
Median	10.0	2.50	37.50
Section 4	**(4 – 20)**		
Min. – Max.	4.0 – 18.0	1.0 – 4.50	0.0 – 87.50
Mean ± SD.	10.44 ± 2.71	2.61 ± 0.68	40.27 ± 16.96
Median	10.0	2.50	37.50
Section 5	**(4 – 20)**		
Min. – Max.	8.0 – 19.0	2.0 – 4.75	25.0 – 93.75
Mean ± SD.	14.51 ± 2.43	3.63 ± 0.61	65.69 ± 15.21
Median	15.0	3.75	68.75

SD: **Standard deviation**

Based on the chi-square test results shown in Table (6) and p-values ranged (0.333:0.710) greater than 0.05, there is no statistically significant association between occupation and all the questions in Section 4 on the effectiveness of the IMO and STCW in dealing with the impact of technological innovation on the maritime industry which are the respondents' perspectives on crucial aspects of technological innovation in the maritime industry.

The data strongly indicate that the occupation of the individuals surveyed does not exert a statistically significant influence on their beliefs regarding the recognition of technological innovation in the STCW convention, the potential efficacy of a new IMO model course in enhancing graduates' knowledge and skills, the customization of curricula and conventions to accommodate autonomous ships, and the alignment of technical expertise with evolving transportation needs.

Table (6) Relation between occupation and Section 4 (n = 400)

Q	Section 4	Q5 What is your current occupation?												χ^2	p
		Cadet (n = 97)		O.O.W (n = 168)		Master (n = 53)		Chief Engineer (n = 48)		Instructor (n = 21)		Others (n = 13)			
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%		
1															
	Disagree	68	70.1	115	68.5	37	69.8	29	60.4	12	57.1	9	69.2	9.689	$^{MC}p=$ 0.447
	Neutral	10	10.3	17	10.1	10	18.9	6	12.5	5	23.8	2	15.4		
	Agree	19	19.6	36	21.4	6	11.3	13	27.1	4	19.0	2	15.4		
2															
	Disagree	42	43.3	74	44.0	29	54.7	19	39.6	10	47.6	6	46.2	7.454	0.682
	Neutral	22	22.7	38	22.6	9	17.0	12	25.0	4	19.0	0	0.0		
	Agree	33	34.0	56	33.3	15	28.3	17	35.4	7	33.3	7	53.8		
3															
	Disagree	57	58.8	97	57.7	30	56.6	29	60.4	10	47.6	4	30.8	7.167	0.710
	Neutral	15	15.5	27	16.1	9	17.0	6	12.5	5	23.8	5	38.5		
	Agree	25	25.8	44	26.2	14	26.4	13	27.1	6	28.6	4	30.8		
4															
	Disagree	49	50.5	84	50.0	28	52.8	16	33.3	11	52.4	10	76.9	11.326	0.333
	Neutral	14	14.4	34	20.2	10	18.9	11	22.9	3	14.3	1	7.7		
	Agree	34	35.1	50	29.8	15	28.3	21	43.8	7	33.3	2	15.4		

χ2: **Chi square test** MC: **Monte Carlo**

p: p value for comparison between the studied categories

*: Statistically significant at $p \leq 0.05$

6. Conclusion

The analysis of the research findings explored a significant gap between maritime intelligence innovation and the knowledge and skills possessed by graduates and mates in the industry. The findings suggested the need for improvement in areas such as Innovation Intelligence and Computational Thinking Skills, simulator-based training, industry collaboration, and understanding the impact of technological innovation. These findings highlight a discrepancy between the advancements and demands of the maritime industry and the preparedness of graduates and mates to effectively navigate and utilize emerging technologies.

Addressing this gap is crucial to ensure that maritime professionals are equipped with the necessary knowledge and skills to meet the challenges and opportunities presented by maritime intelligence innovation, Respondents also have conflicting views on the potential impact of an IMO model course on these critical factors.

The feedback provided was considered, and revisions were made to enhance the rigor and validity of the research paper, including the incorporation of open-ended questions in the questionnaire. However, should be noted that further research and investigation may be necessary to gain a comprehensive understanding of the intricate dynamics of technological innovation in the maritime industry, as well as the implications for the development of knowledge and computational skills related to innovation intelligence among the workforce.

Survey participants are appreciated for their valuable contributions, and response limitations are acknowledged. This study improves the understanding of maritime professionals' perceptions of innovation intelligence, computational skills, and training effectiveness. The insights obtained guide policymakers, educators, and industry stakeholders in enhancing workforce readiness amidst technological advancements. Further research is needed to explore the evolving landscape of technological innovation and its impact on innovation intelligence and computational skills in the maritime industry.

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