Dar es Salaam
Maritime
Institute

PROCEEDINGS OF THE 2ND DAR ES SALAAM MARITIME INSTITUTE BLUE ECONOMY CONFERENCE (2023)

JUNE 27, 2023 DAR ES SALAAM, TANZANIA

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Proceedings of the 2nd Dar es Salaam Maritime Institute Blue Economy Conference (2023)

June 27, 2023
Dar es Salaam, Tanzania

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First Print June, 2024

Published by
pS Counseling Consultants
P. O. Box 90516
Dar es Salaam, Tanzania
Hotline: +255 (0) 754 861161 WhatsApp: 0786 448577
Emails: mcdoulos7@yahoo.com / mcdoulos3@gmail.com

ISBN: 978-9987-858-28-6 • **ISSN:** 2961-614X

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PREFACE

The 2nd Dar es Salaam Maritime Institute Blue Economy Conference was convened at the Julius Nyerere International Convention Centre in Dar es Salaam, Tanzania on 27th of June, 2023. The conference seeks to encourage regional communications and collaborations, promote professional interaction and lifelong learning procedures, recognize outstanding contributions of individuals and organizations, and encourage researchers to pursue studies and careers in the developments of Blue Economy, share the research findings, exchange ideas, and connect with one another.

The aim of the conference was to bring together all pertinent stakeholders to share experiences and understanding on the Blue Economy and deliberate on how professionals and the community at large can tap the opportunities available at sea for the sustainable development of the community.

A total of 8 papers were presented and formed part of the 2nd Blue Economy conference proceedings 2023. All submissions were peer-reviewed through a double-blind review process by the panel of at least two expert referees and decisions were taken based on research quality. We are grateful for the submissions of the authors and the participants, this providing an ideal forum to exchange results and ideas. We also would like to express our sincere gratitude to our colleagues in the disciplines who have kindly volunteered in the review process. And special thanks go to the organizers and chairs of the conference and the sessions.

The Technical Program Committee of the Blue Economy conference assembled an excellent program that included presentations from two Keynote Speakers: Capt. Gilbert Mokiwa (Retired Captain) and Mr. Donald Chidowu (Retired Director of Legal Services). Moderation of the presented papers was done by seven diversified experts: Capt. Mussa

H. Mandia, Prof. Matobola Joel Mihale, Prof. Costa Mahalu, Mr. Julias Nguhulla, Dr. John N. Layaa, Capt. Ibrahim M. Bendera, and Dr. Lucas P. Mwisila.

On behalf of the Organizing Committee, I wish to express my deep appreciation to all participants including all speakers and authors of the papers selected for presentation and publication. Special thanks go to the paper reviewers and the members of the organizing committee for their contributions and commitment that made event successfully. I wish everyone best of luck in their research endeavours and career pursuits. I look forward to seeing many of you in person at the next Blue Economy conference 2024.

Blue Economy Conference Chair

Dr. Lucas Pastory Mwisila
Dar es Salaam Maritime Institute, Tanzania

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ABBREVIATIONS AND ACRONYMS

AMOS	Autonomous Marine Operations and Systems
AU	African Union
AWAI	Autonomous Waterborne Applications Initiative
BE	Blue Economy
CCM	Chama Cha Mapinduzi
CMB	Corridor Managing Body
COSTECH	Tanzania Commission for Science and Technology
DFI's	Development Finance Institutions
DMI	Dar es Salaam Maritime Institute
DRC	Democratic Republic of Congo
EAC	East African Community
ETA	Estimated Time of Arrival
FYDPs	Five-year Development Plans
IAPHWF	International Association of Ports and Harbors Women's Forum
ICS	International chamber of Shipping
IFIs	International financial institutions
ILO	International Labor organization
IMO	International Maritime Organization
ISWA	International seafarers' welfare and Assistance Network
ITF	International Transport Workers Federation
IWSF	International Women Seafarers Foundation

KRISO	Korea Research Institute of Ship and Ocean Engineering
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LTA	Lake Tanganyika Authority
LTPP	Long Term Perspective Plan
MASS	Maritime Autonomous Surface Ship
MHCL	Mpulungu Harbour Corporation Limited
MLC	Maritime Labor Organization
MUNIN	Maritime Unmanned Navigation through Intelligence in Networks
NACTVET	National Council for Technical and Vocational Education and Training
NG	Natural Gas
NGOs	Non-Government Organizations
ODA	Official Development Assistance
PacWiMA	Pacific Women in Maritime Association
PPP	Public-Private Partnerships
RCCs	Remote Control Centres
SADC	Southern African Development
SDGs	Sustainable Development Goals
SOLAS	International Convention for the Safety of Life at Sea
STCW	Standard of Training, Certification and Watch keeping
TASAC	Tanzania Shipping Agency Cooperation
TDV	Tanzania Development Vision
TPA	Tanzania Ports Authority

VHF	Very High Frequency
VTS	Vessel Traffic System
WB	World Bank
WiMAC	Women in Maritime Association, Caribbean
WIMAFRICA	Women in Maritime Africa
WISTA	Women's International Shipping and Trading Association
MET	Maritime Education and Training
CoP	Community of Practice
VUCA	Volatile, Uncertain, Complex and Ambiguous
CK	Content Knowledge
PK	Pedagogical Knowledge
TK	Technological Knowledge

OVERVIEW OF DAR ES SALAAM MARITIME INSTITUTE

Dar es Salaam Maritime Institute (DMI) is the sole Maritime Training Institute in the country and it is under the Ministry of Transport (MoT). The Institute was established by an Act of Parliament No. 22 of 1991 to provide training, research and consultancy in the maritime sector.

The Institute evolved from the Dar es Salaam Training Unit (DMTU) which was formed by Cabinet Resolution on 3rd July 1978 as a Training Wing in the by then Ministry of Communication and Transport.

The DMTU was established as a project under supervision of the Norwegian Agency for Development Cooperation (NORAD) to train employees on the Tanzania Coastal Shipping Lines (TACOSHILI) and fulfil the needs for well-trained Seafarers. It should be noted that before the establishment of DMTU, all shipping companies in the East African region, had to send their cadets abroad for training as Ratings and Marine officers.

DMI is recognized as the Centre of Excellence in Maritime Education and Training in the East African region. The Institute is also ISO 9001: 2015 certified by an international classification society called Det Norske Veritas (DNV) to provide maritime related education, certification, crewing agency services and servicing of life saving appliances (life rafts and fire extinguishers).

The Institute is accredited by the National Council for Technical and Vocational Education and Training (NACTVET) to offer academic programmes under Competence Based Education and Training (CBET) from Basic Technician Certificates (NTA Level 4) to Master's Degree (NTA Level 9).

The academic programmes currently offered at DMI are:-

1. Marine Operations (NTA Level 4).
2. Maritime Transport and Nautical Science (NTA Level 5 – NTA Level 8).
3. Marine Engineering Technology (NTA Level 5 – NTA Level 8).
4. Shipping and Logistics Management (NTA Level 4 – NTA Level 8).
5. Naval Architecture and Offshore Engineering (NTA Level 4 – NTA Level 8).
6. Oil and Gas Engineering Technology (NTA Level 4 – NTA Level 8).
7. Mechanical and Marine Engineering (NTA Level 4 – NTA Level 8).
8. Marine Welding and Fabrication Engineering (NTA Level 4 – NTA Level 6).
9. Procurement, Logistics and Supply Chain Management (NTA Level 4 – NTA Level 8).
10. Transport and Supply Chain Management (NTA Level 4 – NTA Level 9).
11. Cargo Tallying and Supply Chain System (NTA Level 4).
12. Shipping Economics and Logistics (NTA Level 9).
13. Marine Engineering Management (NTA Level 9).
14. Maritime and International Trade Law (NTA Level 9); and
15. Maritime Transport Management and Nautical Science (NTA Level 9).

DMI is also accredited by the Tanzania Shipping Agencies Corporation (TASAC) under the auspices of the International Maritime Organization

(IMO) to offer certificates of Competency (CoCs) programmes. The provisions of the CoCs courses are in accordance with the International Convention on Standards of Training, Certification and Watch- keeping for Seafarers (STCW 1978 as amended).

The programmes offered under STCW Convention are Officer in Charge of an Engineering Watch on Ships Less than 750 KW; Officer in Charge of a Navigation Watch on Ships Less Than 500 GT; Electro-Technical Officer; Officer in Charge of an Engineering Watch; Officer in Charge of a Navigational Watch; Master on Ships Less Than 500 GT; Master and Chief Mate on Ships Between 500 GT and 3000 GT; and Chief Engineer Officer and Second Engineer Officer.

ABOUT THE CONFERENCE

The African Union's Agenda 2063 recognizes the significant potential of the Blue Economy in driving socio-economic transformation. This involves leveraging knowledge in marine and aquatic biotechnology, fostering the growth of a continent-wide shipping industry, advancing sea, river, lake transport and fishing, as well as tapping into the exploitation and beneficiation of deep-sea minerals and other resources.

The overarching goal of the AU is to position the Blue Economy as a central force in Africa's economic and social transformation within the global context of Agenda 2063. The specific focus is to offer a unique opportunity for the AU Commission and key stakeholders to engage in constructive policy discussions on maximizing the transformative economic potential of the Blue Economy in their respective member countries.

In that perspective, the Blue Economic agenda has emerged as a key priority in the Tanzania Development Plan. This initiative is spearheaded by the two presidents, Her Excellency Samia Suluhu Hassan and His Excellency Dr. Hussein Ali Mwinyi. In her inaugural State of the Nation address, Honorable Hassan underscored Blue Economy as a focal point, while His Excellency Hussein Mwinyi took further steps by establishing a dedicated Ministry for Blue Economy and Fisheries.

Building on these initiatives, the 2nd Blue Economy Conference 2023 is hosted by the Dar es Salaam Maritime Institute, aiming to assemble prominent figures from news media, academia, maritime professionals, higher education students, public officials, and other stakeholders in the maritime sector. The objective is to facilitate the exchange of experiences, insights, and perspectives on various aspects of Blue Economy for sustainable national development.

Additionally, the conference serves as an interdisciplinary platform for policymakers, senior managers, researchers, legal professionals, and educators to present and discuss contemporary innovations, trends, and issues aligned with practical approaches for effectively harnessing opportunities at sea.

The conference themes revolve around the interconnections between Blue Economy concepts and the current National Development Plan for the years 2022/2023-2025/2026.

CONFERENCE REPORT

Introduction

The following is a brief report on the proceedings of the 2nd DMI-BEC2023 held on 27th June 2023 at Julius Nyerere International Convention Centre (JNICC) Dar es Salaam. The theme of the conference was "Contribution of Maritime Sector in Tanzania for Sustainable Economic Development."

The aim of the conference was to bring together all pertinent stakeholders with the aim of sharing experiences and understanding on the Blue Economy and deliberate on how they can share views on how Tanzania and the community at large can tap the opportunities available at sea for the sustainable development of the community.

Conference Preparations

Dar es Salaam Maritime Institute (DMI) arranged and prepared the conference under the direction of Dr. Tumaini S. Gurumo, the Institute's Rector.

The goal was to bring together stakeholders such as academicians, government officials, ambassadors, maritime practitioners, and students from higher education institutions to share knowledge and experience on how to capitalize on maritime opportunities for Tanzania's and the world's long-term development.

Presentations

A total of 8 scholarly presentations were made from which various issues were raised and discussed in details in line with the opportunities which can be tapped from the Blue Economy. The details on the presentations are available in this document as attachment in annex 1.

Opening of Conference

The conference was officially opened by Hon. Masoud Makame (MP), Minister for Blue Economy and Fisheries (SMZ). The Minister commended DMI for organizing the second exceptional Blue Economy Conference, aiming to explore how our government and community can leverage the blue economy for sustainable wealth creation and economic growth.

Also, comments that Shipping plays a critical role in the global supply chain and is essential for future sustainable economic growth. Nonetheless, the Minister assured the Institute that the government has promised to provide the necessary funds that are required for expansion of DMI educational facilities, in order to provide contemporary training.

Closing of Conference

The conference was officially closed by Hon. Suleiman Masoud Makame, Minister of Blue Economy and Fisheries from Zanzibar. The Minister commended DMI for preparing such important conference second year in a raw. He also anticipated fruitful discussions leading to sustainable outcomes, contributing to our shared goal of sustainable development and a thriving blue economy. He also gave highlights on the milestone achievements made by Zanzibar on the Blue Economy Sector.

It has gone further by establishing a specific ministry in the sector which is known as the Ministry of Blue Economy and Fisheries. This gives a great impetus on pushing the agenda forward for the benefit of the Zanzibar is and the community at large. He encouraged DMI to continue preparing this kind of conferences and dialogues for the benefit of the

community at large and assured them a close collaboration.

Conclusion

Generally, the conference was successful as it had fruitful deliberations which came up with six (6) suggestions from which it was agreed that the Steering Committee of the Conference would come up with resolutions to be forwarded to higher authorities for further actions.

Recommendations

Despite the achievements attained, it was recommended that the DMI should use the experience gained and lessons learnt from the 2nd DMI-BEC2023 for a better preparation of the next conference. Specifically, the following issues were recommended for future preparations:

Steering Committee/Secretariat should visit the venue of the meeting and make a thorough rehearsal on protocol issues prior to the conference:

i. Rapporteurs should be facilitated in terms of a specific seating place and facilities for proper carrying out of their task.

ii. Rapporteurs should be supplied with pertinent documents for the conference so that they can carry out their duty properly.

iii. Presenters should be given a reasonable time to present the proceedings as compared to the last event.

Resolutions Derived by Steering Committee

As stated in conclusion section, the participants gave nine observations from which it was agreed that the Secretariat shall develop the pertinent observations:

The Government should develop a comprehensive Maritime Policy which includes all relevant sectors:

i. The Government establish mechanisms for continuous monitoring and evaluation of Blue Economy initiatives to ensure

their effectiveness and adaptability to evolving economic and environmental conditions

ii. The Government should establish public awareness and engagement in understanding the opportunities and challenges of the Blue Economy, fostering economy, a sense of responsibility and participation among citizens; DMI should be on the forefront in initiating and making follow-up on the development of the Comprehensive Maritime Policy.

The Government should support initiatives that promote research and innovation in Blue Economy-related sectors, fostering advancements in areas such as marine biotechnology, renewable energies, and fisheries;

DMI should be equipped with modern equipment and training facilities so as to continue being the focal point of maritime training in the East African region.

The Government should introduce maritime training and education from the lower level of education by introducing the Maritime Education Curriculum from the Primary Education level to enable creating awareness of Blue Economy from the grassroot.

ANNEX 1
CONFERENCE PAPERS

SUB-THEME 1

THE IMPACT OF SCIENCE AND TECHNOLOGY

PRESSURE MATCHING FOR OFFSHORE GAS WELLS IN TANZANIA: FOCUS ON ACTUAL PUMP PRESSURE TO SIMULATED FRICTION PRESSURE DROP USING CONVENTIONAL MODELS

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ABSTRACT

The pressure matching for section 17.5 inches of a well RTX in offshore Tanzania was studied using three conventional models: Bingham, Power law, and Herschel-Buckley. The relative percentage error, root-mean- square (RMS), root-mean-square error (RMSE), and the coefficient of determination (R2) were used to compare the pressure drop for different models in the section. The power law model was found to have a reduced RMSE of 0.214 while the Herschel-Buckley and Bingham plastic models had RMSEs of 0.3612 and 0.3935 respectively, that are

relative higher.

The power law model is considered the best fit as the ratio of the yield stress (τy) and the yield point (YP) was approached zero, indicating the fluid behaviour more like pseudo plastic fluids that is good for hole cleaning and well stability. The mud weight ranged from 11.5 to 12.5 ppg and was a decent approximation of the actual Pump pressure (2400 psi) that ranged from 1964.95 to 2358.276 psi. Using mud weights ranging from 17.2 to 18.5 ppg resulted in greater pump pressures ranging from 3200.44 to 3222.831 than pump pressure. The increase in simulated pump pressure indicates the abrupt increase in hydrostatic pressure induced by large mud weight, which could harm the formation (reservoir) when underbalanced drilling is utilized in Tanzania's offshore gas well drilling campaign.

Keywords: Pump Pressure, Friction Pressure Drop, Drilling Fluid, Rheological Models, Offshore Gas Well Drilling, Statistical Approach

1.0 INTRODUCTION

An offshore vertical gas well RTX of 2115m was drilled in Songosongo gas field in the southern coast of Tanzania. The drilling programme of a well RTX started in early December 2015 to mid-February 2016.The well was drilled from 32.1 m using water-based mud as drilling fluid to the targeted measured depth as shown in Table 1 (PanAfricaEnergy, 2016). Calculations of the friction pressure drop during the drilling process were done using the drill bit data, which included standpipe pressure and fluid flow rates. Drilling fluids that flow in pipe and the annulus are subjected to shear-or-lord-rate, time, and spatial orientation (Faergestad, 2016) and hence results to pressure drops. The fluids often show time-dependent properties and behave viscoelastically under certain condition due to interaction among various components and the complex response of each component under

different shearing conditions (Bui and Tuntuncu, 2016).

The nature of circulated drilling fluid plays a big role in friction drop in the system as it is defined by its rheology. Fluids rheology's have since been important for effective fluid circulations, for improved hole cleaning and keeping the well pressure under control (Werner *et al.,* 2016). Good designing and implementation of rheological model for a particular drilling fluid help to protect the well from sloughing shale's, drill pipe sticking, poor hole cleaning and other drilling challenges (Raj *et al.,* 2016).

But due to complexities of drilling fluids, downhole conditions, and some uncertainties, the rheological model of fluid, while still important, no longer is the defining element of the circulated fluid. For example, surface and downhole mud weight conditions differ in most of extreme–temperature wells. Such circumstance can override model-related and affecting pressure loss calculations in the well (Zamora *et al.,* 2005).

For a well, it is necessary to match the real pressure drop to the simulated drilling fluid friction drop. However, it hasn't been documented in the literature as a baseline for Tanzanian offshore gas wells. As a result, the offshore gas field's RTX well will serve as a baseline study to enlighten the community and stakeholders for better understanding and well performance. Thus, this study aims to match the actual pressure drop with simulated drilling fluid friction drop in section "17 ½" of RTX well. In that regard, the drilling fluid properties must be assumed not constant from the top to the bottom of the hole as opposed to Fontenot and Clark (1974).

The drilling fluid used includes KCL/Polyamine for the two sections (17 ½" and 12 ¼") and FLO-PRO (KCL/NaCl/CaCO3) for section 8 ½" as shown in Table 1. Furthermore, in this work three rheological models have been considered for simulated friction pressure drop calculations in the 17 ½ inches section of well RXT as indicated in Figure 1.

These models are Bingham plastic, power law and Herschel-Buckley Figure 2 that have been widely applied in the drilling industry. One of the common advantages of these models is that they have a simple mathematical form that relates shear stress to shear rate. The selected

rheological models describe the shearing rate and shear stress applied to the flow of materials (fluids) (Bui and Tutuncu, 2014)

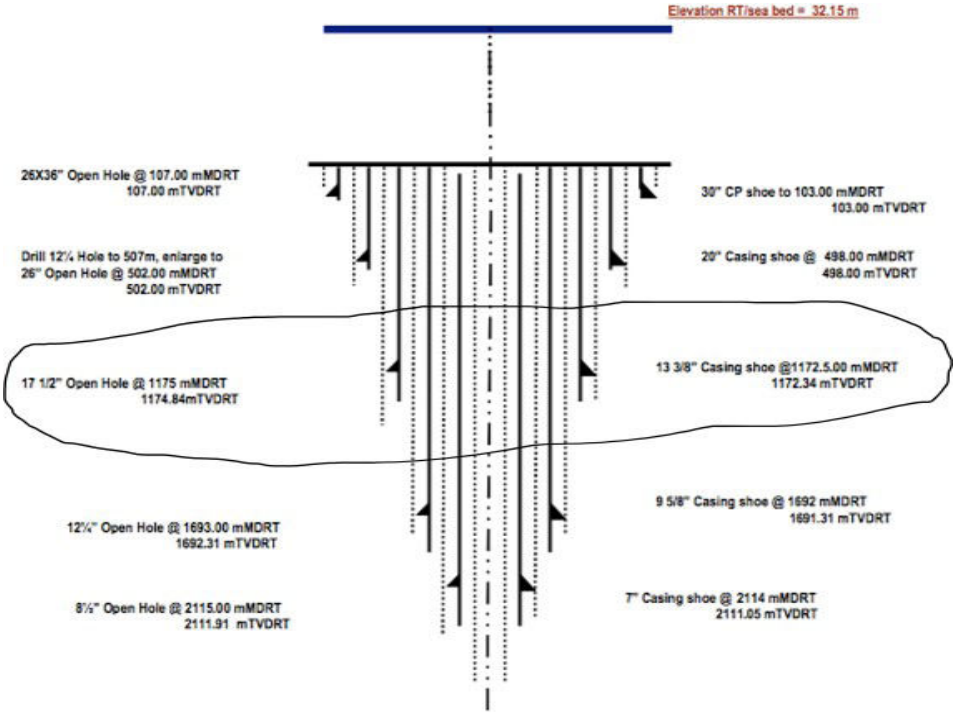

Figure 1: Wellbore Profile for RTX Well

Table 1: *Drilling parameters used in sections 17½" (Pan Africa Energy, 2016)*

Section	Start Depth (m)	End Depth (m)	Casing Size (in)	Mud Weight (ppg)	Mud Type	Pressure Drop (psi)	Flow Rate (gpm)
17 ½"	602	1172	13⅜"	11.5	KCL/Polyamine	2400	910

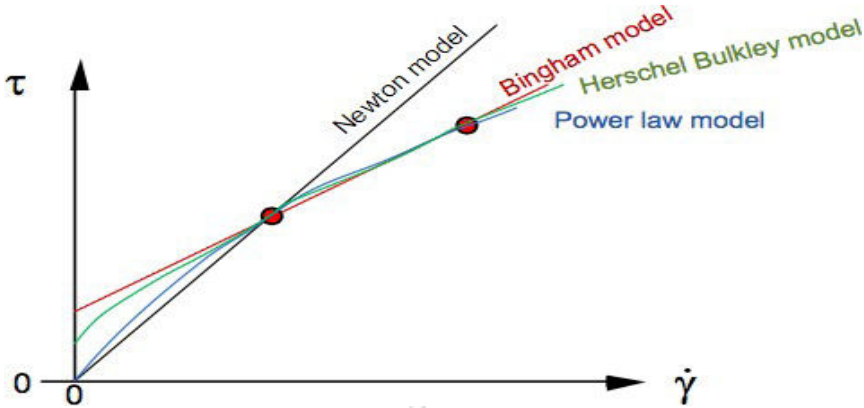

Figure 2: Four Rheological Models for Different Fluid Samples (Skalle, 2013).

From each model, parameters such as plastic viscosity, yield point and yield stress were used in the constitutive equations to calculate pressure drops. Using rheological model parameters to calculate pressure drop gave actual predictions of pressure drop in each section drilled. Thereto, the study informs the community and public about the best fit model for maintaining safety and efficiency offshore gas well drilling campaign (Bui and Tuntuncu, 2016).

2.0 METHODOLOGY

The selected rheological models require the Fann Viscometer data. The historical data indicated in Table 2 were converted to standard SI-unit for shear stress and shear rate and then established the rheological constants.

Statistical approach such as relative percentage error, Root-Mean-Square Error (RMSE) and Coefficient of determination (R^2) were used to compare which model fits the best for 17 ½ inch section. The following procedures were adopted to establish rheological model parameters that were used for pressure drop calculations.

2.1 Shear Stress and Shear Rate

To establish shear stress and shear rate, the flow of drilling fluids was considered as a function of shear-or-load-rate, time and spatial orientation in the pathways and walls. Downhole conditions such as temperature, pressure and the rate and duration of shear affected the rheological properties of fluids (Faergestad, 2016).The dial reading (0) and rotor speed (RPM) were used to obtain shear stress, and shear rate, $\dot{\gamma}$ values as indicated in Equations 1 and 2 (Speers, 1983).

$\tau = \theta * 1.06 * 0.4788$ in Pa	(1)
$\dot{\gamma} = RPM * 1.703$ in S^{-1}	(2)

2.2 Rheological Parameters for Standard Models

The rheological parameters used in friction pressure drop calculation were established based on Bingham plastic model, Power law model and Herschel-Bulkley model.

Bingham plastic model exhibit a linear relationship relating shear stress and shear rate at constant viscosity, Power law model has a nonlinear relationship relating shear stress and shear rate (pseudo static) and Herschel-Bulkley model takes the form of the unified model (Zamora *et al.,* 2005).

2.3 Rheological Parameter for Bingham Model

The Bingham model has been widely used in drilling fluids for relating shear stress and shear rate. It takes the form of Equation 3. The rheological constant yield stress constant and viscosity were obtained by two approaches (Skalle, 2013). That is explained here under considering oil field approach.

$\tau = \tau_y + \mu_{pl}\dot{\gamma}$	(3)

2.4 A 2-Data Points Oil Field Approach

The Fann viscometer has been calibrated to suit the Bingham model. At shear rate 300, it was designed to be equal to one shear rate unit, making

equation below simply a difference between two numbers.

$\mu_{pl} = \theta_{600} - \theta_{300}$	(4)
$\tau_y = \theta_{300} - \mu_{pl}$	(5)

2.5 Rheological Parameter for Power Law Model

This model does not exhibit a linear relationship between the shear stress and shear rate of fluids. To calculate the power law index (n) and consistency coefficient (k) from oil field viscometer data and an estimate of n is calculated using log $\dot{\gamma}$ to yield.

$\tau = k\dot{\gamma}^n$	(6)
$\eta = \frac{\log_{600}\tau - \log_{300}\tau}{\log_{600}\dot{\gamma} - \log_{300}\dot{\gamma}} = \frac{\log\frac{\tau_{600}}{\tau_{300}}}{\log\frac{\dot{\gamma}_{600}}{\dot{\gamma}_{300}}}$	(7)

Once an estimated value of n was calculated, then k can be determined as;

$k = \frac{\tau}{\dot{\gamma}^n}$	(8)

2.6 Rheological Parameter for Herschel-Buckley Model

Herschel-Buckley model has been categorized as yield power law model. It was termed as yield pseudo plastic, the fluid exhibits a yield stress as well as a nonlinear relationship between shear rate and shear stress once the flow was initiated (Robertson and Stiff Jr, 1976).

The yield power law index (n) was obtained as in power law model whilst a consistency factor in yield power law model was calculated based on equation 10. Such that is the ratio of difference between maximum and minimum shear stress to maximum and minimum shear rate.

$\tau = \tau_y + k\dot{\gamma}^n$	(9)
$k = \dfrac{\tau_{600} - \tau_y}{\dot{\gamma}^n{}_{600} - \dot{\gamma}^n{}_y}$	(10)

where

$\tau_{600} = \tau_{max}$ *is the maximum shear stress*
$\tau_y = \tau_{min,}$ *is the minimum shear rate*
$\dot{\gamma}_{600} = \dot{\gamma}_{max}$ *is the maximum shear rate*
$\dot{\gamma}_y = \dot{\gamma}_{min}$ *is the minimum shear rate*

However, the third parameter "the yield stress" , from a classical definition, it is that stress below which no flow can be observed under conditions of experimentation (Zamora and Power, 2002). Yield stress (τ_y) can be measured direct or indirect (by extrapolation analytically or numerically). Direct measurements rely on some independent assessment of the yield stress as the critical shear stress at which the fluid yields or start to flow (Ngyuen and Boger, 1992). Generally, direct measurements have to be preferred because the yield stress is the material property of the fluid and independent of the rheological model (Zamora and Power, 2002).

The yield stress can be approximated from the low shear yield point for given shear stress against shear rate. For reading at 6 rpm and 3 rpm can be used to approximate the low shear yield point (LSYP=2R3-R6). Unfortunately, dial reading and rotor speed at 3rpm values were not available from the recorded data, so this option was not considered in this research paper. The indirect method for yield stress determination was considered thereof. Indirect determination of the yield stress simply involves extrapolation of the experimental shear stress-shear rate data to obtain the yield value as the shear stress limit at zero rate of shear as shown in Figure 2 and Figure 3 for same shear stress against shear rate.

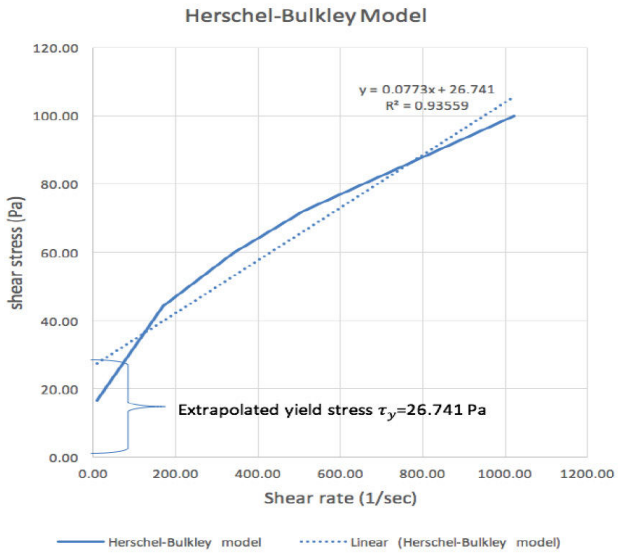

Figure 2: Extrapolation of Yield Stress by Linear Regression.

The linear regression gives higher values of yield stress $\tau_y = 26.741\ Pa$ with a lower coefficient of determination $R^2 = 0.93559$ as shown in Figure 2. However, when a third order polynomial was employed gave a true approximation of the yield stress as elaborated in (Ngyuen and Boger, 1992). A third order polynomial that is the conventional statistical-analysis techniques found in Microsoft Excel have been adequately used to complete the analysis. This third order polynomial curves fits worked particularly well and were employed throughout for consistency (Power and Zamora, 2003). For example, of curve fitting using the third order polynomial gives a good approximate of yield stress $\tau_y = 14.734\ Pa$ with a coefficient of determination $R^2 = 0.99942$ as shown in Figure 3.

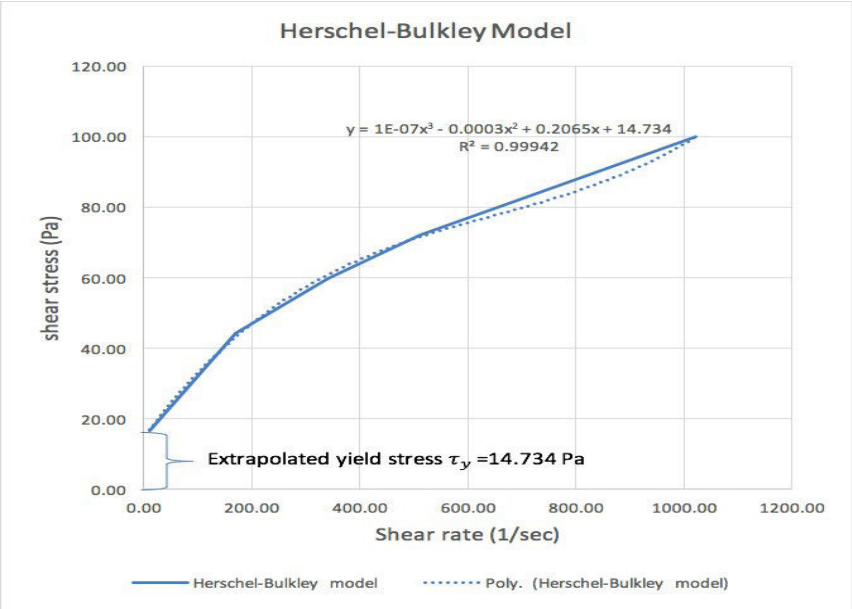

Figure 3: Extrapolation of Yield Stress Using Third Order Polynomial.

2.7 Modelling Friction Drop Using Statistical Approach

Statistical approaches were used to compare the pressure drop for different models, the relative percentage error, the root-mean-square error (RMSE) and coefficient of determination (R^2) (Bui and Tuntuncu, 2016). The Equations 3, 4 and 5 were set into Microsoft Excel. The values for relative errors %, RMSE and R^2 were computed for each predicted model using the equations written in the spreadsheet.

The lower the percentage relative error and RMSE the better the model. Nevertheless, the closer the R^2 value is to 1, the better the fit while coefficient of determination ranges from 0 to 1. They were defined below as follows:

a) Relative error (%)

Error is the difference between the exact values to the approximation value. Relative error % was expressed as the ration of the magnitude of absolute error to the actual value multiplied to 100.

$$\text{Relative error } \% = \frac{(y_i^c - y_i)}{y_i} * 100$$	(11)

Where y_i and y_i^c are the actual value and the calculated value

b) Root-mean-square error (RMSE)

It is a frequently statistical tool used to measure the difference between the experimental values and the model results. The difference was obtained and was termed as residual. The individual residue was squared and the sum was computed and divided to number of data points. The RMSE was obtained as shown below:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{N}(y_i^c - y_i)^2}{N}}$$	(12)

Where y_i and y_i^c are the actual value and the calculated value and N was the number of data points.

c) Coefficient of determination

It is statistical approach used to predict the future model or outcome or testing based on the related information from the oil field viscometer. It provides the base to compare how well the observed outcomes are replicated by the model.

$$R^2 = \left[\frac{\sum_{i=1}^{N}(y_i^c - \overline{y_i^c})(y_i - \overline{y_i})}{\sqrt{\sum_{i=1}^{N}(y_i^c - \overline{y_i^c})^2}\sqrt{\sum_{i=1}^{N}(y_i - \overline{y_i})^2}}\right]^2$$	(13)

Where y_i and y_i^c were the actual value and the calculated value; $\overline{y_i}$ and $\overline{y_i^c}$ were the mean of actual values and calculated values; and N was the number of data points (Bui and Tuntuncu, 2016).

2.8 Friction Pressure Drop in Section 17½" Sections of Well RXT

The drilling pipes was made of different tool joints that have definite size and length as seen on Figure 4. When the drilling fluid passes along

each tool joint a noticeable pressure drop was obtained. The pressure drop in each part was calculated using the pressure loss equations like for drilling pipe (inside BHA) and annulus (outside BHA) and equation were dividing by 14.5 to convert to standard Psi values.

Figure 4: Drilling String Used in Drilling Section 17 ½ Inch.

From the excel sheet Table 3, Pressure drop-in drill pipe was as drill pipe inside BHA=625.26 Psi and drill pipe outside BHA = 182.778 Psi. Then total pressure was given as Equation 14.

3.0 RESULTS AND DISCUSSIONS

Table 2 indicates the rheological model comparison for section 17.5. The measured pump pressure of 2400 psi,11.5 ppg and flow rate of 910 ppg were used in section 17.5". Bingham law model was observed to be a good fit for fluid rheology as compared to Herschel -Buckley and Power model. The relative error for the Bingham model was 0.905 while 0.971 for Power and Herschel-Buckley Models respectively. Thereby RMSE was employed to validate the rheological results for calculation of friction pressure loss as indicated in Table 4, Table 5, and Table 6.

Table 2: *Rheological Model Comparison for Section 17.5”*

Experimental data		power law model		Bingham power law		Herschel-Bulkely model	
Shear rate (1/sec)	Shear stress (Pa)	shear stress (Pa)	Relative error %	Shear stress (Pa)	Relative error %	Shear stress (Pa)	Relative error %
1021.80	92.37	92.37	0.00	92.37	0.00	94.595	2.409
510.90	63.94	57.61	-9.90	63.76	0.28	61.252	-4.204
340.60	51.77	43.71	-15.57	54.22	-4.74	47.917	-7.443
170.30	43.14	27.26	-36.81	44.69	-3.58	32.139	-25.500
10.22	7.61	4.01	-47.30	35.72	-369.22	9.838	29.225
Average Relative Error (%)			21.92		75.45		1.103
RMSE			8.605		12.637		5.532
R^2			0.971		0.905		0.971

Table 3: *Pressure Drop Calculation in Section 17.5” Herschel-Buckley Model*

MW	PV	YP	Y_Stress	DP drill_pipe	DP BHA Inside	DP_bit	DP BHA outside	Dp annulus	Total simulated pressure	Measured Pump pressure	Error	Square Error
11.5	44	35	5.9894	1315.11	625.26	342.15	182.778	46.465	2511.94	2400	111.94	0.002175445
11.5	28	44	13.824	865.397	411	342.15	295	75.315	1988.862	2400	-411.138	0.02934626
17.2	58	70	15.577	1487.64	707	511.74	424	108.12	3238.5	2400	838.5	0.122062891
18.5	52	63	15	1511.04	718	550.42	384	97.907	3261.367	2400	861.367	0.358902917
12.5	44	52	13.462	1099.36	523	371.91	316	80.76	2391.03	2400	-8.97	0.139689062
												0.652176574
Total pressure=DP drill_pipe+DP BHA_inside+DP_bit+DP BHA_out+DP_annulus										Number of sample		5
										RMSE		0.361158296

Table 4: *Bingham Plastic Model Pressure Drop Calculation for Section 17.5”*

MW	PV	YP	Y_Stress	Y-stress/YP	DP drill_pipe	DP BHA Inside	DP_bit	DP BHA outside	Dp annulus	Total Simulated pressure	Measured Pump pressure	Error	Square Error
11.5	44	35	35.149	1.004257143	1292.24	614	342.15	259	65.979	2573.369	2400	173.369	0.0052182
11.5	28	44	17.568	0.399272727	1079.22	411	342.15	295	75.315	2202.685	2400	-197.315	0.00675924
17.2	58	70	19.82	0.283142857	1820.9	866	511.74	506	130.02	3834.66	2400	1434.66	0.35733495
18.5	52	63	12.21	0.193809524	1857.76	883	550.42	458	117.01	3866.19	2400	1466.19	0.37321408
12.5	44	52	26.094	0.501807692	1341.96	638	371.91	379	96.648	2827.518	2400	427.518	0.03173119
													0.77425765
Total pressure=DP drill_pipe+DP BHA_inside+DP_bit+DP BHA_out+DP_annulus											Number of sample		5
											RMSE		0.39351179

Table 5: *Power Law Model Pressure Drop Calculation for Section 17.5"*

MW	PV	YP	Y_Stress	Y_stress/YP	DP drill_pipe	DP BHA Inside	DP_bit	DP BHA outside	Dp annulus	Total Simulated pressure	Measured Pump pressure	Error	Square Error
11.5	44	35	2.466	0.070457143	1076.98	512	342.15	173	44.251	1967.01	2400	-432.99	0.03254867
11.5	28	44	1.2384	0.028145455	863.131	410	342.15	278	71.017	1964.95	2400	-435.05	0.03285912
17.2	58	70	1.6803	0.024004286	1482.92	705	511.74	399	101.78	3200.44	2400	800.44	0.11123337
18.5	52	63	1.2712	0.020177778	1505.77	716	550.42	359	91.641	3222.831	2400	822.831	0.11754355
12.5	44	52	1.8449	0.035478846	1095.13	521	371.91	295	75.236	2358.276	2400	-41.724	0.00030224
													0.22907916
Total pressure=DP drill_pipe+DP BHA_inside+DP_bit+DP BHA_out+DP_annulus											Number of sample		5
											RMSE		0.21404633

Power law model had a better approximation of the friction pressure loss in section 17.5". It has the RMSE of 0.214 Table 2. The Herschel-Buckley model was better than the Bingham model. The RMSE's for the two models were 0.3612 and 0.3935 for Herschel-Buckley and Bingham plastic models respectively.

Power law model had a better approximation of the friction pressure loss in section 17.5". It has the RMSE of 0.214. The Herschel-Buckley model was better than the Bingham model. The RMSE's for the two models were 0.3612 and 0.3935 for Herschel-Buckley and Bingham plastic models respectively.

The power law model has a better result as the ratio of $\frac{\tau_y}{YP}$ was approached zero ($\tau_y \rightarrow 0$),the fluid behaviour more like pseudo plastic fluids (Zamora and Power, 2002) as shown Table 5 column number 6.

The mud weight ranging from 11.5 to 12.5 had a good approximation of the Pump pressure (2400 psi) that ranged from 1964.95 to 2358.276 psi. Using mud weight ranged from 17.2 to 18.5 ppg resulted to higher pump pressure of 3200.44 to 3222.831 than pump pressure.

The increase in simulated pump pressure informs the drastic raise in hydrostatic pressure caused by heavy mud weight that could damage the formation when underbalanced drilling is conducted.

4.0 CONCLUSION

Based on the findings of this research, it can be concluded that mud weights ranging from 11.5≤ m_w ≤12.5 are suitable for use to estimate the

friction pressure loss (2400 Psi) using a power law model. The drilling fluids must be designed such that, mud weight should be within the range defined. Moreover, the plastic should have a viscosity range of 28 to 44 centipoise to yield to a stress of 35 to 52 Pa.

Funding: The research paper received partial support from the Dar es Salaam Maritime Institute (DMI), with the remaining funding being self-funded.

Data accessibility: Data used remains confidential as source not disclosed.

Acknowledgments: The authors would like to extend their gratitude to the editor and anonymous reviewers for their valuable comments and ideas.

Conflicts of Interest: The author confirms that there are no conflicts of interest to declare.

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A REVIEW ON OFFSHORE WIND ENERGY IN TANZANIA: UNEXPLOITED OFFSHORE RENEWABLE ENERGY RESOURCE

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ABSTRACT

Wind energy is recognized as a promising renewable energy source, which has acquired greater recognition because of its potential attributes such as sufficient availability, and sustainability ina nature. . Wind energy has been classified in two ways of blowing which are onshore wind energy and offshore wind energy.

This article has clearly focused on providing a potentiality review information on offshore wind energy worldwide, the continent of Africa, and Tanzania as the primary study target. In conclusion, there have a suggestion and recommendations based on offshore

wind energy's presently status which seems to be untapped yet apart from its vast availability countrywide continentally, and globally.

Keywords: Wind energy, Offshore Wind Energy Potential, Tanzania

1.0 BACKGROUND

The International Energy Agency (IEA) forecasts revealed that the worldwide electricity need will be expanded by 56% in 2050 [1]. The observed and experimented data highlights that more than 40% of world energy-related CO_2 emissions are highly contributed by presently globe-generated electricity [1]. To prevent the negative environmental impact ignited by using of fossil fuels, it was accepted at the 2015 United Nations Climate Change Conference (COP21) in Paris, France to control the increases of global temperature to below 1.5 °C above pre-industrial levels [2].

In COP21, Tanzania was one of the nations that signed to commit to reducing carbon emissions. Tanzania has pledged to decrease carbon emissions by a significant 30-35% by 2030 [3]. However, Tanzania has been using 62.69% of her generated electric power from fossil fuels which produces a lot of harmful emissions to the surrounding environment [4]. So that's one way out of this harmful effect is the utilization of available abundant wind energy resources in the country, and this is due to the environmental impact that resulted from the use of fossil fuels as a source of energy for electric power generation.

According to [5] have noticed that offshore wind energy is a proper practice for attaining the transition of low carbon energy. Thus, talking about the offshore wind energy implementation challenge is a major objective to reaching the needed transitions [5].

The wind energy history is vast and comprises studies that differentiate the characteristics of onshore versus offshore power. According to [6], offshore wind farms are regarded to reduce environmental impact when compared to onshore wind farms. In addition to that, there have a

number of benefits that offshore wind energy is regarded to have when it is compared to onshore wind energy such of those benefits are; the availableness of huge uninterrupted areas appropriate for vital projects, higher wind speeds, and smaller turbulence, which permits the turbines to reap the obtainable energy more productively and decrease the turbine fatigue loads [7].

The previous 15 years have seen the offshore wind farms evolution, but many obstacles must be controlled before well offshore wind farm is accomplished. According to [8] finalized that proper accomplishment of offshore wind energy needs satisfactory modern technology. Also, various studies concentrated on the offshore wind farm's technical issues from different technical perspectives [9].

According to [10], [11] declare that financial elements are the pivotal factors that limit the offshore wind energy resource's efficient implementation. Other research studies [12], [13] notify the technical factors of energy generation, such as the mechanical features that focus on turbines and the electrical features that investigate the connecting grid. Other studies [14], [15] investigate geographic features such as the roughness of the sea, the level of the sea, space, and so on.

2.0 OFFSHORE WIND ENERGY TODAY

Up 2022 there is a total installed capacity of about 63,200 MW offshore wind farm, (Figure 1) where there have an increase of more than 21,000 MW of new installed and grid-connected offshore wind power when it is compared to the year 2021 [16]. Offshore wind energy expanded between 2010 and 2018 by 30% and is expected to grow fivefold between 2020 and 2025 [16].

A special report by the International Energy Agency (IEA) on offshore wind energy concludes that the potential for offshore wind energy is huge. Although the wind energy field is restricted to deep water areas near the coast, the IEA declares that the best offshore wind area can produce and deliver more than the total electricity produced today [16].

3.0 OFFSHORE WIND ENERGY DEVELOPMENT

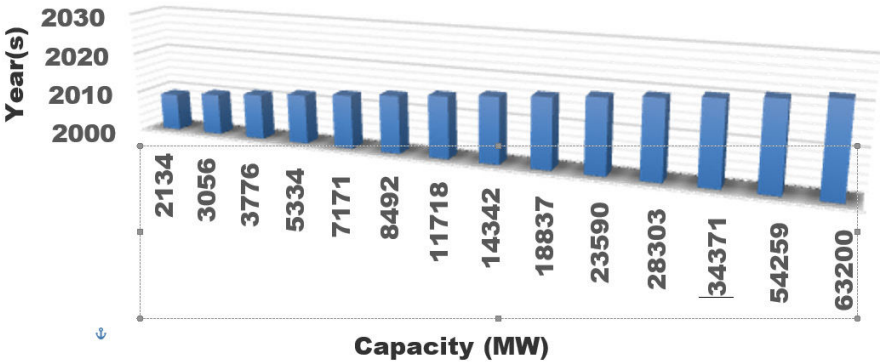

Figure 1: Offshore Wind Energy Capacity Worldwide From 2009 to 2022 (In Megawatts).

4.0 OFFSHORE WIND ENERGY IMPLEMENTATION FOCUS

In 2021, Global Wind Energy Council (GWEC) and International Renewable Energy Agency (IRENA) signed a United Nations Energy Compact, committing to work together to deliver the 2,000 GW of offshore wind power needed by 2050 to achieve net-zero emissions [17], [18].

This needs a large improvement in installations, with 35GW of offshore wind to be added per annum in the future decade, beginning from a worldwide total of just over 60 GW present only China has so far proven the capability to deliver offshore wind energy at that scale and speed. In addition to net-zero targets, many countries have specific offshore wind targets - at least 16 governments have established or increased them since 2022 [17]. This includes sub- national jurisdictions such as the Australian state of Victoria (9GW by 2040) and the Canadian province of Nova Scotia (5GW by 2030) [17].

Energy ministers from the nine members of the North Seas Energy Cooperation (NSEC) agreed in September 2022 to achieve a minimum

of 260 GW of offshore wind capacity by 2050 [17]. China aims to achieve 100 GW in 2025, 200 GW in 2030, and 1000 GW in 2050 [17]. The Tenth Base Plan for South Korea, published in December 2022, aims for 14.3 GW by 2030 [17]. Despite the establishment of such ambitious goals, countries and governments are still struggling to transform them into actions at the speed needed to power the global energy transition [18].

Offshore wind is a complex infrastructure that needs broad understanding and experience from powerful marine governance structures, electricity and supply chain market plans, and industrial strategy [18], [19]. GWEC notices that many markets are still lacking enough policies and rules to ease offshore wind development. However, there is a substantial deal of worldwide finest practice to master, especially through public-private collaborations, to assist young and emerging markets accelerates the governing process [17].

5.0 OFFSHORE WIND ENERGY TECHNOLOGY

Offshore wind farms are found over water bodies - generally the ocean - where the wind gets to higher speeds than onshore [20]. Two main wind turbine installation types can be found in offshore wind farms [20], [21]: Fixed-Bottom Offshore Wind Turbines (BFWs) are constructed on fixed foundations in lacking depth water bodies while Floating Offshore Wind Turbines (FOWTs) are built on floating structures in bottomless water bodies, where bottom-fixed offshore wind turbines cannot be installed.

Generally, FOWTs permit more area to be utilized for wind energy generation, lower visibility from the shore, and can be built in locations with powerful and more persistent winds. Mainly three types of FOWTs have been applied as commercial and prototype where these FOWTs platforms are spar-buoy, spar-submersible and tension-leg (Figure 2).

At the current , there are about 121 MW of FOWTs installed capacity, although it is forecasted that this will improve to 18.9 GW by 2030 and to 264 GW by 2050 [22]. The first remarkable research on FOWTs platforms began in the 1990s, and the earliest prototype of FOWTs was

implemented in 2007 [22]. Since then, there has been a vast increase in FOWT research development. In turn, this has led to a huge improvement in add up of platform designs which are being developed and examined [22].

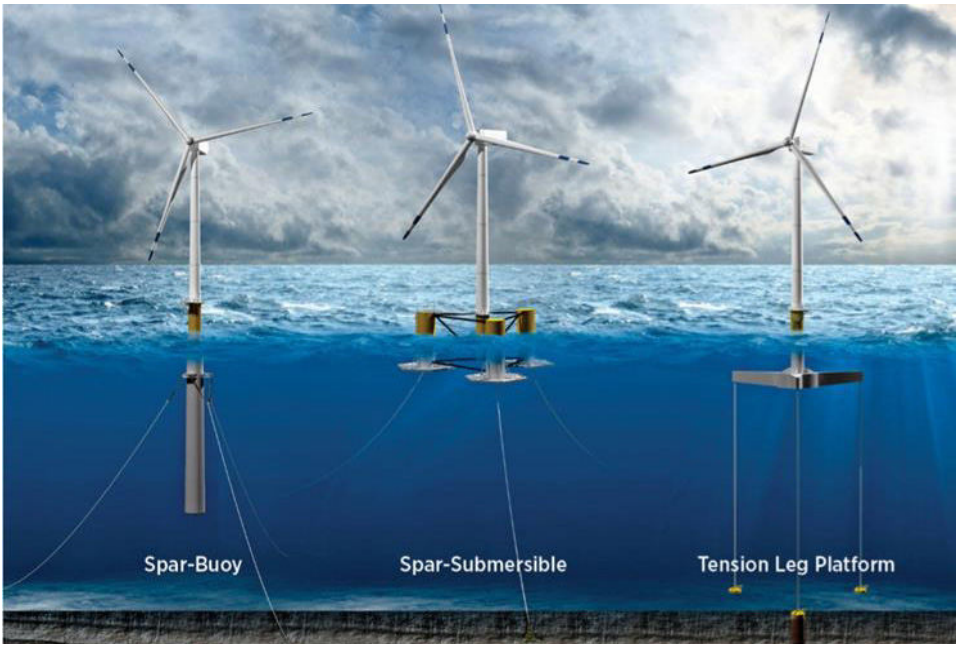

Figure 2: Platforms Types Applied for Floating Offshore Wind Turbines [20].

6.0 OFFSHORE WIND ENERGY FINANCING

From the demonstration development of current offshore projects of various sizes, it appears that sufficient equity capital is available to finance an offshore wind farm project [7]. Several major oil and gas and utility companies have announced projects that can be financed with corporate equity [7]. However, it remains to be decided under what conditions (due diligence, approval, insurance etc.) the bank loan will be granted for the offshore wind farm project. Only trial and demonstration projects

will provide the information to enable an answer to this question [7].

7.0 OFFSHORE WIND ENERGY IN AFRICA

The African Union Agenda 2063, with its ambition to support the development of Africa based on inclusive growth and sustainable development, recognizes the 'Blue Economy' where the marine environment is used sustainably to promote growth, as a preference [23]. This acceptance of opportunity led to the development of Africa's Blue Economy Strategy, where the potential use of marine energy resources is one of its cornerstones [23]. Offshore wind power is regarded to be already a cornerstone of the 'Blue Economy' in some parts of the world but still not yet in Africa. In total, 11.1 GW of new capacity is expected to be added in the next five years (2023–2027), of which 5.3 GW will come from South Africa, 3.6 GW from Egypt, and 2.2 GW from Morocco [24].

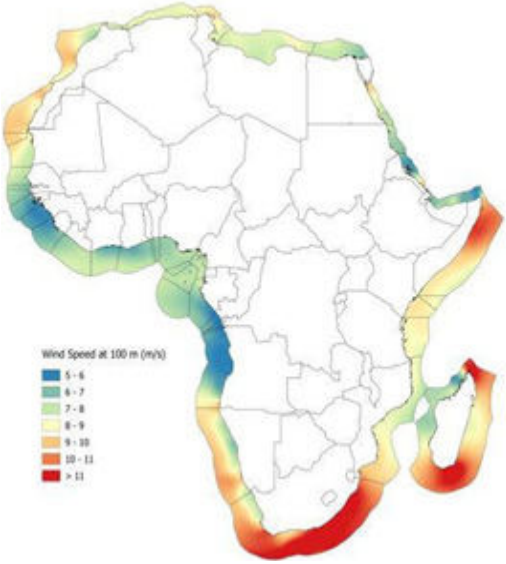

Figure 3: Africa Offshore Wind Energy Resource 100m Above Sea Level Map [24].

On the onshore wind energy side, Egypt, South Africa, and Morocco are the key leaders for onshore wind power generators in the continent [24]. Egypt is regarded to have excellent wind energy resources, with wind speeds of an average near the Suez Gulf reaching more than 10.5 m/s. Egypt's Ras Ghareb Wind Farm and West Bakr Wind Farm produce of about 262.5 MW and 252 MW of electricity power respectively [25]. The Zafarana Wind Farm is mentioned to be the largest onshore wind farm in Egypt constructed between 2000 and 2010 in eight phases, with a combination of installed generation capacity of 544.82 MW [25].

The Tarfaya Onshore Wind Farm in Morocco is mentioned to be on the list of largest installed wind farms in Africa, with an installation capacity of 301.3 MW [26]. The country also has the Aftissat 1 Wind Farm that generate 201.6 MW since 2018 and Aftissat 2 Wind Farm that will generate about 200 MW which planned to commence its operation later this year. Other pivotal wind power installations in Morocco are the Akhfenir 1 and 2 Wind Farms with together having of 202 MW installed capacity [26].

Not only northern African countries that have installed onshore wind farms but also South Africa has regarded to be one the countries in the sub-Saharan part of Africa to have installed wind power. The country has about 3.024 MW of onshore wind power installed capacity [27].

The Lake Turkana Wind Power Station, located in the Loiyangalani District in Kenya, is one of Africa's largest wind power installations [28]. The 310 MW capacity installation can supply energy to nearly one million homes and includes 365 wind turbines [28].

Also, in horn of Africa, there are Ethiopia's Adama I and II Wind Farms, with a combined capacity of 204 MW, operational since 2012 [29]. The largest wind power installation in West Africa is Senegal's Taiba N'diaye Wind Farm, with an installed capacity of 158.7 MW fully operational since 2021 [30].

8.0 OFFSHORE WIND ENERGY IN TANZANIA

The wind energy resource is very potent in Tanzania, which lies between the wind speeds of 6 m/s to 8 m/s, especially in the Rift Valley around regions and the country's coastline part, Table 1 [31]. Also, Tanzania as a country, is regarded to have an abundance of offshore wind energy potential, although to date there have been no installed offshore wind farms in the country on the onshore wind energy side, already there have one privately owned onshore farm located in Usokami Village - Mwenga in the Mufindi district which generates 2.4 MW.

The wind farm is owned privately by a private company called Rift Valley Energy Group. It consists of three 800-kW Enecorn wind turbines. The wind farm grid provides electricity to more than 4,500 homes and businesses in around 32 villages. However, it's planned to continually improve to more than 6,000 connections within the following two years [32]. Also, Tanzania is a country recognized to have an abundance of offshore wind energy potential, although to date there have been no installed offshore wind farms in the country.

Table 1. *Wind Resource in Tanzania [31]*

Site	Study	10 (m) wind speed (m/s)	30 (m) wind speed (m/s)
Makambako (Njombe)	Original Wind East Africa	7.6	8.7
Singida	Wind East Africa	8.2	9.4
Karatu (Arusha)	DANIDA/ Risø/TANESCO	4.9	5.5
Mkumbara (Tanga)	DANIDA/ Risø/TANESCO	4.14	4.9
Gomvu (Dar es Salaam)	DANIDA/ Risø/TANESCO	3.56	4.28
Litembe (Mtwara)	DANIDA/ Risø/TANESCO	3.21	4.47

9.0 CONCLUSION

The offshore wind energy in Tanzania seems promising for future electric power generation, the government of the Republic of Tanzania or the private sector can invest in the sea regions which regarded to have high wind speed through the construction of the large-scale wind farm that will harness the wind energy and connected to the national power grid. The author of this study also recommends that renewable energy researchers should invest in their future research to focus on offshore wind energy potential in Tanzania.

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ASSESSING THE EFFECTIVENESS OF MARINE ROBOTICS TECHNOLOGIES FOR OFFSHORE OIL SPILL AND MICROPLASTIC MITIGATION: A COMPARATIVE STUDY

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ABSTRACT

Marine ecosystems are facing significant challenges due to the detrimental impacts of marine oil spillage and microplastics. In an attempt to combat these environmental issues, marine robotics technologies such as autonomous underwater vehicles (AUVs), remotely operated vehicles (ROVs), and unmanned surface vehicles (USVs) have emerged as potential solutions. Thus, the purpose of this study is to evaluate the extent to which these marine robotics technologies

address the problems of offshore oil spills and microplastics.

The Grey Relational Analysis with Technique for Order of Preference by Similarity to the Ideal Solution (GRA-TOPSIS) and the Analytic Hierarchy Process (AHP) and combined AHP and GRA-TOPSIS methods were used to assess marine robotics technologies resulted in the following rankings, expressed as percentages; Unmanned Surface Vehicle (USV), 81.55%, Autonomous Underwater Vehicle (AUV), 78.18%, and Saildrone, 40.94%. The average consistency ratio was found to be 0.073095238. Moreover, a one-way sensitivity analysis was conducted to understand how alterations in input data could impact the results of the decision-making process.

The analysis revealed that the USV/UUGs ratio is the most sensitive variable in the pairwise comparison, with a sensitivity of 47.5%. The rankings indicate that the USV and AUV are the most promising marine robotics technologies for addressing marine oil spills and microplastic removal, based on their comprehensive evaluation.

While marine robotics technologies may have the ability to manage and conserve marine ecosystems, they do not address the structural problems that result in environmental problems like oil spills and microplastic pollution.

It is essential to consider this sensitivity analysis when making decisions about selecting the optimal marine robotics technology for oil spillage and microplastic removal. Based on the evaluation of marine robotics technologies, it is recommended that the implementation and further development of USVs and AUVs be prioritized for addressing marine oil spills and microplastic eradication. These technologies have shown superior performance and high effectiveness in managing and conserving marine ecosystems.

Keywords: Marine ecosystems, Marine robotics technologies, GRA-TOPSIS, AHP analysis, Sensitivity analysis, Marine environment

1.0 INTRODUCTION

The protection and preservation of marine ecosystems have become an urgent priority, as human activities continue to inflict considerable damage upon these delicate habitats (Giménez *et al.,* 2020; Onyena *et al.,* 2021). Rising challenges such as pollution, overfishing, and habitat destruction demand innovative solutions to combat these issues effectively (Zolich *et al.,* 2019). Marine robotics technologies hold promises as efficient, cost-effective, and minimally invasive tools for studying, monitoring, and conserving marine environments (Zolich *et al.,* 2019).

Numerous scholars have illustrated the potential of marine robotics in tackling a range of challenges within marine conservation. For instance, autonomous underwater vehicles (AUVs) have been deployed to explore marine habitats (Bruzzone *et al.,* 2020), while remotely operated vehicles (ROVs) have been utilized to monitor marine species and ecosystems (Elvander and Hawkes, 2012; Macreadie *et al.,* 2018).

Furthermore, unmanned surface vehicles (USVs) have been employed to gather oceanographic data and observe marine pollution (Fish, 2020; Utne *et al.,* 2019). In light of the growing demand for effective marine robotic technologies to address environmental conservation challenges, this study endeavors to compare the efficacy of various marine robotic technologies using two decision-making methodologies; the Grey Relational Analysis with Technique for Order of Preference by Similarity to the Ideal Solution (GRA-TOPSIS) and the Analytic Hierarchy Process (AHP).

By applying these techniques, the study aims to offer valuable insights for researchers, policymakers, and environmental organizations in selecting the most suitable marine robotic technology for addressing marine environmental pollution. Oil spills and microplastics pose significant threats to marine ecosystems, necessitating effective measures to mitigate their impact (Fiorati *et al.,* 2020). As a result, the focus of this work is on evaluating the potential of various marine robotic technologies to address the aforementioned issues. By evaluating the

efficacy of various marine robotic systems, the present study intends to support stakeholders and decision-makers in making informed choices that will protect the marine environment.

1.1 Marine Robotics Technology (MRT)

Autonomous Underwater Vehicles (AUVs), Remotely Operated Vehicles (ROVs), and Unmanned Surface Vehicles (USVs) represent three key types of marine robotics technologies. AUVs are untethered robots that autonomously perform underwater tasks, with research focusing on improving navigation, localization, and control systems (Bruzzone *et al.,* 2020) and collaborative capabilities (Jorge *et al.,* 2019).

ROVs, tethered underwater robots controlled by an operator on a surface vessel, have been used in various industries and research fields. Studies have aimed at enhancing ROV stability, control systems, and developing new tether management systems (Galceran and Carreras, 2012). Moreover, USVs, robotic boats operating on water surfaces without humans onboard, have seen research targeting advanced control systems (Jorge *et al.,* 2019), communication and collaboration (Ferri *et al.,* 2017), and applications such as environmental monitoring and surveillance (Mukhopadhyay *et al.,* 2012).

Unmanned Underwater Gliders (UUGs), bio-inspired underwater robots, and submersible drones represent another group of marine robotics technology. UUGs are buoyancy-driven vehicles with research focusing on energy efficiency (Hamurcu and Eren, 2020), trajectory optimization control algorithms, and oceanographic research applications (Ferri *et al.,* 2017; Klemas and Klemas, 2023). Bio-inspired underwater robots, designed based on biological principles, emphasize understanding locomotion and sensing mechanisms in aquatic animals and developing robotic systems that mimic these mechanisms.

Submersible drones, small remotely controlled or semi-autonomous vehicles, are often used for recreational, educational, or light industrial purposes, with research focusing on cost-effectiveness, ease of use, and accessibility to non-experts (Fish, 2020; Yekeen and Balogun, 2020), as well as environmental monitoring, marine research, and underwater

photography applications (Kemper *et al.,* 2016).

Wave Gliders, BathyFloats, Saildrones, and Seagliders have emerged as innovative platforms (Cokelet *et al.,* 2015; Mitchell *et al.,* 2013). Wave Gliders utilize wave energy for propulsion, enabling long-duration missions and data collection. BathyFloats provide precise depth measurements and seabed mapping. Saildrones navigate vast oceanic regions for various purposes, while Seagliders conduct energy-efficient surveys and monitoring. These platforms contribute to advancing marine exploration and research (Bongiorno *et al.,* 2018; Ludvigsen *et al.,* 2016; Rhodes, 2019).

Tethered and untethered underwater crawlers, as well as autonomous surface and underwater manipulators, represent additional marine robotics technologies. Underwater crawlers move along the seafloor or submerged structures using wheels or tracks, with research on untethered crawlers (Al-Khatib *et al.,* 2015) improving mobility and adaptability to different terrains (Williams *et al.,* 2016).

Autonomous surface and underwater manipulators, used for tasks such as inspection, maintenance, and repair, have been studied in terms of their design, kinematics, and control systems (Agnisarman *et al.,* 2019; Garilli *et al.,* 2021) as well as the development of new sensors and actuators for enhanced dexterity and perception (Ferri *et al.,* 2017; Klemas and Klemas, 2023).

1.2 Selecting Marine Robotics Technologies (MRT)

In marine robotics, decision-making entails picking the best technology for a certain task or objective. The GRA TOPSIS and the AHP are two popular decision-making methodologies (Sedghiyan *et al.,* 2021). GRA-TOPSIS is a multi-criteria decision-making system that rates options based on how closely they resemble the ideal solution (Hamurcu and Eren, 2020; Nguyen *et al.,* 2020).

AHP, on the other hand, is a methodical method of breaking down a big choice into smaller, more manageable portions (Nguyen *et al.,* 2020). When it comes to marine robotics selection, comparing TOPSIS and AHP can assist decide which strategy is more beneficial for various

decision-making circumstances (Emovon and Emovon, 2016).

1.3 Evaluation of MRT using Analytic Hierarchy Process (AHP)

The AHP, proposed by Saaty (1988), is another popular multi-criteria decision-making (MCDM) method that employs pairwise comparisons to derive the priority weights for each criterion and alternative. AHP's flexibility and ability to handle complex decision-making problems have led to its application in numerous domains, such as renewable energy, transportation, and environmental conservation (Dinmohammadi and Shafiee, 2017; Ghamgosar *et al.,* 2011).

The procedure starts with describing the decision problem and building the hierarchy, followed by identifying the aim and appropriate criteria (Equations, 1-5). A matrix is then used to do pairwise comparisons to determine the relative importance of the criteria. To maintain consistency, the pairwise comparison matrix is normalized, and a weight vector is created to indicate the priority weights of the criterion or alternatives.

To test the trustworthiness of the comparisons, a consistency check is done. Aggregation and ranking are performed using the overall priority weights, and sensitivity analysis is used to assess the robustness of the results (Sharma *et al.,* 2020).

Step 1: Define the decision problem and establish the hierarchy.
Decision problem: Clearly articulate the decision problem and identify the goal. Hierarchy: Identify the criteria and sub-criteria.

Step 2: Pairwise comparison.
Pairwise comparison matrix (X) as indicated in equation (1)

$$X = \begin{bmatrix} A_{11} & A_{12} & \cdots & A_{1n} \\ A_{21} & A_{22} & \cdots & A_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ A_{m1} & A_{m2} & \cdots & A_{mn} \end{bmatrix} \quad (1)$$

Step 3: Calculate normalized pairwise comparison matrix (Y) as shown in equation (2)

$$Y = \begin{bmatrix} y_{11} & y_{12} & \cdots & y_{1n} \\ y_{21} & y_{22} & \cdots & y_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ y_{m1} & y_{m2} & \cdots & y_{mn} \end{bmatrix} \quad (2)$$

Step 4: Calculate weight vector (W)
The weight vector (W) can be calculated as indicated in equation (3)

$$W = \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix} \quad (3)$$

Step 5: Consistency check
Consistency index (CI) and consistency ratio (CR) may be calculated as indicated in equations (4) and (5).

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

$$CR = \frac{CI}{RI} \quad (4)$$

Where: CI represents the Consistency Index and RI is the Random Index.

Step 6: Aggregation and ranking
Calculate the overall priority weights for the alternatives at the lowest level.

Step 7: Sensitivity analysis
Assess the robustness of the results and evaluate the impact of parameter changes.

1.4 Evaluation of the MRT using GRA TOPSIS

The TOPSIS is widely-used MCDM method, which ranks alternatives based on their relative closeness to an ideal solution and distance from a negative or anti-ideal solution (Hamurcu and Eren, 2020; Hasanzadeh *et al.,* 2023; Nguyen *et al.,* 2020; Quan *et al.,* 2019; Sedghiyan *et al.,* 2021; You and Wang, 2018). TOPSIS has been applied in various fields, including environmental management, to evaluate and select the best alternatives considering multiple conflicting criteria (Hamurcu and Eren, 2020; Kacprzak, 2021).

The evaluation process begins by defining the criteria and assigning appropriate weights to each A decision matrix is then created, consisting of the strategies and criteria. The decision matrix is normalized to ensure all criteria are treated equally, facilitating comparisons between strategies. Grey relational coefficients are calculated to represent the degree of association between alternatives and the criteria.

Positive and negative ideal solutions are determined to assess each strategy's potential performance (Jiang *et al.,* 2010). Finally, the similarity to the positive ideal solution is calculated using the GRA-TOPSIS method, enabling the ranking of strategies based on their overall performance relative to the ideal solution (Equations, 6-20).

Step 1: Define the evaluation criteria and weights

The evaluation criteria and their respective weights can be represented as a vector: $[w_1, w_2, \ldots, w_m]$ (6)

Where m is the number of evaluation criteria and w_i is the weight assigned to criteria on C_i

Step 2: Create a decision matrix with the alternatives and criteria

Step 2 involves creating a decision matrix with the marine robotics technologies alternatives and criteria. Each alternative is given a score according to the criteria using the decision matrix (D. Liu *et al.,* 2019; You and Wang, 2018). The decision matrix X is made up of m rows and n columns, where m represents the number of alternatives and n

represents the number of criteria. Each matrix element A_{ij} indicates the evaluation of alternative A_i with criteria on c_i. The greater the value of A_{ij}, the better the performance of alternative concerning criteria on C_j.

$$X = \{A_{ij}\} = \begin{array}{c} C_1 \\ C_2 \\ \vdots \\ C_m \end{array} \begin{bmatrix} A_{11} & A_{12} & \cdots & A_{1n} \\ A_{21} & A_{22} & \cdots & A_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ A_{m1} & A_{m2} & \cdots & A_{mn} \end{bmatrix} \tag{7}$$

Step 3: Normalize the decision matrix

The normalized decision matrix is calculated by dividing each element in the decision matrix by the sum of the corresponding column multiplied by its weight (D. Liu *et al.,* 2019; You and Wang, 2018):

Using for as indicated in the equation (8) and (9).

$$Y = \{y_{ij}\} = \begin{bmatrix} y_{11} & y_{12} & \cdots & y_{1n} \\ y_{21} & y_{22} & \cdots & y_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ y_{m1} & y_{m2} & \cdots & y_{mn} \end{bmatrix} \tag{8}$$

$$= \tag{9}$$

Where $y_{ij} = \frac{A_i}{\sum_1^m w_i A_{ij}}$ for $i = 1,2,\ldots,m$ and $j = 1,2,\ldots,n$

Step 4: Determine Positive-Ideal Solution (PIS) denoted by and the Negative-Ideal Solution (NIS) denoted by .The equations for calculating the PIS, $Y^+ = (y_1^+, y_2^+, \ldots, y_n^+)$ and NIS $Y^- = (y_1^-, y_2^-, \ldots, y_n^-)$ are as shown in equations (10) and (11).

$$y_j^+ = \max y_{ij} (i = 1,2,\ldots,m, j = 1,2,\ldots,n), \tag{10}$$

$$y_j^- = \min y_{ij} (i = 1,2,\ldots,m, j = 1,2,\ldots,n) \tag{11}$$

Calculating the separation of each alternative from the PIS and NIS (Quan *et al.,* 2019)

To determine how far apart each choice is from the PIS and NIS, the Euclidean distance is used as indicated in equations (12) and (13) below:

$$D_j^+ = \|y_i - Y^+\|_2 = \sqrt{\sum_{j=1}^n (y_{ij} - y_j^+)^2} \quad (i = 1,2,\ldots,m) \tag{12}$$

$D_j^- = \|y_i - Y^-\|_2 = \sqrt{\sum_{j=1}^{n}(y_{ij} - y_j^-)^2} \quad (i = 1,2,\dots,m)$	(13)

Where D_j^+ Represents the distance between alternatives y_i and Y^+.
D_j^- represents the distance between alternatives y_i and Y^-.

Step 5: Estimate the grey relational coefficients.

Let the PIS and NIS be the referential sequences, and each of the strategies can be determined. Then, the grey relation coefficients for each strategy to the PIS and the NIS may be calculated by;

$r_{ij}^+ = \dfrac{\min_i \min_j \lvert y_j^+ - y_{ij}\rvert + \zeta \max_i \max_j \lvert y_j^+ - y_{ij}\rvert}{\lvert y_j^+ - y_{ij}\rvert + \zeta \max_i \max_j \lvert y_j^+ - y_{ij}\rvert} = \dfrac{\zeta v_j}{v_j - y_{ij} + \zeta v_j}$ $(i = 1,2,\dots,m, j = 1,2,\dots,n)$	(14)

$r_{ij}^- = \dfrac{\min_i \min_j \lvert y_j^- - y_{ij}\rvert + \zeta \max_i \max_j \lvert y_j^- - y_{ij}\rvert}{\lvert y_j^- - y_{ij}\rvert + \zeta \max_i \max_j \lvert y_j^- - y_{ij}\rvert} = \dfrac{\zeta v_j}{v_j - y_{ij} + \zeta v_j}$ $(i = 1,2,\dots,m, j = 1,2,\dots,n)$	(15)

Where ζ is the distinguishing coefficient, ζ □ [0, 1]; $\zeta = 0.5$ is usually applied following the rule of least information.

Step 6: Calculating the consolidated results and grey relational degree (Hasanzadeh *et al.,* 2023; Quan *et al.,* 2019)

$r_{ij}^+ = \dfrac{1}{n}\sum_{j=1}^{n} r_{ij}^+ (i = 1,2,\dots,m),$	(16)

$r_{ij}^- = \dfrac{1}{n}\sum_{j=1}^{n} r_{ij}^- (i = 1,2,\dots,m),$	(17)

Equations (11) and (12) are used to execute dimensionless processing

on and generate integrated results.

$q_i^- = \beta \frac{D_i^-}{\max(D_i^-)} + \gamma \frac{r_i^+}{\max(r_i^+)} \ (i = 1,2,\ldots,m)$	(18)
$+\gamma \quad q_i^+ = \beta \frac{D_i^+}{\max(D_i^+)}$	(19)

Where β is a measure of how closely an alternate solution comes to the ideal option in terms of proximity. γ represents the closeness's influence on the grey relational degree of the ideal and alternate solutions. β, γ □ [0, 1], β + γ = 1.

Step 7: Calculating and grading the options' closeness (Quan *et al.,* 2019).

$C_i = \frac{q_i^+}{q_i^+ + q_i^-} \ (1,2,\ldots,m)$	(20)

The closeness is specified to establish the ranking order of all options. The closeness coefficient compares an option's proximity to the positive ideal solution to its proximity to the negative ideal solution. A greater C_i value suggests a closer match to the positive ideal solution.

Both AHP and GRA-TOPSIS offer unique advantages and limitations, making them useful tools for evaluating and selecting marine robotic technologies for addressing marine environmental pollution (Hamurcu and Eren, 2020; Kacprzak, 2021; You and Wang, 2018).

1.5 Key Criteria for Selecting MRT in Relation Oil Spill and Microplastic Mitigation

When choosing MRT key considerations are versatility, efficiency, safety, and cost (Hamurcu and Eren, 2020). A versatile MRT can handle different spills and pollution types, making it more effective in mitigating environmental damage (Klein, 2021; Tikanmäki *et al.,* 2021). An efficient MRT quickly and effectively cleans up spills without

causing further harm.

Safety is crucial, so look for technology designed with safety in mind (Chang *et al.,* 2012; Dave and Ghaly, 2011; X. Liu and Wirtz, 2007). Cost is important too, choose technology that offers value for money and long-term usability without excessive expenses. By evaluating these criteria, you can select effective, safe, and cost-efficient MRT to mitigate environmental damage.

For versatility, consider if the MRT can operate in different depths, and temperatures, and handle various pollutants and weather conditions (Prendergast and Gschwend, 2014; Rehn *et al.,* 2018). Efficiency entails speed, pollutant removal effectiveness, and prolonged operation without downtime.

Safety includes compliance with regulations, remote or autonomous operation to reduce human risk, and minimal impact on marine life and ecosystems (McAuliffe *et al.,* 2015). Choose environmentally-friendly technology that doesn't harm the ecosystem. Cost factors in the initial purchase, long-term cost-effectiveness, and availability of financing options (Jaurola *et al.,* 2019).

Table 2 lists the key criteria and sub-criteria to consider when selecting MRT for oil spill and microplastic mitigation. The alternatives listed in the table include AUV, ROV, USV, UUV, Glider, Wave Glider, BathyFloat, Saildrone, and Seaglider (Seegers *et al.,* 2017).

The sub-criteria for each key criterion include maneuverability, pollution handling capability, and adaptability for versatility; rate of change, sustainability, and reliability for efficiency; compliance, level of automation, and minimal risk for safety; and initial purchase cost, running cost, and funding options for cost.

These sub-criteria are essential in making an informed decision when selecting MRT for oil spill and microplastic mitigation (Beaverson, 2015; Klein, 2021; Tikanmäki *et al.,* 2021).

Table 2: *Key Criteria and Sub-criteria to Consider When Selecting MRT for Oil Spill and Microplastic Mitigation*

		AUV	ROV	USV	UUV	UUGs	Wave Glider		Saildrone	Seaglider	
Versatility	Maneuverability										(Klein, 2021; Tikanmäki *et al.,* 2021)
		✓	✓	✓	✓	✓	✓	✓	✓	✓	
	Pollution handling capability	✓	✓	✓	✓	✓	✓	✓	✓	✓	(Beaverson, 2015; Jorge *et al.,* 2019)
	Adaptability										(Hamurcu & Eren, 2020; Jorge *et al.,* 2019)
		✓	✓	✓	✓	✓	✓	✓	✓	✓	
Efficiency	Rate of change	✓	✓	✓	✓	✓	✓	✓	✓	✓	(Hamurcu & Eren, 2020)
	Sustainability	✓	✓	✓	✓	✓	✓	✓	✓	✓	(Hamurcu & Eren, 2020)
	Reliability	✓	✓	✓	✓	✓	✓	✓	✓	✓	(Hamurcu & Eren, 2020)
Safety	Compliance										(Hamurcu & Eren, 2020) (Chang *et al.,* 2012; Dave & Ghaly, 2011; X. Liu & Wirtz, 2007)
		✓	✓	✓	✓	✓	✓	✓	✓	✓	
	Level of automation										(Hamurcu & Eren, 2020; Jorge *et al.,* 2019)
		✓	✓	✓	✓	✓	✓	✓	✓	✓	
	Minimal risk	✓	✓	✓	✓	✓	✓	✓	✓	✓	(Hamurcu & Eren, 2020)
Cost	Initial purchase cost										(Hamurcu & Eren, 2020) (Jaurola *et al.,* 2019)
		✓	✓	✓	✓	✓	✓	✓	✓	✓	
	Running cost	✓	✓	✓	✓	✓	✓	✓	✓	✓	(Hamurcu & Eren, 2020)
	Funding options	✓	✓	✓	✓	✓	✓	✓	✓	✓	(Hamurcu & Eren, 2020)

Furthermore, Table 3 presents data on autonomous and unmanned vehicles used for oil spill cleanup. It includes information on oil types, spill sizes, primary cleanup methods, maximum oil encounter rates, and modifiers for oil type, spill size, and method. The vehicles listed are AUV, ROV, USV, UUV, UUGs, Wave Glider, BathyFloat, Saildrone, and Seaglider.

Table 3: *Autonomous and Unmanned Vehicles for Oil Spill Cleanup (Dave and Ghaly, 2011; Prendergast and Gschwend, 2014)*

Oil Type	Spill Size	Primary Cleanup Method Primary Cleanup Method	Maximum Oil Encounter Rate [ha/h]	Oil Type Modifier (ti)	Spill Size Modifier (si)	Method Modifier (mi)	AUV	ROV	USV	UUV	UUGs	Wave Glider	BathyFloat	Saildronedrone	Seaglider
No. 2 fuel	<34 t	In-situ burning	18	0.18	2.00	0.25	✔	-	-	-	-	-	-	-	-
Light crude	34e340 t	Dispersants	160	0.32	0.65	0.46	-	-	-	-	-	-	-	-	-
Crude	340e1700 t	Mechanical recovery	54	0.55	0.27	0.92	-	✔	✔	✔	✔	-	-	-	-
Heavy crude	1700e3400 t	-	-	0.65	0.15	-	-	-	-	-	-	-	-	-	-
No. 6 fuel	3400e34,000 t	-	-	0.71	0.05	-	-	-	-	-	-	-	-	-	-
No. 4/5 fuel	>34,000 t	-	-	1.82	0.0	-	-	-	-	-	-	-	-	✔	✔

1.6 Methods Adopted

The study adopted a systematic approach in its methodology. Initially, a thorough and comprehensive review of pertinent literature was conducted to gather empirical data from diverse conservation projects that have utilized AUVs, ROVs, and USVs (Macreadie *et al.,* 2018). This systematic literature review ensured the acquisition of relevant and reliable information to support the subsequent analyses as indicated in Figure 1.

Figure 1: Method Adopted.

Following the literature review, a comparative analysis employing two distinct methodologies, namely the AHP)and the GRA-TOPSIS, was undertaken (Emovon and Emovon, 2016; Jiang *et al.,* 2010; Quan *et al.,* 2019; You and Wang, 2018). These methodologies allowed for the evaluation and assessment of the collected data using predefined metrics and key criteria. The key criteria encompassed versatility, efficiency, safety, and cost, each of which consisted of specific sub-criteria to ensure a comprehensive assessment.

The AHP analysis facilitated the prioritization and weighting of the criteria and sub-criteria based on their relative importance (Chang *et al.,* 2012; Sedghiyan *et al.,* 2021; Sharma *et al.,* 2020). On the other hand, the GRA-TOPSIS analysis encompassed several steps, including normalization, identification of positive and negative ideal solutions, separation of alternatives, and estimation of grey relational coefficients. These steps enabled a thorough evaluation of the alternatives and their performance concerning the predefined criteria.

Subsequently, a combined analysis of AHP and GRA-TOPSIS was conducted to consolidate the results derived from both methodologies (Dinmohammadi and Shafiee, 2017; Nguyen *et al.,* 2020; Sedghiyan *et al.,* 2021; Sharma *et al.,* 2020). This integrated analysis yielded valuable insights for ranking the alternatives based on their performance and allowed for a comprehensive understanding of their relative strengths and weaknesses.

2.0 RESULTS AND DISCUSSIONS

The research findings and discussions about MRT concerning oil spills and microplastic removal are thoroughly summarized in this section. The use of the GRA-TOPSIS approach and the AHP analysis to assess several MRT options is what is highlighted. The section offers thorough tables and graphics that clearly show how the analysis's criterion, weights, and ratings were determined. The part also underlines the significance of weighing a variety of factors while evaluating MRT alternatives, such as adaptability, efficiency, safety, and cost. The findings show that

efficiency, followed by cost, safety, and versatility, is the criterion with the most weight. The criteria are comprehensively ranked according to their relative importance.

The section also underlines the significance of weighing a variety of factors while evaluating MRT alternatives, such as adaptability, efficiency, safety, and cost. The findings show that efficiency, followed by cost, safety, and versatility, is the criterion with the most weight. The criteria are comprehensively ranked according to their relative importance. The part also offers a comprehensive examination of the MRT alternatives using the GRA-TOPSIS approach and AHP analysis. Based on how well each alternative performed against the various criteria, the AHP analysis determined a relative ranking of the alternatives. The GRA-TOPSIS method, therefore, makes it easier to determine an overall rating for the alternatives by considering how well they performed across all criteria as indicated in Figure

Figure 2: Indicates the Goal, Criteria, and Subcriteria Used.

In addition, Table 4 results indicate the relative priorities of different criteria. The criteria considered are Versatility, Efficiency, Safety, and Cost. The weights assigned to each criterion represent their relative importance. Efficiency is assigned the highest weight of 52.12%, indicating its significant importance in the analysis. The cost weighs 23.14%, while Safety and Versatility have weights of 16% and 8.73% respectively. These results highlight the emphasis placed on Efficiency and provide a ranking of the criteria in terms of their importance.

Table 4: *Relative Priorities (%)*

Criterion	Weight
Versatility	8.73
Efficiency	52.12
Safety	16
Cost	23.14

In AHP analysis, weighted Attributes refers to the criteria or factors that are considered in the evaluation of alternatives. These attributes represent the different aspects or characteristics of the options being assessed as indicated in Figure .

Each attribute is assigned a weight or importance value to reflect its relative significance in the decision-making process. The values assigned to each option under each attribute represent the performance or effectiveness of the options with that specific attribute. The higher the value, the better the option performs in that attribute.

On the other hand, for the case of maneuverability attribute, the AUV option has a value of 0.009703023, while the ROV has a slightly lower value of 0.009090505. This suggests that, according to the weighted attribute of maneuverability, the AUV is perceived to have a higher level of maneuverability than the ROV.

Similarly, for each attribute, the values assigned to the options indicate their comparative performance concerning that particular attribute. By considering all the attributes and their respective weights, the AHP analysis provides a comprehensive evaluation of the options.

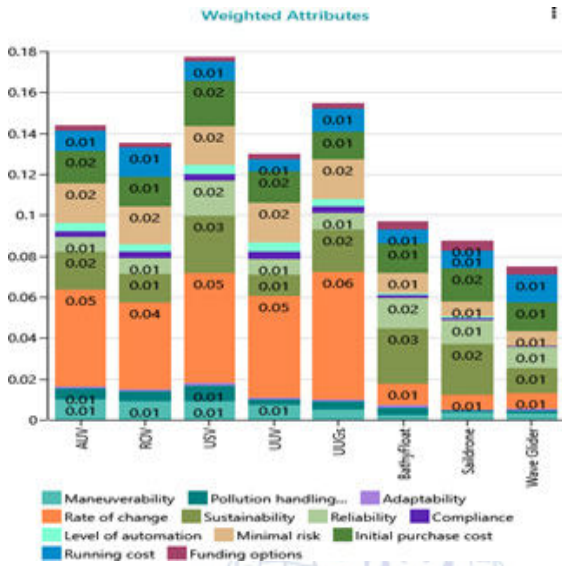

Figure 3: Weighted Attributes.

Additionally, Figure shows various attributes and their values assigned to different alternatives in a decision- making process that used the AHP analysis. The alternatives are different types of Marine Robotics Technology, and the attributes include maneuverability, pollution handling capability, adaptability, rate of change, sustainability, reliability, compliance, level of automation, minimal risk, initial purchase cost, running cost, and funding options. Each alternative is assigned a value for each attribute, and the values are used in the AHP analysis to determine the best alternative based on a set of criteria and weights.

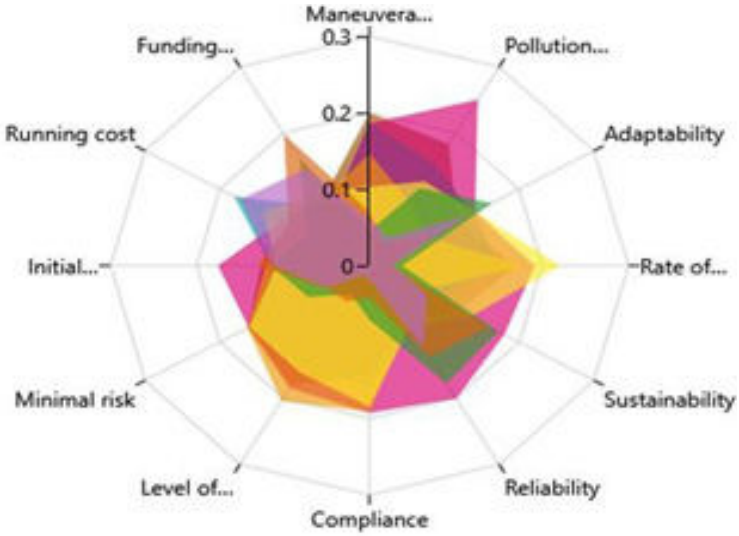

Figure 4: Attributes.

On the otherhand, Table 5 represents the option priorities resulting from an AHP (Analytic Hierarchy Process) analysis. The "Value" column indicates the numerical values assigned to each option, representing their relative importance or preference in the analysis. The "Value in %" column displays the corresponding percentage values for better understanding. Based on the table, the top three ranked options according to the AHP analysis are as follows:

- The Unmanned Surface Vehicle (USV) has the highest priority value of 0.177422588, which accounts for approximately 18% in terms of relative importance. This indicates that the USV is considered the most preferred option among the listed alternatives.
- The second-ranked option is the Unmanned Underwater Gliders (UUGs) with a priority value of 0.154809802, corresponding to approximately 15% in relative importance.
- The Autonomous Underwater Vehicle (AUV) secures the third position with a priority value of 0.143706081, which accounts

for approximately 14% in terms of relative importance.

These rankings and percentage values provide insights into the relative significance of each option according to the AHP analysis.

Table 5: *Option Priorities Resulted from AHP Analysis*

S/no	Option	Value	Value in %
1	AUV	0.143706081	14%
2	ROV	0.135171355	14%
3	USV	0.177422588	18%
4	UUV	0.129750307	13%
5	UUGs	0.154809802	15%
6	BathyFloat	[illegible]	10%
7	Saildrone	0.087573421	9%
8	Wave Glider	0.074730728	7%

AUV ROV USV UUV UUGs BathyFloat Saildrone Wave Glider

A one-way sensitivity analysis was conducted to understand how alterations in input data could impact the results of the decision-making process. The analysis revealed that the USV/UUGs ratio is the most sensitive variable in the pairwise comparison, with a sensitivity of 47.5%. Any modifications to the ratio of these two options could significantly affect the overall outcome. It is essential to consider this sensitivity analysis when making decisions about selecting the optimal Marine Robotics Technology for oil spillage and microplastic removal.

Therefore, decision-makers must consider the sensitivity of this variable when considering the trade-offs between the different alternatives. They should also consider other factors such as cost, efficiency, and safety when selecting the best option. It is also important to note that sensitivity analysis is an essential tool in decision-making processes that involve complex systems and multiple variables. It can help decision-makers understand the robustness of their decisions and identify the most critical variables that could impact the outcome.

The one-way sensitivity analysis conducted in this study highlights

the importance of carefully considering the USV/UUGs ratio when selecting the optimal Marine Robotics Technology for oil spillage and microplastic removal. Decision-makers must also consider other critical factors and conduct further analysis to ensure the robustness of their decisions. The average consistency ratio is 0.073095238 which is less than 0.1 (Figure 5).

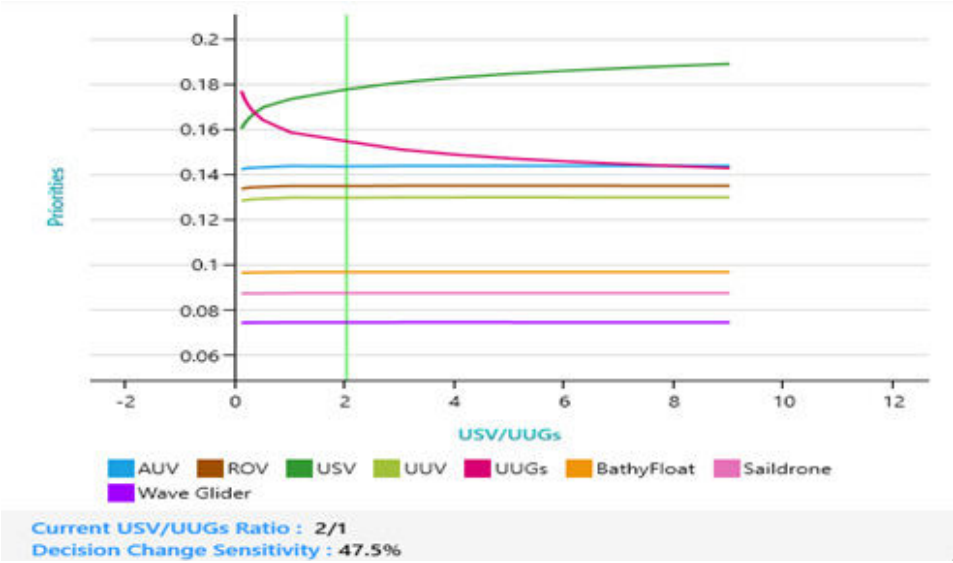

Figure 5: One Dimensional Sensitivity Analysis.

2.1 MRT Evaluation Results Using GRA TOPSIS Method

Step 1: Evaluation criteria and weights are as defined in Table 4 resulting from the subcriteria of the AHP analysis

Step 2: Create a decision matrix with the alternatives and criteria

The decision matrix in Table 5 represents the ratings of various alternatives (AUV, ROV, USV, UUV, UUVs, BathyFloat, Saildrone, Wave Glider) based on different criteria (Versatility, Efficiency, Safety, Cost) using the GRA-TOPSIS method. The ratings range from 2 to 7, indicating the performance or suitability of each alternative for each criterion. The percentages in parentheses indicate the weights assigned

to each criterion.

The decision matrix serves as input for the GRA-TOPSIS method, which calculates the relative closeness of each alternative to the ideal solution. This analysis helps in determining the overall ranking of the alternatives based on their performance across all the criteria. By assigning ratings and weights, the decision matrix provides a structured approach to evaluate and compare the alternatives, aiding in the decision-making process.

Table 6: *Decision Matrix with the Alternatives and Criteria*

Alternatives	Versatility (8.73%)	Efficiency (52.12%)	Safety (16%)	Cost (23.14%)
AUV	4	6	4	5
ROV	4	4	3	6
USV	5	7	4	5
UUV	5	5	6	6
UUVs	4	6	3	4
BathyFloat	5	3	2	3
Saildrone	6	6	2	5
Wave Glider	3	4	3	4

Step 3: Normalized decision matrix

Step 3 in the process involves normalizing the decision matrix as indicated in Table 7. In this step, the ratings in the decision matrix are transformed into normalized values to ensure consistency and comparability across the different criteria. The normalized values represent the relative performance of each alternative for each criterion on a scale of 0 to 1. The normalized decision matrix presented in the table assigns a normalized value to each alternative for each criterion.

The values range from 0 to 1, with 1 indicating the highest performance for a specific criterion. The normalized values allow for a fair comparison among alternatives and facilitate the subsequent steps of the decision-making process, such as calculating the weighted normalized decision

matrix and determining the ideal and anti-ideal solutions.

Table 7: *Normalized Decision Matrix*

Alternatives	Versatility (8.73%)	Efficiency (52.12%)	Safety (16%)	Cost (23.14%)
AUV	0.3076	0.2308	0.25	0.2174
ROV	0.3076	0.1538	0.1875	0.2609
Alternatives	**Versatility (8.73%)**	**Efficiency (52.12%)**	**Safety (16%)**	**Cost (23.14%)**
USV	0.3846	0.2692	0.25	0.2174
UUV	0.3846	0.1923	0.375	0.2609
UUVs	0.3076	0.2308	0.1875	0.1739
BathyFloat	0.3846	0.1154	0.125	0.1304
Saildrone	0.4615	0.2308	0.125	0.2174
Wave Glider	0.2308	0.1538	0.1875	0.1739

In the GRA-TOPSIS method, the Positive-Ideal Solution (PIS) represents the best values for each criterion, while the Negative-Ideal Solution (NIS) represents the worst values. PIS is the highest value achieved for each criterion, and NIS is the lowest value. In the given Table 8, the PIS values are 6 for Versatility, 7 for Efficiency, 6 for Safety, and 3 for Cost. These values represent the ideal performance across all criteria. On the other hand, the NIS values are 3 for Versatility, 3 for Efficiency, 2 for Safety, and 6 for Cost. These values represent the worst performance.

Step 4: Positive-Ideal Solution (PIS) denoted by Y^+ and the Negative-Ideal Solution (NIS) denoted by Y^-

Table 8: *Positive-Ideal Solution denoted by Y^+ and the Negative-Ideal Solution Denoted by Y^-*

Criteria	Positive-Ideal Solution (PIS)	Negative-Ideal Solution (NIS)
Versatility	6	3
Efficiency	7	3
Safety	6	2
Cost	3	6

Step 5: Separation of each alternative from the PIS and NIS(Quan *et al.,* 2019)

In Step 5 of the GRA-TOPSIS method, the alternatives' separation from the Positive-Ideal Solution (PIS) and Negative-Ideal Solution (NIS) is determined as indicated in Table 9. The values in the table show the separation measures (Dj+) from the PIS and (Dj-) from the NIS for each alternative. Smaller Dj+ values indicate better performance, while smaller Dj- values indicate worse performance.

Table 9: *Separation of Each Alternative From the PIS and NIS*

Alternatives (Options)	Dj+	Dj-
AUV	0.5478	0.4862
ROV	0.7017	0.3913
USV	0.5434	0.4862
UUV	0.5831	0.3913
UUGs	0.5225	0.5869
BathyFloat	0.7595	0.7479
Saildrone	0.3981	0.4862
Wave Glider	0.9092	0.7479

In Step 6 of the GRA-TOPSIS method, the grey relational coefficients are estimated. The table provides the grey relational coefficients r_{ij}^+ and r_{ij}^- for each alternative. These coefficients represent the degree of

relationship between each alternative and the Positive-Ideal Solution (PIS) or Negative-Ideal Solution (NIS). A higher r_{ij}^{+} the value indicates a stronger positive relationship with the PIS, while a higher r_{ij}^{-} the value indicates a stronger negative relationship with the NIS.

Table 10: *Grey Relational Coefficients* (Hasanzadeh *et al.,* 2023; Quan *et al.,* 2019).

Alternatives (Options)	r_{ij}^{+}	r_{ij}^{-}
AUV	0.3846	0.2174
ROV	0.1538	0.3913
USV	0.3846	0.2174
UUV	0.1923	0.3913
UUGs	0.2308	0.5869
BathyFloat	0.1154	0.7479
Saildrone	0.2308	
Wave Glider	0.1538	

Moreover, step 7 of the GRA-TOPSIS method, involves calculating the consolidated results and the grey relational degree. Table 11 presents the calculated values for each alternative. The values q_i^{+} and q_i^{-} represent the summation of the positive and negative grey relational coefficients, respectively, for each alternative. These values indicate the overall degree of similarity or dissimilarity of each alternative with the decision criteria.

The value C_i represents the grey relational degree, which is the difference between the positive and negative summations (q_i^{+} - q_i^{-}). This indicates the relative performance of each alternative based on the grey relational analysis. A higher C_i value implies a stronger overall performance of the alternative compared to others.

Table 11: *Results of Calculating the Consolidated Results and Grey Relational Degree*

Alternatives (Options)	r_{ij}^{+}	r_{ij}^{+}	q_i^{+}	q_i^{-}	C_i
AUV	0.3846	0.2174	0.6385	0.3615	0.6381
ROV	0.1538	0.3913	0.2814	0.7186	0.2810
USV	0.3846	0.2174	0.6385	0.3615	0.6381
UUV	0.1923	0.3913	0.3288	0.6712	0.3279
UUGs	0.2308	0.5869	0.2814	0.7186	0.2805
BathyFloat	0.1154	0.7479	0.1337	0.8663	0.1332
Saildrone	0.2308	0.4862	0.3224	0.6776	0.3218
Wave Glider	0.1538	0.7479	0.0939	0.9061	0.0936

On the otherhand, Figure 6 displays the outcomes of various analysis methods, including GRA-TOPSIS, AHP Analysis, and Combined AHP and GRA-TOPSIS. The purpose of these analyses was to evaluate different alternatives or options (AUV, ROV, USV, UUV, UUGs, BathyFloat, Saildrone, and Wave Glider) by each analysis method. By considering the combined numerical value derived from the analysis, the top three alternatives can be identified.

The USV emerges as the highest-ranked option, with a combined numerical value of 0.8155, indicating its superiority based on the evaluated criteria. Moreover, the AUV appears close to USV, securing second place with a combined numerical value of 0.7818, indicating its impressive performance. Despite having a slightly lower score than the top two choices, the Saildrone, which is in third place with a cumulative numerical value of 0.4094, provides a competitive option among the alternatives.

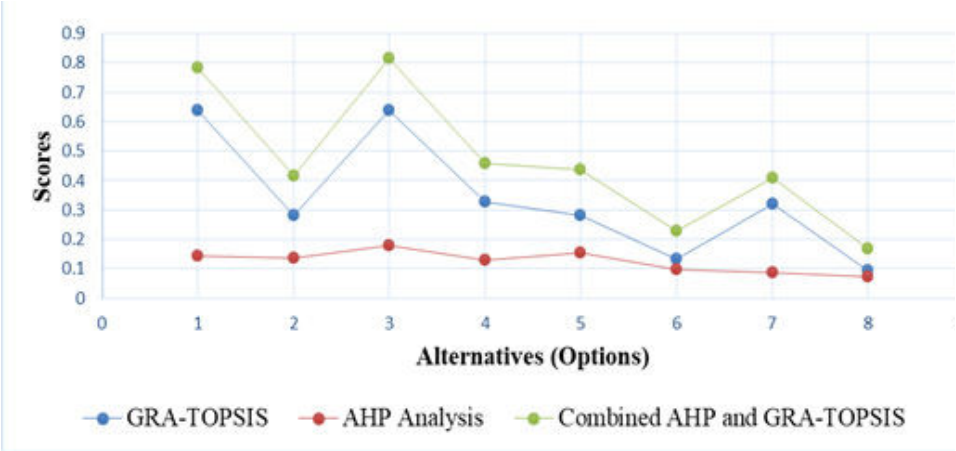

Figure 6: Efficacy of Marine Technology Using Combined AHP and GRA-TOPSIS Methods.

3.0 CONCLUSIONS

Marine ecosystems are facing numerous threats from human activities, highlighting the urgent need to evaluate the efficacy of available marine robotics technologies in addressing these challenges and promoting environmental conservation efforts. This study aimed to compare the effectiveness of various marine robotics technologies and understand their potential for environmental conservation.

The GRA-TOPSIS and the AHP was used as decision-making methodologies to select the most suitable marine robotic technology for addressing marine environmental pollution, specifically oil spills and microplastics. The key criteria for selecting marine robotics technologies for oil spill and microplastic mitigation include versatility, efficiency, safety, and cost.

The study evaluated various marine robotics technologies, including AUVs, ROVs, USVs, UUVs, Gliders, Wave Gliders, BathyFloats, Saildrones, and Seagliders, and their sub-criteria in terms of maneuverability, pollution handling capability, adaptability, rate of change, sustainability, reliability, compliance, level of automation,

minimal risk, initial purchase cost, running cost, and funding options.

The results indicated that USVs obtained the highest score of 81.55%, followed by AUVs with 78.18%. UUVs, UUGs, ROVs, sail drones, bathy floats, and wave gliders received scores of 45.77%, 43.53%, 41.62%, 40.94%, 23.00%, and 16.83%, respectively. Furthermore, the average consistency ratio obtained was 0.073095238 which is less than 0.1. Both GRA-TOPSIS and AHP exhibit distinct advantages and limitations, rendering them valuable tools for assessing and selecting marine robotic technologies to combat marine environmental pollution.

By scrutinizing these criteria, stakeholders and decision-makers can make informed choices about adopting effective, safe, and cost-efficient marine robotics technologies to mitigate environmental harm and support marine conservation efforts. Based on the findings, USVs and AUVs should be prioritized for use in addressing marine oil spills and the removal of microplastics. When it comes to managing and conserving marine ecosystems, these technologies have proven to be highly effective. To strengthen USVs and AUVs' ability to address environmental issues in marine ecosystems, future research and funding should concentrate on optimizing and enhancing these systems' capabilities.

Funding: The research paper received partial support from the Dar es Salaam Maritime Institute (DMI), with the remaining funding being self-funded.

Data accessibility: No specific statement is applicable in this case.

Acknowledgments: The authors would like to extend their gratitude to the editor and anonymous reviewers for their valuable comments and ideas.

Conflicts of Interest: The author confirms that there are no conflicts of interest to declare.

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SUB-THEME 2

MARITIME SAFETY, SECURITY AND ENVIRONMENTAL PROTECTION

MINI-REVIEW ON THE UTILIZATION OF ELECTRIC MOTORS AS ALTERNATIVES TO INTERNAL COMBUSTION ENGINES IN MARINE VESSELS FOR REDUCED EMISSIONS

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ABSTRACT

An examination of the literature reveals a strong and consistent link between the dangers of environmental pollution and diseases related to internal combustion (IC) engine emissions. There are recommendations to replace the IC engine with electric motors, which have environmental benefits and lower operating costs. According to studies, IC engines can produce dangerous pollutants, which include carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NO_x), unburned hydrocarbons (HC), and particulate matter (PM). Findings

highlight the benefits of electric propulsion for ships, such as the reduced number of moving parts in electrical motors that increase reliability. Second, compared to IC engines, maintenance costs for electric motors are reduced. Thirdly, electric motors provide instant torque at low speeds, which facilitates maneuvering. Moreover, the paper examines power converters, such as the cycloconverter (CC), synchro converter (SC), pulse-frequency modulator (PFM), and pulse width modulator (PWM), for controlling propulsion motor speed.

The study concludes that switching marine vessels' IC engines out for electric motors will revolutionize the sector. Electric propulsion technology leads toward a cleaner, more sustainable maritime future by reducing emissions, enhancing vessel performance, and opening prospects for better efficiency. Accepting this paradigm shift is crucial for preventing climate change as well as guaranteeing a better and more affluent planet for future generations.

Keywords: Electric Motor, Internal Combustion Engines, Marine Vessel

1.0 INTRODUCTION

The transition from traditional internal combustion (IC) engines to electric motors (EM) in marine vessels marks a revolutionary shift towards a more sustainable and environmentally friendly future. The impact of this transition cannot be overstated, as it not only eliminates harmful emissions but also opens up new possibilities for innovation and efficiency. The decision to embrace electric propulsion is a crucial step towards a cleaner and greener maritime industry.

The most significant advantage of replacing IC engines with EM in marine vessels is the complete elimination of emissions. Traditional engines are notorious for their contribution to air and water pollution, releasing toxic substances such as Nitrogen oxides (NO_x), Carbondioxide (CO_2), Sulfur oxides (SO_x), and particulate matter. The mentioned

pollutants have severe consequences on human health as well as the environment, including climate change, respiratory diseases, and marine ecosystem degradation (Jelić *et al.,* 2021).

EMs, on the other hand, produce zero direct emissions during operation. By utilizing electricity from renewable energy sources, such as solar, wind, or hydroelectric power, the emissions associated with vessel propulsion can be virtually eliminated. This transition significantly reduces the carbon footprint of the maritime industry, making a substantial role to global efforts to battle climate change. In addition to the environmental benefits, electric propulsion offers several advantages in terms of vessel performance. EMs provide instant torque, resulting in quicker acceleration and more responsive maneuverability. This enhanced control allows for improved safety and precision, particularly in congested waterways or during critical operations. Furthermore, the absence of vibrations and noise associated with traditional engines creates a quieter and more comfortable onboard experience for passengers and crew members (Jelić *et al.,* 2021).

The adoption of electric propulsion technology also opens up opportunities for increased efficiency and reduced operational costs. EMs are known for their higher energy conversion efficiency compared to internal combustion engines, which often waste a significant portion of the energy as heat. Electric propulsion systems can achieve efficiencies above 90%, maximizing the use of energy and reducing the amount of power required for vessel operation.

This efficiency translates into longer ranges, extended battery life, and potentially lower fuel costs, making electric-powered vessels a financially viable alternative in the long run. While there are challenges to overcome, such as developing adequate charging infrastructure and optimizing battery technology, the marine industry is already witnessing promising advancements.

Several companies and research institutions are investing in the development of fast-charging solutions, high-capacity batteries, and hybrid propulsion systems to address the range limitations and power demands of larger vessels. These advancements, coupled with

government incentives and stricter emissions regulations, are accelerating the transition to electric propulsion and fostering innovation across the maritime sector.

1.1 Fundamentals of Electric Motors

Literature shows that EMs convert electrical energy into mechanical energy. They are widely used in various applications, ranging from industrial machinery to household appliances. Here are some fundamental concepts related to electric motors:

1.1.1 Basic principle: EMs operate based on the principle of electromagnetism. When an electric current flows through a wire placed in a magnetic field, a force is exerted on the wire, causing it to move. This force is known as the Lorentz force and is the basis for motor operation.

1.1.2 Components: EMs consist of several key components, including a stator, rotor, and commutator (in certain types of motors). The stator is the stationary part that contains the field windings, which create a magnetic field. The rotor is the rotating part that carries the armature windings or permanent magnets.

1.2 Types of Motors

There are various types of electric motors based on the review, including;

(i) **Direct current (DC) motors:** DC motors rely on the interaction between the stator's magnetic field and the rotor's armature windings. DC motors can be further classified into brushed and brushless DC motors.

(ii) **Alternating current (AC) motors:** AC motors are powered by an alternating current and are classified into different types based on their construction, such as induction motors, synchronous motors, and reluctance motors.

2.0 IC ENGINES VS ELECTRIC PROPULSION MOTORS

IC engines and electric propulsion motors are two common options for powering marine vessels. Each technology has its own operational advantages as highlighted below:

2.1 Advantages of Internal Combustion Engines Over Electric Propulsions

i. **Power and range:** IC engines can produce high power outputs, making them suitable for vessels requiring significant propulsion force. They provide an excellent range due to the high energy density of liquid fuels such as diesel or gasoline.

ii. **Fuel availability:** Fossil fuels are readily available in most parts of the world, making it easier to refuel marine vessels powered by IC engines.

iii. **Quick refueling:** Refueling IC engines is relatively fast compared to recharging electric propulsion systems. This is especially advantageous for vessels with time-sensitive operations, such as commercial shipping or emergency response.

iv. **Established infrastructure:** There is an extensive infrastructure in place to support the distribution and storage of fossil fuels, making it convenient for vessels powered by IC engines to operate in various regions.

2.2 Advantages of Electric Propulsion Motors

i. **Efficiency and environmental benefits:** Electric propulsion motors are highly efficient compared to IC engines. They convert a higher percentage of the energy stored in the battery into useful work, resulting in lower energy waste and reduced emissions. This contributes to improved environmental performance and compliance with stricter emission regulations.

ii. **Quiet operation:** Electric motors produce significantly less noise and vibrations compared to internal combustion engines, leading to quieter and more comfortable onboard experiences for passengers and crew. Additionally, reduced noise levels can be beneficial in applications such as scientific research or marine wildlife observation.

iii. **Reduced maintenance:** Electric propulsion systems have fewer moving parts and generally require less maintenance than IC engines. There are no oil changes, spark plugs, or complex engine systems to manage, resulting in lower operating costs and reduced downtime.

iv. **Flexibility and design options:** Electric propulsion motors offer more design flexibility, allowing for innovative vessel layouts. The compact size of electric motors and the ability to distribute them throughout the vessel can free up valuable space for other purposes or enable unconventional hull designs.

It is important to keep in mind that the decision between IC engines and electric propulsion motors is influenced by several variables, including the vessel's special needs, operational characteristics, legal concerns, and the accessibility of infrastructure. Hybrid propulsion systems that combine both technologies are also being investigated to maximize their benefits and minimize their downsides.

2.3 The Electric Propulsion

Electric propulsion is an ideal source of renewable energy due to its high efficiency, low emissions, and excellent adaptability to inland rivers and oceans (Jin *et al.,* 2019). Pure-electric and hybrid-electric propulsion ships constitute the majority of electric propulsion ships. Pure-electric propulsion ships utilize a single battery cell as their energy source, and this is the optimal propulsion method for achieving zero emissions.

There are unresolved issues, such as the high cost of lithium batteries, their poor compatibility, and their low energy density (Nuchturee *et al.,* 2020). Thus, hybrid-electric propulsion ships perform an essential

function in modern society. It uses numerous energy sources as power, effectively reducing the limitations of battery packs and enhancing power redundancy; it can be used as an alternative propulsion method prior to 2030, when battery technology is not mature (Jafarzadeh and Schjolberg, 2018). Series hybrid-power systems, parallel hybrid-power systems, and series-parallel hybrid-power systems comprise the majority of the current hybrid-power systems.

The propulsion system and electrical system of ships with electric propulsion are closely related. Due to the benefits of conserving space and eradicating a portion of the propeller shafts, ships with electric propulsion offer more options for propulsion (Inal *et al.,* 2022). Direct shaft propulsion, shaftless rim propulsion, and pod propulsion are the three primary propulsion methods for spacecraft with electric propulsion. The integration of the electrical systems with the various propulsion systems onboard has a significant impact on the ship's propulsion efficacy.

3.0 POWER CONVERTERS FOR REGULATION PROPULSION MOTORS SPEED

The kind of electric motors addressed in the preceding sections need power conversion and control equipment to regulate speed effectively. Power converters frequently operate as the technology behind motors. Without an appropriate controller or converter, the motors discussed in previous chapters are of limited utility. The controllers must be designed to precisely control the speed of the motor while introducing minimal harmonics. There are various AC converters utilized to control massive propulsion motors such as; Cycloconverter (CC), Synchroconverter (SC), Pulse-Frequency Modulation (PFM), and Pulse Width Modulation (PWM).

i. Cycloconverter (CC)

Cycloconverters are known as direct frequency converters. They convert a utility-frequency AC supply to a variable

frequency. The output frequency of the cycloconverter ranges from 0.5 fs to fs, where fs is the supply frequency (Krishnan, 2017). For Typically, the output frequency is capped at 0.33s for improved waveform control and to reduce harmonics. This narrow frequency variation range is appropriate for low- speed, high-power applications such as ship drives.

Numerous huge vessels, including icebreakers and cruise ships, currently employ cycloconverters. Cycloconverters are not suitable for use on a small warship where space is at a premium due to their enormous size in comparison to other converters. Other limitations include a limited output frequency range, a low power factor, input and output harmonic spectra that require passive filtering, and a large number of power devices to control (De Doncker, Pulle, and Veltman, 2020).

ii. Synchroconverter

Synchro converters are indirect frequency converters with rectification (AC-DC) and inversion (DC-AC) stages. A substantial link inductor separates the rectifier stage from the inverter stage. The synchro converter is also known as a Current-Source Inverter (CSI) and a Line Commutated Inverter (LCI). This form of converter is widely utilized within the cruise ship industry (Zeraoulia, Benbouzid, and Diallo, 2006). The inverter section consists of thyristor devices that are commutated naturally by the machine's back EMF. For the machine to be inherently commutated, it must operate with a dominant power factor (Zeraoulia *et al.,* 2006).

To assure thyristor commutation at low speed, where the back EMF is low, the converter control must be more complex. The large link inductor produces a direct current that is transmitted through the respective thyristors and machine phases to generate quasi-rectangular phase currents (Miller,

2004). Significant phase current harmonics result in drive derating, torque harmonics, poor input current quality, and dv dt(Nguyen *et al.,* 2021).

High values of dv dt (voltage surges) can re-trigger power devices, such as thyristors, during their recovery period. The thyristor can be damaged by re-triggering, so the dv dt must be minimized. Limiting the output frequency of a cycloconverter is the switching frequency of the Silicon Controlled Rectifiers (SCR) (Levi, Barrero, and Duran, 2015). This form of converter has the smallest number of components and can be connected in series with other converters.

iii. Pulse-Frequency Modulation (PFM)

PFM is a direct AC-AC frequency conversion strategy that has been investigated by the Royal Navy of the United Kingdom. The PFM operates by receiving discrete energy sequences from the input, storing the energy in a capacitor, and then controlling the release of the stored energy to achieve the desired output frequency. Since thyristors have a highpower rating, there is no need for paralleling or multi-level topologies.

Due to the limited switching frequency of thyristors, it is necessary to interleave thyristor units to obtain waveform accuracy. This form of converter has several advantages, including a low dv/dt and a very high efficiency due to its soft-switching operation. Additionally, these devices have a very highpower density. According to estimations, a 25 MW power converter can attain a power density of 5.5 MW/m3 with a power factor close to unity (Zeraoulia *et al.,* 2006).

iv. Pulse Width Modulation (PWM)

The PWM converter is a frequency converter as well. These converters include a rectifier and an inverter stage. In place

of the previous converter's link inductor, the PWM uses a DC link capacitor to provide constant control voltage. The configurations can be classified loosely as H-bridge, conventional or multi-level (Zeraoulia *et al.,* 2006). Conventional configurations can be further divided into hard-switched and soft-switched categories.

Typically, PWM converters deliver stair-stepped phase voltages with high- frequency notches and relatively sinusoidal phase currents with steady motor torque. Current technologies enable converters with power densities on the order of 750 kW/m3; innovations in the field are expected to enhance this to 2.0 MW/m3 (Wettstein, Penzin, and Lyumkis, 2002).

3.1 Podded Propulsion

The commercial shipping industry is reaping significant benefits from pod propulsion systems. These devices are also present on a number of recreational cruise liners. Shipbuilders began employing modules in the late 1980s, and their use has increased steadily since then (Berg and Helldén, 2007). Mermaid, the Alstom/Kamewa pod system, is presently the industry leader, with many of these units already deployed on cruise ships. The potential advantages of deploying modules on surface combatants. In addition, the two types of propulsors including the Azimuthing thrusters and podded propulsors are discussed and compared.

3.1.1 Azimuthing thruster

With the introduction of the Azimuthing Thruster (AT), the concept of a propulsion system without a propeller shaft was born. AT is a propulsion configuration in which the prime mover (in this instance an electric motor) is connected to the propeller via one or two right angle gearing referred to as L or Z drives, respectively (Van Terwisga *et al.,* 2001). In the commercial shipping industry, these varieties of propellers are extensively utilized. Because of

concerns regarding noise, vibration, robustness, and survivability, the U.S. Navy's propulsion requirements are plainly very distinct from those of the commercial sector. Because of the additional commotion and vibration caused by the AT's L or Z gearing, the U.S. Navy does not actively pursue the use of the AT for ship propulsion(Van Terwisga et al, 2001).

3.1.2 Podded propulsors

Pods differ from the original thruster in that the propeller is directly driven by an electric motor housed in the hub beneath the strut. Pod propulsion systems are more efficient and maneuverable than shafted systems. The Navy is presently conducting research into the application of modules to future surface combatants (McCoy, 2002). The effectiveness, durability, and dependability of the modules have yet to be demonstrated on a warship, despite their success on large commercial vessels.

3.1.3 Benefits of using pods

Among the advantages of using modules are increased efficiency and maneuverability, as well as greater design versatility (McCoy, 2002). Pods enhance manueverability by being able to rotate 360 degrees to provide propulsion in any desired direction. The elimination of the conventional drive's long shaft line increases design flexibility. By applying hydrodynamic pod and hull design enhancements, it is possible to reduce fuel consumption and increase propulsion efficacy (Nicod and Simon, 1998).

Additionally, pods facilitate the shipbuilding process. Complete pod-based propulsion systems can be delivered and installed in a matter of days, eliminating the time-consuming installation of conventional systems. Using modules can eliminate a significant amount of the auxiliary and support apparatus required by a conventional propulsion system. In a podded system, for instance, the rudder, steering gear, propeller, propulsion motor, main propulsion shaft, shaft bearings, thrust bearing, and shaft seals

are incorporated into a single unit. Figure 1 depicts a comparison between a pod drive and a conventional drive.

The capsule depicted in the upper half of Figure 1 contains all of the components of the conventional shaft line depicted in the lower half. Figure 2(a) is a comprehensive illustration of a typical pod. Two commercial vessels appear in Figure 2(b). Pods affixed beneath the vessel's aft section in the hauling configuration.

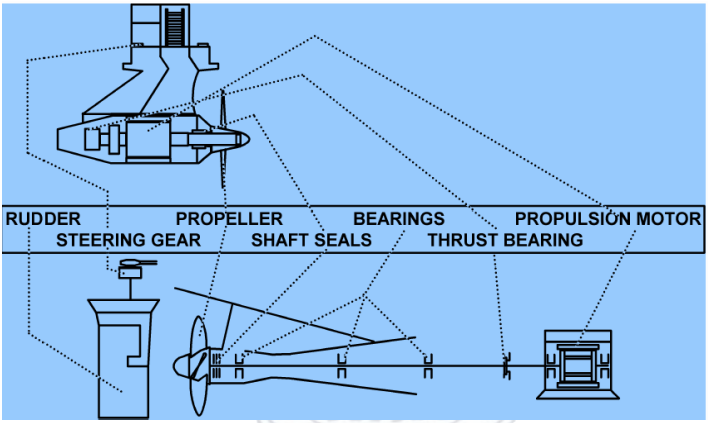

Figure 1: Integrated Architecture of Pods Versus Conventional Propulsion Systems.

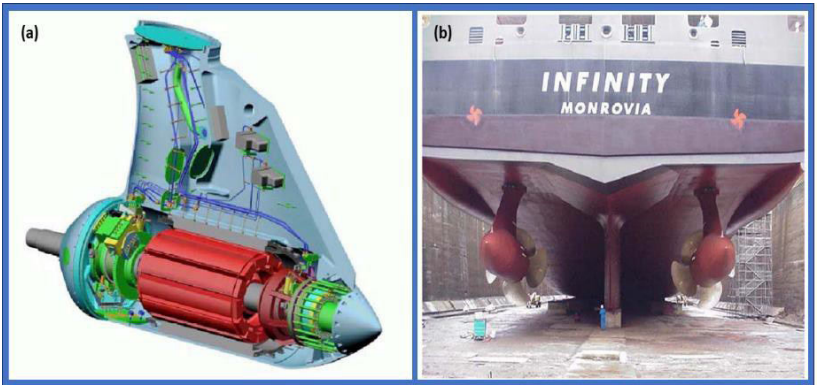

Figure 2: (a) Typical Design of a Podded Propulsor.
(b) Installed Pulling Type Pods in Ship.

3.4 Efficiency Benefits of Pods

Pods can be of the drawing or pushing variety, meaning that the propeller can be affixed at either the front or rear of the unit. Pulling-type pods are significantly more efficient than pushing-type pods. Due to the absence of a center or shaft, the wake field through the propeller is unaffected. Hydrodynamically, pushing segments are comparable to a standard propeller arrangement.

Unlike conventional systems, in which the propeller axis must be roughly parallel to the ship's keel, pod-mounted propeller shafts can be oriented in any direction. This capability enables the pod shaft to be aligned parallel to the water flow along the ship's aft superstructure, resulting in a greater correlation with the wake field. Using containers can increase productivity by 10 to 15%. The improvement in efficacy reduces the amount of power usage (Nicod and Simon, 1998).

4.0 CONCLUSIONS

This work has provided a review of the available power converters for ship propulsion applications. Their properties, advantages and disadvantages were reviewed and presented. Moreover, the converters and propulsion motors for use in Podded Propulsors (Pods) on surface ships were discussed.

The prospective benefits of pod propulsion systems were also reviewed. The azimuthing thruster and the direct-drive pod propulsion system were highlighted as the two primary forms of pod propulsion systems. The findings demonstrate that substituting internal combustion engines on marine vessels with electric motors will revolutionize industry. Electric propulsion technology improves vessel performance, lowers emissions, and creates opportunities for greater efficiency, all of which contribute to a more environmentally friendly and sustainable marine future. Accepting this paradigm shift is essential for halting climate change and ensuring that future generations will live in a better, healthier environment.

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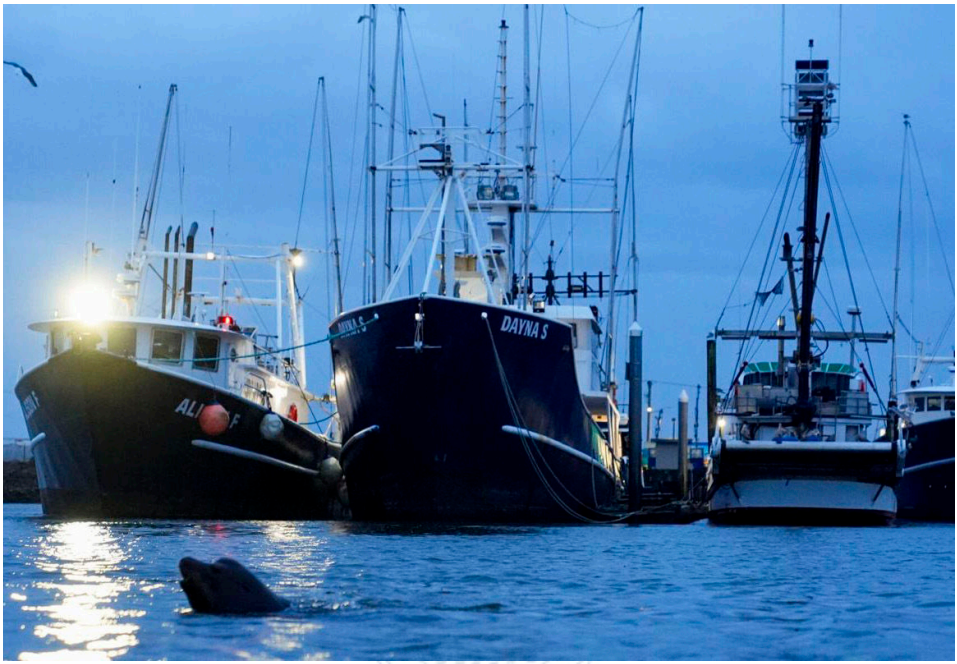

SUB-THEME 3

MARITIME TRANSPORT, PORTS AND LOGISTICS

MARITIME WELFARE: ADDRESSING THE CHALLENGES AND BEST PRACTICES IN PROMOTING THE PHYSICAL AND MENTAL WELL-BEING OF SEAFARERS

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ABSTRACT

This systematic review examines seafarers' physical and mental challenges and explores the best practices to promote their welfare. The role of international organizations such as the International Maritime Organization (IMO) and the International Labor Organization (ILO) in establishing and enforcing standards for seafarers' welfare is also discussed. The review underscores the need for seafarers to possess skills to manage their psychological well-being while at sea and the significance of preventing and addressing bullying and harassment in the maritime sector. The Minimum Requirements for the provision of welfare facilities and services for seafarers under the MLC Convention 2006 are well highlighted, along with the Comprehensive Mental Health Action Plan 2013-2030

provided by the World Health Organization (WHO) to enhance mental health and ensure quality mental health care access. The review also discussed compliance monitoring with standards established by international organizations such as the IMO and ILO, and support or assistance provided to seafarers in need by organizations such as the ITF and ISWAN. The article concludes by emphasizing the unique responsibilities of ship owners, seafarers, governments, and other stakeholders in promoting seafarers' well-being. Overall, the paper stresses the significance of stakeholder collaboration in addressing the challenges faced by seafarers and promoting their well-being.

Keywords: Seafarers, Mental Health and Wellbeing, IMO, MLC

1.0 INTRODUCTION

Maritime welfare refers to seafarers' overall well-being and safety, including the physical, social health and mental well-being of seafarers who work on ships at sea. Seafarers play a critical role in global trade and commerce, as it accounts for over 80% (UNCTAD, 2022) of it, with over 1.6 million seafarers working to ensure that this mode of transportation is secure, efficient, and eco-friendly (Shan and Zhang, 2021).

Seafarers worldwide face human rights hazards and labour risks, indicating the urgent need to address structural issues. They deserve fair and secure working conditions, remuneration, and social protection, including medical, employment, and retirement concerns (SSI, 2021). Furthermore,

The COVID-19 epidemic has significantly affected the welfare of seafarers, with many stranded-on ships for extended peri ods, unable to disembark and denied access to necessities such as food, water and medical care (INTERTANKO, 2021; Pauksztat *et al.,* 2022). This has led to a growing recognition of the need for international action to address the issue of crew welfare.

To address these challenges and promote the well-being of seafarers,

it is important to consider best practices and the role of international organizations in promoting maritime welfare as was stated by the former Secretary-General of the International Maritime Organization Mr. Koji Sekimizu (International Committee on Seafarers' Welfare Awards, 2012), that we have worked tirelessly to raise public awareness of seafarers and the crucial part they play in the daily lives of regular people across the world, individuals who often don't think twice about how the food, fuel, goods, and commodities they use daily actually got to them. In this essay, I will explore the challenges seafarers face and discuss best practices for promoting their well-being, the role of international organizations, and the importance of collaboration in addressing these challenges.

2.0 CHALLENGES FACED BY SEAFARERS

Seafarers face many challenges that can significantly impact their physical and mental well-being. Some of the major challenges they face include:

2.1 Hours of Work

Seafarers spend extended periods at sea, often working long hours with limited opportunities for rest and leisure. This can result in fatigue, stress, and burnout, which can negatively impact their physical and mental health (Brooks and Greenberg, 2022). The ILO convention C180 seafarers of hours of work and manning of ships convention 1996, as revised by MLC 2006, establish guidelines for working hours and rest periods for seafarers (ILO, 1996).

However, these guidelines are not always strictly enforced, and many seafarers continue to work excessive hours. As a result, crew members may experience prolonged periods of stress and tiredness. This can be caused by a variety of causes, such as tight timetables, last- minute changes to voyage plans, employee shortages, harsh weather, technical issues, and security events.

2.2 Limited Access to Healthcare

The ILO Health Protection and Medical Care (Seafarers) Convention, was adopted in 1987 and revised by the MLC, in 2006. This convention aims to ensure that seafarers have access to adequate health protection and medical care while working on board ships (ILO, 1987b)but inadequate medical facilities and personnel on board ships make it difficult to provide necessary care for ill or injured seafarers. Without national health insurance coverage, high medical costs often prevent timely treatment, leading to long- term health issues.

2.3 Social Isolation

Isolation can be exacerbated by a variety of factors, such as language barriers, cultural differences, and limited opportunities for social interaction. Many seafarers report feeling isolated and disconnected from their friends and loved ones, which can hurt their mental health and well-being. In addition, the nature of work at sea can be physically and emotionally demanding, and seafarers may not have access to adequate support networks or mental health resources. This can lead to high levels of stress and burnout and may contribute to the development of mental health issues, such as depression and anxiety.

2.4 Physical Hazards

Physical hazards at sea can result in injury and illness, as well as long-term health problems, such as musculoskeletal disorders and heart disease. Seafarers are exposed to many physical hazards, including rough weather conditions, dangerous cargo, and poor working conditions leading to stress, anxiety, and depression. This can further compound the negative effects of physical hazards and result in a reduced quality of life for seafarers.

Exposure to physical hazards can also impact a seafarer's ability to work, leading to reduced productivity, increased absenteeism, and

increased costs for shipping companies. This can hurt the overall efficiency and profitability of the shipping industry.

2.5 Inadequate Pay and Benefits

Seafarers' lack of job security and benefits can lead to financial uncertainty and emotional strain, increasing stress and anxiety levels. Inadequate salary and perks may also result in feelings of undervaluation and low self-worth, leading to exhaustion and reluctance to seek help. Many seafarers believe that they are not appropriately paid for their work since it takes a lot of time, effort, and personal sacrifice to be a seafarer. This may result in feelings of anger, irritation, and financial stress, all of which may harm the person's mental and emotional health.

2.6 Living Conditions

The conditions on board vessels can be extremely harsh, and many seafarers have to endure cramped and uncomfortable living quarters on many vessels, lack of privacy can contribute to feelings of confinement, and limited access to basic amenities such as clean water and hygiene facilities. This can lead to physical health problems and may also hurt mental health and well-being, as seafarers may feel frustrated, isolated, and disconnected from the outside world.

3.0 BEST PRACTICES IN PROMOTING MARITIME WELFARE

Protecting the maritime environment and encouraging maritime well-being both require safeguarding the health and safety of seafarers (Brooks and Greenberg, 2022). Here are some best practices to promote maritime welfare:

3.1 Providing Safe and Healthy Working Conditions

Ensuring that the working environment and equipment meet

international safety standards and that workers are trained in the proper use of equipment and safety procedures, is essential for promoting maritime welfare. This includes providing proper safety gear and equipment and implementing measures to prevent accidents and injuries.

3.2 Access to Medical and Psychological Support

Seafarers spend long periods away from home and are often subjected to stressful and hazardous working conditions. It's crucial to provide access to medical and psychological support services, such as onboard medical clinics, telemedicine services, and confidential counseling services.

3.3 Promoting a Positive Workplace Culture

Creating a positive and inclusive workplace culture, where seafarers feel valued and supported, is essential for promoting maritime welfare. This includes promoting open communication and collaboration, fostering teamwork, and encouraging employee participation in decision-making processes.

3.4 Providing Adequate Rest and Leisure Opportunities

Seafarers often work long hours and have limited opportunities for rest and leisure. It's important to provide adequate rest and leisure opportunities, such as access to recreational facilities, exercise equipment, and entertainment options, to help maintain their mental and physical well-being in fulfillment of MLC 2006 as an amended requirement.

3.5 Implementing Fair and Equitable Employment Practices

Providing fair and equitable employment practices, such as fair wages, regular working hours, and safe working conditions, is crucial for promoting maritime welfare. This also includes ensuring that seafarers have access to legal support and representation in the case of disputes with their employers.

3.6 Providing Access to Training and Professional Development

Providing access to training and professional development opportunities is essential for promoting maritime welfare. This includes training in areas such as safety, health, and environmental protection, as well as opportunities for seafarers to further their education and advance their careers.

3.7 Encouraging Family and Community Support

Many seafarers spend long periods away from their relatives and communities. Supporting the families of seafarers via initiatives like financial aid and educational possibilities, as well as through giving them opportunities to keep in touch with their loved ones, is crucial for fostering their well-being.

4.0 CONCLUSIONS

Maritime welfare is a crucial issue that must be addressed in the shipping industry to ensure the physical and mental well-being of seafarers. The unique working and living conditions at sea pose significant challenges to seafarers' health, safety, and welfare, making it essential to implement best practices in promoting their well-being. To achieve this, collaboration among stakeholders, including ship owners, managers, and regulatory bodies is necessary.

The implementation of appropriate policies, guidelines, and training programs, as well as the provision of essential facilities and resources, can help to promote the health and well-being of seafarers (Jonglertmontree *et al.,* 2022). Additionally, recognizing the contributions of seafarers to the global economy and prioritizing their welfare is critical to ensure a sustainable and resilient maritime industry.

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SUB-THEME 4

MARITIME LAW AND POLICY

TANZANIA'S LEGAL REGIME FOR COMPENSATION IN CARRIAGE OF PASSENGERS BY SEA

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ABSTRACT

Tanzania aspires to enhance its economy through the maritime industry in accordance with the existing national development plan. The carriage of passengers and their luggage by ships is particularly important to Tanzania as has a significant passenger trade and ferry services. To obtain economic advantage of carriage of passengers, maritime law should effectively safeguard stakeholders in this context. However, the existing maritime regime raises concerns including the compensation aspect in case of death, personal injury, loss and damage to luggage. In passenger ships, rights of a passenger are determined by a contract containing terms known only to carrier. Such concerns raise questions as to whether the national maritime law can enable the country to enhance the economy

effectively. This paper seeks to address these concerns. It examines the adequacy of the existing legal framework based on implementation of maritime conventions into national legislation aspect.

The study employs doctrinal legal research methodology supplemented by comparative and historical methods. The study is delimited to marine insurance in Tanzania focusing on liability aspect of carrier's to passengers and their luggage in terms of compensation. After the consideration of the above issues, the study recommends for articulation and enactment of sound and effective legislation for ease of enforcement.

Keywords: Marine Insurance, Career's Liability, Compensation, Passenger-ships

1.0 INTRODUCTION

International maritime legislation consists of international legal instruments, such as maritime conventions, through which states agree to create new norms or change existing practices in selected areas of maritime law.

1: In the interests of uniformity, international maritime legislation is not only desirable, but is necessary so that those who own, operate and regulate ships and shipping are not burdened with legal uncertainties and contradictions.

2: For a state to become bound by a convention however, it has to become a party to the convention in the first place and thereafter is obliged to implement it by transforming the same into its body of national law.

3: If the state fails to do so, it cannot enforce it against non-compliant unless that convention becomes part of the law of the land by whatever legal process applicable in that jurisdiction.

This paper examines the adequacy of Tanzania's legislation with regard to career's liability in respect of carriage of passengers and their

luggage by sea in line with the relevant international legal framework. The discussion begins with an overview of marine insurance.

1. Shah, Maritime Law and the Developing Countries: Attitudes and Trends', (1986) 6 Ocean Yearbook 107 at p. 109.
2. ibid.
3. Mukherjee, P.K., Maritime Legislation, WMU Publications, 2002.

2.0 INSURANCE OVERVIEW

A term insurance can be defined as method of coping with risk. The main core objective is to substitute certainty for uncertainty as regards the economic cost of loss producing events. It can be defined more formally as a system under which the insurer, for a consideration usually agreed upon in advance, promises to reimburse the insured or to render services to the insured in the event that certain accidental occurrences result in losses during a given period. An insurance contract is referred to as a policy. There are several kinds of insurance depending on the insurance policy requirements. Some examples include fire marine, aviation, property liability, life insurance.

3.0 INSURANCE IN TANZANIA

In 1967 Tanzania was following socialist policies where the state-owned major pillars of the national economy. Thus, the Insurance (Vesting of Interest and Regulation) Act, 1967 was enacted. In this Act all insurance business in Tanzania was vested in the National Insurance Corporation. However, since the liberalization policies of the late 80's insurance business in Tanzania is now governed by the Insurance Act, 1996. This Act repealed the section of the 1967 Act that monopolized insurance business and makes provisions allowing people to invest in companies relating to the carrying out of insurance business and related matters in the whole of the United Republic.

Under this Act, section 36 distinguishes between two types of

insurance businesses, namely the long-term business and the short-term business. The types of insurance falling under the long-term business are listed in the First Schedule and it deals mainly with life insurance, commonly referred to as assurance.

The second schedule lists short term insurance business including but not limited to accident, sickness, land vehicles, railways, aircraft, ships, goods in transit, and fire. The Act also defines three types of business in the insurance market, namely the insurers, the brokers and insurance agents. The insurers are the insurance companies which can be independent companies or association of underwriters.

4.0 MARINE INSURANCE

Marine insurance is a branch of commerce with a long history of more than three thousand years from the times of Phoenician traders. All along, traders realized that trade missions by sea transport was very risky business, therefore a few merchants were ready to offer compensation for the losses incurred due to accidents, provided that the assured paid a consideration. We can therefore say that it is the traders themselves who through usage created marine insurance. Only later on was this type of commerce regulated by the state.

5.0 MARINE INSURANCE PRACTICE IN TANZANIA

In Tanzania Marine insurance is regulated by the Marine Insurance Act, 1906. This is a British statute of general application applicable in Tanzania as received law. Therefore, a study in marine insurance practice in Tanzania resembles the British marine insurance practice. Under this Act, marine insurance is defined in section 1 as a contract whereby the insurer undertakes to indemnify the assured, in manner and to the extent thereby agreed, against marine losses, that is to say, the losses incident to marine adventure.

In consideration of payment of "premium'" the underwriter agrees

to indemnify the assured against loss or damage caused by "maritime perils" defined by the Act as "Perils consequent on, or incidental to, the navigation of the sea, that is to say, perils of the seas, fire, war perils, pirates, rovers, thieves, captures, seizures, restraints and detainments of princes and peoples, jettisons barratry, and any other perils, either of the like kind or which may be designed by the policy."

Marine insurance contracts cover four major types of property interest that is the vessel or hull, cargo, freight and legal liabilities as follows:

a. The vessel or hull

Hull insurance covers losses to the vessel itself from specified perils. This cover usually contains a geographical limitation to the trade area that the vessel trades.

b. The cargo

Cargo insurance covers the loss or damage to the cargo usually as specified in the Bill of Lading.

c. The freight revenue

The ship owner or charterer may insure against the loss of revenue due to perils of the sea.

d. Third party liabilities

These may arise either due to negligence or otherwise that the ship owner or charterer may insure against.

Under marine insurance, the following interests can be deduced:

1. Cargo interests include cargo ownership, shipping costs or freight, insurance charges, anticipated profit, partial ownership, defeasible interest, contingent interest etc.
2. Hull interests include ownership, partial ownership, insurance charges, charterer's interest, freight, third party liability, P and I interest.
3. Incidental interests like Master's and crew wages, reinsurance, etc.

6.0 THIRD PARTY LIABILITY AND NEGLIGENCE

Liability for insurance purposes means legal liability. The purpose of the liability cover afforded by a marine insurance policy is to reimburse the assured for a sum of money which he has paid to another because of his legal responsibility for the loss suffered by that other person. There are two broad categories of liability, namely contractual liability and third-party liability. A contractual liability is the one found in the contract itself. An example of contractual liability is the that of the ship owner to the crew he employs, or to the cargo owners that his ship carries.

Except by special arrangement, marine insurance tend generally not to insure contractual liability and ship owners who incur large amounts in respect of contractual liability usually enter their ships in a P and I Club which cover such liabilities. P and I Clubs are mutual societies supported by contributions from members.

Third party liability is a liability incurred as a result of some form of negligence whereby loss or damage is suffered by someone, who is not a party to a contract with the person who caused the loss or damage.

A contract is based on the doctrine of privity of contract which means only the parties to a contract can accrue rights and as such has a right to sue. Any other person outside the contract is termed as third party. This means a third party liability is one incurred in the absence of a contract.

To establish the extent of the liability it is usually necessary to obtain a court ruling. If the loss is due to negligence the action against the wrong doer or tortfeasor is in tort. An example of third-party liability that a ship owner has is that arising out of collision of his ship with another ship. The other ship and its cargo may get damaged.

In Tanzania s. 11 of the Merchant Shipping Act, 2003, mandates every Tanzanian ship to carry insurance cover over the liabilities to the crew, cargo and passengers carried on board as well as to third party liabilities.

Apparently, it is not compulsory for a ship owner to insure his ship, but what the MSA 2003 has done is to mandate the ship owner to insure against specific risks including third party liabilities. As a general practice, most hull marine insurance policies do also cover third party liabilities.

7.0 LIMITATION OF LIABILITY

How much liable is a ship owner to third party liabilities? This is an important legal question since the ship owner does not have unlimited resources. A ship of low value, lets say Tsh. 20 million may get involved in a collision with a high value speed boat valued at Tsh. 1,200 million. Hence there is a need to limit the liability of a ship owner in such cases. Various rules and statutes have granted the ship owner the right to limit his liability and the Brussels Convention 1957 forms the basis of limitation of liability for ship owners. This has been adopted in various UK statutes including the British MSA 1894 and is also included in our MSA 1967 and now in the MSA 2003 under part XVIII.

In principle, the law states that a ship owner and salvors may limit their liabilities in accordance to that part of the statute and that shall not be liable to make good to any extent whatever any loss or damage happening without his fault or privity to cargo lost or damaged by fire or to loss of precious items like gold, silver, jewels etc., kept on board without his knowledge as to the true value.

8.0 LEGAL OVERVIEW ON CARRIAGE OF PASSENGERS BY SHIPS

The international law on carriage of passengers and their luggage by ships is contained in the Athens Convention relating to the Carriage of Passengers and their Luggage by Sea, (PAL).4 The Convention establishes a regime of liability for damage suffered by passengers carried on a seagoing vessel.5 It declares a carrier liable for damage or loss suffered by a passenger if the incident causing the damage occurred in the course of the carriage and was due to the fault or neglect of the carrier.6 The Convention was amended by the 2002 Athens Protocol, which came into force on 23 April 2014.

The Protocol introduces compulsory insurance to cover passengers on ships and raises the limits of liability. It also introduces other mechanisms to assist passengers in obtaining compensation, based on

well-accepted principles applied in existing liability and compensation regimes dealing with environmental pollution.7 These include replacing the fault-based liability system with a strict liability system for shipping related incidents, backed by the requirement that the carrier take out compulsory insurance to cover these potential claims.8

Under the protocol, national courts have mandate, although are at liberty, to exercise such mandate to compensate for death, injury or damage up to these limits.

The Protocol also includes an "opt-out" clause, enabling state parties to retain or introduce higher limits of liability (or unlimited liability) in the case of carriers who are subject to the jurisdiction of their courts.

Before going any further, worth noting at this juncture that, in the case of international carriage, a journey passing through the waters of more than one country, a multiplicity of legal systems may be relevant and conflicts between those systems might arise.

Hence the need for international regulation. However, a legal issue arising from the domestic carriage of passengers on ships will ordinarily be covered by the national regime in which the carriage took place. Equally, this calls for an effective national law.9

Worth noting also that, as to the contents of international regulation, passengers' rights against a carrier by sea are determined by a contract, evidenced by the issuance of a ticket. The terms of such contracts are normally written by carriers without any opportunity for the passengers to negotiate. That being the case, as in many other areas of international regulation, the law has increasingly sought to increase protection for the weaker party, in this case, passengers.

9.0 CONCLUSION

The Athens Convention relating to the Carriage of Passengers and their Luggage by Sea is fairly specialized. Such maritime conventions are often "relegated to the bottom of the priority heap by draftsmen simply because they do not posses the necessary drafting skills and while also lacking appreciation" of the issues at the same time. Compensation issues

have always been at the top in maritime business. Many countries do not have draftsmen specializing in maritime legislation. For all concerned with carriage of goods by sea therefore, a brief analysis such as this will hopefully be of some usefulness.

10.0 RECOMMENDATION

The implementation of convention law within the national legislative domain is of crucial importance if any meaningful application and enforcement of the law is envisaged. Equally, in the field of carriage of passengers and their luggage by ship is particularly important in Tanzania which have a significant passenger trade of ferry services. It is therefore recommended that, although the provisions of Athens convention are limited to seagoing vessels, our country should derive any benefits from the convention for articulation and enactment of sound and effective legislation to ensure smooth enforcement.

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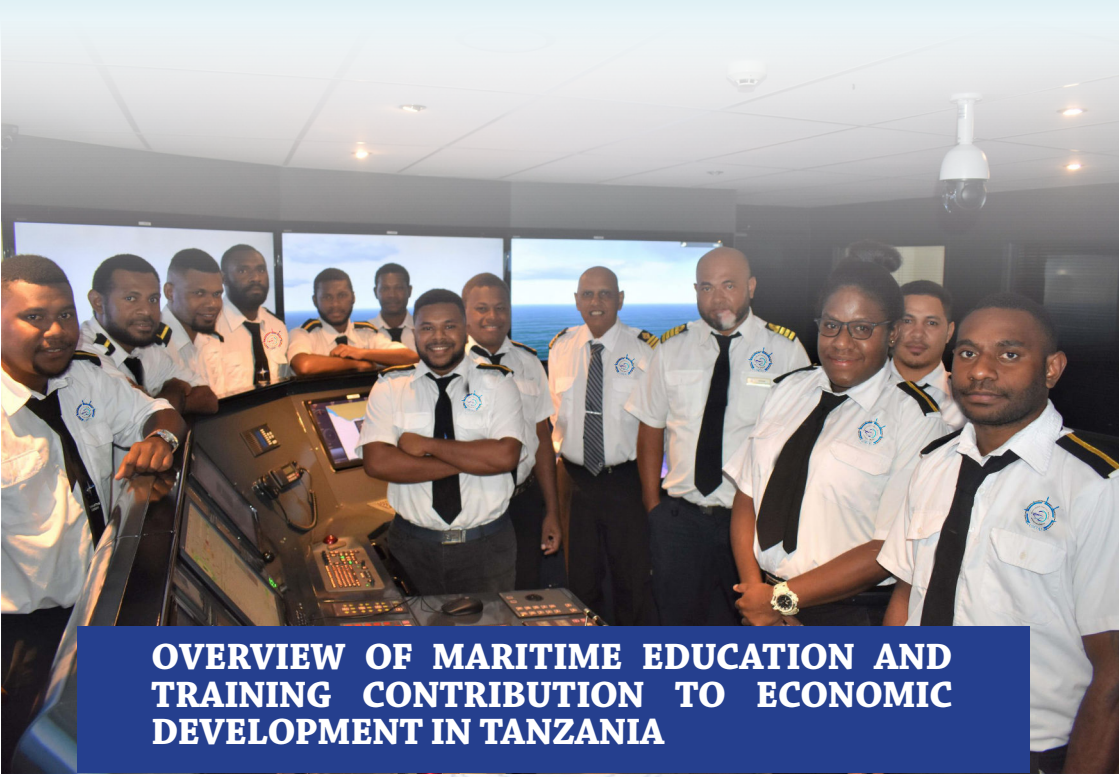
SUB-THEME 5

MARITIME EDUCATION AND TRAINING



OVERVIEW OF MARITIME EDUCATION AND TRAINING CONTRIBUTION TO ECONOMIC DEVELOPMENT IN TANZANIA

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ABSTRACT

Shipping embraces numerous economic opportunities and is number one mode of transportation due to its ability to carry large amount of goods from one region to another in the world. However, shipping is a highly technical and professional sector that requires careful handling. Similarly, in today's world it is not easy to grab any opportunity without having proper education, skills or knowledge regarding respective profession. In this context, relevant personnel especially seafarers require good education and training through which knowledge, strong

skills, and competencies can be acquired.
This article focuses on Tanzania concentrating on the contribution of maritime education and training to economic development in Tanzania. To achieve this objective, challenges facing the shipping industry are discussed. The article also recommends on the measures that should be taken so that economic advantages of maritime education and training in the country can be realised. This study therefore enlightens the Government and other key stakeholders such as shipping agencies on the need to develop the maritime industry through effective maritime education and training so that existing maritime resources can be used effectively for national economic development.
Equally, since the available literature has revealed that most of economic activities related to oceans, seas and other water bodies are poorly conducted or not thoroughly enhanced, this study presents a way forward for the improvements in terms of highlighting the role of Government, shipping companies, maritime education and training institutions in line with the need to engage properly trained personnel in the sector.

Keywords: Economic Development, Maritime Education, Contribution

1.0 INTRODUCTION

Shipping embraces numerous economic opportunities. However, it is a highly technical and professional sector that requires careful handling. Professionals including the seafarers as one of the major maritime workforce operate it. Given the important role this sector plays in terms of economic development, personnel especially seafarers require good education and training through which they are empowered with knowledge, strong skills, and competencies.

This article comments on the contribution of Maritime Education and Training to the economic development in Tanzania. The article aims to disclose the contribution of maritime education and training

in the economic development, particularly in Tanzania and to suggest effective measures to be executed to add more contribution to economic development in the country.

In today's world, it is not easy to grab any opportunity without having proper education, skills or knowledge regarding respective profession. Therefore, the study enlightens the contribution of maritime education and training institution, shipping agencies, to develop the maritime industry so that the nation can develop economically using existing resources.

Most of economic activities related to oceans, seas and coasts are poorly conducted or not thoroughly enhanced, therefore, this study assists the country and interested bodies to properly train single or groups of individuals in the sector to be competitive in the global shipping labour market while at the same time increasing their knowledge for exploitation of the numerous resources including; fishing, harbour services, ship chandlers and repair services, ship chartering, ship management, ship brokering, crewing of ships, cargo forwarding and clearing, cargo logistics, liner services, salvage operations. The subsequent part elaborates the contribution of maritime education and training in the economic development in Tanzania. Then the challenges that face shipping industry will follow before presenting a way forward for the improvements.

2.0 MARITIME EDUCATION AND TRAINING

Tanzania is gifted with vast navigable water resources, with the most prominent being the Indian Ocean, Lake Tanganyika, Lake Nyasa and Lake Victoria. The ports on the Indian Ocean act as gateways to East and Central Africa, while Lakes Victoria and Tanganyika play critical roles in inland transportation and have the potential for cruise tourism, and water sports. The main ports in the country are Dar es Salaam, Mwanza, Mtwara, Kigoma, Mbeya, and Tanga with another one (Bagamoyo port) that is currently under construction.

Thus, these ports play a major role in the growth of the economies

of the region. Coastal and inland waterways transport also plays an important role in transportation of goods and passengers. There are many challenges facing the Maritime administrations and Ports sectors in East Africa, including port congestion, poor infrastructural development, ageing ship repair facilities lack of human capacity and insecurity, among others.

In Tanzania, the Tanzania Shipping Agencies Corporation has the mandate to regulate, coordinate and oversee maritime affairs. Among other functions, the Authority is mandated to plan, monitor and evaluate training programmes to ensure conformity with standards laid down in the International Conventions on Standards of Training, Certification and Watch keeping (STCW), 78 as amended.

This body play a regulatory role for the maritime industry, which includes regulating the training for the maritime and issuing the Certificate of Competence (CoC) for seafarers, but are not involved directly in the training. The training institution offering Maritime Education and Training in Tanzania (DMI) is also regulated by the NACTVET, as well as Professional boards.

The contribution of maritime education and training to economic development can be analysed in various components including promotion of the growth of the maritime industry, improvements of ports operations, building the country's capacity to globally exportation of more human resources to the offshore, maritime transport and port sector.

Others include creation of more qualified and competent offshore and onshore workforce, expanding economic development, awareness creation, increase of gross domestic product (GDP), the Government earns more foreign currency remittances of seafarers and offshore technicians working with foreign companies.

3.0 PROMOTION OF THE GROWTH OF THE MARITIME INDUSTRY

According to (Demirel and Mehta, 2009) Maritime education and training are very vital to the maritime industry. Investing in seafarer education, training and certification as well as other maritime professionals will therefore promote the growth of the maritime industry. The overall contribution of maritime education and training to this is very important, dynamic, and fastest-growing sector of the economy cannot be underestimated.

4.0 IMPROVEMENTS OF PORT OPERATIONS

The shipping industry, as a global phenomenon, links the nations of the world through international trade. This activity cannot run without proper trained workforce and other professionals like the port managers, logisticians, shipping agents, shipbrokers and the like. There is therefore an absolute need to maintain a high level and effective standard of education and training for the workers.

5.0 BUILDING THE COUNTRY'S CAPACITY TO GLOBALLY EXPORTATION OF MORE HUMAN RESOURCES TO THE OFFSHORE, MARITIME TRANSPORT AND PORT SECTOR

The human element is very important in the maritime industry. Its relevance therefore, grows with the industry. It is best said that without education and training of ship captains, engineers and seafarers in particular, as provided by the STCW 78 convention as amended, advanced skills and competences will be greatly vulnerable and ship will be unsafe (Fei, 2018). The fluctuating demand for seafarers most often is due not only to income variations but also to the technical competence and attributes of the seafarers and to which all originate from the education and training given to them. The preceding analysis of the seafarer situation as an example,

however, points to the important role played by maritime education and training (Bach *et al.,* 2005; Winchester *et al.,* 2005). In this way, the education and training of shipping professionals within the region, also takes into account the local realities.

6.0 CREATION OF MORE QUALIFIED AND COMPETENT OFFSHORE AND ONSHORE WORKFORCE

The growth of the maritime industry may have some undesirable consequences on the environment. The human element is again seen to be very important to ensure the high standards of safety and guarantee of environmental protection and sustainability. The achievement of the United Nations sustainable development goals - SDG, cannot succeed without education and training.

Although education and training are important in the attainment of these SDGs, goal number 4 on quality education, in particular, is important. Obtaining quality education is the basis for the improvement of people's lives and sustainable development. Through continuing education and training, the maritime industry can be sustained. This is due to the rapidly changing socio-economic, political, and cultural environments. It is only through education and training that such volatility in the maritime sector can be easily; (Cunningham, 2015).

7.0 EXPANDING ECONOMIC DEVELOPMENT

Maritime Education and Training in this contemporary era proven to be very useful to the growing maritime industry (Cunningham, 2015). Largely, maritime education and training enhances growth, expansion, and positive change (Heirs, S. and Manuel, M. 2021). The views of many scholars regarding maritime education and training and influence on the maritime industry as seen above, are therefore similar.

Generally, the desire to work brings about changes in Science through discoveries and technology. Maritime education and training, therefore,

provides knowledge and skills needed by the shipping industry. Through maritime education and training, maritime safety is ensured.

Prior to accident causality, was the reliance of the maritime industry on the employment of multicultural crews. Though good, many misunderstandings coming from such a mixed crew were responsible for the many accidents that occurred. Maritime education and training, however, helps to narrow or eliminate such gaps (Horck, 2006).

8.0 AWARENESS CREATION

Another important contribution of maritime education and training to the economic development is the creation of awareness. The potential benefits of the maritime industry to the youths and other stakeholders can be understood better through the dissemination of information and the best way to do so is through education. This researcher believes that youths constitute future cadet trainees.

Once empowered with the necessary knowledge, skills, and competencies, they can pick up good and well-paid jobs as seafarers. This is most likely to have a positive effect on the reasoning of their peers who may eventually join the same jobs to the advantage of the maritime industry labour supply. This helps in building the career path for such interested persons (Cunningham, 2015).

9.0 INCREASE OF GROSS DOMESTIC PRODUCT (GDP)

Shipping activities and port authority are very instrumental in determining coasts and ocean development either directly or indirectly. Shipping as an international mode of transportation influences coastal settlements, hence economic development. Today, these aspects of shipping and ports seem to be collaborative in integrated coastal development concepts. Due to the relevance of the coastal and economic activities generated, shipping activities grow.

Maritime Education and Training provides an avenue for new

knowledge, greater professional values, and practices which are later used to manage both the actors and their activities, in relation to how shipping affects coastal development, its growth, and preservation (McConnel, 2002).

The government earns more foreign currency remittances of seafarers and offshore technicians working with foreign companies.

According to the United Nations Conference on Trade and Development the number of seafarers in Tanzania as per 2021 is 4,365. These people can be employed in other countries in the world since the Government of Tanzania, on 28 June 2017, ratified two ILO conventions – the seafarers' identity documents convention No 185 (2003) and the Maritime labour convention (MLC 2006) which enables seafarers to be employed in both local and international shipping companies, thus facilitating both individual and national incomes.

Ratification of the identity documents convention will not only boost creation of employment opportunities and reduce poverty, but also enables seafarers to benefit from training and skills acquired from local maritime education and training institution.

10.0 CHALLENGES THAT FACES SHIPPING INDUSTRY

The reviewed literature reveals that the shipping sector faces numerous challenges including but not limited to:-

a) Inadequate and poor use of modern technology tools hinders the growth of the industry.
b) Growth of ports not sustainable because of political infiltration.
c) Corruption is very present and a common practice at many ports.
d) The cost of training experts in the maritime sector is too high (many programmes are not present in the country.
e) Maritime professionals are not continuously trained on new ways of doing port business.

f) Inadequate number of female students interested in the seafarer profession.

g) The inclusion of maritime education and training in the curriculum at the secondary school level is good for the future of the maritime industry.

h) Continuous education and training improves port performance and growth.

i) The limited scope for the training of maritime professionals makes maritime education and training institutions unable to contribute much to the growth of the maritime industry.

j) Maritime education and training as a system is not a separate and so needs collaboration from stakeholders to be able to attain its objectives.

11.0 WAY FORWARD FOR IMPROVEMENT

Based on the findings presented above, for maritime education and training to effectively contribute to the economic development, the stakeholders in the sector such as shipping companies, Maritime Education and Training Institution, and the government, have to work singularly as undermentioned below:

12.0 TO THE GOVERNMENT/POLICY MAKERS

Ensuring sustainable growth of the industry, the government as the overseer should eliminate or reduce administrative blocks, which tend to delay decision-making and implementation. Devolution of managerial powers should equally be given to the various maritime districts to facilitate activities.

a) Stakeholders and the government should establish a curriculum document that meets international standards. Incidentally, the country's trained port personnel become employable internationally. This is most likely to boost local economies and encourage development.

b) Maritime positions should be headed and performed by experts in the various domains for better performance.

c) The government is encouraged to get into strong macro-policy for building the human resource capacity at both institutional and national levels.

d) Maritime Education and Training in Primary and Secondary Schools. To prepare the people and the society that will embrace this challenging future, therefore, needs lifelong all-engaging education and training, be it formal, informal, or digital. Therefore, training the primary and secondary school levels guarantees the sustainability of the maritime industry in the end, all things being equal. Without education and training to the young generation, the new challenges and opportunities for adaptation would be difficult hence fail to create the workforce that can be better trained for the future.

e) The cost of training experts in the maritime sector is generally too high. It is therefore highly recommended that the government has to subsidise the Maritime Education and Training Institution (DMI) so that it can provide more programmes which are found in foreign countries. This will help further reduce training cost and create greater awareness of the scope of the training.

13.0 TO MARITIME EDUCATION AND TRAINING INSTITUTION

a) Teaching and training by using modern technology instruments in both the training of maritime labour force and port operations is inevitable. This will not only help to reduce the dwell time within the ports but also cut down on corrupt practices within the industry.

b) More researches need to be done to uncover opportunities found in maritime industry which will help to create awareness in the society to grab those opportunities hence

further economic development.

c) There should be emphasis on the capacity building of maritime professionals especially the teachers who constitute the trainers. Still in this light, retraining and training programmes should be developed with expert to suit the prevailing demands.

d) Up to this moment it is important to include Maritime Education and Training in the curriculum at the secondary school level. This will help create greater awareness and arise the interest of the youths in a career and other maritime issues which is good for the future of the maritime industry.

e) It is highly recommended that effective monitoring of program execution and quality control systems should be put into use so that the Institution will continue producing highly qualified and competent experts in their areas of study.

14.0 TO THE SHIPPING COMPANIES

a) Shipping companies should continue to assist the government in supporting specialized higher institutions of learning in training maritime professionals.

b) Shipping companies should embark on periodic infrastructural development and upgrade of their level of their personnel through continuous education and training, and technology to meet current standards.

c) Shipping companies should employ qualified personnel according to their areas of specialization so that they perform their duties to bring about the expected outcomes.

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INVESTIGATING THE NEEDS OF COMMUNICATION SKILLS MODULES FOR STUDENTS IN MARITIME TRAINING INSTITUTIONS

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ABSTRACT

This study investigates the needs of Communication Skills Modules for Students in Maritime Training. The aim is to design Communication Skills Modules (CSM's) that cater the needs of the industry. The study involved a total of 70 students from Dar es Salaam Maritime Institute who were randomly picked, whereas the respondents were selected through convenience sampling. The study used questionnaires, interviews and a group discussion from maritime students, module-specialists and human resource managers working in locally-based maritime industry to collect the data.

These tools found out actual information about the learners, existing language proficiency and language use outside the classroom. The second part found out their perceived needs of different aspects of language skills areas. The third part was to understand language and skills the learners need to attain in order to function successfully in the target situation.
Finally, the study assessed the cognitive and affective needs of maritime students in order to perform successfully in both academic and professional environment. The findings shows that there is a clear indications for the need of communication skills tutors to get used to new approaches of teaching communication skills that are no longer merely directed towards the development of students' responsive skills and expert or professional vocabulary. CSM's need to be more collaborative, nurturing students' useful skills by revealing them to both realistic and virtual field-related careers and making use of reliable materials to the students' area of specialization. Part of the CSM's emphasized on educating students' intercultural business consciousness, necessary for their professional careers. Academically, the current study proposed a framework to needs analysis, and suggests ideas to make teaching/learning process helpful for all stakeholders. It is the researcher's expectation that the results of this study will be a valuable reference when developing new CSM's curriculum or revising existing ones.

Keywords: Communication Skills, Maritime Students, Academic Writing

1.0 INTRODUCTION

The importance of communication skills in the maritime sector has been recognized by various organizations, including the International Maritime Organization (IMO). The IMO's International Convention on Standards of Training, Certification and Watchkeeping for Seafarers

(STCW) requires seafarers to have a basic level of literacy and numeracy to meet the demands of their work (IMO, 2017).

Effective communication skills play a pivotal role in maritime industry, where clear and efficient communication is crucial for ensuring the safety and success of maritime operations. As maritime professionals engage in diverse interactions with colleagues, superiors, crew members, and port authorities from different cultural backgrounds, their ability to communicate effectively becomes paramount (IMO, 2017). Thus, understanding and addressing the specific needs of communication skills modules for students in maritime training institutions is essential to prepare future seafarers for the challenges they will encounter in their careers.

In recent years, there has been a growing recognition of the significance of communication skills within the maritime sector. Not only does communication facilitate seamless collaboration and coordination on board ships, but it also enhances interactions with shore-based stakeholders, such as clients, agents, and regulatory authorities (Keefe andCopeland, 2011). Consequently, maritime training institutions have an increasing responsibility to equip their students with the necessary communication competencies to excel in their professional endeavors.

According to Sikiti (1998), "communication is a determined process of expressing, receiving and understanding messages containing factual information, feelings, ideas and needs by two or more individuals through common symbols." Communication Skills is one of the fundamental modules taught in most maritime institutions. Asemanyi (2015) adds that communication skills is a module that enables students to have knowledge or the capacity to use the necessary skills to communicate properly.

The nature of CSM appears unique from other subjects. Tortor (2006, cited in Asemanyi, 2015) pointed out that the Communication Skills course in maritime institutions is designed to provide students with the necessary skills to communicate effectively in the maritime industry. The course typically covers various topics related to communication, including interpersonal communication, business communication, and

cross-cultural communication.

Interpersonal communication topics may include active listening, responding to messages, and nonverbal communication. Business communication topics may include writing effective emails and memos, giving presentations, and negotiating. Cross-cultural communication topics may include understanding cultural differences, managing intercultural conflicts and developing cultural awareness.

Similarly, the modules cover specific communication skills relevant to the maritime industry, such as communicating effectively with port officials and crew members from different cultural backgrounds over radio or other communication devices. Additionally, the course emphasizes the importance of communication for safety and efficiency in the maritime industry. This may include case studies, examples of communication breakdowns that have led to accidents or delays, and future strategies for preventing such breakdowns.

Overall, the Communication Skills course in maritime institutions is designed to provide students with a solid foundation in communication skills and their application in the context of the maritime industry (Tortor, 2006 (cited in Asemanyi, 2015). The course aims to equip students with the necessary skills to communicate effectively and contribute to safe and efficient operations in the industry. Thus, communication skills as a course expose students to conceptual skills like sentence pattern, concord, ambiguity, and many others.

The study by Wambura et al. (2018) investigated the communication skills of maritime students in Tanzania and found that the students understood the importance of communication skills in the maritime industry. However, the study also identified gaps in the student's communication abilities, particularly in active listening, speaking clearly, and using appropriate language.

This study aims to investigate the communication needs of students in maritime training institutions in Tanzania and assess the adequacy of current CSM. The study utilized a mixed-methods approach, including surveys, interviews with students and faculty members, and a review of existing literature on communication skills in the maritime industry.

By identifying the specific communication needs of students and assessing the effectiveness of current CSM, this study aims to provide recommendations for improving communication skills training in maritime training institutions in Tanzania.

2.0 COMMUNICATION SKILLS IN MARITIME INSTITUTIONS

The problem in this study is the lack of understanding of the specific communication skills needed by students in maritime training institutions in Tanzania. While communication skills are essential for success in the maritime sector, there is a lack of research on the specific needs of CSM for students in Tanzania's maritime training institutions. This gap in the literature is significant because it hinders the development of effective CSM that can prepare students for the demands of the industry.

The maritime sector is a crucial part of Tanzania's economy. Still, it faces numerous challenges that affect its efficiency and safety. Poor communication is one of the main causes of accidents, errors, and delays in the sector (IMO, 2019). Therefore, it is essential to equip maritime professionals with the necessary communication skills to ensure safe and efficient operations. The lack of research on the specific communication skills students need in maritime training institutions in Tanzania is a significant problem because it hinders the development of effective training programs. CSM that are not tailored to the specific needs of students may not adequately prepare them for the industry's challenges (Said, Zhuang, and Chen, 2019). As a result, students may struggle to communicate effectively with colleagues and stakeholders, leading to inefficiencies and safety risks.

This study addresses this problem by investigating the specific communication skills students need in Tanzania's maritime training institutions. The results of this study will inform the development of effective CSM that can prepare students for the demands of the industry, thus contributing to the sector's efficiency and safety.

According to the Bank of Tanzania (2021), the maritime sector plays

a critical role in the economic development of Tanzania. According to the World Bank, Tanzania's ports handle over 90% of the country's international trade and provide a gateway to landlocked countries in East and Central Africa (World Bank, 2019). Effective communication skills are crucial for the success of maritime professionals in today's globalized and interconnected world. Poor communication can lead to errors, delays, accidents, and even loss of life (IMO, 2019).

Most maritime institutions face challenges accessing up-to-date resources and materials to support their communication skills programs. Limited resources can lead to ineffective communication skills training and can negatively affect the quality of education provided to the students (Mngomezulu, 2017). Furthermore, the lack of appropriate resources may also result in a limited pool of qualified and experienced lecturers. Many maritime institutions in developing countries face difficulties recruiting experienced and qualified instructors due to insufficient funds, lack of incentives, and limited job opportunities. This can result in a staff shortage to effectively teach communication skills, leading to substandard education (Abdullah *et al.,* 2018).

Therefore, maritime institutions should prioritize investing resources and facilities for communication skills training. This may involve collaborating with industry partners to provide access to up-to-date resources and tools, funding research and development initiatives, and offering professional development opportunities to lecturers to enhance their teaching skills (Mngomezulu, 2017). Overall, investigating the needs of CSM for students in maritime training institutions has several potential benefits, but there are also some potential drawbacks to consider. Institutions should carefully plan and execute their investigation to maximize the benefits while minimizing the challenges.

3.0 METHODOLOGY

The study employed descriptive research design and adopted qualitative research approach. Descriptive design was selected for it systematically describes a situation or phenomenon in a targeted population. The study

used three methods of data collection. The methods were observation, questionnaire and interview. Observation, questionnaire and interview guides were used as data collection tools.

To obtain the data for research question number 1, researchers documented Maritime English curriculum; a document was approved by NACTVET. Furthermore, interview and documentation of teachers' lesson plans were used to collect data for question number 2. The targeted population was standard three teachers.

Therefore, standard three related curriculum materials were used for documentation and only standard three teachers were interviewed. The sample of this study was a composition of four schools from two different districts and eight standard three teachers, two from each school. The selection of the two districts was purposive and based on the criteria that these districts were representing urban/rural locations. It was important to consider these two districts to see how geographical locations would have influenced practices in language teaching.

Further, the selection of teachers in the sample was also purposive because only standard three teachers were sampled for the study. The fact that standard three was chosen as a case in this study based on the reason that it is a class where English language is taught for the first time. Thus, it was thought to be a stage where students should be involved to a number of activities for a better understanding of this new subject. In general, the collected data were thematically analysed.

4.0 RESULTS AND DISCUSSION

A total of 70 students from three maritime training institutions completed the survey on communication skills. The results showed that the most important communication skills identified by students were listening (84%), speaking (78%) and writing (72%). These were followed by nonverbal communication (63%), intercultural communication (56%), and teamwork (50%).

4.1 Qualitative Findings

In-depth interviews were conducted with 30 students and 10 instructors from the three maritime training institutions. The analysis of the interview data identified three main themes related to the needs of CSM for students in maritime training institutions.

Theme 1: Relevance and applicability

The participants emphasized the importance of relevant and applicable CSM to their future maritime industry careers. They suggested that the modules focus on practical skills such as communicating with crew members, port authorities, and customers and dealing with emergencies and crises.

Theme 2: Instructor qualifications and teaching methods

The participants highlighted the importance of qualified, experienced instructors who effectively teach communication skills. They suggested that instructors use various teaching methods, including role-playing, simulation exercises, and case studies, to enhance students' learning experiences.

Theme 3: Assessment and feedback

The participants emphasized the importance of assessment and feedback in communication skills training. They suggested that assessments should be integrated into the training program to measure students' progress and provide feedback to help students improve their skills.

4.2 Technical Communication Skills

The research findings indicate that maritime students possess a solid foundation in technical communication skills, such as using radio communication protocols and understanding maritime terminology. However, there is a need for further emphasis on enhancing their proficiency in these areas to ensure clear and effective communication during critical operations.

4.3 Interpersonal Communication Skills

The investigation reveals that interpersonal communication skills require significant attention in maritime training institutions. Students should be equipped with the ability to adapt their communication styles to various cultural backgrounds, resolve conflicts, and engage in effective teamwork. The research highlights the importance of developing active listening, empathy, and non-verbal communication skills for successful collaboration on board ships.

4.4 Language Proficiency

The findings emphasize the need for improving students' language proficiency, particularly in English, as it is the primary language of communication in the maritime industry. Students with a strong command of English exhibit better communication competence and are more effective in conveying critical information.

4.5 Practical Learning Experiences

The research underscores the significance of incorporating practical learning experiences within communication skills modules. Role-playing exercises, simulations, and case studies enable students to apply their communication skills in realistic maritime scenarios, enhancing their ability to handle real-time communication challenges.

4.6 Industry Alignment

The investigation highlights the importance of aligning communication skills modules with industry requirements. Collaboration with industry stakeholders, such as shipping companies and professional associations, is crucial for keeping the curriculum up-to-date and relevant to the evolving needs of the maritime sector.

4.7 Evaluation and Feedback

Continuous evaluation and feedback mechanisms are essential for assessing the effectiveness of communication skills modules. Feedback from students, alumni, and industry professionals allows for refinement

and improvement of the curriculum, ensuring its efficacy in preparing students for successful maritime careers.

Integration of Findings

The findings from the quantitative and qualitative data were integrated to provide a comprehensive understanding of the needs of CSM for students in maritime training institutions.

The results suggest that students' most important communication skills are listening, speaking, and writing and that the modules should focus on practical skills relevant to the maritime industry. In addition, the findings highlight the importance of qualified and experienced instructors who use various teaching methods, as well as assessments and feedback, to help students improve their skills.

Overall, the research findings indicate the need to strengthen both technical and interpersonal communication skills in maritime training institutions. Enhancing language proficiency, providing practical learning experiences, and fostering collaboration with industry stakeholders are key factors in addressing these needs and ensuring that students are equipped with the necessary communication competencies to excel in the maritime industry.

5.0 CONCLUSIONS

The investigation into the needs of communication skills modules for students in maritime training institutions has shed light on the significance of effective communication in the maritime industry. Through an in-depth analysis of existing literature, industry reports, and conference papers, this research study has identified key areas that require attention to ensure the development of well-rounded maritime professionals equipped with strong communication competencies.

The findings of this study emphasize the importance of incorporating both technical and interpersonal communication skills into the curriculum of maritime training institutions. While technical communication skills, such as radio communication and maritime terminology, remain essential

for efficient and safe operations, interpersonal communication skills have emerged as equally crucial. The ability to adapt communication styles to different cultural backgrounds, engage in effective teamwork, and resolve conflicts is vital for building successful working relationships both on board ships and with shore-based stakeholders.

Furthermore, this research study has highlighted the need for practical and experiential learning opportunities within communication skills modules. Traditional classroom-based lectures alone are insufficient to develop the necessary communication competencies for real-world maritime scenarios. Integrating role-playing exercises, simulations, and case studies can provide students with practical exposure and enhance their ability to apply communication skills in authentic situations.

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ANNEX 2

CONFERENCE SPEECHES

OPENING SPEECH BY THE MINISTER, MINISTRY FOR BLUE ECONOMY AND FISHERIES DURING THE 2ND BLUE ECONOMY CONFERENCE AT JULIUS NYERERE INTERNATIONAL CONFERENCE CENTRE HELD ON 27TH JUNE, 2023 AT DAR ES SALAAM

- Chairman, Board of Governors of Dar es Salaam Maritime Institute, Capt. Ernest Bupamba,
- Rector, Dar es Salaam Maritime Institute, Dr. Tumaini S. Gurumo,
- Keynote speakers:
    1. Capt. Gilbert Mokiwa
    2. Mr. Donald Chidowu
- Head of Academic Institutions and or their representatives from sister institutions present,
- Distinguished participants,
- Ladies and gentlemen,

I would like to begin by expressing my deep appreciation to the Management of DMI for the kind invitation extended to me and the entire community to participate in this 2nd DMI Blue Economy Conference at Julius Nyerere International Conference Centre.

To the sponsors, your support is a big contribution to this important and very relevant Conference which will greatly contribute to shaping the future of the maritime industry in Tanzania. The outcome of this 2nd conference is expected to once again serve as a road map in the sustainable development of the blue economy and, indeed, ocean governance in our country.

To the participants, I am very pleased that you accepted the invitation to join and work with DMI in the spirit of cooperation on this important

theme namely "Contribution of Maritime Sector in Tanzania for Sustainable Economic Development."

I believe that this theme echoes with the objective of the conference and it is at the core of the blue economy concept. The general objective of this conference and the ensuing discussion is to explore and provide guidance on how our government and the community at large may leverage the blue economy for sustainable wealth creation and economic growth.

Ladies and gentlemen,

It is my belief that nobody in this room needs any persuading that shipping, together with all its related maritime activities, is a critical part of the global supply chain and equally an essential component of any program for future sustainable economic growth.

By facilitating and providing improved access to basic materials, goods, services and products through commerce, and assisting in the creation of prosperity among people, shipping is helping to lift people out of poverty.

Accordingly, not only Tanzania but also the world needs a sustainable and efficient shipping industry to keep the wheels of our global society in constant motion in a safe, secure and sustainable manner.

The importance of the world's oceans and Blue Economy in particular for our future is undeniable. This importance is underlined by the UN 2030 Agenda and its Sustainable Development Goals, in particular, SDG 14, including the call for action by the UN Oceans Conference in 2017.

In particular, the concept of Blue Economy has a tremendous potential for boosting economic growth, employment and innovation as the ocean economy encompasses ocean-based industries such as shipping, fisheries, renewable energies, maritime transportation, sea ports, tourism and marine biotechnology as well as its natural assets, such as carbon dioxide absorption. All these aspects calls for maritime education and training in line with people's awareness and this can best be attained through conferences.

As you all know, all Ministries are core stakeholders to blue

economy. This scenario reflects the fact that, realizing the full potential of Blue Economy in our country will require a strong collaboration and cooperation among all ministries.

Worth noting also that, as the Ministry responsible for shipping affairs, the Ministry of Works and Transport is, as you all understand, heavily engaged in matters concerning the concept of blue economy. In particular, the Government under the distinguished leadership of Her Excellency Hon. Dr. Samia Suluhu Hassan has and is continuing to invest heavily in the shipping industry and such measures have already positively impacted the sustainable development of our country in terms of blue economy concept. A key objective for the Government is to ensure shipping can continue making its contribution to the sustainable growth of our economy.

Excellences, distinguished panelists and guests,

At this juncture, please allow me to congratulate Dar es Salaam Maritime Institute for organizing the blue economy conference once again. With this strategy, you prove to the Tanzanian community that you are determined to fulfill your responsibilities to educate us sincerely about the whole concept of the blue economy, especially to recognize the opportunities brought by this concept so that we can finally get rid of poverty.

Finally, I wish you all a fruitful discussion and look forward to sustainable outcomes from the Conference. I am confident that the exchange of ideas will make a positive contribution towards the objective we all share – to contribute to sustainable development and a thriving blue economy.

Good morning honourable Ministers, The Board Chair and the management, distinguish guests, ladies and gentlemen,

Finally, it's the second Blue Economy, let us all applause this initiative First of all I would like to congratulate the Dar es Salaam Marine Institute for taking such great initiative in arranging this meeting again. As we all know Dar es Salaam Maritime Institute (DMI) was established by Act of Parliament No. 22 of 1991 to cater to the greater needs of the Shipping Industry in the region. The Institute (DMI) originated from what was known as Dar Es Salaam Maritime Training Unit (DMTU), which was established on the 3rd July 1978 as a training wing of Tanzania Coastal Shipping Line (TACOSHILI) to fulfill the need of well-trained seafarers.

I would like to touch on our achievements in terms of Maritime Industry in Tanzania mainland and Zanzibar from Tanzania's maritime sector boasts key ports such as Dar es Salaam and Zanzibar, with Dar es Salaam Port serving as a vital gateway for East African trade. The government actively invests in infrastructure development to meet growing trade demands, aiming to enhance efficiency and capacity while addressing congestion issues.

In terms of shipping connectivity, Tanzania mainland collaborates with regional and international partners to improve maritime routes, facilitating the movement of goods and people. Efforts to strengthen the regulatory framework emphasize safety, security, and environmental sustainability in maritime activities.

Zanzibar plays a strategic role, positioning itself as a regional maritime hub through initiatives like port development and the promotion of maritime-related tourism. Tanzania, as a whole, explores opportunities in the blue economy, focusing on sustainable use and conservation of marine resources, including fisheries management and aquaculture.

Finally, I wish you all a fruitful discussion and look forward to sustainable outcomes from the Conference.

Good afternoon honourable Ministers, The Board Chair and the management, distinguish guests, ladies and gentlemen,

Maritime sector is important to societies. But the public has a limited knowledge on its influence and role in economic development. Maritime sector brings employment opportunities and other economic benefits. Shipping industry has increased its fleet and capacity to fish. Shipping is a long-time mode of transportation. Shipping has connected numerous areas in the coastal cities, Dar es Salaam included. Dar es Salaam has been an essential communication hub and has utilized water transportation.Maritime activities continue to expand and bring benefits to all persons across the world.

This has been caused by commercial fishery and cruise companies which are part of the future industry, using maritime sector as a catalyst for socio-economic development and international competitiveness.

It refers to exploitation, preservation and regeneration of the maritime environment. It is about sustainable use of marine resources for economic growth, improved livelihoods and job creation while protecting health of marine and costal ecosystems. Sustainable development is a balanced economic growth free of indebt Ness and over-consumption of factors of production, and activities that take account of the environment for future generations.

Activities Under Blue Economy

- Fisheries and fish processing industry.
- Shipbuilding and repair.
- Ports.
- Warehouse and water projects.
- Marine transport and coastal tourism.
- Aquaculture.
- Martine extraction of oil and gas.
- Desalination.
- Coastal environmental protection.
- Ocean energy which is about all forms of renewable energy derived from the sea and blue bio-economy/biotechnology.

ENABLERS OF BLUE ECONOMY

These refer to the above-named activities of the blue economy. They have been present since time immemorial. The law and practice has developed to govern these areas in the peculiar way;

Fisheries Sector

It is one of the established sector which is old as the human race. The Continental Shelf Convention of 1958 under Article 2(1) – (4) states on the rights of exploration and exploitation of natural resources and over the continental shelf. The provision gave rights to coastal states but did not put limitations of the continental shelf clearly. Parties had to agree with the equidistance principle.

Fish Processing Industry

The industry is about processes associated with fish and its products from the time the fish are caught to when the final product is delivered to customers. Today, fish processing is done by artisan fishermen, or on-board fishing, or fish processing levels, and fish processing plants. Global fish production has reached an estimate of 179 million tonnes in 2018 and with a total dish sales value estimated at US$401 billion of which 82 tonnes valued at US$250 came from aquaculture production.

Shipbuilding and Repair Sector

Shipbuilding is done by contracts for sale and the scope is limited to agreements to buy and sell ships. Ship repairs are naval auxiliary ships designed to provide maintenance and support warships and commercial. Ship repair for commercial and military are referred to as naval engineering.

The Ports Sector

A port is defined as a place within land protected against waves and winds, and affording vessels a place of safety. It is a place in which vessels may arrive and discharge their cargos. They are part of the internal waters of a coastal state. The internal waters are comprised of bays, estuaries, and ports, and waters enclosed by straight baselines. According to public international law, the ports of every State must be open to foreign vessels and can only be closed when the vital interests of the State so require.

Coastal Tourism Sector

Tourism is the act of travelling or sightseeing, especially away from one's home. It is the industry of sightseeing and travelling. In respect of maritime setting, the marine tourism sector includes activities such ocean and coastal traditional economic lines and there includes activities such as ocean and coastal water transport, hotel and restaurants, island and beach resorts, sea sports and recreation. The largest industries contributing trillions of dollars and support the livelihood of an estimated one in ten people worldwide.

In many States, tourism is viewed as an engine of economic growth and a pathway for improving fortunes and communities that may otherwise struggle to grow and prosper.

Aquaculture

It is the farming of aquatic organisms, including fish, molluscs, crustaceans and aqua plants. It includes intervention in the rearing process to enhance production, such as regular stocking, feeding, protections from predators, etc. Aquaculture is the equivalent of farming on land. It covers farming of animals, crustaceans, fin fish and molluscs, plants such as seaweed and freshwater macrophytes.

The Mariculture Sub-sector

This is part of aquaculture, it is a specialized branch which involves

cultivation of marine organisms for food and other products in the open ocean, an enclosed section of the ocean, or in tanks. This is the aquaculture that involves the use of sea water, it can be done next to an ocean/sea with a sectioned off part of the ocean or its ponds separate from the ocean or sea, but containing seawater all the same.

Marine Oil and Gas Industry Sector

The oil sector's definition can be derived basing on their multiple types from heavy to light crude oil based on the trade specificaitons. Fuel is a common term meaning a wide range of fuels that includes other forms such as kerosene and diesel. The reservoirs are located underneath the ocean floor and this is an area which becomes relevant to the marine oil sub sector.

Gas Sub-sector

Gas extraction is part of the emerging sectors in the blue economy. Raw natural gas that comes from oil wells is called 'associated gas' as it can exist separately from oil in the formation of (free gas). In the 1990s, offshore oil and gas production accounted for around one-third of the total world production and some estimate that 70% of the worlds undiscovered reserves lie offshore.

Desalination Emerging Sector

It is the process of removal of salt from sea water so as to make drinking water. It is done by thermal distillation, electrical and pressure desalination processes.

Coastal Environmental Protection

These measures aim at protecting the coast against coastline retreat, and thus, protecting infrastructure, the coast and hinterland from erosion at the expense of losing the beach and dynamic landscape.

THE UN CONVENTION ON THE LAW OF THE SEA (UNCLOS), 1982

The Convention was done at Montego Bay on the 10th of December 1982. It reflects the status of jurisdiction by States, existing in the previous conventions, high seas, continental shelf, territorial and contiguous zone conventions. It altered the political geography of the world through enclosing large areas under the national jurisdiction of sovereign States, for ocean governance and on how States should act in discharge of responsibilities under the Convention.

Provisions of Law on Blue Economy Emerging Sectors under UNCLOS

UNCLOS provides that coastal States can exercise rights in exploring and exploiting its natural resources. Resources include minerals and other non-living resources of the seabed and sub-soil together with non-living resources of the seabed. Tanzania stands benefits from blue economy sector as Article 56(1)(a) of the UNCLOS allows States in exclusive economic zone to benefit from the same.

A caution is raised that coastal or land locked States should enjoy the freedoms under Article 87 of navigation and overflight and laying submarine cables and pipelines.

Coastal Environmental Protection

Part XII of the UNCLOS, 1982 provides for the obligation of States to protect and preserve the environment. This includes reduction of pollution of the marine environment from any source.

Ocean Energy Emerging Sector

Articles 56(1)(a) and 77(4) give coastal States sovereign rights in exploring and exploiting the economic zone or the continental shelf for production of energy form water, currents and winds. The oceans

represent a vast and largely unexploited source of energy in the form of surface waves, fluid flow, salinity gradient thermal energy. Different devices have been used by the USA such as:

- Wave power convers in open coastal areas with significant waves.
- Tidal turbines placed in coastal estuarine areas.
- In-stream turbines for fast moving rivers.
- Ocean current turbines in areas of strong marine currents.
- Ocean thermal energy converts in deep tropical waters.
- Aquaculture subsector.

Article 61(2)(3) of the UNCLOS allow coastal States to determine the allowable catch of the living resources in its exclusive economic zone. This should be done when considering the best scientific evidence and proper conservation and management measures which protect the exclusive economic zone from over exploitation.

Again, the measures should be designed to maintain or restore population of harvested species and take into account needs of fishing communities, and fishing patterns. The law insists on scientific fish farming or aquaculture for sustainable use of resources for sustainable development of the people of a nation, especially coastal communities that have meagre resources.

Tanzania Zanzibar's Blue Economy

Tanzania Zanzibar is formed by two major aisles, Unguja and Pemba and other small islands. Zanzibar has territorial sea, contiguous zone and her continental shelf in which blue economy can be exercised. About 98% of Zanzibar's international trade by volume is seaborn. The blue economy activities contribute to 29% of the Zanzibar GDP and employs one-third of the population.

The tourism sector takes 30% of all revenue of Zanzibar and it contributes to a greater part of the GDP. The sector has provided more than 72,000 jobs and contributes to 80% of the foreign currency. By November 2019, Zanzibar had 509 hotels at different levels of hotel standards, 26 of which were five-star hotels, 20 four-star hotels and

other at different levels. In 2018, there were 520,000 tourists and in 2019 there was an increase to 538,268 tourists who visited Zanzibar. This was an increase of 3.4%. Thus, tourism is a leading sector to Zanzibar's economy in the contribution of GDP.

Zanzibar has implemented the integrated strategic action plan and the "Big Z" project to increase value of tourism of through widening the scope, quality or excellence and uniqueness of products served to tourists. The aim is to;

- Increase foreign tourists from 538,264 in 2019 to 850,262 in the year, 2025;
- Increase foreign tourists, days of stay at the average of annual seven days in 2019 up to 8 days in the year, 2025; and
- Increase expenditure by a foreign tourist at the average of US$262 per day in 2019 up to US$350 in the year, 2025.

Fisheries Sector

Fishery activities are as old as Zanzibar. They involve deep sea area of 12 nautical miles through the deepest area that is involved in Unguja and Pemba is 4,000 and 2,720 Kilometers, respectively. The BE of Zanzibar is already in other sectors of blue economy if not of emerging blue economy sectors, likewise, in exploration and exploitation of oil and gas, as well as seaweeds.

Seaweed Production

Seaweed was introduced to Zanzibar in 1988. Seaweed farming currently employs many individuals especially women who in 2014 were about 2,500. An upwards of people (150,000) benefit indirectly from the industry. Zanzibar seaweed is in demand, but the farming takes place in deep seawater and is highly specialized. Women farmers are unable to farm the high value variety. Seaweed farming has fixed-rate sales with agents and it limits the value of the farmer's seaweed.

In the north-east of Unguja, a project was introduced and helped 2,500 women farmers to grow better quality and made more money from their harvest. Their projects included;

3. helping them to produce higher-quality seaweed by training them in deeper water cultivation techniques;
4. helping them to add extra-value to their harvest by developing processing facilities such as drying the seaweed and extracting products like agar (a gelatinous material or food additive obtained from the marine algae or seaweed), and carrageenan (a food additive made from purified extract of red seaweed) that can be sold for extra income; and
5. supporting the women in farming groups that can make or access small loans to group members and also negotiate collectively to get better prices for their seaweed.

Conclusion

Maritime sector has contributed greatly to many nations since time immemorial regarding all maritime sectors in totality for development of societies and states. The UNCLOS, 1982 improved much more in the international customary law as know and the precedent of conventions, especially 1958, as regards to the BE. The UNCLOS has contributed significantly to marine scientific research and transfer of technology from developed nations to developing states including SIDS, Zanzibar inclusive. Scient and technology as reflected in the UNCLOS has contributed greately in marin scientific research and transfer of technology to the workd at large and in particular to developing states.

CLOSING REMARKS BY HON. SULEIMAN MASOUD MAKAME, MINISTER OF THE MINISTRY FOR BLUE ECONOMY AND FISHERIES, ZANZIBAR DURING CLOSING CEREMONY OF THE 1ST BLUE ECONOMY CONFERENCE AT JULIUS NYERERE INTERNATIONAL CONVENTION CENTRE ON 22ND JUNE, 2022 AT DAR ES SALAAM

- Chairman, Board of Governors of Dar es Salaam Maritime Institute, Capt. Ernest Bupamba.
- Rector, Dar es Salaam Maritime Institute, Dr. Tumaini S. Gurumo.

Keynote speakers

- Head of Academic Institutions and or representatives from sister institutions present,
- Distinguished participants,
- Ladies and Gentlemen,

I would like to express my warmest thanks to Dar es Salaam Maritime Institute for inviting me to participate in this conference

As has been said earlier, this is the second time to have the conference on blue economy concept convened in Tanzania. I believe that, all of us have obtained a fruitful discussion in this 2nd Blue Economy Conference whose main theme is "Contribution of Maritime Sector in Tanzania for Sustainable Economic Development." For sure, we have learned a lot from the keynote sessions delivered by the amazing keynote speakers and discussion sessions which have been delivered by very interactive conference discussants. Equally, invited speakers have shared their interesting experience. On behalf of the

host, thank you for delivering such important materials so that all of us can deepen our knowledge about the maritime sector in general and particularly blue economy opportunities.

Ladies and Gentlemen,

We are all witnesses that our Heads of State are determined to invest heavily in the blue economy as stipulated in the 2022/2023-2025/2026 National Development Plan. We equally understand that, apart from maritime training and education, Dar es Salaam Maritime Institute is the sole institution vested with a duty to offer maritime consultancy to the government and other institutions. Now that government leaders have set goals on blue economy, the duty which remains is for Dar es Salaam Maritime Institute to work and see that blue economic benefits in Tanzania are realized. In this regard, I urge you to carry out as much maritime research as possible so that you can be able to offer tangible consultancy.

Ladies and Gentlemen,

Now that we have come to the end of this conference, it remains for me to thank the host Dar es Salaam Maritime Institute once again for inviting me to close this excellent conference, and I hope that you have all found it a fruitful event, so to speak!

A special thank you goes to Conference Coordinator, organizing committee members and not to forget all DMI staff as without their assistance this conference would not have been possible to arrange.

To this end, it is a great pleasure for me now to officially declare postponement of the 2nd DMI Blue Economy Conference (2023).

Thank you!

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ANNEX 3
LIST OF SPONSORS

Conference Sponsors

Tanzania Shipping Agencies Corporation (TASAC)

Association of Women in the Maritime Sector in Eastern and Southern Africa (WOMESA), Tanzania Chapter

ANNEX 4

CONFERENCE PROGRAMME

Conference Day: Tuesday, 27th June, 2023

Date	Time	Description	Resource Persons
27th June, 2023	0630 - 0830	Arrival and Registration	DMI MC
	0830 - 8:40	National and EAC Anthems	All Participants
	0840 - 0845	Welcome Remarks	Dr. Tumaini Shabani Gurumo, Ag. Principal, DMI
	0845 - 0855	Keynote Speakers, Russia Ambassador	Russia Ambassador
	0855 - 0905	Keynote Speaker, Seychelles Ambassador	Seychelles Ambassador
	0905 - 0915	Statement by Chairperson for Board of Governors of Dar es Salaam Maritime Institute	Capt. Ernest Bupamba
	0915 - 0925	Official Address	Hon. Masoud Makame (MP), Minister for Blue Economy and Fisheries (SMZ)
	0925 - 0945	Keynote Speech STCW Contribution of Maritime Transport Blue Economy and Law of the Sea	 Chief Mayagilo Capt. Gilbert Mokiwa Mr. Donald Chidowu
	0945 - 0955	Group Photo	All Participants
	0955 - 1020	**Tea Break**	**-All Participants**
Sub-Theme 1: Maritime Project Financing and Investment			
Date	**Time**	**Paper**	**Author(s)**
	1020 - 1030	The Use of Cashew Nut Solution Liquid for Offshore-gas Well Drilling Campaign in Tanzania. A Value Addition Approach	Daniel Charles Rukonu

27th June, 2023	**1030 - 1040**	Pressure Matching: Actual Pump pressure Versa Via simulated friction pressure drop in 17 ½-inches	Daniel Charles Rukonu
		Section for offshore gas well in Tanzania.	
	1040 -1050	Discussion on Maritime Project Financing and Investment	Moderators Dr. Jovin Mwemezi Capt. Mussa H. Mandia
Sub-Theme 2: The Impact of Science and Technology			
Date	**Time**	**Paper**	**Author(s)**
27th June, 2023	**1050 - 1100**	Assessing the Effectiveness of Marine Robotics Technologies for Marine Oil Spill and Micro plastic Mitigation: A Comparative Study	Michael Maiko Matonya
	1100- 1110	Offshore Wind Energy-Tanzania Unexploited Offshore Renewable Energy Resource. A Review	Enock Michael Kandimba
	1110 - 1120	Analysis of Electronic Commerce Payment and Security Systems to the Development of Networking System	Leonce Mwesiga
	1120 - 1140	Discussion on the Impact of Science and Technology	Moderators Prof. Matobola Joel Mihale Prof. Costa Mahalu-Moderator
Sub-Theme 3: Blue Economy Opportunities			
Date	**Time**	**Paper**	**Author(s)**
27th June, 2023	**1140 - 1150**	Barriers Facing Fishery and Fishing Industry in Tanzania.	Athuman Ismail Buko
	1150 - 1200	Discussion on the Blue Economy Opportunities	Mr. Julias Nguhulla

Sub-Theme 4: Maritime Safety, Security and Environmental Protection			
Date	**Time**		
27th June, 2023	**1200 - 1210**	A Review of a Game-Changer for Marine Vessels: Replacing Internal Combustion Engines with Electric Motors to Eliminate Emissions.	Anaeli Elibariki Mtui
	1210 - 1220	A Review on the impacts of ship greenhouse gas emissions and preventive measures under IMO instrument.	I, K, Mpapi
	1220 - 1230	Discussion on Maritime Safety, Security and Environmental Protection	Rtd General S.S. Omary-Moderator
Sub-Theme 5: Maritime Transport, Ports and Logistics			
Date	**Time**	**Paper**	**Author(s)**
27th June, 2023	**1230 - 1240**	Maritime Welfare: Addressing the Challenges and Best Practices in Promoting the Physical and Mental Well-Being of Seafarers	Elvis Wellspring Abayo
	1240 - 1250	Discussion on Maritime Transport, Ports and Logistics	Dr. John N. Layaa-Moderator
Sub-Theme 6: Maritime Law and Policy			
Date	**Time**	**Paper**	**Author(s)**
27th June, 2023	**1250 - 1300**	Tanzania's Legal Regime for Compensation in Carriage of Passengers by Sea	Ms. Hiacinter Rwechungura
	1300 - 1330	Discussion on Maritime Law and Policy	Capt. Ibrahim M. Bendera

	1330 - 1400	Lunch Break	All Participants
Sub-Theme 7: Maritime Education and Training			
Date	**Time**	**Paper**	**Author(s)**
27th June, 2023	**1400 - 1410**	The Contribution of Maritime Education and Training to Economic Development in Tanzania	Elinathan Blasius
	1410 - 1420	Investigating the needs of Communication Skills Modules for Students in Maritime Training Institutions	Mashambo
	1420 - 1430	Discussion on Maritime Education and Training	Moderators Mr. Casian Ngamilo Moderator Dr. Lucas P. Mwisila
Date	**Time**	**Description**	**Resource Persons**
	1430- 1440	Evaluation of the Season	Mr. Lwamwasha, Repotours
	1440 - 1450	Concluding Remarks	Deputy Permanent Secretary Ministry of Works and Transport, Tanzania
	1450 - 1500	Certificates and Prices	MC
	1500 - 1510	Vote of Thanks	Dr Lucas Mwisila, Ag. Principal
	1510 - 1520	Concluding Remarks and Invitation of Guest of Honour to officially close the Conference	Capt. Ernest Bupaba, DMI Chairman of Board of Governors
	1520 - 1530	Closing Speech	Minister for Ministry of Works and Transport, Tanzania
END OF THE CONFERENCE			

The 2nd Dar es Salaam Maritime Institute Blue Economy Conference convened on 27th June, 2023 provided a setting for maritime professionals, academia and other stakeholders of blue economy to connect with one another. It was a platform for sharing research findings, exchange ideas, encourage collaborations, promote professional interactions and encourage researchers to work on the matters of Blue Economy for realization of sustainable economic development.

Participants of the conference shared experiences and understanding on the Blue Economy and deliberated on how professionals and the community can tap the opportunities available at sea to accelerate national development. A total of 8 papers were presented and thus form part of the 2nd Blue Economy conference proceedings of 2023.

For more information please contact:

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ISBN 978-9987-858-28-6
9 789987 858286 >