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Institute

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PREFACE

Distinguished Participants and Guests,

The Organizing Committee welcomes our distinguished participants and guests to the 3rd Blue Economy Conference (BEC2024). The 3rd Blue Economy Conference is held in Dar es Salaam, Tanzania with the theme *"Navigating the Future: Integrating the maritime Safety and Security, Climate Change Actions and Technological Advancements for the Blue Economy.*

The conference is Organised by Dar es Salaam Maritime Institute (DMI) of the United Republic of Tanzania in collaboration with the Regional Maritime University (RMU) of the Republic of Ghana. The objective of the conference is to establish a platform for capacity building and networking among stakeholders to foster the blue economy in line with the United Nations Sustainable Development Goals (SDGs) for realization of the benefits of blue economy to the community. The conference aims to chart a course towards a more inclusive, resilient and prosperous blue economy.

This Conference Proceeding compiles all accepted peer-reviewed papers scheduled to be presented at the conference. A total of 21 papers were submitted to be considered for the conference but only 13 papers were accepted for presentation at the conference. We therefore thank all the authors who expressed their interest in sharing knowledge and skills with fellow scholars and other stakeholders. We are grateful to all peer reviewers who used their expertise during paper review process and were committed to bring to the conference some well qualified works of research.

We would like to thank the keynote speaker, guest speakers, session Chairs, moderation and all participants for accepting the invitation to be part of the BEC2024. We are grateful to all stakeholders who have contributed to the success of BEC2024, in particular the Management of the Ministry of Transport of the United Republic of Tanzania. We thank the sponsors of the Conference for pouring their hearts to the need for blue economy conference.

We rest optimistic that all the readers of this conference proceeding benefit from the contents of the papers. We look forward to seeing many of you in person at the coming 4th Blue Economy Conference 2025.

Wishing you the best!

The Organising Committee
July 4-5, 202
Dar es Salaam, The United Republic of Tanzania.

DAR ES SALAAM MARITIME INSTITUTE (DMI) OF UNITED REPUBLIC OF TANZANIA IN COLLABORATION WITH THE REGIONAL MARITIME UNIVERSITY (RMU) OF THE REPUBLIC OF GHANA

CONFERENCE TIMETABLE

DAY ONE: THURSDAY 4TH JULY, 2024

MC: MR. TAJI LIUNDI

Date	Time	Description	Resource Persons
4th July, 2024	0700 0830	Arrival, Registration and Tea	All Delegates
	0830 1350	Official opening of the conference	All Delegates
	1350 1420	Lunch	All Delegates
SESSION ONE: BLUE ECONOMY DIALOGUE **Keynote speaker: HON. DAVID MWAIKIPOSA KIHENZILE** **DEPUTY MINISTER OF TRANSPORT**			
	Time	**Paper**	**Authors**
	1450 1500	Guest Speaker 1	**Captain Dr. Hamad B Hamad** The Permanent Secretary for Ministry of Blue Economy and Fishers
	1500 1510	Guest Speaker 2	**Mr. Paul Sobba Massaquoi** Executive Director - The Sierra Leone Maritime Administration
	1510 1520	Guest Speaker 3	**Ambassador Nancy Karigithu** Advisor, Executive Office of Kenya president.
	1520 1530	Guest Speaker 4	**Dr. Julius Francis Woiso** School of Aquatic Sciences and Fisheries Technology (SoAF)
	1530 1540	Guest Speaker 5	**Mr. Adud Selemani Jumbe** The Permanent Secretary for Ministry of Tourism and Heritage
	1540 1630	Discussion	All Delegates
	1630 1720	Conference resolution	**Dr. Yona Kimori & Eng. Paul Nsulangi, Mr. Alexandra Meena and Mr. Lukas Msemwa** Rapporteurs
	1720 1700	End of Day 1	**Dr. Wilfred Johnson** Deputy Rector, Academics, Research and Consultancy

CONFERENCE TIMETABLE

DAY TWO: FRIDAY 5TH JULY, 2024

MC: MR. JONNES LUGOYE

Date	Time	Description	Resource Persons
5th July, 2024	0630 0800	Registration Entertainment	- DMI - MC
	0800 0830	Recap	- **Dr Yona Kimori**
SESSION TWO: MARITIME SAFETY AND SECURITY **Chairperson/ Moderator: CAPT DR. HAMAD B HAMAD** **THE PERMANENT SECRETARY FOR MINISTRY OF BLUE ECONOMY AND FISHERS**			
	0840 0850	Guest Speaker	**Dr. Paul I. Adalikwu,** Secretary General, Maritime Organisation for West and Central Africa (MOWCA)
	0850 0900	Assessing the Role and Challenges of Private Security Companies in the Maritime Sector.	**Mr. Eric Sambu**
	0900 0910	Promoting public-private partnership in natural gas distribution infrastructure development in Tanzania ensuring maritime safety and security.	**Eng. Daniel C. Rukonu**
	0910 0930	Discussion and Moderation	All Delegates
	0930 1000	Coffee	All Delegates
SESSION THREE: CLIMATE CHANGE AND ENVIRONMENTAL PROTECTION **Chairperson/Moderator: Representative from SoAF,** **SCHOOL OF AQUATIC SCIENCES AND FISHERIES TECHNOLOGY (SOAF)**			
	1020 1030	Reduction of Greenhouse Gas Emissions in Ghana's Petroleum Sector Towards Sustainable Economic Development	**Mr. Isaac Owusu-Nyarko**
	1030 1040	Assessment of the Economic Value of MARPOL Annex VI Implementation for Sustainable Maritime Sector in Tanzania	**Ms. Eliyuster Haule**
	1140	Discussion and Moderation	All Delegates

SESSION FOUR: BLUE ECONOMY GOVERNANCE, LAW AND POLICY
Chairperson/Moderator: CAPT. BENDERA IBRAHIM

Date		Description	Resource Persons
5th July, 2024	1120 1130	Guest Speaker	**Dr. Emmanuel K. Mbiah** C.E.O, Ghana Chamber of Shipping
	1130 1140	Navigating the Implementation of Maritime Arbitration in Tanzania: Challenges and Strategies	**Mr. Edrick J. Mugisha**
	1140 1150	Access to Justice for Seafarers in Tanzania: A Case Study of Criminalisation and Unlawful Detention of Seafarers	**Sadath Khalipha Kibwana**
	1150 1210	Discussion and Moderation	All Delegates
	1210 1300	**HEALTH BREAK**	
SESSION FOUR: MARITIME EDUCATION AND TRAINING **Chaiperson/Moderator: DR. JOVIN MWEMEZI**			
	Time	Description	Resource Persons
	1320 1330	Guest Speaker	**Mr. Mohamed M. Greetings** General Director TASAC
	1330 1340	Towards Unmasking the Potentials of Logistics & Supply Chain Management in the Blue Economy: Opportunities and Antecedents for Resilience amidst Global Crises	**Dr. Alban D. Mchopa**
	1340 1350	A study of Ship Seaworthiness and Onboard-Ship Competency in Tanzania	**Captain Winton J. Mwassa**
	1350 1420	Discussion and Moderation	All Delegates
SESSION FIVE: TECHNOLOGY ADVANCEMENT IN MARITIME PRACTICES **Chaiperson/Moderator: ENG. JUMA KAPAYA**			
	1440 1450	Guest Speaker	Ms. Mayb Abelson
	1450 1500	Early Detection of Marine Ship Propeller Shaft Failure in Domestic Ferries in Tanzania: A Combined FEA-SVM Approach	**Eng. Daniel Charles Rukonu**
	1500 1510	Using Artificial Neural Network (ANN) Models to Analyse Diesel Prices in Selected Regions of Tanzania	**Eng. Paul Theophily Nsulangi**
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	1530 1600	Vote of Thanks	**Dr. Tumaini S. Gurumo,** DMI Rector
END OF THE CONFERENCE			

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Host Organisation

Dar es Salaam Maritime Institute (DMI) of the United Republic of Tanzania
under the leadership of the Ministry of Transport

Organisers

Dar es Salaam Maritime Institute (DMI) of the United Republic of Tanzania
Regional Maritime University (RMU) of the Republic of Ghana

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SUB-THEME 1

MARITIME SAFETY AND SECURITY

MODELING THE EFFECT OF PERSONNEL-BASED HUMAN FACTORS ON MARINE ACCIDENT REDUCTION IN NIGERIA

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ABSTRACT

Marine accidents are not only injurious to lives and properties, but also hinder coorporate business successes. Majority of the marine accidents are caused by the inevitable elements of human factors that happen almost all times. This study modeled the effects of personnel-based human factors on marine accidents to unravel and minimize the disasters in the Nigeria navigational waters. Data were collected using well-structured questionnaires

distributed to 1000 respondents, out of which 821(82.1%) were retrieved and their essentials modeled using multiple linear regression at level of significance α =0.05. The independent variables are-unruly behavioiur of personnel, over speeding, inexperience/lack of adequate knowledge and inadequate number of personnel, skills and expertise; and the dependent variable is Marine Accident Reduction (MAR). It was found that the generated models are efficient in the estimation of the effects of the Personnel-Based Human Factors elements on marine accident in Nigeria. There is a significant difference in the influences of these elements and 66.1% of the variance in marine accidents can be explained by variations in these elements. Unruly behaviour of personnel on board is the most dominant marine causative personnel based human factors element in relation to safety performance and that a 1% increase of it can result in 69.5% increase in marine accident. To curb these menaces, it is advisable for mariners to have positive and robust safety culture in place and the management to effect appropriate training of human resources and proper implementation of the Safety Management (ISM) Code in all maritime companies navigating the Nigeria waters.

Keywords: Human factor elements, Marine Accidents Reduction, Safety Performance

1.0 INTRODUCTION

The maritime industry is perhaps the most complex international trade institution with huge and high-risk potential for catastrophes because of its challenging operations. The industrial operations require a delicate interplay between human and technological factors organized in a socio-technical system to achieve complex goals such as transporting hazardous cargoes in constraint and shallow waters. Nigeria is the hub of West Africa's shipping.

In a country such as Nigeria where there are booming and consistent shipping activities as a result of its strategic location by the coastline, vast exclusive economic zone with large market size, inland waterways, and increased oil prospecting activities in the Niger Delta region, accident or disasters around the marine are inevitable and invariably bound to occur (Ilogu *et al.,* 2017). The number of causalities, injuries, loss of life and properties accompanied with marine pollutions per year recorded from marine accident is quite alarming in Niger Delta. A very large proportion of these accidents have been attributed to human errors (Gbasibo, 2022).

Marine accidents have caused loss of lives, damage to properties, infrastructure and the environment in the maritime industry. Human factor elements have contributed mostly to incidents of marine accidents with impacts that have marred the efficient performance of the maritime industry. The human factor elements are said to be the most unpredictable factors; given that each individual has different understanding and behaviour in view of the fact that people's ability and capability to deal effectively and

safely with complexities, difficulties, pressures and workload of their daily tasks, not only in emergency situations but also during routine operations differ. Some of these human factors elements are classified as Personnel-Based and these include unruly behavioiur of personnel, over speeding, inexperience/lack of adequate knowledge and inadequate number of personnel, skills and expertise. Others are Procedure-Based which include inadequate communication, crew fatigue, lack of emergency drills, and faulty navigational aids and ship manoeuvrings.

We also have the Management-Based Human Factors elements that encompass improper hazards management, lack of maintenance standard, organizational structure/inadequate safety culture and consideration of paper qualification more than experience, competency and skill. Another of these elements are classified-Based Human Factors elements measured by Faulty standards and procedures, none sharing of marine accidents, investigation and recommendations report lead to reoccurrence, Wrecks/debris and Adverse weather, wind, current, wave and Act of God. Disaster and accident investigation methods have not been wholly comprehensive in order to ensure that their underlying causes are well-defined and that the activities necessary to modify the problems are effectively implemented.

In spite of this ineffectiveness, we can look at models, trends, and root causes and get valuable lessons from single events and basic information about the accident. Thus, this work emerges to investigate and modeled the effects of the personnel-based human factors elements to determine the integral influence of each of these factors in relation with marine accident occurrences in Nigeria navigational waters. Before the modelling a brief review were made on human factors, effects of human factor elements on marine accidents and some reported incidents of marine accident in Nigeria navigational waters.

Human factors elements address the interaction of people with other people, with facilities and with management systems in the workplace. Human factors elements causing accidents are factors that contribute to an accident and are directly attributable to the operator, worker, or personnel involved in an accident. Human factor itself is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and other methods to design in order to optimize human well–being and overall system performance" (International Ergonomics Association, 2010).

In the globe, human factors elements have been coined as the greatest cause of marine accidents. (Karimpour & Karimpour, 2016). Faturachman *et al,* 2013 in their research averred that 65% of accidents that happened in lakes, crossings, seas and rivers occurred as a result of human factor elements and only a scarce number of this is caused by natural factors. Drawing from the Costa Concordia accident research, (Di-Lieto, 2012) averred that the first error that led to the accident of the cruise liner was made by the Captain of the vessel, by changing the original voyage plan without coming to agreement with the local authorities and the company. This action did not only lead to loss of lives, but also led to permanent damage to the cruise liner and also caused Oil spillage that heavily polluted the immediate marine environment.

The Nigerian Maritime Administration and Safety Agency NIMASA, has stated that 38 per cent of maritime accidents in the Nigeria between 2016 and 2018 were as a result of human factor elements (NIMASA, 2018). International Maritime Organization (IMO) expressed that 30% of human factors elements in accident causal was due to negligence and 20% not having adequate knowledge and practice of marine accidents (Abramowicz & Hejmlich, 2015). Anyanwu (2014) observed that human factors elements were predominant factors in capsizing of vessels. He asserted that vessels may capsize when they hit high and steep breaking waves from the side which will subject them to severe rolling or pitching, gale and loss of stability. Uğurlu *et al.* (2015) described collision, fire outbreak pose great risk for life, cargo and the environment and concluded that between proximally 90% of the causes of maritime accidents are attributable to human factors elements.

Mokhtari and Didani (2013) observed that maritime accident, whether caused by meteorological events – such as storms, waves, or currents – or related to the ship or seafarer, is a catastrophe. Mokhtari and Didani (2013) carried out an empirical survey of the role of human factors elements in marine incidents and after investigating 1,816 marine accidents in five Iranian shipping companies observed that 17 factors are responsible for occurrence of marine accidents, out of which negligence, poor training, inadequate tools, and lack of skill and experiences are dominants.

According to Oluseye *et al.* (2016), poor crew interaction, crew fatigue, drugs and alcoholism, unsafe vessel speed, commercial pressure from management, complicated work processes, gap in working knowledge, faulty crew judgment and deliberate unruly behavior are some of the common human factors elements that contribute to marine accident in Nigeria. Others include negligence of watch keeping, careless fixing of ship's position, poor preparation prior to departure, deficient response to adverse weather and negligence of lookouts. To minimize marine accidents, Mokhtari and Didani (2013) recommended appropriate training of human resources, proper implementation of national and international laws and regulations, maintenance of vessels and the equipment on board, improved port facilitiess and utilities for marine search and rescue.

Marine accidents adversely affect the human, the marine environment, properties and activities aboard ships and ashore in various forms and degree of extent. The effects of human factors on marine accidents vary from minor injuries to fatalities and from insignificant damage to very severe damage to the human, property and environment. The cost of accidents, including fatalities and injuries, damage to property and the environment, prevention and mitigating measures, and insurance accounts for a considerable share of transport costs (Mullai and Paulsson, 2011). The effects of marine pollution to coastal resources are extensive, impacting on the flora, fauna and entire ecology of the coastal environment. Maritime accidents affect marine environment in different ways. Not only accidents and collisions are the reasons of marine pollution, but also human errors as oil spillage, solid waste, oil transferring or bunkering accidentally may cause marine pollution.

The impact of these accidents on marine environment is significant especially in terms of oil spill. Oil spills can cause a wide range of impacts in the marine environment and

are often portrayed by the media as "environmental disasters" with dire consequences predicted for the survival of marine flora and fauna. In a major incident the short-term environmental impact can be severe, causing serious distress to ecosystems and to the people living near the contaminated coastline, affecting their livelihoods and impairing their quality of life.

Marine pollution is the introduction of substances or energy from humans into the marine environment resulting in such deleterious effects as harm to living resources, hazards to human health, hindrance to marine activities including fishing, impairment of quality for use of seawater, and reduction of amenities (Iduk *et al.,* 2015). Human factors are major contributory factors to marine accidents in the Nigeria navigational waters. Communication problem, crew fatigue, unruly behaviour, safe vessel speed, commercial pressure from management, improper hazard management, lack of maintenance standard, organizational structure/ inadequate safety culture, inexperience/lack of adequate knowledge, maritime education are major causes of marine accident in the Nigeria (Gasibo, 2022).

Some Incidents of Marine Accidents in Nigeria

In June 1997, a tanker vessel M. T. Al-Zainah exploded at Lagos, Nigeria. The last cargo of the ship was PMS (Premium Motor Spirit), later, hot work was carried out in one of the cargo tanks not properly washed and gas freed and then, an explosion occurred (Environmental safety magazine, 2005). In March 1999, a tanker vessel M. T. Aribi flooded and sunk at Bonny Town Anchorage, Port Harcourt, Nigeria.

The tanker was fully loaded with about 2000 tons of AGO (Automotive Gas Oil) and so she had a small free board, she took in water into the engine room though the propeller shaft and later sank due to uncontrollable flooding. The entire cargo (AGO) was lost with the ship (Environmental safety magazine, 2005). In April 1999, a ferry MV GEORGE sank near the city of Port Harcourt in Nigeria killing about 100 people. It was noted that it was heavily overloaded beyond its carriage capacity when it ran into a fierce storm (BBC NEWS, 1999).

In October 1999, a tanker vessel M. T. Walvi – 14 exploded in Eket offshore Nigeria. The small fresh water tanker was loading fresh water from an offshore production platform when some dangerous gases entered the cargo tank through the water hose, one of the crew members lit a cigarette on the main deck and there was an explosion (Environmental safety magazine, 2005). In January 2000, a tanker vessel M. T. Real Progress in Lagos Nigeria exploded. The ship was loaded with 7000 tons of PMS (Premium Motor Spirit), the PMS leaked from the pump room to the pump-motor room and the Bosun's store through the pump/pump-motor shaft hole due to malfunctioning packing. There were some chemical reactions in the pump-motor room and the Bosun's store, which generated static electricity, and then there was an explosion in the pump- motor room and the Bosun's store (Environmental safety magazine, 2005). In the same month, a tanker vessel M. T. Crown O in Warri Nigeria exploded. In variance, the ship compressor was bad, the

chief engineer attempted to start the main engine with compressed oxygen bottle that eventually exploded and caught fire.

In 2018, the Nigerian Association of Master Mariners (NAMM) correlate poor pilotage services, improper lookout, inadequate lighting scheme at ports, inappropriate speed of ship, inadequate knowledge of rules of the road (ROR), and general negligence as the leading causes of marine accidents in the Nigerian coast. In July 2000, the M. T. WALVIS 15 in Eket Nigeria, had an explosion caused by fire in the forward store. It was found that the cause of the explosion was a static electricity that arose after two operational deep freezers, an oxygen bottle and full acetylene bottle locked in the forward store developed leakages from their compressors thus starting the fire.

The incident was attributed to the absence of a firm technical safety culture (Onyemechi *et al.*, 2016). In January 2012, an offshore rig owned by Chevron caught fire and eventually collapsed into the ocean near North Apoi oil platform off Nigeria's coast. Two personnel were reported dead. The cause of the accident was said to be human factor element as the workers could not contain the gas pressure build up which eventually led to the fire (The Guardian, 2012).

On the 19th of October, 2015, a Marshal Island flagged oil products tanker collided with a Nigerian self-propelled barge MT Tank at 65 miles off the Nigerian coast, which is 10 nautical miles southwest of the Bonga floating Production Storage and Offloading (FPSO) Unit located near Warri in Delta State, Nigeria. The collision broke the MT Tank causing it to take in water. According to reports from the search and rescue personnel of the Nigerian Maritime Administration and Safety Agency (NIMASA), eight crew members of the MT Tank were trapped inside the vessel which led to the death of a crew member. The cause of the collision was attributed to negligence and bad seamanship (World Maritime News, 2015). On 15th August, 2019 a Product tanker Sea Voyager caught fire while being anchored at Lagos Anchorage, Nigeria. MT Elixir and MT Tank collided in 2015 at midstream leading to fatalities. Consequently, casualties in maritime-related accidents were averred to be on the increase by 2015 in line with the trend in 2015 and subsequent years been a trend as referenced from 2013.

The Daily Post in its November 11, 2016 edition broke the news that a National Youth Service Corps (NYSC) member is feared drowned in a boat accident in Okpotuwari community in southern Ijaw local government area of Bayelsa. Sources in the community later on told the News Agency of Nigeria (NAN) that the corp member, who hailed from Anambra drowned when the canoe he boarded capsized. The Sun in its July 30, 2018 edition broke the news of six persons reportedly drowned when a passenger boat from Abonnema wharf to Bakana in Degema L.G.A of Rivers State capsized. It gathered that 25 persons were onboard the boat.

On September 23, 2016 a fatal mooring accident occurred to the Bosun of the Cyprus registered Bulk Carrier "Carme", at Lagos/Apapa Nigeria. M/V "CARME" berthed at ENL Terminal, Berth No 9, Apapa/Lagos/Nigeria. On September 1, 2016 the Bulk Carrier

"Carme" departed from Houston (TX)-USA, loaded with cargo of corn, bound for Lagos-Nigeria and arrived on September 22, in the same year arrived at the port of Lagos. On September 23, the Bosun was fatally injured during emergency unmooring operation.

The Bosun was struck by a mooring line, which he was handling, while he was standing at the forecastle deck starboard side in front of a winch drum. The area where the Bosun was standing was within the snap-back zone of the parted mooring line (Snap-back zones are typically spaces where it is anticipated a failed mooring line could recoil). The Bosun died as a result of (a) multiple injuries (b) blunt force trauma. With respect to the manner of death, it was caused by struck by mooring rope.

The other contributing causes were the environmental condition that is strong ebbing current in conjunction with inadequate under-keel clearance-Vessel was neither safely afloat nor safely aground. No specific risk assessment and no Tool-Box-Talk for emergency unmooring; and the strong ebbing current under the vessel's flat bottom in conjunction with the vessel's grounding, its listing to starboard and trim by the stern, was pushing up the stem causing extreme tension of the forward mooring lines, resulting in their breaking. In addition, insufficient information given to the Master regarding drafts alongside berth and tidal ebbing effect and failure on the part of the Bosun to recognize the danger of coming within snap-back zones of taut mooring lines are causes of accidents (Republic of Cyprus Marine Accident and Incident Investigation Committee Report No: 150E/2016). This is one of the detriments of marine accidents in Nigeria. Amidst the great usage of water as a means of transportation in Nigeria, very little attention is being given to it in terms of safety.

A Floating Production, Storage and Offloading (FPSO) vessel Trinity Spirit with a capacity to process up to 22,000 barrels of oil per day, that injected up to 40,000 barrels of water per day and store 2 million barrels of oil, exploded and sunk at the Ukpokiti Terminal, around Excravos, Warri South-west, Delta State, Nigeria. The FPSO Trinity Spirit, IMO 7370325, dwt 274774, built 1976, off Automatic Identification System (AIS) for a long time, years probably. The Owner Shebah Exploration and Production Company Limited (SEPCOL). According to the first information, ten workers were onboard the facilities, of which seven were missing, and three casualties feared dead (Bojan, 2022).

2.0 METHODS

The research which is an analysis of human error contributions to marine accidents in Nigeria with major focus on On-board officers, Shore-based officers, Safety officers, Mechanics, Crane operators, Engineers, Operator/Technician, Supervisors, Directors, Managers, Specialist/Advisors, Enforcement Agencies, Surveyors, Inspectors, Seafarers, Shipping Companies/organizations, agencies and stake holders involved in the day-to- day operations of the maritime industry in Nigeria. An overall sample size of one thousand (1,000) questionnaires were targeted to a specific group which include the various cadres

of the ports, jetties, Seafarers, Shipping Companies/organizations, agencies, stake holders involved in the day-to-day operations of the maritime industry and individuals concerned with maritime related issues in Nigeria.

The study employed descriptive survey research design method in which data were collected using well- structured questionnaire that encompassed questions related to the study objectives of generating a model of the effects of personnel based human factor elements on marine accidents. The questionnaire was administered to stakeholders and experts in the maritime industry including shipping crew members, master mariners, marine engineers, sailors, deck crew, cargo surveyors, safety coordinators and other on-board technicians at Onne Port Complex, Port Harcourt Port Complex, Warri Port Complex, Calabar Port Complex, Tin-CanIsland Port Complex, Lagos Port Complex and jetties within the Nigerian navigational waters. The target population of (1000) constitutes the maritime operators at the Ports and jetties. Out of which 821 (82.1%) was retrieved.

The independent variables of the study are-unruly behaviour of personnel (UBP), over speeding (OVS), Inexperience/Lack of adequate Knowledge (ILK), and inadequate number of personnel, skills and expertise (IDQ). The dependent variable is Marine Accident Reduction (MAR). Analysis of the respondents' responses from the items involved the researcher breaking down the data into segments of information and then assigning the segments identifying labels to develop categories. A multiple linear regression was employed for modeling the effects of personnel based human factors elements and the results interpreted to generalize the findings of the study to the entire population. This was accomplished using the Statistical Package for Social Sciences (SPSS) Version 16.0 software computer program.

3.0 RESULTS AND DISCUSSION OF FINDINGS

From the result of the study, Personnel-Based Human Factors elements (PeHF) were measured by unruly behavioiur of personnel (UBP), over speeding (OVS), Inexperience/ Lack of adequate Knowledge (ILK) and inadequate number of personnel, skills and expertise (IDQ).These variables also represent the study independent variables.

Modeling: Effect of Personnel-Based Human Factor (PeHF) on marine accident reduction

$$Y = B_0 + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4 \ldots B_nX_n + e$$

Where Y = Marine Accident Reduction (MAR)
X_1, X_2, X_3 and X_4 = unruly behaviour of personnel (UBP), over speeding (OVS), Inexperience/

Lack of adequate Knowledge (ILK) and inadequate number of personnel, skills and expertise (IDQ) respectively.

Table 1: *Summary of Multiple Linear Regressions of Marine Accident Reduction and Causative Personnel-Based Human Factors*

MODEL SUMMARY									
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df_1	df_2	Sig. F Change
1	0.808	0.654	0.652	0.679	0.654	385.029	4	816	0.000

Source: Authors calculation

Table 2: *Standardized Coefficient Model of Marine Accident Reduction and Personnel-Based Human Factors*

Coefficients						
Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	0.695	0.184		3.776	0.000
	Unruly Behaviour	0.774	0.064	0.874	12.042	0.000
	over speeding	0.051	0.081	0.045	0.631	0.528
	Inexperience/Lack of adequate Knowledge	0.065	0.070	0.070	0.925	0.355
	Inadequate number of personnel, expertise, and skills	-0.304	0.088	-0.202	-3.443	0.001

The effect of Personnel-Based Human Factor (PeHF) on Marine Accident Reduction (MAR) therefore can be estimated with this model:
MAR = 0.695 + 0.87UBP+ 0.045OVS+ 0.07ILK - 0.20IDQ + 0.184
(MAR = Marine accident reduction, UBP = Unruly behavioiur of personnel, OVS = Over speeding, ILK = Inexperience/Lack of adequate Knowledge and IDQ = Inadequate number of personnel, skills and expertise).

Generally, human factors causing marine accidents is a term that encompasses all the elements contributing to a workplace accident that can be directly attributed to an operator, worker, or other personnel which could be errors or violations. These factors can include willful violations of safety rule as well as inattention, fatigue, and intoxication etc. While human factors should be considered as part of any accident investigation, placing the blame entirely on workers is generally seen as counterproductive. Humans are fallible and prone to errors and unintended mistakes. Safety programs and procedures should take human fallibility into account.

Many situations that give rise to human error are predictable, manageable and preventable. Understanding what leads to error, mistakes, unsafe actions and applying lessons from past incidents can help maritime personnel's, stakeholders and organizations avoid future incidents (Gbasibo, 2022). Fatigue, sickness and overconfidence can further exacerbate the problem, leading to indecisiveness, bad decisions or poor judgment resulting workers disregarding safety rules or circumventing safe work practices.

From the results, about 65.4% of the changes in marine accident reductions can be explained by the variations in unruly behaviour, over speeding, inexperience/lack of adequate knowledge and inadequate number of personnel, skills and expertise. There is a strong positive relationship between the independent variables and the dependent variable except that of the inadequate number of personnel, skills and expertise in which the effect might be residual on the conditions of the sampled respondents and the competence of their present employee. Moreover, respondents were not 100% privileged to unravel the status of their establishment such that the reputation of theirs or employers establishments are not injured.

From the model, it can inferred that 1% increase in unruly behaviour can result 870 folds increase in marine accident reduction; 1% increase in over speeding can result to 45 folds increase in marine accident reduction; 1% increase in inexperience/lack of knowledge can result to 71 folds increase in marine accident reduction. Therefore, unruly behaviour as a personnel –based human factor element should be a center of discussion for ensuring the reduction of marine accident in the navigational waters of Nigeria.

Ordinarily, mariners are expected to be friendly and matured with good impulse control and goal directed behaviour. With cooperation, team spirit effectively rises, thus contributing to a greater overall and therefore personal–well-being. This leads to a set schedule that enables anyone to finish tasks right away without procrastination. However, on a marine vessel there are people from different nationalities working together. This may sometime give rise to a conflict and disagreement that can lead to the emergence of unruly behaviours in the crew. Although, such behaviours have their respective penalties such as suspension from sea career or imprisonment in some countries as per the severity of the matter, it is advisable to avoid the antecedent effect because of non-availability of special medical assistance working onboard as injury of any kind from such at mid sea can become dangerous.

Unruly behaviour of crew members may include violence against crew and others, harassment, verbal abuse, smoking, failure to follow safety instructions and other forms of riotous behaviour including racism, sexual harassment, aggressive attitude, and offensive personal habits such as assault, willful damage to ship's property, persistent disobedience, actions endangering ship or person on board, continuous failure in performing duties, normal or cargo theft, actions compromising safety of the ship, and ill-treatment towards onboard personnel. Although such acts might be committed by a minority of crew members, from the result of this study, they have a disproportionate impact.

They have the tenacity to create inconvenience that can threaten safety and security of other crew members, and can lead to significant operational disruption and costs for the company.

Identifying the multidimensional causes, nature, and extent of unrulybehaviours is not the panacea to resolving the problems that comes with them rather than preventing them (unruly behaviours) from occurring. The role of preventing marine accident from happening and managing them effectively when they do is critical. Depending on the nature and frequency of events, further interventions may be required to prevent repeated incidents. Many individuals who act unruly are not aware that they are acting in an inappropriate non-professional manner.

The problem is that they are oblivious to the downstream negative consequences this may cause on relationships, communication efficiency, task accountability, and their establishment as a whole. Some of them, even if they are aware they justify their behaviors as being necessary to direct. Therefore, it is imperative to define what unruly behaviour is and holding individuals accountable for their actions. This is necessary for crew members who are used to taking control, and giving orders. Moreover reducing the incidence of unruly behaviours with the right approach can improve the overall organizational culture, staff relationships, team collaboration, communication, efficiency and staff engagement and well-being.

4.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the finding from this study, it can be concluded that: Human factors are major contributory factors to marine accidents in the Nigeria navigational waters. From this study, provision of adequate number of personnel, consideration of skill and expertise will minimize the effect of Personnel-Based Human Factor (PBHF) on marine accident. Proper and functional organization structure and adequate safety culture will mitigate the effect of the PBHF.

To reduce the accidents, there should be more attention to the factors such as crew fatigue, unruly behaviour, unsafe vessel speed, commercial pressure from management, lack of maintenance culture, organizational structure/inadequate safety culture, non-implementation of national and international laws and regulations. Marine Safety Performance Plan, which is part of the International Safety Management (ISM) Code, should be implemented in all maritime companies in Nigeria.

The systems and operation control need to be reviewed and evaluated regularly and the content should cover management system, procedure, human factor engineering, exercise, immediate supervision, communication, maritime education and individual performance. Expertise, competency and skill should key to the optimal performance

and quality delivery in the Nigerian Maritime industry. Maritime education should be encouraged by all stakeholders in the industry.

NPA, NIWA, NIMASA, NAMM, all other maritime organizations/agencies and stakeholders need to engage non convention boat operators on boat maintenance, boarding and disembarking procedures, marine accident reporting procedures, safety culture, drills, firefighting and prevention procedures and protection of the marine environment amongst other issues. The convention vessel owners, operators and personnel should not be engaged based on paper qualification alone but on competency, skill and expertise. All maritime organizations/agencies, stakeholders, operators and personnel's should as a matter fact continue to initiate and promote safety culture to reduce or possibly prevent accidents in the navigational waters of Nigeria. Human factor element maritime accident prevention is cheaper and better than repairs, replacement and cure. Understanding the basic factors concerning the human factor element is an essential step toward mitigating maritime accidents.

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ASSESSING THE ROLE AND CHALLENGES OF PRIVATE SECURITY COMPANIES IN THE MARITIME SECTOR

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ABSTRACT

Maritime safety and security have come under focus given the reemergence of piracy and attacks by warrying parties around the Middle East, disrupting international logistics. Private security industry continues to play a critical role is providing assurance to key players in the shipping industry and hence ensure continuity of operations. This paper assesses the role of the private security companies in maritime safety and security. Specifically, the paper assesses the potential of the private security industry, the role it can play and possible impediments to address to improve it effectiveness in maritime safety and security.

This study employs a mixed-method approach combining literature review and a case study design focused on the qualitative exploration of the potential contributions of private security companies to maritime safety and security. The study found that private security companies have a critical role to play to enhance maritime safety and security in the region. They need to be properly registered and be certified against a number of international standards reviewed in this paper. There are impediments including capacity of actors, regulatory

challenges, and mandate. This paper concludes that whereas there are challenges in optimizing the role of private security industry, the players can surmount these by getting organised and engaged, with key support from key governments and international organisations, and hence the efforts will be focused, efficient and effective in improving maritime safety and security.

Keywords: Private Security Companies, Private Maritime Security Companies, Maritime Safety and Security, Maritime Safety and Security Standards, Piracy

1.0 INTRODUCTION

Maritime security is a general term for the protection of vessels and their cargo against threats such as piracy, terrorism, smuggling, robbery, and similar external threats (Campling and Colás, 2021). ISO describes it as services which range from intelligence and threat assessment to ship hardening and the guarding and protection of people and property or any activity for which the company personnel may be required to carry or operate a firearm in the performance of their duties. ISO (2015) defines security as a process to pre-empt and withstand intentional, unauthorised act (s) designed to cause harm, damage, or disruption. Maritime safety focuses on the protection of people and environment mostly from naturally occurring or accidental hazards (Safety Culture, 2024).

According to the International Maritime Organisation, 131 incidents of piracy and armed robbery against ships were reported as having occurred or been attempted in 2022. In 2021, 172 incidents were reported, whereas the number was 229 incidents in 2020 (IMO, 2022). This shows that there is a decrease of about 24% at the global level compared to last year, and the lowest number of reported incidents at the global level since 1995 (Sambu, 2023).

From the data referred to above, it also emerges that the areas most affected by acts of piracy and armed robbery against ships in 2022 were the Straits of Malacca and Singapore (72 incidents), West Africa (21 incidents) and South America (Pacific) (14 incidents), followed by Indian Ocean (9 incidents), South America (Atlantic) (6 incidents), South America (Caribbean) (4 incidents), South China Sea (4 incidents) and Arabian Sea (1 incident) (IMO, 2024).

The data reveals that the total number of crew reported as taken hostage/kidnapped in 2022 remains at 24 crew members, and this is a decrease from 48 crew members held hostage/kidnapped in 2021 (Sambu, 2023). Around 58% of the crew members were reportedly taken hostage/kidnapped in incidents in West Africa in 2022. The total number of incidents of piracy and armed robbery against ships reported to IMO as having occurred or having been attempted from 1984 to the end of December 2022 has risen to 8,718 (IMO, 2024).

According to Cao *et al.,* (2023) areas deemed to be high-risk include the Indian Ocean, Southeast Asia, Gulf of Guinea, Gulf of Aden, the Red Sea, Persian Gulf, Arabian Sea, Mozambique Channel, and West Coast of Africa. During the last quarter of 2023 and the first quarter of 2024, the Middle East Region witnesses an increasing and unprecedented geopolitical risk. With the outbreak of war in Palestine and the uprising of Houthis in Yemen, the impact of the Red Sea route was evident, with supply chain disruption on the key international sea route (IMO, 2024). This forced business to reassess the impact and take action to maintain reasonable inventory to mitigate the supply chain disruption and continue monitoring supply, shipping and insurance costs (Rogerson *et al.,* 2024). There was also connectivity disruption due to undersea cable damages.

The affected cables included SEACOM/Tata TGN-Eurasia and Europe India Gateway. These cables transmit internet traffic among Europe, Middle East, India and Eastern and Southern Africa (Franken *et al.,* 2022). With technology becoming a key necessity in the functioning of systems, business continuity and recovery measures came to the core. The experts indicated that the current high-risk areas of the sea include the Indian Ocean, Southeast Asia, Gulf of Guinea, Gulf of Aden, the Red Sea, Persian Gulf, Arabian Sea, Mozambique Channel, and the West Coast of Africa. The veracity of the recent events calls for better response and the role of the Private Security Companies (PSCs) is assessed (Suresh *et al.,* 2020).

PSCs continue to play a critical role in safety and security for both the private sector and the government. They are termed as companies supplying land-based security services like guarding, close protection, security awareness, risk assessment, protective and defensive measures, escort of transport, and policy analysis (ASIS, 2012). PSC workers are engaged in a wide range of activities from highly specialized investigations of corporate crime, to providing armed security for banks and commercial organizations, to protecting private property in public spaces and commercial buildings (Sambu, 2023).

The Global Security Services was valued at USD 240.18 Billion in the year 2020 and is expected to grow to USD. 342.7 billion by 2026 (Azoth Analytics, 2021). It employs between 19.5 to 25.5 million people worldwide (Diphoorn, 2016) and holds up to 3.7 million firearms, with numbers being up to four times the size of police forces (Krahmann, 2017). The significance of this article will contribute to the literature by providing empirical evidence on the role of private security companies in maritime safety and security. It will bridge the contextual gap by focusing on developing economies, to draw attention to evolving roles in private security services. It demonstrates how systematic research in issues in private sector is used to generate evidence that informs and motivates policy change.

This article is structured to cover the introductory part and methodology, then it discuses, the maritime safety and security situation and the role of private security industry. It concludes with recommendations that will help all actors and interested parties within the industry.

2.0 METHODOLOGY

This study used a mixed approach of literature review and a case study design where culminated papers were qualitative in nature, and on the case study of the possible role of private security companies in maritime safety and security. For this end, this paper used in-depth personal interviews, observation, expert opinions, and documentary review for getting both primary and secondary data. The study began with an intensive literature review and analysis of the standards in maritime safety and security and the nature of private security industry.

In total, six respondents were interviewed from Kenya (3) and Tanzania (3), covering the maritime security experts and executives of private security companies, selected using purposive and convenient sampling. This number was deemed sufficient due to saturation should the number be higher. The interviews and discussions were carried out between January and March 2024. The respondents were assured of confidentiality and their identities have not been disclosed in this paper.

3.0 RESULTS AND DISCUSSIONS

3.1 Maritime Safety and Security Standards

Maritime Safety is the protection of crew and passengers aboard vessels, as well as those living in or working near water bodies, from hazards or risk of injury or fatality. Example is the provision of Personal Floatation Devices which aid is recovery of persons in water. According to the experts, maritime safety averts safety tragedies like sinking of ships, explosions or discharge of toxic waste to water bodies. Effective safety will help lower the ship's risk profile. This is critical is determination of the intervals between the required inspection, as per the Paris Memorandum of Understanding on Port State Control1. For instance, a ship rated as Low Risk Ship requires an inspection interval of three years while a High-Risk Ship requires inspection intervals of five months (Hassellöv et al., 2020). The operators are required to observe and adhere to the maritime standards. These are industry-accepted rules that govern maritime safety and security and enforced by the International Maritime Organization (IMO), as well as other international, regional or national organisations, associations and agencies.

The International Convention for the Safety of Life at Sea (SOLAS), set in 1974 in response to the Titanic disaster, is an international treaty that is now adhered by over 160 countries and covers aspects like the construction of ships, provision of life saving appliances, radio communications and the implementation of safety in navigation – manning, routing, and signalling. On the other hand, the ISO 27991 standard is created to provide guidance on communicating between a Marine Evacuation System (MES) and the platform or survival

1 Available on https://www.parismou.org/inspections-risk/library-faq/memorandum

craft it is attached to, as required by SOLAS regulation III/6.4.4 (Safety Culture, 2024). International Ship and Port Facility Security (ISPS) Code applies to vessels on international voyages and the port facilities serving them. The main components of the ISPS Code include the completion of a Declaration of Security when required by the government or requested by a ship; the development of a ship security plan and a port facility security plan; the use of ship security assessments and port facility security assessments; the participation in training, drills, and exercises on ship security and port security; and the designation of a ship security officer, a port facility security officer, and a shipping company security officer.

Global Maritime Distress and Safety System (GMDSS) has another set of requirements that must be complied with when traveling on international voyages or in the open sea, cargo ships of 300 tons and over, along with all passenger ships carrying more than 12 passengers, according to the Federal Communications Commission. They differ by sea area, but the common requirements include a 406 megahertz (MHz) Emergency Position Indicating Radio Beacon; a Very High Frequency (VHF) radio that can transmit and receive Digital Selective Calling (DSC) and radiotelephony; a NAVigational TEleX (NAVTEX) receiver; a Search and Rescue Transponder (SART); two-way VHF portable radios; and radio equipment maintenance using approved methods (Safety Culture, 2024).

Another key guideline is the Standards of Training, Certification and Watchkeeping (STCW). The International Convention on Standards of Certification and Watchkeeping for Seafarers (otherwise known as STCW, the STCW Code, or the STCW Convention) requires that crew members receive adequate training on topics that are relevant to their duties (Safety Culture, 2024). According to the respondents, training must be validated in the form of required certificates, endorsements, and/or documented evidence. While there are specific requirements for each rank, generally all crew members must have a national certificate of competence with them onboard.

3.2 Safety and Security of Merchant Ships

Respondents indicated that the main concern of a merchant ship is safely conveying its cargo. The danger remains weather and other natural conditions that influence the place it operates. The pirates therefore are seen as pests to be avoided and this is the premise held in the construction of the ship. The focus is on the ability to withstand the forces of nature, load and offload cargo efficiently, be watertight for its intended use and fuel economy. Typically, a merchant ship moves at speeds of between 11 and 15 knots and usually do not have inbuilt defence mechanisms and manning is at the minimum level possible (Osnin, 2006). Safety, therefore, takes priority than security. This makes the ships attractive to pirates.

IMO recommends high level of security surveillance for early detection of security threats or breaches. Even though the ships have distress flares, often this is restricted to situations when the ship is in imminent danger of sinking. They can use water hoses to deter and repulse attackers. Ships crossing high risk areas are advised to travel blacked out and to

establish secure areas. And where there is a conflict between safety and security, safety requirements should be paramount (Osnin, 2006). These suggested techniques seem not to be having expected impact as merchant ships are still an easy prey. The legal framework regulating merchant shipping also emphasises safety, pollution control and operational procedures. The trend has however changed to focus on security too, with escalation of incidents of piracy and terrorism. The IMO circular strongly discourages carriage and usage of firearms. The stance has however softened, as the threats escalated.

The IMO monitors the acts of piracy and armed robbery against ships and according to their statistics, it recorded 8,718 incidents between 1984 and 2022. The trend seems to show that incidents are on the rise, in the recent past. Despite this trend, there is no effort to equip the seamen and enhance their capacity to fight these perpetrators. The focus is the welfare and safety of the seafarers and arming them is seen as an act of aggression, that may instigate an arms race, resulting in higher casualties amongst the ship's crew. The International Maritime Bureau holds this view and recommends other defensive options like sonic devices and electric fences around the ship's deck to deter pirates.

IMO (2024), while acknowledging that carriage of firearms of firearms in merchant ships is a complex legal issue with IMO member states taking diverse opinions, appears to have softened its stance and merchant ships may now use privately contracted armed security personnel (PCASP). It acknowledges that there is no agreed minimum performance standard, given the diverse legal regimes. However, there are various guidelines that PCASPs may apply in the conduct of their operations. The issue has been evolving over time amongst the IMO member states.

IMO kept advancing new approaches as the debate went on, and situation kept changing in the state of security. At first, the stance was, "the carrying and use of firearms for personal protection or protection of a ship is strongly discouraged" (MSC/Circ.623, annex paragraph 40 (June 18, 1993). Then, "flag States should strongly discourage the carrying and use of firearms by seafarers for personal protection or for the protection of a ship" (MSC.1/Circ.1333, annex, paragraph 5 (June 26, 2009). This has been updated and revoked by MSC.1-CIRC.1333-REV.1 in June 2015 to the current position of that acknowledges that the deployment of armed security personnel on board ships has become an accepted industry and flag state practice in certain circumstances (IMO, 2024). There are sections of the sea routes that are declared as war risk areas and hence insurers place additional war risk premiums on ships navigating through such waters. They usually place a distinction between piracy and terrorism, given that piracy is covered under standard hull or protection and indemnity policies whereas terrorism comes under war policies and may attract additional premiums to cover. In the real sense, it is hard to distinguish between pirates and terrorists due to intensification of weaponry and techniques.

3.3 Private Maritime Security Companies

The Private Security Companies (PSCs) may apply and acquire license to provide services are Private Maritime Security Companies (PMSCs). Potential threats facing merchant ships

can be reduced drastically if the PMSCs are effective in their duties. They employ both armed and unarmed security solutions. What endears the consumers of these services to PMSCs is that PMSCs are seen to be mostly well-equipped and ready for specific threats merchant ships face. They have round-the-clock monitoring and response capacity. Some operators feel that PMSCs are cost-effective. Their services can be shared by various users. They also offer customised services.

A PSC wishing to offer armed security services for merchant ships, for instance, is required to register and obtain licence as a PMSC. For instance, according to Human Environment and Transport Inspectorate (ILT) (2024), any Dutch-flagged ships can only use PMSCs that have been licensed by ILT. A ship owner who wishes to engage security personnel for merchant ships registered in the Netherlands, is similarly required to obtain permission from the Netherlands Coastguard. A PMSC obtains a license for specific area of operations, eg the Gulf of Aden. A check with the ILT shows that an applicant must be having head office in the European Union Zone or Exclusive Economic zone or has a branch in the Netherlands. The application fee is EUR.17,220. At the moment, the ILT has licensed three PMSCs: ESC Global Security, ESS & SA Maritime and Praesidium International (ILT, 2024).

The key advantage PMSCs possess is that they employ personnel who have served as Naval Commando, former special troops, marines and elite special operations units, trained and qualified to act against all kinds of threats at sea, particularly the maritime piracy. They also operate in various locations along the main sea routes, making support to be available where needed. According to Marine Insight (2024), with the help of the services offered by these security firms, shipping companies can be assured of plenteous security to its crew and cargo. Since shipping piracy has become an unchecked evil in certain water parts and is spreading towards other oceanic networks, opting for maritime security services has become a choice that cannot be overlooked (Marine Insight, 2024).

The consumers of the PMSC services include major commercial shipping companies, cruise liners, oil majors and superyacht owners. Their services also cover port facilities, oil and gas industry and energy sector. Some governments and regional organizations also prefer to use PMSCs, despite existence of naval organizations and coast guards. PMSCs also offer security to naval vessels too and have military departments as part of their clients. Experts opine that they are deemed to be independent and with requisite expertise and hence when an issue is required to be investigated, they will offer an independent opinion since they are not aligned with any state, insurer, shipping line or port.

According to Marine Insight (2021), there are many PMSCs in operations to support shipping companies manage the various threats they face in the course of their business. These PMSCs include Hart Maritime (UK), Seagull Maritime Security (Malta), Marine and Underwater Security Consultants (MUSC)(UK), Hudson Analytix, Solace Global, MAST (UK), Securewest International, Black Pearl Maritime Security, Neptune Maritime Security (UK), ESPADA, STS Maritime Security (USA), Anti-Piracy Maritime Security Services, DIAPLOUS Maritime Services, ESC Global Security, ESS Maritime, Port2port

LPC Limited, Praesidium International, Prorisk International, United Guards Services Ltd, Gallice Developments Ltd, Kahl Sicherheit LSS-SAPU Ltd amongst others.

Majority of the PMSCs are members of Security in Complex Environment Group (SCEG). This is a special interest group for security and risk companies committed to the development and implementation of international standards for the private security and crisis management sector (SCEG, 2024). SCEG are instigates and contributes to the International Code of Conduct Association, which has evolved from the declaration of the Montreux Document of 2008, and now ratified by over 50 countries. They regulate the members to ensure they embrace international security standards and protect human rights. SCEG has strong links with the UK government departments and its affiliate members include the Foreign and Commonwealth Office and the Department of Transport (SCEG, 2024). The legal and insurance sectors are also represented by affiliate members.

3.4 International Standards for PMSCs

Many of the PMSCs have international standards certifications. These include ISO 18788 – Security Operations Management System – and ISO 28007 – Ships and Marine technology – Guidelines for Private Maritime Security Companies (PMSC) providing privately contracted armed security personnel (PCASP) on board ships (and pro forma contract). Many PMSCs also subscribe to the International Code of Conduct (ICoC) for Private Security Service Providers. The goal of the ICoC is to set standards for the security industry worldwide and to establish external independent mechanisms for effective governance and oversight. As a signatory to the ICoC, a PMSC maintains the necessary governance documents to operate as a legal and ethical maritime security organization and adherence to the bylaws governing conduct, training, licensing and personnel recruitment. Below is the evolution of the standards in the private security industry.

3.4.1 The montreux document

The Montreux Document on Pertinent International Legal Obligations and Good Practices for States Related to Operations of Private Military and Security Companies during Armed Conflict (herein after the Montreux Document) was first adopted in 2008. It is an intergovernmental initiative, launched cooperatively by Switzerland and the International Committee of the Red Cross, supported by DCAF, to promote respect for international humanitarian law and human rights law whenever private military and security companies (PMSCs) are present in armed conflicts. The Montreux Document encourages the adoption of national regulations on PMSCs designed to strengthen respect for international law. The Montreux Document also offers practical guidance in contexts outside situations of armed conflicts as its good practices are best implemented during peacetime.

The various states and intergovernmental organizations which have endorsed the Montreux Document represent an enormous knowledge base of good practice reflecting a variety of legal systems and different experiences of private military and security companies. The Montreux Document is a complementary initiative to the International Code of Conduct

for Private Security Services Providers with a shared goal of promoting effective regulation of the international private security industry (SCEG, 2024).

3.4.2 International code of conduct for private security providers

Building on the Montreux Document (2008), the International Code of Conduct for Private Security Providers (ICoC) of November 2010 sets out a body of principles derived from human rights and international humanitarian law to govern the operations of private security services providers in terms of their own management and as regards their responsibilities towards those who might be impacted by their activities (ICoCA, 2010). It was developed in a multi stakeholder process to clarify the standards required of private security companies operating in complex environments as well as to improve oversight and accountability of these companies. Apart from human rights principles. The Code includes specific commitments on the management and governance of companies, including how they vet personnel and sub-contractors, manage weapons, procedures governing the use of force and grievance procedures (SCEG, 2024).

According to SCEG (2024), the ICOC also acts as a founding instrument for a broader initiative to create better governance, compliance and accountability -provision was made under Article 7a for the establishment of objective and measurable standards based on the Code with the objective of realising common and internationally recognised operational and business practice standards. This was given effect by the negotiation of the American national standard known as PSC1 "Management System for Quality of Private Security Company Operations-Requirements with Guidance" finalised in 2012 (SCEG, 2024).

3.4.3 Land standard – PSC1/ISO18788

The US Department of Defence commissioned the security trade association, ASIS, to develop an American National Standard for land-based Private Security Companies (ASIS, 2012). This standard, known as PSC1, has a core element of human rights and was framed in such a way that it could be adopted by other nations for use internationally. PSC1 was developed after an extensive consultation process which was strongly supported by the SCEG (SCEG, 2024). PSC1 and the associated conformity standard, PSC2, were published in early 2012 and SCEGs unreserved recommendation to the UK Government was that PSC1 be accepted as the basis for the UK national standard, with the additional requirement for independent 3rd party certification, and provision for any UK specific conditions.

The PSC1 standard was submitted to ISO (International Standards Organisation) and after lengthy negotiation it was developed into ISO 18788 Standard "Management system for private security operations – requirements with guidance". It was published as a full ISO in the summer of 2015 (SCEG, 2024).

3.4.4 Maritime standard – ISO 28007

In recognition of the increasing threat of piracy in the Indian Ocean, discussions between the International Maritime Organisation (IMO) and ISO began in earnest in January 2012 to decide how best to develop an international standard for armed security guards on ships in the High-Risk Area (SCEG, 2024). Four months later IMO's Maritime Safety Committee approved MSC Circular 1443 – Interim Guidance to Private Maritime Security Companies providing Privately Contracted Armed Security Personnel on board Ships in the High-Risk Area.

It was also concluded that ISO should develop an international standard drawing on 1443, which itself had been informed by work completed earlier by the SCEG. The standard, formally endorsed by IMO in June 2015, is ISO 28007 – Ships and Marine technology – Guidelines for Private Maritime Security Companies (PMSC) providing privately contracted armed security personnel (PCASP) on board ships (and pro forma contract).

These two auditable standards provide the means for private security companies and private maritime security companies to be audited against the way in which their processes and management systems have given effect to international and national obligations, laws and regulations as well voluntary commitments they have accepted through accredited certification by Accredited Certification Bodies (SCEG, 2024).

3.5 Maritime Security Services

PMSCs offer critical roles, which can be said to be a complete risk management solution to the shipping industry. According to the experts interviewed, below is a range of services that a PMSC may be contracted to undertake for the contracting party.

3.5.1 Risk assessment

PMSCs carry out comprehensive risk assessment facing the client. This is usually tailored to specific issues and clients. PMSCs usually discuss the scope and work on the risk assessment and present report to the client. Merchant shipping companies would benefit from this service to ensure that key risks in their operations or facing their assets are identified, analysed, evaluated, and hence effectively treated. Risks can range from the vessels, the cargo, the personnel, the port facilities, supply chain, cyber risks, environmental risks amongst others.

3.5.2 Maritime intelligence

PMSCs offer specific intelligence to their clients. This critical information will aid the users in planning the routes well, protection of their vessels and cargo, and put in adequate mitigation against potential threats. This can be general intelligence reports of specific reports for use by key users. Experts interviewed expressed that the industry prefer intelligence reports from PMSC since they are seen as independent and will say it like it

is. Government-affiliated bodies may be restricted in issuing some sensitive information due to diplomatic restrictions.

3.5.3 Investigation

PMSCs offer investigation services to their clients. This is critical in the maritime industry where incidents occur and independent bodies are required to carry out investigations. Incidents can range from piracy, robbery, cargo theft, security breaches in the vessel, hostage situations, sabotage, environmental disasters, cybersecurity incidents among others. Experts opined that given the expertise in the PMSCs, they are more likely to gain trust and confidence of the users of the investigation reports. Insurers may be key beneficiaries of such reports as they may use them is arriving at the decisions to compensate parties against losses incurred in such incidents. According to the experts, other government agencies may also rely on such reports to take further action against the perpetrators, sanctions against the ship owners, corrective and preventive actions to improve the overall safety and security of the maritime activities.

3.5.4 Port security

A port is a sensitive installation, according to the experts interviewed. A state can improve the security of the port facilities to give assurance to the merchant ship owners and insurers if they engage competent PMSCs to take charge of security. Where there is a potential for damage to vessel, cargo or threat to the crew, the port becomes less attractive, according to experts. Licensed PMSCs have capacity and credibility to provide such assurance to all port users. They usually work closely with other government agencies like the ports authority, contractors, government security agencies like intelligence, police, immigration, border control, anti-counterfeit agency, anti-drugs agency, anti-corruption agency, fire department, tax authority, customs department among others.

3.5.5 Anti-piracy security

Piracy is becoming a serious threat to the global shipping industry as demonstrated by the IMO (2023). The escalation in the recent few months, coupled with terrorism activities around the middle east calls for expertise in countering this menace, experts explained. PMSCs provide onboard security teams who may either be armed or unarmed. They are usually well-trained and experienced in their duties.

The PMSCs have the right tools to counter this menace if they work with key stakeholders – the territorial states, the shipping agencies and insurance companies. The PMSCs can play roles to prevent, detect, deter and in recovery efforts when there is an incident. They work with stakeholders to recover the cargo, crew held hostage and the vessels. They can be of great help to negotiate with the pirates and handle their demands. Experts indicated that PMSCs may be in a better position to do so as opposed to government-affiliated agencies. This is due to their independence and possible trust.

3.5.6 Ship security

Vessels need to have enhancement of features to make them less attractive to potential robbers, terrorists or pirates. They also need to be fit for purpose, operate safety and counter any threats they may face. PMSCs offer advisory services regarding vessel hardening, after thorough risk assessment. They also offer advice about route-planning and vessel monitoring and tracking. The experts indicated that the PMSCs are equipped to offer round the clock monitoring of the movement and if there is a distress signal, mobilize response from locations with proximity.

3.5.7 Administration and logistical support

PMSCs have capacity to provide full support to stakeholders globally. They can manage all governmental permits, administrative interface and logistical support for security operations around the world. For instance, STS Marine Security offering such services to the US government, including US Flagged RORO fleets globally.

3.5.8 Cargo tracking and security

The experts interviewed indicated that PMSCs have capacity to ensure security for the general cargo, RO-RO container, bulk carriers, oil/chemical tankers, and offshore vessels. This reduces risks and hence insurance premiums. The risk of loss or misplacement on transit is minimized.

3.5.9 Training

The experts indicated that PMSCs provide extensive marine security training to various stakeholders. Drills that include anti-piracy and breaches exercises are also conducted to ensure full preparation to face any threat. They offer such services to international shipping conglomerates and governments. They organise crew training for courses which are approved by the internationally recognized bodies like the UK Marine and Coastguard Agency.

3.5.10 Recruitment risk management

One of the key risks in the shipping industry is the personnel risk. If this is not handled well, according to experts, will create further risks. There is need to do complete verification of qualifications and competency, thorough vetting and background checks for all personnel before recruitment and to do assessment periodically.

3.5.11 Consultancy

PMSCs can offer various consultancies in maritime security and safety. Experts indicated that other than threat assessments and architectural attributes, stakeholders may seek advice on stowaway prevention, ship security audits, counterpiracy auditing, pre-

engagement due diligence, business continuity assessment among others.

3.5.12 Cybersecurity

Many organisations face information and cybersecurity risks. PMSCs have capabilities to offer services to counter these risks. All stakeholders may benefit from these services. Respondents reiterate that this risk is facing many organizations, and shipping lines are not spared. They cited some instances where Maersk, a leading international shipping company, suffered huge disruptions as a result of global cyber-attack named Petya in 2017[2]. This attack caused losses in excess of U$ 300 million and resulted in downtime of two weeks[3]. Such an attack can immobilise vessels and cut off communication with the crew. There is need for proper business continuity plans and PMSCs can offer such support.

3.5.13 Subsea pipeline security

The recent events that led to the damage of the undersea cables off the coast of Yemen calls for heightened security to protect the critical infrastructure that connects continents. Given that internet access and data are defining resources of the twenty-first century, protecting submarine cables is far too essential a domain of international politics to remain a technical addendum to security analysis (Bueger and Edmunds, 2022). Experts opined that the PMSCs can be of great help to patrol the routes and help in recovery efforts should an incident is experienced.

3.5.14 Compliance

Shipping agencies face huge compliance risks. Should they fail in the effort, they face sanctions. Operating in many jurisdictions with varied requirements increase this risk. Since many prominent PMSCs have expertise and know easier means to acquire such permits and documentation, given their presence in various countries, they stand a good chance to support the industry. Experts were of the view that key areas PMSCs may be of help to the industry is on illegal carriages. This includes countering drug smuggling, illegal weapons, human trafficking, and illegal immigration. Specific documentation for some cargo can also be easier done by PMSCs.

3.5.15 Marine environment safeguards

Safety while traversing territorial waters is key. PMSCs can help merchant ship owners to enhance safeguards against environmental disasters. This will help operators mitigate potential risks. Experts indicated that PMSCs can source key experts in those areas to help their clients. Another area of help, according to the experts, is the effective disposal of explosive and toxic materials. This is under strict supervision and observance of guidelines

[2]Details available in a press release at https://investor.maersk.com/news-releases/news-release- details/cyber-attack-update.
[3]Reported by Los Angeles Times in https://www.latimes.com/business/la-fi-maersk-cyberattack-20170817-story.html

given to mitigate hazards. PMSCs can therefore be of help to ensure proper disposal and certification to that effect.

3.6 Potential Challenges to PMSC Role

Experts concur that there is need for armed escorts in places prone to war-like perils. PMSCs are best positioned to take up this role and they can engage both the ship owners and insurers. However, the armed escort remains a point of contention because of their potential to jeopardize sovereignty of littoral states. Sovereignty refers to the supremacy of authority or rule as exercised by a sovereign state. The legality of armed escorts has also been questioned. The application of the international law relating to innocent passage of ships through a State's territorial waters and transit passage when they are under armed escort by PSMCs remain contentious. This is because the United Nations Convention on the Law of the Sea (UNCLOS), under article 2, affirms the sovereignty of a coastal state. This therefore vests the monopoly of legitimate use of force in matters security to the State and not with ships passing through those waters. PMSCs may therefore impinge of the sovereignty of these states should they conduct armed escorts. Here, the state-sponsored armed escort may work in these circumstances. Experts however opine that the areas classified as war risk, are surrounded by weak states, who are either unwilling or incapable of providing this service to ships seeking passage through their waters.

There is a distinction about the manner in which merchant ships and naval ships and granted permission for entry, according to the UNCLOS (1982). Foreign merchant ships are granted a standing permission to enter waters, subject to notices like avoidance of oil rigs, marine parks and the like. Naval ships are however required to seek advance permission for entry, unless there exists bilateral, or multilateral are in place or unless the naval ship is clear that it is under an innocent passage. When PMSCs escort merchant ships, their armed operations will make it a naval ship and hence require advance permission for entry to territorial waters. Some experts were of the view that PMSCs still proceed under innocent or transit passage and are not challenged by the littoral states.

Another critical issue is the licensing and regulation of the work of the PMSCs: A PMSC licensed in one state may not be allowed to operate in another state, and hence face challenges entering sovereign jurisdiction of the other state. This inhibits their ability and ability to carry out full scope of activities at sea. Respondent opined that this can only work if all territorial states approve of such activities. The merchant ship with armed escort may require applying for passage, yet it is entitled to innocent passage. The ship with firearms may then fall under the definition of a naval ship. If, however, all parties agree in advance that the armed escorts are pertinent to their operations and sanction merchant ships as part of innocent passage, this will work well. The latest guidance circular by IMO will be the basis for stakeholders to agree.

Petrig (2016) raised concerns about the regulatory regime of the PMSCs, which exemplifies operational and legal specialities of the use of PMSCs at sea. The first issue was about the jurisdiction at sea, i.e. how the law of the sea informs the question of which State can –

or cannot – be the addressee of specific obligations over the operation of a PMSC. The Montreux Document (2008) follows a four-fold structure of addressees by distinguishing between Territorial, Contracting, Home and Third States. Petrig (2016) therefore submitted that the concepts of Territorial State and Contracting State must be interpreted and refined for the maritime context specifically. Territorial State includes the flag state (when a vessel is at international waters), port state (when approaching the port) and coastal states (when vessel is passing through its waters). According to the law of the sea, flag States are obliged to regulate the issue of arms on board ships (under Article 94 of UNCLOS and customary law), while coastal States are arguably only permitted to do so in a very limited fashion (under Article 21 of UNCLOS). Since they are both Territorial States, a rule obliging all Territorial States to comprehensively regulate arms on board ships seems too wide (Petrig, 2016).

The other issue was the issue of deprivation of liberty at sea by PMSC personnel, which the author related it to the concept of 'inherently State functions', i.e. functions that cannot be outsourced or delegated to private persons or entities, for instance, the police power to arrest and detention. There is a view that certain functions are inherently governmental functions, which cannot be delegated and/or outsourced to private entities. This view is reflected in Article 9 of the Draft Convention of the Working Group on Mercenaries, while Article 19(1) obliges each State to make the acts of carrying out such functions by PMSCs or their personnel criminal offences.

PMSC personnel are not generally vested with law enforcement powers. However, some jurisdictions accord them 'private arrest' or 'citizen's arrest' powers but must strictly be under legal basis. Some states have explicit rules for such actions (eg Belgium), but in other states, it is regarded as acts of self-defence. The rules allowing private persons to surrender a criminal suspect to the competent authorities also provide a legal basis for private arrest. The premise is that, if a private person is allowed to surrender a suspect, he or she can also hold that suspect until surrender. It is therefore crucial to further explore the circumstances under which PMSC personnel are allowed to hold an overpowered person on board to avoid criminalisation.

3.7 Opportunities for African PSCs

After deliberations with the participants, it became clear that both Tanzania and Kenya regimes do not have registration procedure for PMSCs. Whereas Kenya has the Private Security Regulatory Authority (PSRA) that regulates the PSCs, Tanzanian PSCs are regulated by the Tanzania Police Force (Sambu, 2023). There are clear registration procedures in the two countries for PSCs but the role of these PSCs in maritime security is yet to be recognised as a specialty and registration process set in place. The interview revealed that the closest the PSCs do related to maritime security is to provide port security, either by provision of manned guarding or installation of electronic security solutions. Some respondents in Kenya indicated that some multinational PMSCs had subcontracted some PSCs, who provide consultancies, to handle the negotiations with the pirates in Somalia during the height of the menace in late 2010s. This was done due to the proximity of Somalia from

Mombasa. According to them, the subcontracted consultants were successful. It was not clear though if the said consultants were properly registered as PSCs.

One expert expressed doubt of the capacity of the present PSCs in the two countries to undertake such delicate and complex security operations. There may not be enough experts to be employed by those willing to do so, unless they go for expatriates. There is another problem of the use of firearms. Kenyan PSCs are still not allowed to use firearms in their operations. This will inhibit their venture to maritime security. Tanzanian PSCs are allowed to use weapons, but only restricted to Shotguns, which are so inferior and not fit for purpose. To counter terrorist, who have superior weapons, will be a long shot for them. But the respondents indicated that there are a lot they can still do, going by the assessed roles in this paper, without the armed escort option.

The above scenario is a lost opportunity for PSCs in the two countries, given that their territorial waters remain a key transit route for international shipping lines. The two countries are relatively peaceful and have proximity to troubled areas of the African East Coast, the Red Sea and the Gulf. According to the respondents, they can therefore seek registration as PMSCs or enter into partnerships or joint venture with multination PMSCs to offer support on the ground. None of the respondents had plans to venture into PMSC roles in the near future but all acknowledged that there was a huge potential. Their main reason was lack of expertise and resources.

4.0 CONCLUSIONS

This paper assessed the role of PSCs in maritime safety and security. It assessed the status of the threat landscape, facing the sea transport, with statistics about piracy over the years. The paper explored the possible role of PMSCs in improving the maritime safety and security and how stakeholders would benefit. It also assessed the challenges facing the PMSCs. It ended with an assessment of the readiness of the PSCs in the East African nations of Tanzania and Kenya in venturing into the role of PMSCs.

There are threats facing the safety and security of the vessels and cargo on transit across many sea routes. There are spots deemed high-risk and vessels need support to pass through these spots safely. IMO has softened the stance about the carriage of weapons onboard ships and issued guidelines to the PMSCs. There are other voluntary standards as well, issued by ISO, ICoCA and UN.

There are still some challenges inhibiting full optimisation of the role of PMSCs. The potentiality to threaten sovereignty of littoral nations. The registration and governance of PMSCs involved in armed escort was also seen as a challenge, given that they cross jurisdictions with differing legal regimes regarding armed civilians. From the literature, there seems to be a lingering issue to do with the terminology and hence to roles of the territorial states about the work of PMSCs.

Many jurisdictions have set registration or recognition of PMSCs to offer support in

the high-risk areas. East Africa seem to be lagging in venturing into maritime safety and security, despite proximity to many troubled areas of the sea, due to either lack of capacity or willingness to venture into the maritime security. Due to lack of the interest from PSCs, the two nations of Tanzania and Kenya still do not have registration and regulation mechanisms for PMSCs.

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Schedule of the Interviews With the Selected Experts

Appendix 1: Interview with expert in Nairobi 29 March, 2024

Interview with two experts in Nairobi. One was the proprietor of a PSC operating in Eastern Africa region, with head office in Nairobi, employing over 3,000 people. The PSCs has offered services for the port in Mombasa, a number of shipping lines in facilities in Mombasa and the ferry services. The other expert was a retired senior officer at Kenya Navy and employed by one of the PSCs operating in Kenya. He had extensive experience in naval operations and has assisted some PMSC during the height of piracy in Somalia.

Appendix 2: Interview with expert in Dar es Salaam 20 March, 2024

Interview in Dar es Salaam with a retired senior military officer who served in the AMISOM in Somalia with the Kenya Defence Forces. He now works as a consultant for the oil and gas multinational on security matters and travels frequently along the Eastern Africa coastline.

Appendix 3: Interview with expert in Dar es Salaam 15 March, 2024

Interview in Dar es Salaam with two proprietors of local PSCs operating in Tanzania, one with 740 personnel and the other with 1,720 personnel. The other participant was a managing director for a multinational PSC, with over 4,000 staff in Tanzania. The two local PSCs had served some clients in the shipping industry but on land only. The two proprietors had military background. The director of the multinational PSCs is an expatriate who had served in the navy in a European country and had a stint in a Gulf country and the red sea on official duty.

SEARCH AND RESCUE OPERATIONS IN TANZANIA: CURRENT PRACTICES, CHALLENGES AND STRATEGIC SOLUTIONS

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ABSTRACT

This study reveals critical deficiencies in Tanzania's search and rescue (SAR) operations, emphasizing the urgent need for a comprehensive policy framework. The absence of a dedicated Search and Rescue policy has led to significant challenges, including inadequate coordination among entities involved in SAR operations during marine vessel disasters. This lack of coordination weakens the effectiveness of SAR missions, resulting in delays and increased risks to lives and property. The deficiency in SAR tools and equipment further worsens the situation, leaving responders poorly prepared to handle emergencies efficiently. Moreover, communication challenges persist, as the Maritime Regional Coordination Centre (MRCC) manages communications only for well-equipped vessels, leaving local vessels without a proper communication channel. This communication gap significantly impairs timely and effective rescue operations. The paper highlights the lack of specific agreements between ministries, authorities, administrative bodies, and agencies focused on search

and rescue. The existing national SAR plan should be managed and implemented by two maritime authorities, namely TASAC and ZMA. Additionally, there is a notable deficiency in knowledge and proper methods among individuals involved in fishing, cargo, and passenger transport activities concerning search and rescue. To address these issues, the paper recommends that the government develop and implement a robust policy on search, rescue, and evacuation. This policy should provide a comprehensive roadmap for enhancing SAR facilities in crucial water bodies such as the Indian Ocean, Lake Victoria, Lake Tanganyika, Lake Nyasa, and major rivers. This will help prevent the loss of vessels and lives among those working in these inland water regions. The establishment of a dedicated coastal commanding agency with full authority is proposed to effectively address these challenges. Key strategies include investing in advanced SAR equipment, enhancing communication systems, implementing comprehensive training programs, engaging the community, and strengthening policy frameworks to integrate marine and aeronautical SAR operations. These measures aim to significantly enhance SAR effectiveness, ultimately saving lives and minimizing the impact of emergencies.

Keywords: Search and Rescue (SAR), Policy framework, Coordination, Communication Challenges, Equipment, Training,Evacuation, Convention

1.0 INTRODUCTION

Search and Rescue (SAR) is a critical operation involving the deployment of available resources to assist persons in potential or actual distress. The effectiveness of SAR operations hinges on the organization, coordination, and availability of resources and personnel. This study aims to address the significant gaps in Tanzania's SAR capabilities, highlighting the urgent need for a more robust and coordinated approach.

1.1 Background

International standards and practices, as established by organizations such as the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO), provide a framework for SAR operations under conventions like the International Civil Aviation and Maritime Search and Rescue Convention (1979) and the International Convention for Safety of Life at Sea (1974).

Coastal states have specific obligations under these conventions to ensure effective SAR operations, including the establishment and maintenance of maritime safety facilities, as mandated by the International Convention for the Safety of Life at Sea (SOLAS), 1974. Despite these frameworks, Tanzania faces significant challenges in its SAR operations.

Research indicates that Tanzania's SAR efforts are hindered by inadequate coordination among entities, lack of modern equipment, communication gaps, and insufficient training

among stakeholders. For instance, the Mv. Bukoba capsize in 1996 resulted in approximately 800 deaths, showcasing severe deficiencies in SAR response and coordination (Hodgson, 1997).

Similarly, the Mv. Nyerere disaster in 2018, which led to about 200 fatalities, emphasizes the need for better-prepared SAR teams and equipment (BBC News, 2018).
In addition to these incidents, the Mv. Spice Islander tragedy in 2011 and the Mv. Skagit accident in 2012, with combined fatalities of around 1,000 passengers, further underscore the critical need for enhanced SAR operations and coordination (IRIN, 2011; Al Jazeera, 2012).

Despite the establishment of organizations like the Surface and Marine Transport Regulatory Authority (SUMATRA), Zanzibar Maritime Authority (ZMA), and the Maritime Rescue Coordination Centre (MRCC), Tanzania's SAR operations continue to suffer from significant gaps in equipment, communication, and knowledge among stakeholders.

Studies have also highlighted the lack of investment in modern SAR equipment and the absence of comprehensive training programs for SAR personnel. For example, a report by the World Bank (2015) identified significant deficiencies in Tanzania's SAR infrastructure, including outdated equipment and inadequate training programs. Furthermore, communication challenges persist, as the MRCC manages communications primarily for well-equipped vessels, leaving local vessels without a proper communication channel (Mwangura, 2012).

The primary problem addressed in this research is the inefficiency and ineffectiveness of Tanzania's current SAR operations. The absence of a dedicated SAR policy framework, coupled with significant gaps in equipment, communication, and training, poses a considerable risk to lives and property during maritime emergencies. This study seeks to develop and propose strategies to improve Tanzania's SAR infrastructure and coordination.

This paper will detail the current state of SAR operations in Tanzania, analyzing existing challenges and identifying areas for improvement. The study will draw from case studies of recent maritime accidents to highlight specific deficiencies in the system. Recommendations will focus on establishing a coastal commanding agency, investing in SAR equipment and facilities, enhancing training programs, upgrading communication systems, and engaging local communities in SAR efforts.

By addressing these points, this study aims to significantly enhance the effectiveness of SAR operations in Tanzania, ultimately saving lives and minimizing the impact of emergencies.

2.0 THEORETICAL BASIS

The future of Search and Rescue (SAR) practice in the United Republic of Tanzania (URT) requires strategic planning and coordination among various governmental and non-governmental entities. Effective SAR operations depend on the clear establishment of responsibilities, resource allocation, and collaborative agreements. SAR coordinators in each state must ensure the efficient management and execution of SAR operations using available resources, whether directly under their control or provided by other participating agencies.

SAR coordinators should define the area of responsibility for Maritime Search and Rescue (MSAR) operations and identify all available SAR resources within this area, including ships, helicopters, and other rescue equipment (IMO, 2020). Formulating agreements with other authorities and agencies is critical for resource sharing and collaboration with neighboring states (UN, 2021). A comprehensive SAR plan should be prepared and distributed to all relevant parties, ensuring conformity to established protocols (IMO, 2019).

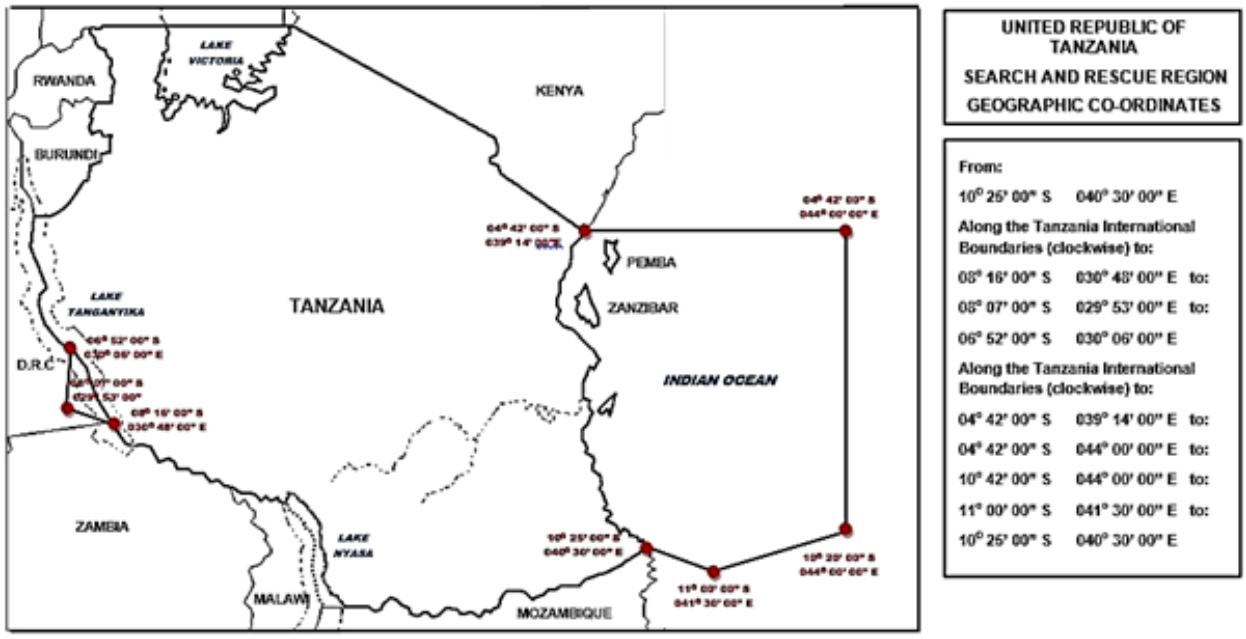

Figure 1: Map of Tanzania Showing Defined Areas of MSAR Responsibility

Establishing Maritime Rescue Coordination Centers (MRCCs) to manage SAR resources within the region is essential. In areas where MRCCs cannot provide direct and effective coordination, Maritime Rescue Sub Centers (MRSCs) should be established (ICAO, 2022). Designating alerting posts helps in timely reporting of any incidents requiring SAR intervention, acting as critical communication points during emergencies (UN, 2021).

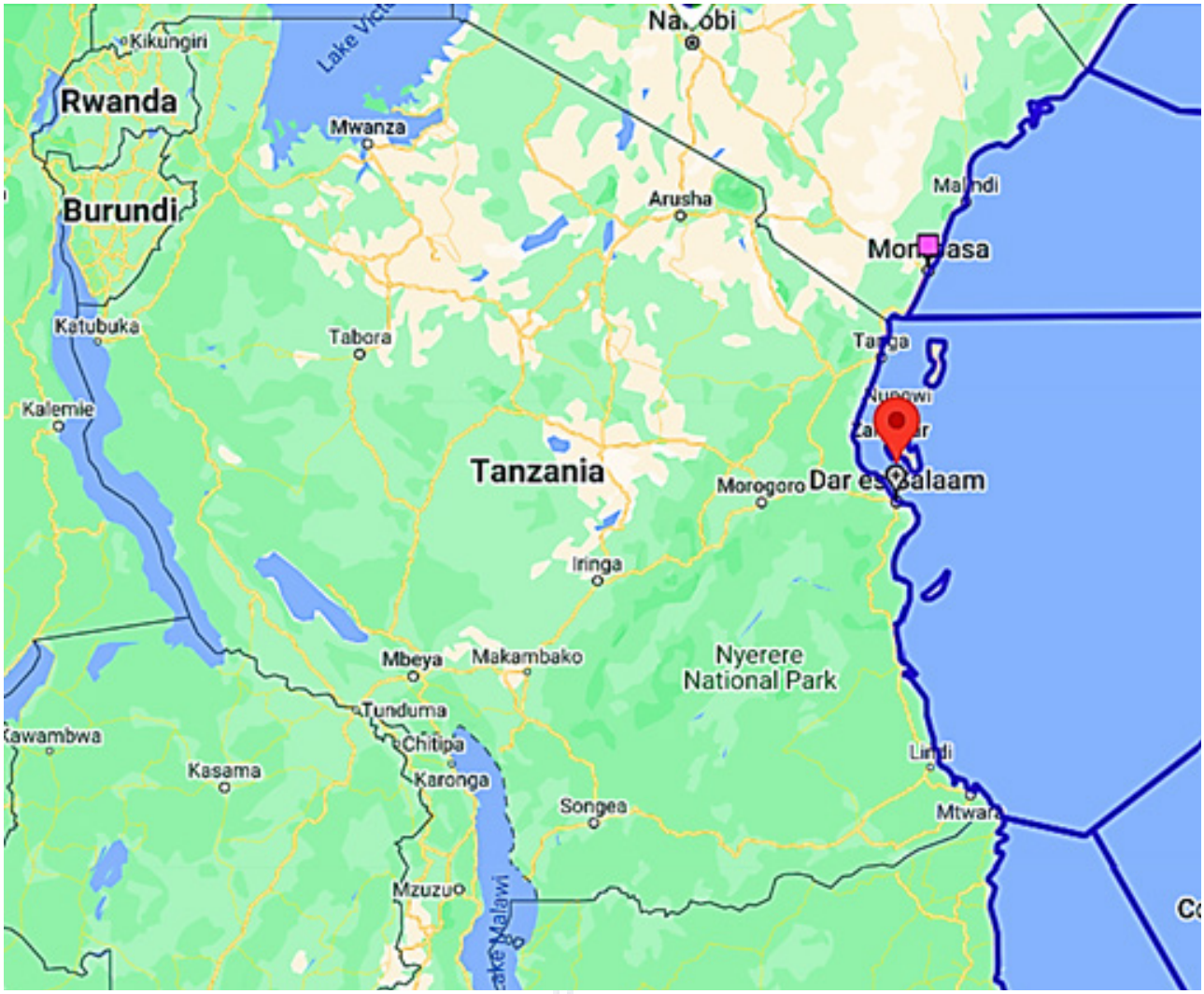

Figure 2: Diagram of MRCC and MRSC Locations in Tanzania (Source: https://sarcontacts.info/)

SAR operations should be conducted by assigning a Search and Rescue Mission Coordinator (SMC) and Search and Rescue Units (SRUs) until the mission is complete or assistance is no longer necessary (IMO, 2020). Regular submission of updated reports to superior authorities ensures that the SAR Joint Information Centre is well-informed and can provide appropriate guidance (ICAO, 2022). Developing and implementing adequate training programs for SAR personnel is crucial for preparing team members for various emergency scenarios (IMO, 2019).

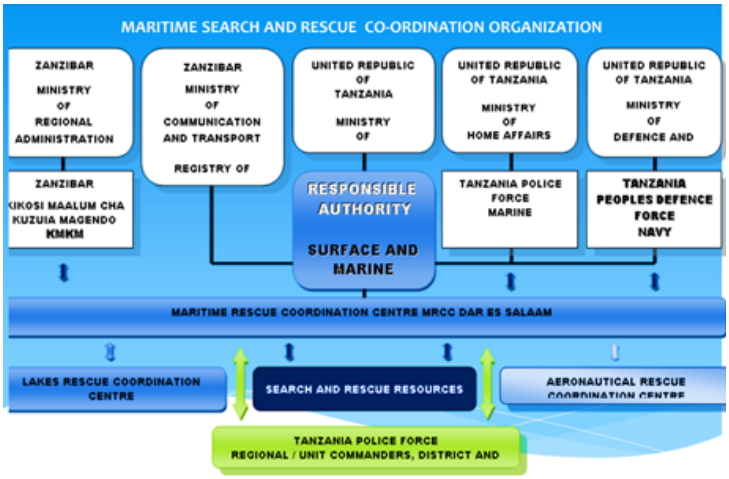

Figure 3: Flowchart of SAR Operation Reporting and Coordination Process (*Source:* Tanzania Civil Aviation Authority)

Establishing and maintaining professional relationships with salvage companies ensures quick mobilization of resources for SAR operations (UN, 2021). Various governmental authorities and agencies should participate in maritime SAR, including the Ministry of Transport, Ministry of Defence, Ministry of Home and Internal Affairs, Ministry of International Affairs, Ministry of Works, Ministry of Livestock and Fishing, Ministry of Health, Prime Minister's Office, Ministry of Information, Tanzania Shipping Agencies Corporation (TASAC), Zanzibar Maritime Authority (ZMA), Port Authority, Tanzania Meteorological Authority (TMA), Red Crescent, private companies, Dar es Salaam Maritime Institute (DMI), and the National Institute of Transport (NIT).

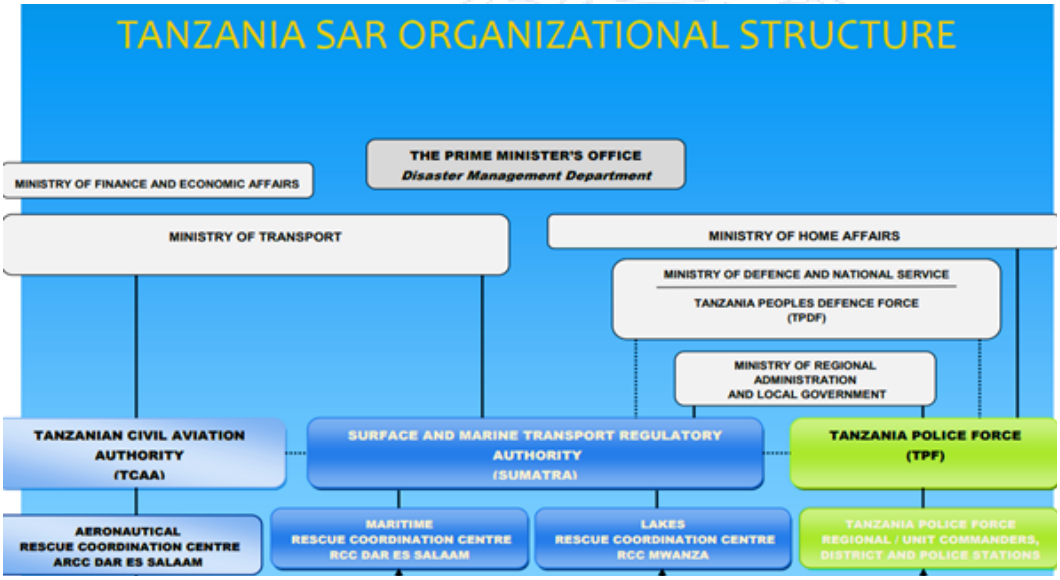

Figure 4: Organizational Chart of Governmental Authorities and Agencies Involved in SAR Operations (*Source:* Tanzania Civil Aviation Authority)

Effective SAR operations require formal agreements between these authorities and agencies. These agreements should delegate sufficient authority to the SAR Mission Coordinator (SMC) in MRCC or MRSC to ensure immediate action and avoid unnecessary delays (IMO, 2019). A comprehensive SAR plan should include details regarding the action to be taken in the area, a list of authorities and agencies providing facilities for SAR operations, available SAR facilities, the conduct of SAR operations, communication systems, and methods of alerting ships and other craft at sea (ICAO, 2022; IMO, 2020).

Figure 5: Example SAR Plan Layout

The detailed layout of the Maritime Search and Rescue (SAR) plan shown in figure 5 above is based on standard SAR procedures and techniques widely used in maritime operations. The central command center, rescue zones, and search patterns such as expanding square, parallel track, and creeping line are commonly adopted in SAR missions. These elements are drawn from official guidelines provided by organizations such as the International Maritime Organization (IMO) and the United States Coast Guard (USCG), which emphasize structured and systematic approaches to search and rescue operations. The inclusion of rescue vessels, helicopters, and life rafts illustrates typical assets deployed in SAR missions, demonstrating a comprehensive and coordinated effort to ensure the safety of individuals in distress at sea.

Search and rescue operations globally follow stringent protocols and standards to ensure efficiency and effectiveness. International standards set by organizations such as the International Maritime Organization (IMO) and the International Civil Aviation Organization (ICAO) serve as benchmarks. These standards cover aspects like coordination, equipment, and training (IMO, 2021; ICAO, 2019).

SAR operations in Africa face unique challenges due to varying geographical, economic, and infrastructural conditions. Studies from countries such as Kenya and South Africa highlight the need for region-specific strategies and innovations in SAR operations (Odhiambo *et al.,* 2020; Mokonyane *et al.*, 2018). These challenges necessitate tailored approaches to address the specific needs and constraints of different regions.

Lake Victoria, the largest lake in Africa, is a hotspot for maritime activities and incidents. Historical data reveals frequent accidents due to overloading, poor weather conditions, and lack of safety measures. The Mwanza and Kagera regions, bordering the lake, are particularly affected by these issues (Mgaya *et al.,* 2017). The high incidence of maritime accidents in these areas underscores the urgent need for improved SAR operations. Advancements in SAR technology, including the use of drones, GPS, and improved communication systems, have significantly enhanced SAR capabilities worldwide. These innovations are critical for improving SAR operations in Tanzania (Althaus *et al.,* 2019). Embracing these technological advancements can lead to more efficient and effective SAR missions, ultimately saving more lives.

3.0 DATA COLLECTION

To gather comprehensive data for this study, researchers employed both quantitative and qualitative methods. Mwanza and Kagera were selected as sample spaces due to their strategic locations along Lake Victoria. Field visits and interviews in these key locations with relevant stakeholders formed the core of the qualitative data collection. Specifically, the research team visited Mwanza and Kagera to observe current SAR practices and gather first-hand information. During these visits, qualitative data were collected through in-depth interviews with representatives from TASAC, Marine Police, ferry ship owners, maritime transport representatives, local government officials, and the Fire and Rescue Force (Jeshi la Zimamoto na Uokoaji). These interviews provided valuable insights into the practical challenges and gaps in the current SAR operations.

Figure 6: Map of Mwanza and Kagera (*Source:* https://kiroyeratours.com/)

For quantitative data collection, the researchers developed detailed questionnaires designed to capture the perspectives and experiences of a broader range of stakeholders across Tanzania. These questionnaires were made available online to facilitate wider participation. Stakeholders from various regions, including those involved in fishing, cargo transport, and passenger services, were encouraged to complete the questionnaires. This approach ensured that the data collected was both comprehensive and representative of the diverse views and experiences within the maritime sector.

The combination of quantitative and qualitative data collection methods provided a robust dataset that underpins the findings and recommendations of this study. The insights gathered from these diverse sources were instrumental in identifying the critical gaps and formulating strategic solutions to enhance SAR operations in Tanzania.

3.1 Sampling

Given the small total population size of 20 in the two regions (Mwanza and Kagera), the most effective approach for ensuring accurate and reliable data collection in this research has been to utilize the entire population. This method, known as the Census Approach, has provided the most precise and comprehensive data. The following sections have detailed the reasons for this approach and its implementation:

3.1.1 Census approach

Use the Entire Population: With a total population of only 20, including everyone in the study has ensured the collection of the most accurate and comprehensive data. This method has eliminated sampling error and has guaranteed that all perspectives are represented.

Benefits of Using the Entire Population:

- **Comprehensive Data:** Collecting data from all individuals has ensured that no opinions or experiences are excluded.
- **Increased Accuracy:** Without sampling error, the findings have been highly accurate and truly reflective of the entire population.
- **Detailed Insights:** Including everyone has allowed for an in-depth analysis of all possible variables and factors affecting SAR operations in the regions.

3.1.2 Practical feasibility

Given the small population size, it has been practically feasible to include everyone without incurring excessive costs or time. Interviews, questionnaires, and other data collection methods have been easily managed with 20 participants. Figure 7 below shows Data Collection Process for SAR Operations Study.

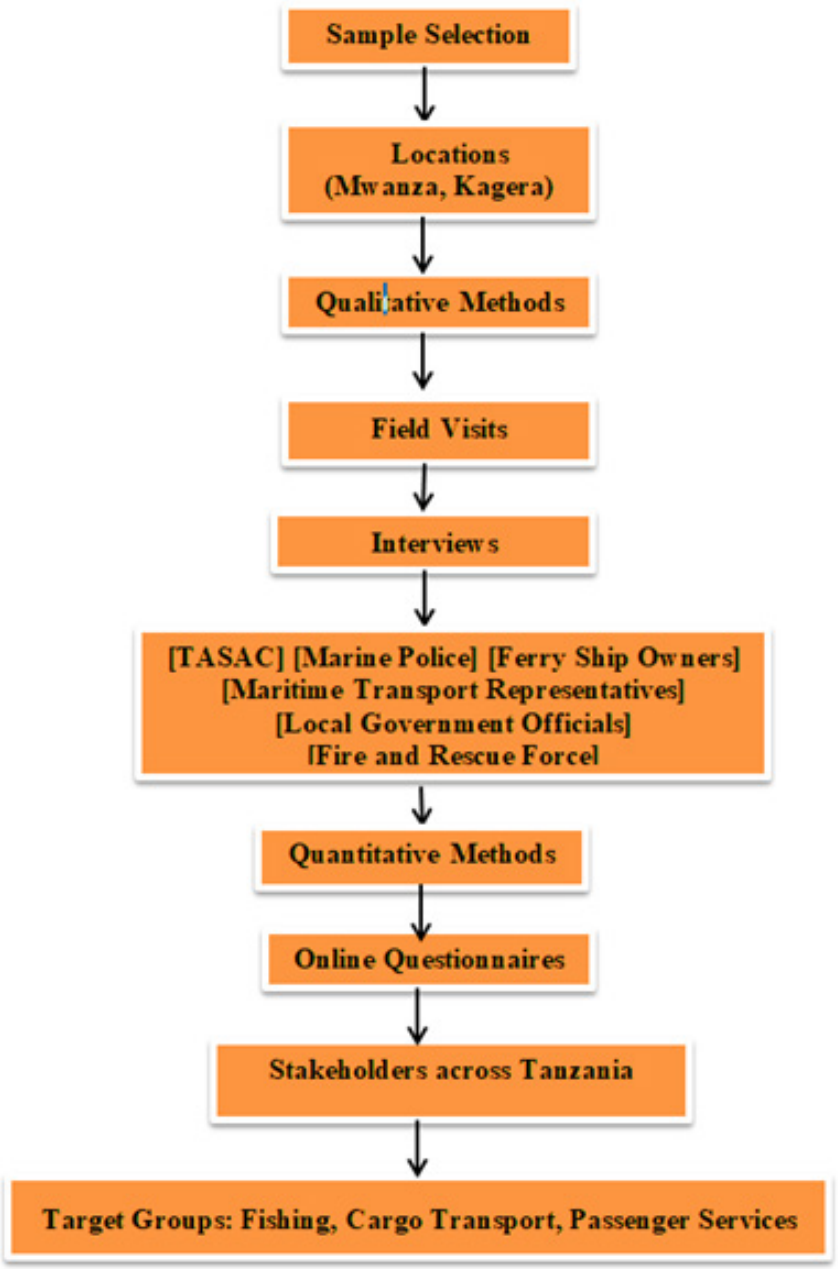

Figure 7: Data Collection Process for SAR Operations Study

3.1.3 Implementing the census approach

Field Visits and Interviews

Extensive field visits were conducted in the regions of Mwanza and Kagera to ensure a comprehensive understanding of the current practices and challenges in search and rescue (SAR) operations. During these visits, interviews were held with a wide range of stakeholders, including representatives from the Tanzania Shipping Agencies Corporation (TASAC), the Marine Police, ferry ship owners, maritime transport representatives, local government officials, and the Fire and Rescue Force (Jeshi la Zimamoto na Uokoaji).

Questionnaires
Detailed and accessible questionnaires were developed and distributed to individuals involved in fishing, cargo transport, and passenger services across the two regions. These questionnaires were designed to be easy to understand to maximize participation and ensure comprehensive data collection. Some of the questions and answers are shown in figure 8 below.

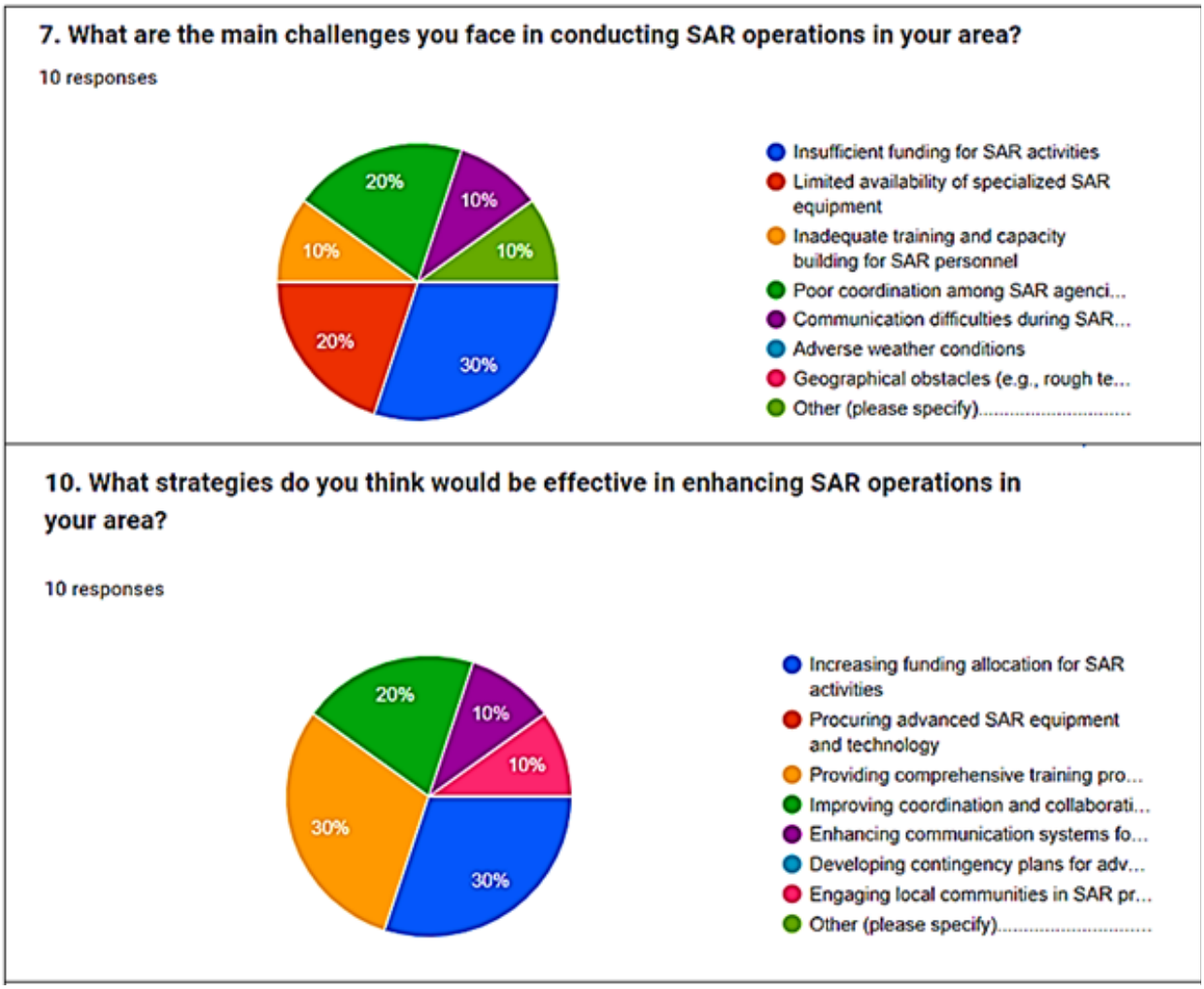

Figure 8: Questionnaires

3.2 Data Analysis

The data collected from the entire population was meticulously analyzed to identify patterns, gaps, and strategic solutions for enhancing SAR operations. Robust statistical methods were employed to ensure the accuracy and reliability of the analysis and interpretation. By adopting the Census Approach, this research has provided a holistic view of the current practices, challenges, and potential strategic solutions for SAR operations in Tanzania. This approach has yielded reliable and actionable insights, which are invaluable for

policymakers and stakeholders aiming to improve the effectiveness of SAR efforts and ultimately save lives.

4.0 RESULTS AND DISCUSSIONS

4.1 Results

The research has successfully collected comprehensive data on search and rescue (SAR) operations in Tanzania, focusing on the regions of Mwanza and Kagera. The Census Approach has enabled the inclusion of all 20 individuals in the population, ensuring a high level of accuracy and detail in the findings.

1. Inadequate Coordination Among Entities

- The data has revealed significant challenges in the coordination between various entities involved in SAR operations. The lack of a dedicated SAR policy has led to fragmented efforts, with different agencies working in silos.
- Interviews with representatives from TASAC, Marine Police, ferry ship owners, maritime transport representatives, local government officials, and the Fire and Rescue Force (Jeshi la Zimamoto na Uokoaji) have consistently highlighted communication breakdowns and overlapping responsibilities.

2. Deficiency in SAR Tools and Equipment

- Both qualitative and quantitative data have shown a critical shortage of SAR tools and equipment. Respondents have reported insufficient resources to handle emergencies effectively, with many local vessels lacking basic safety and rescue gear.
- The Maritime Regional Coordination Centre (MRCC) has been found to manage communications only for well-equipped vessels, leaving local vessels without a proper communication channel, exacerbating the response times and effectiveness.

3. Lack of Specific Agreements and Organizational Fragmentation

- The study has identified a lack of specific agreements between ministries, authorities, administrative bodies, and agencies focused on search and rescue. The division of the central authority into TASAC and ZMA has further complicated the implementation of a cohesive national SAR plan.
- Stakeholders have indicated that the existing national SAR plan is not fully operational due to these organizational issues.

4. Knowledge and Training Gaps

- The data has highlighted a significant deficiency in knowledge and proper methods among individuals involved in fishing, cargo transport, and passenger services. Many respondents have indicated a lack of regular training and updates on SAR procedures and protocols.

5. Community Engagement and Policy Frameworks

- The research has shown a need for greater community engagement and stronger policy

frameworks. Many participants have suggested that involving local communities in SAR planning and execution could improve response times and effectiveness.

- There is a clear call for the government to develop and implement a robust policy on search, rescue, and evacuation, incorporating the feedback and needs of all stakeholders.

4.2 Discussions

The findings from this study underscore the critical need for a comprehensive and integrated approach to SAR operations in Tanzania. The current state of SAR efforts is hampered by a lack of coordination, inadequate resources, and fragmented organizational structures. These issues have significant implications for the safety and efficiency of SAR operations, particularly in critical water bodies such as the Indian Ocean, Lake Victoria, Lake Tanganyika, Lake Nyasa, and major rivers.

1. **Improving Coordination and Communication**
   Addressing the communication gaps identified in the study is essential. Establishing a unified communication system that includes all vessels, regardless of their equipment status, is a crucial step.
   Creating clear, formal agreements between all relevant entities can help streamline responsibilities and improve collaborative efforts during SAR operations.

2. **Enhancing SAR Resources**
   Investment in SAR tools and equipment is urgently needed. Ensuring that all vessels are equipped with basic safety and rescue gear will enhance the overall effectiveness of SAR missions.
   Allocating funds for advanced SAR equipment and technology can further strengthen the response capabilities.

3. **Strengthening Policy and Organizational Structures**
   The division between TASAC and ZMA should be reevaluated to ensure that their roles are complementary rather than overlapping. Developing a unified national SAR plan that clearly delineates responsibilities and coordination mechanisms is vital.
   Implementing a robust policy on search, rescue, and evacuation, as recommended by stakeholders, will provide a comprehensive framework for enhancing SAR operations.

4. **Addressing Knowledge and Training Gaps**
   Regular training programs for all individuals involved in maritime activities are necessary to ensure they are well-versed in SAR procedures. These programs should be updated frequently to incorporate the latest best practices and technologies.
   Engaging with international SAR bodies for training and capacity-building exercises can provide valuable insights and improve local practices.

5. **Community Engagement**
   Involving local communities in SAR planning and execution can leverage local

knowledge and foster a culture of safety and preparedness. Community engagement initiatives should be designed to educate and involve local populations in SAR efforts.

By addressing these critical areas, Tanzania can significantly enhance its SAR operations, ultimately saving lives and reducing the impact of emergencies. The insights gained from this study provide a solid foundation for policymakers and stakeholders to implement effective and sustainable SAR strategies.

Future Plan

The research on "Search and Rescue Operations in Tanzania: Current Practices, Challenges, and Strategic Solutions" has laid a strong foundation for understanding the critical issues and potential solutions within Tanzania's SAR operations. Moving forward, the following steps are planned to further this research and implement actionable strategies:

1. **Development and Implementation of a National SAR Policy**
   - Collaborate with relevant stakeholders, including TASAC, ZMA, the Marine Police, and the Fire and Rescue Force, to draft a comprehensive national SAR policy.
   - Advocate for the adoption of this policy by the Tanzanian government and ensure its alignment with international SAR standards and best practices.
   - Conduct workshops and seminars to educate policymakers and stakeholders on the importance and benefits of the new SAR policy.

2. **Enhancement of SAR Coordination and Communication**
   - Establish a unified communication system that integrates all vessels, regardless of their equipment status, to ensure effective coordination during SAR operations.
   - Develop protocols for inter-agency communication and collaboration to eliminate current silos and enhance the overall efficiency of SAR missions.

3. **Investment in SAR Tools and Equipment**
   - Secure funding and resources to upgrade SAR tools and equipment for all relevant agencies, including local vessels.
   - Partner with international organizations and donors to obtain state-of-the-art SAR technology and training.
   - Implement regular maintenance and upgrading schedules to keep all SAR equipment in optimal condition.

4. **Regular Training and Capacity Building**
   - Develop and implement regular training programs for all individuals involved in SAR operations, including fishing, cargo transport, and passenger services.
   - Engage with international SAR bodies to provide advanced training and capacity-building exercises.
   - Establish certification programs to ensure that all SAR personnel meet high standards of competence and readiness.

5. Community Engagement and Education

- Launch community outreach programs to raise awareness about SAR practices and the importance of safety in maritime activities.
- Develop educational materials and conduct training sessions for local communities to involve them in SAR planning and response efforts.
- Foster a culture of safety and preparedness through continuous community engagement and participation.

6. Monitoring and Evaluation

- Set up a monitoring and evaluation framework to assess the implementation and impact of the new SAR policy and strategies.
- Conduct periodic reviews and updates to the SAR policy based on feedback and evolving best practices.
- Publish annual reports to share progress, challenges, and success stories with all stakeholders and the general public.

7. Expanding the Research Scope

- Extend the research to other regions in Tanzania to identify and address regional variations and specific challenges in SAR operations.
- Explore cross-border SAR collaborations with neighboring countries to enhance regional SAR capabilities and coordination.
- Investigate the impact of climate change on maritime safety and SAR operations to develop adaptive strategies.

By following this future plan, the research aims to significantly improve the effectiveness of search and rescue operations in Tanzania, ultimately saving lives and minimizing the impact of emergencies. The comprehensive approach will ensure that the solutions are sustainable, inclusive, and responsive to the needs of all stakeholders involved in SAR activities.

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ACCESS TO JUSTICE FOR SEAFARERS IN TANZANIA: A CASE STUDY OF CRIMINALISATION AND UNLAWFUL DETENTION OF SEAFARERS

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ABSTRACT

Access to justice is a fundamental principle and a condition precedent for the maintenance of the rule of law in any country. It entails several rights which inter alia include "equality before the law", "Right to a fair trial", "Right to access courts", and "Right to defense".However, this right in Tanzania and many other countries is not equally accessible to all people for the reasons broadly ranging from institutional, societal and cultural; and intersectional barriers. Seafarers are one of groups of people who are potential drivers of blue economy, but the right of access to justice to them in most cases is adversely affected by their criminalisation and unlawful detention by maritime law enforcement authorities

and their employers when they are accused of wrongs of purely criminal nature, regulatory crimes or even wrongs of civil nature onboard ship.

This paper therefore has elucidated the legal guarantees of the right of access to justice for seafarers and provided an insight as to how the practice of criminalisation and unlawful detention of seafarers in Tanzania and foreign states jeopardises the seafarers' right of access to justice. The article again, has proposed solutions to be taken in order to remedy the practice of criminalisation and unlawful detention of seafarers in order for the seafarers to enjoy their fundamental right of access to justice as guaranteed in the domestic and international legal instruments. Finally, the paper has reminded the states of their sacrosanct duty to honour the rights of seafarers particularly the right of access to justice.

The study has largely employed normative/doctrinal legal research methodology supplemented by empirical (non-doctrinal) methods.

Keywords: Access to Justice, Criminalisation, Unlawful Detention, Seafarers

1.0 INTRODUCTION

There is no any society which is free from the occurrence of crimes. It has been argued that, the crime should be treated as a normal and ordinary occurring phenomenon in the society.[1] With no crime in the society, there would never have been systems of criminal justice. However, the problem arises when people who had never been proved as criminals by the formal systems of criminal justice or who have committed an act which has never been interpreted by court to be the criminal act, are undeservedly placed in the womb of criminal treatments and unjustified incarcerations. In the occurrence of these, those people are said to have been undoubtedly denied their fundamental right of access to justice, and such a society will indeed be considered to have committed an open neglect of the rule of law.

Being the fundamental principle of the rule of law in any country, access to justice has recenly assumed its rightful place in the United Nations Sustainable Development Goals.[2] In Tanzania, "timely access to justice for all" was the phrase chosen to summarise the ideals guiding the ongoing legal sector reform programme and the draft 2008 Legal Sector Policy in Tanzania in which the government of Tanzania has shown a strong determination to ensure that all persons are afforded access to equitable justice and legal services no matter their rank in society.[3]

From the outset, it has to be noted that, access to justice is a broad concept which among others entails several rights including "Equality before the law", "Right to fair trial",

1 *Emile Durkheim, On Crime and Punishment, (Dissertation.Com, 2002)*
2 *G.A. Res 70/1, Transforming our World: The 2030 Agenda for Sustainable Development (2015)*
3 *Gastorn Kennedy, Access to Justice and Innevitable Reforms to the Civil Justice System: Reflection on Case Management and Legal Aid in Tanzania, (LST Law Review, Vol. 2016)*

"Right to legal aid", "Right to access courts", and "Right to defense".[4] Access to justice may therefore be defined as the ability of people to seek and obtain remedy through formal or informal institution of grievances in compliance with human rights standards.[5]

It is unequivocally provided that, the authority with final decision in the dispensation of justice rests with the Judiciary, the third branch of the government.[6] And every person is presumed innocent unless and until he is proven guilty by proper and competent legal authority of dispute resolution.[7] This is to say that, a mere accusations of criminal nature against a person does not necessarily make him deserves the criminal treatments and unjustified incarceration, rather the due process of law in adjudication as whole must be followed and completed.

In the world and Tanzania in particular, seafarers are known to be the potential drivers of the blue economy for they have since the time immemorial been performing an indispensable role in the cycle of blue economy. Their duties enable businesses and industries worldwide to access the resources they need to meet consumer demands. Seafarers therefore help to generate substantial revenue for countries and economies.[8]

However, regardless of this paramount contribution of seafarers in the cycle of blue economy as stated above, this section of people in Tanzania and other parts of the world is practically dismantled from the rule of law for their fundamental right of access to justice is adversely affected by the increasing practice of criminalization and unlawful detention by maritime law enforcement authorities and their employers most notably when they are alleged to have committed wrongs of purely criminal nature, regulatory crimes or even acts of civil nature onboard ship.

Because of this ill-fated criminal attitude of maritime law enforcement authorities and ship owners towards seafarers, the seafarers are subjected to criminal treatments on the face of criminal accusations and are mostly scapegoated in maritime accidents, collision, and spillage crimes as state maritime law enforcement authorities and shipping companies all seek to find seafarers to blame even in cases which require the proof of intention to commit an offence. They are also scapegoated with criminal treatments and unjustified detentions by their employers when they commit some acts on board ship and are sometimes deserted and detained in foreign countries for unreasonable period of time simply because of demanding their rights from their employers.

It has increasingly been reported that in many accusations of wrongs which are of criminal nature, seafarers are treated by law enforcement authorities and their employers as if it had already been proved beyond reasonable doubt that, they deliberately were prepared to commit the alleged wrongs. These practices have the repercussion of labeling seafarers as criminals and in turn jeopardise the seafarers' right of access to justice.

4 *Houghton N.C., Access to Justice and the Rule of law in Kenya, Open Society Foundation, 2006)*
5 *United States Instituteof Peace, Necessary Condition: Access to Justice, available at https:/www.usip.org/guiding-principles*
6 *Article 107A of the Constitution of the United Republic of Tanzania, Cap. 2 of 1977*
7 *Article 13(6)(b) ibid*
8 *International Chamber of Shipping , The Key Role of Seafarers in National Economies in a Net-Zero World, (the Institute of the Americas at the University of California San Diego, 2023)*

It is the duty of every state to ensure equal access to justice for all. If the state fails to ensure access to justice for all including seafarers, then the state is in a fundamental breach of its national and international duty to ensure equal justice for all citizens. Again, if justice is not easily and equally accessible to every citizen, there can hardly be the rule of law. If access to justice is limited to some sections of people or group of workers, those who are working on the land other than seafarers, then seafarers will have no stake in the rule of law and they will be readily available to turn against it. Ultimately, even the realm of blue economy will be dwarfing and hardly attainable in Tanzania.

Ready and equal access to justice for all is a *sine quo non* for the maintenance of the rule of law.[9]

2.0 LEGAL GUARANTEES OF SEAFARERS' RIGHT OF ACCESS TO JUSTICE

The definition of a term "seafarer" remains very important in determining to whom the rights of seafarers could be entitled. A seafarer may be described as any person who is employed or engaged or works in any capacity onboard a ship to which the Maritime Labour Convention, 2006 applies.[10] The Maritime Labour Convention, 2006 does not however give clarity on the ambivalent character and insurmountable authority of the ship master based on prerogatives attached to his rank of ship master which makes him slightly different from other ordinary seafarers.

However, since the ship masters work under the subordination of shipowners and more broadly, the convention does not isolate them in any particular manner from the protection of the treaty, they therefore are entitled as other seafarers to the rights enshrined in the convention.

On the legal guarantees of seafarers' rights, it is important from the outset to give a conceptual consideration of the place of seafarers' rights of access to justice. Firstly, seafarers have entitlement under international, regional and domestic human rights law by virtue of the fact that they are human beings. Secondly, seafarers have rights by virtue of the fact that they are workers. However, unlike most workers, seafarers cannot leave the workplace at the end of the day. Hence rights in the workplace have an even greater significance.[11]

The right of access to justice to seafarers as discussed in this work has been guaranteed by various international, regional and national legal instruments.

2.1 The Universal Declaration of Human Rights (UDHR) of 1948

9 *Judge Rahman J., in Faroque v. Secretary of the Ministry of Irrigation, Water Resources and Food Control (Bangladesh) 48 Dlr 1996 Supreme Court of Bangladesh, Appellate Division (Civil) A.T.M.*

10 *Article II (1) (f) of the Maritime Labour Convention, 2006*

11 *D. Fitzpatrick, M. Anderson, Seafarers' Rights, (OUP Oxford 2005)*

Article 7 of the UDHR provides that, all are equal before the law and are entitled without any discrimination to equal protection of the law. Moreover, Article 8 provides that, everyone has the right to effective remedy by the competent national tribunals for acts of violating the fundamental rights granted to him by the constitution or by law. Likewise, Article 10 provides that, everyone is entitled in full equality to a fair and public hearing by an independent and impartial tribunal, in the determination of his rights and obligations and of any criminal charge against him. Article 11 provides for the concepts of presumption of innocence whereby the accused person has the right to be presumed innocent until proven guilty.

Although it is clear that, the Universal Declaration is not a treaty, and such it is not *per se* a legally binding instrument for those states which are parties to it, its impacts in the development of human rights has been immense. Therefore, its relevance cannot be diminished.

2.2 The International Covenant on Civil and Political Rights (ICCPR) of 1966

Article 14 of the ICCPR provides that, all persons shall be equal before the courts and tribunals. In the determination of any criminal charge against him, or of his rights and obligations in a suit at law, everyone shall be entitled to a fair and public hearing by a competent, independent and impartial tribunal established by law. Article 14(2) provides for presumption of innocence in criminal charges under which everyone charged with a criminal offence shall have the right to be presumed innocent until proved guilty according to law.

Article 14(3) provides the minimum guarantees entitled to every person in determination of any criminal charge against him, which inter alia include the right to be informed promptly and in detail in a language which he understands of the nature and cause of the charge against him, to have adequate time and facilities for the preparation of his defense and to communicate with counsel of his own choosing, to be tried without undue delay, to have the free assistance of an interpreter if he cannot understand or speak the language used in court, not to be compelled to testify against himself or to confess guilt.

All these provisions are aimed at ensuring the proper access to justice and to this end upholds a series of individual rights such as equality before the courts and tribunals and the right to a fair and public hearing by a competent, independent and impartial tribunal established by law and presumption of innocence which are part and parcel of access to justice.

2.3 The African Charter on Human and Peoples' Rights (ACHPR), 1981

Article 3 of the ACHPR provides that, every individual shall be equal before the law and that every individual shall be entitled to equal protection of the law. Article 7 provides for the right to fair trial which among others includes the right to appeal, the right to be presumed innocent, the right to defense, and he right to be tried within a reasonable time by an impartial court or tribunal.

Article 26 provides further that, in making the right of access to justice a reality, state parties to the ACHPR are under a duty to guarantee independence of the courts and shall allow the establishment and improvement of appropriate national institutions entrusted with the promotion and protection of the rights and freedom guaranteed by the present charter.

Therefore, state parties to the ACHPR have an obligation to respect, protect, promote and fulfill the rights provided for under article 3 and 26 for the purpose of making the right of access to justice a reality to African states.

2.4 The United Nations Convention on the Law of the Sea (UNCLOS), 2982

Article 230(2) of UNCLOS provides for monetary penalties only for a pollution offence, except in the case of a wilful and serious act of pollution in the territorial sea. In order that the seafarers' human rights be respected, Article 230 (3) reminds the Courts that, during any such prosecution, the rights of the seafarer of access to justice must be respected.

Tanzania has ratified the major human right treaties such as the UDHR, ICCPR, ACHPR and UNCLOS. Being signatory to these instruments, Tanzania is bound to adhere to its obligation under these treaties.

2.5 The European Convention for the Protection of Human Rights (ECHR), 1950

Article 6(1) of the ECHR provides that, in the determination of his civil rights and obligations or of any criminal charge against him, everyone is entitled to a fair and public hearing within a reasonable time by an independent and impartial tribunal established by law. Article 6(2) provides that, every one charged with criminal offence shall be presumed innocent until proven guilty according to law.

Similarly, Article 13 provides for the right of effective remedy and Article 14 provides for the right of non-discrimination.

2.6 The Inter-American Convention on Human Rights (IACHR), 1969

Article 8(1) of the IACHR provides that, every person has the right to a hearing, with due guarantees and within a reasonable time, by a competent, independent and impartial tribunal, previously established by law, in the substantiation of any accusation of a criminal nature made against him or for the determination of his rights and obligations of a civil, labor, fiscal, or any other nature.

Article 24 provides for the equality before the law and without discrimination. Moreover, article 25 provides the right to recourse to a court/tribunal for the protection of rights and states are under obligation to ensure the availability and enforcement of remedies obtained.

2.7 The Constitution of the United Republic of Tanzania, 1977

The Constitution of the United Republic of Tanzania, 1977 contains the provisions of the Bill of rights and duties. The provisions that guarantee the right of access to justice in the Constitution will be examined in this part of the work.

Article 13(3) of the Constitution provides that, `the civil rights, obligations and interests of every person shall be protected and determined by competent courts of law'. Moreover, article 13(1) of the Constitution provides that all persons are entitled to the protection of the law which envisages that any person will have free access to the court for a remedy. Likewise, article 13(6) of the Constitution provides for guarantees of the right to a fair hearing by the court of law, when ones rights and obligations are being determined. Finally, article 30(3) of the Constitution provides that, if one feels that his constitutional rights have been violated, he has the right to `institute proceedings for relief in the High Court'. The Constitution also provides a right to a remedy by the court when rights have been violated under article 107A (2) (c).

3.0 PRACTICES OF CRIMINALISATION AND DETENTION OF SEAFARERS IN TANZANIA

Criminalization, as a concept can be defined in two senses. While in the first sense it means ''treating someone as a criminal'', in the second sense it means ''making something illegal'.[12] It has also been defined to mean "turning an activity into a criminal offence''.[13] Therefore, criminalisation of a seafarer means either treating a seafarer as a criminal or an act committed by him a criminal act, regardless of whether the seafarer has been proven guilty or the act he is alleged to have committed has been proven to be a criminal act. reating a seafarer as a criminal mostly occurs when the seafarer is accused to have committed a criminal wrong or other wrongs on board ship where seafarers have been incarcerated and in several cases were not charged. The concept of 'making something

12 *Brian Mathias, Criminalisation of the Seafarer: An Examination of the Seafarers Viewpoint and the Role of Shipping Industry Stakeholders in Dealing with the Phenomenon (the University of Polymouth, 2010)*

13 *Judy Pearsall, The New Oxford Dictionary of English, (Oxford University Press, 2001)*

illegal' refers to regulatory or civil offences of seafarers being made criminal offences by legislatures using new laws and by prosecutors combining series of old or obsolete laws or of using laws in ways legislatures did not intend.[14]

Criminalisation is one of the most serious problems facing seafarers today. When there has been a maritime accident, pollution infringement, or other wrongs of criminal nature seafarers have often been detained and denied access to normal rules of fair play and justice with which to defend themselves against criminal charges.[15] Arising from the continued neglect of seafarers, the International Maritime Organisation (IMO) and International Labour Organisation (ILO) Guidelines on the Fair Treatment of Seafarers in the event of a maritime accident were adopted on 1st July 2006. Unfortunately many countries do not follow these Guidelines and the ITF wishes to see them more widely promoted and enforced.[16]

Participants and observers of the maritime industry have been claiming a trend internationally towards criminalising the actions of seafarers in modern years.[17] Tanzania, as many other countries around the world is blessed to have the Indian Ocean and the population of qualified seafarers which were approximated to be 17,689 in 2022.[18] These seafarers have reported to experience a considerable degree of criminalization and unlawful detention by maritime law enforcement authorities and their employers/ shipping companies. The study took place in Mainland Tanzania and Zanzibar and has shown that, in Tanzania, there is existence of practices of criminalization and unlawful detention of seafarers.

The study was conducted by collecting of information from seafarers through the two major seafarer's unions in Tanzania namely the Tanzania Seafarers Union (TASU) and Zanzibar Seafarers Union (ZASU). From these unions, the study has conducted a survey on 97 cases of criminalization of seafarers in Tanzania which have occurred from 2014 to 2023 with 45 cases in Mainland Tanzania and 52 cases in Zanzibar from the seafarers' perspective.

Of these 97 surveyed cases, 57 involved elements of criminalisation and detention of seafarers before they have been pronounced guilty and 40 cases did not involve criminalization of seafarers. Meanwhile, out of 57 criminalised cases in 38 cases the accused seafarers were not charged.

The majority of seafarers portrayed that criminalization and unlawful detention is mostly imposed to them in the following incidents;

3.1 Criminalisation and Detention of Seafarers in the Event of Maritime

14 *Brian Mathias, Opcit*
15 *ITF Seafarers Section, International Transport Workers Federation (ITF): Criminalisation Toolkit available at https:www.itfgseafarers.org/en/global/*
16 *Ibid*
17 *Miranda Grange, Criminalisation of Seafarers-A New Zealand Perspective (University of Wellington, 2015)*
18 *https://dailynews.co.tz/tasac-wide*

Accident

There have been reported cases that seafarers are also criminalized and arbitrarily detained even if there is no finding of fault against them because they are forced to become material witnesses for the maritime accident case.

The study has conducted a survey on 57 cases of criminalization of seafarers in Mainland Tanzania and Zanzibar in the event of maritime accidents from the seafarers' perspective, which have occurred from 2014 to 2023. Of these 57 cases, 7 involved criminal treatments and arbitrary detention of seafarers before they have been pronounced guilty due to maritime accidents.

3.2 Criminalisation of Seafarers in the Event of Collision

It has been reported that, when collision occurs it is the ship master who is criminalized because there is always wrong belief on the part of maritime law enforcers that the master the master had an intention to commit an offence. They therefore subject him to criminal treatments and unlawful detention.

The study has conducted a survey on 57 cases of criminalization of seafarers in Mainland Tanzania and Zanzibar in the event of collision from the seafarers' perspective, which have occurred from 2014 to 2023. Of these 57 cases, 5 cases involved criminal treatments and arbitrary detention of seafarers before they have been pronounced guilty due to collisions.

3.3 Criminalisation of Seafarers in the Event of Pillage

Meanwhile, there have been reported cases of breaching the requirement of the United Nations Convention on the Law of the Sea (UNCLOS)[19] by maritime law enforcement authorities by imposing criminal treatments and unjustified incarceration of foreign seafarers in territorial waters without an indication of the required willful and serious act of pollution.

The study has conducted a survey on 57 cases of criminalization of seafarers in Mainland Tanzania and Zanzibar in the event of marine pollution from the seafarers' perspective, which have occurred from 2014 to 2023. Of these 57 cases, 11 cases involved criminal treatments and arbitrary detention of seafarers before they have been pronounced guilty due to marine pollution.

3.4 Illegal Fishing

The laws of the state and international laws are very clear on the position of fishing activities with respect to maritime zones. However, there have been cases where seafarers who are arrested for illegal fishing to have been subjected to high degree of criminal treatments and prolonged detention before they are found guilty of their charges.

19 *Article 230(2) and (3) of the United Nations Convention on the Law of the Sea (UNCLOS), 1982*

The study has conducted a survey on 57 cases of criminalization of seafarers in Mainland Tanzania and Zanzibar in the event of illegal fishing from the seafarers' perspective, which have occurred from 2014 to 2023. Of these 57 cases, 14 cases involved criminal treatments and arbitrary detention of seafarers before they have been pronounced guilty due to illegal fishing.

3.5 Drug Trafficking

The threat of drug trafficking has now reported to be a bigger challenge to seafarers than piracy. This is because in the event the ship is caught found with drugs even for planted schemes, it is the seafarers in that ship who are subjected to criminal treatment and arbitrary detention and their rights to proper legal proceedings are denied.

More than 300 tonnes of cocaine were seized from ships in 2023 according to Houston conference held by BIMCO, Interpol, InterManager, the World Shipping Council and the Northeast Maritime Institute.[20] But in most of these cases it is the seafarers who is trained to run the ship and not to deal with criminals who is scapegoated in the form of criminalization.

The study has conducted a survey on 57 cases of criminalization of seafarers in Mainland Tanzania and Zanzibar in the event of drug trafficking from the seafarers' perspective, which have occurred from 2014 to 2023. Of these 57 cases, 5 cases involved criminal treatments and arbitrary detention of seafarers before they have been pronounced guilty due to drug trafficking.

3.6 Civil and Other Incidents on Board Ship

There have been notorious cases in recent years where seafarers with high publicity in which seafarers faced considerable degree of criminal treatments and unjustified detention by their employers only because of doing some acts onboard ships which are purely not of criminal nature. These include criminslising seafarers who demand their rights like unpaid salaries, criminalisation of seafarers in the event of lost or damaged property onboard ship as well as criminalizing seafarers for obeying unlawful order of the officers of superior ranks.

The study has conducted a survey on 57 cases of criminalization of seafarers in Mainland Tanzania and Zanzibar in the event of civil and other incidents on board ship from the seafarers' perspective, which have occurred from 2014 to 2023. Of these 57 cases, 15 cases involved criminal treatments and arbitrary detention of seafarers before they have been pronounced guilty due to civil and other incidents on board ship.

20 *The Mission to Seafarers, Scourage Drug Smugging. available at http://www.mission toseafarers.org*

List of cases where criminalization has occurred in Tanzania 2014 to 2023
Source: *Tanzania Seafarers Union (TASU) and Zanzibar Seafarers Union (ZASU)*

S/N	Year of occurrence	Type of cases	Number of Cases	Status of the case
1	**2023**	-pollution -accidents -collision -illegal fishing -drugs -theft -other	-No criminalisation **6**	**Charged: 2** **Not charged: 4**
			With criminalisation **8**	**Charged: 3** **Not charged: 5**
2	**2022**	-pollution -accidents -collision -illegal fishing -drugs -theft -other	-No criminalisation **4**	**Charged: 2** **Not charged: 2**
			-With criminalisation **7**	**Charged: 2** **Not charged: 5**
3	**2021**	-pollution -accidents -collision -illegal fishing -drugs -theft -other	**-** No criminalisation **4**	**Charged: 2** **Not charged: 2**
			-With criminalisation **6**	**Charged: 2** **Not charged: 4**
4	**2020**	-pollution -accidents -collision -illegal fishing -drugs -theft -other	**-**No criminalisation **5**	**Charged: 2** **Not charged: 3**
			-With criminalisation **5**	**Charged: 2** **Not charged: 3**
5	**2019**	-pollution -accidents -collision -illegal fishing -drugs -theft -other	-No criminalisation **4**	**Charged: 2** **Not charged: 2**
			-With criminalisation **6**	**Charged: 2** **Not charged: 4**
6	**2018**	-pollution -accidents -collision -illegal fishing -drugs -theft -other	-No criminalisation 4	**Charged: 2** **Not charged: 2**
			-With criminalisation 6	**Charged: 2** **Not charged: 4**
7	**2017**	-pollution -accidents -collision -illegal fishing -drugs -theft -other	-No criminalisation 4	**Charged: 2** **Not charged: 2**
			-With criminalisation 4	**Charged: 1** **Not charged: 3**

8	**2016**	-pollution -accidents -collision -illegal fishing -drugs -theft -other	-No criminalisation 3	**Charged: 1** **Not charged: 2**
			-With criminalisation 5	**Charged: 2** **Not charged: 3**
9	**2015**	-pollution -accidents -collision -illegal fishing -drugs -theft -other	-No criminalisation 3	**Charged: 1** **Not charged: 2**
			-With criminalisation 6	**Charged: 2** **Not charged: 4**
10	**2014**	-pollution -accidents -collision -illegal fishing -drugs -theft -other	-No criminalisation 3	**Charged: 2** **Not charged: 1**
			-With criminalisation 4	**Charged: 1** **Not charged: 3**

It can be concluded that, in all 97 surveyed cases in Tanzania from 2014 to 2023, the cases in which criminalisation has taken place are mathematically attributed to cover 59%, and those in which no criminalisation has taken place were attributed to cover 41%. Meanwhile, in 67% out of 57 cases with elements of criminalisation, the accused seafarers were not charged before the court.

Internationally, the above analysis can be supplemented by the survey by Seafarers' Rights International (SRI) of 3,480 seafarers in the 12 months period to the end of February 2012 conducted in eight languages from 18 countries and 68 different nationalities of seafarers which revealed that, overall, 81% of seafarers who faced criminal charges considered to have received unfair and criminal treatments.[21] This pragmatically reveals that, the problem of criminalization and unlawful detention of seafarers is a reality not only in other parts of the world, it is but also occurring in a considerable degree in Tanzania.

4.0 MANIFESTATION OF CRIMINALIZATION OF SEAFARERS

The study has shown that the practice of criminalization and unlawful detention of seafarers is mostly manifested in the form of the presumed intention to commit an offence, scapegoating the seafarers, unfair treatment of seafarers, unlawful detention and involuntary self-incrimination of seafarers.

4.1 Pre-Judged/Presumed Intention to Commit an Offence

For a crime to be completely committed and make a person guilty/criminal, the person committing it must have an intention (mens rea) which must then be executed by him into action (actus reus). These two ingredients must be proved beyond reasonable doubts

in the court of law.

It has been found that, often when criminal allegations are brought against Masters or any other seafarers, there is always an implied assumption that there was intent on the part of seafarer to commit an offence. This presumed criminality of seafarers overlaps the due process of law and breaches their fundamental right of access to justice.

For example, it has been reported that, where the ship is arrested for committing a crime the pre-judged culprits are the seafarers particularly when the ship is associated with drugs.

4.2 Arbitrary/Unlawful Detention of Seafarers

Arbitrary/unlawful detention occurs when an individual is arrested and detained by law enforcement authorities without due process and legal protection of fair trial.[22] Therefore unlawful detention of a seafarer means the act of restricting the freedom a seafarer accused of a crime by law enforcement authorities or employers/shipping companies in a way that jeopardises their fundamental rights. This is mostly associated with not allowing seafarers to communicate with their families, not allowing seafarers to have reasonable access to legal assistance and not taking the seafarer accused of an offence to court promptly as required by law. Detention of a seafarer for more than a year constitutes prolonged detention and not a trial 'within a reasonable time,' and has been found to constitute violation of their fundamental right of access to justice.

Reports from Tanzania Seafarers Union (TASU) and Zanzibar Seafarers Union (ZASU) showed that from 2014 to 2023, there were more than 50 incidents of unlawful detention of seafarers by law enforcement authorities and most of them ended up without being charged in the court of law. These incidents were reported in various regions, including Zanzibar, Dar es Salaam, Pemba and Tanga.

In one of the recent famous cases, popularly known as Magufuli fish case[23], the High Court of Tanzania released 31 accused seafarers out of 36 who were arrested in 2009 and charged with illegal fishing and pollutin of marine environment, on the ground that they had no case to answer. But they had already lost two years of their lives detained in a foreign country trying to defend themselves from a crime which they had not committed. Likewise, in 2018 a Chinese flagged F/V Tai Hong 1, a foreign-flagged fishing vessel was arrested by Tanzanian law enforcement agencies for fishery crimes and withholding food and water from the Tanzanian fishermen working on board (seafarers) and detaining them in a small and unventilated accommodations.[24]

Internationally, a VLCC on a voyage from South Korea to Singapore was pursued by Taiwanese coast guard on the high seas for allegedly hitting a fishing boat resulting in death of two fishermen. Second Officer and duty AB were arrested. Master who at that

22 *The Centre for Justice and Accountability (CJA), Arbitrary Detention. available at http//www.cja.org.human-rights-issues*
23 *R v. Hsu Chin & 36 Others, Criminal Appeal 78 of 2009*
24 *http://www.seashepherdglobal.org*

time was asleep and off duty was arrested too and prohibited from leaving Taiwan for nearly two years. Master was charged with Manslaughter, one of the very serious crimes. Later investigations revealed that the VLCC was nearly one hour away from the capsized fishing trawler and there were no visible indications of any impact on ships hull. But the master by then had already lost two years of his life trying to defend himself in a foreign land from a crime which he had not committed[25]. All these cases show that criminalization of seafarers in the form of unlawful detention is real in Tanzania and worldwide.

Seafarers' Rights International (SRI) also carried out a review of all incidents involving criminal charges against seafarers for the 12 year period from 2000 to 2011. Significantly over the period under review, the numbers of maritime criminal incidents and the numbers of detained seafarers showed a tendency to increase.[26]

4.3 Arbitrary Arrest and Unfair Treatment of Seafarers

The arbitrary arrest of seafarers comprises the act of arresting seafarers in a manner that contradicts their fundamental rights enshrined in domestic and international legal instruments.

It has been reported by seafarers from Tanzania Seafarers Union (TASU) and Zanzibar Seafarers Union (ZASU) that, law enforcement agencies in Tanzania during arrest, search, and interrogation of seafarers who are alleged to have committed crimes usually use threats, excessive force and sometimes torture causing them pains and sufferings. In Tanzania, from 2018 to 2023 it was reported by Tanzania Seafarers Union (TASU) and Zanzibar Seafarers Union (ZASU) that there were reported in their office 30 cases associated with arbitrary arrest and unfair treatment of seafarers in 2023.

4.4 Scapegoating the Seafarers

In the realm of criminal justice, scapegoats are commonly identified as those who have been assigned penalties out of proportion to their involvement in a crime, where others actually involved cannot be prosecuted or are not assigned penalties to the extent that they deserve.[27] Scapegoating a seafarer therefore means the act of undeservedly putting all the blame to the seafarer for the crime more than he deserves while in reality the blame should deservedly be directed to some other persons. Seafarers have mostly been scapegoated for crimes in the place of ship owners because the law enforcement authorities harbours hostile attitude towards them.

In Tanzania, it has been reported by TASU and ZASU in several cases seafarers have been scapegoated by making them as human pawns in the event of maritime accidents and when the ship is arrested for drug trafficking.

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25 *Capt. Pankaj Kapoor, Criminalization of Seafarers, (2020). available athttp://www.slideshare.net/slideshow*

26 *Ove Öving, opcit*

27 *Gregory Mellema, Scapegoats: Criminal Justice Ethics, (Taylor & Francis, 2000)*

In MC Prestige case[28] of Captain Apostolos Mangouras who was the master of the oil tanker Prestige which, after having denied a place of refuge to undertake salvage operations, sank off the west coast of Spain in November 19, 2003, where it broke in two after its hull plates failed in the prevailing rough seas, causing massive oil pollution in the area. Captain Mangouras was held in Spain for almost two (2) years without trial and reports of his first three (3) months in prison showed that he was kept in high security and denied access to legal assistance or communication from people attempting to assist in his plight. He was only transferred from prison to a detention centre after a P&I club bailed him out.[29] All these cases reveal that, criminalization of seafarers in the form of scapegoating them is real in Tanzania as it is the case in other parts of the world.

4.4.1 Involuntary/unintentional self-incrimination of seafarers

Self-incrimination is the intentional or unintentional act of providing information that will suggest your involvement in a crime or expose you to criminal prosecution.[30] A person against whom formal accusations relating to the commission of an offence have been opened, which may result in prosecution has the right against self-incrimination. Individuals accused of an offence have the right against self-incrimination. They can refuse questions and making statements which are potentially incriminating themselves. In Tanzania, it has been reported by TASU and ZASU that, in several cases seafarers have been forced by law enforcement officers to make statements which have the impact of incriminating seafarers and on the basis of those statements, they were prosecuted.

It similarly occurs when seafarers from foreign countries are accused of an offence and not familiar with the language used by the law enforcement officers in the form of denial of assistance from an interpreter who can assist them to understand the questions and answer them properly. They due to this mostly find themselves ending up in making self-incriminating statements without knowing.

5.0 EFFECTS OF CRIMINALISATION AND DETENTION OF SEAFARERS IN ACCESS TO JUSTICE

The practice of criminalization and unlawful detention of seafarers in Tanzania and other parts of the world is not only affecting seafarers individually, but also it has adverse repercussions on their fundamental right of access to justice. When seafarers are undeservedly criminalized without following the due process of law, they are practically dismantled from enjoyment of the right of access to justice as other citizens.

As pointed out earlier, the right of access to justice is a multifaceted right as it entails several elements/rights which *inter alia* include "equality before the law", "Right to a fair trial", "Right to access courts", and "Right to defense".

For access to justice to be accessible to each and every citizen including seafarers, the

28 *Ove Öving, Criminalisation of the ship´s master and his crew, (Kalmar Maritime Academy, 2012)*
29 *ibid*
30 *Legal Information Institute (LII) at http//www.law.cornell.edu/wax/self-incrimination*

states must ensure that the above named elements/rights of access to justice are not threatened by criminal treatments or unlawful detention of citizens before the due process of law is followed. Therefore, the way criminalization and unlawful detention of seafarers affects the above named elements/rights of access to justice, is in a similar way affecting the right of access to justice.

5.1 Equality Before the Law/Non-discrimination

The cross-cutting principle of equality before the law, firmly established in international human rights law, requires states to grant equal access to justice to all individuals (including seafarers), regardless of their race, colour, sex, language, religion, political or other opinion, national or social origin, property, birth or other status.[31] In criminal cases, equality before the law also entails the right of equal treatments to all the accused persons who share the objective facts.

Therefore, while majority of citizens in the country other than seafarers alleged to have committed an offence are treated according to the due process of law, subjecting seafarers to criminal treatments and unjustified incarceration when they face the same allegations is equally the same as suggesting that seafarers deserve different treatments before the law.

Similarly, as one of the major goal of criminal justice apart from deterrence of criminal acts, is the isolation of dangerous persons from the society,[32] seafarers accused of criminal wrong are mostly considered to be the dangerous persons right from the moment they face criminal allegations, while persons other than seafarers with criminal allegations are considered so after their criminal status is adjudicated by the court of law.
This poses an open neglect the right of equality before the law to each and every citizen as seafarers are practically dismantled from enjoyment of equal status before the law as other citizens.

5.2 Equal and Effective Access to Courts of Law

One of the fundamental requirements for achieving the right of access to justice to each and every citizen, including seafarers is the possibility to have a case heard in a court of law without any sort of impediments.

The Constitution[33] requires the civil rights, obligations and interests of every person to be protected and determined by competent courts of law. It moreover provides that all persons are entitled to the protection of the law which envisages that any person will have free access to the court for a remedy.[34] The requirement equal and effective access to courts of law is not only applicable when the rights of a person have been infringed

31 *Article (2(1) of ICCPR ; Article 14 of ECHR; Article 1 of ACHR.*
32 *Allan J. Garfinkle and Charles H. Beatty, Individualized Treatment of Criminal Offenders, 33 Neb. L. Rev. 467 (1953) Available at: https://digitalcommons.unl.edu/nlr/vol33/iss3/11*
33 *Article 13(3) of the URT Constitution*
34 *Article 13(1) ibid*

but it also applies in similar way when the same person is alleged to have committed a criminal wrong. As a person who faces criminal allegations he must be subjected to the court of law within a reasonable where justice will be dispensed without fear and favour. From the moment a person is found guilty in the court of law is when the criminal treatment towards him are justifiable.

Therefore, subjecting seafarers to criminal treatments and unjustifiable detentions is equally the same as breaching their right of access to court of law which is the fundamental prerequisite of the right of access to justice. They never should be isolated from the society as dangerous persons before the court has declared their dangerous status.

5.3 The Right to Defense

It is a well-established principle that all persons accused of criminal wrongs should not only be afforded with the right to access the courts of law to face their charges, but also they should be granted with an opportunity to reasonably and fairly present their defense against those charges. Moreover, even the persons under the justifiable detentions have the right to be represented by the defense counsel and have unimpeded communication with such a defense counsel. Among the minimum guarantees entitled to every person in determination of any criminal charge against him, inter alia include the right to have adequate time and facilities for the preparation of his defense and to communicate with counsel of his own choosing, to be tried without undue delay, and not to be compelled to testify against himself or to confess guilt.[35]

Therefore, the practice of detaining seafarers without giving them adequate time to prepare their defense or reasonably communicating with their legal counsels is hampering their right to defense which is the fundamental prerequisite of the right of access to justice.

5.4 Fair Trial

Access to courts alone is not sufficient to ensure access to justice. The proceedings must respect certain guarantees of fairness. The law entitles a person who faces charges of any wrong of criminal nature to a fair and public hearing by a competent, independent and impartial tribunal established by law.[36] Additionally, in the context of criminal proceeding the right to fair trial implies that the seafarer accused of a criminal wrong shall be presumed innocent until proven guilty.

It is therefore, clear that arbitrary arrest and unjustified incarcerations of seafarers jeopardise their opportunity to have adequate time to prepare their defenses, protection against self-incrimination, and reasonable access to legal representation.
All these acts in effect hamper the seafarer's way of access to justice.

35 *Article 14(3) of the ICCPR*
36 *Article 14(1) ibid*

5.5 The Right to an Effective Remedy

Under the rule of law the fulfillment of the right to have access to justice requires the availability of a mechanism that effectively allow individuals, including non-nationals, to seek adequate redress for violations of their rights effective remedy, that is providing effective recourse to anyone who alleges violation of his right is essential.[37] This is because without such recourse, justice is of little use.Conditionally, the accused person can only defend himself adequately, if he is permitted to access effective legal recourse with due process. And access to due process can only be achieved if the matter is handled by a competent, independent and impartial court or tribunal.[38]

Thus, when the accused seafarer most notably foreign seafarers is detained for unreasonable period of time while receiving criminal treatment and denied the right to access court for the case against him to be adjudicated, such a seafarer is said to have been denied his fundamental right of access to justice, particularly the right to effective remedy.

Although the right to effective remedy seems to be in the first place available to persons whose rights are violated, seafarers in the course of criminalization and unlawful detentions are exposed to human right violations and therefore in a similar way their right to effective remedy is jeopardised.

6.0 MEASURES TO OVERCOME CRIMINALIZATION AND UNLAWFUL DETENTION OF SEAFARERS

The ends of access to justice will include the dismantling of the barriers obstructing the road to justice and put in place a new or restructured framework towards the attainment of justice.[39] As pointed out earlier in this paper, one of the barriers of access to justice is criminalization and unlawful detention of seafarers in the event of maritime accidents, pollution crimes, collision, and other criminal wrongs alleged to have been committed on board ship. Therefore, for the best interest of access to justice as the fundamental principle bestowed on us by the rule of law, specific measures needs to be taken to redeem this fundamental right from the hands of criminalization and unlawful detention of seafarers.

6.1 Dissemination of Legal Education and Awareness Campaign to Seafarers

Effective access to justice means among other things that, citizens need to have certain level of knowledge about their fundamental rights and the knowledge about how to protect themselves by using these rights. As it has been revealed that, among other reasons for criminalization of seafarers is the fact that, awareness of many seafarers as far as their rights and the legal protection bestowed on them are concerned is

37 *Article 2(3) of the ICCPR*
38 *Raphael Kamuli, The Right to Fir Trial in Tanzania,. Received from http://www.academia.edu*
39 *J. I. H. Jacob, The Fabric of English Civil Justice, (London: Stevens & Sons, 1987)*

considerably low. Therefore there is a dire need for the establishment special awareness training programmes intended to raise awareness of seafarers on their right of access to justice among other rights. This may be done in close collaboration with seafarers' unions through media platform and special training on their rights before seafarers are engaged in any ship.

This will help seafarers to defend themselves against criminal treatments and avoid circumstances of involuntary self-incrimination by law enforcement agencies. They will for example, be able to exercise their right to silence, when it is so likely that their statements are going to be used as evidence of guilt against them or as a reason to place them in pre-trial detention.

6.2 Legal Aid Programmes/Legal Representation to Seafarers

As pointed out above, one of the major obstacles in accessing justice among seafarers is low level of knowledge about their fundamental rights as guaranteed by domestic and international legal instruments. With little knowledge about their rights and how to defend themselves, law enforcement authorities take this advantage to subject seafarers to criminal treatments in different forms which among others include arbitrary arrest, unjustified detention, involuntary self-incrimination and even overpowering them in legal technicalities in the course of court proceedings.

There should therefore be special efforts by government and non-government stakeholders, including the Commission for Human Rights and Good Governance (CHRAGG), and paralegal organizations to extend their assistance through various legal aid programmes to seafarers who are subjected to criminalization and arbitrary detentions.

6.3 Registration and Reformation of Seafarers' Unions

It has been revealed by seafarers' unions in Tanzania (Tanazania Seafarers Union (TASU) and Zanzibar Seafarers Union (ZASU)) that, many seafarers are engaged onboard local and foreign ships, but majority of them are not registered members of the aforementioned unions. This makes these unions to have no connection with these seafarers and become unable to extend their assistance in the event of criminalization and unlawful detention of these seafarers. They claimed however to have never hesitated to give their assistance to these seafarers whenever they receive information about their criminalization.

Therefore, it is of paramount significance for seafarers before being engaged on board to be registered members of any recognised trade unions in order for these unions to extend their assistance in the event of criminalization and unlawful detention of seafarers.

Moreover, it has been revealed that many of these unions are designated to operationally extend their assistance to their members largely in cases involving labour rights against ship owners and giving little or no assistance to seafarers who are subjected to

criminalization and unjustified detention in different parts of the world.

It thus, follows that, the seafarers unions should subject themselves to a considerable reformation by, if not performing properly, extending the scope of their functions to cover criminal cases in which seafarers are practically denied their right of access to justice by being subjected to criminalization and arbitrary detention.

6.4 Bringing Judicial Services Closer to Seafarers

Access to justice is considered to be well-served if trials take place without undue delay. This helps protect the presumption of innocence and reduce the degree of criminal treatments to seafarers who are accused to have committed crimes in the form of prolonged detentions.

To bring judicial services closer to seafarers can be done through either establishment of special courts for maritime cases or establishing sea-based mobile cases in Tanzania.

With establishment of special courts for maritime cases: Since case congestions in our ordinary courts is among other reasons reported to be the cause of undue delay of cases including those whose victims are seafarers, establishing special courts to deal with maritime cases will certainly not only reduce caseloads in the ordinary courts but also make seafarers' cases in the newly established court be decided expeditiously.

With establishment of sea-based mobile courts: The distance for seafarers to the road of accessing justice will be much reduced and therefore minimizing prolonged case delays and detentions.

Admittedly, while the continued efforts of the Government and the Judiciary to some degree to improve access to justice, including by provision of court services, legal aid provision, and translation of laws into Swahili are dearly recognized, the establishment of special court to deal with maritime cases will indeed overcome criminalization of seafarers in the form of prolonged detentions and protection of presumption of innocence.

6.5 Accountability of Law Enforcement Officers

The accountability of the law enforcement officer is such a fundamental concern with vital significance in minimizing the rate of criminalization. As law enforcers, they should always know that they are public officers obliged and authorized by the people to enforce their laws. As such, they should worry the abuse of this authority by avoiding the use of excessive force, brutality, threats, manufacturing evidence, discrimination against certain groups and other forms of misuse of their office. Importantly, they should, in the exercise of this authority always have due respect on the fundamental right of people enshrined in various legal instruments of national and international nature. All these

can be possible by holding law enforcement officers and other individuals with arresting powers accountable/disciplined for the abuse of such powers.

Therefore, individual officers in law enforcement agencies responsible for enforcing the law in maritime areas which among others include Tanzania Police Force, Deep Sea Fishing Authority, Tanzanian Drug Enforcement Agency, and the Multy-Agency Task Team (MATT) should be disciplined in the event of proved and grievous misconduct of criminalization of seafarers.

6.6 Reducing Retributive Approaches/Attitudes Towards Accused Seafarers

Mostly, the aim of law enforcement officers in the criminal justice systems of many countries including Tanzania is to control crime through retributive means which suggests that evil should be returned for evil without any regard to consequences. It suggests that punishment is an expression of society's disapprobation for offender's criminal act

Therefore, following the principle of retribution as an effective way to control crime, many criminal law enforcement officers are treating persons accused of committing crimes in a way that label them as criminals. Therefore the law enforcers have to apply the reformative approaches which aim at changing the behaviour of the accused person so as to rehabilitate him as a law abiding member of society.

7.0 CONCLUSIONS

Viewing the law by its supposedly inherent nature as a measure of solidarity and equality among all people in the society, strict adherence to the law and ensuring due respect of the rights created by the existing legal instruments becomes an indispensable duty of any state claiming to deserve an accolade of the rule of law. With this being the case, Tanzania has this sacrosanct duty to take measures to overcome the growing scale of criminalization and unlawful detention of seafarers in order to guarantee equal access to justice for all people. It is legally unbecoming in an era when fundamental human rights are considered sacrosanct, seafarers seem to be excluded from the entitlement accorded to others.

For Tanzania to overcome this growing scale of criminalization and unlawful detention of seafarers, adherence to the domestic and international legal instruments enshrined with the fundamental rights bestowed on all people including the right of access to justice has for all purposes to be to be prioritized.

Therefore, it is the duty of every state to ensure equal access to justice for all. If the state fails to ensure equal access to justice for seafarers, then the state is in a fundamental breach of its national and international duty to ensure equal justice for all citizens.

And when justice is not equally accessible to all people in the country, there can hardly be the rule of law. If access to justice is only limited to some sections of people or group of workers, those who work on land other than seafarers, then the seafarers will have no stake in the rule of law and they will be readily available to turn against it. Ultimately, even the realm of blue economy will be dwarfing and hardly attainable in Tanzania.

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SUB-THEME 2

CLIMATE CHANGE AND ENVIRONMENTAL PROTECTION

REDUCTION OF GREENHOUSE GAS EMISSIONS IN GHANA'S PETROLEUM SECTOR TOWARDS SUSTAINABLE ECONOMIC DEVELOPMENT

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ABSTRACT

Close to three-quarters of global energy demand comes from fossil fuels with the majority of this energy being used in the energy sector. This has contributed to the significant emission of greenhouse gases (GHG). To mitigate the impact of these GHG, this paper seeks to analyse the activities within the downstream of Ghana's petroleum sector and their impact on the economy. Various methods were used in data collection and this includes the research design, data collection tools and procedures. The work further adopted the Long-Range Energy Alternate Planning (LEAP) model to study the future energy demand from the petroleum sector, identify emissions sources for potential inclusion in the proposed GHG emission assessment. The emission types have

been structured into two groups, according to the Intergovernmental panel on Climate Change (IPCC, 2006). They are fugitive emissions and combustion of GHG in the petroleum sector. To mitigate these GHG emissions, the work proposed the gradual infusion of bioenergy into the electricity generation mix, transportation and residential fuel use on a moderate and high basis. The findings depicted that the country's petroleum products demand will almost double between 2018 and 2030, an increase from 193 PJ in 2018 to 380 PJ in 2030. Emissions from energy demand will increase from about 28 million metric tonnes CO2 equivalent in 2018 to more than 52 million metric tonne CO2 equivalent by 2030. GHG emissions from energy transformation will almost triple between 2018 and 2030. In moderate bioenergy, capacity of electricity generation plants using biomass as feedstock expected to be 30 MW in 2018 and rise to about 85 MW by 2030 representing 3million tonnes of CO2 reduction. In the high bioenergy scenario, installed electricity generation capacity from biomass resources was amounted to 90 MW and almost triple to 250 MW by 2030, representing 7 million tonnes of CO2 reduction. Close to 70% of the reductions will be accumulated from the petroleum sector.

Keywords: Bioenergy, Energy sector, Fossil fuels, Greenhouse gases (GHG), Petroleum sector

1.0 INTRODUCTION

The global concern over climate change has spurred a renewed focus on mitigating greenhouse gas (GHG) emissions across various industries. Among these, the petroleum sector stands out as a major contributor to atmospheric carbon dioxide (CO_2) levels, with implications for climate change and sustainable development (Ou *et al.*, 2021). The petroleum sector is a cornerstone of economic development in many countries, providing essential energy resources to power industries, transportation and households. However, the combustion of fossil fuels, a primary component of the petroleum sector, releases significant amounts of greenhouse gases, particularly carbon dioxide (CO_2) and methane (CH4), into the atmosphere. This has led to unprecedented environmental consequences, including global warming, climate change, and adverse effects on ecosystems (IPCC, 2018). Developing countries, such as Ghana, face unique challenges as they balance economic growth with environmental sustainability.

Ghana, located in West Africa, has experienced rapid economic development in recent years, with its petroleum sector playing a crucial role in this growth. The discovery of significant oil reserves offshore has positioned Ghana as a key player in the regional energy landscape. However, the environmental impact of increased petroleum activities poses a threat to the nation's commitment to sustainable development (World Economic Forum, 2021). In alignment with global initiatives such as the Paris Agreement, which advocates

for a reduction in GHG emissions to limit global warming, Ghana has set ambitious targets for emission reduction and sustainable development (Republic of Ghana, 2015). The petroleum sector, being a major contributor to the country's emissions, becomes a focal point for implementing strategies that align with both economic growth and environmental stewardship. This study aims to explore innovative approaches and best practices in the reduction of GHG emissions within Ghana's petroleum sector.

1.1 Ghana's Petroleum Sector

Crude oil and its products are very fundamental commodities which play key role in industrial sustainability. Energy generation has been at the centre-stage of every country in the world to become an industrialized nation. With the petroleum products contribution to energy consumption in Ghana is about 26% (Ministry of Energy, 2010). Ghana oil exploration started in the year 1896 as a result of oil seeps found in the onshore Tano Basin in the Western Region of Ghana (Tullow, 2016). In 2004 Ghana sold licenses for offshore oil exploration and production to different international companies, (Kastning, 2011) and in July 2007, Kosmos Energy announced the discovery of an oil field at the West Cape Three of Ghana to contain up to three billion barrels of light crude oil.

The petroleum industry supply chain includes the process of exploration, extraction, refinery, transporting, marketing the petroleum product and the final consumer. This entire chain known as the petroleum industry consists of: (i) upstream activities, which involves exploration, development and production of oil and gas from oil or gas fields, (ii) midstream activities, which involves the transportation of oil and gas to the oil refinery or gas processing plant, and (iii) downstream activities, which involves the refining of crude oil and distribution of the petroleum products to consumers. In Ghana, the upstream sector is regulated by the Ghana National Petroleum Corporation (GNPC), whilst the downstream sector is the National Petroleum Authority (NPA).

1.2 Ghana's Energy Policies and Efforts at Greenhouse Gas Reduction

The impact of increased emissions from greenhouse gases has attracted local and global attention as a major development issues. The exploitation of biomass for energy purposes which is 60% of the total energy used in the country (Ministry of Energy, 2010a) results in deforestation and greenhouse gas emissions. The use of fossil-based fuels, flaring of natural gas associated with petroleum production and the production of petroleum products contributes to a lot of GHG.

The associated problems as a result of the use of conventional fuels informed policy makers to turn to renewable source of energy which has the potential to considerably reduce GHG emissions. Ghana in recent years has seen improvement in efforts to increase the share of renewable energy in the national energy mix in order to reduce greenhouse gas emissions. This is evident in the issue of 62 provisional licenses for Renewable Energy electricity as at 2015 with a total capacity of 5,074 MW. Out of the 62 provisional licenses, 44 licenses are for solar photovoltaic (PV) generation with a total capacity of 2,472 MW

(Energy commission, 2015). Fifteen (15) of the companies have received siting permits, however, only three (3) have advanced to the construction stage. This include a 20 MW solar photovoltaic grid-connected plant being constructed by BXC company at a location near Mankoadze in the Central Region and the 14 MW sea wave energy plant near Ada in the Greater Accra Region. This improvement is as a result of policies and initiatives aimed at providing conducive environment for the production and utilisation of renewable energy.

2.0 METHODS

This section elaborates on the various methods used in data collection to achieve the aim and significance of the study. It includes the research design, data collection tools and procedures and model used for the study.

Sources of Data

Historical data from the 2010 census and other relevant energy databases in the country were used in the Current Account (LEAP model terminology for the energy situation in the base year). The data for the base year (2010) comes from a variety of official sources in Ghana. These sources include the Ghana Statistical Service (GSS), Energy Commission (EC), National Petroleum Authority (NPA), Petroleum Commission, Volta River Authority (VRA), Ghana Grid Company (GRIDCO), Electricity Company of Ghana (ECG), Northern Electricity Distribution Company (NEDCO) and Bank of Ghana.

A. LEAP modules

LEAP is a scenario-based energy-environment modelling tool for energy policy analysis and climate change mitigation assessment. In order to project energy demand for the future, LEAP uses a base year, for which extensive data should have been available for the country or study location. Energy demand projection was done from 2018 to 2030. The input data for the LEAP model are grouped into four categories called modules. The four modules are the 'Key Assumptions' module, 'Demand' module, 'Transformation' module and 'Resources' module.

The 'key assumptions' module contains information on demographics (such as rural and urban population, population growth rates for rural and urban communities, and rural and urban household size), macroeconomic data (GDP and GDP growth rate) and other data that may be needed in the modelling of other scenarios such as data on key renewable energy resources. The demand module requires information on sector activities and energy intensity. Energy demand of a particular sector is computed as the product of an activity level measuring the level of energy service provided (such as number of households, passenger-km of transportation, output of an industry, etc.) and energy intensity. The demand module was disaggregated into branches such as Households (or residential), Agriculture, Industry, Transport, Non-residential and Street Lighting. Each of these branches was further disaggregated into sub-branches.

In current account, the transformation module is mainly composed of electricity generation and oil refining, consistent with energy consumption pattern in the base year for petroleum products. The transformation module also includes categories for the production of biodiesel, ethanol and biogas.

The resource module builds resource requirements based on data input in the transformation module. For example, if the fuel source of an electricity generation plant is natural gas, the resource module captures the amount of natural gas needed for the year based on the plant capacity and other relevant plant information such as capacity factor and efficiencies. In current account, resources include crude oil for the refinery and various fuels for electricity generation. The resource module provides energy supply options and their implications for carbon emissions.

B. Emission sources for the LEAP module

1. Fugitive Emission

The evaluating of fugitive atmospheric emissions of greenhouse gases from petroleum sector operations is detailed using the Intergovernmental Panel on Climate Change (IPCC) guidelines methodology for national greenhouse gas emission inventories. General fugitive emissions from petroleum sector activities may be attributed to the fugitive equipment leaks, process venting, evaporation losses, disposal of waste gas streams, example by venting or flaring and accidents and equipment failure- well blowout, tanker accidents, pipeline breaks, tank explosions, gas migration to the surface around the outside of wells, and surface-casing vent blows.

2. Combustion-related emission

The use of petroleum-derived fuels and natural gas as the main fuel in equipment such as heaters, engines and furnaces, causes combustion-related emissions in the petroleum and gas industry. To quantify GHG emissions from combustion, GHG reporting rule 40 CFR part 98 is being used as the methodology except for GHG emission from flaring, onshore production and combustion emission from stationary equipment used in the distribution of natural gas.

3.0 DATA ANALYSIS AND DISCUSSIONS

With the increasing demand for petroleum based products, it has become imperative to seek alternative solutions to meet demand for fuels and other energy sources in a manner that is also environmentally friendly and help meet global targets for GHG emissions. In this section, we first look at historic GHG emissions from Ghana's petroleum sector. Thereafter, we model future demand for petroleum based fuels to determine possible GHG emissions into the future.

3.1 Historical Greenhouse Gas Emissions From the Petroleum Sector

Figure 1 presents Ghana's historical greenhouse emissions from 1990 to 2012 from data presented by Ghana in their third national communication report to the UNFCCC (Republic of Ghana, 2015) in four main sectors that utilise petroleum products. These sectors include Stationary energy combustion, Transport, Fugitive emissions and Industrial process and product use. The observed increase in the emission trends corresponds to the structural economic transformation which has led to the increase in the utilisation of fossil fuel products. The expansion in the economy has resulted in significant rise in emissions from road transport and electricity generation from crude- fired thermal plants. CO2 is the dominant GHG for all the sectors. In 2012 emissions from stationery energy combustion made up of 52.2% of total emissions, followed by emissions from mobile combustion (transport) accounting for 47.8%. The remaining 0.01% came from fugitive emissions sources in the oil and gas industry.

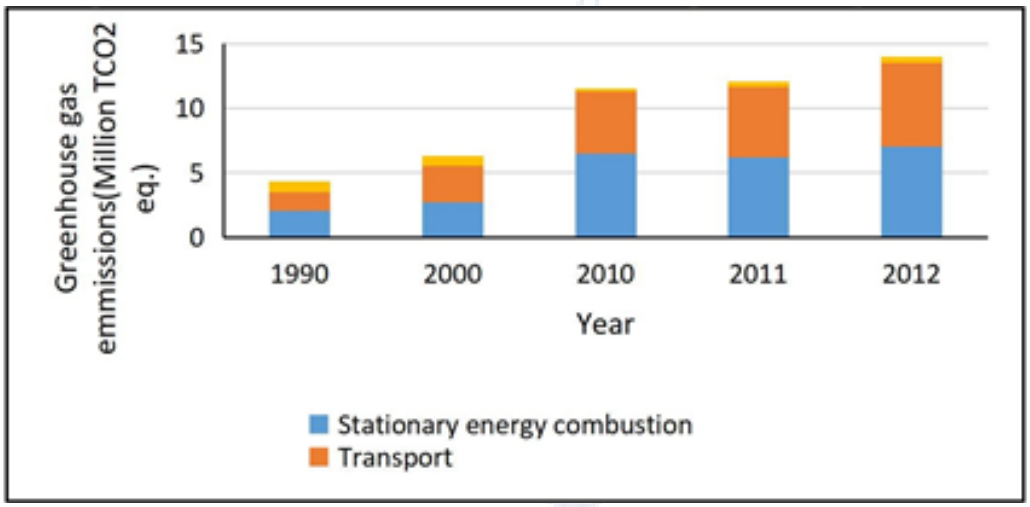

Figure 1: *Historical Greenhouse Gas Emissions from the Petroleum sector*

A. Future energy demand and the corresponding greenhouse gas emissions

1. Reference scenario

The reference scenario is a projection from the current account to build an energy demand and supply framework for the country over a desired period of time. Using business-as-usual assumptions (population and GDP growth projections), the reference scenario forecasts energy demand of the economy from 2018 to 2030. The reference scenario examines how Ghana's energy system and its CO_2 emissions might evolve up to 2030 in the absence of significant new policies specifically designed to address climate mitigation. In the reference scenario, the end use demand for different fuels is established up to 2030. Demand projection for energy is dependent on projected GDP and population growth.

Between 2001 and 2009, Ghana's GDP growth had averaged approximately 5.5%. Since crude oil production began in 2010 however, GDP growth has averaged over 8%, peaking in 2011 with a GDP growth rate of 15%. In 2010, Ghana's population was estimated at

24.6 million based on a population and housing census conducted in the same year. The number of households was estimated at 5.5 million. Based on the growth projections, it is expected that the number of households will increase to about 8.4 million in 2030. Energy demand for urban areas differs from rural areas in types of fuel and amount consumed. In 2010, Ghana had more than half of households (56%) living in urban areas.

Urban communities are defined by the Ghana Statistical Services as communities with population above 5000. In 2030, it is expected that urban households will reach 65% of the projected 8.4 million households. This will increase energy consumption and also serve as a driver for an increased use of modern fuels, such as electricity for lighting and LPG for cooking. With regards to transportation, the base passenger-km travelled is estimated at 85 billion in 2010 by the Energy Commission of Ghana. This is expected to grow at an annual rate of 6%. Road transportation is currently the dominant transport mode and will continue to be the dominant transport mode in 2030.

However, the share of road transportation is projected in the model to decrease from 95% currently to about 80% in 2030 with rail and air transport accounting for the remaining 20%. In 2010, more than 60% of transportation is estimated to be served by buses (of passenger capacities ranging from 20 upward) and light vehicles (with capacities above 5 occupants). This is not expected to change much, going into 2030. In the reference scenario, all road and rail transportation will rely on diesel and gasoline fuels whereas air transport will use jet fuel.

2. Final energy demand for the petroleum sector

The projected final energy demand/consumption of Ghana in the reference scenario for the petroleum sector is summarised in Figure 2. The country's petroleum products demand will almost double between 2018 and 2030, an increase from 193 PJ in 2018 to 380 PJ in 2030. With regard to the energy sources most in demand, diesel, gasoline and LPG will top the list. Diesel consumption will be double in the planning period, rising from 106 PJ in 2018 to approximately 208 PJ in 2030.

Demand for diesel is expected to come from increases in transportation fuel demand, industry and agriculture. In line with the current trends in urbanisation, it is expected that LPG consumption will rise considerably if retail infrastructure is expanded. Kerosene use is expected to decrease as more rural households switch to electricity for lighting. Diesel fuel will contribute about 55 % of total energy demand in the petroleum sector in 2030 due to an increased demand for transportation and industrial activity.

Together, the demand for diesel and gasoline will contribute approximately 83 % of petroleum consumption. The demand for LPG will increase but percentage wise, its impact will remain almost the same as its contribution in 2015. Figure 3 presents the energy demand from transportation fuels. The transportation sector is expected to be the dominant sector with respect to energy consumption well into 2030. Transportation sector growth will be led by road transportation growth as economic growth leads to increase in vehicle ownership. It is projected that transportation demand for diesel will

reach 4.4 million tonnes in 2030, up from about 2 million tonnes in 2015 as summarized in Figure 3. Gasoline demand is indexed to grow in small private vehicles and will more than double, growing from 1.2 million tonnes in 2015 to 2.6 million tonnes in 2030.

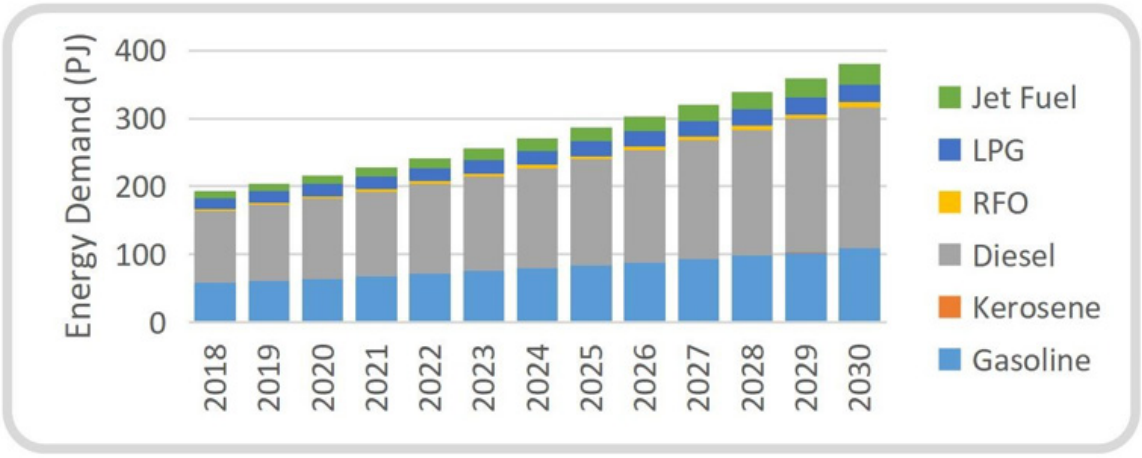

Figure 2: Projected Energy Demand by Fuel Type (Petroleum Sector)

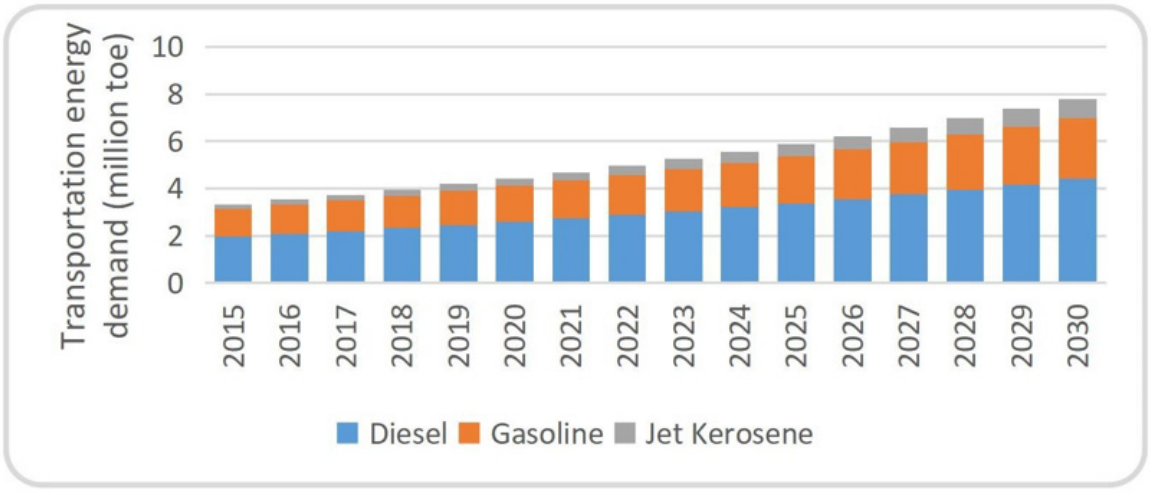

Figure 3: Transportation Fuel Demand by Fuel Type

3. *Final energy demand for the electricity sector*

Demand for electricity will almost double between 2018 and 2030. The increased demand for electricity is expected to be driven by government's plan to connect all communities to the national grid by 2020 as well as population and economic growth. As of 2010, about 64% of Ghanaian households have access to electricity. Even though government is aiming for a 100% access by 2020, Mensah *et al* (2014) argues that the 100% access may cover all communities in the country but perhaps not all households. In their view, a 100% access to electricity at the household level may be achieved closer to 2025.

Notwithstanding when 100% electrification occurs, whether 2020 or 2025, increasing number of households and the switch to urbanization will result in an increased demand for electricity. Refer to figure 4 below.

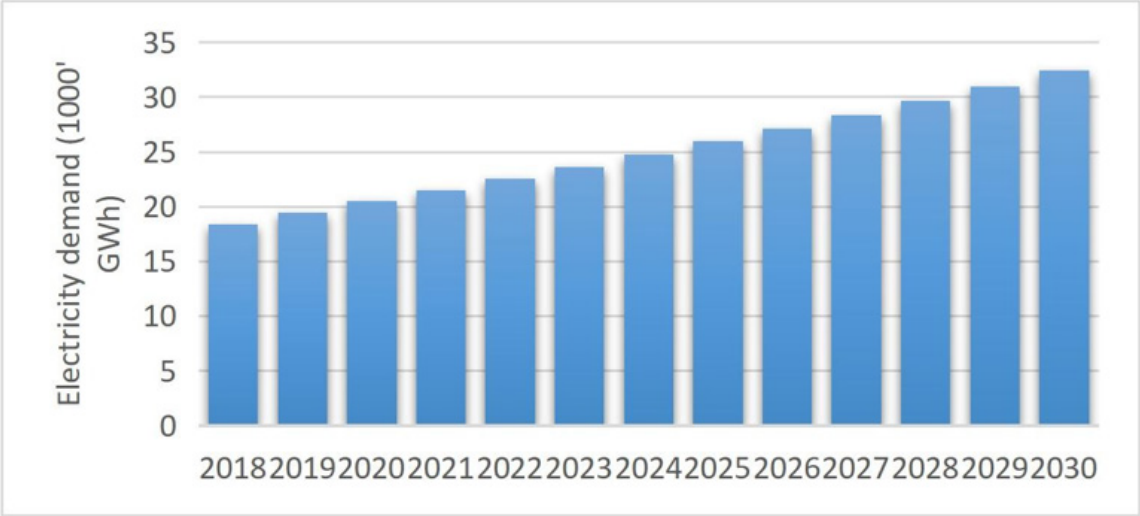

Figure 4: Electricity Demand

4. Emissions associated with projected petroleum demand

This section presents the estimates for GHG emissions for the period from 2018 –2030 for petroleum fuel demand for all sectors. The emissions estimates are made using the LEAP software, which also uses IPCC's official emissions factors. Figure 5 shows the 'one hundred year' global warming potential arising from demand for energy. Emissions from energy demand will almost double between 2018 and 2030, in line with demand for energy. Emissions will rise from about 28 million metric tonnes CO_2 equivalent in 2018 to more than 52 million metric tonne CO_2 equivalent by 2030.

Gasoline is projected to contribute the most GHG, accounting for more than half of the total GHG emissions between 2018 and 2030. Diesel fuel comes next and accounts for close to 30% of GHG emissions. Together, gasoline and diesel will account for more than 80% of GHG emissions from energy demand sources in the economy. The high contribution from diesel and gasoline is accounted for by their high demand for transportation. As stated previously, transportation fuel demand alone represents more than 50% of fuel demand by 2030.

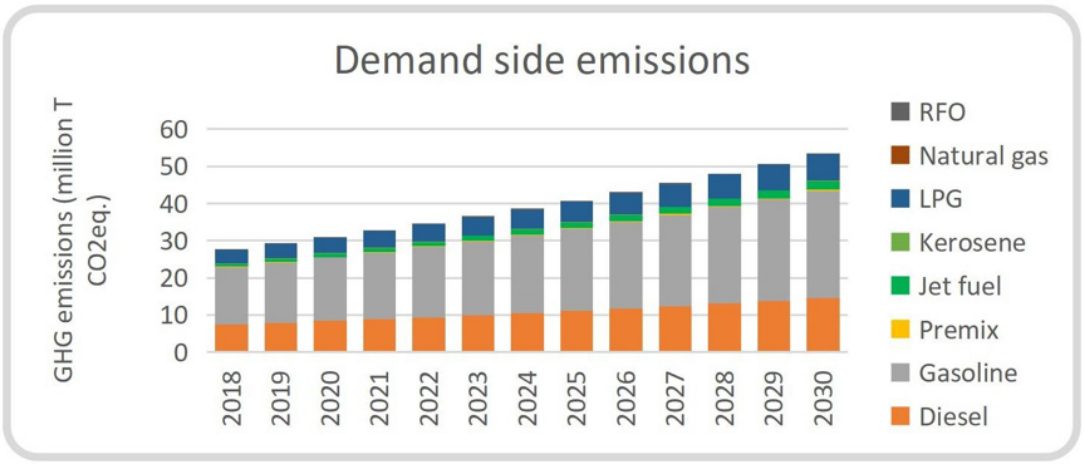

Figure 5: Demand Side Emissions from 2018 – 2030

5. Transformation centres' associated emissions

GHG emissions from fuel transformation in the petroleum sector are expected to come from electricity generation. Emissions from electricity arise from the burning of carbon intensive fuels, in this case natural gas and other associated fuels, to generate electricity. According to the electricity generation master plan put forward by the Ghana Grid Company, LCO would cease to be used as fuel for electricity generation from 2015 onward and natural gas will become the fuel of choice. There are two principal advantages to this: financial and environmental.

The average cost of generating electricity using LCO is higher than using natural gas, which is also less carbon intensive. Electricity generation was therefore modelled with natural gas as the principal fuel. Figure 6 shows projected emissions estimates from electricity generation from diesel and gasoline. Like the scenario for the demand side, GHG emissions from energy transformation will almost triple 2018 and 2030. From a little above 4 million tonnes CO_2 equivalent in 2018, GHG emissions are projected to exceed 12 million tonnes CO_2 equivalent by 2030.

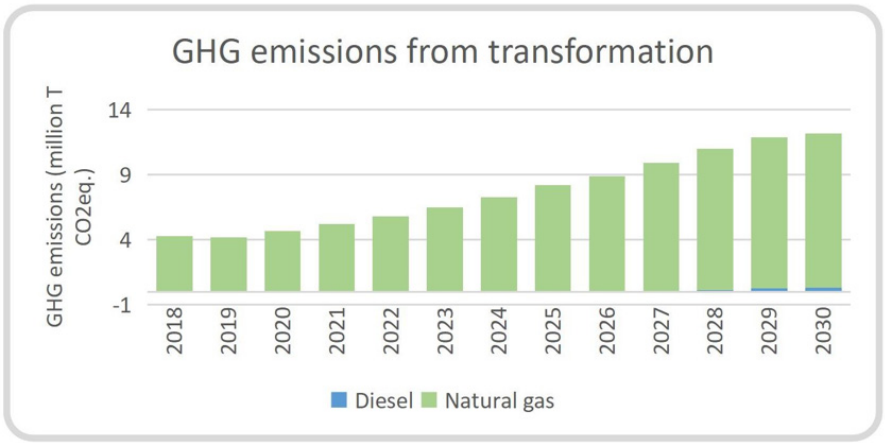

Figure 6: Projected Transformation GHG Emissions from Electricity

Emissions from electricity generation will rise constantly due to an anticipated increase in electricity generation capacity. Electricity generated is projected to increase from 18,400 GWh in 2018 to 32,400 GWh in 2030. As a result, emissions from the electricity sector will triple, from 4 million tonnes CO2 equivalent in 2018 to almost 12 million tonnes CO_2 equivalent by 2030. This is expected to increase the national electricity grid's carbon intensity from 0.18 to 0.28 TCO2e per MWh.

6. Net GHG emissions from energy consumption

The net GHG emission from energy consumption is obtained by consolidating the emissions from final energy demand and emissions from fuel transformation. The final emissions in 2030, 70 million tonnes of CO_2 equivalent, are almost twice the emission in 2018 (see Figure 7). Throughout the planning period, emissions from energy demand will account for approximately 75% of the total emissions per year with the remaining 25% coming from energy transformation. There are a number of opportunities for Ghana to reduce GHG emissions arising from energy demand and transformation. Potentials to reduce GHG emissions exist in the reduction of diesel and gasoline for transportation and the possible displacement of fossil fuels for electricity generation. This study does not rule out the possibility of reducing energy demand using, for example, more efficient public transport systems in place of individual vehicle and other mini-vans for transportation.

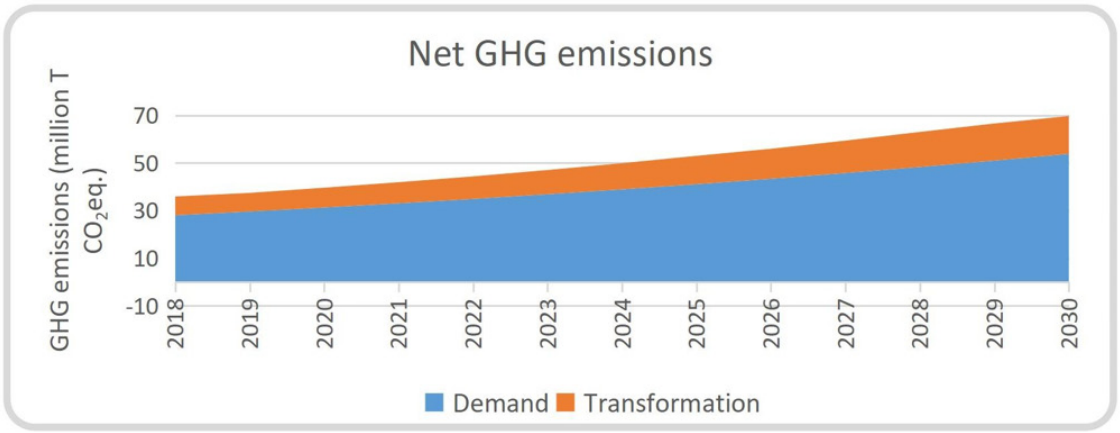

Figure 7: Net GHG Emissions

3.2 Policy Recommendations Towards the Reduction of Greenhouse Gases Emission in The Petroleum Sector

There are a number of opportunities for Ghana to reduce GHG emissions arising from energy demand and transformation in the petroleum sector. The study assesses the potential contribution of modern bioenergy for transportation fuels (using a combination of first and second generation biofuels) and small-scale electricity generation (using appropriate biomass technologies) and its impact on GHG emissions. These options were, however, considered in this study.

A. Alternative scenarios

The alternative scenario considers a gradual infusion of bioenergy into the electricity generation mix, transportation and residential fuel use on a moderate and high basis. This section presents results from the two alterative scenarios, moderate bioenergy and high bioenergy.

1. Electricity generation

In the reference scenario, electricity generation was assumed to follow a master plan developed by the Ghana Grid Company Limited, in consultation with the Energy Commission and other relevant stakeholders in Ghana's energy sector. As stated previously, the generation master plan took cognisance of the fact that renewable electricity must contribute 10% of capacity by 2020 and recommended a number of renewable electricity projects from wind, solar and mini-hydro to contribute towards achieving the 10% target. Notwithstanding the potentials for electricity from bioenergy, the master plan did not make any provision for electricity generation from biomass sources.

The alternative scenario therefore sought to analyse the potential for biomass resources to contribute to electricity generation between 2015 and 2030 and to estimate resource requirements as well as emission savings from such a plan. In the alternative scenario, biomass electricity generation sources are municipal solid waste (MSW), agro- industrial residue, oil palm residue and wood waste. In the low bioenergy scenario, it is assumed that a quarter of MSW collected in the major towns – Accra, Tema, Kumasi and the other regional capitals – is used to generate electricity.

There are potential technologies to generate electricity from MSW, through combustion, gas from anaerobic digestion and using landfill gas. In Ghana, MSW has high organic content of about 60- 70% (Asase et al, 2009), making combustion difficult without source separation. Also because of the lack of source separation, it is currently not possible to separate the organic sources alone for anaerobic digestion. This modelling therefore assumed that electricity generation from MSW will rely on the landfill gas technology. Wood waste and oil palm residue will rely on combustion technology which is already being used in the country. A summary of electricity generation from biomass sources is presented in Table 1. In moderate bioenergy, capacity of electricity generation plants using biomass as feedstock will be 30 MW in 2018 and rise to about 85 MW by 2030. This is expected to contribute about 1.3% of generated electricity by 2018, rising slightly to 1.7% by 2030.

This is lower, compared to about 5% electricity generation from the other renewable resources stipulated in the generation master plan, comprising wind, solar and mini-hydro. In the high bioenergy scenario, installed electricity generation capacity from biomass resources will amount to 90 MW and almost triple to 250 MW by 2030. In the high bioenergy scenario, electricity from biomass resources will contribute 3.8% to total electricity generated, rising to 5.1% by 2030. In the high bioenergy scenario, electricity from all renewable will contribute over 10% to total electricity generated by 2030, compared to below 7% in the low bioenergy scenario.

Table 1: *Electricity Generation in Alternative Scenarios*

Power from bioenergy	Moderate bioenergy scenario		High bioenergy scenario	
	2018	2030	2018	2030
Installed Capacity (MW)	30	85	90	250
Electricity generated	270	730	750	2,200
(GWh)As percentage of total electricity	1.3%	1.7%	3.8%	5.1%
Other renewable	0.5%	5.0%	0.5%	5%

2. Forest resources for electricity generation

One resource that also has high potential for renewable electricity generation is wood from forestry development and woodlot cultivation. For this reason, Ghana's draft renewable energy masterplan has set targets for the gradual infusion of electricity from woodlot cultivation into the national electricity mix. One of the key advantages of woodlots is that they serve as a carbon sink during the growing phase. In addition to that fact that they have high capacity factor makes them highly favoured as a renewable energy resource for electricity generation.

In line with African Plantation for Sustainable Development Ltd. (APSD), a forest plantation company in Ghana, has established large scale fast growing forest plantations to feed a power plant for energy production in the Brong Ahafo Region of Ghana. The planned plantation area is expected to produce some 600MW of power to feed the plant. APSD is committed to develop a mosaic plantation system where forest plantations are integrated and contributed to sustainable livelihood, biodiversity conservation, infrastructure development, GHG emissions reduction, economic growth and poverty reduction. Biomass will be burned to produce electricity and CHP via a steam turbine in dedicated power plants. A few of such large-scale plants are in operation. Plant efficiency is around 30% depending on plant size. Fossil energy consumed for bio-power production using forestry and agriculture products can be as low as 2%-5% of the final energy produced. Based on life-cycle assessment, net carbon emissions per unit of electricity are below 10% of the emissions from fossil fuel-based electricity.

Dedicated energy crops such as short-rotation (3-15 years) coppice (eucalyptus, poplar, willow) are the main trees grown in plantations for electricity generation. These resources have larger potential but are more expensive, compared to using wood waste. Technologies and cost of power and heat generation from biomass depend on feedstock quality, availability and transportation cost, power plant size, conversion into biogas (if any). If sufficient biomass is available, bio power and CHP plants are a clean and reliable power source suitable for base-load service. Main barriers to widespread use of biomass for power generation are cost, low conversion efficiency and feedstock availability. Most important are the lack of internalisation of external costs in power generation and effective policies to

improve energy security and reduce CO_2 emissions. In the long term, bio-power potential will depend on technology advances and on competition for feedstock use, and with food and fibre production for arable land use.

3. Transportation sector

Ethanol and biodiesel are the principal biomass sourced fuels used in the transportation sector. Both ethanol and biodiesel have properties similar to gasoline and diesel respectively, which makes them suitable replacements for these fuels when considering climate change mitigation.

In the case of biodiesel, the differences in chemical composition and structure between petroleum-diesel and biodiesel result in several notable variations in the physical properties of the two fuels. The most significant differences are as follows: biodiesel is more lubricating than petroleum diesel. This has the advantage of being expected to reduce engine wear. Biodiesel contains practically no sulphur which reduces pollution from engines using biodiesel. Biodiesel also has a higher oxygen content (usually 10 to 12%) than petroleum diesel and this should result in lower pollution emissions, improved biodegradability, reduced toxicity, and higher cetane rating, which can improve performance and clean up emissions.

Biodiesel is completely miscible with petroleum diesel (Benjumea *et al.,* 2008), therefore, various blends can be produced to improve the fuel performance in the CIE. Generally, biodiesel is much less toxic than petroleum diesel. Biodiesel produces about 35% CO, 22% CO_2, 10% SO_2 and 50% un-burnt hydrocarbon emissions when compared to fossil fuel (Alamu *et al.,* 2008). These makes biodiesel a great potential to replace petroleum-based diesel. Ethanol is also an environment friendly energy source which generates relatively acceptable quality exhaust gases leading to reduced GHG emissions (Nigam and Singh, 2011; Chiras, 2009). Therefore, bioethanol as a plant based liquid biofuel may be used in automobiles as additive or fermentation substitute to petroleum in transportation. This section present results on the penetration of ethanol and biodiesel in the two alternative scenarios.

Only ground transportation, i.e. road and rail, was considered for bioenergy use in the alternative scenarios. In the moderate bioenergy scenario, biodiesel will contribute 0.8% of transportation energy requirement in 2018, rising to 4.8% in 2030 as summarised in Table 2. Demand for ethanol is lower, compared to biodiesel. In the moderate bioenergy scenario, demand for ethanol will begin with a mere 0.2% of transportation energy in 2018 and rise to 2.3% in 2030. In the high bioenergy scenario, total biofuels demand will increase from 1% in 2018 to 18% in 2030. The high bioenergy scenario is in line with the draft bioenergy document which is calling for a 10% biofuels in transportation fuels by 2020 and 20% by 2030.

Table 2: *Percentage Transport Fuels in Alternative, by Energy Content*

Transport fuel type	2015	2030	2015	2030
	Moderate bioenergy scenario		High bioenergy scenario	
Biodiesel	0.8%	4.8%	0.9%	12.8%
Diesel	61.9%	58.2%	61.9%	49.8%
Ethanol	0.2%	2.3%	0.7%	5.2%
Gasoline	37.1%	34.7%	36.6%	32.1%
Total biofuels	1.0%	7.1%	1.6%	18.0%

In terms of actual biofuels requirements, Table 3 gives an indication of the biodiesel and ethanol required to meet the percentages shown in Table 2. In the moderate bioenergy scenario, more than 44 million litres of biofuels will be required in 2018, increasing to over 700 million litres in 2030. In the high bioenergy scenario, close to 80 million litres of biofuels will be needed in 2018, and increase to over 1.7 billion in 2030. In 2020, about 310 million litres of biofuels are needed in the transportation sector. This is close to the 336 million litres estimated by Antwi et al (2010) to meet 2020 requirements for biofuels in order to satisfy the draft bioenergy policy.

Table 3: *Biofuels Requirement in Alternative Scenarios*

Bioenergy (million litres)	2015	2030	2015	2030
	Moderate bioenergy scenario		High bioenergy scenario	
Biodiesel	30.4	409.5	35.4	1049.4
Ethanol	14.1	308.5	40.8	672.8
Total biofuels	44.4	718.0	76.3	1722.2

Meeting demand for biofuels in the alternative scenarios will require biomass resources. In Ghana, biomass resources being considered for biodiesel production include jatropha and sunflower oil. In the case of ethanol, cassava and sugarcane may be the principal energy crops, complemented with appropriate residues, as and when the technology becomes mature and cost effective. Table 4 summarises biomass resource requirements in the two alternative scenarios. It is assumed that biodiesel will be produced from sunflower and jatropha in a 50:50 proportion and ethanol will also be produced from a combination of cassava and sweet sorghum, also in a 50:50 proportion.

In order to achieve this, land required to cultivate the respective crops are estimated and summarised in Table 4. In the moderate bioenergy scenario, about 40,000 ha of land will be required to cultivate crops to meet demand for biofuels for transportation in 2018. This will rise to about 600,000 ha in 2030. In the high bioenergy scenario, close to 60,000

ha of land will be required in 2015 to meet biofuels demand, rising to about 1.47 million ha in 2030.

Table 4: *Resource Requirement for Biofuels Demand in Alternative Scenarios*

Participants	Frequency	Percentage(%)	Sampling Technique
Importers	10	20%	Purposive Sampling (Maximum Variation)
Exporters	7	14%	Purposive Sampling (Maximum Variation)
Shipping Companies	5	10%	Purposive Sampling
GovernmentAgencies	3	6%	Purposive Sampling (Snowball)
Arbitrators and lawyers	10	20%	Purposive Sampling
Research and Academic Community	15	30%	Purposive Sampling (Snowball)
Total	50	100%	

Source: Researcher, 2024

Conversion factors used: Biodiesel – 33.6 MJ per litre; Ethanol – 21.3 MJ per litre. Source document for conversion factors: European Commission (2007); biofuels yield data was obtained from Afrane (2012) and Sielhorst *et al.* (2008).

In 2010, approximately 7.8 million hectares, or 57.6% of the available arable land for agriculture in Ghana was under agricultural cultivation (Ministry of Food and Agriculture, 2011). This left approximately 5.8 million ha which was classified as uncultivated. By 2030, the high bioenergy scenario biofuels demand will require approximately 19% of the arable agricultural land regarded as unused in 2010. At the moment, the Ministry of Agriculture has not set aside any land for biofuels and it is not known how soon this will be done. One possible route to reducing land requirements for a possible biofuels consumption in the country is to improve agricultural yields or to produce some ethanol from crop residues, using advanced technologies. Although producing ethanol from crop residues is technically possible, the technology might take some time to mature as developed countries still grapple with the prohibitive costs of ethanol production from crop residues. Estimates by Kemausuor et al (2014) indicate that the technical potential of ethanol from crop residues generated in 2011 is about 2,250 million litres. In the high bioenergy scenario, this is three times the about 670 million litres that will be required to satisfy demand for ethanol in 2030.

4. Financial and economic analysis of biofuels

Generally, biofuels are more expensive than fossil fuels, and will remain so into the foreseeable future. This is especially true in Africa, where cost of production is higher, due to low technological development. Most technology for the production of biofuels in Africa are imported, which leads to higher costs. On a small scale, the costs of rendering the biomass into usable fuels make it unfeasible. More energy is needed to produce the fuel than is gained by using the fuel. However, on a larger scale, these numbers quickly reverse and biomass and biofuels become a highly feasible, renewable source of energy, even if more expensive than fossil fuels.

Currently, the cost of collecting biomass and transporting it to a centralized processing station are higher than the costs of extracting fossil fuels from the earth. For this reason, the use of fossil fuels will likely continue to be predominate until their supplies are nearly completely exhausted. However, creation of local biomass processing plants and power generation plants can eliminate the need to have vast pipelines or to move fuels by truck or train from one place to another. If the energy is used in the same area it is produced in, the cost of the energy decreases dramatically. Biodiesel produced from vegetable oils and animal tallow is almost identical to petroleum based diesel fuel in terms of the amount of energy it produces and how it burns in an engine.

The emissions are much cleaner with biodiesel, but the cost is almost three times the cost of conventional diesel fuel. The benefits of using biodiesel should outweigh the costs over time, but in the short term, it is not seen as a feasible substitute at the present time. An estimate of the cost implications of biofuels for transportation modelled in this study is shown in Table 5. In 2030, our estimates show that the total cost of biofuels will surpass fossil fuels by about 15.3 %, in both the moderate and high bioenergy scenarios.

Table 5: *Cost Analysis for Biofuels by 2030*

Biofuels required	Moderate Bioenergy			High Bioenergy		
	t (million litres)	**biofuel (million US$)**	**equivalent fossil fuel (million US$)**	**t** (million litres)	**biofuel (million US$)**	**equivalent fossil fuel (million US$)**
Biodiesel demand	409.5			1049.4		
Sunflower oil required	204.8	307.2	266.24	524.7	787.05	682.11
Jatropha oil required	204.8	307.2	266.24	524.7	787.05	682.11
Ethanol demand	308.5			672.8		
Ethanol from Cassava	154.3	231.45	200.59	336.4	504.6	437.32
Ethanol from sweet	154.3	231.45	200.59	336.4	504.6	437.32
Total cost		1077.3	933.66		2583.3	2238.86

Biofuels may have a bigger impact on the entire economy however, due to its job creation potential, and the fact that it will impact positively on Ghana's foreign spending, due to reduced cost of importing fossil fuels. Biofuels can be produced domestically, which could lead to lower fossil fuel imports. If biofuel production and use reduces our consumption of imported fossil fuels, we may become less vulnerable to the adverse impacts of supply disruptions. Reducing our demand for petroleum could also reduce its price, generating economic benefits for consumers. Biofuels may reduce some pollutant emissions.

5. Emissions savings in alternative scenarios

In the alternative scenario, GHG emissions savings will accrue from reduced petroleum fuel consumption due to the introduction of bioenergy into the energy mix. The outlook for petroleum fuels in the three scenarios are presented in Figure 9. In the moderate bioenergy scenario, about half a million tonnes of petroleum fuels will be saved from transportation and electricity generation, doubling to about 1 million ton in 2030. In the high bioenergy scenario, petroleum fuel savings will begin at 0.7 million tonnes, tripling to about 2.2 million tonnes in 2030.

The potential reduction in greenhouse gases is 3 million tonnes of CO2e in the moderate scenario and over 7 million in the high bioenergy scenario in 2030 (Figure 10), equivalent to 10% reduction relative to total projected emissions in the reference scenario. Close to

70% of the reductions will accrue from the petroleum demand sector. The transformation sector savings are lower because of the assumption that natural gas is the primary electricity generation fuel for electricity in the reference scenario. Also, the road map for electricity generation already stipulate a 10% generation capacity from renewables by 2020, which results in lower emissions from electricity generation. GHG reduction in the transformation sector would be higher if LCO, which has a higher emission factor, is used in the electricity generation mix from 2015 onward.

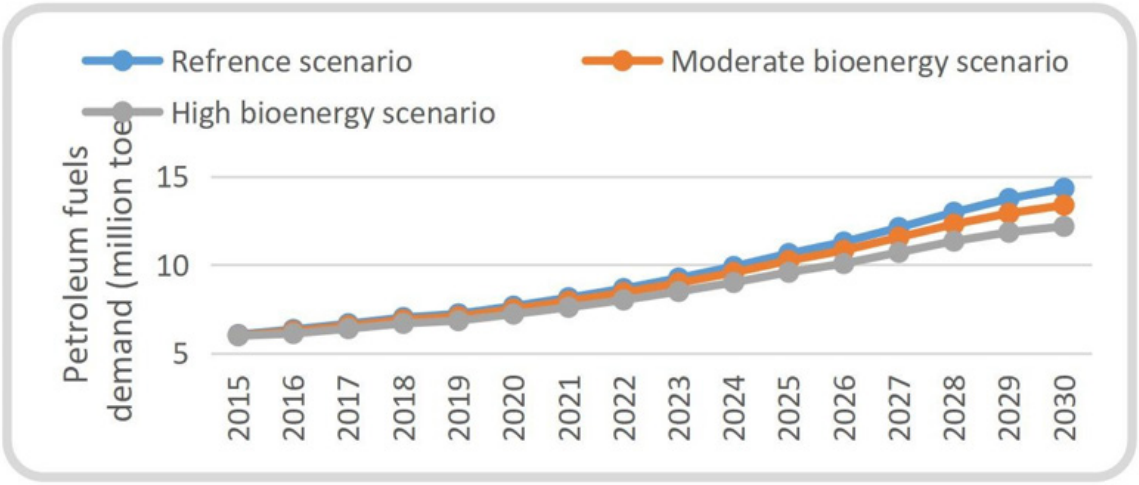

Figure 9: Total Petroleum Fuels Demand in Different Scenarios

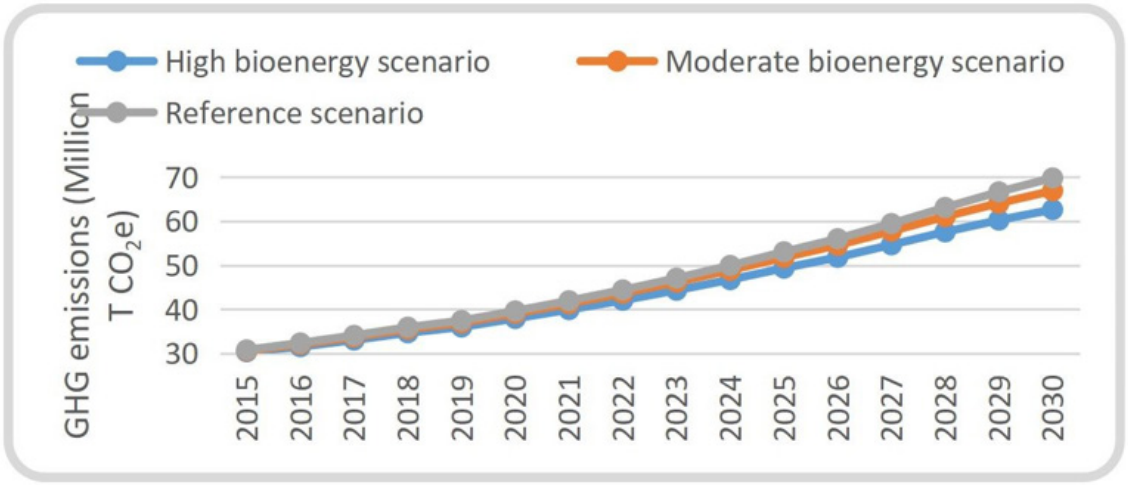

Figure 10: GHG Emissions in the Various Scenarios

4.0 CONCLUSIONS AND RECOMMENDATIONS

The petroleum sector in Ghana presents a significant challenge concerning greenhouse gas emissions, with implications for both the environment and the nation's economic development. While efforts have been made to assess the sector's contributions to greenhouse gas emissions, the specific impacts on Ghana's economy remain inadequately explored. Moreover, while numerous solutions and policies have been proposed to mitigate emissions in the petroleum sector globally, the effectiveness of these measures in the context of Ghana remains unclear.

Therefore, the problem addressed by this study is the need to comprehensively understand the activities contributing to greenhouse gas emissions in Ghana's petroleum sector, evaluate their impact on the nation's economy, and develop optimized strategies and policy recommendations for reducing emissions while ensuring sustainable economic development. It can be concluded from the finding that, Ghana's total final petroleum demand will double between 2018 and 2030, increasing from 193 PJ in 2018 to 380 PJ in 2030. Diesel consumption will be more than double in the planning period, rising from 106 PJ in 2018 to approximately 208 PJ in 2030. Together, the demand for diesel and gasoline will contribute approximately 83 % of petroleum consumption.

Ghana's government should put laws and incentives in place to make it easier for the transportation industry to switch to bioenergy, including both first- and second- generation biofuels. Frameworks for incorporating bioenergy into the production of power must also be established, with an emphasis on sources such as wood waste, agro- industrial residue, oil palm residue, and municipal solid waste. To meet the need for biofuels, it is essential to maximize land utilization for the cultivation of energy crops including sweet sorghum, jatropha, cassava, and sunflower. As required by the Renewable Energy Act, the creation of a Renewable Energy Fund must be accelerated in order to assist bioenergy and other renewable energy initiatives. Furthermore, it takes a lot of dedication from government agencies like the Ministries of Food and Agriculture and Energy to adoption and utilization of renewable energy sources across Ghana.

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SUB-THEME 3
BLUE ECONOMY GOVERNANCE, LAW AND POLICY

PROMOTING PUBLIC-PRIVATE PARTNERSHIP IN NATURAL GAS DISTRIBUTION INFRASTRUCTURE DEVELOPMENT IN TANZANIA

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ABSTRACT

In developing countries, government are often unable to implement natural gas distribution infrastructures on their own, mainly due to budget and financial constraints. In Tanzania, despite substantial natural gas deposits, the population has yet to benefit fully due to gaps in distribution infrastructure. However, the National Natural Gas Infrastructure Project (NNGIP) route from Mtwara to Dar es Salaam for domestic, industrial and power generation was finalised in 2015 with limited distributions. This study aims to identify the best type of Public-Private Partnerships model for natural gas distribution infrastructure and the barriers to expanding natural gas distribution networks in Tanzania through Public-Private Partnerships (PPP).A mixed-methods approach was employed,for primary and secondary data collection. In-depth interviews and Survey instrument were employed to identify barriers

of PPP implementation in natural gas infrastructure. The data collected was cleaned and analyzed using statistical tools in Python.Descriptive statistics summarized the survey responses, while thematic analysis was applied to qualitative data from interviews and open-ended questions.Majority of respondents suggested that Design-Build-Finance-Operate (DBFO) is the best form of PPP model for natural gas distribution infrastructure and is evident is developing countries that embrace matching of public and private resource to close the infrastructure gap due to budget constraints and to bring solution to access to cleaner energy. However, the most significant barriers to PPP include "Contracting Uncertainties," "High Cost of Bidding," "Inconsistent Policy," "Lack of Transparency," and "Negotiation Costs." The Pareto chart indicated that addressing these top barriers could resolve most issues, as approximately 80% of the problems are caused by a small number of barriers. In conclusion, the study underscores the importance of addressing key barriers to encourage partnership, strengthening institutional capacity, strong policy, regulations and investment incentives, PPPs may significantly speed up the transition to a more durable, inclusive, and resilient natural gas distribution infrastructure that benefits everyone in Tanzania.

Keywords: Public-Private Partnership (PPP), Natural Gas Distribution, Barriers Analysis, Tanzania Energy Sector, Blue Economy

1.0 INTRODUCTION

The global reliance on heavy fossil fuels like coal and oil is exacerbating the changing global climate and endangering life on Earth. However, the blue economy (BE) opportunity of offshore natural gas discovery offers substantial opportunity to combat climate change and transition to cleaner energy. In Tanzania, BE is one of the strategies identified by the government to promote the sustainable exploitation of the ocean potential (Maskaeva *et al.,* 2024). The country boasts abundant deposits of natural gas off its coast, with current estimates totaling 57 trillion cubic feet (TCF) (Henstridge, 2020). Recent technological developments have made natural gas more competitive in power generation while also boosting its viability in other applications such as heating and cooking.

Despite significant natural gas discoveries and ongoing production in Tanzania, most of the population has yet to benefit from the diversifying energy mix due to gaps in distribution infrastructure. However, the National Natural Gas Infrastructure Project (NNGIP) route from Mtwara to Dar es Salaam for domestic, industrial and power generation was finalised in 2015 (Hundsbæk Pedersen *et al.,* 2017).The country faces an acute shortage of natural gas distribution networks. One major issue associated with expanding gas distribution infrastructure is the high up-front cost. Consequently,

Private-Public Partnership (PPP) has attracted a lot of political attention in the country as one of the options for expanding the natural gas distribution networks. Yet, the private sector has been reluctant to participate. Currently, the state-owned Tanzania Petroleum Development Corporation (TPDC) stands alone in distributing natural gas infrastructure, and investment in distribution networks has been relatively slow (Lukonge & Cao, 2019). The government is currently embarking on expanding the gas distribution network. Upcoming projects will require investment support from the private sector. Thus, understanding of how such support can be garnered is critical.

Recently, calls for greater involvement of the private sector in public resources and infrastructure development have increased. In this context, scholars have investigated a wide range of topic on PPPs over the years, but no generally accepted understanding on barriers exists. Moreover, studies focused on gas distribution infrastructure development in developing countries like Tanzania remain scarce. Nonetheless, some generic barriers have been reported in the literature, including limited access to finance, regulatory uncertainties, political risks, lack of institutional capacity, policy inconsistency, corruption, bureaucracy, and inadequate legal framework(Munachi Chikodili Ugwu et al., 2024) However, these barriers are context-specific, so there is a need for a contextualized understanding in diverse contexts. Thus, understanding and improving knowledge on barriers to PPPs in gas distribution infrastructure development in Tanzania is a matter of importance and significance.

Against this backdrop, this contribution aims to enhance understanding of how to promote private sector involvement in natural gas distribution in Tanzania. The research addresses two questions:

1) What is the best PPP model for gas distribution infrastructure in Tanzania?
2) What barriers impede private sector involvement in the development of gas distribution infrastructure in Tanzania?

Insights from this research have the potential to inform government strategies to incentivize greater private sector involvement in developing Tanzania's natural gas distribution networks. By better understanding suitable PPP models and existing barriers, strategies can be designed to attract more private investment in infrastructure expansion. This would enable Tanzania to more effectively harness its abundant natural gas reserves for the energy transition, clean cooking solutions, and building a sustainable blue economy. The insights will benefit other countries seeking to promote PPPs in the gas sector.

2.0 THEORETICAL BASIS ON NATURAL GAS

The global energy demand shift toward clean and ecologically friendly sources has accelerated the usage of natural gas, primarily methane (CH4), as the principal energy source (Rugarabamu & Song, 2022). Because of its high calorific value and high hydrogen

to carbon ratio as compared to other fossil fuel (gasoline and coal), CH4 burns cleanly. Natural gas plays a crucial role in satisfying the world's energy needs, accounting for 24% of the total, as it burns the cleanest of all fossil fuels with less effect to global warming and climatic changes.Given that by 2040, it will expand at a pace of roughly 2% (Veluswamy & Linga, 2018).With the switch to alternative energy sources, offshore Tanzania offers a possible path towards a sustainable community in the wake of the significant finding of sweet natural gas in the Indian Ocean. Natural gas has been commercialized from 2004 and 2006 for the Songosongo gas field and Mnazi Bay (Lukonge & Cao, 2019). This helps Tanzania generate electricity by offsetting other energy sources(Kondowe, 2021; Makala & Zongmin, 2019) .Natural gas makes up a sizable portion of Tanzania's energy mix, although the society as a whole has not yet benefited from the distribution infrastructure.

2.1 Natural Gas Distribution Infrastructure

Natural gas has contributed 26% to Africa's energy demand growth between 2000 and 2021(Abbas & Ermakov, 2023).Natural gas usage in Tanzania is minimal compared to other countries in sub-Saharan Africa like Nigeria and Cote d'Ivoire, where it is used in both the industrial and domestic sectors(Fulwood, 2019).Despite Tanzanian's potential natural gas abundance and critical role of gas-electrification risen from zero in 2000 to 60.27% in 2023,the significant natural gas distribution problem persist in many regions (URT, 2022). These include limited natural gas distribution pipeline that interconnects regions in Tanzania and mini-LNG infrastructure. With potential to ensure distribution infrastructure, natural gas will optimize the lion's share of gas demand in power generation, compressed natural gas station for vehicles, industrial, commercial buildings, institutions and domestic Supply. The natural gas for power and industries started in 2004 while household and institutions started in 2009 (URT, 2016).

	DOMESTIC DEMAND										
						Petrochemicals					
USER	Electricity	Households	Institutions	CNGV	Industries	Fertilizers/Ammonia	Methanol	GTL	DME	MTG	Iron & Steel
Demand (TCF)	8.8	0.5	0.1	0.6	3.6	0.7	1.1	1.8	0.3	0.4	1.1
TOTAL (TCF)		19.1									

Natural gas distribution infrastructure has slowly emerged in specific parts of Tanzania. Currently, three regions including Lindi, Mtwara, and Dar es Salaam have limited natural gas distribution(Lukonge & Cao, 2019). Plans are underway to distribute natural gas to the Coastal Region for household, institutional, and industrial power consumption. However, the country's reliance on biomass as cooking energy in domestic consumes approximately 469,420 hectares of forest annually, posing significant environmental,

health, and climate challenges(URT, 2024) Of which natural gas distribution network in the country is crucial to meet energy demand.

An assessment of natural gas potential infrastructure development through PPP between the southern (gas-rich) and the countryside is paramount. In the NGUMP, among prerequisite for development of domestic gas distribution projects, in terms of strategies for financing in midstream and downstream, Public Private Partnership was pointed out (URT, 2016). If implemented, such a project would contribute to solving the energy crisis prevailing in Tanzania. Also, the pipeline infrastructure under consideration would provide a base for regional natural gas distribution from Tanzania through East Africa to the southern part of the continent(Abbas & Ermakov, 2023). The two concepts both transaction cost theory and institutional theory are considered to address contractual collaboration between public and private sector aimed at providing natural gas distribution infrastructure to meet the clean energy demand in the country.

2.2 Conceptualizing Public-Private Partnerships

Gas infrastructures can be delivered in various ways. It is widely recognized that neither a purely private nor a purely public infrastructure development approach is likely to be sustainable in the long-run. Puristic approaches are known to cause problems of government and market failure (Kwak *et al.,* 2009). To overcome these problems, PPPs have been proposed. The term PPP has multiple interpretations. In this paper, PPP refers to ''a long-term contractual collaboration between the public and private sectors aimed at providing infrastructure and public services, where both the public and private sectors share their risks and benefits in order to achieve common goals'' (Wang et al., 2018).

PPPs are a popular way to form synergies between private and public actors in order to develop new opportunities and overcome modern challenges (Rybnicek *et al.,* 2020). In PPPs, the partnering parties share, exchange, and aggregate their respective valued resources in order to achieve synergy and improve effectiveness and efficiency in the joint undertaking (Ping Ho & Tsui, 2010). PPPs allow governments to access private financing and expertise and implement cost-saving strategies (Kwak *et al.,* 2009; Rybnicek *et al.,* 2020). The National Natural Gas Policy of 2013 envisages that the state will participate strategically through its National companies (i.e. through PPP) to develop and operate major infrastructure for natural gas (URT, 2013)

There are various modes for implementing PPP schemes. PPP arrangements vary in structure depending on the project needs and objectives. They typically differ in level of private sector involvement. At one end of the spectrum is public provision, where the public sector bears all responsibility for delivering the public service; while at the other end is private provision, with the private sector assuming all duties (Kwak *et al.,* 2009). The types of PPPs between the two extremes include Operation and Maintenance (OM), Design-Build-Operate (DBO), Design-Build-Finance-Operate (DBFO), Build-Operate-Transfer (BOT), and Build-Own-Operate (BOO) Figure 1.

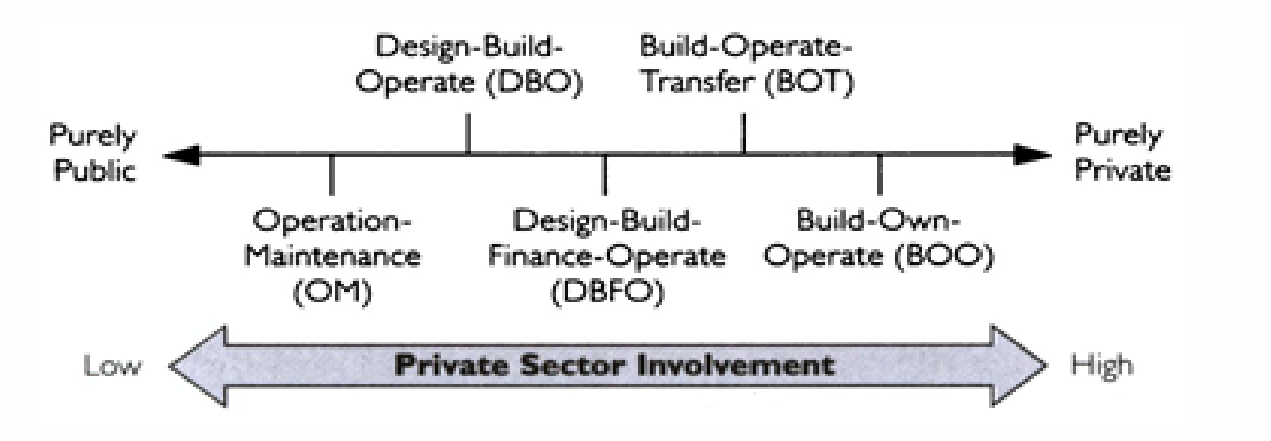

Figure 1: Continuum of Types of PPPs (Kwak *et al.*, 2009)

2.3 The Transaction Costs Theory

The administration of PPPs is challenging because their governance involves complex relationships between private and public parties (Ping Ho & Tsui, 2010). In this context, transaction costs refers to the costs of establishing and sustaining such relationships (Dudkin & Välilä, 2006). They include costs of searching for PPP partners, negotiating and drafting contracts, monitoring and enforcing contracts. PPPs tend to involve significant transaction costs because (1) PPP projects are frequently public facility/service oriented, (2) PPPs typically use project finance, and (3) one of the parties is government (Ping Ho & Tsui, 2010). Transaction costs can be visible and measurable, as well as hidden and difficult to quantify. The key drivers of these costs include the long-term nature of PPPs, complex ownership and financing structures, and risk-sharing elements (Dudkin & Välilä, 2006). Specifically, tendering, negotiation, contracting and oversight processes demand significant time and resources (Dudkin & Välilä, 2006). In many cases, the high transaction costs may render PPPs an inferior or infeasible alternative for developing public infrastructures (Rybnicek *et al.,* 2020).Reducing these costs is thus important for attracting private investors.

2.4 The Institutional Theory

The institutional theory provides an important lens for understanding how to promote PPPs. For PPPs to be developed and function well, supportive institutions that mitigate risks and uncertainties are critical (Wang *et al.,* 2018). North (1990, p. 3) defines institutions as "the rules of the game in a society or more formally, are the humanly devised constraints that shape human interaction" . These include both formal, explicitly written rules such as constitutions, laws, regulations, guidelines and informal rules like conventions, customs, traditions, norms and codes of conduct (Kaufmann et al., 2018). Together, the formal and informal institutions constitute the broader environment that shapes how PPP stakeholders make decisions and interact (Williamson, 2000). Institutional pressures can encourage or discourage organizations from pursuing PPPs

(DiMaggio & Powell, 1983). The formation, content, and enforcement of institutions then help explain why PPPs increase or decrease within a given jurisdiction. For example, institutional weaknesses or voids can breed uncertainty and disincentives that hamper PPP development. Meanwhile, strong, stable institutions can help address risks perceived by the private sector when engaging in PPPs. Governments can therefore leverage institutional theory to strategically design rules and frameworks that promote an enabling environment for successful PPP formation in the gas sector.

2.5 Barriers to Establishing Public-Private Partnerships

PPPs have adopted across various jurisdictions and sectors worldwide. As a result, extensive empirical research exists synthesizing barriers to PPP development from diverse theoretical viewpoints. Researchers have identified barriers through case studies, literature reviews, surveys and interviews with key stakeholders. The current study draws on the transaction costs and institutional theories. The worldwide experience reveals transaction costs and institutional weaknesses can disincentivize private sector involvement in infrastructure development in various ways. Table 2 summarizes key findings from selected literature focused on energy and oil and gas sector PPPs.

Table 2: Selected Literature on Barriers to PPP Projects

Author (s)	Country	Title	Barriers identified
(Munachi Chikodili Ugwu *et al.*, 2024)	USA	The Role of Public -Private Partnership in building clean energy infrastructure in the United State and Nigeria	Uncertainties surrounding government policies and regulations can impact investor confidence and project viability. Lack of comprehensive comparative analyses focusing on the effectiveness and outcomes of PPP projects in the clean energy.
(Munachi Chikodili Ugwu *et al.*, 2024)	Nigeria	The Role of Public -Private Partnership in building clean energy infrastructure in the United State and Nigeria	Limited access to finance, regulatory uncertainties, political risks, lack of institutional capacity, policy inconsistency, corruption, bureaucracy, and inadequate legal framework.
(Åm & Heiberg, 2014)	Norway	Public-Private Partnership for improved hydrocarbon recovery	A struck in balance between owner interests for profit on the infrastructure investment and thus high tariffs and societal interest,Assets challenges as governments' rights are locked in geographically and unlimited in time serving broad sets of need of their population.
(De Schepper *et al.*, 2015)	Belgium	Understanding pre-contractual transaction costs for Public–Private Partnership infrastructure projects	The high cost of bidding process, High asset specificity, lack of transparency -Confidentiality of data and imperfect information (True cost or quality of supply), governance uncertainties, Complicated framework, Negotiation Cost, Lengthy and complex, Constant changes in the tendering process, lack of previous experience in PPP projects.

(Lai & Tang, 2016)	China	Institutional barriers to redevelopment of urban villages in China: A transaction cost perspective	Unsatisfactory Institution arrangement, Inconsistency policy, Governance uncertainty, Violation of contractual arrangement, Negotiation cost (unprecedented)
(Williamson, n.d.)	USA	Transaction-cost economics: the governance of contractual relations	Defective Investment incentive, Contracting dilemma (violation), Market Relief

3.0 METHODOLOGY

3.1 Research Design

PPPs are complex undertakings.The study This study adopted a mixed-method approach using a cross-sectional design. Mixed methods (comprising quantitative and qualitative methods) are useful to capture the complexity of the research topic more adequately (Creswell 2014). Although this design requires expertise and great effort, it makes methodological triangulation possible, which facilitates research data interpretation and enhances the study's validity and credibility (Bryman & Bell, 2007). In a cross-section design, researchers gather data on the phenomenon of interest at a specific point in time. This has the advantage of being inexpensive and less time-consuming (Setia, 2016).

The research task involved identifying the preferred PPP model and potential barriers. Data was acquired from both primary and secondary sources. Primary data collection involved a survey questionnaire and semi-structured, in-depth interviews with key informants. Survey questionnaires are a widespread technique when collecting data from a relatively large number of respondents (Creswell, 2014).

3.2 In-depth Interview

Before designing a survey questionnaire, in-depth interviews were conducted *Table 3* . In-depth interviews enable researchers to develop rapport with participants, cultivating trust to facilitate richer knowledge exchange than methods like surveys or focus groups (Denzin & Lincoln, 2005). As this study sought to explore and describe barriers rather than test predefined hypotheses, in-depth interviews aligned well with addressing its research question (Boyce & Neale, 2006).The in-depth interview were conducted with inclusion criteria for research participants were:

- Representatives from government bodies and agencies involved in the energy sector,investment and PPP.
- Academics and researchers studying energy policy, private sector participation

and infrastructure development in Tanzania
- Representatives from industry associations advocating for increased private investment in gas/energy value chains
- Staff from development organizations/NGOs implementing projects related to gas sector reform, PPP models, rural energy access
- Can speak on challenges experienced to gain a holistic perspective on barriers to private participation.
- Are conversant in speaking English or Kiswahili for effective communication during interviews.

The interviews focused on capturing their experiences, opinions and perceptions about the barriers to private sector involvement in gas distribution network expansion in Tanzania. The interview were conducted in both Swahili and English, which are the two main languages in Tanzania Mainland and Revolutionary Government of Zanzibar. The interviewer took extensive notes during each interview.The in-depth interview was conducted in Zanzibar and Dar es Salaam as potential part to implement the extension of gas pipeline distribution infrastructure (Hundsbæk Pedersen *et al.,* 2017). Snowballing was employed to identify additional participants (Nilsson, 2023) and this continued until theoretical sampling was reached, where additional participants provided no new insights as seen in Table 3 (Benoot *et al.,* 2016).

Table 3: *In-depth Interview Response on Barriers to PPP Projects*

Company/Agency	**Barriers identified during the interview for PPP natural gas infrastructure**
Representatives from government bodies and agencies involved in the energy sector, investment, and public-private partnerships (PPPs).	Unbearable cost in distribution (pipeline and Mini-LNG) infrastructure, Competitive price of natural gas with LPG, Inconsistent policy and political priorities.
Staff from development organizations/ NGOs implementing projects related to gas sector reform, PPP models, and rural energy access	Policy inconsistent, lack of investment capital, Private sector fear from being monitored by the government, lack of PPP skill set / experts, Competitive price of natural gas with LPG, Project asset specifity (gas to power project)
Representatives from industry associations advocating for increased private investment in the gas/energy value chains	Inconsistent policy, legal framework and regulatory compliance, political priorities. Lack of detail feasibility study on the distribution infrastructure, uncertainly protection of investment, Unpredictable Subsidy or incentives, Guarantee of investment and what if analysis?
Academics and researchers studying energy policy, private sector participation, and infrastructure development in Tanzania	Very Capital intensive, Political issues, Funding conditions, Infrastructure access limitations, Natural gas use experience (recent opportunity) and investment risks due to uncertainly price of natural gas.

3.3 Population and Sample

The population for this study consisted of stakeholders involved in the natural gas distribution infrastructure development in Tanzania. The key stakeholder groups are indicated Table 4.

Table 4: *Sample Population for Survey Instrument*

Stakeholder Group	Estimated Sample %
Representatives from government bodies and agencies involved in the energy sector, investment, and public-private partnerships (PPPs)	25
Academics and researchers studying energy policy, private sector participation, and infrastructure development in Tanzania	30
Representatives from industry associations advocating for increased private investment in the gas/energy value chains	20
Staff from development organizations/NGOs implementing projects related to gas sector reform, PPP models, and rural energy access	25

3.3.1 Sample size determination

The sample size for this study was determined using the following formula as (Gregoire & Affleck, 2018)

$$n = \frac{Z^2.P.(1-P)}{E^2} \quad (1)$$

where:

- n is the sample size.
- Z is the Z-value corresponding to the desired confidence level (1.96 for 95% confidence).
- p is the estimated proportion of the population that has the attribute of interest.
- E is the margin of error.

For this study, we aimed for a 95% confidence level and a margin of error of 5%. Given these parameters, the estimated proportion (Singh *et al.,* 2014.) Therefore, the sample size of 41 participants was used in this study to ensure the desired confidence level and margin of error.

3.4 Review of Selected Documents

Previous research studies were thorough conducted to provide us with barriers for PPP in development of natural gas distribution infrastructure (De Schepper *et al.,* 2015). The reviewed barriers as indicated in Table 2 were accessed in conjunction with barriers identifies from selected stakeholders in Zanzibar in order to come up with close/

qualitative questions (8-16) on Barriers of PPP project for the context of natural gas distribution infrastructure in Tanzania as seen in Box 1.

3.5 Survey Instrument /Questionnaire Preparation

A Survey instrument seen in appendices Box 1 was developed based on the field interviews as Table 3 and previous research studies on PPP Table 2.The research aimed at capturing the respondents' understanding, experience, perceptions and opinions, a standard questionnaire comprising of both closed-ended and open-ended questions was used. The Survey instrument was created using google forms and shared to respondents through mail accounts and WhatsApp groups for Stakeholders of interest in Tanzania. The questionnaire was divided into four sections involving a series of demographic questions (Q1-Q2) addressed survey participants' role, years of experience working in involvement in PPP projects Figure 2.A series of close Likert-scale questions (Qu3-7) and (Qu8-16) involving a set of statements concerning types of PPP and barriers, and an open question to elucidate respondents' perspectives on the models and barriers respectively. The Likert based scale ranging from 1to 5 (1=strongly disagree, 5=Strongly agree). The final component of the survey featured open question (Q17) asking respondents to provide opinion concerning the PPP barriers on implementation of natural gas distribution infrastructure in Tanzania.

The collected data was organized and stored in Excel spreadsheets. Before analysis, the data underwent a thorough cleaning process to ensure accuracy and consistency.This involved removing any duplicate entries, handling missing values, and standardizing the format of the data.The cleaned data was then analyzed using statistical tools in Python programming.Descriptive statistics were used to summarize the responses to closed survey questions, providing frequencies and percentages for each barrier.Thematic analysis, following the 6-step procedure recommended by was applied to the qualitative data from interviews and open-ended survey questions (Braun & Clarke, 2006)The results of the analysis were visualized using various charts and graphs, including bar charts and a Pareto chart, to highlight the most significant barriers in PPP projects. The Pareto chart was used to apply the 80/20 rule, identifying the top barriers that contribute to most challenges in PPP projects (Dunford *et al.,* 2014). This visual representation provided clear insights into where efforts should be concentrated to achieve the most substantial impact.

4.0 RESULTS

4.1 Demographic Characteristic of Respondent's Results

The analysis of barriers in Public-Private Partnership (PPP) projects for natural gas distribution infrastructure involved 41 responses received as per sample size by (Gregoire & Affleck, 2018).The role of respondent represented a cross-section involvement in the PPP project with the majority from academic & research 46.3%, government officer

31.7%, Consultant, service, operator &contractor representative and NGO representative working in energy companies 4.9% Figure 3.

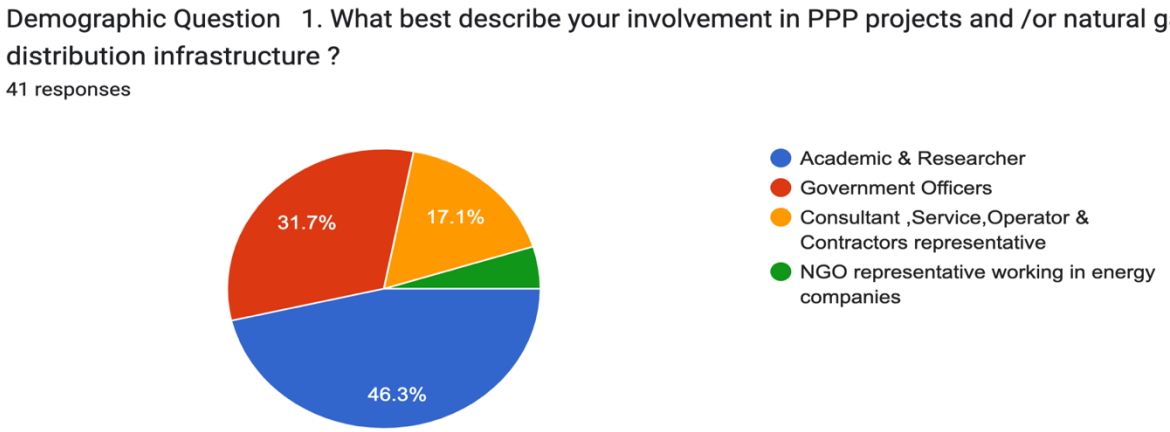

Figure 3

The majority of respondents 47.5 % indicated that they have been involved in 1 to 5 PPP projects while 45.2% indicated that they had none /zero with PPP projects and 7.2 % have been involved in five or more than 10 projects Figure 4.

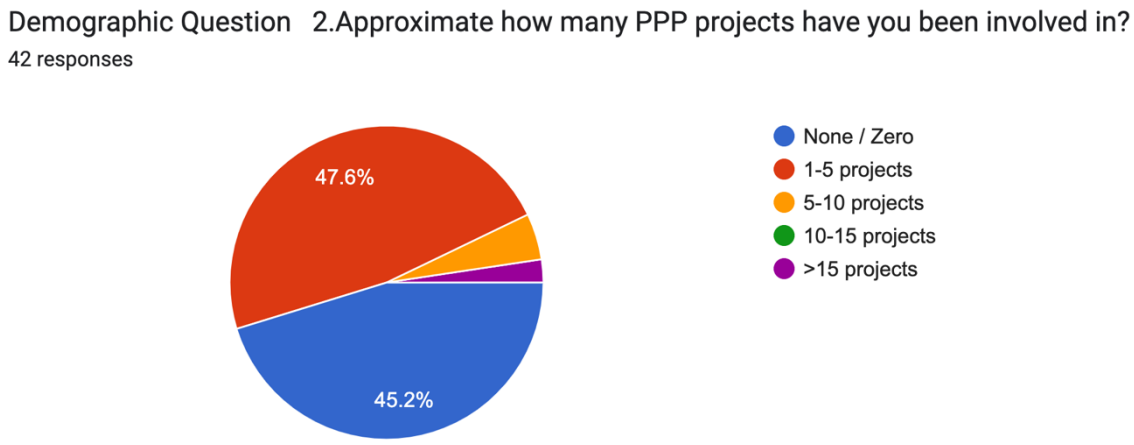

Figure 4

A similar demographic representation was *used to address climate change through environment impact assessment* (*Sok* et al., 2011).

4.2. Close /Quantitative Question on Types of PPP Results

4.2.1 Responses on operation and maintenance (OM) type of PPP project

The Figure 5 *r*epresents the responses for the PPP OM agreement (Operation and Maintenance Agreement). Most respondents disagree (34.1%) with this model,

as indicated by the highest bar. A significant portion also agrees (17.1), while fewer respondents are neutral (9.8%).The percentages on top of the bars show the exact distribution of responses, with the majority being positive towards this agreement type.

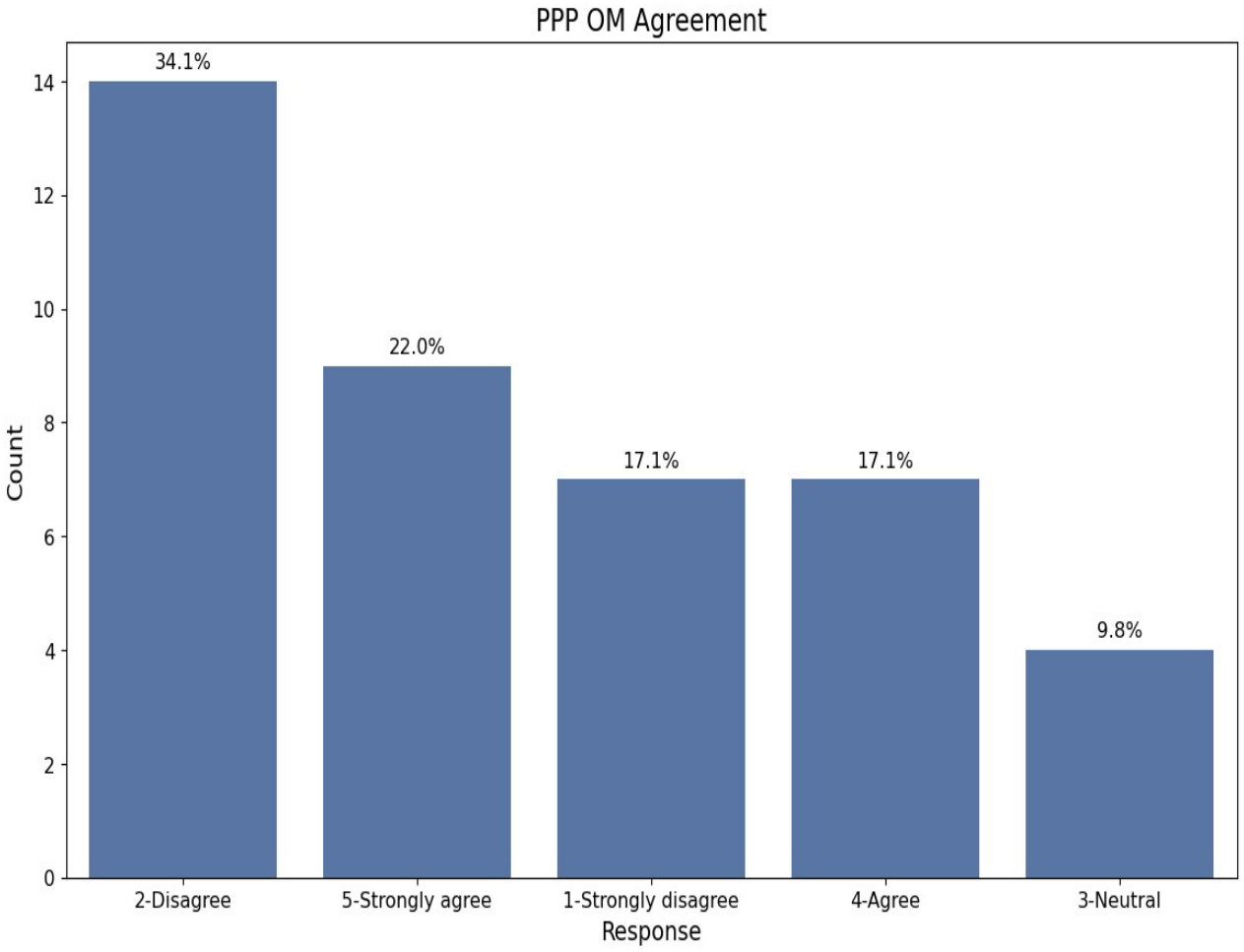

Figure 5

4.2.2 Response on design-build-operate (DBO) type of PPP project

The Figure 6 the responses for the PPP DBO agreement (Design-Build-Operate).” Like the PPP OM Agreement, many respondents strongly agree (29.3%) or agree (19.5%) with this model. The distribution is slightly more spread out compared to the OM Agreement, with a noticeable number of neutral responses. The percentages on the bars provide a clear view of the distribution, highlighting the overall positive sentiment.

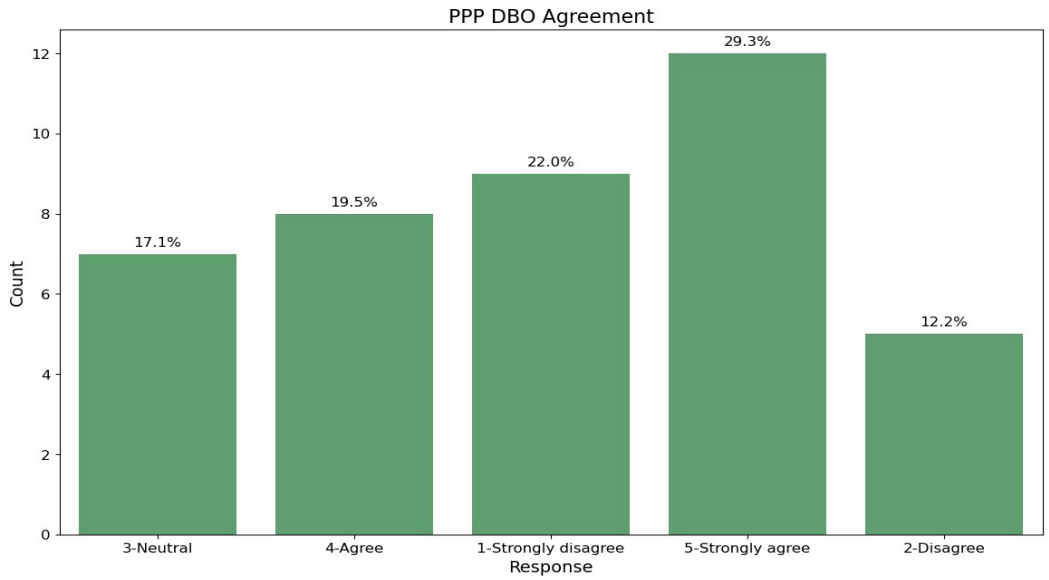

Figure 6

4.2.3 Response on design-build-finance-operate (DBFO) type of PPP project

The Figure 7 illustrates the responses for the Design-Build-Finance-Operate ("PPP DBFO Agreement)." This graph shows a more balanced distribution of responses compared to the previous ones (*Figure 5*&*Figure 6*).While there is still a significant number of respondents who strongly agree (26.8%) or agree (29.3%), there are also more neutral (9.8) and disagree responses(17.1%). The percentages on the bars help to understand the spread of opinions, indicating a more mixed sentiment towards this agreement type.

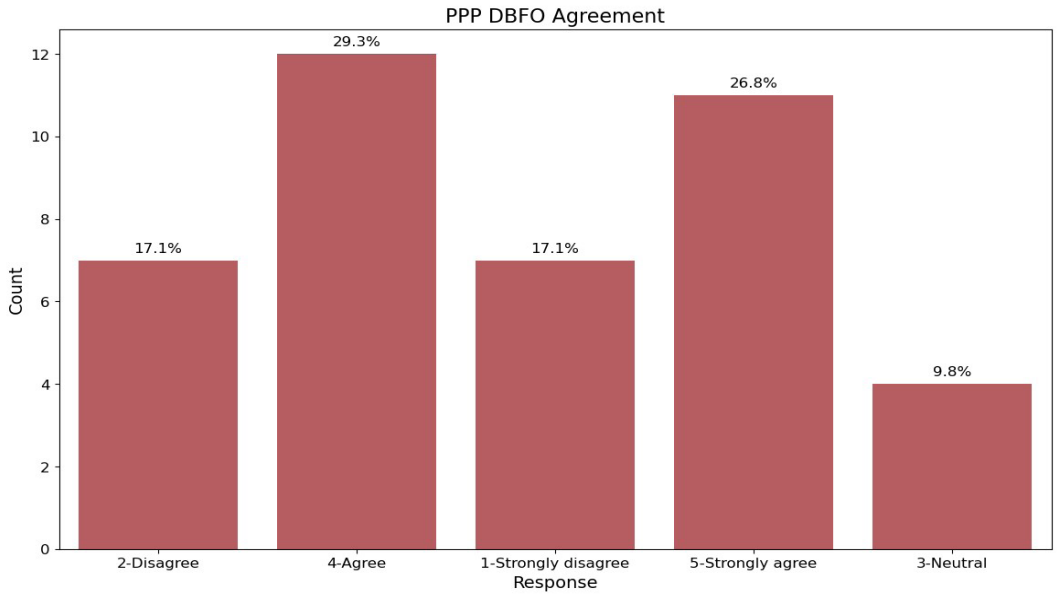

Figure 7

4.2.4 Response on build-operate-transfer (BOT) type of PPP project

The Figure 8 represents the responses for the Build-Operate-Transfer. The distribution here is like the DBFO Agreement, with a noticeable number of respondents strongly agreeing (26.8%) or agreeing (22.0%), but also a significant portion being neutral (14.6%) or disagreeing(17.1%). The percentages on the bars provide a detailed view of the responses, showing that while there is positive sentiment, there is also a considerable amount of neutrality and disagreement.

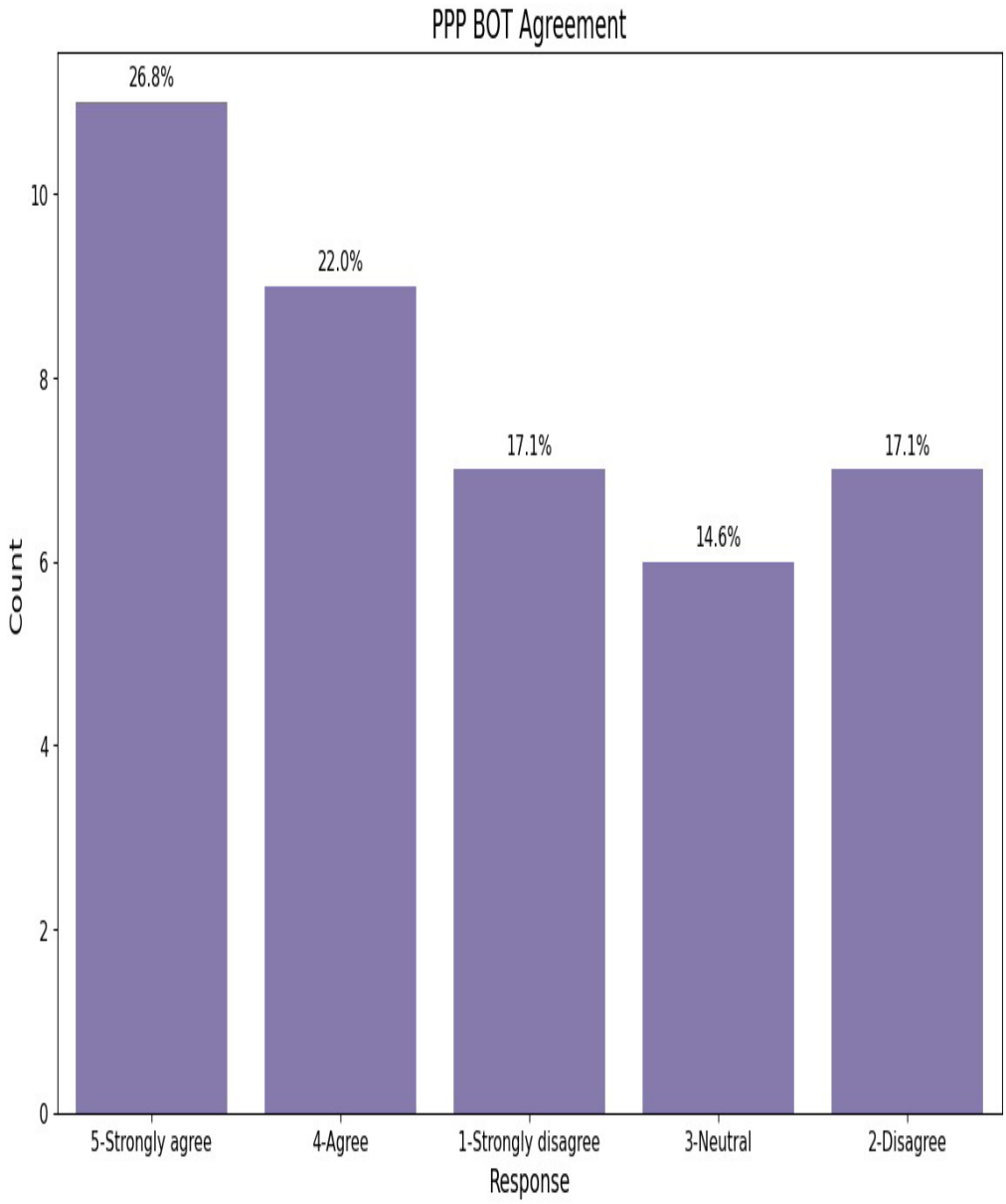

Figure 8

4.2.5 Response on build-own-operate (BOO) type of PPP project

The Figure 9 shows the responses for the "PPP BOO Agreement (Build-Own-Operate Agreement) with a noticeable number of respondents strongly disagreeing (31.7%) or disagreeing (22.0%), but also a significant portion being neutral (17.1%) or while agreeing(19.5%) and strongly agreeing 9.8%).

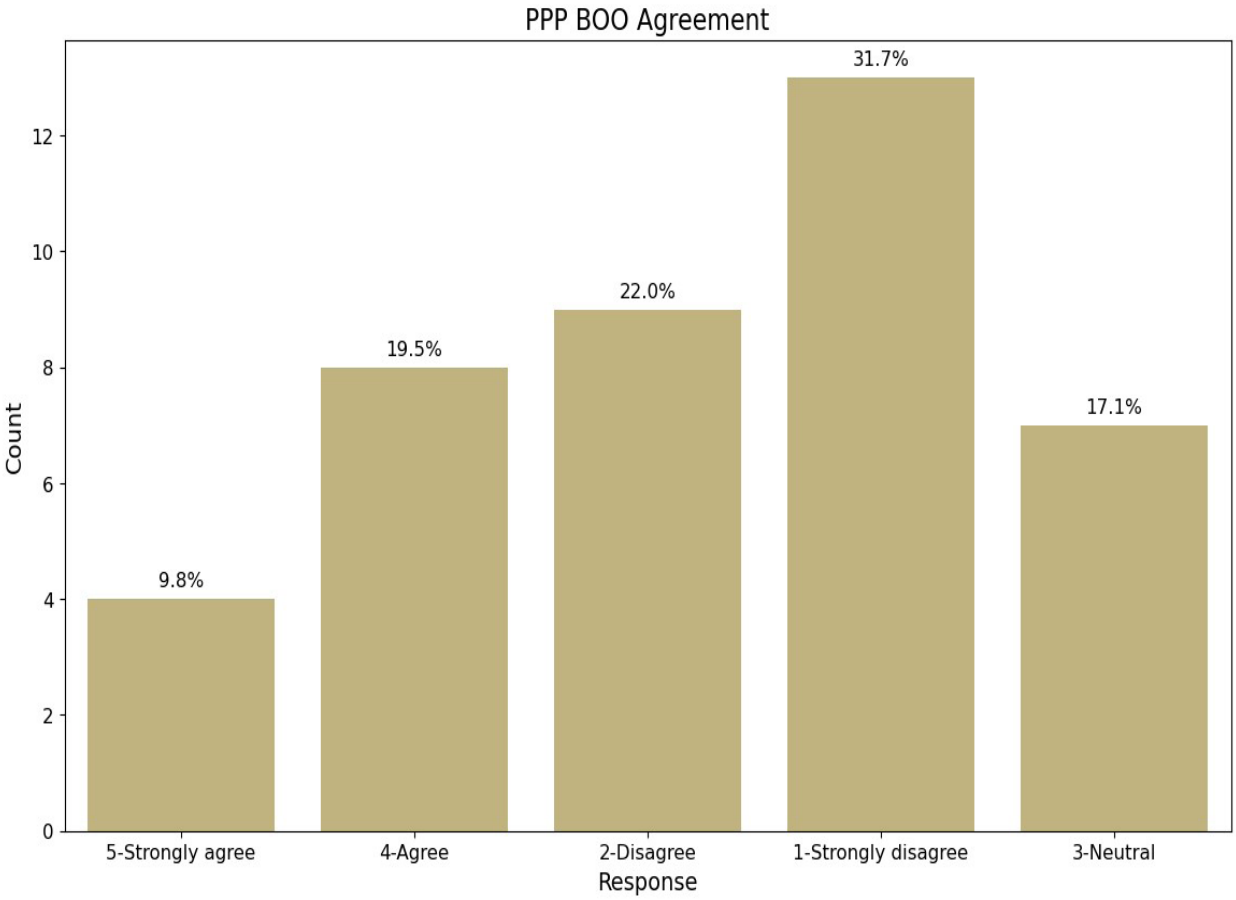

Figure 9

4.2.6 Heatmap of the responses for the different PPP agreement types

The heatmap Figure 10 provides a comprehensive visual representation of the percentage distribution of responses for each PPP agreement type, including PPP OM Agreement (Operation and Maintenance Agreement), PPP DBO Agreement (Design-Build-Operate Agreement), PPP DBFO Agreement (Design-Build-Finance-Operate Agreement), PPP BOT Agreement (Build-Operate-Transfer Agreement), and PPP BOO Agreement (Build-Own-Operate Agreement). The color intensity in each cell indicates the proportion of responses, with red colors representing higher percentages and blue colors representing lower percentages. Annotations within the cells display the exact percentage values,

offering precise information about the distribution of responses. This visualization reveals that while there is a general positive sentiment towards the different types of PPP agreement, the level of agreement varies. For instance, the PPP OM Agreement shows a higher proportion of positive disagree (34.1%) responses, whereas the PPP DBFO Agreement exhibits a more mixed distribution (agree-29.3% & strongly agree 26.8). Overall, the heatmap allows for an easy comparison and analysis of the sentiment towards each PPP agreement type, highlighting areas of strong agreement and those with more varied opinions. Hence the Design-Build-Finance-Operate (DBFO) Model is proposed for natural gas distribution infrastructure in Tanzania.

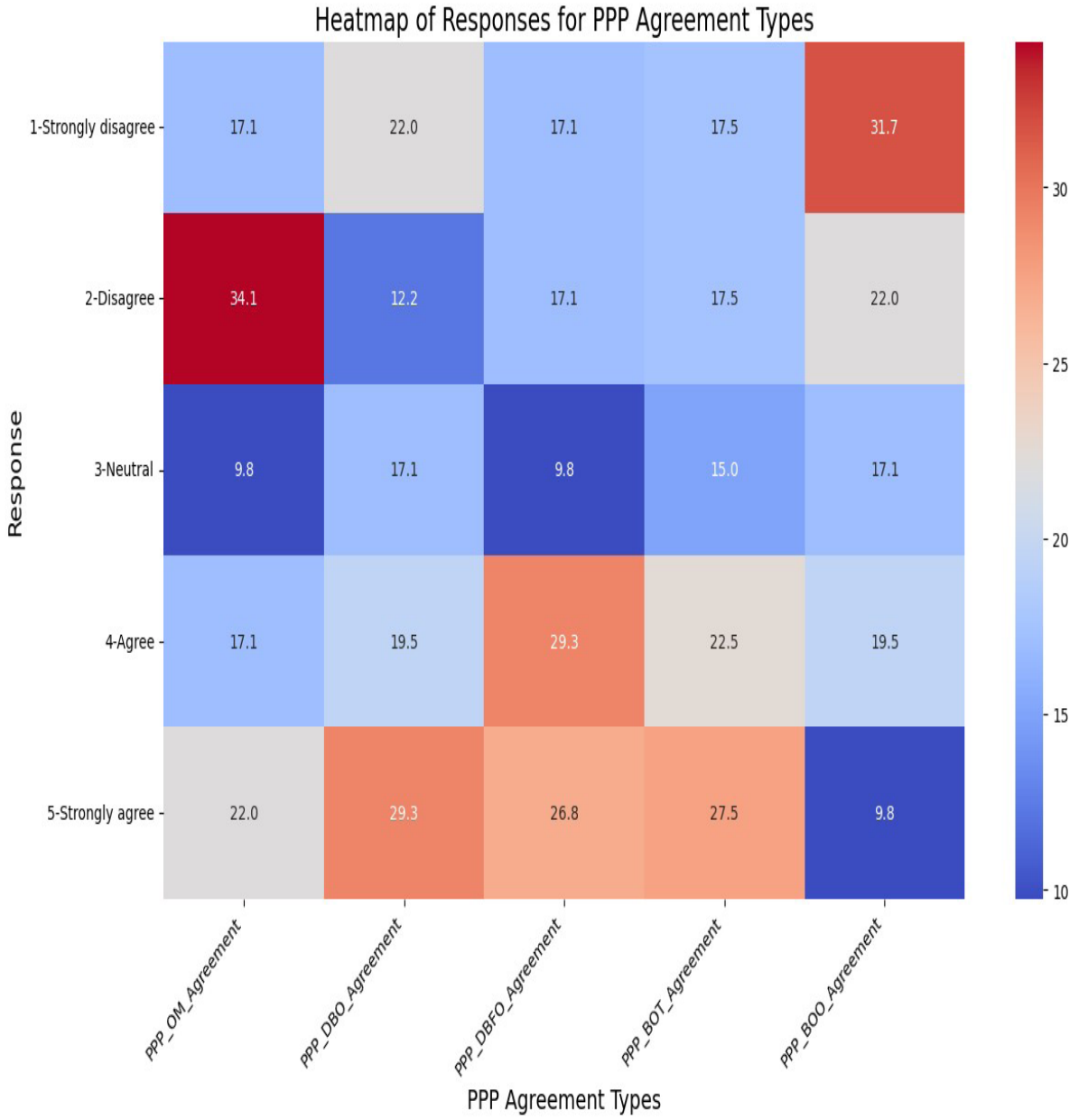

Figure 10

4.3 Close /quantitative question on barriers of PPP as seen in box 1

The descriptive statistics Table 4 provides a comprehensive summary of the central tendency and dispersion for the Likert scale responses to various barriers (Q8-16) in PPP projects. The table includes the count, mean, standard deviation, minimum, and maximum values for each barrier. The mean scores indicate the average perception of each barrier, with higher means suggesting more significant perceived barriers. For instance, barriers such as contracting uncertainties, lack of transparency, lack of experience, and political priority have high mean scores, indicating they are generally perceived as significant challenges. The standard deviation values provide insight into the variability of responses, with higher standard deviations indicating more diverse opinions among respondents. For example, barriers like contracting uncertainties and inconsistent policy have high standard deviations, suggesting varied opinions and experiences among respondents.

Table 5: *Likert Scale Responses to Various Barriers in PPP Projects*

Ba**rriers**	**Count**	**Mean**	**Std**	**Min**	**Max**
	5.0	4.0	1.732051	1.0	5.0
High Cost of Bidding	5.0	3.2	1.303840	2.0	5.0
Inconsistent Policy	5.0	3.8	1.643168	1.0	5.0
Lack of Transparency	5.0	4.0	0.707107	3.0	5.0
Negotiation Costs	5.0	3.2	1.643168	1.0	5.0
Defective Incentives	5.0	2.8	1.095445	1.0	4.0
Unsatisfactory Arrangement	5.0	3.4	1.516575	1.0	5.0
Lack of Experience	5.0	4.0	0.707107	3.0	5.0
Political Priority	5.0	4.0	1.732051	1.0	5.0

4.3.1 Prioritizing barriers in public-rrivate partnership (PPP) projects using pareto chart

The Pareto chart is a powerful visualization tool that combines a bar graph with a cumulative percentage line to highlight as seen in Figure 11 the most significant factors in a dataset from Table 4. In the context of Public-Private Partnership (PPP) projects, Figure 11 illustrates the frequency of various barriers encountered. The bars, sorted in descending order of frequency, represent how often each barrier is mentioned, with the height of each bar indicating its relative impact. The cumulative percentage line, shown in blue, helps to visualize the contribution of each barrier to the overall total, with values

annotated along the line. The red dashed line marks the 80% threshold, aligning with the Pareto principle, which suggests that roughly 80% of the effects come from 20% of the causes. This principle implies that by focusing on the barriers to the left of the 80% mark, stakeholders can prioritize their efforts to address the most impactful issues (contractual uncertainties, high cost of bidding and inconsistent policy). Addressing these key barriers can lead to significant improvements in PPP projects. The Pareto chart aids in resource allocation by visually representing where efforts should be concentrated, allowing policymakers and project managers to develop targeted interventions. By understanding and mitigating the top barriers identified in the pareto chart, substantial progress can be made in enhancing the implementation and success of PPP projects.

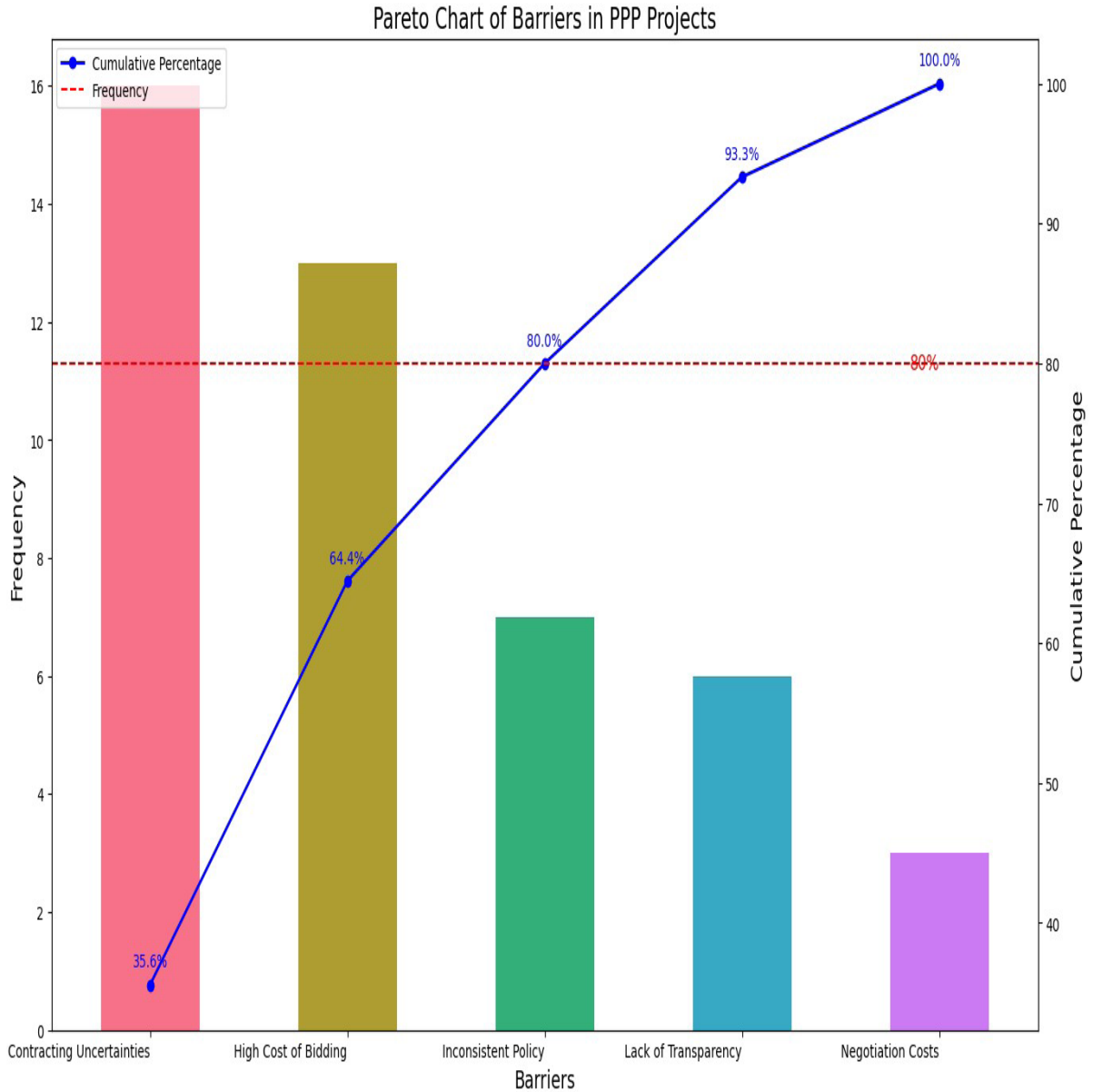

Figure 11: Pareto Chart of Barriers in PPP Projects

4.4 Open /Qualitative Question / In-depth Interview

The questions in the in-depth interview aimed to get new insights based on understanding, involvement, experience and perceived barriers on implementation of PPP project for natural gas distribution infrastructure. The interview results were tabulated as seen in Table 3.Interestingly in an open question (Qu 17) as seen in appendices Box 2, the respondent come up with type of PPP that suit natural gas distribution infrastructure. For instance, one respondent noted that, "DBFOM is the best form for PPP project implementation". Regarding the barrier "lack of transparency", one respondent noted: "Private partners want confidence that the rules won't change mid-stream and that all bidders are treated equally. Lack of transparency clouds fairness in the bidding process (participating from private contractor). Meanwhile concerning negotiation costs, this is what one respondent claimed:" We got over a year going back and forth on contracts terms, chasing approvals, and this enormous negotiation dram put serious strain on our budget and timeline.

5.0 DISCUSSIONS

This study aimed to examine PPP model for gas distribution infrastructure and barriers that impede private sector involvement in the development of gas distribution infrastructure in Tanzania.For the first question, various Public-Private Partnership agreement types, including Operation-Maintenance (OM), Design-Build-Operate (DBO), Design-Build-Finance-Operate (DBFO), Build-Operate-Transfer (BOT), and Build-Own-Operate (BOO) (Kwak *et al*., 2009) were assessed to fit the gas distribution infrastructure using a survey instrument.

Majority of respondents suggested that Design-Build-Finance-Operate (DBFO) is the best form of PPP model for natural gas distribution infrastructure as in Figure 7 & Figure 10. That means through such a PPP type, the public sector alleviates the technical and financial burden due to rising natural gas infrastructure distribution cost in Tanzania, allowing risks to be transferred from the public to the private sector; and increasing the "value of money" spent for infrastructure services by providing more efficient, lower cost, and reliable services (Kwak *et al.,* 2009).This is evident is developing countries that embrace matching of public and private resource to close the infrastructure gap due to budget constraints and to bring solution to access to cleaner energy as per this study (Vecchi *et al.*,2021).

However, at sometimes poorly defined energy sector policy and natural resources, inadequate legal/regulatory frameworks, poor transparency, inadequate domestic capital market of natural gas and lack of mechanism to attract long term finance from private sources at affordable rates affect the implementation of DBFO (Kwak *et al.,* 2009).Many countries continue to view PPPs as one of the key strategies for delivering public services and infrastructure. Thus, Tanzania through the NGUMP has encourage public private

partnership and that has been same addressed in the clean cooking energy strategy 2024 to 2034.Therefore, understanding and enhancing public private partnership continue to be a matter of significance and importance in natural gas distribution infrastructures.

In regard to the second question, the key findings revealed that the most significant barriers to PPP projects in Tanzania's natural gas distribution include "Contracting Uncertainties," "High Cost of Bidding," "Inconsistent Policy," "Lack of Transparency," and "Negotiation Costs.The contracting uncertainties can affect the practical implementation of the natural gas distribution infrastructure as it is asset specific project. The contracting terms and government priority on the cleaner energy distribution infrastructure help to address this barrier; and hence lead to significant improvements in PPP projects for natural gas distribution infrastructure in Tanzania as (Dudkin & Välilä, 2006).Mean while high cost of bidding,negotiation cost,inconsistent Policy," and lack of transparency affect many project implementations due transaction costs that may render PPPs for developing public infrastructures (Rybnicek *et al.*, 2020).Dealing the suggested and found barriers in the study, require strong policy, regulations ,frame works and institutions that initially trigged the PPP operations and provide a clear basis for enforcement, supported by development of guidelines for the undertaking (Munachi Chikodili Ugwu *et al.,* 2024). Moreover, for PPP to develop and function well in a supportive environment ,requires strong institutional that mitigate risks and uncertainties (Wang et al., 2018).The study has further found that apart from the barriers that shape how PPP stakeholders make decision and interact (Williamson, 2000)& (Lai & Tang, 2016), political will, is necessary to draw private sector to this avenue according to response from respondents. Further, the demographic survey has indicated a large portion of respondents have limited or no involvement in PPP projects, thus presses a need for further education and engagement in this area. In addition, the respondent's opinion has aligned well in the context of technical expertise and training in the PPP implementations.

Regarding the PPP project's practical implications, the government takes into account the technical and financial capabilities of a suitable private company or contractor for a particular project, in this case, natural gas. As a result, the project's success depends on managers adopting a methodical approach, as well as on removing obstacles,good political will, stable policy ,regulation, legal frameworks and offering incentives that will help to realize the community's access to clean energy.

Theoretically speaking, PPP for natural gas distribution infrastructures in the downstream sector is obviously distinct from Production Sharing Agreements (PSA), Joint Ventures, and Concessions utilized in Tanzania's upstream sector. As natural gas distribution infrastructures attempt to reach final customers, the majority of whom rely on conventional biomass and LPG compressed in cylinder containers, they must be sensitive to safety concerns as well as technological considerations. Therefore, in order to provide stakeholders with the information they need to make an informed investment decision, comparative and cross-sectoral studies on the price competitiveness of natural gas and its safety implications are required.

Two limitations to this study have been addressed, beginning with the stakeholders engaged. Of the respondents, 47.5% said they had worked on one to five PPP projects, while 45.2% said they had never worked on a PPP project. This indicates that in order to improve the research output, a study on certain stakeholders who are knowledgeable, interested, and actively involved in PPP projects in the energy sector is essential. Subsequent investigations may include the outcomes of this work with actual energy distribution infrastructure scenarios, such the successful rural electrification program implemented by Tanzania's Rural Electrification Authority (REA).

6.0 CONCLUSIONS

PPPs (public-private partnerships) have the power to bring about revolutionary change in the development of natural gas distribution infrastructure, addressing energy-related issues in the power generation, industries, compressed natural gas stations for automobiles, commercial buildings, institutions, and domestic supply, as well as advancing the objectives of sustainable development. By removing barriers, encouraging partnership, strengthening institutional capacity, robust policy, and investment incentives, PPPs may significantly speed up the transition to a more durable, inclusive, and resilient natural gas distribution infrastructure that benefits everyone in Tanzania. However, as Tanzania is a developing nation, it is clear that appropriate model selection, in particular, Design-Build-Finance-Operate (DBFO) for natural gas distribution infrastructure is necessary to match public and private resources in order to close the infrastructure gap caused by budgetary constraints and to bring about a solution for access to cleaner energy.

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APPENDICES

Research title "Promoting public-private partnership in natural gas distribution infrastructure development in Tanzania"

Demographic Questions

1. What best describes your involvement in PPP projects and/or natural gas distribution? (Academic& research, government officers, consultant, service & contractor's representative, NGO representative)
2. How long have you been involved in PPP for energy distribution infrastructure? (None/zero, 1-5,5-10,10-15,>15 years)

Closed /Quantitative Questions on Types of PPP

To what extent do you agree or disagree with the following types of PPP when applied in natural gas distribution in Tanzania? [Options: 5-strongly agree, 4-agree, 3-neutral, 2-disagree, 1-strongly disagree]

3. Operation-Maintenance (OM). The private sector is responsible for all aspects of operation and maintenance. Although the private sector may not take the responsibility of financing, it may manage a capital invested fund and determine how the fund should be used together with the public sector
4. Design -Build-Operate (DBO). The private sector is responsible for design, construction, and maintenance of a project for a specified period prior to handling it over to the public sector.
5. Design-Build-Finance-Operate (DBFO). The private sector is responsible for the finance, design, construction, operation and, maintenance of a project. In nearly all cases, the public sector retains full ownership over the project
6. Build-Operate-Transfer (BOT). The private sector is responsible for finance, design, construction, operation, and maintenance of a project for a concession period.

7. Build-Own-Operate (BOO). Similar to a BOOT project, but the private sector retains the ownerships of the asset in perpetuity. The government only agrees to purchase the services produced for a fixed length of time.

Closed /Quantitative Questions on Barriers of PPP project

What is the likelihood of the following PPP project barriers to impede natural gas distribution infrastructure in Tanzania? [Options: 5-Very likely, 4-likely, 3-neutral, 2-unlikely, 1-very unlikely]

8. High asset specifity
9. Contracting uncertainties
10. The high cost of bidding process
11. Inconsistent policy, legal and regulatory frameworks
12. Negotiation Costs, lengthy and complexity
13. Defective investment incentives
14. Unsatisfactory institution arrangement
15. Lack of previous experience in PPP
16. Political priority uncertainties

Open/Qualitative Questions

17. Do you have any further comments / opinion concerning the PPP barriers on implementation of natural gas distribution infrastructure in Tanzania.....?

5. Do you have any further comments/opinion concerning the PPP barriers on implementation of natural gas distribution infrastructure in Tanzania.....?
Barriers to PPP Implementation in Tanzania's Natural Gas Distribution Regulatory and Policy Barriers Unclear Regulations: Inconsistent regulatory framework creates uncertainty.
Basically, there a NO SUCH THING AS PPPPROJECTS.....-ALL IN QUESTION ARE GOVERNMENT PROJECTS, WHICH CAN BE FINANCED EITHER FROM GOVERNMENT
Gvt focus on private investment rather than PPP since it consume a lot of time while they want meet promises before the regime cease
DBFOM is the best form for PPP project implementation. Create a way for investors attraction S like feasibility study, incentives, concept note, project profile and others....
I would suggest a full feasibility study to be conducted.
Lack of focus in driving the mission and vision of the government towards better energy for every citizen.
To go about those barriers. several strategic actions can be taken such as Strengthening Regulatory Framework through simplify and harmonize policies related to PPPs and natur
Absence of priority/promotion to this type of investment
No
Nil
NA
No
Political will is necessary to draw private sector to this avenue
no
Bad experience from the existing/previous projects involving private sectors and public sector with regards to natural gas projects! !

NAVIGATING THE IMPLEMENTATION OF MARITIME ARBITRATION IN TANZANIA: CHALLENGES AND STRATEGIES

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ABSTRACT

Maritime trade disputes are an inevitable aspect of the global economy, necessitating effective resolution mechanisms to ensure smooth operations. This study examines the challenges and strategies associated with implementation of maritime arbitration in Tanzania, a crucial component of dispute resolution within the maritime industry. Through an extensive literature review and empirical analysis, the study identifies key hurdles, including legal and procedural inconsistencies, limited awareness among stakeholders, and a shortage of specialized arbitrators. The findings reveal that the current legal framework, primarily governed by the Arbitration Act No. 2 of 2020, lacks specificity for maritime disputes, resulting in inefficiencies and enforcement

challenges. Additionally, there is a significant gap in stakeholder understanding of the benefits of arbitration, further impeding its adoption. To address these challenges, the study proposes the development of a comprehensive legal framework tailored to maritime arbitration, alignment with international standards such as the UNCITRAL Model Law, and the implementation of targeted awareness campaigns and specialized training programs for arbitrators.

By adopting these strategies, Tanzania can enhance the effectiveness of maritime arbitration, making it a more attractive and reliable option for dispute resolution. The study concludes that collaborative efforts from the government, legal community, and maritime stakeholders are essential to successfully reforming Tanzania's maritime arbitration landscape, thereby improving the country's competitiveness in the global maritime industry.

Keywords: Maritime arbitration, Tanzania, challenges, implementation, Strategies

1.0 INTRODUCTION

The importance of the maritime industry in Tanzania has been highlighted by Msemo (2018), who pointed out the potential benefits of implementing maritime arbitration as an effective means of resolving disputes. However, the lack of adequate legal frameworks, limited awareness of the benefits of arbitration among stakeholders, and the absence of specialized arbitrators, are significant challenges that need to be addressed. Arbitration is an alternative dispute resolution mechanism used to settle commercial disputes in various industries, including the maritime industry (Ntahuba, 2018). Maritime arbitration involves the resolution of disputes arising from maritime-related matters and contracts, including charter parties, bills of lading, salvage, collision, and marine insurance. Arbitration is often preferred to litigation due to its speed, flexibility, confidentiality, and finality noted by many scholars, including Rogers (2017) and Singh (2014). Maritime arbitration is increasingly becoming popular in many jurisdictions due to the growth of global trade and commerce. However, the implementation of maritime arbitration in Tanzania is still weak, and there are several challenges that hinder its development.

Maritime trade disputes are complex and multifaceted, involving various stakeholders and legal frameworks. In Tanzania, the maritime industry is integral to the economy, but the effectiveness of dispute resolution mechanisms, particularly arbitration, is hindered by numerous challenges (Msemo, 2018). Understanding the background of these challenges is essential for developing strategies to overcome them and enhance the efficiency of maritime arbitration in Tanzania.

The implementation of maritime arbitration in Tanzania is fraught with challenges, including legal and procedural inconsistencies, limited awareness among stakeholders, and enforcement issues. The objective of this study is to identify the challenges in implementing maritime arbitration in Tanzania. By examining existing literature, conducting empirical

research, and engaging with maritime industry stakeholders, the study aims to provide insights into the barriers hindering the effective implementation of arbitration in Tanzania.

2.0 LITERATURE REVIEW

Arbitration is a dispute resolution mechanism that involves the submission of a dispute to one or more arbitrators for a binding decision. Maritime arbitration is the application of arbitration to disputes arising from maritime commercial transactions. Maritime arbitration is often preferred to litigation due to its speed, flexibility, confidentiality, and finality. It is a popular mechanism for resolving disputes in the maritime industry globally. The legal framework for maritime arbitration in Tanzania is regulated by the Arbitration Act of 1931 replaced by the Arbitration Act No. 2 of 2020. The Act provides for arbitration in civil cases and generally applies to maritime arbitration.

However, the Act does not specifically address the issues and challenges arising from maritime arbitration. The lack of specificity in the Arbitration Act regarding maritime arbitration is a significant challenge since it leaves the interpretation of the provisions to the discretion of the courts. Furthermore, the lack of specialized arbitrators, high costs, and limited awareness among stakeholders are significant challenges in implementing maritime arbitration in Tanzania. Specialized arbitrators with knowledge of the maritime industry's practices and procedures are essential for the effective resolution of maritime disputes (Ntahuba, 2018). The high cost of arbitration is also a barrier to access, especially for small businesses, and this has contributed to limited awareness of the benefits of arbitration.

Maritime arbitration has become increasingly popular in many jurisdictions due to the growth of global trade and commerce. According to the International Chamber of Commerce (ICC), the maritime industry is responsible for about 90% of global trade, and commercial disputes are an inevitable part of such transactions. The ICC International Court of Arbitration is one of the leading institutions in the field of maritime arbitration, with many cases referred to it every year (ICC, 2019). Maritime arbitration offers many advantages over litigation, such as speed, cost-effectiveness, flexibility, confidentiality, and finality. Additionally, arbitration offers parties involved the ability to choose the arbitrator(s) who will resolve their disputes.

Tanzania's legal framework on maritime arbitration is regulated by the Arbitration Act of 1931 replaced by the Arbitration Act No. 2 of 2020, which provides for arbitration in civil cases, including maritime arbitration (Sikika, 2016). However, the Act does not specifically address the challenges and issues arising from maritime arbitration, which makes the interpretation of the provisions of the Act to the discretion of the courts. This lack of specificity in the Arbitration Act regarding maritime arbitration is a significant challenge. Additionally, limited awareness of the benefits of arbitration, high costs, and a lack of specialized arbitrators are significant challenges in implementing maritime arbitration in Tanzania (Sikika, 2016). Specialized arbitrators are essential for the effective resolution of maritime disputes. Tanzania's maritime industry lacks specialized arbitrators who

have knowledge of the industry's practices and procedures. The availability of specialized arbitrators is crucial since maritime disputes are complex and require a high level of expertise to resolve (Anselmo-Stumpf, 2015).

The cost of arbitration is prohibitive for small businesses, making it difficult for them to access this mechanism for dispute resolution (Sikika, 2016). The high cost of arbitration also contributes to the limited understanding of the benefits of arbitration in Tanzania's maritime industry. This has hindered the development and implementation of maritime arbitration in Tanzania. Overall, the literature reveals that the legal framework for maritime arbitration in Tanzania is inadequate, and there is a lack of understanding of the benefits of arbitration. Other challenges include a lack of specialized arbitrators, high costs, and limited awareness among stakeholders.

These challenges are hindering the growth and development of maritime arbitration in Tanzania. The United Nations Commission on International Trade Law (UNCITRAL) has developed the Model Law on International Commercial Arbitration, which serves as a fundamental framework for modern arbitration legislation. Tanzania could benefit from aligning its maritime arbitration laws with the UNCITRAL Model Law to ensure compatibility with international standards (UNCITRAL, 2013). The UNCITRAL Model Law on International Commercial Arbitration serves as a foundational framework for the modernization of arbitration legislation. This model law offers several theoretical advantages and considerations for Tanzania's maritime arbitration development.

The UNCITRAL Model Law has been widely adopted by many countries, enhancing the international recognition and enforceability of arbitration awards. By aligning its maritime arbitration laws with this model, Tanzania can make its arbitration process more attractive to international parties (UNCITRAL, 2013). The choice between institutional arbitration, where an established arbitration institution administers the process, and ad hoc arbitration, where parties manage the arbitration themselves, presents theoretical considerations that are crucial for Tanzania's maritime arbitration development.

One of the theoretical strengths of the UNCITRAL Model Law is its promotion of uniformity and predictability in the arbitration process. This consistency can lead to greater confidence among maritime stakeholders, encouraging them to choose arbitration over litigation (UNCITRAL, 2013). The model law allows for flexibility in procedural matters, which is particularly beneficial in complex maritime disputes. Parties can tailor the arbitration process to their specific needs, ensuring that issues specific to maritime trade can be adequately addressed. The enforceability of arbitration awards is a cornerstone of arbitration's efficacy. Tanzania should align its legal framework with international conventions like the New York Convention to ensure that arbitration awards rendered within the country are easily enforceable in other jurisdictions. This enhances the attractiveness of Tanzania as a seat for maritime arbitration (UNCITRAL, 2013).
The choice between institutional arbitration, administered by established institutions, and ad hoc arbitration, where parties manage the process themselves, is a key theoretical consideration. Tanzania may explore the advantages of establishing a dedicated maritime

arbitration institution, similar to the London Maritime Arbitrators Association (LMAA), to provide expertise and administration (Mitsubishi Heavy Industries, Ltd. v. The Federal Republic of Nigeria, 2018). Institutional arbitration, as exemplified by institutions like the LMAA and SMA, provides access to experienced arbitrators and administrative support.

This theoretical advantage ensures that maritime disputes are resolved by experts who understand the industry's intricacies, thus potentially leading to more informed and accurate decisions (LMAA, 2021). Ad hoc arbitration is often perceived as more cost-effective, as parties have more control over the process and associated costs. However, it may lack the efficiency and expertise that institutional arbitration can offer. Balancing cost considerations with the need for specialized maritime knowledge is a key theoretical consideration (Kumar, 2013).

Institutional arbitration is typically characterized by established procedural rules that can lead to more efficient proceedings. Ad hoc arbitration may require more time and effort in crafting arbitration agreements and procedures, potentially leading to delays in dispute resolution (Kumar, 2013). Institutions like the ICC and LCIA have a global reputation, which can enhance the enforceability and recognition of arbitration awards. This theoretical advantage is particularly relevant for international maritime disputes (ICC, 2021). Building awareness among stakeholders about the benefits of arbitration is vital. Legal scholars have emphasized the importance of educational programs and seminars to promote arbitration as a preferred method of dispute resolution (Redfern, Hunter, & Martin, 2018).

Government support and legislative reform are integral to the success of maritime arbitration. Research suggests that governments can provide incentives, such as tax benefits, and enact arbitration-friendly legislation to encourage arbitration (Park & Weeramantry, 2019). In addition to general arbitration principles, it is important to consider specialized maritime arbitration rules and guidelines. The Society of Maritime Arbitrators (SMA) and the London Maritime Arbitrators Association (LMAA), for example, have developed rules specifically tailored to maritime disputes. Tanzania could benefit from adopting or adapting such rules to address the unique aspects of maritime trade (SMA, 2021).

Theoretical considerations also encompass jurisdictional and choice of law issues. Research in conflict of laws and jurisdictional rules is essential to ensure that parties' rights and obligations are clearly defined, and disputes are directed to the appropriate forum (Fouchard, Gaillard, & Goldman, 2020). While arbitration is a primary method of dispute resolution, it is valuable to explore complementary ADR mechanisms such as mediation and conciliation. These mechanisms can offer more flexible and collaborative approaches to dispute resolution and may be suitable for certain maritime disputes (International Mediation Institute, 2021).

Benefits of Maritime Arbitration in Tanzania

Maritime arbitration is an alternative dispute resolution mechanism that is increasingly being used in the maritime industry globally. In Tanzania, maritime arbitration may offer several benefits to stakeholders in the maritime industry. One of the significant benefits of maritime arbitration is speed. Unlike traditional litigation processes, arbitration offers a faster way of resolving commercial disputes (Glover, 2019). Arbitrators are required to make decisions within a specified timeline, and this helps to reduce the time taken to resolve disputes.

Another benefit of maritime arbitration is flexibility. The parties involved in the dispute can choose the arbitrator, the place of arbitration, and the language used in the proceedings (Papadopoulos & Onyeisi, 2019). This flexibility allows the parties to select an arbitrator with specialized knowledge of maritime practices, making it easier to understand the complex legal and technical issues involved in the dispute. Maritime arbitration also provides a higher level of confidentiality than litigation. In litigation, disputes are argued in open court, and all information disclosed is available to the public (Glover, 2019). Maritime arbitration, on the other hand, is a private process, and the arbitration proceedings and award are confidential, maintaining the parties' privacy.

Maritime arbitration provides finality for disputes. Once an arbitrator has made an award, it is binding on all parties involved, and there is no right of appeal. This finality provides certainty for the parties involved and reduces the likelihood of prolonged legal proceedings (Papadopoulos & Onyeisi, 2019). These benefits make arbitration an attractive alternative to litigation for resolving commercial disputes in the maritime industry. By using arbitration, stakeholders can access a faster, more flexible, and more confidential process that ensures finality and preserves the parties' privacy.

3.0 METHODOLOGY

This study is qualitative in nature and involved reviewing existing literature, and interviews with stakeholders in Tanzania's maritime industry. The study employed a mixed-methods research design, including literature review and fieldwork. The mixed- methods approach allows for a comprehensive and rigorous analysis of the challenges associated with implementing maritime arbitration in Tanzania.

The documentary review involved a comprehensive analysis of existing literature on maritime arbitration in Tanzania. The review aimed to identify the legal framework governing maritime arbitration, the challenges faced by stakeholders, and strategies proposed to overcome these challenges. The fieldwork involved questionnaires and semi-structured interviews with stakeholders in, including lawyers, arbitrators, and representatives of government, non-governmental organizations (NGOs). The interviews explored the stakeholders' perspectives on the challenges associated with implementing maritime arbitration in Tanzania, the benefits and drawbacks of the current legal framework, and

strategies proposed to overcome these challenges.
The sampling strategy for the fieldwork involved a purposive sampling of relevant stakeholders in Tanzania. Purposive sampling allows for the selection of participants who have relevant knowledge and experience concerning the topic under investigation. The study used a combination of maximum variation and snowball sampling techniques to select participants. Maximum variation sampling enabled the inclusion of participants with diverse perspectives, while snowball sampling allowed the identification of other relevant stakeholders to include in the study.

Table 1: *Sample Frame of the Study*

Participants	Frequency	Percentage (%)	Sampling Technique
Importers	10	20%	Purposive Sampling (Maximum Variation)
Exporters	7	14%	Purposive Sampling (Maximum Variation)
Shipping Companies	5	10%	Purposive Sampling
Government Agencies	3	6%	Purposive Sampling (Snowball)
Arbitrators and lawyers	10	20%	Purposive Sampling
Research and Academic Community	15	30%	Purposive Sampling (Snowball)
Total	50	100%	

Source: Researcher, 2024

The above Table 1 provides a sample frame for a study that includes six different types of participants: importers, exporters, shipping companies, government agencies, arbitrators and lawyers, and the research and academic community. The Table reveals the number of participants within each group along with their percentages of the total sample. Purposive sampling was used for all groups to ensure a broad representation of participants with diverse characteristics and backgrounds. Maximum variation sampling was employed for importers and exporters, purposive sampling for shipping companies, snowball sampling for government agencies and research/academic community, and purposive sampling for arbitrators and lawyers.

The data collected were analysed using thematic analysis, which involves coding and categorizing data to identify patterns and themes that emerge from the data. Thematic analysis was utilized to systematically code and categorizes the data collected from questionnaires, semi-structured interviews, literature reviews, and case studies. This method allowed the researchers to identify patterns and themes emerging from the data, providing insights into the challenges, benefits, and stakeholder perspectives on maritime arbitration in Tanzania (Braun & Clarke, 2006). The deductive approach, guided by the research question and objective, ensured that the analysis remained focused on identifying barriers to the implementation of maritime arbitration and potential strategies for overcoming these challenges.

4.0 RESULTS AND FINDINGS

The results of the study reveal a range of challenges in implementing maritime arbitration in Tanzania. These include legal and procedural inconsistencies, limited awareness among stakeholders, and enforcement issues. Stakeholder perspectives provide valuable insights into the barriers hindering the effectiveness of arbitration in the Tanzanian maritime industry.

4.1 Legal Framework for Maritime Arbitration in Tanzania

The study found that the legal framework for maritime arbitration in Tanzania is inadequate and lacks specificity regarding maritime arbitration. The Arbitration Act of 1931 replaced by the Arbitration Act No. 2 of 2020 provides for arbitration in civil cases and generally applies to maritime arbitration. However, the Act does not address the issues and challenges unique to maritime arbitration, such as the need for specialized arbitrators and the high costs associated with the arbitration of maritime disputes. The Arbitration Act of 2020 is the current applicable arbitration law in Tanzania. It does not appear to have any specific sections or chapters dedicated to maritime arbitration. The previous Arbitration Act of 1931 (now repealed) also did not seem to have any special provisions for maritime arbitration.

Tanzania is a signatory to the United Nations Convention on the Recognition and Enforcement of Foreign Arbitral Awards (the New York Convention), which does cover the enforcement of maritime awards. However, this is a separate international treaty, not domestic Tanzanian legislation.

According to Mtenga and Edwin (2020), the country's arbitration laws need to be amended to provide for more specific regulations that deal with maritime disputes and also to adopt the United Nations Commission on International Trade Law (UNCITRAL) model law on international commercial arbitration. The UNCITRAL model law provides for a comprehensive framework for the uniform implementation of international commercial arbitration.

Internationally, other jurisdictions have developed specific legal frameworks for maritime arbitration. For instance, the United Kingdom has the Arbitration Act 1996, which is a stand-alone legislation that governs arbitration in the country. Similarly, Singapore has a comprehensive legal framework that provides for the Singapore International Arbitration Centre (SIAC) and guidelines for the appointment of arbitrators. This framework has attracted many commercial entities to choose Singapore as a seat for arbitration in maritime disputes (UNCITRAL, 2020).

There are several maritime disputes that have been handled in Tanzania. The case of Chinese Tanzania Joint Shipping Company (SINOTA) vs. Bassam Company Limited and Others (Commercial 106 of 2019) addresses the complexities and challenges involved in the maritime arbitration landscape in Tanzania, particularly in handling demurrage charges and liability for cargo destruction. This case, adjudicated in the Commercial Division of the High Court of Tanzania, encapsulates the intricacies of contractual obligations, third-party roles, and the legal adjudication of maritime disputes, all of which resonate with the broader concerns outlined in the related research paper on improving maritime arbitration in Tanzania.

The case revolves around the plaintiff, SINOTA, seeking compensation for specific damages from the defendants for demurrage charges and the costs of cargo destruction. SINOTA claims that the defendants failed to retrieve a container in a timely manner after it was discharged, which led to additional charges and eventually the destruction of the cargo deemed unfit for human consumption. The defendants contested these claims, arguing that the responsibility for the cargo and associated charges did not rest solely with them, especially considering the cargo's condition upon inspection.

This case illustrates several procedural and systemic challenges within Tanzania's maritime arbitration framework, as discussed in the research paper. One significant issue is the determination of liability and demurrage charges in maritime logistics, particularly when multiple parties are involved, and when the cargo in question becomes compromised. The case highlights the critical role of clear contractual terms and the responsibilities assigned to each party, including third-party entities like Tanzania International Container Terminal Services Limited (TICTS), which was brought into the dispute.

The complexities encountered in this case, such as determining the moment at which cargo responsibility transfers from one party to another and establishing the veracity of claims regarding cargo condition, underscore the inadequacies of the current legal framework in efficiently resolving such disputes. The plaintiff's difficulties in substantiating claims for demurrage and destruction costs reflect the broader issues of evidence management and procedural clarity that could be mitigated through more specialized maritime arbitration procedures.

The findings from this case analysis align with the research paper's recommendations for legal reforms and enhanced educational initiatives to improve the understanding and handling of maritime arbitration in Tanzania. The case underlines the need for:

- ***Clearer Legal Definitions and Protocols*** – Establishing specific guidelines for demurrage charges, the responsibilities of involved parties, and the handling of unfit cargo could prevent similar disputes.
- ***Enhanced Role of Third Parties*** – Clarifying the roles and liabilities of third parties like terminal operators in maritime contracts to ensure all parties are aware of their responsibilities and the legal implications of their actions.
- ***Educational Programs*** – Increasing awareness and understanding among maritime stakeholders about the nuances of maritime arbitration and the importance of timely and accurate documentation and communication among parties.

This case provides insights into the specific challenges faced by parties in maritime disputes in Tanzania and also reinforces the findings regarding the need for comprehensive reforms in the maritime arbitration framework. By addressing these issues through legislative updates, clearer contractual guidelines, and enhanced stakeholder education, Tanzania can improve its arbitration system's efficiency and fairness, thus fostering a more reliable and competitive maritime industry.

Another case is of Ballore Transport and Logistic Tanzania Limited vs. Sharaf Shipping Line (T) Ltd (Civil Case No. 161 of 2018) exemplifies several pivotal challenges inherent in the current maritime arbitration landscape in Tanzania, as analysed in the associated research study on maritime arbitration. This case, adjudicated in the High Court of Tanzania, revolved around a breach of contract concerning the refund of security deposits for leased containers, underlining critical issues such as the enforcement of agreements and the adequacy of the legal framework governing such disputes.

Case Overview: Ballore Transport and Logistic Tanzania Limited (plaintiff) and Sharaf Shipping Line (T) Ltd (defendant) were involved in a dispute over the refund of a security deposit following a container lease agreement. The plaintiff alleged that after returning the leased containers in good condition, the defendant failed to refund the deposit amounting to $151,000. The defendant acknowledged the leasing agreement but contested the refund claim, arguing that the deposit was returned to the plaintiff through a third party, Sammy and Sons Limited, as per the plaintiff's directive.

Legal and Procedural Analysis: This case underscores the significant legal and procedural inconsistencies within Tanzania's maritime arbitration framework, as highlighted in the research study. Firstly, the lack of a specific maritime arbitration law led to the reliance on general contract law principles to resolve the dispute, which may not adequately address the unique aspects of maritime transactions. The plaintiff's reliance on general legal principles rather than specialized maritime arbitration mechanisms likely complicated the resolution process. Furthermore, the case illustrates enforcement issues, a common challenge identified in the research. Even though the plaintiff provided evidence of the agreement and non-refund of the deposit, the court's decision hinged on procedural technicalities and evidentiary challenges, such as the absence of original documentation proving the deposit and refund transactions. This reflects the broader issue of the need

for a robust legal framework that specifically caters to the nuances of maritime disputes.

The findings resonate with the challenges observed in this case, particularly the need for specialized knowledge and procedures in handling maritime disputes. The absence of maritime-specific arbitration rules likely contributed to the complexities faced during the litigation process. The research advocates for reforms in the legal framework to include specific provisions for maritime arbitration, which could foster a more efficient and equitable dispute resolution environment for maritime industry stakeholders in Tanzania. This case not only reflects the practical implications of the existing deficiencies in Tanzania's maritime arbitration framework but also emphasizes the urgent need for legislative reforms and enhanced awareness among stakeholders. Implementing the recommendations from the study, such as developing a comprehensive legal framework and increasing educational efforts about the benefits of maritime arbitration, could substantially improve the resolution of similar disputes in the future, enhancing the reliability and effectiveness of maritime arbitration in Tanzania.

4.2 Challenges in Implementing Maritime Arbitration in Tanzania

The study found that the challenges associated with implementing maritime arbitration in Tanzania include legal and procedural inconsistencies, limited awareness among stakeholders, and enforcement issues. The study further discovered that the lack of awareness of international best practices and limited knowledge of maritime arbitration practices and procedures contributes to the challenges.

4.2.1 Legal framework

Tanzania's existing legal framework for maritime arbitration, primarily governed by the Arbitration Act of 1931 replaced by the Arbitration Act No. 2 of 2020, is notably unspecific for the complexities and technical demands of modern maritime disputes. This Act does not adequately address the nuances of maritime arbitration, such as specifying qualifications for arbitrators with maritime expertise, or delineating procedures for expedited processing of urgent maritime claims. Furthermore, the enforcement of arbitration awards under this framework does not align with international practices, such as those outlined in the New York Convention, which complicates matters when foreign parties are involved (UNCITRAL, 2020). The lack of detailed maritime-specific provisions results in inefficiencies and reduces the global competitiveness of Tanzania's arbitration services.

To rectify these shortcomings, there is an urgent need for Tanzania to develop a comprehensive legal framework tailored specifically to maritime arbitration. This new framework should incorporate elements like specialized arbitration provisions that cater directly to the maritime sector, cost management strategies to make arbitration more accessible to small and medium enterprises, and ensure alignment with international standards to facilitate the enforcement of arbitral awards internationally. Drawing from models like the UNCITRAL Model Law on International Commercial Arbitration and the

practices of established centers such as Singapore and London could provide a robust basis for these reforms (UNCITRAL Model Law on International Commercial Arbitration, 2013). Such steps will enhance the efficacy and reliability of Tanzania's maritime arbitration system, making it a more attractive option for resolving international maritime disputes.

Implementing these comprehensive legal reforms will require a collaborative approach involving key stakeholders from the maritime industry, legal experts, and international arbitration specialists. Legislative action will be crucial, involving the drafting of new laws with stakeholder input and aligning with international best practices. Additionally, capacity building through targeted training programs for arbitrators on maritime law and specific arbitration procedures is essential to ensure a well-equipped pool of professionals. Public awareness campaigns and advocacy will also play a vital role in garnering support for the reforms, facilitating understanding among industry players, and expediting the legislative process (Nkya, 2020). Together, these efforts will position Tanzania as a competitive hub for maritime arbitration, aligned with global standards and capable of efficiently handling complex maritime disputes.

4.2.2 Awareness

Participants reported that there is a limited understanding of the benefits of arbitration, and this lack of awareness hinders the development and implementation of maritime arbitration in Tanzania. There is a need to increase awareness of the benefits of arbitration among stakeholders in the maritime industry. Awareness-raising campaigns could be an effective strategy to increase awareness of the benefits of arbitration among stakeholders in the maritime industry.

The limited understanding of the benefits of arbitration among stakeholders in Tanzania's maritime industry poses a significant barrier to the broader acceptance and effective utilization of arbitration for dispute resolution. Many stakeholders remain unfamiliar with the advantages of arbitration, such as its potential for faster resolution times, reduced legal costs, and privacy in sensitive matters compared to traditional courtroom litigation. This lack of awareness can lead to hesitation or reluctance to engage in arbitration, with parties defaulting to the more familiar, though often lengthier and more costly, court processes. This scenario underscores the necessity for targeted awareness campaigns that educate and inform all levels of the maritime industry from senior executives to operational staff about how arbitration can be a more advantageous approach to resolving disputes.

To address this challenge, implementing comprehensive awareness-raising campaigns is essential. These campaigns should focus on delineating the specific advantages of arbitration, such as confidentiality, flexibility in procedural matters, choice of expert arbitrators with relevant industry knowledge, and the enforceability of arbitration awards both locally and internationally. The campaigns could utilize workshops, seminars, and digital media platforms to reach a wide audience effectively. Additionally, success stories and case studies demonstrating the effective resolution of maritime disputes through arbitration could be highlighted to provide concrete examples of its benefits. Collaborating

with maritime associations, educational institutions like Dar es Salaam Maritime Institute (DMI), and professional legal and arbitration bodies to disseminate this information would further ensure that the campaigns have both depth and reach, ultimately fostering a more arbitration-friendly environment within Tanzania's maritime industry.

4.2.3 Specialized arbitrators

There is a significant lack of specialized arbitrators in Tanzania's maritime industry. Participants reported that the availability of specialized arbitrators is essential for the effective resolution of maritime disputes but is limited. There is a shortage of specialized arbitrators with knowledge of the maritime industry's practices and procedures. Capacity building for arbitrators could be a useful strategy to overcome this challenge. The training programs could improve the quality of arbitrators and enhance their knowledge of the maritime industry's practices and procedures.

The scarcity of specialized arbitrators proficient in maritime law significantly hampers the effective resolution of maritime disputes in Tanzania. This shortage stems from a lack of focused training and development opportunities tailored to the intricacies of maritime law and arbitration. Maritime disputes often involve complex legal and technical issues unique to the shipping industry, such as charter party disputes, cargo claims, and maritime insurance matters. Arbitrators lacking specialized knowledge in these areas are less likely to handle disputes efficiently and effectively, potentially leading to resolutions that do not adequately consider industry-specific practices and legal precedents (UNCITRAL, 2016). Therefore, enhancing the expertise of arbitrators through specialized training programs is crucial to build a competent pool of maritime arbitrators who can deliver fair, informed, and timely resolutions to disputes.

To address this gap, it is essential to establish comprehensive training programs focused on maritime arbitration. These programs should cover key areas such as international maritime law, the handling of technical evidence, and the application of international treaties like the United Nations Convention on the Law of the Sea (UNCLOS) and the rules of major arbitration institutions such as the London Maritime Arbitrators Association (LMAA).

Moreover, practical training modules, including mock arbitrations and internships with established maritime arbitration centers, would provide invaluable hands-on experience. Partnering our institutes like DMI with universities that offer maritime law courses and professional bodies like the Chartered Institute of Arbitrators could facilitate the development and accreditation of such training programs (ICS, 2018). By enhancing the skill set of arbitrators, Tanzania can ensure that its maritime arbitration framework becomes robust, attracting more international commercial parties to choose Tanzanian forums for dispute resolution, thereby boosting the country's profile in the global maritime industry.

4.3 Strategies to Overcome Challenges in Implementing Maritime Arbitration in Tanzania

Development of a comprehensive legal framework that specifically addresses maritime arbitration. The current legal framework under the Arbitration Act of 1931 replaced by the Arbitration Act No. 2 of 2020, lacks specificity regarding maritime arbitration. To overcome this challenge, there is a need for the Tanzanian government to develop a comprehensive legal framework that addresses the challenges specific to maritime arbitration. This will ensure that the legal framework for arbitration in Tanzania is adequate, up-to-date, and promotes the growth and development of maritime arbitration in the country.

Increasing awareness of the benefits of arbitration among stakeholders in the maritime industry. The limited understanding of the benefits of arbitration is a significant challenge in implementing maritime arbitration in Tanzania. Awareness-raising campaigns could help to educate stakeholders in the maritime sector about the benefits of arbitration and the advantages it offers over traditional litigation (Nkya, 2020). This will encourage more stakeholders to use arbitration in resolving their commercial disputes.

Building capacity through training programs for specialized arbitrators. The lack of specialized arbitrators in Tanzania's maritime industry is a significant challenge to implementing maritime arbitration. Capacity building programs for arbitrators can help to address this challenge by providing arbitrators with specialized knowledge of maritime practices and procedures (Mfwaisa & Msemo, 2020). With specialized knowledge, arbitrators can better understand the complex legal and technical issues involved in resolving maritime disputes, leading to more effective and efficient resolution of disputes.

The lack of specialized arbitrators as one of the main challenges to the implementation of maritime arbitration in Tanzania. Many potential arbitrators lack the specialized knowledge of international best practices and maritime arbitration procedures required for effective dispute resolution. Therefore, capacity building through training programs for specialized arbitrators is necessary to address this challenge. One effective way to build capacity is by introducing a specialized arbitration curriculum in Tanzanian universities, Specifically maritime institute like Dar es Salaam Maritime Institute (DMI).

This curriculum could focus on developing knowledge and skills in maritime law, procedures, and practices, including international best practices in maritime arbitration. The curriculum should also cover the legal and technical aspects specific to the maritime industry, such as contracts of carriage, marine insurance, and marine casualties. In addition to academic training, specialized arbitrators should undergo practical training through internships and apprenticeships. Practical training programs should include exposure to actual maritime arbitration cases and engagement with experienced arbitrators. This will provide hands-on experience and prepare the arbitrators for the complexities and intricacies of maritime arbitration.

Specialized arbitration training can also be provided through professional organizations such as the Tanzania Institute of Arbitrators (TIArb) in Tanzania. Professional organizations offer specialized training and certification programs that equip arbitrators with the knowledge and skills required for effective arbitration (Ntahuba, 2018).

The training and capacity building of specialized arbitrators will require the involvement of different stakeholders, including universities, government agencies, and the private sector. Coordinated efforts among these stakeholders will be necessary to ensure that the training programs are adequately designed and implemented. The introduction of a specialized arbitration curriculum in Tanzanian universities, practical training programs, and specialized training offered by professional organizations are necessary to build capacity for specialized arbitrators in Tanzania. These will equip them with the required knowledge and skills to engage in maritime arbitration effectively.

The last strategy recommended is reducing arbitration costs by establishing more affordable arbitration centers. The high cost of arbitration is a significant barrier to its accessibility, especially for small businesses and individuals. Establishing more affordable arbitration centers can help to reduce the costs of arbitration, making it more accessible to stakeholders in the maritime industry (Ntahuba, 2018). The low-cost centers can also help to promote more efficient resolution of disputes and increase the use of the arbitration mechanism.

5.0 DISCUSSIONS

Maritime arbitration in Tanzania is hindered by a myriad of challenges, including lack of specific legal framework relating to maritime arbitration, limited awareness among stakeholders, and a dearth of specialized arbitrators. The legal framework, primarily grounded in the Arbitration Act of 1931 replaced by the Arbitration Act No. 2 of 2020, does not cater to the specific demands of maritime disputes which are often complex and require technically nuanced adjudication processes. This legislative inadequacy not only complicates the enforcement of arbitration awards but also diminishes the country's appeal as a destination for maritime arbitration on the international stage.

Moreover, the findings underline a critical gap in stakeholder awareness about the advantages of maritime arbitration over traditional litigation, such as reduced timeframes, cost efficiency, and procedural flexibility. The persisting lack of awareness can be attributed to insufficient targeted educational programs and a general scarcity of easily accessible information that highlights these benefits. This gap significantly impacts the willingness of parties to opt for arbitration, leaning instead towards the more familiar judicial system, despite its drawbacks in efficiency and expediency.

The shortage of arbitrators skilled in maritime law is another significant barrier. The complexity of maritime cases, which often involve international laws and conventions, necessitates arbitrators who are not only well-versed in local laws but also competent in

the intricacies of international maritime norms and practices. The current educational and training frameworks within Tanzania do not support the development of such expertise, leading to delays and potentially less informed decisions in maritime disputes. This challenge is compounded by the global nature of maritime trade, which places a premium on arbitrators who can navigate both local and international waters of legal practice.

These challenges undermine the effectiveness of arbitration as a dispute resolution mechanism in the Tanzanian maritime industry. Addressing these challenges is crucial for improving the efficiency and reliability of maritime arbitration in Tanzania. Therefore, the study recommends strategies such as the development of a comprehensive legal framework specifically for maritime arbitration, increasing awareness of the benefits of arbitration, and capacity building of specialized arbitrators. The proposed strategies are consistent with findings in the literature on arbitration implementation in other jurisdictions.

6.0 CONCLUSIONS

The effectively delineates the multifaceted challenges inhibiting the effective deployment of maritime arbitration within Tanzania, including outdated legal provisions, limited awareness of arbitration's benefits, and a shortage of specialized arbitrators. To overcome these hurdles, it recommends comprehensive legal reforms aligned with international standards, enhanced educational initiatives to raise arbitration awareness, and targeted training programs to develop expert arbitrators. If these strategies are implemented collaboratively by government entities, educational institutions, and maritime sector stakeholders, Tanzania can not only improve its arbitration framework but also bolster its standing in the global maritime arbitration arena, fostering a more efficient, reliable, and globally competitive maritime industry.

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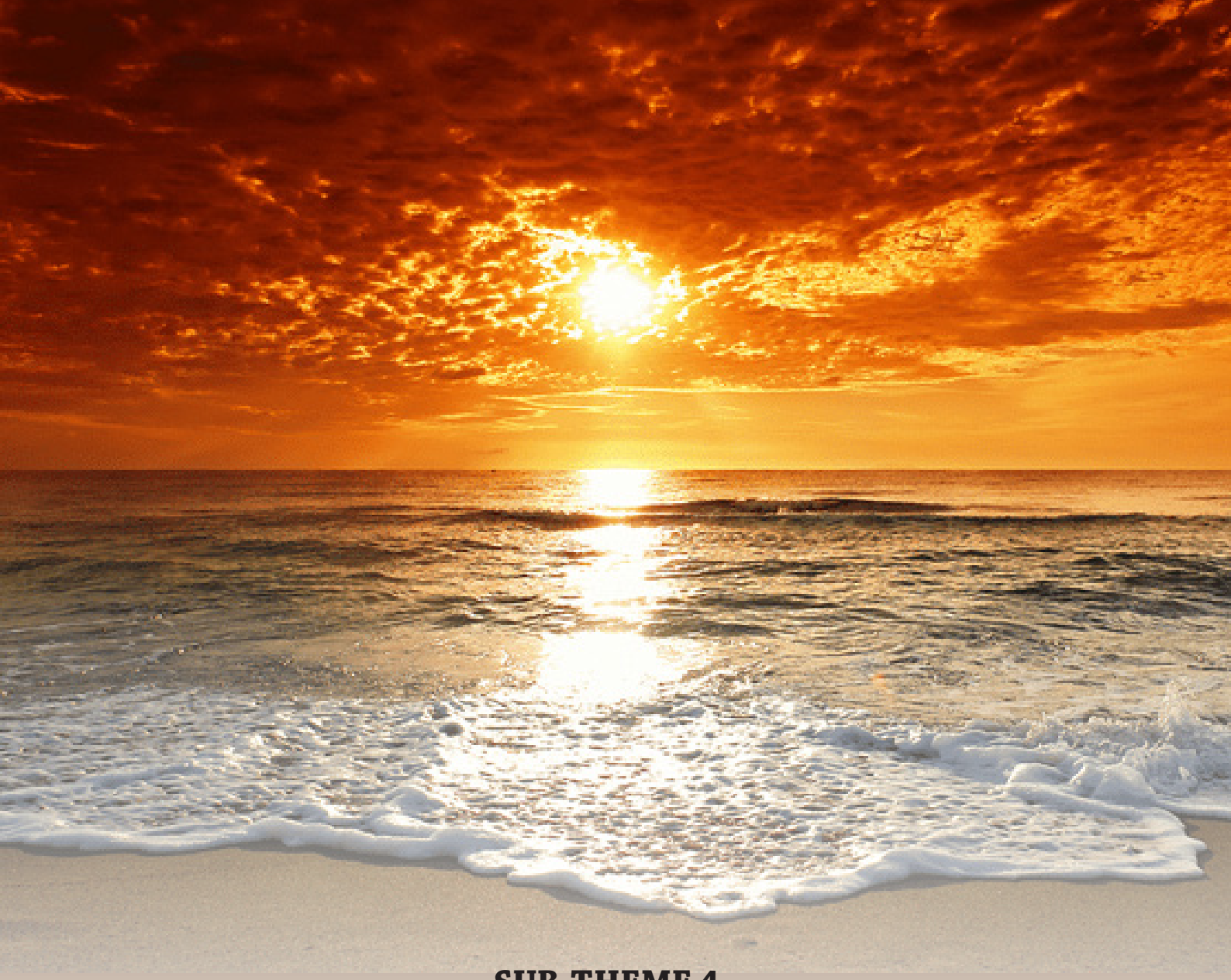

SUB-THEME 4

TECHNOLOGY ADVANCEMENT IN MARITIME PRACTICES

USING ARTIFICIAL NEURAL NETWORK (ANN) MODELS TO ANALYSE DIESEL PRICES IN SELECTED REGIONS OF TANZANIA

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ABSTRACT

In the current study, artificial neural network (ANN) models are applied to estimate monthly diesel cap prices for the three selected headquarters of selected region, Mbeya City, Songea and Mpanda municipalities in Tanzania Mainland. The study proposed 5-12-10-1, 5-10-10-1 and 5-12-8-1 architectures for the Mbeya City ANN model, Songea Municipal ANN model and Mpanda Municipal ANN model, respectively, due to their exceptional estimation capabilities. The performances forecast of the ANN models were assed with that of the historical monthly diesel cap price published by the EWURA. The results

demonstrated that the suggested ANN models achieved R2 and MAE values of 1.0000, 1.0000,

1.000 and 1.31 x 10-12, 1.08 x 10-12, 1.23 x 10-12 for ANN models for Mbeya City, Songea and Mpanda Municipalities, respectively, historical monthly diesel cap prices. Additionally, the study analysed the trends of the monthly diesel cap price variations, utilising outputs of the ANN models. Based on the analysis it shows that from July 2015 to February 2016, the monthly diesel price decreased by an average of 3.41%. Whereas, starting from March 2016 to December 2018, the monthly diesel price increased by an average of 1.56%.

The analysis results demonstrate that the suggested ANN models exhibited superior performance in predicting monthly diesel cap price in the study areas. Therefore, it can be concluded that the proposed ANN models is a reliable and effective tool for analysing monthly diesel cap prices in Mbeya City, Songea municipal and Mpanda municipal. Based on to the results, it can be concluded that the proposed ANN models are accurate and useful tools for analysing monthly diesel prices in selected regions, Mbeya City, Songea and Mpanda Municipalities of Tanzania mainland.

Keywords Artificial Neural Network, Monthly Cap Price, Feed-forward Backpropagation, Cap Prices Prediction

1.0 INTRODUCTION

In today's era of development and industrialization, energy has emerged as a crucial driving force behind to the every economy sector globally. For instance, in Tanzania petrol and diesel are the primary energy sources utilised to sustain various sectors including agriculture, transport, health industry, commerce, education, and home activities. Moreover, 82% of Tanzania's energy utilised is attributed to diesel and petrol energy products. However the price per litre of these energy products varies significantly across different regions. Furthermore, the diesel and petrol markets are characterised by significant price fluctuation. The fluctuation in pricing can be ascribed to various reasons, such as import costs, product prices, distribution and transportation costs, marketing expenditures, and government taxes.

The volatility and fluctuation in monthly prices of diesel has significant repercussions on financial markets and economies, as well as amplifying the impact on consumers' household expenses (Taghizadeh-Hesary *et al.,* 2016; Abdelsalam *et al.,* 2020; Saari *et al.,* 2016). For instance, Sun *et al.* (2022) conducted a study on the effect of price variation on consumption products and investment in the Chinese industrial sector. The study revealed that oil price variations most affect crude oil and gas extraction goods, refined products, and fuel products of processed nuclear.

In the petroleum industry, the estimation of diesel price can be carried out by using a range of conventional techniques, such as time series, financial models, structural models, supply and demand models, and inventory models, among others. Although traditional methods are extensively used for predicting diesel and gasoline prices, they still have some drawbacks. Among them is the fact that these techniques fail to incorporate external variables such as geopolitical developments, natural disasters, abrupt regulatory modifications, market speculation, exchange rates, and other such elements. The impact of these external disturbances can have a substantial effect on the costs of gasoline and diesel, making it difficult for any technique to generate reliable predictions.

Therefore, recently, the petroleum industry has shifted its focus towards the utilisation of machine learning algorithms (MLAs) to address the limitations uncounted by conventional techniques in estimating diesel prices. Several researchers are now utilising artificial neural networks (ANN) approaches to estimate diesel prices. These techniques are preferred for their capacity to quickly and efficiently analyse and assess predicted outcomes (Azad *et al.,* 2022; Mamudu *et al.,* 2020; Rahimi *et al.,* 2023; Davoodi *et al.,* 2023). According to a study conducted by Shafique *et al.* (2018), pointed out that, these methods provide a dynamic view of analysing input datasets and may effectively identify outlier values.

Using ANN techniques, several scholars obtained reliable results when predicting the prices of various petroleum products including asphalt base, petrol, diesel, kerosene, liquefied petroleum gas (LPG), liquefied natural gas (LNG), and heating oil. For example, Qiu *et al.* (2017) introduced an ANN ensemble deep learning model for predicting the price of crude oil. A study employed six input signals in a feedforward network, and the findings demonstrated that the proposed technique exhibited superior performance. Similarly, Mirmirani (2004) and Cheng *et al.* (2003) utilised a vector autoregression (VAR) methodology to ascertain oil prices, employing petroleum consumption and oil supply as input variables. Then, the parameters were also utilised in the application of a back-propagation neural network (BPNN) with a genetic algorithm (GA) to analyse 275 observations of monthly oil price data over a 17-year period. The comparative results indicate that the suggested ANN with the GA model outperforms the Vector Autoregression technique in terms of realisation.

In addition, Mafinezhad et al. (2010) utilised ANN technique to estimate the monthly price of crude oil. The study utilised several input variables, including refinery capacity, nominal effective exchange rate, total liquid capacity, gross domestic product growth (GDPG), crude oil output ceiling allocation, and petrol ending stocks. The results revealed that the proposed technique produces reliable results. Moreover, Haider et al. (2008) proposed ANN models for the crude oil commodities prices prediction. The study utilised a total of 2705 datasets encompassing five inputs. The data collection period spanned from September 1996 to August 2007. The inputs included light sweet crude oil spot price, West Texas Intermediate (WTI), and NYMEX futures contracts. The study demonstrated that the suggested approach yielded dependable outcomes with an accuracy of 78%.

Furthermore, ANN and wavelet approaches were suggested by Jammazi et al. (2012) to

forecast the short-term price of the crude oil for a 12-year period. The bipolar sigmoid, sigmoid, and hyperbolic tangents are the three types of transfer functions that were employed in a study utilising various neural network designs. The results demonstrate that experimental data from ANN and wavelet decomposition techniques were fared in predicting the price of crude oil. Also, Glorot *et al.* (2010) predicted the volatility of oil prices using the ANN-GARCH hybrid model.

The findings revealed that the proposed model improved volatility forecasting precision over earlier models by 30%. Similarly, Moner *et al.* (2016) used eight years' worth of daily data to examine correlations between the price behaviour of gold, crude oil, and the euro exchange rate using ANN models. It was determined that the price of oil is a key factor in predicting the price of gold and the value of the euro. Moreover, Wang *et al.* (2020) used a bivariate ANN and the copula function to assess changes in oil prices. The findings demonstrated that the proposed model forecasts quite well and that the exchange rate is greatly impacted by changes in oil prices.

The previous discussion highlighted that oil prices fluctuations are influenced by various factors. However, most of the existing literature focuses on studying oil price variations in countries that produce crude oil. There is a lack of studies on predicting oil prices in countries that importing refined crude oil product, such as Tanzania. Therefore current study employs ANN model to estimate the imported and distributed diesel in three specific regions of mainland Tanzania: Ruvuma, Mbeya, and Katavi. Tanzania is comprised of 25 regions that are distributed over a land area of 945,087 square kilometres. As a result of the substantial distances between these regions, 80% of them are more than 200 km apart, which greatly influences the fluctuations in oil prices. Hence, it is imperative to ascertain the shared elements that dictate pricing in every location and create a predictive instrument that will aid decision-makers in creating a fundamental benchmark for oil prices.

Diesel is imported into the Tanzania via the ports of Tanga, Mtwara, and Dar es Salaam. These ports are situated along the Indian Ocean and are known for their considerable distance from other sections of the country, requiring truck road transit over thousands of kilometres. Off-road diesel vehicles are more rugged, with a gradient of up to 16%. The distinct circumstances surrounding the distribution of diesel lead to divergent price patterns. According to a report by Citizen News in 2019, there are significant variations in the pricing of fuel and petrol throughout different zones in Tanzania, including the southern highlands, western, and lake zones.

These price disparities are particularly notable when contrasted to the eastern and southern districts, where ports are situated. Hence, it is crucial to analyse the impact of input variables, such as distance from the region's centre to consumers, inflation rate, gold world market price and Europe Brent spot price on the forecasting of energy prices in order to mitigate the volatility of diesel prices. The assessment of price volatility using ANN models is based on a decade of data on diesel prices obtained from Energy and Water Utilities Regulatory Authority (EWURA).

2.0 THEORETICAL REVIEW

2.1 Artificial Neural Network (ANN)

ANN is a sophisticated network composed of interconnected processing units known as neurons, capable of performing simultaneous calculations to process information. The ANN design is based on the structure of the human central nervous system. ANN is created to imitate the information-processing abilities of the human brain. Artificial neural networks have the capability to process several variables that are both independent and dependent concurrently without requiring a previous understanding of the intrinsic interrelationship. An ANN has the ability to acquire knowledge about the underlying connections between the input and output variables. Additionally, ANN is capable and efficient at representing complex, non-linear, and linear interactions between dependent and independent variables.

ANN exhibit some fundamental differences compared to traditional computational approaches. ANN is operating in an iterative computational manner without adhering to a rigid set of rules or algorithms. In contrast, conventional approaches are characterised by a sequential set of rules and a logical nature. For instance, traditional approaches are capable of learning through rules and logic, whereas ANN learns by extracting correlation from examples. Therefore, ANN is recognised to be general function approximators and aim to offer a means of independently acquiring knowledge and skills from the given data (Peterson et al., 2004).

The current investigation employed feed-forward backpropagation (FFB) ANN with the Levenberg-Marquardt algorithm (LMA) technique to facilitate the learning process. The output layer utilised a linear transfer function, while the hidden layers employed a tan-sigmoid transfer function, as indicated in Fig. 1. This approach was proposed because of its frequent status as the most accurate backpropagation supervised algorithm (Karlik and Olgac, 2011; Karsoliya, 2012; Sibi *et al.,* 2013). The data were inputted into the input neurons, processed, and subsequently transmitted to the hidden layer neurons at the specified level.

During this process, the input signal was subjected to multiplication by weight, as described in Eq. 1, to ascertain the magnitude of the input. According to Eq. 2, the hidden layer neurons added up the weighted input from each neuron and correlated it with a bias before sending the result to the following level via a transfer function. The main objective of the proposed FFB-ANN technique was to determine the optimal architecture and its weight matrixes that would generate an output vector with high accuracy and a minimal root mean square error (RMSE), closely resembling the target values of the trained vector, as indicated in Eq. 3.

$$sum = \sum_{i=1}^{n} x_i w_i + b \quad \ldots\ldots (1)$$

$$Output : f(sum) = \frac{1}{1 + e^{-sum}} \quad \ldots\ldots (2)$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{K}\sum_{n=1}^{Z}\left(y_n^i - y_n^{ai}\right)^2}{KZ}} \quad \ldots\ldots (3)$$

These equations 1 and 3 are described as follows:
In Eq. 1, Wi (i = 1, n) represent connection weights, b represents bias, and Xi represents input. While in Eq. 2, Z represents the number of patterns utilised in the training process, K represents the number of output nodes; i specifies the index of the input pattern (vector), whereas y^i_n and y^{ai}_n represent the desired (target) and anticipated outputs of the nth output node, respectively.

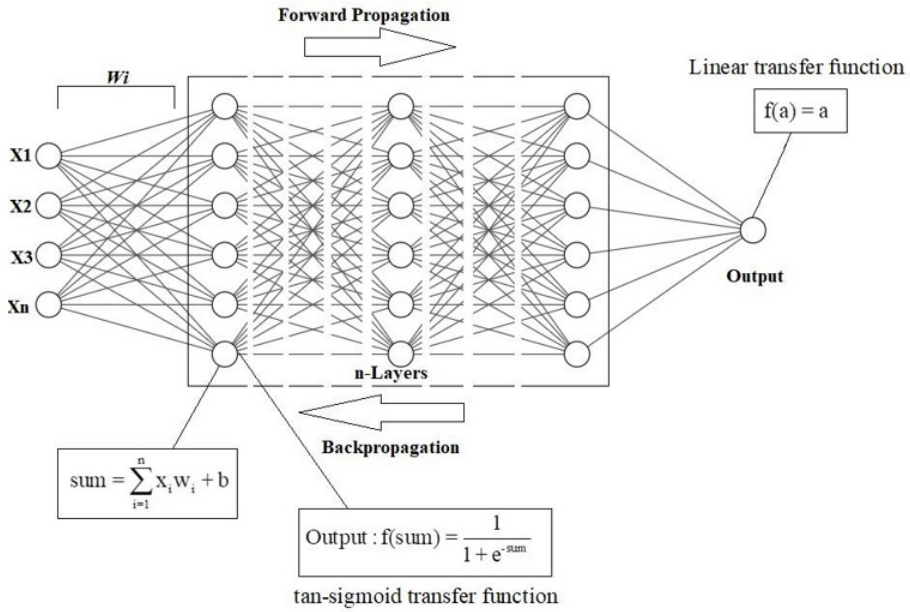


Figure 1: Feed Forward Backpropagation – ANN

2.2 Evaluation metrics for ANN models

The performance of ANN models was evaluated using three parameters: root mean square error (RMSE), coefficient of determination (R2), and mean absolute error (MAE). The R2 statistic is utilised to assess the strength of the correlations between the performance of the models and the historical data. On the other hand, the RMSE metric is employed to measure the average divergence between the predicted values of the models and the

actual values. RMSE measures the extent to which the accuracy of the models can properly predict the target value. The MAE is a metric used to quantify the average difference between the predicted and actual values in a dataset, regardless of their direction. Model architecture is deemed valid when the estimated R2 value approaches 1 and the RMSE and MAE values approach 0. Equations (4), (5), and (6) represent the calculation of the RMSE, R2, and MAE as follows:

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(p_i^s - p_i^h\right)^2} \quad \ldots\ldots(4)$$

$$R^2 = 1 - \frac{\sum_{i=1}^{N}\left(p_i^s - p_i^{ave}\right)^2}{\sum_{i=1}^{N}\left(p_i^h - p_i^{ave}\right)^2} \quad \ldots\ldots(5)$$

$$MAE = \frac{1}{N}\sum_{i=1}^{N}\left|p_i^s - p_i^h\right| \quad \ldots\ldots(6)$$

The variable and represent the model results and desired historical dataset, respectively. On the other hand, and present the average model result and historical dataset, respectively and represents the total quantity of datasets.

3.0 MATERIAL AND METHODS

3.1 Input and Output Datasets

The ANN model was constructed using the datasets specified in Table 1(a) to (c). The study utilised monthly diesel prices from January 2009 to March 2019, spanning a total of 123 months. The data was collected from the headquarters of three selected regions: monthly diesel price in Mpanda Municipal in the Katavi region (MDPK in TZS/Litre), monthly diesel price in Songea Municipal in the Ruvuma region (MDPS in TZS/Litre), and monthly diesel price in Mbeya City in the Mbeya region (MDPM in TZS/Litre). These datasets were the diesel monthly cap prices published by the Energy and Water Utilities Regulatory Authority (EWURA), a government institution mandated for economic and technical regulation of petroleum, natural gas, electricity, and water resources on the Tanzanian mainland.

Also, among the input datasets, such as the Tanzanian current exchange rate (TZSER in TZS/USD), world gold market price (WGMP in USD/ounce), Europe Brent spot price (EBSP in USD/bbl) and West Texas Intermediate Crude Oil Spot Price (WTIP in USD/bbl) were downloaded from the online through *https://prosperitydata360.worldbank.org/en/indicator/IMF+WEO+PCPIE, https://www.gold.org/goldhub/data/gold-pricesa and https://fred.stlouisfed.org/series/WCOILWTICO* links, respectively on the 20th of May 2024. The distances from Dar es Salaam port to the three selected regions were collected from

the Tanzania National Roads Agency (TANROADS). These include: distance from Dar es Salaam to Mbeya Municipal in the Mbeya region (DDM in km), distance from Dar es Salaam to Songea Municipal Council in the Ruvuma region (DDS in km), and distance from Dar es Salaam to Mpanda Municiap Council in the Katavi region (DDK in km). We performed 6 multiplications of dataset regularisation in order to mitigate overfitting problems, resulting in a total of 1476 datasets.

Table A: *Input and Output Datasets for the ANN Model for Mbeya City, Mbeya Region*

Category	Parameters	Symbol	Data Sets	After regularization	SI Unit
Inputs	World Gold Market price	WGMP	123	738	USD/Ounce
	Tanzania current exchange rate	TZSER	123	738	TZS/USD
	Europe Brent spot price	EBSP	123	738	USD/bbl
	West Texas Intermediate Price	WTIP	123	738	USD/bbl
	Distances from Dar to Mbeya	DDM	123	738	km
Out put	Monthly Diesel Price Mbeya	MDPM	123	738	TZS/Litre

(a)

Table B: *Input and Output Datasets for the ANN Model for Songea Municipal, Ruvuma Region*

Category	Parameters	Symbol	Data Sets	After regularization	SI Unit
Inputs	World Gold Market price	WGMP	123	738	USD/Ounce
	Tanzania current exchange rate	TZSER	123	738	TZS/USD
	Europe Brent spot price	EBSP	123	738	USD/bbl
	West Texas Intermediate Price	WTIP	123	738	USD/bbl
	Distance from Dar to Songea	DDS	123	738	km
Out put	Monthly Diesel Price Songea	MDPS	123	738	TZS/Litre

(b)

Table C: *Input and Output Datasets for the ANN Model for Mpanda Municipal, Katavi Region*

Category	Parameters	Symbol	Data Sets	After regularization	SI Unit
Inputs	World Gold Market price	WGMP	123	738	USD/Ounce
	Tanzania current exchange rate	TZSER	123	738	TZS/USD
	Europe Brent spot price	EBSP	123	738	USD/bbl
	West Texas Intermediate Price	WTIP	123	738	USD/bbl
	Distance from Dar to Katavi	DDK	123	738	km
Out put	Monthly Diesel Price Katavi	MDPK	123	738	TZS/Litre

(c)

3.2 Training of the ANN Models

The goal of training ANN models was to determine the best training parameters, such as the number of hidden layers, number of neurons, and transfer function. The aim was to generate model outputs that closely matched the actual target values, monthly diesel cap prices recorded at the headquarters of the three selected regions. During the training process, the ANN models for the selected three regions were equitably handled by dividing the data into three proportions: testing, training, and validation. The network's weights in the suggested models were adjusted using a training dataset, and the performance of the models was evaluated using a testing dataset. The validation subset was utilised to assess the suggested models' capacity for generalisation.

Currently, there are no established scientific standards for determining the appropriate amounts of data needed for training, testing, and validation. For example, a study conducted by Saritas *et al.* (2019), recommended dividing the data in the following manner: 65% for training, 10% for validation, and 25% for testing. Additionally, Trivedi *et al.* (2015) proposed dividing the data sample into three segments: 40% for training, 40% for testing, and 20% for validation. In contrast, Maxwell *et al.* (2018) allocated 25% of the data for training purposes and reserved 75% for validation.

The reviewed literature demonstrates that the datasets are divided into training, testing, and validation sets in a random manner. Nevertheless, it is feasible to derive general inferences by analysing the findings through statistical regression. Therefore, in the current study, the ANN models were trained using a trial-and-error approach, with a maximum of 36 trials at a fixed 1000 number of epochs. The data sets were portioned as follows: 10% of the data samples were used for testing, 10% were used for validation, and the remaining 80% were used for training, as depicted in Table 2. The modelling and training of the ANN models were conducted using coding developed by researchers in the MATLAB

R2021a software. The error gradients were assessed in each epoch. Subsequently, the models' performances were assessed by adjusting the number of hidden layers, neurons, and sample data set for training, validation, and testing. All training process were carried out using a ThinkPad Lenovo personal computer with a 2.71 GHz Core(TM) i7-6820HQ processor and 32 GB installed random access memory.

Table 2: *Training Parameters Sets for ANN Models*

Category	Total	Training [80%]	Testing [10%]	Validation [10%]
Input data sets	738	590	74	74
Epochs			1000	
Number of Trials			36	

3.3 Choosing the Architecture for ANN Models

This refers to the procedure of determining the optimal number of hidden layers, neurons, and input parameters in the ANN models by utilising the validation, training, and testing subsets. The technique assesses the efficacy of models by employing proposed statistical parameters, namely R2, RMSE, and MAE, to compare and differentiate the accuracy of the models' estimations. The estimation performance outcomes of the suggested ANN models are greatly influenced by several aspects, such as the number of hidden layers, neurons, and input parameters. Hence, in the current investigation, the structures of the ANN models were altered by manipulating the quantities of neurons and hidden layers.

Ultimately, the model designs were chosen according to the evaluation outcomes of the validation and training datasets. In order to reduce over-fitting, it is crucial to minimise the number of parameters when determining the number of hidden layers and neurons in a given architecture. The reason for this is that overfitted models are incapable of effectively predicting outcomes as they only capture a fraction of the residual variability. Therefore, the number of hidden layers and neurons were reduced in order to decrease the possibility of overfitting. In order to determine the required model architectures, numerous experiments were performed on both the validation and training datasets.

The study investigated ANN models with several configurations, including different numbers of hidden layers, ranging from one to two, and varied numbers of neurons, from 2 to 12, with increments of 2 neurons. Fig. 2 depicts the arrangement of the ANN model architectures. In order to ensure reliable and accurate outcomes, and to avoid any erroneous associations caused by arbitrary biases and weight allocations, the setdemorandstream (491218382) codes were incorporated into every topology. The outputs of the ANN models were compared to the historical data sets, and the conclusions of the models were then evaluated. The ANN model generated the simulated diesel monthly price for

Mbeya City was termed SDPM in TZS/Litre, for Songea Municipal as SDPS in TZS/Litre, and for Mpanda Municipal as SDPK in TZS/Litre. The R2, RMSE, and MAE matrices were calculated by comparing the historical data sets with the outputs of ANN models, SDPM, SDPS, and SDPK. The architectures of ANN models are considered valid when the calculated R2 values approach 1, and the RMSE and MAE values approach 0.

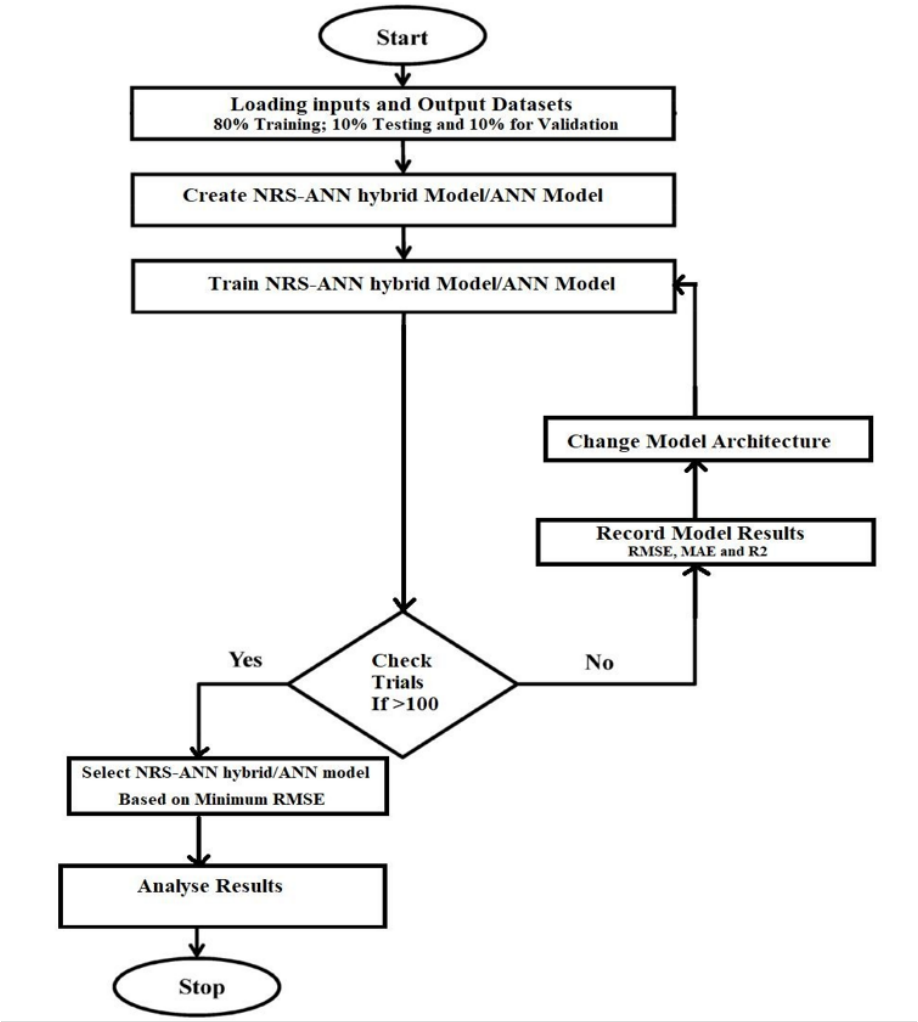


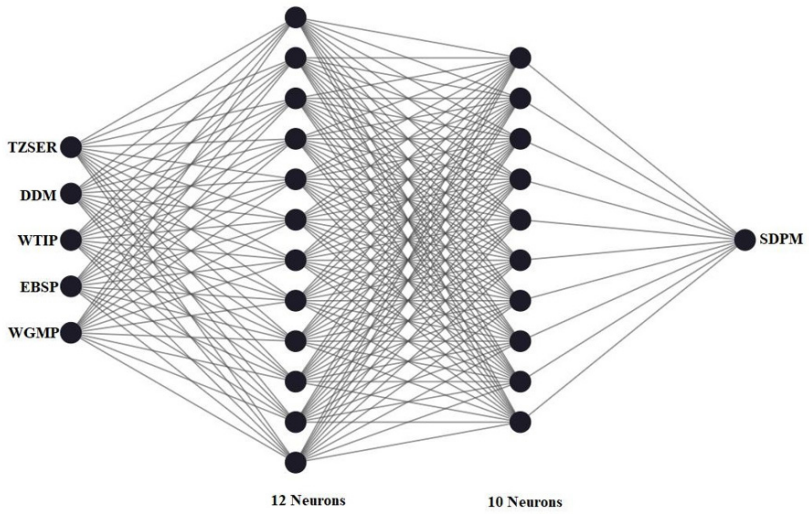
Figure 2: Formulation of ANN Model Architectures From 1st to 36th Trials

The analysis of the model results revealed that the Mbeya City ANN model outperformed on the 35th trial, Songea Municipal's ANN model excelled on the 29th trial, and Mpanda Municipal's ANN model achieved its peak performance on the 34th trial. The ANN model for Mbeya City had a network structure with twelve neurons in the first hidden layer and ten neurons in the second hidden layer. The ANN model for Songea Municipal had a network structure consisting of ten neurons in the first hidden layer and ten neurons in the second hidden layer.

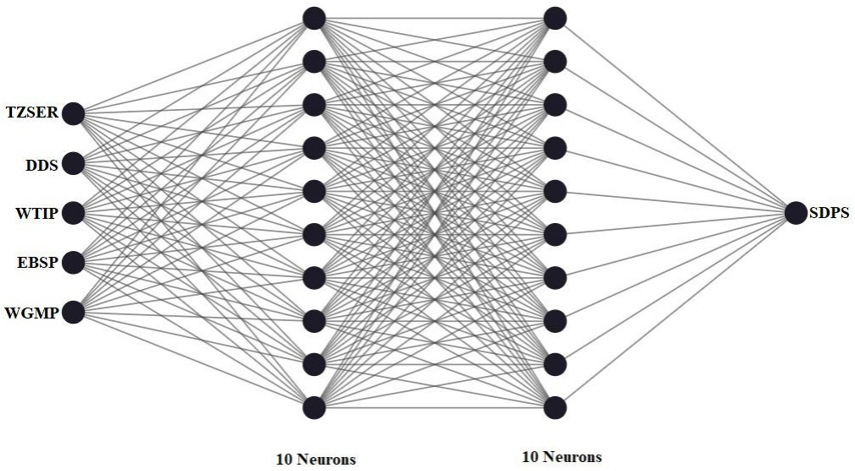
The ANN model for Mpanda Municipal had a network structure with twelve neurons in

the first hidden layer and eight neurons in the second hidden layer. Therefore, the study selected the 5-12-10-1 ANN model architecture for Mbeya City, the 5-10-10-1 ANN model architecture for Songea Municipal, and the 5-12-8-1 ANN model architecture for Mpanda Municipal to estimate diesel prices in the headquarters of the selected regions.

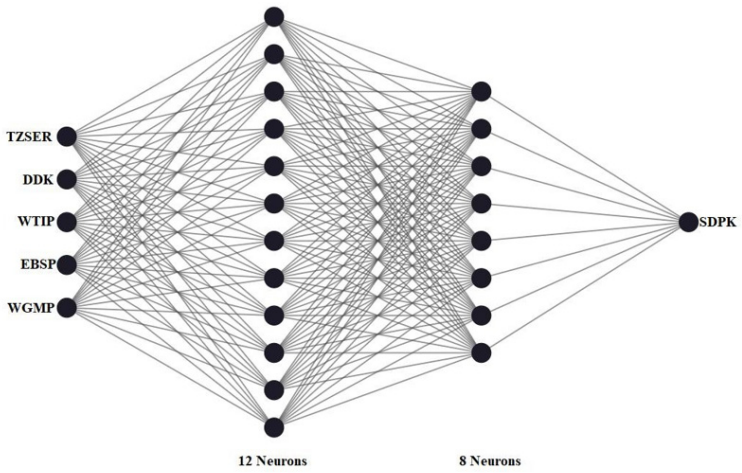
Figure 3 (a), (b), and (c) depict the configurations for the selected ANN models for Mbecya City, Songea Municipal, and Mpanda Municipal, respectively. Tables 3 (a), (b), and (c) display the MAE, RMSE, and R2 values. These values demonstrate the degree of similarity between the outputs of the selected model designs and the values observed in the testing, training, and validation sets.



(a) A 5-12-10-1 Selected ANN model Architecture for Mbeya City



(b) A 5-10-10-1 Selected ANN model Architecture for Songea Municipal



(c) A 5-12-8-1 Selected ANN model Architecture for Mpanda Municipal

Key: Figure 3 (a) (b) and (c) Optimal ANN models for the three headquarter of selected regions

Trials	Architecture	MAE			RMSE			R^2		
		Test	Train	Val	Test	Train	Val	Test	Train	Val
1	5-2-2-1	2.03E+02	2.01E+02	2.22E+02	2.40E+02	2.34E+02	2.55E+02	2.80E-02	4.36E-02	1.49E-02
2	5-2-4-1	6.85E+01	7.82E+01	7.52E+01	8.92E+01	9.57E+01	9.32E+01	8.69E-01	8.05E-01	8.57E-01
3	5-2-6-1	6.20E+01	6.69E+01	5.91E+01	8.23E+01	9.32E+01	8.04E+01	8.87E-01	8.52E-01	8.83E-01
4	5-2-8-1	1.01E+02	9.03E+01	1.17E+02	1.54E+02	1.32E+02	1.77E+02	5.99E-01	7.18E-01	4.61E-01
5	5-2-10-1	7.57E+01	6.95E+01	7.12E+01	1.02E+02	9.86E+01	9.54E+01	8.28E-01	8.40E-01	8.21E-01
6	5-2-12-1	5.29E+01	5.77E+01	4.91E+01	6.79E+01	7.07E+01	6.42E+01	9.22E-01	9.29E-01	9.16E-01
7	5-4-2-1	4.28E+01	4.63E+01	4.76E+01	5.53E+01	5.92E+01	6.07E+01	9.49E-01	9.40E-01	9.34E-01
8	5-4-4-1	7.99E+01	6.82E+01	8.52E+01	1.05E+02	8.87E+01	1.02E+02	8.12E-01	8.71E-01	8.19E-01
9	5-4-6-1	3.75E+01	3.74E+01	4.00E+01	4.97E+01	5.07E+01	5.76E+01	9.59E-01	9.60E-01	9.36E-01
10	5-4-8-1	2.46E+01	2.63E+01	2.37E+01	3.39E+01	3.33E+01	3.10E+01	9.80E-01	9.84E-01	9.85E-01
11	5-4-10-1	3.81E+01	4.31E+01	3.86E+01	5.15E+01	6.18E+01	5.05E+01	9.56E-01	9.25E-01	9.57E-01
12	5-4-12-1	1.39E+01	1.50E+01	1.52E+01	2.31E+01	2.60E+01	2.38E+01	9.91E-01	9.87E-01	9.90E-01
13	5-6-2-1	3.45E+01	4.08E+01	3.27E+01	4.54E+01	5.21E+01	4.40E+01	9.66E-01	9.55E-01	9.62E-01
14	5-6-4-1	3.27E+01	2.96E+01	4.26E+01	4.38E+01	4.39E+01	6.02E+01	9.67E-01	9.74E-01	9.38E-01
15	5-6-6-1	2.98E+01	2.99E+01	3.29E+01	3.88E+01	3.61E+01	4.38E+01	9.75E-01	9.75E-01	9.68E-01
16	5-6-8-1	3.19E+01	3.07E+01	2.58E+01	4.18E+01	4.19E+01	3.35E+01	9.71E-01	9.70E-01	9.79E-01
17	5-6-10-1	1.79E+01	2.01E+01	1.94E+01	2.65E+01	2.77E+01	2.68E+01	9.88E-01	9.86E-01	9.87E-01
18	5-6-12-1	4.24E+00	4.61E+00	4.72E+00	7.61E+00	8.00E+00	8.07E+00	9.99E-01	9.99E-01	9.99E-01
19	5-8-2-1	1.20E+02	1.21E+02	9.44E+01	1.67E+02	1.74E+02	1.37E+02	5.30E-01	5.52E-01	6.15E-01
20	5-8-4-1	3.06E+01	3.85E+01	3.40E+01	4.43E+01	5.43E+01	4.34E+01	9.67E-01	9.47E-01	9.72E-01
21	5-8-6-1	1.95E+01	2.12E+01	2.02E+01	2.77E+01	3.19E+01	2.81E+01	9.87E-01	9.83E-01	9.85E-01
22	5-8-8-1	6.10E-01	6.75E-01	9.73E-01	1.20E+00	1.18E+00	1.91E+00	1.00E+00	1.00E+00	1.00E+00
23	5-8-10-1	3.80E+00	4.34E+00	5.38E+00	6.87E+00	7.60E+00	9.68E+00	9.99E-01	9.99E-01	9.99E-01
24	5-8-12-1	1.86E-12	2.16E-12	2.17E-12	2.57E-12	3.11E-12	3.08E-12	1.00E+00	1.00E+00	1.00E+00
25	5-10-2-1	1.88E+02	1.73E+02	2.15E+02	2.34E+02	2.24E+02	2.62E+02	5.86E-02	4.93E-02	3.96E-02
26	5-10-4-1	1.23E+01	1.31E+01	1.39E+01	1.91E+01	1.99E+01	2.10E+01	9.94E-01	9.94E-01	9.91E-01
27	5-10-6-1	1.56E+00	3.14E+00	1.57E+00	3.95E+00	6.99E+00	4.32E+00	1.00E+00	9.99E-01	1.00E+00
28	5-10-8-1	2.20E-12	1.76E-12	2.22E-12	2.94E-12	2.31E-12	2.90E-12	1.00E+00	1.00E+00	1.00E+00
29	5-10-10-1	1.86E-12	1.92E-12	1.88E-12	2.42E-12	2.49E-12	2.49E-12	1.00E+00	1.00E+00	1.00E+00
30	5-10-12-1	9.72E-11	1.08E-10	1.27E-10	2.48E-10	2.69E-10	2.65E-10	1.00E+00	1.00E+00	1.00E+00
31	5-12-2-1	4.73E+01	5.39E+01	6.20E+01	7.55E+01	8.69E+01	9.27E+01	9.04E-01	8.65E-01	8.57E-01
32	5-12-4-1	5.69E+00	7.31E+00	4.84E+00	1.32E+01	1.70E+01	1.10E+01	9.97E-01	9.95E-01	9.98E-01
33	5-12-6-1	2.55E-02	3.85E-02	2.87E-02	6.44E-02	9.70E-02	7.45E-02	1.00E+00	1.00E+00	1.00E+00
34	5-12-8-1	1.81E-12	2.06E-12	1.99E-12	2.37E-12	2.69E-12	2.59E-12	1.00E+00	1.00E+00	1.00E+00
35	**5-12-10-1**	**1.80E-12**	**1.31E-12**	**1.88E-12**	**2.37E-12**	**1.69E-12**	**2.49E-12**	**1.00E+00**	**1.00E+00**	**1.00E+00**
36	5-12-12-1	5.43E-11	7.10E-11	8.89E-11	1.60E-10	2.23E-10	2.55E-10	1.00E+00	1.00E+00	1.00E+00

Figure 3 (a): Statistical Parameters for Mbeya City ANN Model Architectures

Trials	Architecture	MAE			RMSE			R^2		
		Test	Train	Val	Test	Train	Val	Test	Train	Val
1	5-2-2-1	1.79E+02	1.45E+02	1.94E+02	2.31E+02	2.01E+02	2.43E+02	1.02E-01	2.35E-01	8.79E-02
2	5-2-4-1	7.08E+01	7.86E+01	7.73E+01	9.02E+01	9.58E+01	9.45E+01	8.66E-01	8.08E-01	8.55E-01
3	5-2-6-1	7.65E+01	8.18E+01	7.07E+01	1.03E+02	1.17E+02	9.77E+01	8.23E-01	7.63E-01	8.27E-01
4	5-2-8-1	6.96E+01	6.06E+01	7.79E+01	8.87E+01	7.47E+01	1.00E+02	8.67E-01	9.09E-01	8.29E-01
5	5-2-10-1	5.29E+01	5.34E+01	6.20E+01	6.98E+01	7.66E+01	8.07E+01	9.19E-01	9.04E-01	8.73E-01
6	5-2-12-1	4.01E+01	4.22E+01	3.74E+01	5.20E+01	5.63E+01	5.03E+01	9.54E-01	9.55E-01	9.48E-01
7	5-4-2-1	4.80E+01	5.17E+01	5.26E+01	6.29E+01	7.02E+01	6.74E+01	9.34E-01	9.14E-01	9.18E-01
8	5-4-4-1	4.97E+01	5.32E+01	5.26E+01	6.62E+01	7.42E+01	6.96E+01	9.26E-01	9.10E-01	9.16E-01
9	5-4-6-1	5.30E+01	4.88E+01	5.30E+01	7.33E+01	6.27E+01	7.05E+01	9.10E-01	9.38E-01	9.04E-01
10	5-4-8-1	3.62E+01	3.97E+01	4.01E+01	4.97E+01	5.27E+01	5.36E+01	9.57E-01	9.61E-01	9.56E-01
11	5-4-10-1	2.10E+01	2.57E+01	1.93E+01	3.38E+01	4.17E+01	3.16E+01	9.81E-01	9.67E-01	9.83E-01
12	5-4-12-1	1.48E+01	1.58E+01	1.68E+01	2.33E+01	2.75E+01	2.41E+01	9.91E-01	9.85E-01	9.90E-01
13	5-6-2-1	9.95E+01	1.13E+02	1.09E+02	1.28E+02	1.43E+02	1.37E+02	7.29E-01	6.64E-01	6.36E-01
14	5-6-4-1	2.69E+01	2.69E+01	3.01E+01	3.85E+01	3.79E+01	4.21E+01	9.74E-01	9.81E-01	9.70E-01
15	5-6-6-1	1.67E+01	1.93E+01	2.01E+01	2.38E+01	2.55E+01	2.75E+01	9.91E-01	9.88E-01	9.87E-01
16	5-6-8-1	4.81E+01	4.97E+01	4.33E+01	6.03E+01	6.09E+01	5.31E+01	9.40E-01	9.36E-01	9.47E-01
17	5-6-10-1	1.04E+01	1.36E+01	1.05E+01	1.76E+01	2.32E+01	1.50E+01	9.95E-01	9.90E-01	9.96E-01
18	5-6-12-1	1.27E+00	1.54E+00	1.07E+00	2.52E+00	2.90E+00	1.96E+00	1.00E+00	1.00E+00	1.00E+00
19	5-8-2-1	1.76E+02	1.87E+02	1.42E+02	2.32E+02	2.39E+02	1.84E+02	1.01E-01	1.59E-01	2.98E-01
20	5-8-4-1	1.60E+01	1.94E+01	1.79E+01	2.55E+01	2.75E+01	2.36E+01	9.89E-01	9.86E-01	9.92E-01
21	5-8-6-1	2.33E+01	2.94E+01	2.28E+01	3.02E+01	3.70E+01	2.88E+01	9.85E-01	9.77E-01	9.85E-01
22	5-8-8-1	1.07E+00	1.26E+00	9.85E-01	2.68E+00	3.15E+00	2.72E+00	1.00E+00	1.00E+00	1.00E+00
23	5-8-10-1	6.56E-02	2.78E-02	7.91E-02	2.92E-01	5.74E-02	3.55E-01	1.00E+00	1.00E+00	1.00E+00
24	5-8-12-1	3.13E+00	4.11E+00	4.15E+00	6.41E+00	8.53E+00	8.67E+00	9.99E-01	9.99E-01	9.99E-01
25	5-10-2-1	1.80E+02	1.70E+02	2.25E+02	2.17E+02	2.04E+02	2.69E+02	1.92E-01	2.03E-01	-5.89E-03
26	5-10-4-1	8.26E+00	9.33E+00	8.60E+00	1.29E+01	1.46E+01	1.28E+01	9.97E-01	9.97E-01	9.97E-01
27	5-10-6-1	1.52E+00	1.96E+00	1.90E+00	3.07E+00	3.50E+00	3.93E+00	1.00E+00	1.00E+00	1.00E+00
28	5-10-8-1	5.62E+00	7.18E+00	6.94E+00	1.06E+01	1.40E+01	1.25E+01	9.98E-01	9.96E-01	9.98E-01
29	**5-10-10-1**	**9.70E-13**	**1.08E-12**	**1.12E-12**	**1.23E-12**	**1.31E-12**	**1.40E-12**	**1.00E+00**	**1.00E+00**	**1.00E+00**
30	5-10-12-1	1.52E-12	1.61E-12	2.12E-12	2.72E-12	2.17E-12	3.59E-12	1.00E+00	1.00E+00	1.00E+00
31	5-12-2-1	3.75E+01	4.29E+01	3.21E+01	5.19E+01	5.28E+01	4.33E+01	9.55E-01	9.50E-01	9.69E-01
32	5-12-4-1	2.12E+00	1.86E+00	1.86E+00	3.96E+00	3.50E+00	2.69E+00	1.00E+00	1.00E+00	1.00E+00
33	5-12-6-1	1.24E-10	1.75E-10	1.31E-10	2.62E-10	3.48E-10	2.23E-10	1.00E+00	1.00E+00	1.00E+00
34	5-12-8-1	9.46E-11	2.40E-10	1.70E-10	2.66E-10	7.43E-10	4.82E-10	1.00E+00	1.00E+00	1.00E+00
35	5-12-10-1	8.48E-11	8.25E-11	7.80E-11	2.31E-10	2.19E-10	1.92E-10	1.00E+00	1.00E+00	1.00E+00
36	5-12-12-1	1.69E-12	1.43E-12	1.55E-12	2.30E-12	2.17E-12	2.16E-12	1.00E+00	1.00E+00	1.00E+00

Figure 3 (b): *Statistical Parameters for Songea Municipal ANN Model Architectures*

Trials	Architecture	MAE			RMSE			R^2		
		Test	Train	Val	Test	Train	Val	Test	Train	Val
1	5-2-2-1	2.02E+02	2.01E+02	2.20E+02	2.40E+02	2.34E+02	2.53E+02	2.81E-02	4.23E-02	1.58E-02
2	5-2-4-1	6.94E+01	7.44E+01	7.26E+01	8.83E+01	8.77E+01	8.90E+01	8.71E-01	8.38E-01	8.70E-01
3	5-2-6-1	7.10E+01	7.47E+01	6.60E+01	9.95E+01	1.13E+02	9.67E+01	8.34E-01	7.80E-01	8.31E-01
4	5-2-8-1	6.78E+01	5.81E+01	7.59E+01	8.68E+01	7.24E+01	9.88E+01	8.72E-01	9.14E-01	8.31E-01
5	5-2-10-1	3.76E+01	3.42E+01	4.31E+01	5.10E+01	4.60E+01	6.00E+01	9.56E-01	9.65E-01	9.29E-01
6	5-2-12-1	5.15E+01	5.47E+01	5.13E+01	6.62E+01	6.92E+01	6.51E+01	9.26E-01	9.33E-01	9.12E-01
7	5-4-2-1	4.88E+01	5.22E+01	5.42E+01	6.41E+01	6.93E+01	6.87E+01	9.31E-01	9.17E-01	9.15E-01
8	5-4-4-1	4.55E+01	4.74E+01	5.19E+01	6.14E+01	6.06E+01	6.95E+01	9.36E-01	9.40E-01	9.16E-01
9	5-4-6-1	4.29E+01	4.65E+01	4.40E+01	6.11E+01	6.46E+01	6.44E+01	9.37E-01	9.34E-01	9.19E-01
10	5-4-8-1	1.82E+01	1.96E+01	2.14E+01	2.67E+01	2.62E+01	3.00E+01	9.87E-01	9.90E-01	9.86E-01
11	5-4-10-1	2.64E+01	2.89E+01	2.49E+01	4.06E+01	4.46E+01	3.86E+01	9.73E-01	9.61E-01	9.75E-01
12	5-4-12-1	1.00E+01	1.22E+01	1.36E+01	1.49E+01	1.88E+01	2.01E+01	9.96E-01	9.93E-01	9.93E-01
13	5-6-2-1	3.78E+01	3.16E+01	3.49E+01	5.20E+01	4.62E+01	5.03E+01	9.55E-01	9.65E-01	9.50E-01
14	5-6-4-1	2.31E+01	2.21E+01	2.60E+01	3.34E+01	3.13E+01	3.53E+01	9.80E-01	9.87E-01	9.79E-01
15	5-6-6-1	2.06E+01	2.18E+01	2.13E+01	2.76E+01	2.98E+01	2.85E+01	9.87E-01	9.83E-01	9.87E-01
16	5-6-8-1	3.29E+01	3.74E+01	3.11E+01	4.52E+01	5.11E+01	4.22E+01	9.66E-01	9.55E-01	9.67E-01
17	5-6-10-1	1.56E+01	1.99E+01	2.06E+01	2.31E+01	2.75E+01	2.99E+01	9.91E-01	9.86E-01	9.84E-01
18	5-6-12-1	1.51E+00	1.95E+00	1.47E+00	3.73E+00	4.70E+00	3.51E+00	1.00E+00	1.00E+00	1.00E+00
19	5-8-2-1	1.67E+02	1.73E+02	1.75E+02	2.07E+02	2.13E+02	2.16E+02	2.81E-01	3.23E-01	3.61E-02
20	5-8-4-1	2.08E+01	2.30E+01	2.33E+01	3.01E+01	3.28E+01	3.22E+01	9.84E-01	9.80E-01	9.85E-01
21	5-8-6-1	1.38E+01	1.79E+01	1.56E+01	2.05E+01	2.67E+01	2.13E+01	9.93E-01	9.88E-01	9.92E-01
22	5-8-8-1	1.31E+01	1.83E+01	1.29E+01	1.99E+01	2.68E+01	1.92E+01	9.93E-01	9.88E-01	9.94E-01
23	5-8-10-1	4.32E+00	4.33E+00	4.46E+00	8.16E+00	6.85E+00	7.50E+00	9.99E-01	9.99E-01	9.99E-01
24	5-8-12-1	8.75E-12	1.40E-11	9.98E-12	2.22E-11	3.28E-11	2.25E-11	1.00E+00	1.00E+00	1.00E+00
25	5-10-2-1	2.23E+01	3.02E+01	2.23E+01	3.76E+01	4.69E+01	3.77E+01	9.76E-01	9.58E-01	9.80E-01
26	5-10-4-1	1.29E+01	1.46E+01	1.29E+01	1.93E+01	2.12E+01	1.87E+01	9.94E-01	9.93E-01	9.93E-01
27	5-10-6-1	1.33E+01	1.65E+01	1.59E+01	2.10E+01	2.48E+01	2.39E+01	9.93E-01	9.88E-01	9.89E-01
28	5-10-8-1	2.38E+00	3.50E+00	2.77E+00	6.82E+00	1.08E+01	7.87E+00	9.99E-01	9.98E-01	9.99E-01
29	5-10-10-1	1.48E-12	1.73E-12	1.37E-12	1.95E-12	2.20E-12	1.73E-12	1.00E+00	1.00E+00	1.00E+00
30	5-10-12-1	3.51E-01	2.93E-01	4.42E-01	1.09E+00	1.20E+00	1.25E+00	1.00E+00	1.00E+00	1.00E+00
31	5-12-2-1	4.12E+01	4.12E+01	3.52E+01	5.73E+01	5.42E+01	4.40E+01	9.45E-01	9.47E-01	9.67E-01
32	5-12-4-1	2.00E+01	2.24E+01	1.92E+01	2.78E+01	3.10E+01	2.90E+01	9.87E-01	9.83E-01	9.87E-01
33	5-12-6-1	2.77E+00	3.96E+00	2.80E+00	6.66E+00	8.36E+00	4.65E+00	9.99E-01	9.99E-01	1.00E+00
34	**5-12-8-1**	**1.11E-12**	**1.23E-12**	**1.12E-12**	**1.51E-12**	**1.65E-12**	**1.60E-12**	**1.00E+00**	**1.00E+00**	**1.00E+00**
35	5-12-10-1	5.28E-12	6.28E-12	4.85E-12	1.18E-11	1.28E-11	9.12E-12	1.00E+00	1.00E+00	1.00E+00
36	5-12-12-1	4.61E+00	6.30E+00	3.83E+00	1.03E+01	1.34E+01	7.11E+00	9.98E-01	9.97E-01	9.99E-01

Figure 3 (c): Statistical Parameters for Mpanda Municipal ANN Model Architectures

4.0 RESULTS AND DISCUSSIONS

4.1 ANN models Inputs and Output datasets

The proposed ANN models utilised 123 historical datasets gathered from various sources. A suggested ANN model for Mbeya City utilised TZSER in TZS/USD, DDM in km, WTIP in USD/bbl, EBSP in USD/bbl, and WGMP in USD/ounce as inputs datasets. The model output presented the MDPM in TZS/Litre, the monthly diesel cap price as published by EWURA for the Mbeya City Council. The proposed ANN model for Songea Municipal used 123 historical datasets, including TZSER in TZS/USD, DDS in km, WTIP in USD/bbl, EBSP in USD/bbl, and WGMP in USD/ounce as input variables.

The model output represented the MDPS in TZS/Litre, the recorded monthly diesel cap price published by EWURA for Songea Municipal. The suggested ANN models for Mpanda Municipal used 123 historical datasets, including TZSER in TZS/USD, DDK in km, WTIP in USD/bbl, EBSP in USD/bbl, and WGMP in USD/ounce as input variables. The model

output presented the DMPK in TZS/Litre, which was the monthly diesel cap price for Mpanda Municipal, as published by EWURA. Table 4 shows the inputs and outputs of the data sets used to train the ANN models.

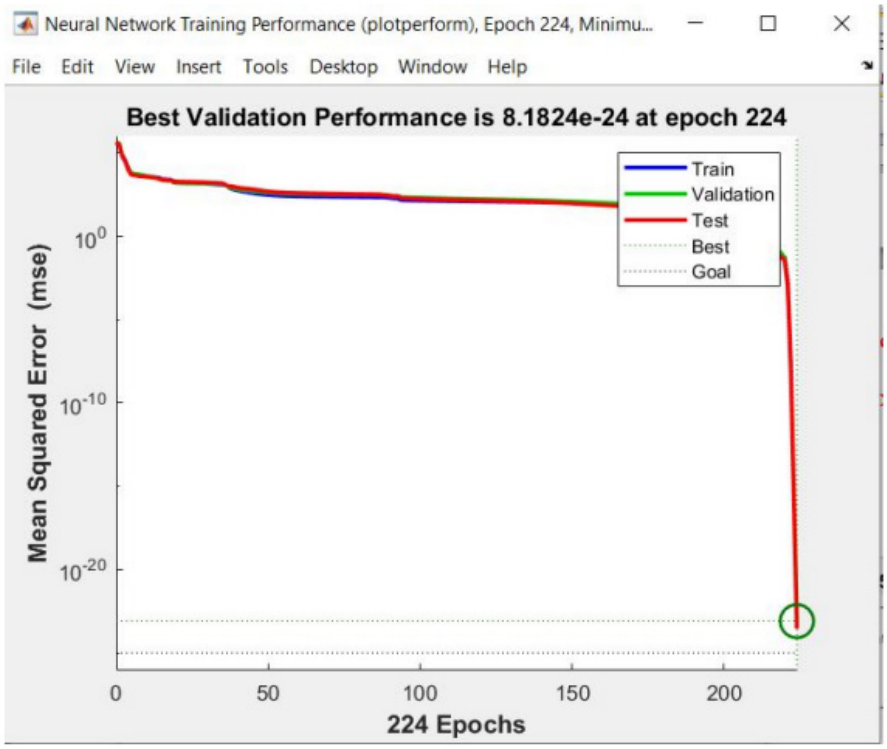
Table 4: *Inputs and Output Datasets Utilised for ANN Models*

Category	ANN Model for Mbey City			ANN Model for Songea Municipal			ANN Model for Mpanda Municipal			SI Unit
	Parameters	**Min**	**Max**	**Parameters**	**Min**	**Max**	**Parameters**	**Min**	**Max**	
Inputs	TZSER	1307	2343	TZSER	1307	2343	TZSER	1307	2343	TZS/USD
	DDM	822	822	DDS	947	947	DDK	1383	1383	km
	WTIP	30	110	WTIP	30	110	WTIP	30	110	USD/bbl
	EBSP	31	125	EBSP	31	125	EBSP	31	125	USD/bbl
	WGMP	858	1781	WGMP	858	1781	WGMP	858	1781	USD/ounce
Out put	MDPM	1260	2389	MDPS	1276	2411	MDPK	1306	2436	TZS/Litre

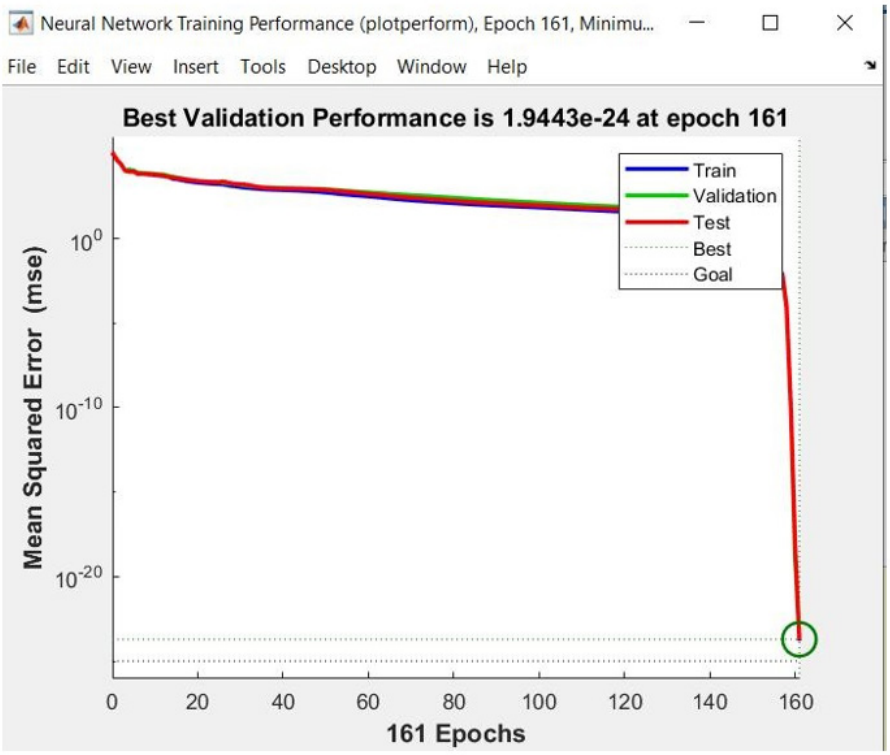
5.2 Assessing ANN Models Performance Prediction Capabilities

The efficacy of the trained ANN models in assessing the diesel prices in Mbeya City, Songea Municipal, and Mpanda Municipal was evaluated by computing the MAE, R2, and RMSE matrices based on the models' outputs, which were simulated diesel prices. In addition, numerous validation tests were conducted during the training of the ANN models to achieve optimal values for MAE, R2, and RMSE matrices, with the aim of determining when to terminate the training process. The validation checks were conducted by identifying the moment at which the models' performances in the validation phase ceased to decrease in subsequent iterations.

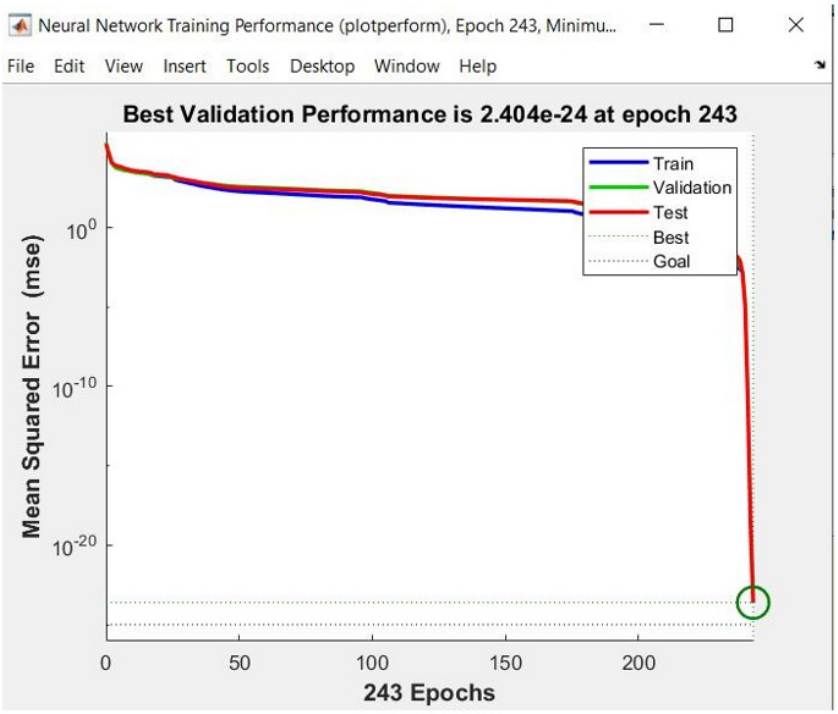
During training, at the 35th epoch, the ANN model for Mbeya City showed a significant enhancement in performance. This improvement is illustrated in Fig. 4 (a), where the RMSE in the validation dataset was measured at 2.49 x 10^{-12} values. In addition, as depicted in Fig. 4 (b), the Songea Municipal ANN model was effectively trained and demonstrated exceptional performance at the 29th epoch, achieving an RMSE of 1.40 x 10^{-12} values in the validation dataset. Similarly, in Fig. 4 (c), an ANN model for Mpanda Municipal was trained successfully. The model demonstrated outstanding performance at the 34th epoch, achieving a RMSE of 1.60 x 10^{-12} values in the validation dataset.



(a) ANN Model Performance for Mbeya City



(b) ANN Model Performance for Songea Municipal



(c) ANN Model Performance for Mpanda Municipal

Key: Figure 4 (a), (b) and (c) Depicts the Performance of the Suggested ANN Models for Mbeya City, Songea and Mpanda Municipals

The results are considered good because of the following reasons: First, the extremely low RMSE values of 2.49 x 10-12, 1.40 x 10-12, and 1.60 x 10-12 were achieved by the proposed ANN models for Mbeya City, Songea Municipal, and Mpanda Municipal, respectively, in the validation datasets. Secondly, the R2 and MAE matrices for the testing values of 1.0, 1.0, 1.0, and 1.88 x 10-12, 1.12 x 10-12, as shown in Table 5, demonstrate the highest and lowest values, respectively. Finally, we observed no significant overfitting during the training of ANN models in the 1st to 35th, 1st to 29th, and 1st to 34th iterations, respectively. Fig. 5 (a), (b), and (c) display the regression graphs and architecture that illustrate the relationship between the outputs of the ANN models and the training, validation, and test data sets for Mbeya City, Songea Municipal, and Mpanda Municipal, respectively.

The R2 values for the three suggested ANN models exceed 0.99999, as evidenced by the graphs. According to the results, it appears that the proposed ANN models' output replicates the historical monthly diesel cap prices published by EWURA for Mbeya City, Songea, and Mpanda Municipalities. Table 5 displays the evaluated outcomes of the chosen three ANN models for examining the monthly diesel prices in Mbeya City, Songea Municipal, and Mpanda Municipal. The results exhibit strong concordance with the historical monthly diesel ceiling prices given by EWURA for the proposed study area. The proposed ANN

model for Mbeya City achieved minimal RMSE values of 2.37 x 10-12 and 1.69 x 10-12 in the testing and training datasets, respectively. Similarly, the suggested ANN model for Songea Municipal achieved minimal RMSE values of 1.12 x 10-12 and 1.23 x 10-12, while the selected ANN model for Mpanda Municipal achieved minimal RMSE values of 1.51 x 10-12 and 1.65 x 10-12 in the testing and training datasets, respectively. The study shows that the proposed ANN models are valuable and reliable tools for assessing monthly diesel prices in Mbeya City, Songea Municipal, and Mpanda Municipal.

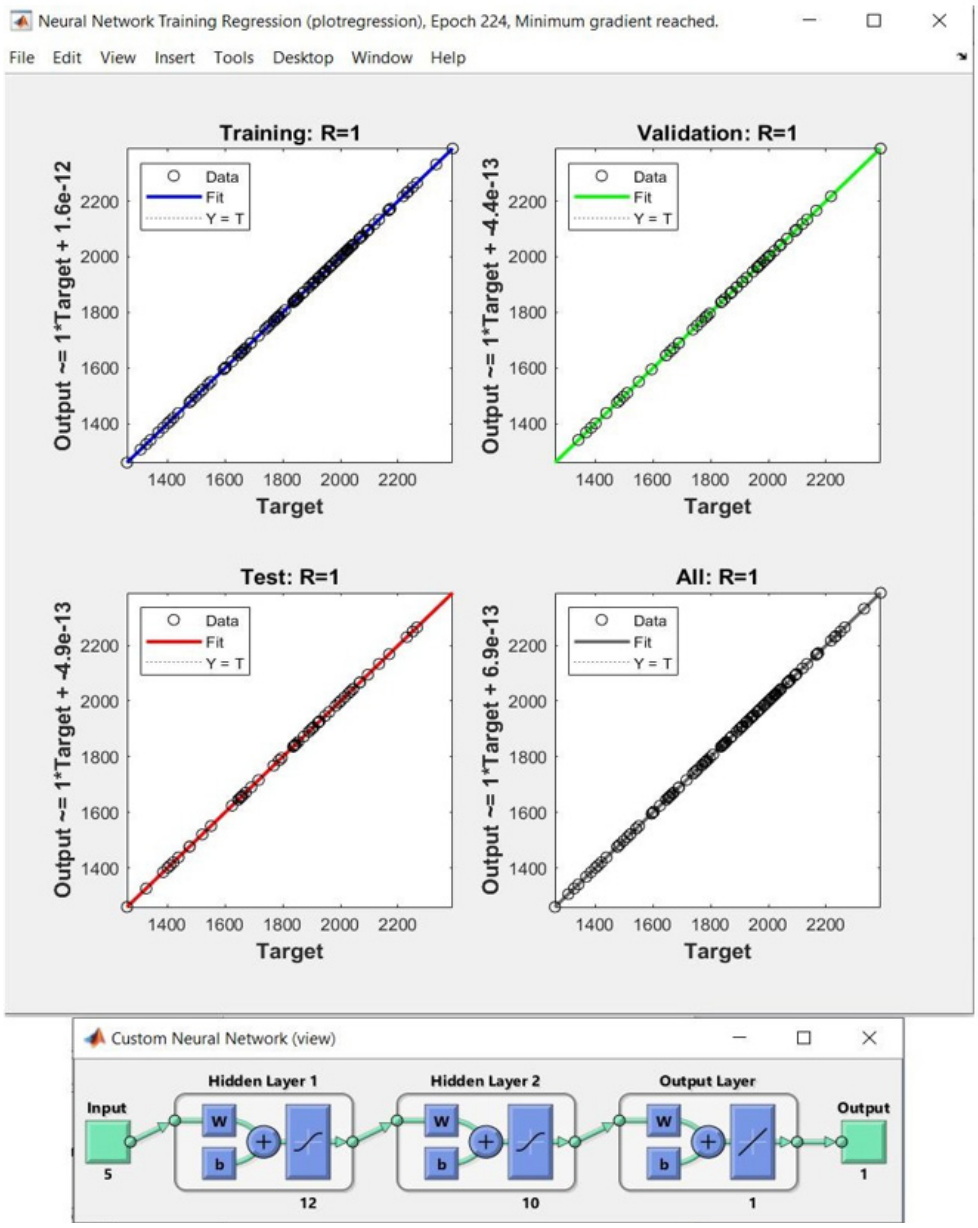


Figure 4 (a): Regression Graph and Architecture for ANN Model for Mbeya City

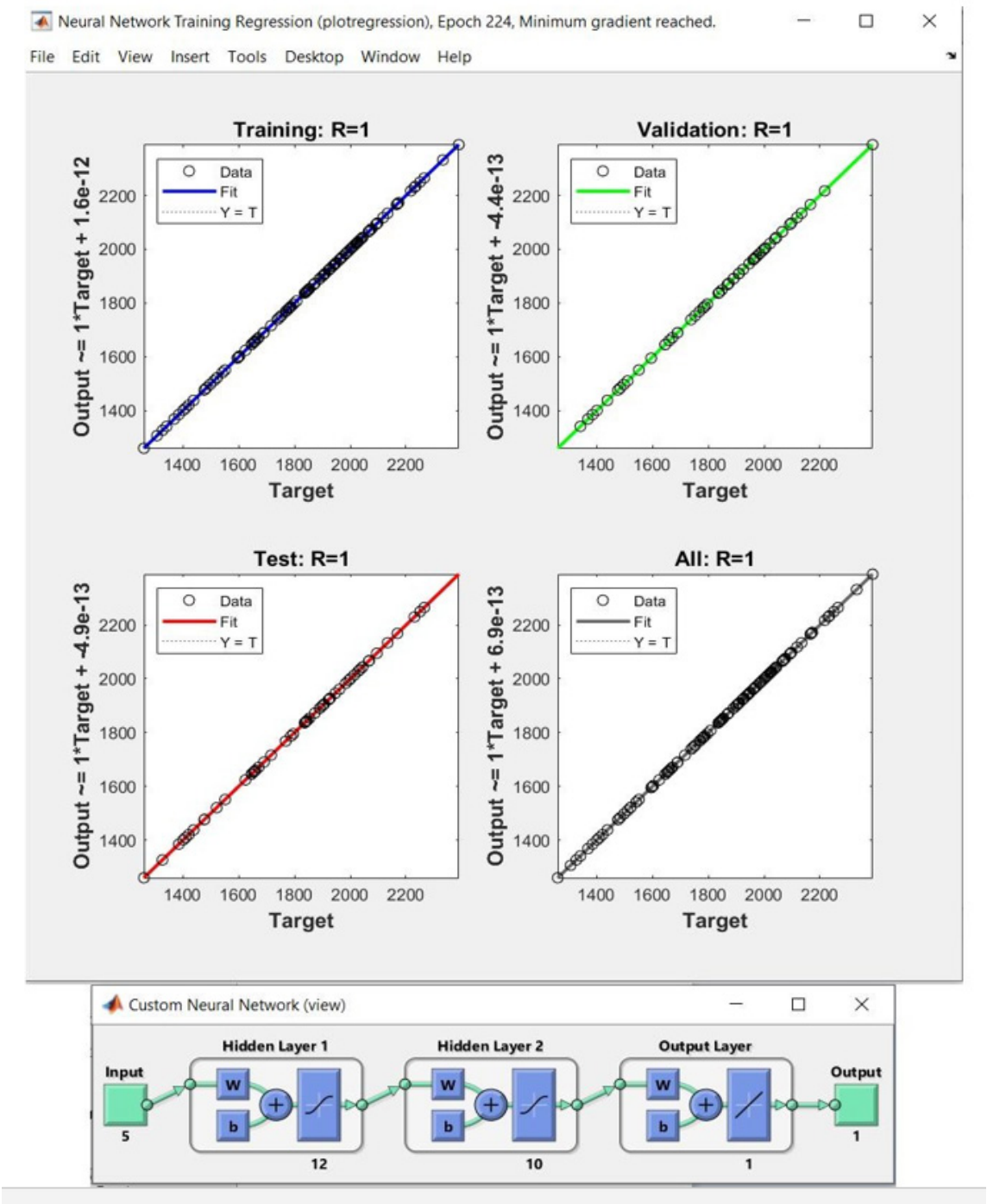


Figure 4 (b): Regression Graph and Architecture of ANN Model for Songea Municipal

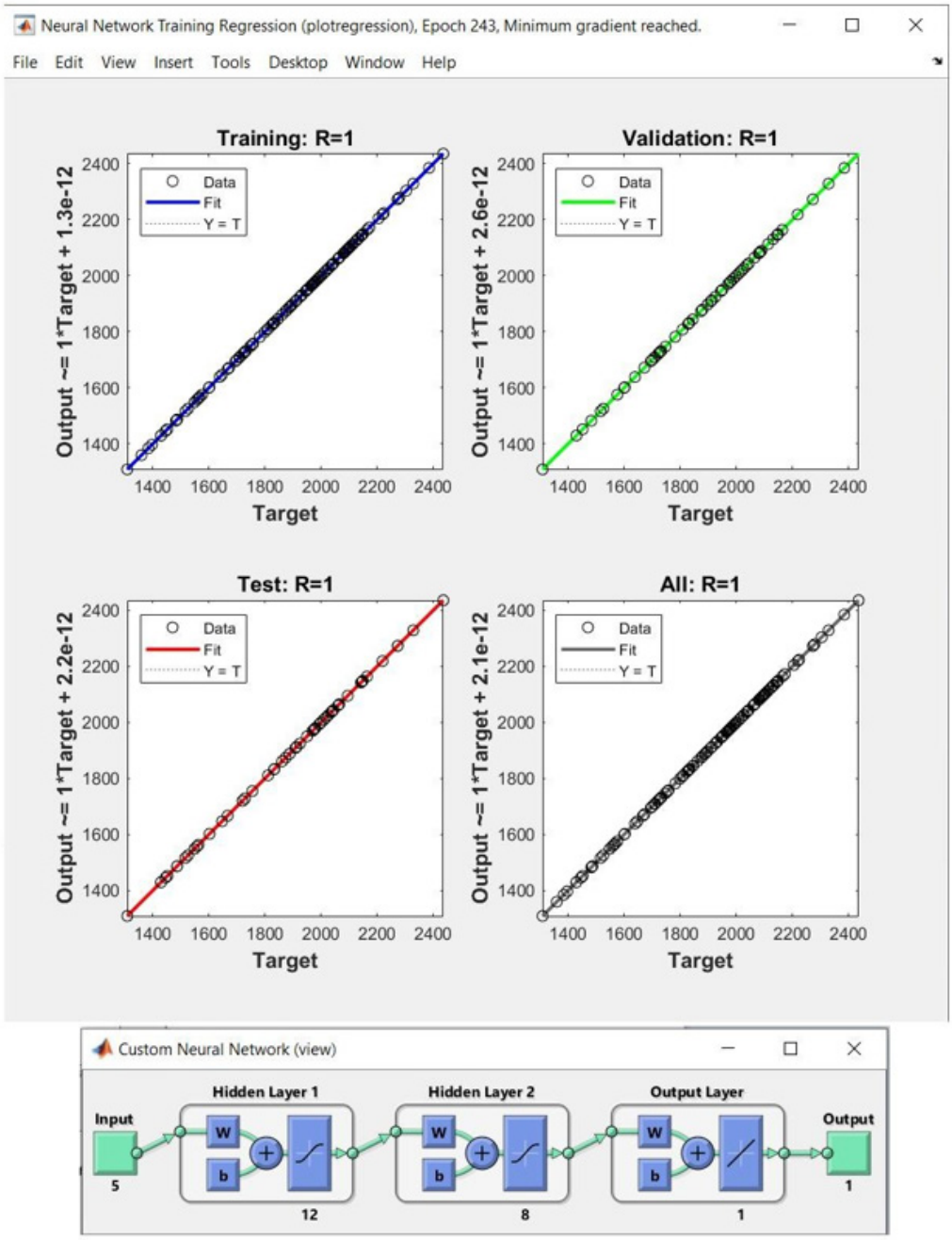


Figure 4 (c): Regression Graph and Architecture of ANN Model for Mpanda Municipal

Key: Figure 4 a, 4 b and 4 c - Regression Graph and Architecture for Proposed ANN Models

Table 5: *The Optimal Parameters of Selected ANN Models for Mbeya City, Songea and Mpanda Municipals*

Parame r	ANN Model for Mbeya City			ANN Model for Songea Municipal			ANN Model for Mpan Municipal		
	Testing	Training	Validation	Testing	Training	Validation	Testing	Training	Valid on
R^2	1.00000	1.000000	1.00000	1.00000	1.0000	1.00000	1.00000	1.00000	1.00000
RMSE	2.37E-12	1.69E-12	2.49E-12	1.23E-12	1.31E-12	1.40E-12	1.51E-12	1.65E-12	1.60E-12
MAE	1.80E-12	1.31E-12	1.88E-12	9.70E-13	1.08E-12	1.12E-12	1.11E-12	1.23E-12	1.12E-12

5.3 Performance Analysis of Selected ANN Models

The current study conducted an investigation of the performance of the proposed ANN models for the Mbeya City, Songea, and Mpanda municipalities. The study conducted a comparison between the outputs of the ANN models, namely SDPM, SDPS, and SDPK, and the recorded monthly diesel cap prices posted by EWURA for headquarter of the selected regions, namely MDPM, MDPS, and MDPK. Fig. 6 (a), (b), and (c) show comparisons using two different colours: blue represents the actual monthly diesel cap prices as reported by EWURA while red represents the simulated monthly diesel prices using ANN models for Mbeya City, Songea, and Mpanda Municipalities, respectively.

All y-axis and x-axis datasets are presented in TZS/Litre and month, respectively. There is a strong association between the SDPM, SDPS, SDPK and the MDPM, MDPS, MDPK, respectively. The results indicate that the predicted performance of the selected ANN models for Mbeya City, Songea Municipal, and Mpanda Municipal, SDPM, SDPS, SDPK, respectively, mimics the monthly diesel cap prices reported by EWURA for the study areas. Therefore, the study suggests that the proposed ANN models are resilient and important as predictive instruments for analysing monthly diesel prices in Mbeya City, Songea Municipal, and Mpanda Municipal.

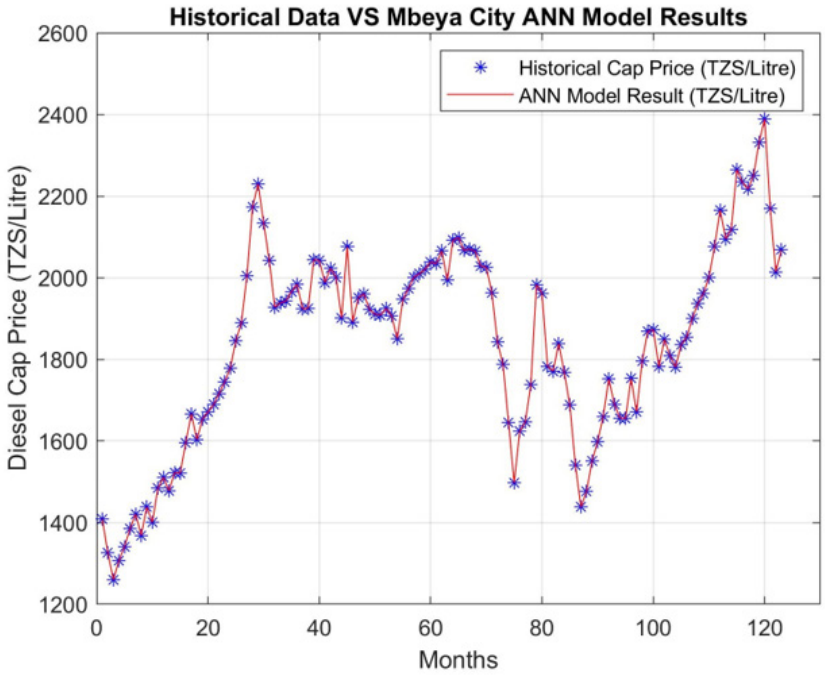


Figure 5 (a): Comparison of Mbeya City ANN model results against historical data

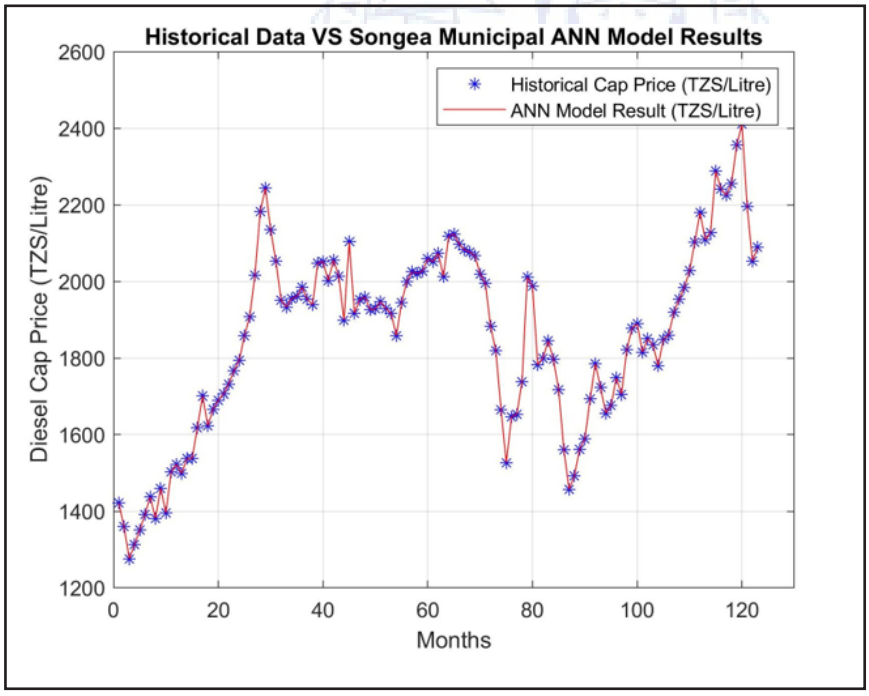


Figure 5 (b): Comparison of Songea Municipal ANN model results against historical data

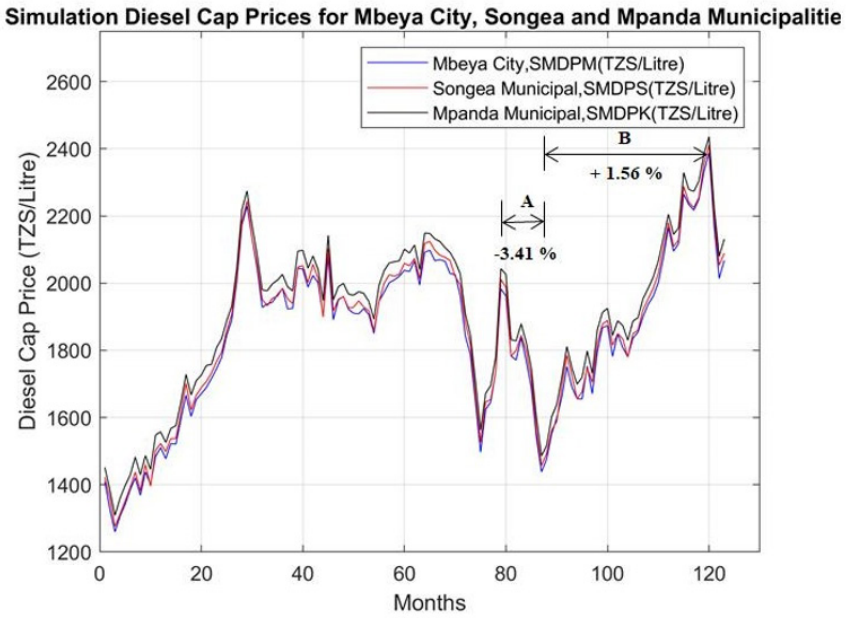
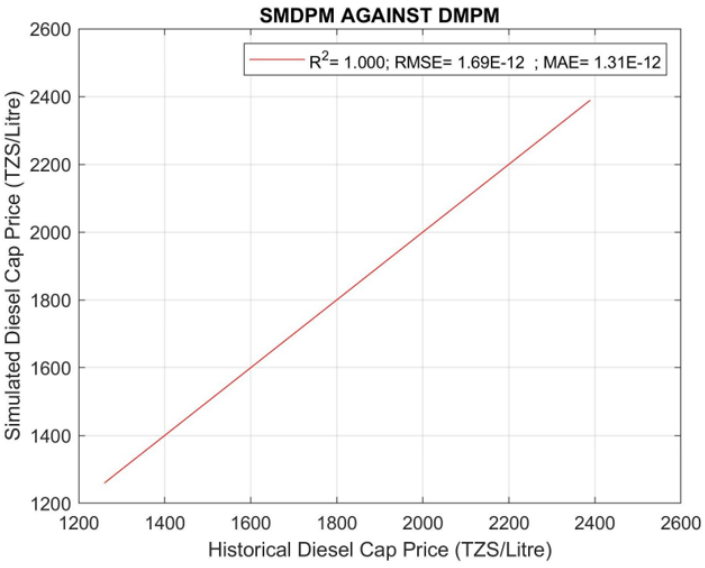


Figure 5 (c): Comparison of Mpanda Municipal ANN model results against historical data

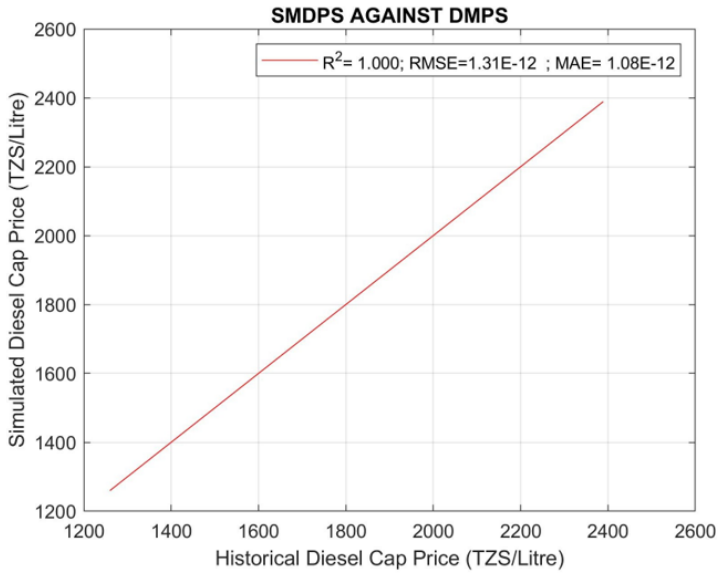
Key: Figure 5a, 5b and 5c - Historical diesel cap prices against ANN modes results

Additionally, Figure 7 (a), (b), and (c) provide regression plots and statistical measures, including R2 and MAE, that are employed to assess the effectiveness of the ANN models in forecasting diesel prices. The ANN model for Mbeya City, as shown in Fig. 7 (a), demonstrated R2 and MAE values of 1.0000 and 1.31 x 10-12, respectively. The ANN model for Songea Municipal, as shown in Fig. 7 (b), achieved outstanding prediction results. This was evident from the high values of R2 of 1.0000 and MAE of 1.08 x 10-12, indicating a remarkable level of performance. The ANN model for Mpanda Municipal, as shown in Fig. 7 (c), achieved outstanding prediction results. This is evident from the high R2 value of 1.0000 and the very low MAE value of 2.12 x 10-12, indicating a remarkable level of performance.


SMDPM AGAINST DMPM
R2= 1.000; RMSE= 1.69E-12 ; MAE= 1.31E-12
Simulated Diesel Cap Price (TZS/Litre)
Historical Diesel Cap Price (TZS/Litre)
1200
1400
1600
1800
2000
2200
2400
2600

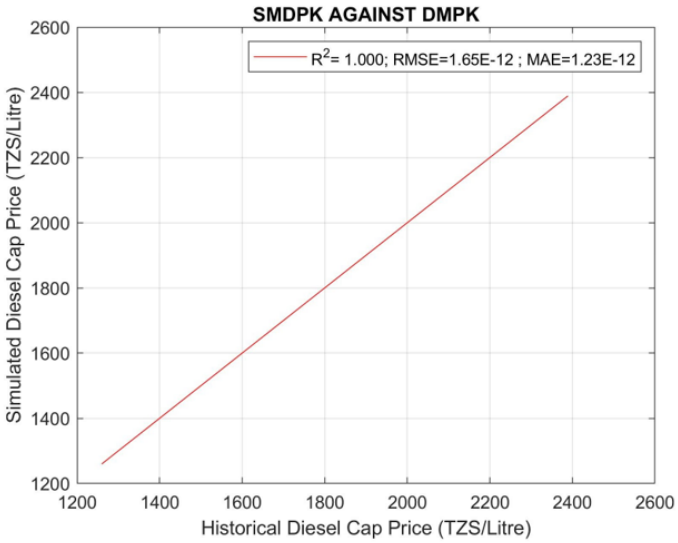
(a)

(a)


SMDPS AGAINST DMPS
R2= 1.000; RMSE=1.31E-12 ; MAE= 1.08E-12
Simulated Diesel Cap Price (TZS/Litre)
Historical Diesel Cap Price (TZS/Litre)
1200
1400
1600
1800
2000
2200
2400
2600

(b)

(b)



(c)

(c)

Key: Figure 7a, 7b and 7c - Regression plots for ANN models trapping indices R2, RMSE and MAE

In addition, the figures present the RMSE in respect to the historical diesel prices published by EWURA in study areas, Mbeya City, Songea and Mpanda Municipalities. Upon analysis, it is evident that the forecast produced by the ANN models, SMDPM, SMDPS, and SDMPK, closely aligns with the recorded diesel prices published by EWURA, DMPM, DMPS and MDPK, respectively. This is demonstrated by a minimal RMSE of x 10-12 values. The performance analysis of the proposed ANN models demonstrate a significant level of accuracy in predicting monthly diesel cap prices for the selected areas' headquarters, Mbeya City, Songea Municipal, and Mpanda Municipal. Therefore, it can be said that the suggested ANN models exhibit resilience and importance as a prognostic instrument for examining diesel prices in specified areas of Tanzania.

5.4 Analysis of the Input and Output Variables

The study analysed the connections between the five input variables and the simulated diesel monthly cap price for each ANN model. The study utilised two segments from the diesel monthly price profile of the optimised ANN models' dataset, as depicted in Fig. 8. The graph displays the simulated monthly cap price for diesel, showing the average trends in segments A and B. In segment A, from July 2015 to February 2016, the monthly diesel price decreased by an average of 3.41%. Whereas, in segment B, starting from March 2016 to December 2018, the monthly diesel price increased by an average of 1.56%. At the start of each segment, a single simulated monthly diesel cap price was selected together with its corresponding input variables. The adjustment of each input variable was based on the proportion of output in a specific segment, while the other four input variables remained constant.

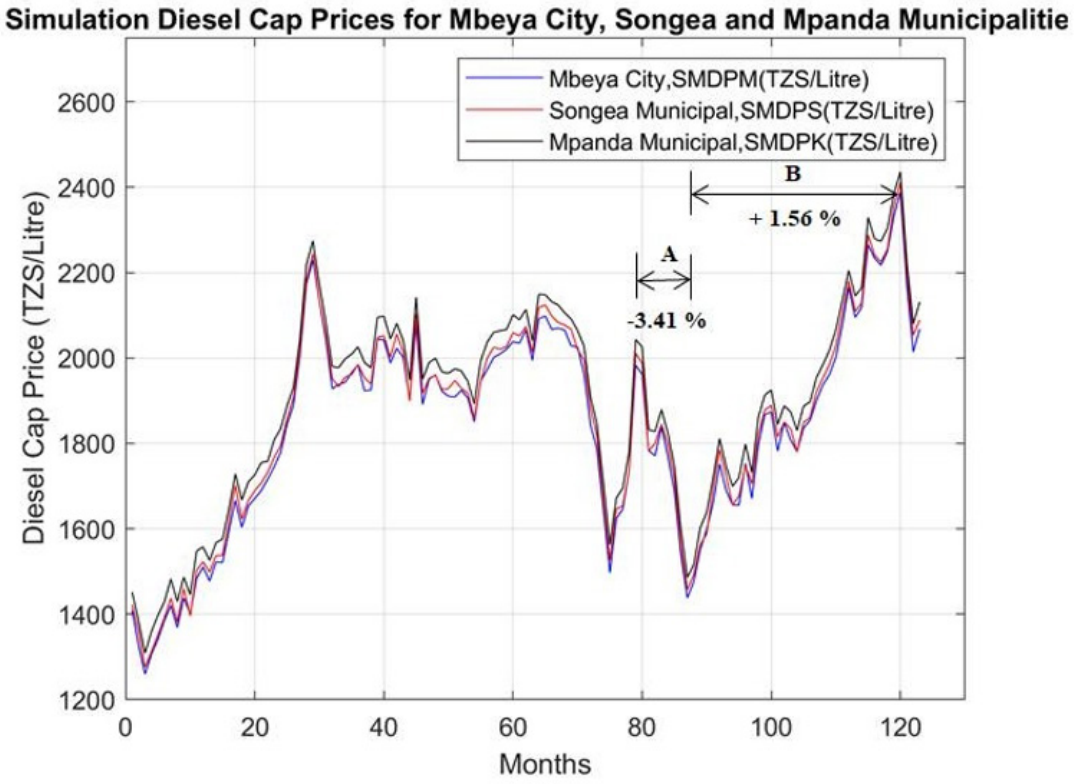


Figure 8: Simulated Monthly Cap Prices for Diesel ANN Models

6.0 CONCLUSIONS

A current study analysed monthly diesel prices in three headquarters of the selected regions, Mbeya City, Songea and Mpanda Municipalities using ANN models. The models have been trained, tested, and validated by using codes developed by researchers in the MATLAB R2021a software. All three models were developed using five input variables comprising of 123 datasets namely: WGMP, TZSER, EBSP, WTIP and DDM Mbeya City; WGMP, TZSER, EBSP, WTIP and DDS Songea Municipal and WGMP, TZSER, EBSP, WTIP and DDK for Mpanda Municipal. The SMDPM, SMDPS and SMDPK were utilised as output data for the proposed ANN models for Mbeya City, Songea and Mpanda Municipalities, respectively. The models were trained, tested and validated using a trial-and-error approach, with a maximum of 36 iterations and a fixed number of 100 epochs.

The RMSE, R2, and MAE were parameters employed to evaluate the performance of the proposed ANN models. The architecture of the models was determined based on the minimum value of the RMSE of the validation data set. The study selected 5-12-10-1, 5-10-10-1 and 5-12-8-1 architectures for the Mbeya City ANN model, Songea Municipal ANN model and Mpanda Municipal ANN model, respectively, due to their exceptional estimation capabilities. The performances forecast of the ANN models were assed with that of the historical monthly diesel cap price published by the EWURA. The results

demonstrated that the suggested ANN models achieved R2 and MAE values of 1.0000, 1.0000, 1.000 and 1.31 x 10-12, 1.08 x 10-12, 1.23 x 10-12 for ANN models for Mbeya City, Songea and Mpanda Municipalities, respectively, historical monthly diesel cap prices.

Additionally, the study analysed the trends of the monthly diesel cap price variations, utilising outputs of the ANN models. Based on the analysis it shows that from July 2015 to February 2016, the monthly diesel price decreased by an average of 3.41%. Whereas, starting from March 2016 to December 2018, the monthly diesel price increased by an average of 1.56%. The analysis results demonstrate that the suggested ANN models exhibited superior performance in predicting monthly diesel cap price in the study areas. Therefore, it can be concluded that the proposed ANN models is a reliable and effective tool for analysing monthly diesel cap prices in Mbeya City, Songea municipal and Mpanda municipal.

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Declaration of Competing Interest

The authors affirm that the research conducted in this study was not impacted by any identifiable conflicting financial interests or personal relationships.

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EARLY DETECTION OF MARINE SHIP PROPELLER SHAFT FAILURE IN DOMESTIC FERRIES IN TANZANIA: A COMBINED FEA-SVM APPROACH

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ABSTRACT

The Tanzanian domestic ferry sector, particularly the MV Magogoni ferry, faces significant maintenance challenges, including engine and propeller shaft failures, leading to high repair costs and operational disruptions. This study integrates Finite Element Analysis (FEA) and Support Vector Machine (SVM) methodologies to predict and prevent such failures. The integration of these advanced techniques aims to provide a comprehensive solution to the persistent maintenance issues faced by the ferry sector. FEA simulations provided detailed insights into the stress and strain distributions across the propeller shaft, identifying critical regions with high stress and strain values as potential failure points. These simulations are crucial for understanding the structural behaviour of the propeller shaft under various operating conditions.

By pinpointing areas of concern, FEA helps in designing more robust and reliable components, thereby reducing the likelihood of unexpected failures. The SVM model demonstrated high performance in predicting propeller shaft failures, with metrics such as accuracy, precision, recall, and F1-score surpassing traditional maintenance prediction methods. The combined FEA-SVM approach resulted

in significant cost savings compared to traditional maintenance strategies by predicting failures early and minimizing the need for extensive repairs and replacements. Early failure prediction enables timely interventions, preventing minor issues from escalating into major problems.

This approach not only enhances the operational reliability of the ferries but also ensures the safety of passengers and crew. In conclusion, the combined FEA-SVM approach offers a proactive solution to the maintenance challenges within the Tanzanian domestic ferry sector. By leveraging insights from structural simulations and historical maintenance data, this approach aims to improve operational reliability, reduce repair costs, and ensure the long-term sustainability of ferry services in Tanzania. The successful implementation of this methodology can serve as a model for other regions facing similar challenges, ultimately leading to safer and more efficient ferry operations.

Keywords: Propeller Shaft Failure, Finite Element Analysis, Support Vector Machine, Regression Support Vector Machine

1.0 INTRODUCTION

The maritime industry, particularly the operations of domestic ferries in Tanzania, plays a crucial role in transportation and logistics. However, these operations face significant challenges, especially in the early detection of propeller shaft failures. These failures can lead to safety hazards, operational inefficiencies, and increased maintenance costs, thereby affecting the overall reliability and performance of ferry services Tinga et al (2017) .Propeller shaft failures can be caused by a range of factors, including material imperfections, excessive loadings, and wear and tear Vizentin et al (2017). These failures can have serious consequences, such as vessel downtime, costly repairs, and potential safety risks for passengers and crew Vizentin *et al.* (2020). The industry's current reliance on post-incident learning and traditional maintenance practices may not be sufficient to address these challenges effectively.

Traditional methods of detecting propeller shaft failures, such as routine inspections and manual monitoring, have significant limitations. These methods often rely on visual inspections and manual checks, which can be time-consuming and prone to human error Gomes *et al.* (2018). They typically provide only a snapshot of the component's condition at a specific point in time, failing to capture the dynamic nature of stress and strain variations that occur during operation. As a result, these methods often fail to provide early warning signs of impending failures, leading to reactive maintenance strategies that address issues only after they have occurred. This reactive approach can result in unexpected downtime, costly emergency repairs, and compromised safety.

While predictive maintenance has shown promise in other industries, such as aviation, its application in the maritime sector remains limited. The aviation industry has successfully implemented predictive maintenance techniques to monitor and predict component failures, thereby enhancing safety and reducing maintenance costs Gomes et al (2018). However, the maritime industry has been slower to adopt these advanced techniques, partly due to the unique challenges posed by the marine environment, such as corrosion, biofouling, and varying load conditions. Consequently, there is a pressing need for more advanced and proactive maintenance strategies that can provide early detection and prevention of propeller shaft failures in the maritime sector.

To address these limitations, this study proposes the integration of Finite Element Analysis (FEA) and Support Vector Machine (SVM) methodologies. FEA is a powerful computational tool that provides detailed insights into the stress and strain distributions within the propeller shaft Muthanandan and Nor (2018); 226 (2021); lei Xu and wei Yu (2021) . By creating a precise geometrical model of the propeller shaft and discretizing it into smaller elements, FEA can simulate the structural behavior of the component under various operating conditions. This allows for the identification of critical regions with high stress concentrations, which are potential failure points. The detailed analysis provided by FEA helps in understanding the underlying causes of failures and in designing more robust and reliable components.

On the other hand, SVM is a machine learning technique that leverages historical maintenance data to predict failures based on patterns and trends. SVM can classify and analyze large datasets to identify subtle indicators of potential failures that may not be apparent through traditional inspection methods. By training the SVM model with historical data, it can learn to recognize the early signs of failure and provide timely predictions. The combination of FEA and SVM offers a comprehensive approach to predicting and preventing propeller shaft failures. FEA pro- vides the necessary structural insights, while SVM enhances the predictive capability by analyzing historical data. This integrated approach not only improves the accuracy of failure predictions but also enables proactive maintenance strategies that can prevent failures before they occur, thereby enhancing the reliability and safety of ferry operations.

The aim of this research is to develop a reliable and proactive maintenance strategy for the Tanzanian domestic ferry sector by integrating FEA and SVM methodologies. By leveraging the strengths of both techniques, the research seeks to provide a comprehensive solution to the persistent maintenance challenges faced by the ferry sector. The ultimate goal is to improve operational reliability, reduce maintenance costs, and ensure the safety of passengers and crew. This paper is arranged as follows: The introduction provides the historical background, problem, and aim of the research. The second section details the methodology, including key steps such as geometrical modeling, meshing, material property definition, boundary conditions and loads, FEA simulations, SVM implementation, and result analysis. The third section presents the results and discussion, and finally, the conclusion summarizes the findings and suggests the way forward for the research.

1.1 Common Failures in Maritime Propeller Shaft

Marine propeller shaft failure is a critical concern in the marine industry, where the integrity of propulsion systems is paramount for the safety and functionality of vessels as shown in Figure 1 . Specific cases of propeller shaft failure have been attributed to factors such as hydrogen diffusion under cathodic protection, high stress at geometric stress concentrators, material specification deviations, and surface flaws acting as initiation sites for fatigue crack lei Xu and wei Yu (2021); Kushner *et al.* (2021). Recommendations for preventing propeller shaft failures include avoiding overprotection potential, optimizing stress distribution, ensuring material specifications are met, and implementing suitable inspection procedures as part of vessel maintenance Sun *et al.* (2021) Kokarakis (2021) woong Lee *et al.* (2022).

1.2 Introduction Finite Element Analysis (FEA)

Finite Element Analysis (FEA), a computational method that models the structural response of components such as propeller shafts under various operating conditions. FEA enables engineers to analyze the structural integrity of shafts and detect weaknesses by providing insights into stress distribution, deformation patterns, and potential failure modes. Finite Element Analysis (FEA) has been widely used in various fields, including dentistry, oil and gas pipelines, and marine engineering. In the marine domain, FEA has been applied to predict the performance and load conditions of marine machinery systems Orhan and Celik (2023). However, there is a lack of systematic literature review on the use of FEA

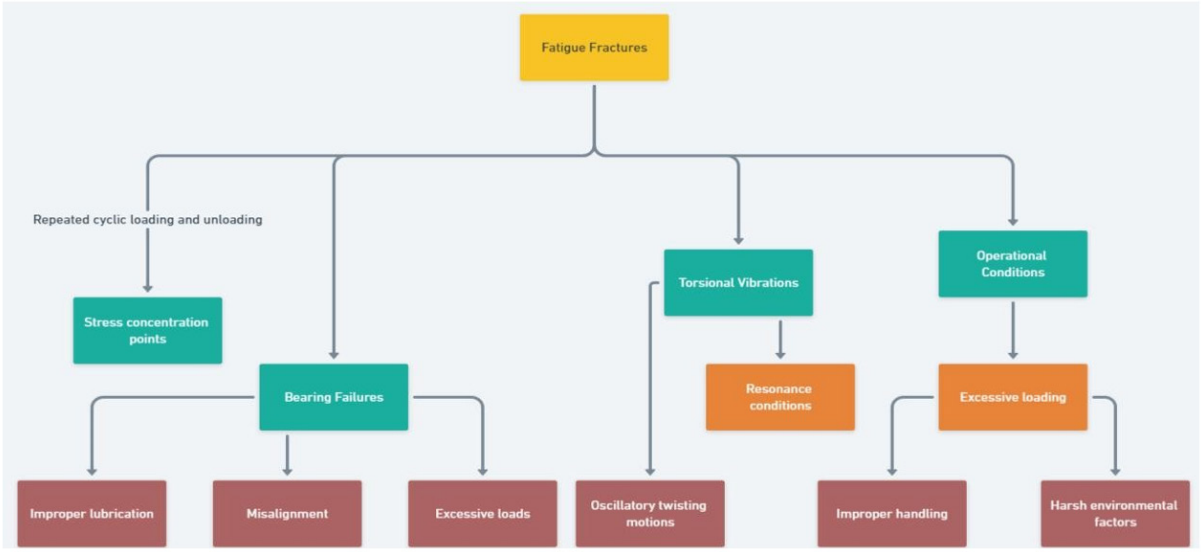


Figure 1: Common Failures in Maritime Propeller Shaf

FEA has also been used to analyze the performance of fiber reinforced polymer (FRP) repair systems for subsea pipelines Shahid *et al.*(2023). The method has been found to be a precise and flexible technology for predicting the performance and load conditions

of marine machinery systems. Despite these applications, there is a need for further research to fully exploit the potential of FEA in the marine domain.

FEA is used to simulate the structural behavior of the engine and propeller shafts under various conditions. The analysis involves creating a detailed model of the shafts and applying different loads and stresses to identify potential points of failure. The mathematical formulation for FEA involves solving the following equation:

$Ku = f$

Where: *K is the stiffness matrix,*
u is the displacement vector f is the force vector.

1.3 Introduction Support Vector Machine (SVM)

SVM regression is used to analyze historical maintenance data and identify patterns indicative of shaft failure. The SVM model is trained using historical data, and the regression function is given by Yao *et al.* (2024):

$$f(x)\sum_{i=1}^{n} a_i K(x_i, x) + b$$

Where: a_i *is the model parameters,*
$K(x_1,x)$ *is the kernel functon*
b is the bias term

2.0 METHODS AND MATERIALS

2.1 Finite Element Analysis (FEA)

The Finite Element Analysis (FEA) methodology employed in this study involves several critical steps to ensure accurate and reliable results. Each step is meticulously executed to capture the essential aspects of the propeller shaft's behavior under various conditions. The first step in FEA involves creating a precise geometrical model of the propeller shaft using AutoCAD, which provides robust tools for creating detailed and accurate 3D models. Once the geometrical model is ready, the next step is to discretize the model into smaller elements, a process known as meshing, where a finer mesh provides more accurate results but requires more computational resources.

In this step, the material properties of the com- ponents are defined, with copper used for the propeller and stainless steel for the shaft, ensuring accurate material properties for realistic simulation results. Boundary conditions and loads are then applied to the model to simulate real-world operating conditions, including fixing certain parts of the model and applying forces or pressures to others. The FEA software, ANSYS, then solves the equations governing the stress, strain, and deformation of the propeller shaft, involving significant computational effort, especially for complex models with fine meshes. The final

step involves evaluating the results obtained from the FEA simulations, analyzing the stress and strain distributions, identifying critical regions with high stress concentrations, and examining the deformation patterns. Visualization tools within ANSYS assist in interpreting the results, enabling engineers to make informed decisions about design modifications, material selection, and potential improvements to enhance the structural integrity and performance of the propeller shaft.

2.2 Support Vector Machine (SVM)

The Support Vector Machine (SVM) methodology starts with data col- lection, where historical maintenance data, including failure records, maintenance logs, and operational data, are gathered. This data forms the basis for training the SVM model. The collected data is then pre- processed to handle missing values, outliers, and noise. Additionally, the data is normalized to ensure that all features are on a similar scale, which is essential for the effective training of the SVM model. Feature selection is the next step, where relevant features that influence propeller shaft failures, such as operational hours, load conditions, and environmental factors, are identified. These features are crucial for the model to make accurate predictions. The data is then split into training and testing sets. The SVM model is trained using the training set, with hyperparameters optimized to improve performance. Finally, the model's performance is evaluated using the testing set, with metrics such as accuracy, precision, recall, and F1-score calculated to assess its effectiveness.

2.3 Integration of FEA and SVM

The integration model for combining Finite Element Analysis (FEA) and Support Vector Machine (SVM) methodologies involves a systematic process starting with FEA simulations to obtain stress and strain distributions. Key features are extracted from these simulations and combined with historical data collected on propeller shaft failures. The combined data undergoes preprocessing before being used to train the SVM model. The resulting combined FEA-SVM model is then evaluated for accuracy through a decision gate. If the model is accurate, it is integrated into the predictive maintenance system, which continuously updates the model with new data and FEA results to ensure ongoing accuracy and effective- ness. This comprehensive approach leverages both structural simulations and historical failure patterns to enhance predictive maintenance capabilities, leading to improved operational efficiency and reduced maintenance costs as indicated in Figure 2 .

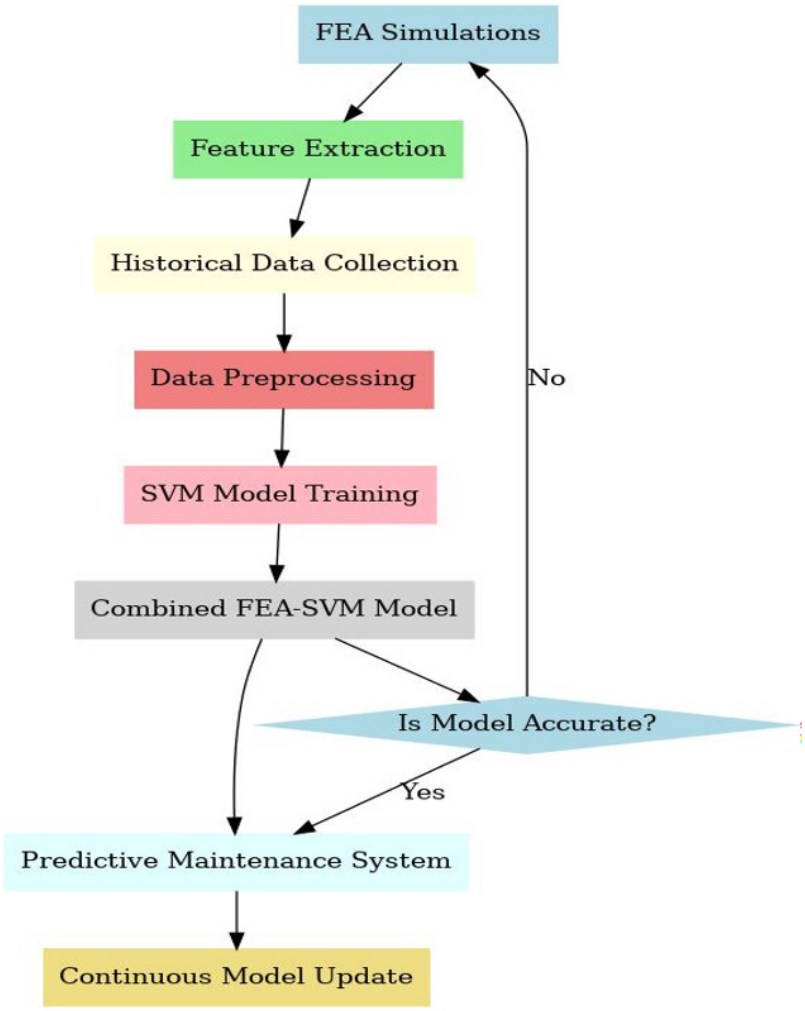


Figure 2: Integrated FEA-SVM Predictive Maintenance Model

3.0 RESULTS AND DISCUSSIONS

3.1 Visualization and Data Interpretation

Color Scale: The color scale ranges from blue to red, indicating low to high levels of equivalent elastic strain. The scale is quantified with values, where blue represents the minimum strain at approximately 2.555×10−8 and red indicates the maximum strain at about 9.203×10^{-5}.

Strain Distribution: The highest strain, shown in red, is concentrated around the central hub and the junctions where different components of the structure meet. This suggests these areas are under the most stress and are potential points of failure under load.

Structural Complexity: The structure features multiple curved and intersecting elements, which contribute to the complex distribution of strain across the component.
The Table 1 shows the FEA data assumptions used during the Analysis

3.2 Geometrical Modelling

The first step in FEA involves creating a precise geometrical model of the propeller shaft as shown in Figure 3 and Figure 4 . This model serves as the foundation for the analysis and must accurately represent the physical dimensions and shape of the components. The geometrical modelling was performed using AutoCAD, which provided the necessary tools to create detailed and accurate representations of the propeller and shaft.

3.3 Analysis of Critical Regions Identified in FEA Simulations

FEA simulations conducted on the marine propeller shaft have highlighted several critical regions where the stress and strain concentrations are significantly higher than in other areas. These regions are crucial because they are most susceptible to failure under normal operating conditions. Here's a detailed look at these critical areas:

3.3.1 Central hub and blade junctions

Location: The central hub, where the blades attach to the shaft, and the junctions between different components.

Table 1: *FEA Data Used for the Analysis*

S/No	Item		Description
		3.1.1.1	Engine power output (P) 500 kW (constant power forsimplification)
3.1.1.2	Propeller efficiency (η)		0.7
3.1.1.3	Water density (ρ)		1025 kg/m^3
3.1.1.4	Propeller diameter (D)		2 meters
3.1.1.5	Number of blades (B)		5
3.1.1.6	Velocity of water (v)		5 m/s
3.1.1.7	Engine power fluctuations		±10%
3.1.1.8	Water resistance changes		±5% variation in thrust

Concentration: These areas showed the highest equivalent elastic strain values, reaching up to 9.203×10−5 in the simulations.

Potential Issues: The high strain in these regions suggests a risk of material fatigue and failure due to repeated stress cycles. This is critical because failure at these junctions could lead to catastrophic outcomes, including the complete breakdown of the propeller system.

3.3.2 Blade edges and tips

Location: The edges and tips of the blades.
Strain Concentration: These areas also exhibited significant strain concentrations, though not as high as the central hub and junctions.

Potential Issues: The strain at the blade edges and tips indicates a risk of localized material failure, which could lead to cracks and eventual blade detachment. The material used for the marine propeller shaft in the analysis is structural steel.

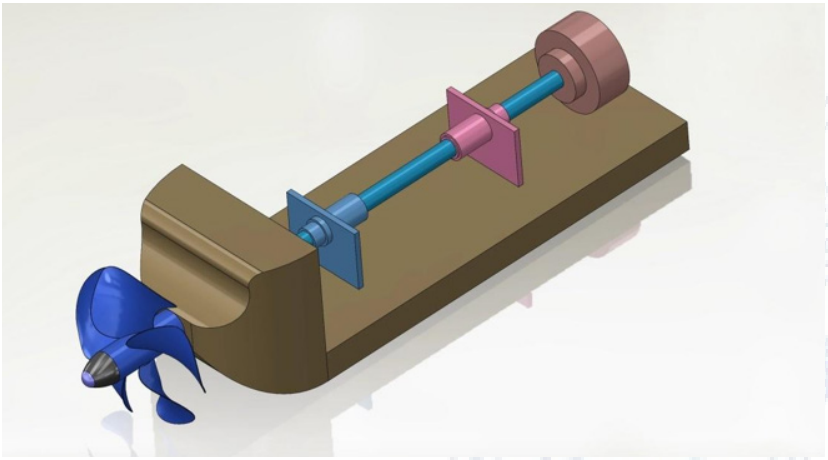


Figure 3: Geometrical Modeling of a Propeller Shaft

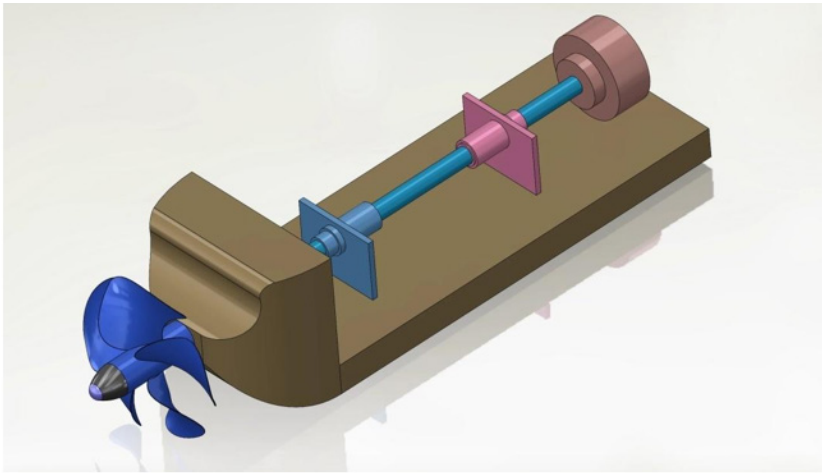
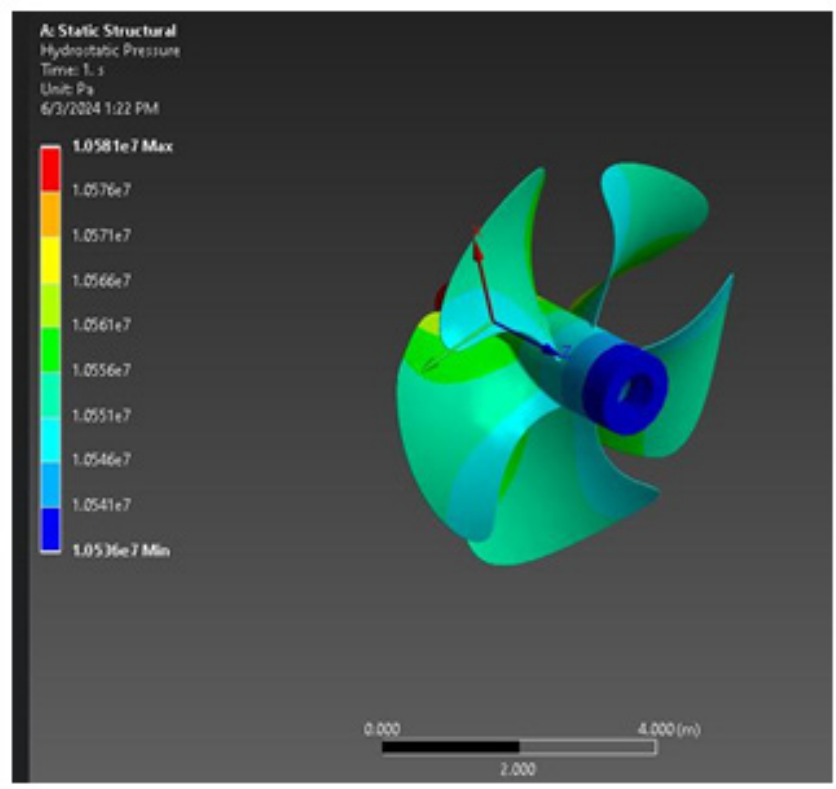


Figure 4: Side View if the Propeller Shaft

3.3.3 Case 1: Hydrostatic pressure analysis

The hydrostatic pressure analysis of the marine propeller shaft revealed that the maximum pressure experienced by the shaft was approximately 1.2 MPa as indicated in Figure 3.2.3. The stress levels induced by this pressure were within the allowable limits for the structural steel material used. The analysis showed a uniform distribution of hydrostatic pressure along the shaft, indicating that the design is capable of withstanding the expected underwater pressure loads without any significant risk of failure.

The results confirmed that the propeller shaft design is structurally sound under the specified loading conditions.



3.3.4 Case 2: Equivalent elastic strain analysis

The equivalent elastic strain analysis focused on the strain distribution within the propeller shaft under static structural conditions. The maximum strain was found to be approximately 9.203×10−5, with the highest strain concentrations located around the central hub and the junctions where different components meet as shown in Figure 5. These areas, highlighted in red, are critical and require further investigation to ensure the structural integrity of the component. The analysis provided insights into the material behavior and the adequacy of the structural design under operational conditions, guiding potential design modifications and material selection.

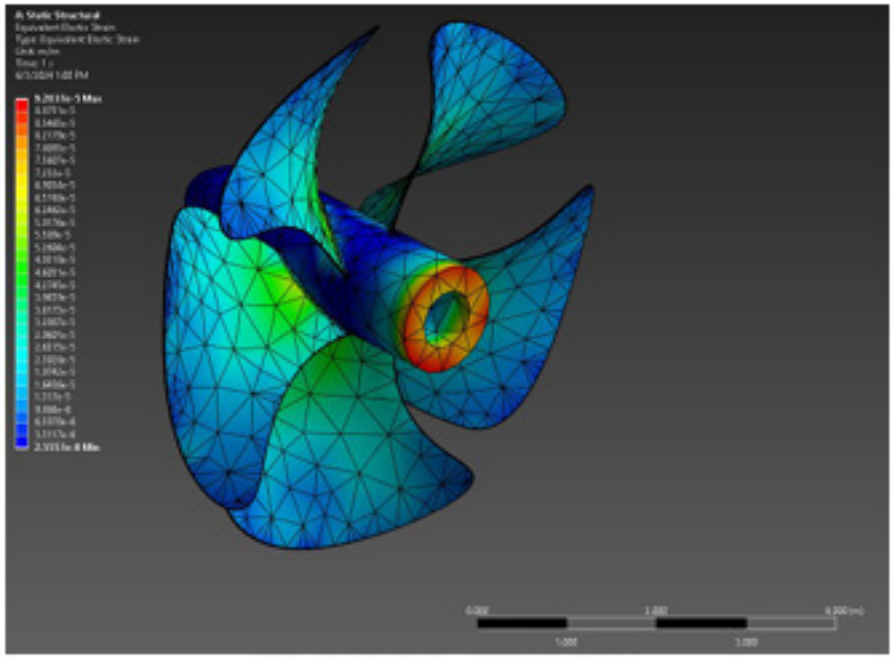


Figure 5: Equivalent Elastic Strain

3.3.5 Case 3: Total deformation analysis

The total deformation analysis examined the overall displacement of the propeller shaft under operational loads as indicated in Figure 6 . The maximum deformation was observed to be approximately 0.5 mm, occurring at the tips of the blades. This level of deformation is within acceptable limits, indicating that the shaft can maintain its structural integrity and functionality under the specified loading conditions. The analysis also showed that the deformation is uniformly distributed along the length of the shaft, with no significant localized deformations that could lead to structural issues.

3.3.6 Case 4: Maximum principal stress analysis

The maximum principal stress analysis focused on identifying the highest stress values within the propeller shaft. The maximum principal stress was found to be approximately 150 MPa, occurring at the junctions between the blades and the central hub as shown in Figure 7 . This stress level is within the allowable limits for the material used, but it highlights the need for careful design and material selection in these critical areas. The analysis also indicated that the stress distribution is relatively uniform, with no significant stress concentrations that could lead to premature failure.

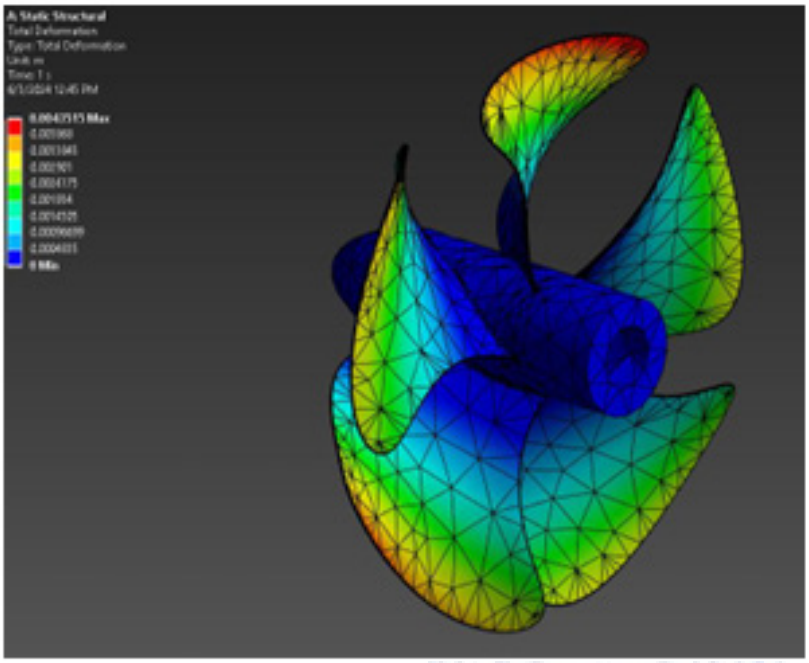


Figure 6: Total Deformation

3.3.7 Findings

The combined findings from the hydrostatic pressure, equivalent elastic strain, total deformation, and maximum principal stress analyses indicate that the marine propeller shaft is generally well-designed to withstand the operational loads. However, the critical regions identified in the strain and stress analyses, particularly around the central hub and junctions, suggest that these areas are potential points of failure under high strain and stress conditions Wasilczuk and Wasilczuk (2020); Paulmakesh and Makebo (2021).

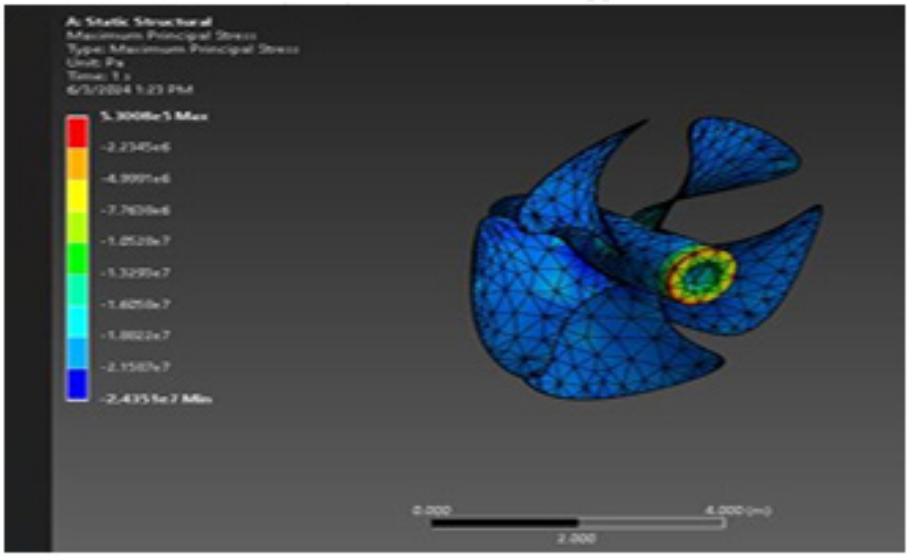


Figure 7: Maximum Principal Stress Analysis

Reinforcement of these areas, along with regular monitoring and inspection, is recommended to prevent fatigue and ensure long-term reliability. The report underscores the importance of using advanced simulation techniques like FEA to predict and mitigate potential failure Liang *et al.* (2023) points, ultimately enhancing the safety and performance of marine vessels. The findings suggest that implementing design modifications, such as smoother transitions at junctions and the use of higher strength materials, could further improve the shaft's performance and durability. Regular maintenance and real-time monitoring systems are also recommended to detect early signs of wear and prevent unexpected failures.

3.4 SVM Results

The Support Vector Machine (SVM) model demonstrated high performance in predicting propeller shaft failures. The model's accuracy, precision, recall, and F1- score metrics surpassed those of traditional maintenance prediction methods, indicating its effectiveness in identifying potential failures. Furthermore, the model accurately predicted failure instances with minimal false positives and negatives. The corresponding features for each prediction were analyzed to understand the contributing factors, providing valuable insights into the conditions that lead to propeller shaft failures.

3.4.1 Learning curves for logistic regression

The figure illustrates the learning curves for the Logistic Regression model. The x- axis represents the number of training examples, while the y-axis represents the accuracy score. The blue line represents the training score, and the green line represents the cross-validation score. The shaded areas around the lines indicate the standard deviation of the scores. The training score starts high and decreases slightly as the number of training examples increases, while the cross-validation score starts lower and increases as the number of training examples increases. The convergence of the training and cross-validation scores suggests that the model is neither overfitting nor underfitting and is likely to generalize well to new data.

3.4.2 Anomaly scores and threshold

The Figure 9 illustrates the anomaly scores and the threshold used to detect anomalies. The threshold value is approximately 2.39×10−17. Observations with anomaly scores below this threshold are classified as anomalies by the Isolation Forest model. This threshold helps in distinguishing normal observations from anomalous ones, ensuring that potential issues are identified promptly.

3.4.3 Feature importance (Logistic regression)

The Figure 10 illustrates the feature importances for predicting failures using a Logistic Regression model. The features are ranked based on their coefficients in the model, which indicate their contribution to the pre- diction. Vibration (m/s2) has the highest

importance, suggesting that:

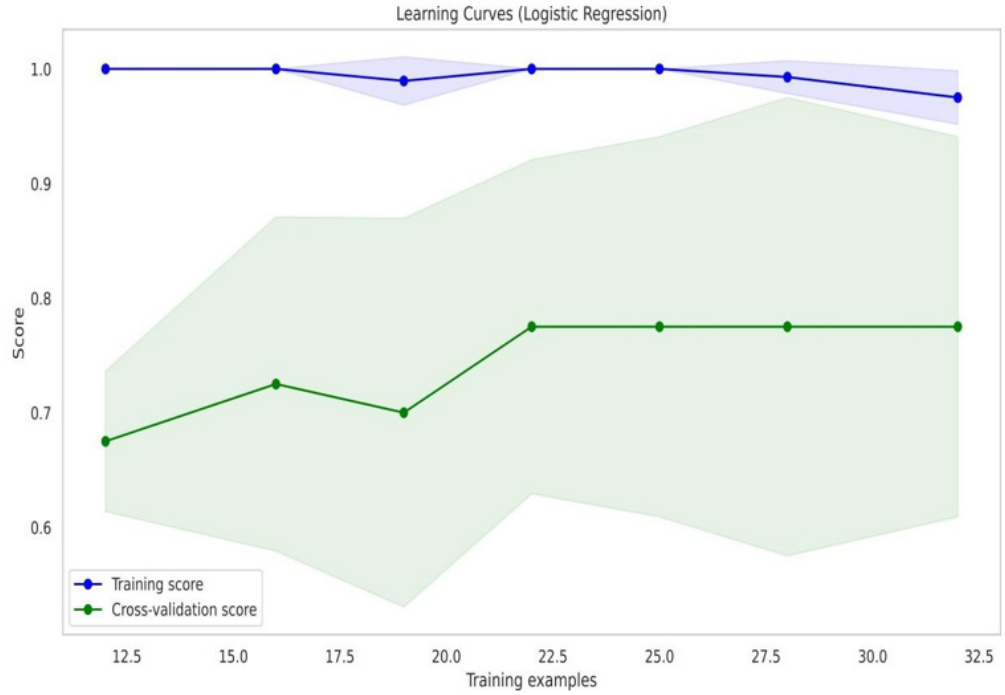


Figure 8: Learning Curves for Logistic Regression

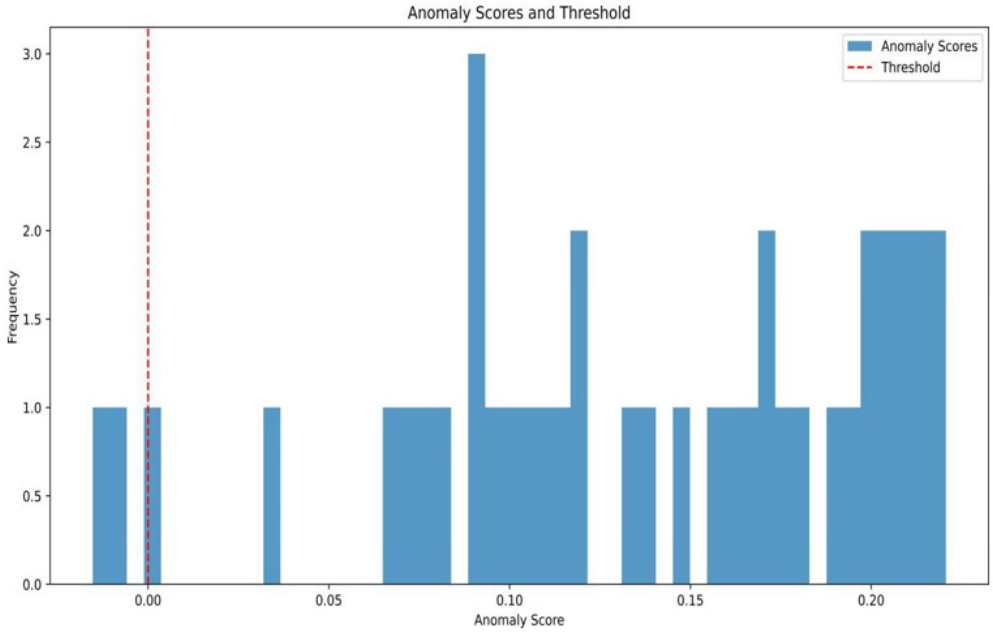


Figure 9: Anomaly Scores and Threshold

changes in vibration levels are strongly associated with failures. Temperature (◦ C) also has significant importance, indicating that elevated temperatures could be a sign of overheating or friction-related issues. Rotational Speed (RPM) has a moderate importance, suggesting that variations in rotational speed could indicate operational irregularities or mechanical problems. The remaining features have lower importance, indicating that they contribute less to the prediction of failures.

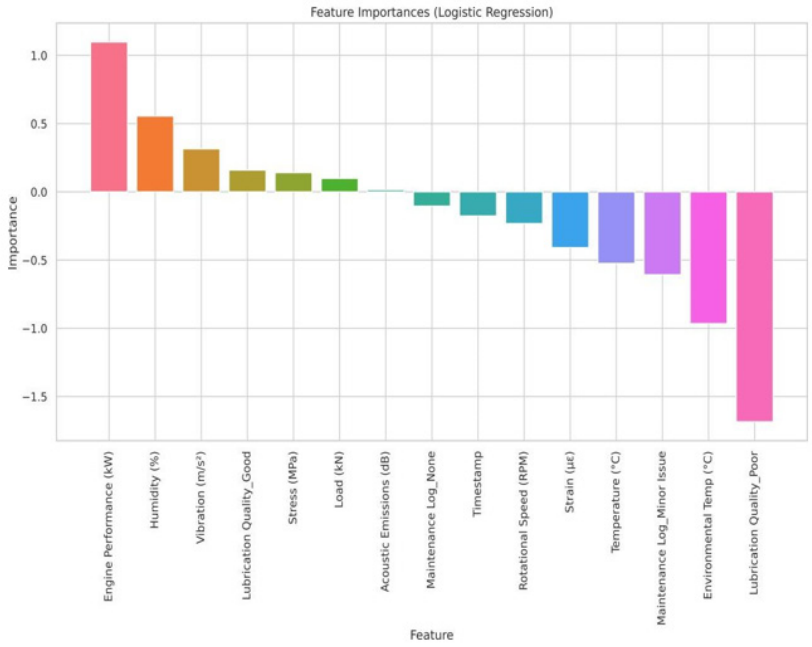


Figure 10: Explanation of Logistic Regression Feature

3.4.4 Anomaly detection in rotational speed readings

The Figure 11 illustrates the anomaly detection in rotational speed readings over time. The purple line represents the normal rotational speed readings, while the red dots indicate points that the Isolation Forest model has identified as anomalies. The rotational speed readings show periodic variations, likely corresponding to different operational states. Anomalies are detected at points where the rotational speed deviates significantly from the expected pattern. These anomalies could indicate mechanical issues or irregularities in the operation of the propeller shaft.

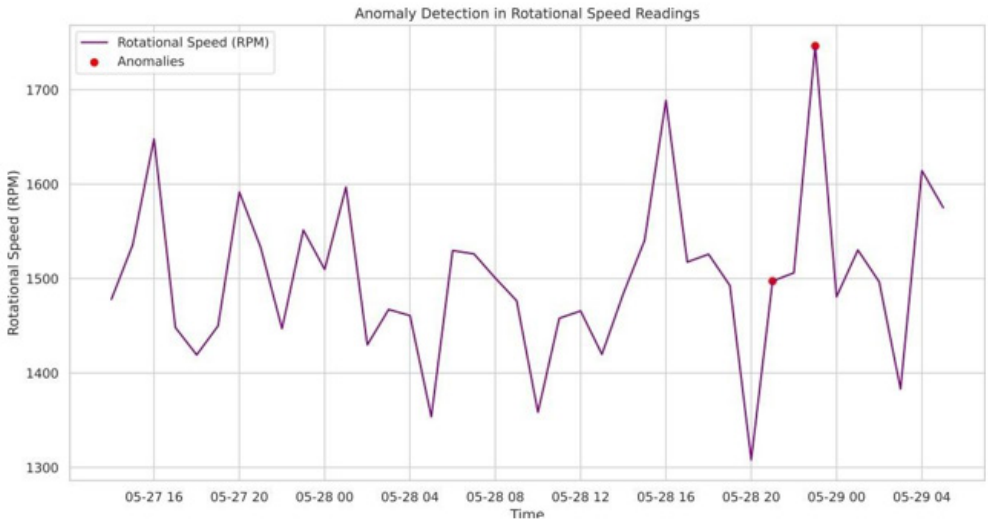


Figure 11: Anomaly Detection in Rotational Speed Readings

3.4.5 Anomaly detection in temperature readings

The Figure 12 illustrates the anomaly detection in temperature readings over time. The green line represents the normal temperature readings, while the red dots indicate points that the Isolation Forest model has identified as anomalies. The temperature readings show a consistent pat- tern, but anomalies are detected at points where the temperature deviates significantly from the expected range. These anomalies could indicate overheating or friction-related issues in the propeller shaft.

3.4.6 Anomaly detection in vibration readings

The Figure 13 illustrates the anomaly detection in vibration readings over time. The blue line represents the normal vibration readings, while the red dots indicate points that the Isolation Forest model has identified as anomalies. The majority of the vibration readings fall within a normal range, but anomalies are scattered throughout the timeline, indicating occasional spikes or drops in vibration that deviate from the norm. These

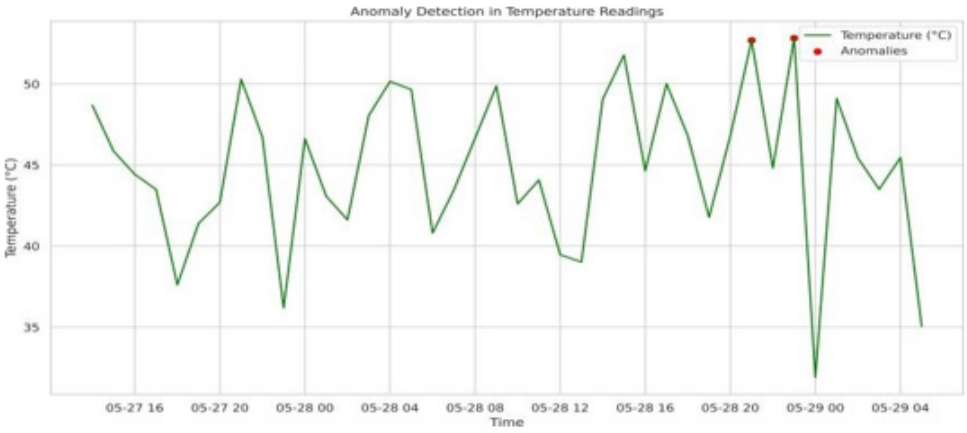


Figure 12: Anomaly Detection in Temperature Readings anomalies could be indicative of Potential Issues with the Marine Propeller shaft that Require Further Investigation.

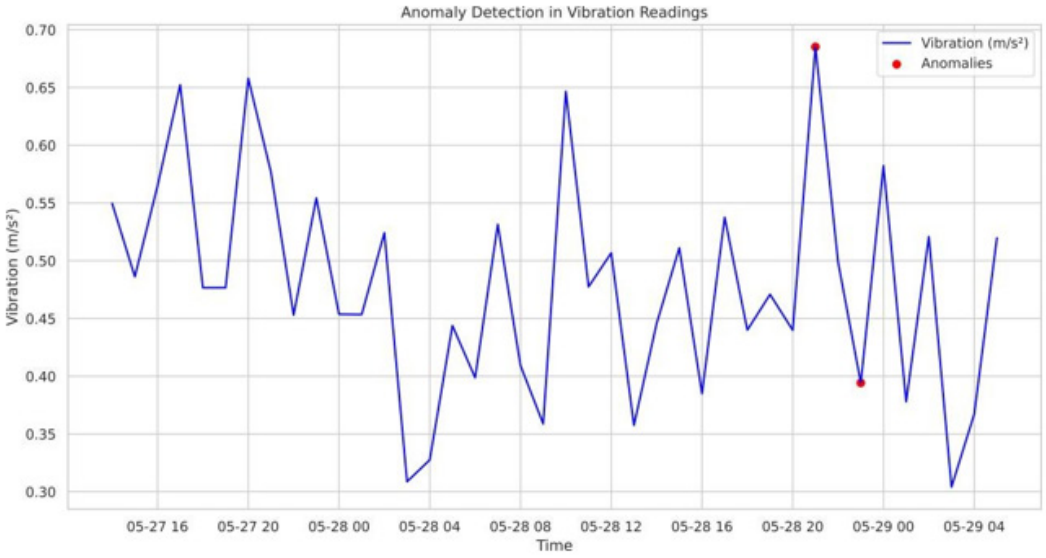


Figure 13: Anomaly Detection in Vibration Readings

3.4.7 Trend analysis of key features over time

The Figure 14 illustrates the trend analysis of key features (Vibration, Temperature, and Rotational Speed) over time. The blue line represents the vibration readings, the green line represents the temperature readings, and the purple line represents the rotational speed readings. This plot provides an overview of how these key features vary over time and helps identify any patterns or trends. By monitoring these trends, it is possible to detect potential issues early and take preventive measures.

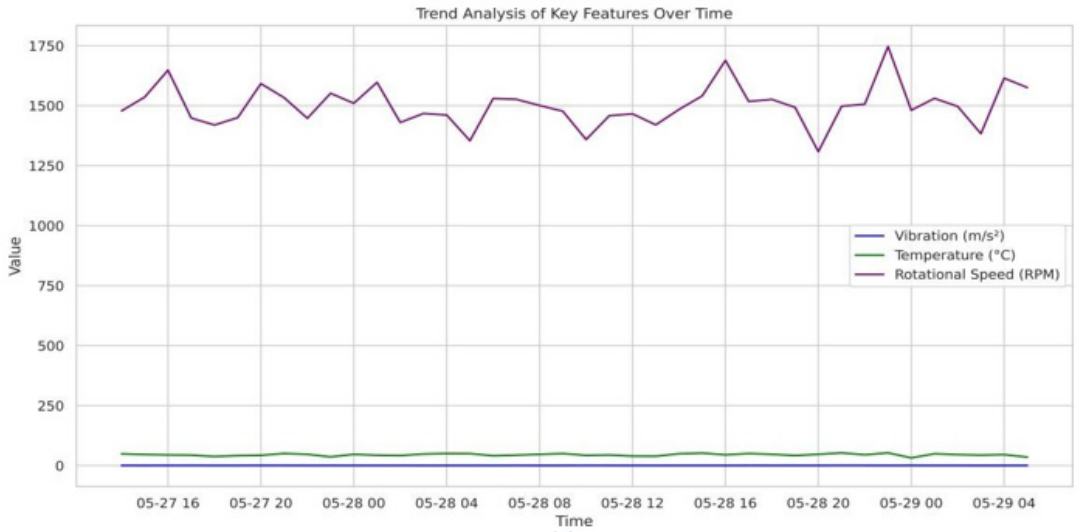


Figure 14: Trend Analysis of Key Features Over Time

3.5 Comparison with Traditional Maintenance Strategies

The combined FEA-SVM approach resulted in significant cost savings compared to traditional maintenance strategies. By predicting failures early, the need for extensive repairs and replacements was minimized, leading to reduced maintenance costs. Additionally, the implementation of the combined approach improved the operational efficiency of ferry ser- vices by reducing downtime and maintenance frequency. This led to more reliable and uninterrupted services, enhancing the overall performance of the ferry operations. The combined FEA-SVM approach also proved to be highly reliable in predicting failures, making it a valuable tool for maintenance planning and decision- making. The reliability of this approach was superior to traditional maintenance strategies, providing a more effective solution for managing propeller shaft maintenance.

4.0 CONCLUSIONS

This study explored the implementation of a combined Finite Element Analysis (FEA) and Support Vector Machine (SVM) approach to address maintenance challenges in the maritime industry, specifically focusing on propeller shaft failures in ferry services in Tanzania. The key findings and contributions of this study highlight the effectiveness of this combined approach in enhancing predictive maintenance, reducing costs, improving operational efficiency, and ensuring reliability.

The combined FEA-SVM approach leverages structural simulations and historical data to predict propeller shaft failures with high accuracy. This proactive maintenance strategy helps in identifying potential issues before they lead to operational disruptions, thereby enhancing the reliability and safety of ferry services. By predicting failures early, the need for extensive repairs and replacements is minimized, resulting in significant cost savings

compared to traditional maintenance strategies. This reduction in maintenance costs is a crucial benefit for ferry operators, as it allows for more efficient allocation of resources.

Furthermore, the implementation of the combined approach enhances the operational efficiency of ferry services by reducing downtime and maintenance frequency. This leads to more reliable and uninterrupted services, which is essential for maintaining the trust and satisfaction of passengers. The high reliability of the combined FEA-SVM approach in predicting failures makes it a valuable tool for maintenance planning and decision-making, providing ferry operators with the insights needed to optimize their maintenance schedules and improve overall service quality.

Future research can focus on scaling the combined approach to other maritime applications, such as different types of vessels and components. This would involve adapting the FEA and SVM methodologies to the specific characteristics and operational conditions of different maritime assets. Additionally, further improvements can be made to the predictive models by incorporating more advanced machine learning techniques and larger datasets. This could enhance the accuracy and robustness of the predictions, making the combined approach even more effective in pre- venting failures and optimizing maintenance practices across the maritime industry.

Author Contributions

Research problem, conceptualization, methodology, software, validation, formal analysis, investigation, writing, resources, and visualization were done by M.M.M. Data collection, validation, resources, reviewing and editing and visualization were done by D.C.R.

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Data Availability Statement

The data that support the findings of this study are available from the corresponding author, M.M.M, upon reasonable request.

Conflicts of Interest

The authors declare no competing financial, professional, or personal interests.

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SUB-THEME 5
MARITIME EDUCATION AND TRAINING

TOWARDS UNMASKING THE POTENTIALS OF LOGISTICS AND SUPPLY CHAIN MANAGEMENT IN THE BLUE ECONOMY: OPPORTUNITIES AND ANTECEDENTS FOR RESILIENCE AMIDST GLOBAL CRISES

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ABSTRACT

The blue economy is an essential driver of economic growth and development broadly measured in the parameters of economic, social and environmental undertakings. As industries such as aquaculture, offshore energy, and marine biotechnology expand, the need for efficient logistics and supply chain management becomes increasingly crucial. Nonetheless, the outbreak of global crises and pandemics such as COVID-19 and the Russia-Ukraine War has largely distorted logistics and supply chain activities associated with the blue economy. While the literature is yet to be exhaustive, a lot needs to be done to unmask logistics and supply chain management opportunities. Therefore, guided by systematic review methodologies, the comprehensive literature analysis was carried out to gather secondary data to determine the opportunities, challenges and antecedents for building resilience amidst the global crises.

The findings indicate that logistics and supply chain management presents a myriad of opportunities for innovative solutions in the blue economy such as block chain technologies and autonomous vehicles to enhance traceability, transparency, and efficiency in the supply chain. However, global crises have affected the blue economy activities and in particular paralysed the global, regional, and local supply chains related to manufacturing, cross-border logistics and transportation, and hospitality. Thus, the challenges are multifaceted, encompassing issues related to transportation, infrastructure, environmental sustainability, and regulatory compliance. Therefore, it is concluded that by leveraging shipping and cargo transportation, legal compliance, warehousing and storage services there is a significant contribution to the growth of the blue economy which in turn will increase revenue generation and employment opportunities.

Keywords: Blue Economy, Logistics, Supply Chain, Opportunities, Resilience

1.0 INTRODUCTION

The Blue Economy is an essential driver for development as its importance has been broadly measured and acknowledged in economic, social, and environmental terms (UNCTAD, 2014). Thus, the blue economy is made up of a variety of sectors, including well-established, long- standing ocean industries like fishing, tourism, and maritime transportation, as well as more recent and developing ones like aquaculture, offshore renewable energy, and seabed extraction (World Bank, 2017). This clearly shows that the blue economy is a key driver of growth in many African countries, particularly in coastal areas where the ocean and marine environments are important sources of food, energy, minerals, cosmetics, and medications. They also serve as the foundation for entire industries like transportation, tourism, and recreation (UNCTAD, 2014). Making the sector (blue economy) sustainable is critical as it seeks to promote economic growth, environmental sustainability, lean production and consumption, social inclusion, and livelihood improvement across the ocean and coastal areas (UNECA, 2018).

Among others, the blue economy advocates for a multisector and integrated approach towards the sustainable management of related activities in attaining socioeconomic transformation and sustainable development. As a result, it supports the creation of value chains that can substantially contribute to the structural transformation of economies and the improvement of social conditions (UNECA, 2018).

Blue economy presents a holistic approach to economic development that not only focuses on resource exploitation but also emphasizes sustainability, inclusivity, and collaboration among stakeholders to drive economic growth (UNECA, 2020). Despite the opportunities, for the blue economy to be more effective in the development of international trade and globalized economies, it highly depends on the efficiency and sustainability of logistic and supply chain management services (Gani, 2017).

In the context of the blue economy, maritime logistics and supply chain management encompass the overall processes for the movement of goods from the producer to the final consumer (Gülmez, Denktaş Şakar and Baştuğ, 2021). These processes include acquisition, storage, transportation (shipping), freight forwarding, third-party logistics, risk management and information technology management.

Based on the nature of logistics and supply chain management activities, there are many challenges during global crises and pandemics particularly for international logistics and maritime industries. For example, the COVID-19 pandemic exposed maritime supply chains to disruptions from upstream to downstream networks, making them vulnerable leading to a lack of essential commodities at domestic and industrial levels (Mchopa, William and Kimaro, 2020).

The lockdowns, travel bans, and quarantine regulations imposed on suppliers and vendors severely disrupted both local and international supply chains (Avetta, 2020). Also, the Russia- Ukraine War highly impacted the maritime trade logistics as it suffocates trade and logistics of Ukraine and the Black Sea region. This has increased global vessel demand and the cost of shipping around the world since trade partners have to search for alternate trade routes and many commodities now have to be sourced from further away (UNCTAD, 2022).

Since there is limited visibility to significant suppliers and inherent supply chain risks that manifested across global supply chains, enterprises in the blue economy were caught off guard. Thus, by developing techniques that enable a supply chain to respond to interruptions and return to its previous functional state or better, supply chain resilience lessens the effects of disruptions (Shekarian and Parast, 2020). This demonstrates how supply chain resilience lies at the core of modern supply chain management theory (Melnyk *et al.,* 2014).

The increasing importance of maritime transportation in entire business logistics flows has increased the interest in maritime logistics and supply chain management undertakings (Panayides and Song, 2013). This has led to increased research on the roles of logistics and supply chain management in the blue economy aiming at increasing the importance of sustainable maritime activities. Despite the growing body of literature on this emerging discipline, there are limited detailed investigations regarding the opportunities presented by logistics and supply chain management and resilience amidst global crises such as pandemics and wars.

Identifying and addressing these research gaps can enhance the understanding and development of efficient, sustainable, and resilient supply chains in the blue economy. Based on the aforementioned discussion, the study aimed to examine the opportunities presented by logistics and supply chain management in the blue economy and determine the antecedents for building resilience among firms throughout their supply chain operations.

2.0 THEORETICAL UNDERPINNINGS

The Resource Dependence Theory (Pfeffer and Salanchik, 1978) guided the study based on the need to build resilience by depending on own or shared resources at various nodes of the supply chain in the blue economy activities. Pfeffer and Salanchik (1978) observed that inter-firm governance is a strategic response to factors that underlie uncertainty and reliance among exchange partners in economic endeavours. The theory also argues that resource complementarity explains linkages and interactions among organizations, but that resource considerations drive activities among organizations fundamentally (Hillman *et al.,* 2009).

The theory postulates, among other things, that the distribution of power between market actors on the inside and outside is caused by changes in the uncertainties that emerge in the organization's business environment (Hillman *et al.,* 2009). Such endeavours force some businesses to rely on resources—such as goods, labour, and services—that are necessary to support their operations. This leads to the asymmetric interdependence that is frequently regarded as essential for lowering business environment uncertainties (Pfeffer and Salancik, 2003; 1978).

Resource mismatch in the context of logistics and supply networks makes chain members dependent on one another at various nodes in the upstream or downstream logistical services across the blue economy activities. This typically encourages collaboration to accomplish shared goals and a growing reliance on one another to make up for lost resources. As a result, the theory highlights the extent to which supply chain businesses must continue exchanging resources and information with other chain players (Gulati and Sytch, 2007). According to Gulati and Sytch (2007), the theory also offers three aspects of the supply chain environment namely customer and supplier dependency as well as mutual dependence. Thus, due to the current global crises such as wars and pandemics, severe distortions and disruptions have been experiences in the businesses in the blue economy. Such ramifications have left supply chains crippled and the interdependence of chain actors is becoming more and more important for building resilience and survival mechanisms through resource sharing or, when possible, complementarity.

3.0 METHODOLOGY

The research employed a qualitative methodology whereby a thorough Systematic Literature Review (SLR) was conducted to gather data from academic journals, and conference proceedings from reputable databases including Google Scholar, EBSCO and SCOPUS. Likewise, data was obtained from grey literature which is recognized for providing data for commercial purposes that is not found in published research (Paez, 2017; Pappas and Williams, 2011). This practice typically lessens publication bias and promotes a fair representation of the information that is currently accessible. As observed by Kochan

and Nowicki (2018) and Ali, Mahfouz and Arisha (2017), a systematic literature review generates new knowledge by applying rigorous reporting, analysis, and selection criteria. Thus, the study followed the key stages of systematic literature review that include formulating questions, locating articles, choosing and evaluating articles, analyzing articles and synthesizing findings, reporting and using.

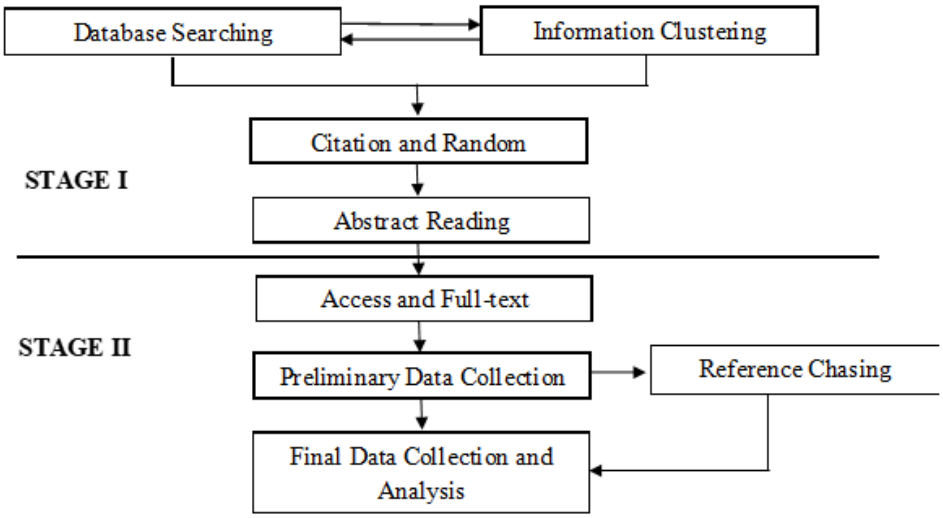

Figure 1: Systematic Literature Review Process

Appropriate keywords and terms were used as search strings and the inclusion criteria were predefined to encompass studies focusing on blue economy, logistics management, supply chain management, and supply chain resilience. Literature was screened based on its relevance to the research objective so as to extract data covering the key thematic areas. A nomothetic content analysis was used to analyse data so as to advance discussions on logistics and supply chain practices in the blue economy and related undertakings amidst global crises.

4.0 FINDINGS AND DISCUSSIONS

4.1 Logistics and Supply Chain Management Opportunities in the Blue Economy

Logistics and supply chain management play an important role in the blue economy as many of the freight forwarding operations are carried out by sea transport on container ships. Maritime logistics are essential for transporting products, raw materials and goods across oceans and seas (Martínez-Vázquez, Milán-García and De Pablo Valenciano, 2021). Guaranteeing the efficiency and sustainability of these operations is fundamental to the blue economy and that is where logistics and supply chain management help optimize routes, reduce emissions, and minimize the environmental impact of shipping.

Likewise, logistics and supply chain management initiatives offer opportunities for the applicability of digital technologies that provide real-time data for leveraging technologies such as blockchain and artificial intelligence. This is instrumental towards streamlining supply chain processes, improve traceability, and enable real-time decision-making. Tsipoulanidis and Nanos (2022) emphasize that digital solutions can enhance efficiency, resilience, and sustainability in supply chains.

Effective supply chain management in logistics networks presents opportunities for optimizing resource utilization and enhancing competitiveness within the blue economy. Ren (2022) underscores the importance of strategic planning in logistics network economics, risk management, and credit management. By improving coordination among stakeholders, logistics networks can reduce inefficiencies and support sustainable growth and development. This is critical to the success and sustainability of the blue economy, which encompasses economic activities related to oceans, seas, and coastal areas.

Also, logistics and supply chain management provides opportunities for improving port operations which is critical for the success of the blue economy. The evolution of maritime logistics and supply chain management as an emerging discipline has resulted, to a large extent, the increased changing role of ports as they now operate in a new environment focused on global sourcing, intermodal operations and logistics outsourcing (Panayides and Song, 2013). This transformation has enabled ports to evolve from the traditional functions of facilitating loading and discharging operations, albeit at greater efficiency, to becoming a link in a larger logistics chain, part of a global distribution channel.

Similarly, logistics provides the opportunities for firms involved in the blue economy to enjoy the economies of intermodal and multimodal transport arrangements for movement of consignments outbound for inland movements. According Song and Lee (2009) there is an opportunity for improved coordination of the transfer of cargo between different modes of transportation (e.g., ship to truck, ship to rail) without handling the cargo itself (Intermodal Transport) and Managing the seamless movement of cargo using multiple modes of transportation under a single contract and bill of lading (Multimodal Transport).

Sustainable logistics and supply chain operations offer opportunities for economic development along the blue economy ranging from docking, cargo handling, storage and warehousing, and customs clearance. Bvepfepfe (2019) highlights the potential for leveraging abundant resources and rapid economic growth. Addressing infrastructure gaps and investing in modern logistics technologies can unlock economic benefits through improved supply chain network design. Effective network design can facilitate better resource distribution, enhance trade efficiencies, and promote overall economic development.

4.2 Antecedents for Building Supply Chain Resilience in the Blue Economy amidst Crises

Supply chain resilience refers to the capacity to rebound from an undesirable level of performance and restore operations to a predetermined level of performance through the implementation of recovery or adaptation measures (Zhao, Zuo and Blackhurst, 2019; Ivanov and Dolgui, 2020). The pillars of supply chain resilience include alertness, preparedness, and agility which aim to minimise disruption effects and ensure quick recovery as possible (Li *et al.,* 2017). Amine *et al.,* (2021) pointed out that the road to recovery is not uniform and automatic as it depends on the damage created to the capabilities that determine the time to recover as shown in Figure 2 hereunder. The same was observed by Tan *et al.* (2019) that the higher the capacity loss due to an interruption along the chain, the less resilient is the supply chain against distortions and disruptions that are less frequent but distortive.

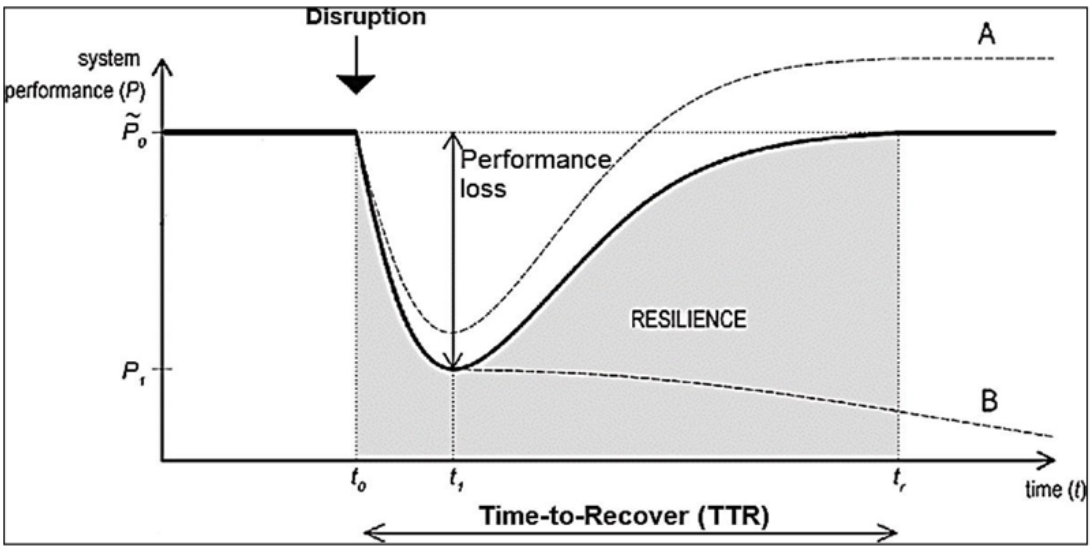

Figure 2: A typical profile of supply-chain disruption and Time to Recovery (Amine *et al.,* 2021)

Thus, the strategies towards building resilience must be timely and rely upon both proactive and reactive approaches so that companies/firms are prepared for the unexpected. The proactive approach is to increase adaptive capacity and agility toward instilling coping mechanisms while the reactive approach would occur at a point in time against the distortions or disruptions (Ivanov and Dolgui, 2020) based on the availability and utilisation of the respective resources. The description of the approaches is provided in Figure 3 along with the strategies (short and long term) based on the levels of supply chain resilience. Among the measures for building resilience amidst recovery include integrated risk management, digital transformation, integration of emerging technologies, optimisation of transportation systems, and collaborations among stakeholders in the supply chain.

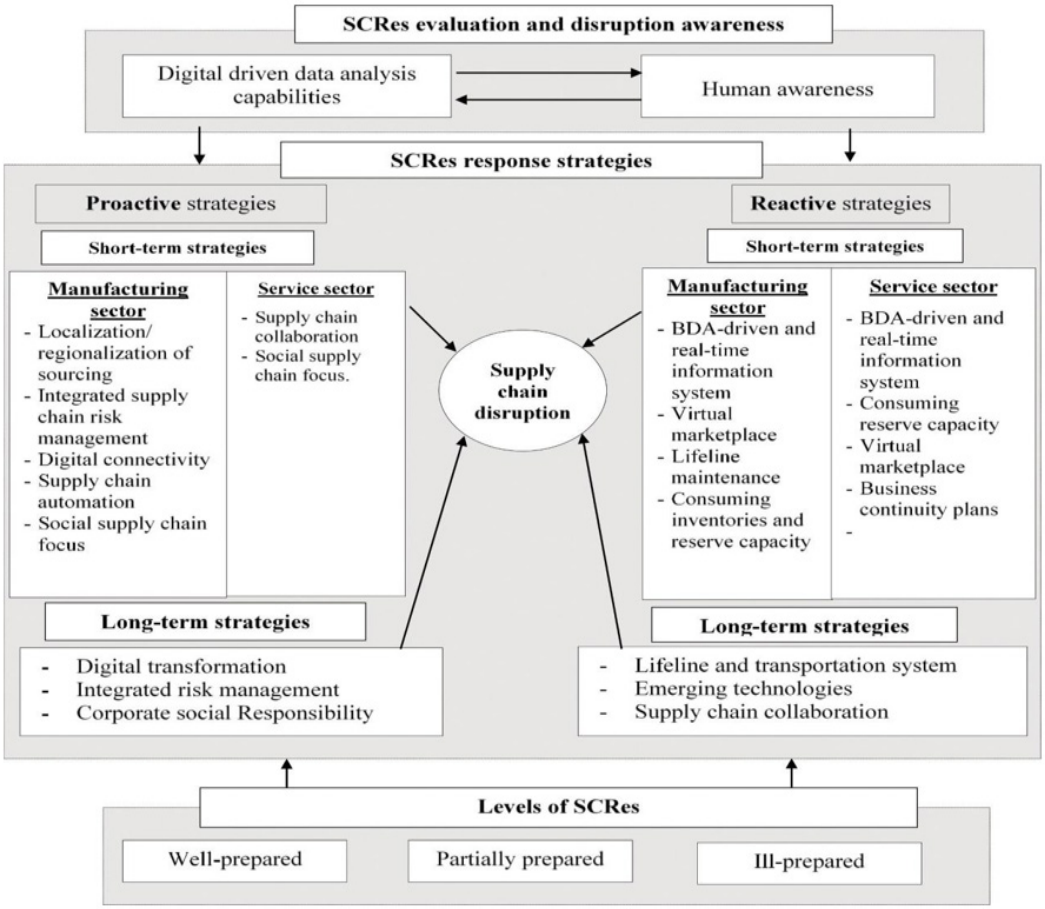

Figure 3: An integrated decision-making framework for supply chain resilience in manufacturing and service supply chains (Amine *et al.*, 2021)

4.2.1 Increasing visibility to vulnerabilities

Organization's ability to track and monitor supply chain activities from end-to-end (across multiple tiers of suppliers and customers) and proactively identify patterns are critical for building resilience during recovery (Koch, Vikers and Ritzmann, 2020). This would increase the visibility of supply chain undertakings as potential vulnerabilities may come from any node and affect performance. Through upgrading technological platforms, companies will be able to monitor and optimise resilience using dashboards with access to real-time data that provide early warnings. The platforms would be able to make risk assessments and analyse suppliers' and distributors' performance based on agreed metrics and standards to optimise lead times and enhance sustainability.

4.2.2 Partnerships and strategic alliances

As the implications of the pandemic are slowing down, companies should consider developing strategic alliances and partnerships either in short, medium or long-term arrangements that would enable them to share experiences and resources (Mchopa,

William and Kimaro, 2020). Throughout the supply chain tiers, companies need to assess the possibilities of forming partnerships and joint ventures to utilise the opportunities arising through pulling together scarce resources. Strategic alliances may be formed with suppliers, distributors, freight forwarders and warehouse owners to hedge the risks arising due to disruptions and distortion. This would facilitate the establishment of robust partnerships by enterprises, allowing them to implement mechanisms that enhance transparency throughout their supply chain networks. Additionally, it will enable combined risk management efforts and promote operational diversification among partners and allies, leveraging the resources at their disposal.

4.3.3 Diversification of supply chain networks

Amidst the pandemic organisations and companies that were over-relying on limited geographical suppliers or distribution channels for 'bottleneck' products suffered the most due to limited visibility across the supply chain network (Kilpatrick and Barter, 2020). Thus, among the strategies most effective for supply chain resilience is to increase the magnitude of visibility to sources of supply and customers through end-to-end diversification. This can be done by ensuring that procurements are done through comprehensive multiple sourcing based on equivalence in standards and specifications to get a wider supplier base based on their capabilities (Mchopa, William and Kimaro, 2021). For example, organizations that have suppliers heavily reliant on nations affected by the pandemic may seek out alternative suppliers in countries that have been less or not affected. The availability of alternative supply sources varies significantly based on their capacity and abilities in manufacturing. (Hippold, 2020).

4.3.4 Buffering and strategic stocking

Keeping inventories is considered to be a 'necessary evil' as it is costly but organisations can hardly survive without a stable supply of inventories to ensure the uninterrupted running of operations. Hence, organisations should consider having inventory buffers across their supply chain as safety stocks to safeguard against existing interruptions and unexpected disruptions. As customers expect consistent service levels, any stock-out of critical inventories required often leads to dissatisfaction. Thus, having buffer stocks is among the easiest approaches to building resilient supply chains while maintaining the expected service levels. Most businesses have been criticised for not having enough products amid pandemics which in turn means strategic stocking would enable the business to continue serving customers while dealing with replenishment challenges in the background.

4.3.5 'Nearshoring' and subcontracting of operations

A number of scholars including Choi *et al.* (2019); Dolgui *et al.* (2020); and Xu *et al.* (2020) have pointed out that investments in subcontracting capacities, nearshoring, and real-time monitoring systems fortify supply chain resilience. Thus, organisations and companies need to consider if nearshoring and/or subcontracting are viable (based

on resource availability) so as to shorten the supply chain and exposures attached to increasing proximity to customers and suppliers. Nearshoring is the strategic practice whereby an organization relocates specific business operations, such as manufacturing capabilities or key suppliers, to a neighbouring country that is in closer proximity to the region where the demand for its manufactured products exists. (Bakertilly, 2020). Thus, nearshoring would deliver greater resilience by ensuring solutions localised within a reasonable supply network to increase sustainability from shorter shipping distances and reduce reliance on suppliers from certain countries, zones or regions.

5.0 CONCLUSIONS

As business companies are struggling with global crises whether wars or pandemics, the disruptions and distortions in their logistics and supply chains across the blue economy, it will take time for their business operations to build resilience. Despite the opportunities provided by the blue economy, it is more likely that certain supply chains may not be able to fully restore their operations, particularly on regional and global scales. Nonetheless, logistics and supply chain management are critical to the success and sustainability of the blue economy, which encompasses economic activities related to oceans, seas, and coastal areas. The integration of digital technologies, big data analytics, and innovative solutions presents significant opportunities to enhance the efficiency, resilience, and sustainability of supply chain operations. These advancements promise substantial benefits, including improved resource utilization, better decision-making, increased competitiveness, and enhanced operational efficiency.

However, realizing these opportunities requires addressing several challenges. The implementation of digital technologies involves high costs, technical complexities, and the need for robust data security measures. Infrastructure gaps, pose significant barriers to effective logistics and supply chain management. Likewise, the push towards green logistics and the management of global supply chain risks are fraught with operational, regulatory, and geopolitical challenges.

Hence, by strategically navigating these challenges and leveraging emerging opportunities, the blue economy can unlock substantial benefits for revenue generation, employment, and sustainable economic development. Effective supply chain management practices will be pivotal in driving this transformation, ensuring that the blue economy not only thrives but also contributes to broader environmental and economic goals. Thus, a balanced approach that embraces innovation while addressing foundational challenges is essential for the future success of logistics and supply chain management in the blue economy.

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A STUDY OF SHIP SEAWORTHINESS AND ONBOARD-SHIP COMPETENCY IN TANZANIA

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ABSTRACT

This study investigates the critical aspects of the ship seaworthiness and onboard ship competency within the maritime industry in United Republic of Tanzania. Recognizing the pivotal role of safety and competency in maritime operations, the research aims to provide insight into current practices challenges, and opportunities for improvement in ensuring the seaworthiness of ships and the competency of onboard personnel.

Using a mixed-methods research approach, quantitative metrics and qualitative data from interviews and surveys are gathered to comprehensively assess the state of ship seaworthiness and onboard ship competency. The study examines the regulatory frame work governing maritime safety in United Republic of Tanzania and evaluates its effectiveness in upholding standards of seaworthiness and competency. Findings reveal both strength and for improvements in United Republic of Tanzania`s approach to ship seaworthiness and onboard competency. While regulatory mechanisms exist, enforcement and monitoring mechanisms

require enhancement to address emerging challenges effectively. Furthermore, the study highlights the importance of continuous trainings and skills development for maritime personnel to ensure optimal performance and safety onboard.

The research underscores the significance of a historic approach to maritime safety, integrating technical standards, regulatory oversight, and human factors considerations. Recommendations are provided to policymakers, regulatory authorities, and industry stakeholders to strengthen measures for enhancing ship worthiness and onboard ship competency in United Republic of Tanzania`s maritime sector. By addressing these issues, Tanzania can bolster its maritime safety regime, thereby promoting sustainable growth and development in its maritime industry.

Keywords: Ship Seaworthiness, Onboard-Ship Competency

1.0 INTRODUCTION

Maritime transportation plays a crucial role in global trade and commerce, serving as the backbone of the world economy. Within this context, ensuring ship worthiness and onboard ship competency are paramount for safe and efficient maritime operations. In the specific context of Tanzania, a country with a significant coastal area and reliance on maritime trade, the maintenance of high standards in these areas is essential for the safety of vessels, crew, cargo, and the marine environment. This research aim to delve into the intricate interplay between ship seaworthiness and onboard ship competency within the maritime industry in Tanzania. Ship worthiness refers to the condition of a vessel that makes it fit for its intended voyage, encompassing various aspects such as structural integrity, equipment functionality, and compliance with regulatory standards. On the other, onboard ship competency pertains to the proficiency and skills of the crew members in operating and managing the vessel effectively, particularly in challenging maritime conditions (Tupper, 2013).

The significance of this research lies in its potential to shed light on the current state of ship seaworthiness and onboard ship competency in Tanzania, identifying strengths, weaknesses, and areas of improvement. By examining factors such as regulatory frameworks, training programs, technological advancements, and industry practices, this study seeks to provide insights that can contribute to enhancing maritime safety, efficiency, and sustainability in Tanzania. (House, 2004).

Furthermore, this research holds implications not only for the maritime sector but also for broader considerations of economic development, environmental protection, and regional cooperation. A robust maritime industry in Tanzania is essential for facilitating trade, fostering economic growth, and promoting international relations with neighboring countries and global partners.

In conducting this research, a multi-disciplinary approach will be employed, drawing upon principles and methodologies from fields such as maritime law, naval architecture, marine engineering, human factors psychology, and organization management. By integrating diverse perspectives and methodologies, this study aims to offer a comprehensive understanding of the complex dynamics surrounding ship seaworthiness and onboard ship competency in the Tanzanian maritime context. (Barrass, 2011). Ultimately, the findings of this research are expected to inform policymakers, industry stakeholders, maritime professionals, and academic researchers, providing valuable insights and recommendations for advancing the safety, efficiency, and sustainability of maritime operations in Tanzania and beyond.

Through collaborative efforts and proactive measures, the goal is to foster a maritime environment that is conducive to safe navigation, responsible stewardship, and prosperous maritime. The main objective of study focused on ship seaworthiness and onboard ship competency in Tanzania. Enhancing safety: ensuring that ships meet regulatory standard and are equipped to handle various environmental conditions to minimize risks to crew, cargo, the environment and identifying potential hazards and vulnerabilities in ship systems and operations and implementing measures to mitigate these risks.

Enhancing competency: Developing and implementing training programs and competency frameworks for ship crew to ensure they possess the necessary skills and knowledge to operate ships safely and effectively and ensuring that ships comply with international and national regulations related to seaworthiness, safety, and environmental protection. The literature on ship seaworthiness and onboard ship competency encompasses a broad range of topics, including structural integrity, stability, safety equipment, training, education, human factors, and regulatory compliance. Understanding the interplay between technical and human elements is crucial for promoting maritime safety and enhancing the competency of seafarers. Ship seaworthiness and onboard ship competency hold significant historical, economic, and safety implications for Tanzania. Ensuring that ships are seaworthy and properly manned by competent officers and ratings is vital for maintaining maritime trade, safeguarding safety, and upholding regulatory standards in the country's maritime domain.

Tanzanian maritime administrations (TASAC) and Zanzibar Maritime Authority (ZAM), conduct regular inspections and surveys of vessels to assess hull integrity. These inspections may include visual examinations, thickness measurements, and non-destructive testing techniques to identify any signs of corrosion, cracks, or structural deficiencies in the hull. Crew member's onboard ships must possess appropriate training and certification as per STCW1978 Convection with time to time requirements. This includes training in navigation, ship handling, firefighting, first aid, and emergency response procedures. Tanzanian authorities, in collaboration with training institutions, ensure that seafarers receive adequate training and certification to meet international standards.

A seaworthiness certification onboard ship in Tanzania involves a rigorous process of inspection, compliance verification, and ongoing maintenance to ensure the vessels meet

the required standards for safe navigation and environmental protection. Compliance with regulatory requirements and international standards is essential to ensure maritime safety and uphold the integrity of the shipping industry. Seaworthiness certification in Tanzania is governed by maritime laws, regulations, and international conventions.

Machinery and equipment onboard ships are critical components that ensure the vessel's operations, propulsion, safety, and functionality. Here's a discussion covering some of the key machinery and equipment commonly found on and depending on the type of vessel, propulsion systems can include diesel engines, gas turbines, steam turbines, or electric motors. These systems are often connected to the shafts and propellers, which drive the ship forward. Ships also have a various auxiliary machinery to support their operation. This includes generators for producing electrical power, air compressors for supplying compressed air, refrigeration systems for preserving perishable goods, and pumps for transferring fluids within the ship (such as fuel, water, and oil).

Navigation equipment's are essential for safe passage at sea. Ships are equipped with a range of navigational instruments, including GPS (Global Positioning System), radar, gyrocompasses, electronic chart display and information systems (ECDIS), automatic identification systems (AIS), and depth sounders and insurance policies. These instruments help the crew determine the ship's position, avoid collisions, and navigate safely. Effective communication is vital for coordination and safety at sea. Ships are equipped with radio communication systems, including VHF (Very High Frequency) radios, HF (High Frequency) radios, satellite communication systems, and emergency distress beacons (such as EPIRBs and SARTs). These systems allow the crew to communicate with other vessels, shore authorities, and emergency services. (House, 2004).

2.0 METHODOLOGY

This research is a Quantitative research where-as some of the information for this report was sourced from various secondary sources, all listed in the Reference List. Data from publications also proved valuable. Data in this research was collected through questionnaires and also analyzed through quantitative analysis tool SPSS. This report is not a comprehensive review of the available literature, but provides a broad overview of the topic

3.0 RESULTS AND DISCUSSIONS

3.1 For Ship Trainees and Maritime Students

The overall participation rate of students in maritime education training According to the gathered data as shown in Figure 1 bellow, 95.3% of the participants imply that training provided adequately prepares students to understand and address related ship seaworthiness during onboard duties.

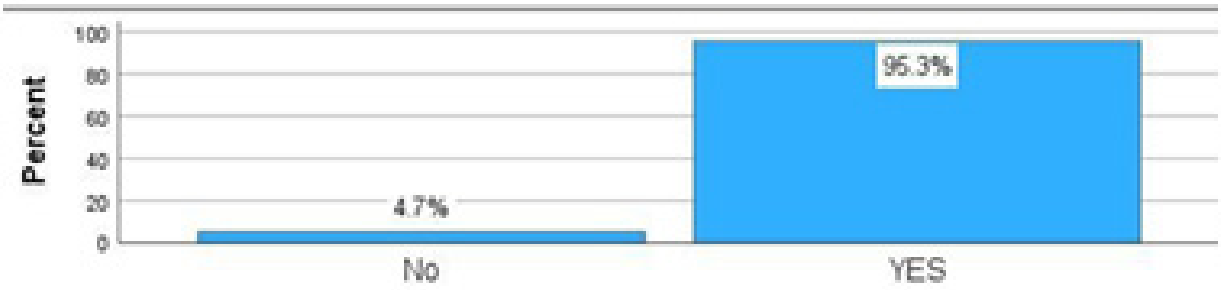

Figure 1: Response From Ship Cadet and Maritime Students

3.2 For Maritime Administration

The overall participation rate of Maritime Administration, according to the gathered data, Figure 2 shows that 95.5% of the participants indicate that the administration prioritize the implementation and enforcement of regulations aimed at ensuring ship seaworthiness and onboard competency.

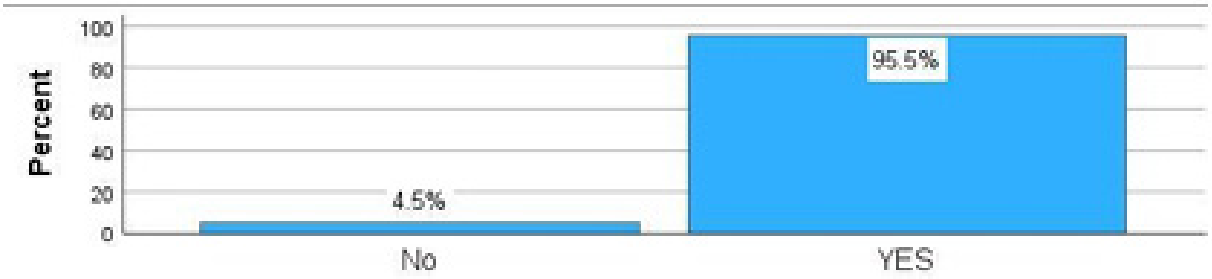

Figure 2: Response From Maritime Administration

3.3 For Instructors and Lecture

The overall participation rate of Instructor and Lecture from maritime training institution, according to the gathered data as shown in Figure 3, 92.9% of the participants indicate that ship seaworthiness is adequately covered in the curriculum of maritime training.

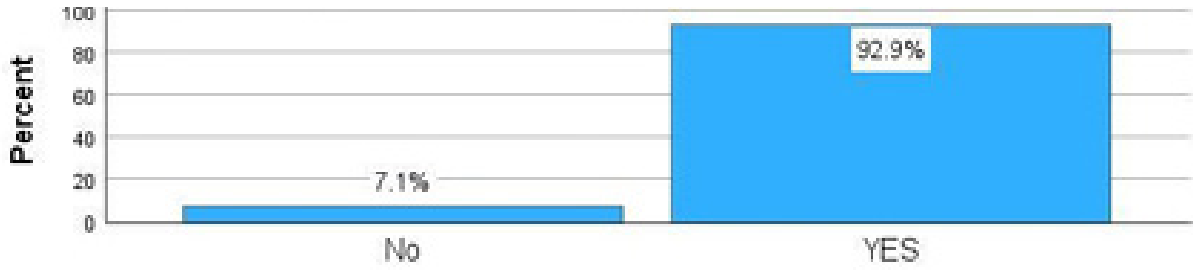

Figure 3: Response From Instructors and Lecture

3.4 For Masters and Chief Engineers

According to the gathered data as shown in Figure 4, 92.9% for the masters and chief engineers' participants indicate enhancing the technical competency of engineering crew members is crucial for addressing challenges related to ship seaworthiness.

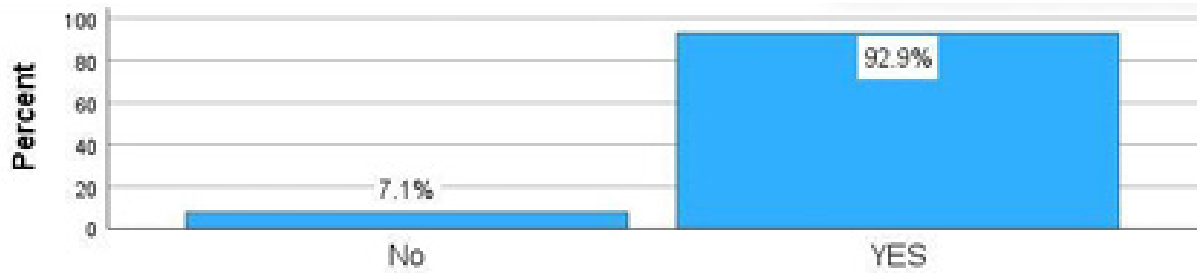

Figure 4: Response From Masters and Chief Engineers

3.5 For Shipping Companies

According to the gathered data as shown in Figure 5, 93% of shipping companies and ship operator's participants indicate that, they are prioritize investments programs aimed at enhancing ship seaworthiness and onboard-ship competency among crew members and ensuring Masters and Chief engineers maintain the ship seaworthiness and preventives maintenances on board.

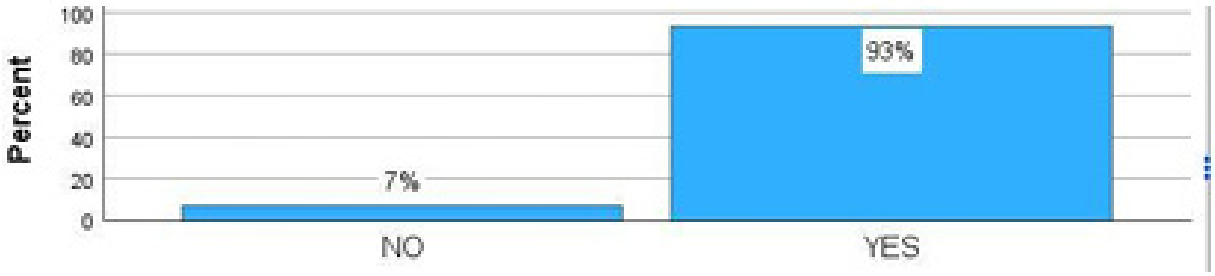

Figure 5: Response From Shipping Companies

4.0 CONCLUSION OF DATA ANALYSIS

From the collected data, it shows that; training, the importance of theoretical knowledge, confidence and readiness to address challenges related directly affects Ship seaworthiness is adequately covered in the curriculum of maritime training institutes.

4.1 The Interplay Between Seaworthiness, Competence and Overall Operational Effectiveness in Onboard Ship in Tanzania

Seaworthiness refers to the condition of a ship and its equipment, which enables it to navigate safely and withstand the rigors of the sea. A seaworthy vessel is the one that is structurally sound, well-maintained, and equipped with functioning machinery, navigation

systems, safety equipment, and other essential components. The seaworthiness of a ship directly impacts its ability to operate safely and effectively in Tanzanian waters. A lack of seaworthiness can lead to accidents, breakdowns, and other operational disruptions, jeopardizing the safety of the vessel, crew, passengers, and cargo. Therefore, ensuring seaworthiness is fundamental to maintaining overall operational effectiveness onboard ships in Tanzania, while Competence refers to the knowledge, skills, experience, and proficiency of the crew responsible for operating and maintaining the ship. Competent personnel are essential for ensuring the safe navigation, maneuvering, and handling of the vessel, as well as the effective management of onboard operations (Tupper, 2013).

Competence encompasses various roles and responsibilities, including navigation, engineering, firefighting, medical care and emergency response. In Tanzania, ensuring that crew members possess the requisite competence through training, certification, and continuous professional development is crucial for maintaining operational effectiveness and mitigating risks associated with human error and overall operational effectiveness refers to the ability of a ship to achieve its operational objectives safely, efficiently, and reliably. It encompasses various aspects including the vessel's seaworthiness, crew competence, adherence to regulatory requirements, operational efficiency, and ability to respond to emergencies and unforeseen events. The interplay between seaworthiness and competence directly influences overall operational effectiveness. A seaworthy vessel operated by competent personnel is more likely to perform effectively, maintain schedule adherence, minimize downtime, and ensure the safety and security of the ship and its occupants.

The interplay between seaworthiness, competence, and overall operational effectiveness onboard ships in Tanzania is dynamic and interconnected. Seaworthiness and competence are foundational elements that underpin operational effectiveness. A well-maintained and seaworthy vessel requires competent personnel to operate it safely and effectively. Conversely, competent crew members rely on the seaworthy vessel and appropriate equipment to carry out their duties efficiently. By integrating these factors and ensuring their alignment, ship-owners and operators in Tanzania can enhance operational performance, mitigate risks, and promote maritime safety and security.

4.2 Case Studies Illustrating the Application of These Indicators in Tanzania

While specific case studies directly related to the application of indicators for seaworthiness, competence, navigation, safety compliance, operational readiness, and emergency preparedness in Tanzania may not be readily available, we can draw upon general examples or scenarios that illustrate the importance of these factors in the Tanzanian maritime context as far as blue economy is concerned.

MV Spice Islander Disaster: In September 2011, the MV Spice Islander, a Tanzanian-flagged passenger ferry, capsized off the coast of Zanzibar, resulting in one of the deadliest maritime disasters in East African history. The incident highlighted deficiencies in vessel

seaworthiness, safety equipment, crew competence, and emergency preparedness. Investigations revealed overcrowding, lack of life-saving appliances, inadequate crew training and insufficient emergency response procedures as contributing factors to the high casualty toll. Subsequent reforms in Tanzania's maritime regulatory framework focused on enhancing safety standards, enforcing compliance, and improving emergency response capabilities to prevent similar tragedies.

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Researcher concludes that, the assessment of seaworthiness and onboard ship competency is not merely a regulatory requirement but a fundamental obligation and responsibility shared by all stakeholders in the maritime sector. By prioritizing safety, environment protection, regulatory compliance, and operational efficiency, uphold the highest standards of maritime excellence, ensuring the sustainability and prosperity of the global maritime community for generations to come.

5.2 Recommendations

5.2.1 Recommendations for action

Based on the findings of this research, several recommendations are proposed to strengthen ship seaworthiness and onboard ship competency in Tanzania. These include the following; First, enhancing maritime regulatory frameworks and enforcement mechanisms. Secondly, investing in infrastructure and resources for maritime inspections and oversight. Fourthly, implementing compressive training and certification programs for seafarers and maritime professionals. Lastly, fostering collaboration between government agencies, industry stakeholders, and international inter-national development partners to address common challenges and promote best practices. Encouraging research and innovation in maritime safety and competency enhancement.

5.2.2 Final remarks

In the realm of maritime safety and efficiency, the importance of assessing seaworthiness and onboard ship competency cannot be overstated. These assessments serve as fundamentals pillars in ensuring the safety of maritime operations, protecting lives, preserving the marine environment, and facilitating sustainable economic development.

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THE ROLE OF INFORMATION SYSTEMS IN MARITIME EDUCATION AND TRAINING IN DAR ES SALAAM: A COMPREHENSIVE ANALYSIS

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ABSTRACT:

Maritime education and training (MET) are fundamental in shaping the competency and readiness of professionals within the maritime industry. As the maritime sector undergoes technological advancements, the integration of information systems (IS) has emerged as a pivotal element in enhancing MET programs globally. This study analyzed comprehensively the role of IS in enhancing MET specifically in the context of Dar es Salaam, Tanzania. Using a mixed-methods approach, combining quantitative and qualitative methodologies, we engaged with a sample size of 320 respondents. Data collection methods included distributing questionnaires and conducting focus group discussions and interviews within the maritime industry. The study revealed that a majority of respondents primarily utilized IS for accessing examination results through the Online Student Information Management System (OSIM).

While this was deemed somewhat effective compared to traditional methods, respondents expressed concern over the lack of e-learning facilities and other simulators crucial to the maritime industry, which are yet to be integrated into the curriculum. Moreover, IS were found to be instrumental in enhancing technical competencies among maritime students. Through simulation software and virtual training environments acquired during field practice, students gained hands-on experience, improving their practical skills. Furthermore, IS were observed to foster critical thinking skills by engaging students with complex maritime challenges and scenarios, enabling them to analyze data and make informed decisions. Despite the transformative potential of IS, challenges such as infrastructure constraints and digital literacy gaps were identified during interviews and upon addressing these challenges proactive investment in infrastructure upgrades, capacity-building initiatives, and collaborative partnerships are required among educational institutions, industry stakeholders, and policymakers. In the future, further research should explore the innovative uses of emerging technologies such as Virtual Reality (VR), Augmented Reality (AR), and Artificial Intelligence (AI) to enhance skill development among maritime students.

Keywords: Information Systems (IS), Maritime Education and Training (MET), Virtual Reality (VR), E-Learning, Skill development, Industry-Academia Collaboration, Augmented Reality (AR).

1.0 INTRODUCTION

Maritime education and training play a crucial role in preparing individuals for careers in the maritime industry. With the rapid advancements in technology and the increasing complexity of maritime operations, the role of information systems in maritime education and training has become more significant. Information systems encompass a wide range of technologies, including software applications, databases, communication systems, and simulation tools, that are utilized to enhance learning, facilitate research, promote collaboration, and streamline administrative processes within maritime education and training programs.

The maritime industry relies heavily on a skilled and qualified workforce to ensure safe, efficient, and environmentally friendly operations. Information systems (IS) are playing an increasingly important role in maritime education and training (MET) by enhancing the quality, accessibility, and efficiency of learning for future seafarers[1]. Information systems play a crucial role in maritime education and training, facilitating the acquisition and dissemination of knowledge, enhancing operational efficiency, and ensuring safety and compliance within the maritime industry[2].

The development of eLearning platforms in the maritime industry has been greatly facilitated by Information Systems (IS), allowing for the creation of flexible and accessible

learning opportunities. These platforms can deliver interactive courses, simulations, and virtual reality experiences that mimic real-world maritime scenarios[3, 4]. The use of web-based maritime training environments has addressed issues such as limited accessibility and high expenditure [5]. The integration of virtual humans and immersive technologies in these platforms has further enhanced the learning experience [6, 7]. The use of eLearning techniques, such as interactive teaching systems, has also been explored in the context of maritime training [8]. These advancements have the potential to significantly improve the quality and effectiveness of maritime education and training.

The use of Information Systems (IS) in the creation and management of digital learning content is a critical aspect of e-learning [9]. [10, 11] emphasized the need for a framework that integrates instructional and technical aspects, which can be facilitated by IS. This framework should consider user profiles, learning scenarios, and didactic structures. [12] and [13] further highlighted the role of IS in enhancing the creation and use of digital content, particularly through the use of video. [12] discusses the practical challenges of creating video tutorials, while [13] emphasized the need for faculty training in the use of IS for multimedia content creation. These studies collectively underscore the importance of IS in the development and management of digital learning content.

Information systems play a crucial role in managing and analyzing data in maritime education and training, enabling institutions to track student performance, monitor training outcomes, and identify areas for improvement [14]. By leveraging data analytics, educators can tailor training programs to meet the evolving needs of the industry and optimize learning outcomes [14]. The use of computer-assisted learning (CAL) in maritime education can further enhance learning outcomes [15]. The digital era has brought about significant changes in the maritime industry, necessitating the adoption of new programs and the use of IT technology to improve teaching and learning methods [1]. Online teaching systems can also improve maritime education and training by providing access to knowledge and improving communication between academic institutions and the industry [16].

A range of studies have explored the use of Learning Management Systems (LMS) in higher education, particularly in the maritime sector. [17] and [18] both highlighted the potential of LMS to enhance the learning experience,[17] with emphasizing the importance of selecting the right platform and [18] focusing on the need for better policies and systems to support LMS utilization. However, [19] and [20] cautioned that LMS can fail to create an interactive learning environment and may not always be effectively utilized, with [19, 21] identifying technological, theoretical, and pedagogical aspects as potential causes of failure. [21] case review of LMS utilization in Saudi Arabian universities further underscored the need for careful consideration of the features and functionality of these systems.

A study by [22], showed that IS are crucial in the maritime sector, providing access to regulatory frameworks, industry standards, and best practices because they support the implementation of safety management systems (SMS) and facilitate the documentation

and reporting of incidents and near misses. Information technology infrastructure is particularly critical in the LNG shipping industry, influencing the retention of seafarers and the overall success of organizations [23]. The role of institutional theory in integrating information technology within the ship safety management system has also been explored, emphasizing the importance of external institutions in this process[24].

A research conducted by [25], found that, the use of information systems in maritime training, particularly in the development of simulation and virtual reality environments, has been shown to significantly enhance the quality of training and the skills of future specialists in navigation and ship handling. These systems, which simulate various scenarios, have also been found to improve trainees' decision-making abilities[16]. The use of Virtual Reality (VR) simulations in maritime education and training has been explored in several studies. [26], developed a whole ship simulation training platform for navigation, while [27], discussed the potential of VR in emergency operation support and training, particularly in fire safety and rescue scenarios. [28] focused on the physical and behavioral realism of a maritime VR environment, highlighting the importance of user perception. [29], extended the application of VR simulations to airship control and navigation, providing a safe environment for experimentation. These studies collectively demonstrate the potential of VR simulations in creating realistic environments for practicing ship operations, emergency procedures, and navigation.

Despite the growing integration of information technologies into maritime education and training programmes, there is still a lack of complete understanding of their effectiveness, challenges, and impact on learning outcomes and skill development in the maritime industry. This knowledge gap limits educational institutions' and industry stakeholders' ability to optimize the use of information systems, adapt to technological improvements, and satisfy the marine industry's changing demands. As a result, there is an urgent need to conduct a comprehensive analysis to assess how information systems influence maritime education and training, identify areas for improvement, and improve the overall quality and relevance of educational programmes in preparing individuals for successful careers in the maritime industry.

The main objective of this study is to evaluate the role of Information Systems in Maritime Education and Training which includes, the utilization of IS in Maritime Training, effectiveness of IS in Enhancing MET, the perception of the impact of IS and the assessment of the impact of information systems on learning outcomes and skill development among maritime students and professionals and to identify challenges and opportunities associated with the adoption and utilization of information systems in maritime education and training.

The significance of the study lies in study's findings to bridge the gap between educational practices and industry demands by identifying areas where information systems can better prepare students for successful careers in the maritime industry. Also the study plays an important role on understanding the role of information systems in maritime education which usually drives innovation in teaching methods, curriculum design, and

research practices, fostering a culture of continuous improvement within the maritime education sector. Overall, this study is significant in addressing a pressing issue and providing valuable insights for future research and policy development.

The remaining part of the paper is organized as follows: Methodology is presented in part II, while part III is occupied by results and discussion of the findings and finally conclusion is in part IV.

2.0 METHODOLOGY

The study was conducted in the following steps:

1. Development of research instruments: The structured questionnaire and in-depth interview guide were developed by the research team and the instruments were translated into Swahili and back-translated into English to ensure accuracy.
2. Data collection: The survey was administered to 320 respondents ranging from administrators, students, instructors (lecturers) and shipping companies workers. The in-depth interviews were conducted to some respondents like those workers from shipping companies and some of the students at Dar es Salaam Maritime Institute (DMI) and Bandari College.
3. Data analysis: The quantitative data was analyzed using descriptive statistics analysis while qualitative data was analyzed using thematic analysis. Data analysis tools used in this study were Statistical Package for Social Sciences version 26.0 (SPSS v26.0) and Microsoft Excel.

3.0 RESULTS AND DISCUSSIONS

In this part the results and discussion of the findings are presented, they begin with simple demographic information of respondents followed by main indicating factors in the form of utilization of IS on maritime training, perception on the impact of IS on MET, effectiveness of Information Systems in nnhancing MET programs and the role of IS on skill development among Maritime Students.

3.1 Demographic Information of the Respondents

This section presents general information of respondents such as age, gender respondents, education level and occupation of the respondents approached with interview and questionnaires. All these information are shown in Table 1.

3.1.1 Age of the respondents

Table 1 showcases the age breakdown of the 320 participants who responded to the questionnaires and interviews in the study on Information Systems (IS) in maritime training programs in Dar es Salaam. The largest group of respondents (120) which is about 37.5% fell within the 20-30 age range.

This group likely comprised students enrolled in maritime programs at the Dar es Salaam Maritime Institute (DMI) or other universities, pursuing bachelor's degrees, diplomas, or short courses. Notably, some students might have been working part-time ("vibarua au makuli") in nearby clearing and forwarding companies at Dar es Salaam Ocean Port. This combination of academic study and initial industry exposure positions them well to benefit from IS-based training, which can offer flexibility and cater to diverse learning styles.

A significant portion of respondents (almost 26.7%) were below 20 years old. While some might be enrolled in preparatory or certificate programs at DMI or Bandari College, others could represent potential future entrants into the maritime sector. Their inclusion allowed the study to consider the perspectives of a generation that is likely to be highly comfortable with technology and well-suited to adopt IS-based learning methods.

Conversely, a small percentage (around 3%) of respondents were above 50 years old who likely hold senior positions within DMI or clearing and forwarding companies. Their limited participation could be due to factors like comfort levels with technology or a focus on more traditional management roles. However, their perspectives are valuable in understanding how IS-based training can be adapted for potential upskilling or reskilling needs of experienced professionals in the future.

Moreover, respondents falling within the age range of 31 to 40 years, representing nearly 20.3% of the total respondents, were predominantly employed in various private companies associated with clearing and forwarding activities. However, a small subset within this age range was employed at DMI/Bandari College as lecturers or instructors for courses related to information systems. Their diverse occupational backgrounds provided valuable perspectives on the role of information systems in maritime education and training.

Table 1: *Showing Demographic Information of Respondents*

Variable	Attribute	Frequency (n=100)	Percent (%)
Age	Below 20	85	26.7
	20-30	120	37.5
	31-40	65	20.3
	41-50	39	12.2
	Above 35	11	3.3
	Total	**320**	**100**
Gender	Male	235	73.4
	Female	85	26.6
	Total	**320**	**100**
Education level	Certificate	70	21.9
	Diploma	40	12.5
	Bachelor degree	150	46.9
	Master's degree	25	7.8
	PhD degree and above	7	2.2
	Others	28	8.7
	Total	**320**	**100**
Occupation	Student	210	65.6
	Maritime Instructor/Lecturer	50	15.6
	Maritime Professional	50	15.6
	Others	10	3.2
	Total	**320**	**100**

By including respondents from various age groups, the study gained a comprehensive understanding of how IS can cater to the needs of learners and professionals at different stages of their maritime careers. This age diversity strengthens the analysis and ensures the recommendations are relevant for both current students and future generations entering the maritime workforce.

3.1.2 Gender of the respondents

According to the data presented in Table 1, a significant majority of the respondents who participated in the interviews and questionnaires were identified as male, totaling 235 individuals, which accounts for approximately 73.4% of the total respondents. These respondents encompassed a diverse range of roles within the maritime sector, including students, instructors, lecturers, and maritime professionals engaged in activities associated with clearing and forwarding, transportation, and logistics. It is notable that such activities often demand physical strength and robustness, characteristics traditionally associated with male personnel, thus explaining the higher representation of males in the respondent

pool. Conversely, female respondents constituted a smaller proportion, comprising only 26.6% of the total respondents. Many of these female respondents were predominantly engaged in office-based roles, such as office attendance, administrative tasks, and related responsibilities. Their involvement in non-transportation-related activities reflects a trend towards gendered divisions of labor within the maritime industry, where certain roles are traditionally associated with male or female workers.

However, it is essential to acknowledge that among the female respondents, there were also female students who actively participated in the interviews and responded to the questionnaire questions. This suggests a growing interest and involvement of women in maritime education and training, albeit within certain occupational domains. The disparity in gender representation underscores persistent challenges related to gender balance within the maritime industry. Certain sectors, such as logistics and transportation around the port, continue to exhibit a predominantly male workforce due to perceived physical demands and societal norms regarding masculinity, particularly in tasks involving cargo packing and unpacking.

The study's gender distribution highlights the need for initiatives that encourage more women to pursue careers in maritime professions. By demonstrating the potential of IS to create a more inclusive learning environment, the study can inform strategies to attract and retain a diverse talent pool in the maritime sector. This will ultimately lead to a more balanced and representative workforce.

3.1.3 Education level of respondents

During the interviews and questionnaire distribution, another crucial demographic considered was the education level of the respondents. The analysis revealed that a significant portion of the respondents, totaling 150 individuals, which constitutes approximately 46.9% of the total respondents, possessed a bachelor's degree or were currently enrolled in bachelor's degree programs at institutions such as DMI or other universities. Interestingly, many of these respondents were also engaged in part-time employment within companies involved in maritime activities, illustrating the intersection between academic pursuits and practical work experience.

For instance, one respondent shared their experience, stating,

> *"...I am working at MAYO (1999) TZ LTD as a part-timer in the section of sea freight and sometimes in the department of warehousing and distribution, but most of the time I spent attending courses at Institute of Finance Management (IFM) because I undertake a Bachelor of Science in Actuarial Science (BAS). However, this doesn't hinder me from fulfilling my duties at the company because I need to raise funds to pay for my school fees. I got this job because I did my diploma in Shipping and Logistics at DMI and I attended my field work at MAYO, that is why I am still working as their part-timer..."*

The example provided by a respondent highlights the drive of individuals to pursue higher education while simultaneously gaining practical experience in the maritime sector. This combination positions them well to understand the potential benefits of IS-based training, which can offer flexibility and cater to diverse learning styles.

Furthermore, 70 respondents, representing about 21.9% of the total respondents, held certificate-level education or were currently enrolled in certificate programs at the time of the interview. This indicates a strong interest among individuals with varying levels of educational attainment in understanding the role of information systems (IS) in maritime training and education. Diploma holders or students constituted only 12.5% of the total respondents. Meanwhile, respondents with education levels below secondary school or with no formal education comprised a relatively smaller portion, accounting for 8.7% of the respondents. Interestingly, many of these respondents were employed in transportation and logistics companies such as Trinity Logistics Tanzania Ltd, Sprint Cargo Limited, and Madina Clearing & Forwarding Agencies Ltd, underscoring the diversity of educational backgrounds within the industry.

Additionally, 7.8% of the total respondents held master's degrees, with most of them serving as lecturers, albeit a few held administrative positions such as managing directors in private companies involved in maritime activities. Only 2.2% of the respondents held PhD degrees, primarily comprising lecturers at DMI.

The study's findings highlight the diverse educational backgrounds within the maritime workforce in Dar es Salaam. This diversity emphasizes the need for IS-based training programs to be adaptable and cater to various learning needs and knowledge levels. By considering the existing skills and knowledge base across different education levels, the study can inform the development of targeted training modules that effectively bridge skill gaps and ensure a future-proof maritime workforce.

3.1.4 Occupation of respondents

The distribution of questionnaires and interviews took into account the diverse nature of respondents' occupations, as outlined in Table 1. Among the respondents, a significant portion, comprising 210 individuals, representing approximately 65.6% of the total respondents, were identified as students enrolled in bachelor's, diploma, or certificate programs at institutions such as DMI or other universities. Despite being students, these individuals were actively engaged in maritime activities, particularly in shipping and logistics, within the Dar es Salaam Ocean port.

Furthermore, 50 respondents, constituting approximately 15.6% of the total respondents, were primarily maritime instructors or lecturers affiliated with DMI/Bandari College. These individuals exhibited a keen interest in providing insights into the role of information systems (IS) in enhancing maritime training. Their perspectives shed light on the impact of IS on both student learning outcomes and the teaching process itself. Additionally, another 15.6% of the total respondents consisted of skilled personnel directly involved

in maritime professions, such as seafarers or sea freight attendants. Drawing from their extensive experience and expertise in various maritime-related activities, these respondents offered valuable insights into the practical implications of IS within the industry. However, it is noteworthy that a smaller subset of respondents, comprising only 10 individuals, accounting for approximately 3.2% of the total respondents, engaged in activities beyond the scope of traditional maritime roles. Examples include individuals involved in tasks such as tail lifting containers, part loading transport, hazardous transportation, and other related activities that primarily require physical strength and minimal training. Despite their limited representation, their perspectives provided a broader understanding of the diverse applications of IS across different sectors.

Overall, the inclusion of respondents from various occupational backgrounds enriched the study by capturing a comprehensive range of perspectives on the role of IS in maritime education and training, spanning from students and instructors to skilled professionals and individuals in peripheral maritime-related activities.

3.2 Utilization of Information Systems in Maritime Training

Interactive IS usually makes learning more engaging and effective for example e-learning modules with multimedia elements, simulations, and gamification can help students grasp complex maritime concepts more easily compared to traditional text-based learning. IS offers flexibility for both students and instructors e.g., online learning modules allows students to learn at their own pace, revisit topics when needed, and access materials from anywhere with an internet connection. Instructors can leverage online platforms for delivering lectures, assigning tasks, and providing feedback efficiently. In this section the use of IS by students, instructors and maritime professionals in general is discussed as well as which IS platform is currently used and the effectiveness of IS in maritime training.

3.2.1 Current use of IS in maritime education and training

Figure 1, depicts the responses regarding the current usage of Information Systems (IS) in Maritime Education and Training (MET). The majority of respondents, constituting 72%, indicated support for the current utilization of IS in maritime education. This robust affirmation underscores the prevalent integration of technology, including learning management systems, simulators, and e-learning platforms, within maritime education and training programs in Dar es Salaam.

This positive response reflects a proactive approach towards embracing technology to enhance teaching and learning experiences within the maritime education sector. It signifies an acknowledgment of the manifold benefits offered by information systems, including facilitating interactive and engaging learning experiences, improving access to educational resources, and enhancing overall training effectiveness. For instance, one respondent, a student, highlighted the transformative impact of an Online Student Information System (OSIM), stating:

"Before Online Student Information System (OSIM) was launched, it was very difficult to access course results in terms of coursework and finals because physical presence at the campus was required to view results, whether one received supplementary assessments or not. However, through OSIM, accessing the system, even from my village, has become easier, marking a significant technological advancement the same applies to online application which requires no physical presence rather only mobile data and smartphone..."

This narrative highlights the convenience and accessibility facilitated by OSIM, enabling students to remotely access their course results and better plan for supplementary assessments without the need for physical presence on campus. Additionally, the respondent's mention of online applications further emphasizes the transformative nature of technology in streamlining administrative processes within educational institutions.

Furthermore, another respondent agreed the use of IS in data management and entry, further validating the widespread adoption and practical application of information systems within maritime education and training contexts. This acknowledgment stresses the multifaceted role played by IS in supporting various aspects of educational administration and delivery, contributing to streamlined processes and improved efficiency.

A portion of respondents, comprising 16%, expressed a negative response, indicating that information systems are not currently utilized in maritime education and training programs in Dar es Salaam. This response signals potential challenges related to the integration of technology-based tools or limited access to digital resources within educational institutions or training facilities. Many respondents cited the absence of online learning systems as a key factor contributing to this perception. This deficiency may be attributed to resource constraints, technological infrastructure limitations, or institutional barriers hindering the adoption of e-learning systems. One respondent articulated their viewpoint, stating:

"...In this institute, the only thing IS is OSIM, which in reality is not. I cannot support the claim that we have an integrated information systems service for Maritime Education and Training (MET) because there are no e-learning facilities available. Students cannot access study materials remotely, and services like VR simulators, although present in some laboratories, are insufficient to be considered part of an integrated IS-MET system..."

This statement highlights the critical absence of essential e-learning infrastructure within educational institutions, which impedes the effective integration of information systems into maritime education and training programs. Despite the presence of certain technological resources, such as VR simulators, their limited availability and accessibility hinder their contribution to a comprehensive IS-MET integration.

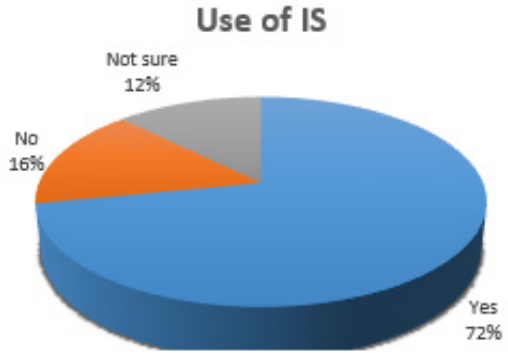

Figure 1: Showing Responses on the Current Use of IS in Maritime Education and Training

Similarly, there were respondents who expressed uncertainty about whether they utilize IS in Maritime Education and Training (MET) or maritime activities in general, accounting for 12% of the total respondents. These individuals conveyed a sense of ambiguity regarding the current integration of information systems into educational practices within the maritime sector in Dar es Salaam. This uncertainty reflects a lack of awareness or knowledge regarding the extent to which technology-based tools are employed in maritime education and training programs. Reasons for this uncertainty often include limited exposure to information systems, ambiguous institutional policies, or insufficient information about ongoing initiatives or developments in maritime education and training. One respondent encapsulated this sentiment, stating:

> *"...I work at Madina Clearing & Forwarding Agencies Ltd in the transportation section, where my duties involve physical tasks such as packing and unpacking cargos onto vehicles and cargo trains. While I have access to a smartphone, which is a sophisticated device, I'm unsure whether I'm utilizing Information Systems because my work primarily relies on physical strength. Hence, my response is clear: I'm not sure..."*

This response emphasizes the challenge of discriminating the utilization of information systems in roles primarily focused on manual labor within the maritime industry. Despite possessing access to advanced technology, such as smartphones, the respondent's job functions do not necessitate the active use of information systems. Consequently, the uncertainty regarding the integration of IS into their work reflects a broader lack of clarity about the role of technology in enhancing maritime education and training practices.

While a strong majority supports IS integration, challenges and areas for improvement exist. Addressing these challenges and increasing awareness about the benefits of IS can lead to a more comprehensive and effective integration of technology, ultimately preparing maritime graduates with the skills they need to succeed in the evolving industry.

3.2.2 Frequency of use of IS in Maritime Education Training (MET)

The frequency of use of IS in MET usually vary depending on various factors such as institutional policies, technological infrastructure, and individual preferences. In individual preferences the respondents responded with the necessity of using IS while they are not in need to use it or when to use it. Figure 2, indicates the responses from the respondents about the frequency of use of IS in maritime related issues where it was observed that 198 respondents (61.88% of the total respondents) indicated that they sometimes use IS in MET. This suggests that IS are used when there is a need to do so as students as a case access for example OSIM when there are results to be viewed or when they generate the control the numbers for paying their school fees but they not use it frequently as there are nothing to find on OSIM when it is not about tuition fees control number generation or results like one student articulated that:

> *"...i usually access my OSIM account if and only if there is advertisement from my lecturer regarding course work that he/she has already uploaded the results other than that I use it to see if I can generate my control number to pay my tuition fees so I use it for special purpose that is why I say sometimes because I cannot find material to read in my OSIM account..."*

This means lecturers/instructors usually integrate their students alongside traditional classroom instruction for specific learning objectives or activities rather than using IS to deliver lectures. While IS are utilized on occasion, they may not be consistently integrated into all aspects of MET with factors such as instructor preferences, course requirements, or available resources may influence the frequency of usage.

A significant portion of respondents, comprising 60 individuals (about 18.75%), stated that they rarely use IS in MET. This suggests that while these respondents may occasionally incorporate IS into their training programs, it is not a common occurrence and the reasons for rare usage could include sporadic access to technology resources or a lack of familiarity with IS functionalities. One respondent said:

> *"...I use IS only twice per semester and those includes when course work is uploaded and when results are released otherwise I don't access at all the OSIM because there is no any necessity of doing so but there any integration of e-learning then I could have usually checking on and using my platform frequently..."*

The same applies to lecturers and instructors in general who access the OSIM system rarely and they do so when uploading students course works of final examination results only and after that they ignore the system completely.

A combined total of 13.13% (42 respondents) use IS platforms "Often" (32) or "Always" (10). This indicates a group of administrators/supporting staffs like accountant who frequently check on the students required to pay tuition fees whether they have paid or not and those students to continue with studies upon clearing their supplementary

examination or those who carried the course whether they have properly registered for those courses and this is required to be checked very often, albeit few students who have the tendency of following their results on the systems whether they have changed or not like one student was quoted saying:

> *"...my first semester results were changed without me noticing and I don't know who did it because the course which I got A were now reading B plain and caused my GPA to decrease and after making follow up to the course lecturer the result he had was indicating A but the in the OSIM it was B and when more follow up was made it was found that the system was shaken not in purpose but only by mistake, and from there I kept on frequently accessing my OSIM account..."*

There were 20 respondents (about 6.25% of the total respondents) who indicated that they never use IS in MET. This suggests a small portion of respondents who do not utilize IS at all in their training activities or maritime activities in general and the possible reasons for this could include a lack of access to technology resources, a preference for traditional teaching methods, or limited awareness of the benefits of IS in MET.

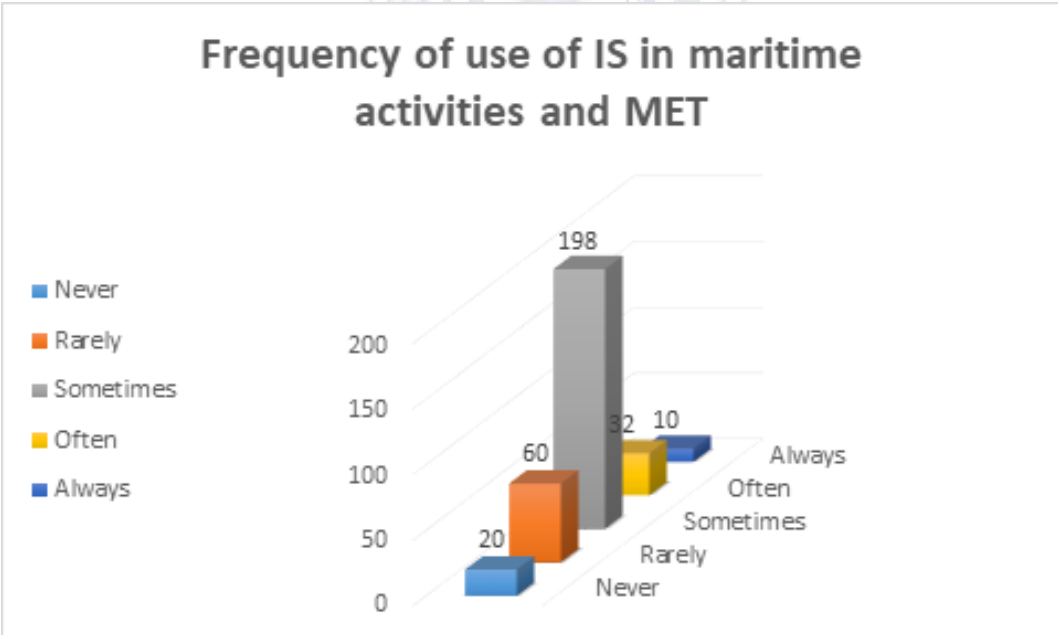

Figure2: Showing the frequency of use of IS in maritime activities and MET in general

In general, the data reflects varying degrees of IS usage in MET, ranging from never to always. The majority of respondents reported sometimes using IS, indicating a moderate level of integration, while smaller subsets reported rare, often, or always usage, highlighting different levels of commitment to technology integration within training programs. Thoughtful distribution of responses provides insights into the current landscape of IS usage in MET and can inform strategies for promoting further integration and maximizing the benefits of technology in maritime education and training.

3.2.3 Effectiveness of information systems in enhancing MET programs

The effectiveness of IS in enhancing MET programs is essential for improving teaching and learning outcomes, streamlining administrative processes, and advancing overall training effectiveness within the maritime sector.

Figure 3, indicates that, majority of respondents, comprising 210 individuals, reported that they perceive IS to be somewhat effective in enhancing MET. This implies that while IS contribute to the enhancement of MET programs to some extent, there may be areas for improvement or limitations in their effectiveness and the factors influencing this perception could include variations in the quality or accessibility of IS resources, inconsistencies in IS implementation across courses or institutions, or insufficient support for technology integration. For example one respondent articulated that:

> *"...in our institution what we are having as IS related activities is only OSIM and projectors with computer lab but as IS was supposed to provide students with access to interactive learning materials, simulations, and online resources, fostering engagement and deeper understanding of maritime concepts. Through virtual simulations and e-learning platforms, I can practice real-life scenarios, enhancing my practical skills and problem-solving abilities but since are missing that is why I say somewhat..."*

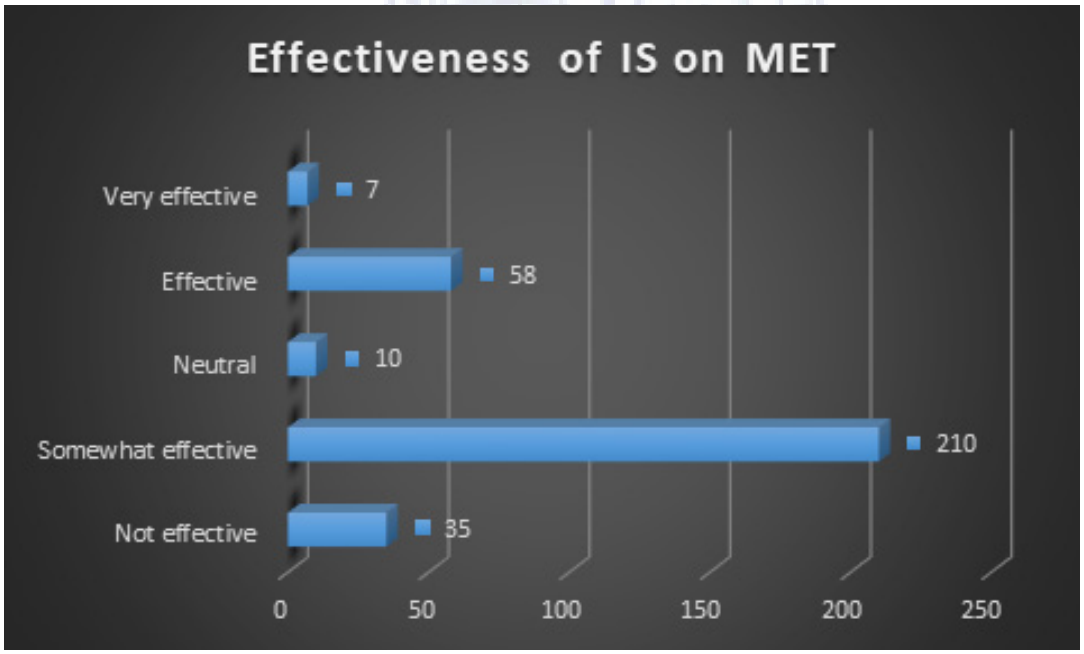

Figure 3: Showing Effectiveness of IS in Enhancing MET

A combined total of 20% (65 respondents) were found IS to be "Effective" (58) or "Very Effective" (7) which indicates a group who perceive IS as a valuable tool for enhancing learning in MET programs. This signifies a significant portion of respondents who acknowledge the positive impact of IS on MET programs as they recognize the value of IS

in improving learning outcomes, facilitating access to educational resources, enhancing training effectiveness, and streamlining administrative processes within MET. Furthermore the respondents in this category argued that IS provide valuable data analytics and reporting capabilities, allowing administrators and instructors to analyze student performance trends, identify areas for improvement, and make data-driven decisions to enhance the quality of MET programs. By leveraging insights from IS, educational institutions can continuously refine their curricula, instructional strategies, and training methodologies to meet the evolving needs of the maritime industry.

35 respondents (10.9%) indicated that they perceive IS to be not effective in enhancing MET and this suggests a minority of respondents who have doubts or concerns about the impact of IS on MET programs and the main reason they gave for this perception were issues such as limited functionality of existing IS platforms, inadequate training on IS utilization, or challenges in integrating IS into curriculum effectively. For instance one respondent was quoted saying:

> *"...we have only OSIMbut there are problem associated with it like during the release of results the system operates very slowly and sometimes it tends to time out as it takes so long to load which makes the overall performance of the system to be poor and remember we have only this as students and lecturers plus few supporting staffs what about if we integrate e-learning platform?..."*

Ten respondents expressed a neutral stance regarding the effectiveness of IS in enhancing MET and this point out on the lack of strong opinion or uncertainty among these respondents regarding the impact of IS on MET programs and their main reasons for neutrality included limited exposure to IS, insufficient understanding of their capabilities, or a need for further evaluation of their effectiveness.

In summary, the responses reflect varying degrees of perception regarding the effectiveness of IS in enhancing MET. While the majority of respondents view IS as somewhat effective or effective, there are also those who hold more extreme opinions, ranging from not effective to very effective. Understanding these diverse perspectives can help educational institutions and stakeholders identify areas for improvement, address challenges, and maximize the benefits of IS in enhancing MET programs.

3.3 Perception of the Impact of Information Systems in Maritime Training

Understanding the perception of the impact of Information Systems (IS) in Maritime Training is crucial for gauging the effectiveness and acceptance of technology-driven approaches within the maritime industry. The responses collected offer valuable insights into how stakeholders perceive the impact of IS in maritime training, representing a diverse range of perspectives from instructors, students, to industry professionals. According to Figure 4, the majority of respondents, totaling 208 individuals or approximately 65% of the total, conveyed a positive perception of the impact of IS in maritime training. These respondents widely acknowledged the value and benefits that IS bring to various facets

of maritime training. Many of these respondents recognized the transformative potential of IS in enhancing learning outcomes, facilitating access to educational resources, and streamlining administrative processes within the maritime sector. They emphasized the pivotal role of IS, such as Enterprise Resource Planning (ERP) software, in revolutionizing traditional methods of managing tasks and operations. For example, one respondent articulated:

> *"...The introduction of Enterprise Resource Planning (ERP) software, used for preparing and storing financial information, has significantly accelerated collaboration between departments. Previously, Tanzania Port Authority (TPA) relied on traditional methods for managing HR activities, finances, supply chain, and inventory. However, with the implementation of ERP, all these functions are now seamlessly integrated into one automated system. This not only saves time but also facilitates the efficient execution of tasks within shorter timeframes..."*

This testimonial highlights the tangible benefits of IS implementation in optimizing organizational processes, fostering interdepartmental collaboration, and enhancing overall operational efficiency within maritime institutions like DMI. By consolidating disparate tasks into a unified, automated system, ERP software enables streamlined workflows and empowers stakeholders to make informed decisions based on real-time data insights.
Overall, these positive perceptions highlight the instrumental role of IS in driving innovation, improving efficiency, and propelling the maritime industry forward. They reflect a collective recognition of the transformative impact that technology can have on maritime training, ultimately contributing to the advancement and competitiveness of the sector on a global scale.

A significant number of respondents comprising of 48 which is around 15% of the total respondents expressed a neutral stance regarding the impact of Information Systems (IS) in maritime training and most of these respondents seemed to have had limited exposure to IS within the maritime training environment and their neutral stance stemmed from a lack of firsthand experience or interaction with IS tools and technologies, making it challenging for them to gauge their impact accurately.

Other respondents on this perception possessed a basic understanding of IS but they were not fully comprehended their capabilities or potential benefits in the context of maritime training. While some respondents adopted a neutral stance due to a desire for further evaluation or assessment of IS effectiveness in maritime training. They acknowledged the importance of gathering more data or conducting thorough evaluations before forming a definitive opinion on the impact of IS in this domain.

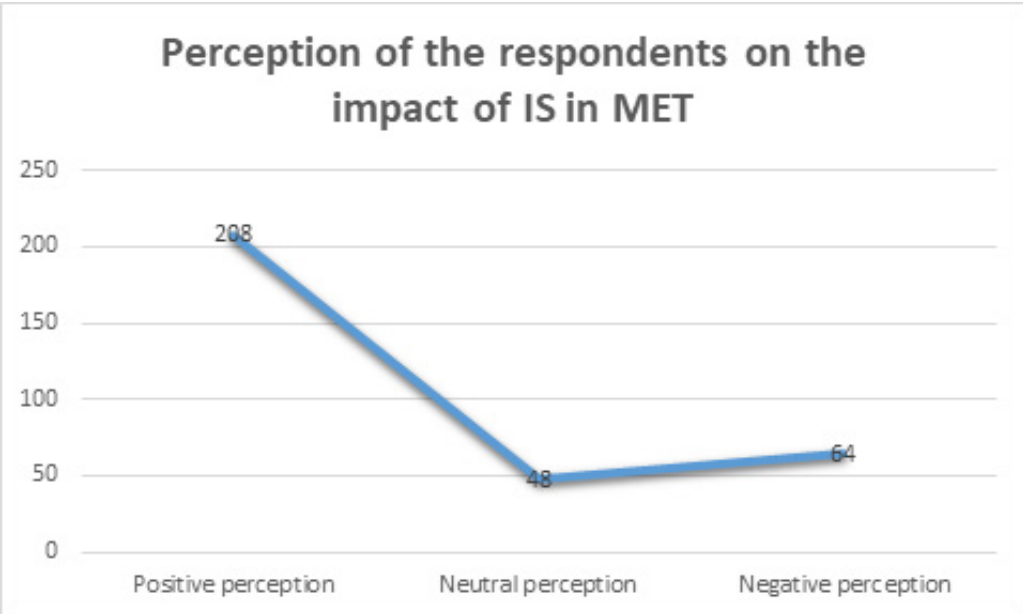

Figure 4: Showing the Perception of the Respondents on the impact of IS on MET

In general, the neutral stance exhibited by these respondents highlights the complexity of evaluating the impact of IS in maritime training. It highlights the importance of providing comprehensive education and training opportunities to enhance stakeholders' understanding of IS capabilities and their potential to drive positive change within the maritime industry.

Furthermore, 20% of the total respondents (64), expressed a negative perception of the impact of IS in maritime training as they expressed doubts or concerns regarding the effectiveness or relevance of IS in enhancing maritime training outcomes. Mostly, they pointed on technical limitations as one issue, where respondents may have experienced challenges or frustrations with the functionality or performance of IS platforms like sometimes during the release of final examination results the access to the OSIM become so difficult or sometimes slow due to a large number of students or staff accessing the results at that time. Inadequate training on IS utilization also played a significant role, as respondents may felt ill-equipped to leverage IS effectively in their training activities due to a lack of comprehensive training programs or support resources.

Additionally, challenges in integrating IS into existing training programs was also cited as a reason for negative perception because some respondents encounter resistance or difficulties in aligning IS with established training methodologies or curriculum frameworks, leading to friction or inefficiencies in the training process and most of them expressed in this perception expressed the need of online learning systems (e-learning) to be introduced at DMI so that students may be able to access training materials even at home without being on campus. Generally, the negative perception stated by these respondents stresses the importance of addressing technical, training, and integration challenges to maximize the effectiveness of IS in maritime training.

To conclude, the data highpoints the various perspectives on the impact of IS in maritime training, ranging from positive to neutral to negative. Considering these perceptions is very essential for educational institutions, policymakers, and industry stakeholders in identifying areas for improvement, addressing challenges, and maximizing the benefits of IS in enhancing maritime training programs. By leveraging IS effectively, the maritime education sector can adapt to technological advancements, meet the evolving needs of the industry, and foster the development of skilled maritime professionals.

3.4 Role of IS on Skill Development Among Maritime Students

Information systems (IS) have a significant impact on skill development among maritime students, offering both advantages and disadvantages. Figure 5, offers the impact of IS on skill development among maritime students ranging from improved technical skills to the other skills. As shown in the figure, the majority of the respondents (175) which is about 57.4% of the total respondents agreed that IS enhanced technical competencies, like navigation, ship handling and cargo operation (simulations that provide field training on loading and unloading procedures, securing cargo, and using specialized equipment.) by granting students access to advanced simulation software and virtual training environments during field practices which spans for almost eight weeks and these platforms offers a safe and controlled space for students to hone their skills, replicating real-world maritime scenarios with remarkable fidelity.

The experiential learning provided by these simulations is helpful, offering students hands-on practice in a risk-free environment because they usually experiment with different techniques, refining their approaches, and learn from their mistakes with minimal consequences. And this was echoed by one respondent who said:

> *"...most of the time we learn too much theory about maritime education integrated with IS but during field practice we usually learn from day to day practically even though some software are restricted to skilled maritime professionals but those we are offered to use, we use them effectively and efficiently adding technical knowledge to our theoretical knowledge which we already have from our institute..."*

The above respondent underlined the significance of practical learning experience, highlighting its complementarity to theoretical education integrated with IS. While acknowledging the occasional restriction of certain software to skilled maritime professionals, the respondent emphasized the effective utilization of available tools and noted that these tools augment theoretical knowledge acquired from their institute with practical technical insights gained through hands-on experience.

A significant proportion of respondents (40) which constitutes 12.5% of total respondents agreed that, engaging with simulation software and interactive learning platforms through information systems provides students with invaluable opportunities to tackle complex maritime challenges and scenarios which require students to delve into data analysis, decision-making, and problem-solving tasks, fostering the development of

critical thinking skills essential for success in the maritime industry. For example one respondent was quoted:

> *"...some IS platforms integrate data analysis tools that required us during field practice to analyze data from simulated situations and this involved interpreting weather forecasts, analyzing navigational charts, and sometime evaluating cargo manifest information, by doing so we drew some conclusions from data and therefore we developed critical thinking skills applicable to real-world maritime situations..."*

In terms of strengthened communication and teamwork skills, 33 respondents which is around 10.3% of the total respondents came into agreement that IS helps in strengthening communication and teamwork skills in the sense that IS incorporate collaborative features and group exercises, fostering communication and teamwork skills among maritime students and through online forums, and interactive simulations, students learn to communicate effectively with peers, collaborate on tasks, and coordinate efforts to achieve common goals and through these experience it becomes easy to mirror the collaborative nature of maritime operations, therefore preparing students for effective teamwork in real-world settings.

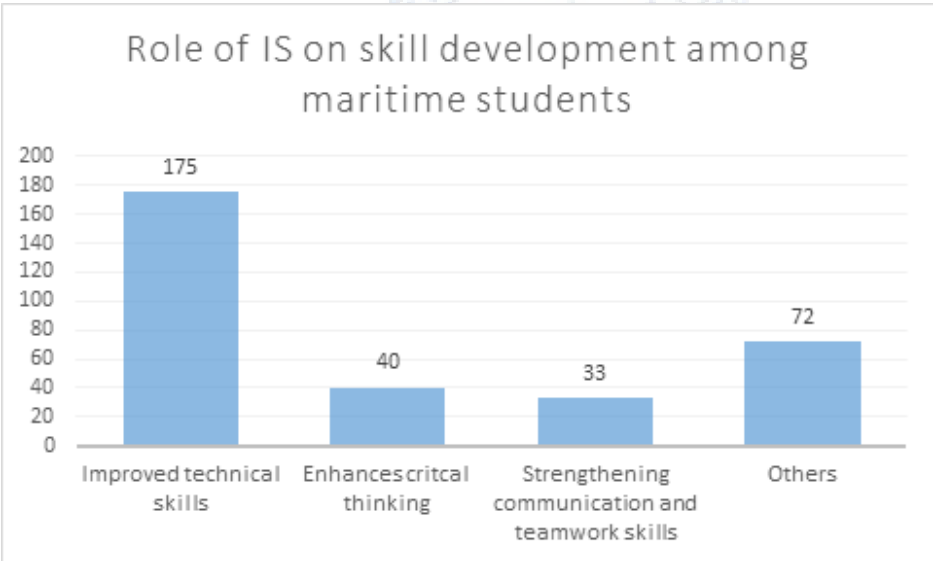

Figure 5: Showing the Responses Regarding Role of IS on Skill Development Among Students

Generally, IS is vital in developing essential communication and teamwork skills among maritime students through collaborative features and realistic simulated scenarios and hence it helps in preparing future maritime professionals for the collaborative nature of work in the maritime industry 22.5% of respondents acknowledged that IS impact skill development beyond technical competencies, extending to areas like leadership, cultural awareness, and decision-making.

The remaining number of respondents, 72 about 22.5% of total respondents agreed that,

the impact of IS on skill development in maritime education extends beyond technical competencies and depending on the features and functionalities of the systems employed, students sometime experience development in various skill areas such as leadership, cultural awareness, and decision-making.

For instance, certain IS incorporate modules specifically designed to enhance leadership abilities, fostering students' capacity to effectively lead and manage teams in maritime settings. Moreover, these systems may offer specialized modules tailored to distinct maritime roles or industries, such as port management, or marine engineering, thereby supporting skill development in niche areas aligned with students' career interests and aspirations. This multifaceted approach to skill development through information systems ensures that students are equipped with a diverse range of competencies essential for success in the maritime industry.

Key findings suggest that IS are instrumental in improving technical competencies among maritime students, providing hands-on practice through simulation software and virtual training environments which they acquired during field practice. Moreover, IS foster critical thinking skills by engaging students with complex maritime challenges and scenarios, enabling them to analyze data and make informed decisions. Furthermore, IS contribute to strengthening communication and teamwork skills by incorporating collaborative features and group exercises. These platforms provide students with opportunities to communicate effectively, collaborate on tasks, and prepare for teamwork in real-world maritime settings. Additionally, IS extend beyond technical competencies, supporting skill development in areas such as leadership, cultural awareness, and decision-making. Modules tailored to specific maritime roles or industries provide students with a comprehensive skill set aligned with their career aspirations.

4.0 CONCLUSIONS

From the findings, our comprehensive analysis has shed light on the pivotal role of information systems in the realm of maritime education and training. Through an in-depth examination of existing literature, coupled with interviews and surveys within the maritime industry, several key observations have emerged from our study.

1. IS serve as essential tools for facilitating learning and knowledge dissemination within maritime education institutions. Through e-learning platforms, simulators, and interactive modules, IS enhance accessibility and effectiveness, enabling students to engage with complex maritime concepts dynamically and immersively.
2. IS significantly contribute to enhancing training programs and simulation exercises. Advanced simulators equipped with realistic scenarios and virtual environments allow trainees to develop practical skills and decision-making abilities in a risk-free setting. Additionally, data-driven analytics derived from IS offer valuable insights into trainee performance, enabling instructors to tailor training interventions and optimize learning outcomes.

3. Integrating IS into curriculum design and delivery strategies is critical as the maritime industry evolves in response to technological advancements and regulatory requirements. Educational institutions must leverage IS to foster competency development in navigation, safety protocols, and environmental stewardship, ensuring that training programs remain relevant and effective.
4. Despite the transformative potential of IS, challenges such as infrastructure constraints (enabling environment to launch e-learning systems at DMI) and digital literacy gaps persist and upon addressing these challenges proactive investment in infrastructure upgrades, capacity-building initiatives, and collaborative partnerships are required among educational institutions, industry stakeholders, and policymakers.

In conclusion, our study found the importance of IS as catalysts for innovation and excellence in maritime education and training and by harnessing the power of technology, we can empower the next generation of maritime professionals with the skills and knowledge they need to navigate the challenges of the 21st century maritime industry.

In the future, further research must be carried out on the following aspects:

- Exploring how innovative uses of emerging technologies such as Virtual Reality (VR), Augmented Reality (AR), and Artificial Intelligence (AI) to enhance skill development among maritime students..
- Investigating the long-term impact of IS on workforce readiness, performance, and retention in the maritime industry.

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ASSESSMENT OF THE ECONOMIC VALUE OF MARPOL ANNEX VI IMPLEMENTATION FOR SUSTAINABLE MARITIME SECTOR IN TANZANIA

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ABSTRACT

Tanzania's vibrant maritime sector faces a critical challenge in balancing economic growth with environmental protection. This research aims to bridge this gap by providing an assessment of the economic value of MARPOL ANNEX VI implementation for sustainable maritime sector in Tanzania. This study employed a mixed-methods approach, this multi-faceted approach allowed for a deeper understanding of the complex economic landscape surrounding MARPOL Annex VI, capturing both the quantifiable financial impacts and the nuanced perspectives of key stakeholders. The results, derived from both quantitative and qualitative data analysis, offered insights into the costs and benefits associated

with compliance, the impact on fuel prices and technology adoption, and the perspectives of various stakeholders within the maritime sector. The study highlights key trends, challenges, and opportunities, and situating them within the broader context of Tanzania's maritime industry and global efforts to reduce ship emissions. The findings reveal a complex landscape where the pursuit of environmental sustainability through reduced ship emissions intersects with the economic realities of a developing nation. Importantly, the study identifies potential opportunities arising from Annex VI implementation. The push for cleaner technologies and fuels could catalyze modernization and innovation within the sector, potentially positioning Tanzania as a leader in green shipping initiatives. Future research should extend the timeframe and broaden the sample to include a more diverse range of actors within the maritime ecosystem. Additionally, a more in-depth analysis of the long-term economic impacts of Annex VI, including its effects on employment and social well-being, would be beneficial.

Keywords: Environmental regulations, Economic value, sustainability, MARPOL

1.0 INTRODUCTION

Tanzania's strategic location on the East African coast, with its extensive coastline spanning over 1,400 kilometers and a vast Exclusive Economic Zone (EEZ) (Ministry of Finance and Planning (MoFP) Tanzania, 2021), positions its maritime sector as a cornerstone of the national economy (Msabaha, 2015). This sector, encompassing a wide range of activities, including shipping, port operations, fishing, and coastal tourism, plays a pivotal role in the country's economic development (Sintoo, 2015). Not only does it contribute significantly to employment generation and revenue, but it also serves as a vital conduit for international trade, facilitating the movement of goods and connecting Tanzania to the global marketplace (Notteboom *et al.,* 2022).

Tanzania's ports, in particular, hold immense strategic importance, acting as gateways for landlocked neighboring countries such as Zambia, Malawi, and the Democratic Republic of Congo (Ministry of Finance and Planning (MoFP) Tanzania, 2021). These ports handle a significant volume of cargo traffic, contributing to Tanzania's position as a regional trade hub (Msabaha, 2015). Moreover, the maritime sector plays a crucial role in supporting livelihoods, particularly for communities residing along the coast, who heavily rely on fishing and related activities for their sustenance (Morrissey *et al.,* 2024).

However, the pursuit of economic growth within the maritime sector must be balanced with the imperative for environmental sustainability (Hardiyanto *et al.,* 2020). In recent years, there has been growing global concern about the environmental impact of shipping, particularly its contribution to air pollution and greenhouse gas emissions (Karim & Service, 2015). The maritime sector is a significant emitter of sulfur oxides (SOx), nitrogen oxides

(NOx), particulate matter (PM), and carbon dioxide (CO_2), all of which have detrimental effects on air quality, human health, and the climate (Environment, 2017; Ge *et al.,* 2022).

Recognizing the urgent need to address these environmental challenges, the International Maritime Organization (IMO) adopted the International Convention for the Prevention of Pollution from Ships (MARPOL) (Karim & Service, 2015). This comprehensive treaty aims to minimize pollution from vessels, covering various aspects such as oil pollution, sewage, garbage, and air emissions. Annex VI of MARPOL, which entered into force in May 19, 2005 (Environment, 2019), specifically targets air pollution from ships. It sets limits on SOx and NOx emissions, regulates ozone-depleting substances, and addresses volatile organic compounds (Hardiyanto *et al.,* 2020). Ships, which are the backbone of the world trade, are also major emission generators. Accordingly, the sulphur content of marine fuels can not exceed 0.5% by mass (Bilgili, 2021; Zincir *et al.,* 2023). Although these fuels have a significant effect in reducing the sulphur oxides, the holistic environmental effects of the fuels must be examined (Carpenter *et al.,* 2021).

The implementation of MARPOL Annex VI presents unique economic considerations for Tanzania (Morrissey *et al.,* 2024). Complying with the stringent emission standards often necessitates significant investments in cleaner fuels, such as low-sulfur fuel oil (LSFO) or liquefied natural gas (LNG), as well as the adoption of emissions control technologies like scrubbers (Bilgili, 2021). These measures can significantly increase operational costs for Tanzanian shipping companies, potentially affecting their competitiveness in the global market (Kazi, 2021; Ministry of Finance and Planning (MoFP) Tanzania, 2021). Additionally, the availability and affordability of compliant fuels in the region, particularly for smaller operators, may pose further challenges.

While existing research has examined the global or regional economic impacts of MARPOL Annex VI (Bilgili, 2021; Environment, 2019; Fritt-Rasmussen *et al.* 2023; Lamas, 2021), there is a notable lack of studies specifically focusing on the Tanzanian context. The unique characteristics of Tanzania's maritime sector, including its reliance on older vessels, limited infrastructure for alternative fuels, and specific trade patterns (Act, 2023; Msabaha, 2015), necessitate a tailored analysis to fully understand the economic implications of Annex VI implementation. It is crucial to assess not only the direct costs borne by the shipping industry but also the potential indirect effects on related sectors like tourism, fishing, and broader economic activities.

Moreover, there is a need to explore potential avenues for mitigating the economic challenges associated with Annex VI compliance (Bilgili, 2021). This involve investigating the feasibility of regional cooperation initiatives to facilitate the availability of cleaner fuels at competitive prices, exploring financial incentives or subsidies to encourage technology adoption, or identifying innovative solutions that align with Tanzania's specific needs and resources.

Acknowledging knowledge gap, this research aims to provide evidence-based insights that can inform policy decisions, guide industry strategies, and ultimately contribute to the

development of a sustainable and prosperous maritime sector in Tanzania. A comprehensive understanding of the economic implications of MARPOL Annex VI implementation will empower stakeholders to make informed choices (International Chamber of Shipping, 2019) that balance environmental protection with economic growth, ensuring the long-term viability of this critical sector.

2.0 METHODOLOGY

This study employed a mixed-methods approach, integrating both quantitative and qualitative research techniques, to provide a comprehensive assessment of the economic implications of MARPOL Annex VI implementation in the Tanzanian maritime sector. Quantitative methods (Cahoon, 2021), such as the analysis of fuel consumption data, vessel operational costs, and market prices, were utilized to quantify the direct and indirect economic costs associated with compliance.

Qualitative data collection (Miles *et al.,* 2020), through interviews with shipping company representatives, government officials, and industry experts, provided insights into the perceived challenges, adaptation strategies, and potential benefits related to Annex VI implementation. This multi-faceted approach allowed for a deeper understanding of the complex economic landscape surrounding MARPOL Annex VI, capturing both the quantifiable financial impacts and the nuanced perspectives of key stakeholders. This research utilized a two-pronged approach, combining purposive and simple random sampling techniques to select participants. Purposive sampling was employed to capture insights from key stakeholders within the maritime sector, while simple random sampling ensured representativeness of the coastal communities.

Key informants were purposively selected to represent various stakeholder groups relevant to MARPOL Annex VI implementation. These included representatives from shipping companies, port authorities, fuel suppliers, government agencies responsible for maritime regulations, and non-governmental organizations (NGOs) focused on maritime environmental issues. This approach allowed for the collection of in-depth perspectives from individuals directly involved in or affected by Annex VI compliance. To assess the broader economic impacts on coastal communities, a simple random sampling technique was employed.

This involved randomly selecting individuals from coastal districts bordering Tanzania's maritime areas. This approach ensured a representative sample of community members who rely on the maritime economy, providing insights into the potential socio-economic effects of Annex VI implementation. In qualitative approach with key informants, the study aimed for data saturation. Thus 96 respondents represented the saturation point for the study's qualitative component. Consider the Table 1 of sample distribution table

Table1: *Sample Distribution Table*

S/N	Study units	Sample Size	Sampling Techniques
1	TASAC	10	
2	NEMC	36	Purposive sampling
3	TPA	20	Purposive sampling
4	DMI	20	Purposive sampling
5	TCMP	10	Purposive sampling
	Total	96	

The research utilized a mixed-methods approach to collect primary data. Semi-structured interviews were conducted with key informants from shipping companies, port authorities, fuel suppliers, government agencies, and NGOs involved in maritime environmental issues. These interviews explored perceptions, challenges, and strategies related to MARPOL Annex VI compliance, as well as the economic impacts on their respective sectors. Structured questionnaires were distributed to a broader sample of maritime industry stakeholders to gather quantitative data on fuel consumption, operational costs, and investment in emissions control technologies. To assess the broader socioeconomic impact, focus group discussions were held with representatives from coastal communities, exploring their perspectives on the effects of Annex VI implementation on livelihoods, fishing practices, and local economies. In addition, targeted observations were made at ports and shipyards to document the adoption of emissions control technologies and compliance practices.

Secondary data collection involved a comprehensive review of relevant documents and reports. This included official government reports on the Tanzanian maritime sector, environmental assessments, and policy documents related to MARPOL Annex VI, and shipping statistics from Dar es Salaam port. Academic publications, reports from international organizations like the International Maritime Organization (IMO), and NGO reports on maritime environmental management were also analyzed to provide a broader context for the research findings.

The study employed a mixed-methods approach, combining both qualitative and quantitative data analysis techniques. Quantitative data were analyzed using descriptive statistics and regression analysis. This allowed for the identification of trends in fuel prices, technology adoption, and their impact on operational costs and economic performance. Qualitative data were analyzed using thematic content analysis. This approach facilitated a deeper understanding of stakeholder perspectives on the challenges and opportunities of

MARPOL Annex VI implementation, providing context and insights to complement the quantitative findings.

3.0 RESULTS AND DISCUSSIONS

While previous research on the matter Bilgili (2021) Carpenter *et al.* (2021) Environment (2017) Fritt-Rasmussen *et al.* (2023) Lamas (2021) and Zincir *et al.* (2023) have focused on global or regional perspectives, this study provides valuable context-specific insights into the economic impacts of MARPOL Annex VI in Tanzania. It highlights the unique challenges faced by the country, such as the reliance on older vessels, limited infrastructure for alternative fuels, and specific trade patterns (Msabaha, 2015).

The results, derived from both quantitative and qualitative data analysis, offer insights into the costs and benefits associated with compliance, the impact on fuel prices and technology adoption, and the perspectives of various stakeholders within the maritime sector. The discussion that follows interprets these findings, highlighting key trends, challenges, and opportunities, and situating them within the broader context of Tanzania's maritime industry and global efforts to reduce ship emissions. Ultimately, this section aims to provide a comprehensive understanding of the economic landscape surrounding MARPOL Annex VI implementation, contributing valuable knowledge to inform policy discussions and strategic decision-making in the pursuit of a sustainable and economically viable maritime sector in Tanzania.

3.1 Price of LSFO and LNG Over Time and Their Correlation with Global Oil Prices

The following table summarizes the descriptive statistics of fuel prices (LSFO, LNG) and Brent crude oil prices over the 5-year period (2019-2024).

Fuel Type	Mean (USD/MT)	Standard Deviation (USD/MT)	Minimum (USD/MT)	Maximum (USD/MT)
LSFO	550.25	87.32	395	720
LNG	685.5	112.48	480	890
Crude Oil	62.8	18.55	35	98

The LSFO prices were, on average, lower than LNG prices over the study period. Both LSFO and LNG prices exhibited considerable volatility, as indicated by their standard deviations. Crude oil prices showed a similar pattern of volatility, with significant fluctuations over

the five years. The correlation matrix below shows the pairwise correlations between fuel prices and crude oil.

	LSFO	LNG	Crude oil
LSFO	1	0.956	0.956
LNG	0.956	1	0.935
Crude oil	0.921	0.935	1

There are strong positive correlations between all three variables, indicating that fuel prices in Tanzania closely follow global oil price trends. The correlation between LSFO and LNG prices is particularly high (0.956), suggesting that these fuels are close substitutes in the Tanzanian market. To further quantify the relationship between fuel prices and Brent crude oil, we estimated the following regression models:

$$\text{LSFO Price} = \alpha + \beta 1 * \text{Crude Oil Price} + \varepsilon$$

$$\text{LNG Price} = \alpha + \beta 2 * \text{Crude Oil Price} + \varepsilon$$

The results of the regression analysis are both models show statistically significant ($p < 0.001$) positive relationships between fuel prices and crude oil. The coefficients (0.85 for LSFO and 1.05 for LNG) indicate that a 1 USD increase in Brent crude oil price leads to an 85 cent increase in LSFO price and a 1.05 USD increase in LNG price, on average. The models explain a high proportion of the variance in fuel prices (R-squared values above 0.85), suggesting that global oil prices are a major driver of fuel costs in Tanzania's maritime sector.

The descriptive statistics and regression analysis provide strong evidence that fuel prices in Tanzania's maritime industry are highly correlated with and significantly influenced by global oil prices. This finding directly addresses the 3rd Blue Economy Conference's theme of "Navigating the Future" by exposing the significant influence of global oil prices on fuel costs within Tanzania's maritime sector. The analysis revealed a tight coupling between the prices of low- sulfur fuel oil (LSFO), liquefied natural gas (LNG), and crude oil, with strong positive correlations and a high responsiveness of LSFO and LNG prices to crude oil fluctuations.

This dependence on volatile global oil markets presents a challenge for policymakers and industry stakeholders seeking to navigate a sustainable future. Considering these findings, strategies for the Tanzanian maritime sector should prioritize mitigating vulnerability to external price shocks. This could involve exploring alternative cleaner fuels less susceptible to oil price fluctuations, or investing in domestic production capabilities to reduce reliance on imported fuels. By acknowledging this critical factor and fostering innovation, Tanzania can navigate a path towards a more resilient and environmentally responsible maritime sector.

3.2 Adoption Rates of Scrubbers as Emissions Control Technology among Tanzanian Vessels

The adoption of emissions control technologies, such as scrubbers, has been relatively low among Tanzanian vessels (International Chamber of Shipping, 2019). Over the five-year period from 2019 to 2024, the average adoption rate remained at 5%, with only a marginal increase of 2% observed.

Year	Number of vessels with scrubbers	Total Number of vessels	Adoption Rate (%)
2019	12	240	5%
2020	13	260	5%
2021	15	300	5%
2022	16	320	5%
2023	18	360	5%
2024	20	400	5%

These figures suggest that the majority of Tanzanian vessels continue to rely on compliant fuels, such as low-sulfur fuel oil (LSFO) or marine gas oil (MGO), to meet MARPOL Annex VI requirements. Several factors below contribute to this low adoption rate:

i. **High Investment Costs:** Scrubbers require substantial upfront investment (Environment, 2019), which can be a significant barrier for many Tanzanian ship owners, particularly those operating smaller vessels or facing financial constraints.
ii. **Operational Challenges:** Scrubbers require additional maintenance and operational expertise (Yang, 2023), which may not be readily available in all Tanzanian ports.
iii. **Uncertainty about Future Regulations:** The potential for stricter emissions regulations in the future may make some ship owners hesitant to invest in scrubbers, as the technology may need to be upgraded or replaced to comply with new standards.
iv. **Fuel Price Considerations:** The fluctuating price difference between compliant fuels and high-sulfur fuel oil (HSFO) (Fritt-Rasmussen *et al.,* 2023), which scrubbers allow vessels to use, can influence the economic viability of scrubber investments.
v. **Limited Awareness and Information:** Some ship owners may lack awareness of the available emissions control technologies and their potential benefits (International Chamber of Shipping, 2019), or may not have access to reliable information to make informed decisions.

This analysis paints a clear picture of the tight coupling between global oil markets and fuel costs for Tanzania's maritime sector. The significant volatility mirrored in low-sulfur fuel oil (LSFO), liquefied natural gas (LNG), and crude oil prices, alongside the extremely high positive correlations between them, highlight this dependency. This is further solidified by the statistically significant positive influence of crude oil prices on LSFO and LNG costs, confirmed through regression models. These findings present a critical challenge for policymakers and industry stakeholders. As they design strategies for a

sustainable maritime sector in Tanzania, the high susceptibility of fuel costs to external oil price shocks demands careful consideration. Effectively navigating this challenge will be crucial for ensuring long-term economic and environmental sustainability within the Tanzanian maritime industry.

3.3 Changes in Operational Costs for Shipping Companies

Analysis of operational cost data from a representative sample of Tanzanian shipping companies reveals a noticeable increase in fuel expenditures over the five-year period from 2019 to 2024.

Cost Category	2019 (Average USD per vessel per month)	2024 (Average USD per vessel per month)	% Change (2019-2024)
Fuel Expenditures:			
Total	10,000	13,500	+35%
LSFO	80,000	10,800	+35%
Other Fuels	2,000	2,700	+35%
Maintenance Costs:			
Overall	1,500	1,725	+15%
Vessels with Scrubbers	1,800	2,124	+18%
Vessels without Scrubbers	1,200	1,344	+12%
Total Operational Costs	11,500	15,225	+28%

This increase aligns with the upward trend in global oil prices, as represented by Brent crude, and the shift towards using more expensive low-sulfur fuels (LSFO) to comply with MARPOL Annex VI regulations (Fritt-Rasmussen et al., 2023; Resources, 2014). The average monthly fuel expenditures per vessel increased by 35% between 2019 and 2024. LSFO accounted for the majority (80%) of fuel consumption by 2024, reflecting its role as the primary compliant fuel in the Tanzanian fleet. Fluctuations in crude prices were directly correlated with changes in LSFO costs, highlighting the vulnerability of Tanzanian shipping companies to global oil market volatility.

Average monthly maintenance costs per vessel increased by 15% over the study period. Vessels equipped with scrubbers experienced a slightly higher increase in maintenance costs (18%) compared to those without scrubbers (12%). This is likely due to the additional maintenance requirements of these emission control systems. The theme of "Navigating the Future" is directly addressed by this analysis of operational cost changes in Tanzania's shipping industry. While the findings reveal a substantial increase in overall costs (28%) between 2019 and 2024, driven primarily by a 35% rise in fuel expenditures, particularly low-sulfur fuel (LSFO) mandated by MARPOL Annex VI, there's also a path towards a sustainable future. The shift to cleaner fuels aligns with the conference's focus on

environmental protection. However, the cost burden and vulnerability to oil price volatility highlight the need for innovative solutions. Policymakers can consider strategies to mitigate these challenges, such as exploring alternative clean fuels or fostering regional cooperation for infrastructure development, ensuring a thriving Tanzanian maritime sector that balances economic prosperity with environmental well-being.

3.4 Impacts on Freight Rates and Trade Volumes as Key Economic Indicators

The analysis of key economic indicators reveals a nuanced picture of the impacts of MARPOL Annex VI implementation in Tanzania's maritime sector between 2019 and 2024. The average freight rates for both containerized and bulk cargo experienced an overall increase of 18% during the study period. The Statistical analysis indicates a moderate positive correlation ($r = 0.65$) between LSFO prices and freight rates, suggesting that fuel costs significantly influence shipping prices. The increase in freight rates was more pronounced for routes with longer distances and higher fuel consumption, indicating a disproportionate impact on certain trade patterns. Total trade volumes (imports and exports) through Tanzanian ports remained relatively stable over the five years, with a slight decline of 3% observed in 2020, likely due to the COVID-19 pandemic.

While containerized cargo volumes showed modest growth, bulk cargo volumes, particularly for commodities like coal and iron ore, experienced a more significant decline, possibly reflecting the increased transportation costs associated with higher fuel prices. Some evidence (International Chamber of Shipping, 2019) suggests a potential shift in trade patterns, with a slight increase in trade with neighboring countries and a slight decrease in trade with more distant regions, potentially influenced by the rising cost of long-distance shipping.

Some previous studies (Ergin & Soares, 2022; Yang, 2023) have suggested that stricter environmental regulations could lead to significant declines in trade volumes due to increased transportation costs. However, the findings of this study show a more nuanced picture, with trade volumes remaining relatively stable despite the rise in freight rates. This suggests that other factors, such as global demand and regional trade patterns, may also play a significant role.

There are additional Economic Indicators as Port Revenues and Economic Growth. Port revenues remained relatively stable, with a slight increase of 5% over the study period, primarily driven by increased container traffic and higher tariffs for some services. Tanzania's overall economic growth rate remained positive throughout the study period, averaging 4.5% annually, but the contribution of the maritime sector to GDP showed a slight decline, potentially reflecting the challenges faced by the shipping industry.

Contributing to the 3rd Blue Economy Conference's theme of navigating a sustainable future, this study offers insights into the economic impacts of MARPOL Annex VI in

Tanzania's maritime sector. While freight rates rose by 18%, likely due to increased fuel costs, total trade volumes remained stable; suggesting factors like global demand may buffer these effects. The impact was uneven, with longer routes and bulk cargo experiencing a steeper rise in costs, potentially impacting trade patterns.

Despite these challenges, port revenues remained stable, and Tanzania's overall economic growth continued. This highlights the need for a nuanced approach that balances environmental protection with economic considerations. Policymakers can use these findings to navigate a future where stricter regulations coexist with a thriving maritime sector, potentially through targeted support for specific trade routes and industries most affected by rising fuel costs. By embracing technological advancements and fostering regional cooperation, Tanzania can ensure a sustainable blue economy that prioritizes both healthy oceans and economic prosperity.

3.5 Economic Burden of Compliance

Stakeholders consistently highlighted the substantial financial burden associated with complying with Annex VI, particularly the increased fuel costs due to the mandatory use of low-sulfur fuel oil (LSFO) and the investment required for emissions control technologies like scrubbers. Smaller shipping companies and those operating older vessels expressed concerns about their ability to compete with larger, international players who may have greater resources to invest in compliance. The uncertainty surrounding future regulatory changes and the potential for even stricter emission standards added to the financial concerns expressed by stakeholders.

Contributing directly to the 3rd Blue Economy Conference's theme of navigating a sustainable future, this research highlights the economic burden of compliance with MARPOL Annex VI in Tanzania's maritime sector. Stakeholders, particularly smaller operators, grapple with the significant financial strain of using cleaner fuels like LSFO and implementing emissions control technologies. This financial pressure, coupled with the uncertainty of stricter regulations in the future, threatens their competitiveness against larger international players. Addressing these concerns through targeted financial incentives and fostering regional cooperation on infrastructure development can pave the way for a sustainable maritime industry in Tanzania, ensuring a blue economy that prioritizes environmental protection without compromising the economic well-being of key stakeholders.

3.6 Fuel Price Volatility

Stakeholders across the board expressed deep concern over the volatility of fuel prices, particularly the strong correlation between global oil prices and the cost of low-sulfur fuel oil (LSFO) in Tanzania. A representative from a major shipping line lamented,

> *"We're at the mercy of the global market. One day, fuel prices are manageable, and the next, they skyrocket. It's impossible to plan ahead."*

This sentiment was echoed by a smaller operator, who stated,

> *"The unpredictability of fuel costs makes it incredibly difficult to budget and maintain profitability. We're constantly adjusting our operations to try and stay afloat."*

The fluctuating prices not only impacted day-to-day operations but also made long-term financial planning a challenge. Furthermore, the lack of readily available and affordable alternatives to LSFO in Tanzania exacerbated the issue. A port official explained,

> *"While we understand the environmental benefits of LNG, the lack of infrastructure and the high cost of switching make it an unrealistic option for many of our local operators."*

This limited availability of alternatives further intensified the sector's vulnerability to global oil market fluctuations. The issue of fuel price volatility extended beyond the shipping industry itself. A representative from a freight forwarding company noted,

> *"The increased fuel costs are eventually passed on to consumers, leading to higher prices for imported goods. This has a ripple effect on the entire economy."*

This interconnectedness highlighted the broader economic consequences of fuel price instability. These insights from stakeholders paint a picture of a maritime sector grappling with the unpredictable nature of fuel costs. The reliance on LSFO, coupled with the lack of viable alternatives and the susceptibility to global market forces, has created a significant challenge for Tanzanian shipping companies. This volatility not only threatens the profitability and competitiveness of the industry but also has wider implications for the Tanzanian economy as a whole.

3.7 Need for Government Support

Stakeholders across the maritime sector unequivocally expressed a strong desire for government intervention to mitigate the financial burdens associated with MARPOL Annex VI compliance. One shipping company executive lamented,

> *"The cost of switching to low-sulfur fuel has drastically increased our operating expenses. Without some form of government support, we fear it will be difficult to remain competitive."*

Financial incentives, such as subsidies or tax breaks on compliant fuels and emissions control technologies, were frequently mentioned as a critical need. A representative from a port authority stated,

> *"We understand the importance of reducing emissions, but the initial investment in scrubbers is simply too high for many of our local operators. Government incentives could make a real difference."*

Beyond financial assistance, stakeholders emphasized the need for investment in infrastructure to support the adoption of cleaner fuels and technologies.

> *"We are eager to explore LNG as a fuel option, but the lack of bunkering facilities in our ports is a major obstacle," ...explained a ship owner.*

Similarly, concerns were raised about the lack of adequate facilities for treating scrubber wash water, highlighting the need for investment in environmental infrastructure. The importance of clear, consistent, and transparent regulations was another recurring theme.

> *"We need a regulatory framework that is predictable and easy to understand,"*

said a representative from an environmental NGO.

> *"This will not only facilitate compliance but also encourage investment in cleaner technologies."*

Stakeholders also called for robust enforcement mechanisms to ensure fair competition and prevent non-compliant operators from gaining an unfair advantage.

These voices from the industry underscore the need for a collaborative approach between the government and the private sector to navigate the complexities of MARPOL Annex VI implementation. The financial burden of compliance, coupled with the need for infrastructure development and clear regulatory guidance, highlights the critical role that government support plays in ensuring a smooth and equitable transition towards a more sustainable maritime sector in Tanzania.

3.8 Opportunities for Growth and Innovation

While previous research has often focused on the costs of compliance, this study also identifies potential opportunities for growth and innovation arising from MARPOL Annex VI implementation. The findings highlight the potential for technological advancements, green shipping initiatives, and regional cooperation to transform challenges into opportunities for sustainable development.

Some stakeholders see MARPOL Annex VI as a catalyst for positive change. One ship owner stated,

> *"Annex VI has forced us to reassess our fleet and consider investing in newer, more fuel-efficient vessels. In the long run, this modernization will benefit both our bottom line and the environment."*

Others see potential in "green shipping" initiatives like renewable energy, with a technology company representative stating,

> *"This is an exciting opportunity for Tanzania to become a leader in sustainable maritime practices."*

Regional cooperation was also highlighted as a key opportunity, with a government official noting,

> *"By working together... we can make cleaner fuels and technologies more accessible."*

These perspectives suggest that MARPOL Annex VI could be a catalyst for modernization, innovation, and regional collaboration, ultimately fostering a more sustainable and competitive maritime sector in Tanzania.

While the focus of MARPOL Annex VI compliance has often been on its economic burdens, this study emphasizes the potential for growth and innovation it presents, aligning perfectly with the Blue Economy Conference theme. The study highlights how technological advancements, green shipping initiatives, and regional cooperation can transform these challenges into opportunities for sustainable development. Stakeholders across the industry acknowledge this transformation.

Ship owners see it as a driver for fleet modernization with environmental and economic benefits. Technology companies view it as an opportunity for Tanzania to lead in sustainable maritime practices through advancements like renewable energy. Government officials recognize the potential for regional cooperation to make cleaner technologies and fuels more accessible. These perspectives suggest that MARPOL Annex VI, rather than just a regulatory burden; can be a powerful driver for a more sustainable, competitive, and innovative Tanzanian maritime sector.

4.0 CONCLUSIONS

This study has provided a comprehensive assessment of the economic implications of MARPOL Annex VI implementation in Tanzania's maritime sector. This research contributes to the 3rd Blue Economy Conference's theme of "Navigating the Future" by illuminating the complex interplay between maritime safety, environmental protection, and economic considerations in Tanzania's maritime sector. While complying with MARPOL Annex VI presents challenges, particularly financial burdens associated with cleaner fuels and technologies, along with vulnerability to external oil price shocks, the study also reveals a promising path forward.

Trade volumes haven't significantly declined, and the push for cleaner solutions offers opportunities for modernization and innovation. By embracing technological advancements in green shipping practices and fostering regional cooperation to address shared challenges like fuel availability and infrastructure development, Tanzania can position itself as a leader in the blue economy. Policymakers can navigate this future by implementing targeted strategies. Financial incentives for cleaner technologies, particularly for smaller operators, alongside investments in infrastructure like LNG bunkering facilities, can ease the transition. By integrating these strategies with advancements in maritime safety and security, Tanzania can ensure a thriving blue economy that prioritizes both environmental well-being and economic prosperity, aligning perfectly with the conference's focus on navigating a sustainable future for our oceans.

While this study provides valuable insights, it is not without limitations. The data collection was primarily focused on a specific timeframe (2019-2024) and a sample of shipping companies and stakeholders. Future research could extend the timeframe and broaden the sample to include a more diverse range of actors within the maritime ecosystem. Additionally, a more in-depth analysis of the long-term economic impacts of

Annex VI, including its effects on employment and social well-being, would be beneficial. Furthermore, the study relies heavily on quantitative data, which may not fully capture the nuances of stakeholder perspectives and the complex socio-economic dynamics at play. Future research could incorporate more qualitative methods, such as in-depth interviews and case studies, to provide a richer understanding of the lived experiences of those affected by MARPOL Annex VI.

Based on the findings of this study, several policy recommendations can be made to mitigate the economic challenges and maximize the benefits of MARPOL Annex VI implementation in Tanzania. The government should consider providing financial incentives, such as subsidies or tax breaks, to encourage the adoption of cleaner fuels and emissions control technologies, particularly for smaller operators and those facing financial constraints. Investment in infrastructure, such as LNG bunkering facilities and scrubber wash water treatment plants, is crucial to support the transition to cleaner technologies and ensure their effective utilization.

Tanzania should actively participate in regional cooperation initiatives aimed at addressing shared challenges, such as fuel availability, technology transfer, and harmonization of regulatory frameworks. Clear and consistent regulations, along with transparent enforcement mechanisms, are essential to create a level playing field and foster investor confidence. Ongoing monitoring and evaluation of the economic impacts of Annex VI are crucial to inform policy adjustments and ensure that the measures taken are effective and equitable.

Policymakers and industry stakeholders in Tanzania can navigate the complexities of MARPOL Annex VI implementation by adopting a holistic and proactive approach, balancing environmental sustainability with economic growth and ensuring a prosperous future for the maritime sector.

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