2nd International Conference on Transport, Logistics and Management (ICTLM 2024)

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THEME:
"Promoting Transport Technologies, Logistics and Supply Chain Management for Sustainable Economy"

THE BOOK OF PROCEEDINGS

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Proceedings for the 2nd International Conference on Transport, Logistics and Management (ICTLM)

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PREFACE

The **2nd International Conference on Transport, Logistics, and Management (ICTLM 2024)** was held from 17th to 19th October 2024 at the Mlimani City Conference Center in Dar es Salaam, Tanzania. The conference was officially inaugurated by the **Hon. Prof. Makame Mbarawa**, the Minister of Transport, and brought together stakeholders from the transport sector to advance discussions aligned with both national priorities and the Sustainable Development Goals (SDGs).

With the theme "**Promoting Transport Technologies, Logistics, and Supply Chain Management for a Sustainable Economy**", the conference featured a robust program, including keynote addresses from distinguished scholars in transport, logistics, and supply chain management from Tanzania and across the globe.

Over the three days, 20 articles were presented in five thematic sessions, covering a wide range of topics related to transport technologies, logistics, and supply chain management. Presenters was allotted 20 minutes to share their insights. Presentations included contributions from prominent organizations such as the Tanzania Ports Authority (TPA), the National Institute of Transport (NIT), and international entities like Global Communities.

This year's conference built on the momentum of the 1st ICTLM 2023, which set out to establish itself as a premier event in the transport sector. ICTLM 2024 furthered this goal by promoting innovative research, advocating for advanced transport technologies, and fostering comprehensive management systems to address industry challenges.

The event brought together 200 participants from over 20 organizations within and beyond Tanzania, providing a unique platform for networking, collaboration, and the exchange of ideas. Participants called for enhanced regulation of the transport, logistics, and management professions to ensure the sector's sustainability and the delivery of high-quality services.

ICTLM 2024 served as a vital forum to showcase the latest trends, technologies, and research developments, emphasizing the need for transformative strategies to address the rapidly evolving global transport landscape.

ACKNOWLEDGEMENT

The National Institute of Transport and the Organizing Committee wish to convey sincere appreciation to all individuals and organizations that contributed to the success of the 2nd International Conference on Transport, Logistics, and Management, held in Dar es Salaam, Tanzania.

We are particularly grateful to the Government of Tanzania, especially the Ministry of Transport, for their steadfast support, which was instrumental to the success of this event.

Our deepest appreciation goes to our valued sponsors, whose generous contributions made it possible to organize this conference. Their unwavering support has been fundamental to achieving the goals of this gathering.

We also extend our gratitude to the paper reviewers for their critical evaluations and constructive feedback, the keynote speakers for their enlightening presentations, and the researchers, scholars, and professionals whose active participation facilitated meaningful discussions.

Finally, we acknowledge all participants for their active engagement, which ensured that the conference served as a valuable platform for sharing knowledge, fostering collaboration, and advancing innovation in the fields of transport, logistics, and management.

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INTRODUCTION

The National Institute of Transport (NIT) is a higher learning Institution mandated by the Government of the United Republic of Tanzania to offer training, conduct research, and consultancy in all modes of transport.

Vision:

To be a World-Class Training Institution Committed to Support a Sustainable Transport Sector.

Mission:

To Provide High-Quality Education and Training, Research, Consultancy, Innovation and Services in Transport and Allied Fields for Sustainable Socio-Economic Development.

Motto:

Excellence in Transport for a Sustainable Economy.

Core Values:

1. Nurturing aspires to groom and develop experts in transport and its allied fields.
2. Integrity delivers quality services with expertise and ensures the highest levels of honesty and impartiality while upholding ethical standards.
3. Teamwork works as a family to accomplish Institute goals and ensure stakeholders' expectations.
4. Cultural Diversity assures a conducive environment for people with different backgrounds, values, norms and thinking styles.
5. Accountability adheres to good governance practices by delivering our services openly with readiness to take full liability and responsibility for our actions.
6. Novelty-We aspire for creativity and innovation.

Overview of the Conference

The **2nd International Conference on Transport, Logistics, and Management (ICTLM 2024)** was held from 17th to 19th October 2024 at the Mlimani City Conference Center in Dar es Salaam, Tanzania. Under the main theme, "**Promoting Transport Technologies, Logistics, and Supply Chain Management for a Sustainable Economy**," the conference sought to address the pivotal role of transport and logistics in fostering sustainable development. This theme emphasized the integration of modern technologies, innovative practices, and effective management systems as essential tools for enhancing efficiency, reducing environmental impact, and supporting global economic growth. The conference was a continuation of the momentum established by its predecessor, ICTLM 2023, reaffirming its commitment to becoming a flagship event for the transport sector in Africa and beyond. The event provided a dynamic platform for sharing ideas, research findings, and practical solutions, while advocating for a forward-thinking approach to solving challenges within the transport industry.

Conference objectives

ICTLM 2024 brought together researchers, policymakers, industry leaders, and practitioners from across the globe, reinforcing its position as a vital forum for collaborative problem-solving and knowledge exchange. As the transport and logistics sectors evolve to meet the demands of a fast-paced, technology-driven world, the conference underscored the importance of staying ahead of global trends and aligning with the United Nations Sustainable Development Goals (SDGs).

The discussions and presentations addressed critical areas such as the adoption of innovative transport technologies, efficient supply chain management strategies, and sustainable logistics practices. These focal points are essential for strengthening national economies, promoting trade, and ensuring resilience in the face of global challenges such as climate change, urbanization, and resource constraints.

By convening stakeholders from academia, government, and industry, the conference highlighted the interconnected nature of transport systems and their profound impact on other sectors, including agriculture, manufacturing, and services. The outcomes of ICTLM 2024 are expected to contribute significantly to policy formulation, capacity building, and the adoption of best practices across the transport sector.

The Conference sub-themes

ICTLM 2024 featured a diverse and comprehensive program structured around ten subthemes, each addressing critical aspects of the transport, logistics, and management fields:

1. Air Transport: Prospect and Challenges
2. Railway Transportation Systems: Infrastructures and Operations
3. Building Resilient Maritime Logistics in Challenging Times
4. Road Transport for Sustainable Economic Developments
5. Pipeline Transportation Prospects and Emerging Opportunities
6. Improving Transport Safety for Economic Sustainability
7. Transport Energy and the Environment
8. Intelligent Transport Systems (ITS) for Sustainable Mobility
9. Planning and Financing Transport Infrastructures
10. Cross-Cutting Issues in the Transport Industry

These themes provided a foundation for engaging discussions and technical presentations, which underscored the importance of multidisciplinary approaches to tackling challenges and leveraging opportunities in the industry. The conference's thematic focus also ensured alignment with broader national and global objectives, emphasizing its significance as a catalyst for sustainable development.

Technical Sessions/Paper Presentations

Session One: Road and Railway Infrastructure Development and their Associated Safety Satisfaction

Paper 1:

Assessment of the Impact of a Project on an Existing Road Network Through an Integrated Approach of Road Safety Inspection, Road Safety Audit and Road Safety Impact Assessment.

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Abstract

A major project to improve transport conditions, including road safety and climate change resilience, was implemented on the N'Djamena - Moundou corridor in Chad. However, this heavily used, densely populated structural axis lacks adequate safety measures: according to ONASER data, more than 60% of crashes recorded on Chad's 22 major roads occur along this corridor. An integrated approach combining Road Safety Inspection (RSI), Road Safety Audit (RSA), and Road Safety Impact Assessment (RSIA) was used to evaluate road safety comprehensively. This paper demonstrates the potential of this approach in assessing the impact of planned project changes on the existing road network. Four scenarios were evaluated: the existing situation, ―Without Project‖ (WOP), ―With Project‖ (WP), and ―With Project after Audit‖ (WPA). Initially, current road safety problems were identified through RSI. Then, a risk assessment was carried out on the existing road using the iRAP methodology. Maintaining the same road features but considering a specific traffic projection, the WOP scenario was assessed to determine the risk level and the estimated number of fatalities and serious injuries. The WP scenario was analyzed on the basis of the detailed design documents, allowing quantitative comparisons to be made between the WOP and WP scenarios. Using the iRAP methodology, the road safety benefits that could result from implementing the detailed design were estimated. Subsequently, a RSA was performed on the design to identify safety problems that still exist after the design. Therefore, the WPA scenario was assessed, which includes the proposed feasible mitigation measures. Results indicated that the WPA scenario significantly improved safety for all road users, achieving the minimum safety levels throughout the corridor. The benefit/cost analysis highlighted the importance of the proposed countermeasures, showing an average reduction of fatalities and serious injuries by approximately 18% compared to the WP scenario.

Key words

Keywords: mobility; inclusiveness; safety audit; impact assessment

1 INTRODUCTION

Road safety in Chad is critical; roads are in poor condition and dangerous. In the capital, N'Djamena, only the main roads are paved. Although the government is continuing its construction program, paved highways are still limited in number and length and the rest of the roads are made of dirt or sand. All drivers should adjust their speed accordingly to avoid damage to vehicles.

Roads, both paved and unpaved, are poorly maintained. At night, the streets are not lit, and drivers frequently drive cars or motorcycles without headlights. This poses a great risk to pedestrians, bicyclists and motorcyclists, as they may not be visible.

Driving tends to be erratic in both urban and rural areas. In cities, particularly N'Djamena, vehicles share the road with a large number of bicycles, motorcycles, pedestrians, and non-motorized vehicles (e.g., hand-held vehicles).

From the data of the ONASER, the National Road Safety Office in Chad, it emerged that between 01/07/2015 and 31/03/2019, there were 10,540 crashes, 911 fatalities and 12,081 injuries in the Chad road network. 95% of the crashes occurred in urban areas, including suburban areas. Excluding crashes that were not attributed to a city, most crashes (83%) occurred in N'Djamena. N'Djamena alone recorded 88% of the total number of injuries and 75% of the total number of fatalities due to the high volume of traffic in the capital. These overall figures are underestimated, in fact, according to the World Health Organization (WHO), the actual number of fatalities in Chad is 3.6 times the official number [1].

In this context, the "Road Safety Impact Assessment (RSIA) and Road Safety Audit (RSA) Technical Assistance to modernize the Chad road network" project was developed.

The study focused on the corridor between N'Djamena and the Cameroon border which is currently not uniform in terms of service level and road maintenance conditions (Figure 1).

Figure 1 – N'Djamena - Moundou - Cameroon border road corridor and high-risk road sections *(Source: Google Maps)*

The corridor serves six provinces internally, and externally towards the nearest coastline, the port of Douala in Cameroon. This corridor is of strategic interest for the dynamics of internal and external trade in Chad and international trade in the Central African subregion. An analysis of the distribution of crashes by road shows that more than 60% of the crashes on the 22 main roads considered occurred along the N'Djamena - Moundou corridor.

As an integral part of the process followed, iRAP assessments were carried out to objectively estimate the current and expected level of safety before and after the implementation of the project and the RSA recommendations for the two high-risk sections highlighted in red in Figure 1. These two sections, which are Section 1: N'Djamena - Guelengdeng (144 km) and Section 3: Ham - Kelo (85 km), were selected as those most in need of rehabilitation works. iRAP believes that improving all the world's roads to a 3-star or better is a critical step towards achieving the United Nations Sustainable Development Goals Target 3.6 of halving the number of road fatalities and injuries by 2030 [2]. Such goals include ensuring that all new roads are built to a standard of at least 3-stars for all road users (sub-target 3), and that more than 75% of vehicle movements are on roads with 3-star or better for all road users by 2030 (sub-target 4).

As part of the study, an approach that combines the RSIA and RSA (together with iRAP assessments) has been developed to ensure that the road safety impacts of the various road components of the project to upgrade the road corridor are fully assessed as part of the design process.

2 METHODOLOGY

The methodology followed is mainly based on Article 3, Article 6 and Annex I of the European Directive 2008/96/EC amended by Directive 2019/1936 [3]. In particular, the approach includes a Road Safety Inspection (RSI), iRAP assessments of the existing situation and the detailed design, a Road Safety Impact Assessment (RSIA), a Road Safety Audit (RSA) on the detailed design and a second iRAP assessment of the design after the implementation of the accepted RSA recommendations (Figure 2).

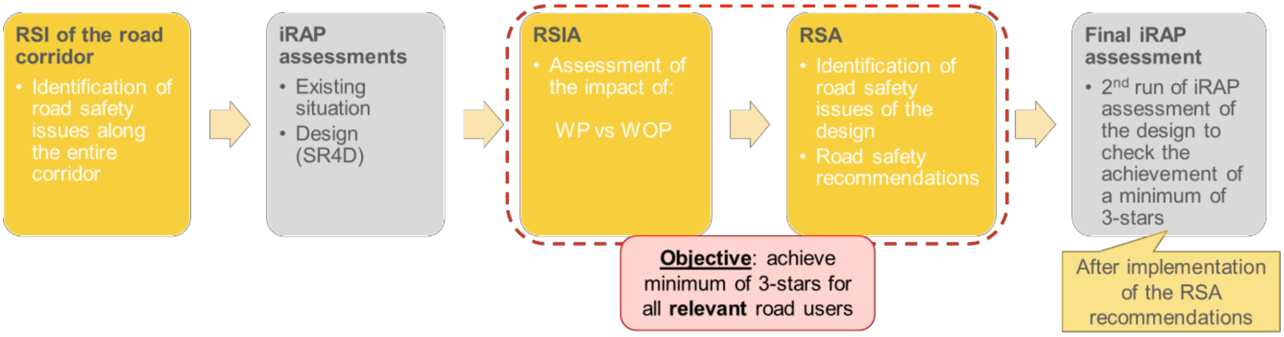

Figure 2 – Methodology process

The approach started with the identification of safety issues on the whole road corridor through a site inspection.

Focusing only on the two high-risk sections, a rough assessment of the current safety conditions was carried out and then the detailed design was evaluated.

To compare the impact that the changes provided by the design have on road safety with the existing situation, a RSIA was carried out. Three scenarios were defined, "Without Project" (WOP) scenario, "With Project" (WP) scenario and "With Project after RSA" (WP after RSA) scenario (Figure 3).

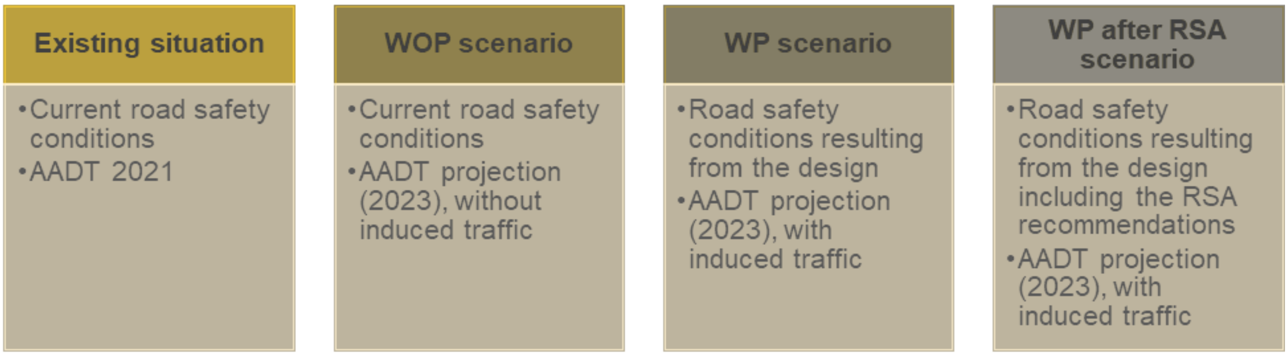

Figure 3 – Scenarios assessed in the RSIA

The *WOP scenario* represents the road safety status under current conditions but with a traffic projection to 2023. The year 2023 was chosen for the comparison with the project because that is when the rehabilitated road will be in operation. This scenario represents the safety condition of the road if the project were not implemented but with the traffic flows increased according to the trend forecast by the traffic studies.

A RSA was carried out on the detailed design of the two high-risk sections to identify any safety issues and propose recommendations to eliminate or mitigate them. To ensure that the project, after implementing the accepted recommendations in the RSA, had reached the minimum target of 3-stars for all relevant road users, a final iRAP assessment was conducted (WP after RSA scenario).

Finally, to complement the procedure, a cost-benefit analysis of the recommendations to be implemented in the design was performed.

2.1 Road Safety Inspection (RSI)

The RSI consists of regular periodic checks of features and defects requiring maintenance action for safety reasons.

The RSI process is composed of three different stages (Figure 4).

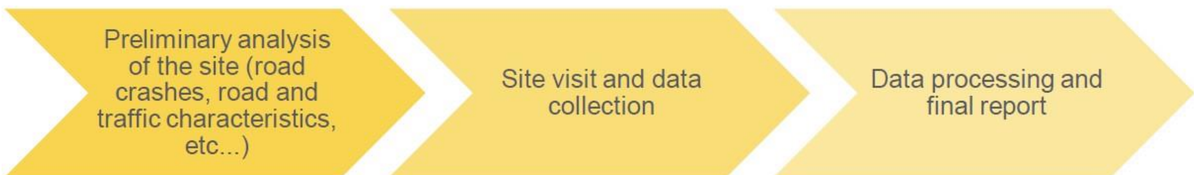

Figure 4 – Road safety inspection process

The first phase of a road safety inspection is the analysis of crash and traffic data. This enables the identification of locations with a high accident number that should be carefully assessed during the road inspection, but also to find out the types of vehicles using the road. The site visit is an integral part of the RSI process during which it is essential to gather as much information as possible about the road. The recording of a geo-referenced video of the road is of great help because it allows the images to be reviewed during the drafting of the inspection report and to be able to give accurate descriptions of the safety problems detected. Through the GPS tracking of the video images, it is possible to locate the problems along the road section examined.

The inspection is conducted with a car, driving on both directions of the road at a speed adequate to the type of road and posted speed limit and under normal traffic conditions. If deemed necessary and safe, stops will be made at dangerous points to carefully assess all risk factors.

On the basis of the issues identified, recommendations are proposed to eliminate or mitigate them. They must be submitted to the client for their approval to establish whether they are accepted or not and whether alternative measures are proposed.

2.2 iRAP Assessments (Baseline and SR4D)

Two different kinds of iRAP assessments can be carried out depending on whether the road is already built, and the aim is to assess the safety of its existing features ("baseline assessment") or whether it is at the design stage and the safety level of the planned features is to be assessed ("design assessment"). Both assessments result in a star rating.

The iRAP Star Rating provides an objective measure of the level of in-built safety of the road for vehicle occupants, motorcyclists, bicyclists, and pedestrians. The Star Rating ranges from one to five stars corresponding to different colours. Five-star

roads (green colour) are the safest, while one-star roads (black colour) are the least safe [4].

The Star Rating is based on an inspection of the road features and design elements that influence the likelihood and severity of crashes. Specifically, the Star Rating focuses on the road attributes that influence the most frequent and severe crash types for the four road user groups. These road attributes are obtained from survey images and/or design drawings that are assigned to each 100 m road segment.

Accordingly, the road attribute coding data and other complementary data are uploaded into

ViDA (iRAP's online software), where they are combined to produce the Star Rating Score (SRS), which is the relative risk of death and serious injury for an individual road user. The SRS is calculated for each road segment of 100 m for the four road user groups.

With regard to road design, the Star Rating for Design (SR4D) is used. Through the SR4D tool it is possible to assess the design and the proposed safety improvements prior to road construction, thereby guiding the safety performance of new roads in line with the global safety targets.

In the methodology followed for this study and shown in the Figure 2, there are two phases of design assessment:

1. Assessment of the drawings provided by the designer.

2. Assessment of the design considering the implementation of the accepted recommendations derived from the RSA.

This second phase aims to ensure that the 3-star target has been reached for all relevant road users after the RSA process.

2.3 Road Safety Audit (RSA) Of the Detailed Design

The Road Safety Audit is a detailed examination of all the information collected on the field and design drawings of the road to imagine how the road would appear from the perspective of future road users who will drive, walk and ride on the upgraded road. Information will include - but not limited to - drawings of the horizontal road layout and vertical alignment, sign and marking, typical cross sections, road works diversions and traffic management plans during construction if available, and other relevant design drawings and documentation for the project.

The RSA is a formal and systematic process carried out independently of the design, which aims to identify safety issues and propose countermeasures to eliminate or mitigate them. Some of the aspects of the road design that are assessed are road function, provision of facilities for all road users, provision for public transport, forgiving road infrastructure, speed management, road legibility, etc.

The design assessment is performed in parallel with a site visit to understand the overall project context, the environment in which the project interventions will take place, the road user behaviours, the level of service and to identify potential risks, etc.

The recommendations provided in the RSA must be submitted to the client and the design team for their approval to establish whether they are accepted or not and whether alternative measures are proposed.

2.4 Road Safety Impact Assessment (RSIA)

The RSIA is a strategic comparative analysis of the impact of the changes contemplated by the design and the impact it will have on the safety level of the existing road network.

The road safety impact assessment follows the process below:

- Review of project drawings.
- Review of existing and forecast traffic flows, including pedestrian and bicycle flows.

- Review of the road patterns of all road users.

- Analysis of potential impacts of the project on existing networks (e.g., accesses, intersections, crossings).

- All effects throughout the study area are considered (e.g., seasonality and weather conditions, provision of spaces that improve roadway conditions such as safe parking

areas, etc.).

- Assessment of the effects of the project in terms of predicted collisions, fatalities and serious injuries.

Quantitative comparisons and assessments are performed using SR4D. It allows comparison of the Star Rating in different scenarios (before and after implementation of the measures proposed by the design).

Using accident data as input, ViDA estimates the annual number of FSIs considering the coded road attributes. Knowing these estimates for the different scenarios, it is possible to make comparisons and obtain the gains in terms of fatalities and serious injuries saved.

3 RESULTS

3.1 Road Safety Inspection (RSI) of the Road Corridor

The objective of the RSI was both to establish a list of general problems that recur on the entire corridor from N'Djamena to the Cameroon border and recommendations to eliminate/reduce the risk of these problems and to obtain the road videos needed for the Sections 1 and 3 (Figure 5).

Figure 5 – Current road safety condition

The inspection of the corridor showed several safety problems for all road users. A summary of the issues identified is given below:

- Unpaved / poor pavement condition roadway.
- Lack of shoulder.
- Roadside hazards (e.g. large tree trunks, open and deep ditches etc.).
- Lack of signage and road markings.
- Lack of safety barriers on high embankments.
- Inadequate barriers along bridges.
- Lack of sidewalks and pedestrian crossings in urban areas.
- Lack of lighting in urban areas.

- Entrance to villages/towns insufficiently indicated.

These problems were mainly present and more serious along the two high-risk sections for which the detailed design has been produced.

3.2 iRAP Assessments of The High-Risk Sections

3.2.1 iRAP assessment of the existing situation

To prepare the assessment of the current situation of the two high-risk sections taking into account both the intrinsic characteristics of the road and the externalities (i.e. traffic and crashes), a rough assessment was carried out using the “Star Rating Demonstrator” tool available on ViDA. For this purpose, the two road sections were previously segmented into homogeneous stretches according to the main attributes of the road (land use, type of area, cross section, etc.).

The coding of the road attributes of a representative image of each stretch was performed and then applied to the entire homogeneous stretch.

The Star Rating is obtained for each road user group involved: vehicle occupants, motorcyclists, pedestrians, and bicyclists.

The results of the iRAP assessment in terms of percentage of road section rated 3-stars or better for the existing situation of the two sections are shown in Table 1.

Table 1 – % of road section rated 3-stars or better for the existing situation

	% of road section rated 3 stars or better	
Road user	Section 1	Section 3
vehicle occupants	23%	0%
motorcyclists	21%	0%
pedestrians	14%	0%
bicyclists	11%	0%

Most of section 1 and the entire section 3 are rated with 1- or 2-stars (Figure 6 and Figure 7). This represents a very high risk in terms of road safety.

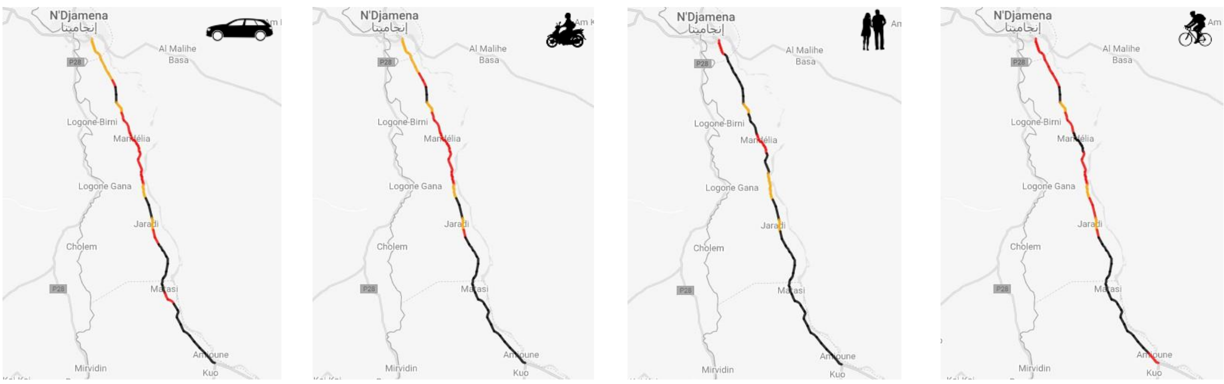

Figure 6 – Star Rating maps for Vehicle Occupants, Motorcyclists, Pedestrians and Bicyclists on Section 1 - Existing condition

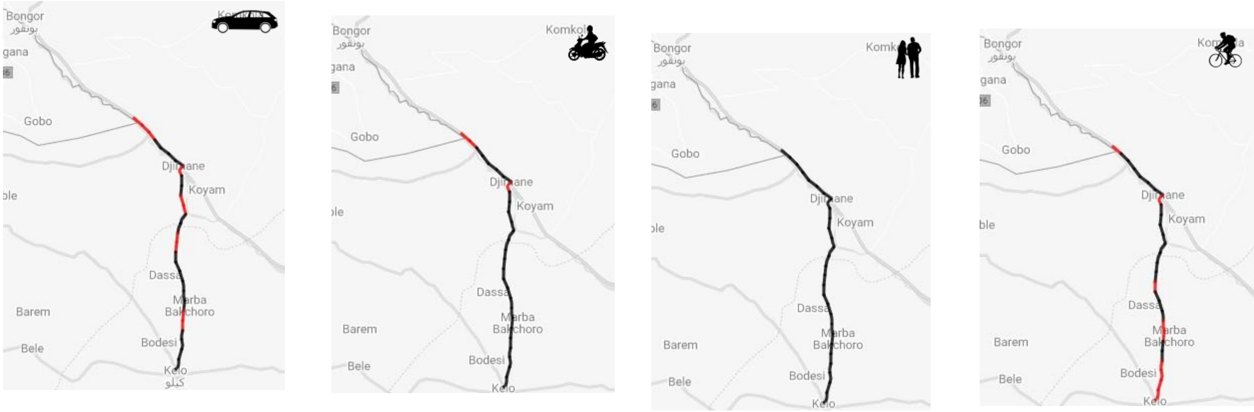

Figure 7 – Star Rating maps for Vehicle Occupants, Motorcyclists, Pedestrians and Bicyclists on Section 3 - Existing condition

Section 3 is entirely rural, with high speed (90 km/h) all along the section. This has a significant negative impact on the star rating of the four user groups, especially for pedestrians and bicyclists who do not have dedicated facilities.

What also causes the prevalence of 1- and 2-star rating for the two road sections is the presence of trees along the edge of the road, which at high speeds pose a very high risk to motorized vehicles.

3.2.2 iRAP Assessment of the Design

All design drawings of the two sections were considered for coding through SR4D. The results of the assessment of the two road sections are shown in Table 2.

Table 2 – % of road section rated 3-stars or better for the WP scenario

	% of road section rated 3 stars or better	
Road user	Section 1	Section 3
vehicle occupants	67%	46%
motorcyclists	53%	39%
pedestrians	18%	0%
bicyclists	93%	97%

In general, the design improved road safety. Indeed, more than 50% of the road section 1 is rated with 3-stars or better for vehicle occupants, motorcyclists, and bicyclists. There have also been significant road safety improvements in section 3.

The improvements in the star rating are mainly due to the resurfacing of the pavement and the completion of the road markings. With the resurfacing of the roadway, operating speeds are expected to increase resulting in a high risk for road users according to the iRAP methodology. In fact, the safety of pedestrians has remained critical, also because the design does not provide facilities for them. However, it is important to emphasize that pedestrian flow in rural areas is not significant (pedestrians are more concentrated in urban areas). In any case, the Star Rating is calculated anyway, even if there is only one user. A better Star Rating is generally obtained in urban areas that have geometric and operational characteristics suited to this type of vulnerable users.

Adding a shoulder does not improve pedestrian safety because shoulders are spaces intended for vehicle use, so pedestrians along this side spaces are always at risk of being run over. On the contrary, the addition of the shoulder improves the safety of bicyclists, who can ride on it.

However, the project does not reach the minimum target of 3-stars over the entire length of the two sections for the four road user groups.

3.3 RSIA for the High-Risk Sections

3.3.1 Assessment of Effects on Road Users

The iRAP assessment of the *WOP scenario* and the proposed *WP scenario*, shows an improved Star Rating for Section 1 from N'Djamena to Guelengdeng and for Section 3 from Ham to Kelo (Figure 8).

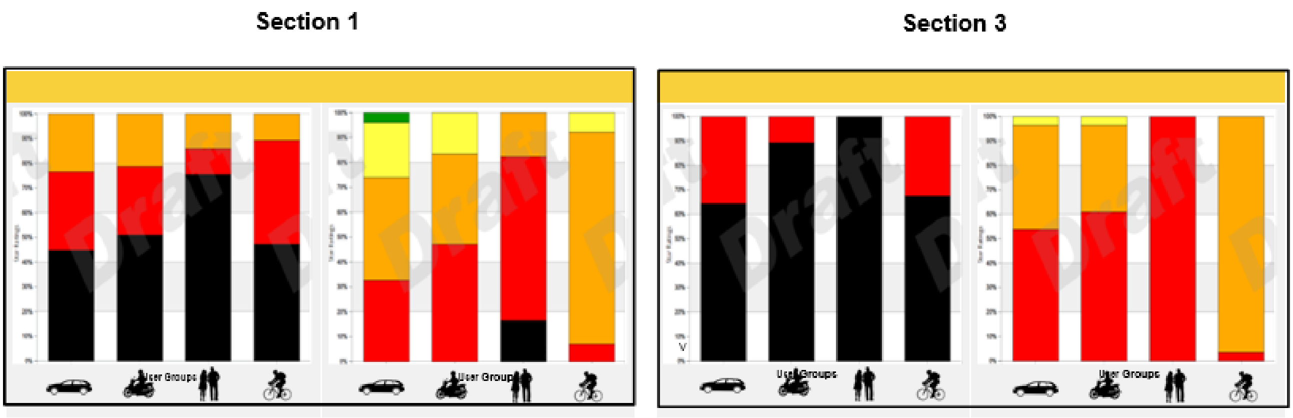

Figure 8 – Star Rating comparison for Section 1 and Section 3

The proposed *WP scenario* for Sections 1 and 3 leads to improved roadway conditions, ensuring continuity of level of service with the rest of the corridor. This rehabilitation results in a reduction in travel times, primarily favoring commercial vehicles. The resurfacing of damaged or unpaved sections of roadway encourages smoother driving for drivers, who do not have to make dangerous maneuvers to avoid potholes or pavement failures.

In addition, the presence of a shoulder facilitates traffic flow, as parked vehicles do not occupy the travel lane, and reduces the risk of crashes with parked vehicles. The shoulder also provides additional safety space for vehicles in the event of a loss of control, reducing the severity of run-off crashes by having more space to stop, slow down or redirect the vehicle.

Comparing the percentages of the section corresponding to each category, there was an improvement in the level of safety for vehicle occupants, motorcyclists, and bicyclists. A small improvement was also observed for pedestrians, as the percentage of road classified with 1-

star decreased from 76% to 17% for section 1, while the entire road section 3 that was classified with 1-star was upgraded to 2-stars in the *WP scenario*.

Quantitative comparisons of the estimated annual FSIs made by ViDA for *WOP* and *WP* scenarios were also made (Table 3).

Table 3 – Estimated annual FSIs by road user type (ViDA) – Section 1 and Section 3 WOP and WP scenarios

Section 1

Estimated annual fatalities (ViDA)					
Dataset	Vehicle Occupants	Motorcyclists	Pedestrians	Bicyclists	Total
WOP option	25	144	42	8	219
WP option	29	192	42	6	269
Variation (%)	+ 16%	+ 33%	0%	- 25%	+ 23%

Estimated annual serious injuries (ViDA)					
Dataset	Vehicle Occupants	Motorcyclists	Pedestrians	Bicyclists	Total
WOP option	254	1,442	414	75	2,185
WP option	285	1,920	422	64	2,691
Variation (%)	+ 12%	+ 33%	+ 2%	- 15%	+ 23%

Section 3

Estimated annual fatalities (ViDA)					
Dataset	Vehicle Occupants	Motorcyclists	Pedestrians	Bicyclists	Total
WOP option	9	51	6	2	68
WP option	7	51	3	1	62
Variation (%)	- 22%	0%	- 50%	- 50%	- 9%

Estimated annual serious injuries (ViDA)					
Dataset	Vehicle Occupants	Motorcyclists	Pedestrians	Bicyclists	Total
WOP option	89	507	64	20	680
WP option	70	507	29	9	615
Variation (%)	- 21%	0%	- 55%	- 55%	- 10%

For section 1, the design leads in an increase in the estimated number of FSIs, with the exception of the bicyclists.

The main reasons why the estimated number of FSIs for the *WP scenario* is higher than in the *WOP scenario* are the increase in traffic generated by the rehabilitation of the road sections and the increase of the operating speed. Higher traffic flows increase road users' exposure to certain types of crashes, such as head-on and run-off crashes.

For section 3, the comparison of the number of estimated FSIs shows a reduction for all user groups except for motorcyclists for whom the estimates remain unchanged.

For this section, despite the increase in induced traffic and operating speed, the project has made improvements that, overall, have reduced the number of FSIs.

3.3.2 Traffic Impact Assessment

The rehabilitation of both sections will contribute to a more consistent level of service of the corridor, reduce transportation delays and improve the overall trade sector with faster connections.

Traffic forecasts on the two sections were made by distinguishing the following types of traffic:

• Normal traffic (NT): which is the traffic that will continue to use the road even if the road is not rehabilitated.

• Induced traffic (IT): this is the traffic that will be generated because of the road rehabilitation. It corresponds globally to 20% for passenger vehicles and 10% for commercial vehicles.

Local roads that connect to the corridor could likely experience increased motorized traffic. They may require improvements to accommodate the higher traffic volumes while ensuring and maintaining the safety of existing roads for all road users.

This increase in traffic may result in negative impacts to the villages along the corridor.

3.3.3 Assessment of Seasonality and Climatic Condition

According to the climate study, N'Djamena’s rainfall is lower than that of Bongor and Bongor's rainfall is lower than that of Moundou and Kelo located in the Sudanian zone.

Section 3 is in a flood plain area where capillary rise phenomena are recurrent and are the cause of various degradations. During these periods of heavy rainfall, some areas of the road along section 3 are likely to be covered with water.

The project aims to solve this problem by proposing a slight increase in pavement height and the use of geotextile at specific locations to prevent safety problems for users while driving.

3.3.4 Assessing the presence of safe parking areas

Some parking areas are planned along the first 40 km of Section 1; however, parking areas are also needed in villages and large urban areas, where there is currently irregular and chaotic parking on the roadway.

However, the addition of a shoulder on both sides of the road in the design already has a positive effect in terms of road safety, as it represents a safe space where vehicles can stop in case of emergency.

3.4 RSA on the Detailed Design of the two High-Risk Sections

The audit carried out on the two sections revealed several problems in the design that impact on road user safety.

In particular, the main issues identified and the corresponding accepted recommendations are listed in the Table 4.

Table 4 – Road safety issues and proposed recommendations

PROBLEM	RECOMMENDATION
Monotonous and straight track on long stretches in rural sections	Installation of side rumble strips and speed limits.
Dangerous speed humps	Replacement of speed humps with rumble strips. Installation of speed humps according to the internationally recognized standard and
Slippery shoulder surfacing	Asphalt concrete pavement.
Dual carriageway cross-section inviting high speeds	Replacement of new jersey with a raised median and installation of speed limit.
Trees along the road	Trees removal.
Concrete milestones	Replacement of concrete milestones with
Dangerous delineation posts	Replacement of concrete posts with plastic or
Inadequate class of guardrails for trucks	Installation of safety barriers tested according to recognized international standards.
Unprotected and dangerous culvert	Installation of safety barriers.
Parking areas located in bends	Displacement of the parking.
Inadequate protection of bridges	Installation of safety barriers.
Steep slopes of embankments	Adoption of a gentler slope.
Dangerous bends	Replacement of concrete posts with plastic or PVC posts. Installation of chevron signs, curve danger sign and no overtaking signs in case of
Lack of speed limits in the design	Installation of speed limit signs.
Entrance to villages/towns not properly marked	Reinforcement of signage.
Lack of sidewalks and pedestrian crossings in urban areas	Installation of sidewalks or pedestrian paths. Installation of pedestrian crossings
Unsafe pedestrian crossings	Relocation and improvement of the pedestrian
Unsafe school locations	Reinforcement of traffic calming measures, speed limits and installation of pedestrian crossings.
Lack of lighting in urban areas	Installation of a lighting system.
Dangerous intersections	Reinforcement of signage.

Many of the recommendations are aimed at improving the safety of vulnerable road users who were found to be the most at risk by the iRAP assessment carried out on the design.

An estimate of the costs of implementing each of the listed recommendations was made to be provided as input to the cost-benefit analysis carried out as a final step.

3.5 Final iRAP Assessment

A final iRAP safety assessment of the road sections 1 and 3 has been performed for the proposed *WP after RSA scenario*, considering the implementation of the countermeasures proposed and accepted in the RSA.

The operating speeds were coded equal to 100 km/h in the rural areas and 40 km/h in urban areas, considering the speed management measures that would be implemented in these zones.

Some of the countermeasures cannot be implemented in the iRAP's Star Rating model as there are no attributes reflecting them. However, it is important to emphasise that these actions actually lead to an improvement in the safety of road users:

- Use of safety barriers with higher performance.
- Improvement of speed humps geometry according to an internationally recognised standard.
- Concrete milestones replaced by breakable mileage signs (plastic or metal material).
- Dangerous delineation posts replaced by plastic or PVC markers.
- Installation of vertical approach signs before dangerous intersections.
- Improvement of unsafe parking area layouts.

The results of the star rating are shown in the Figure 9 and Figure 10.

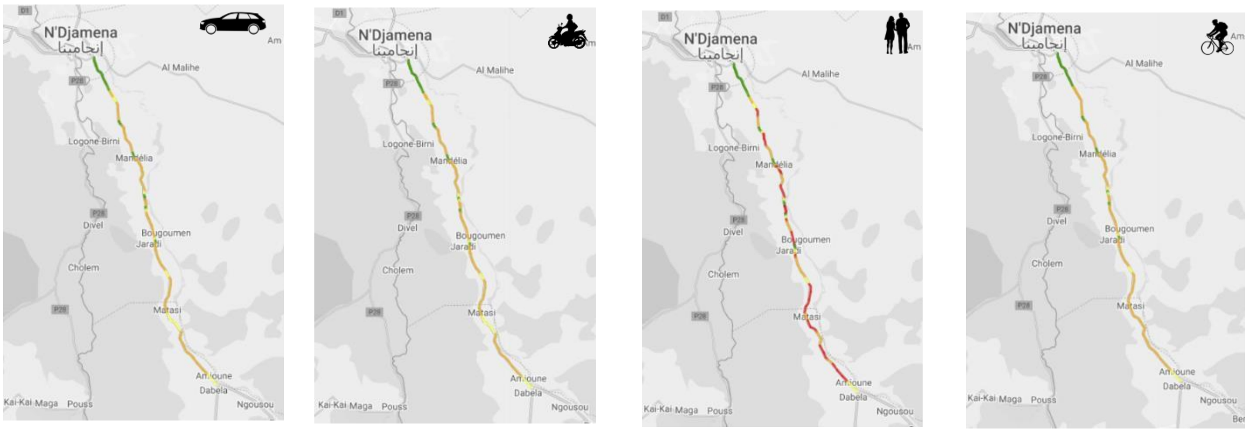

Figure 9 – Star Rating maps for Vehicle Occupants, Motorcyclists, Pedestrians and Bicyclists on Section 1 – WP after RSA scenario

Figure 10 – Star Rating maps for Vehicle Occupants, Motorcyclists, Pedestrians and Bicyclists on Section 3 - WP after RSA scenario

Overall, the implementation of the countermeasures improves greatly the road safety as shown in Table 5.

Table 5 – % of road section rated 3-stars or better for the WP after RSA scenario

	% of road section rated 3 stars or better	
Road user	Section 1	Section 3
vehicle occupants	100%	100%
motorcyclists	100%	100%
pedestrians	64%	29%
bicyclists	100%	100%

100% of the road is rated with 3-stars or better for vehicle occupants, motorcyclists, and bicyclists on the two road sections.

For pedestrians, road safety improves but is still not optimal, especially in rural areas where there are no safe facilities for them. Additionally, the high operating speed of vehicles in the rural sections (100 km/h) pose an important threat to pedestrians.

On the contrary, very good results were obtained in urban areas, with a clear improvement for pedestrians.

Table 6 shows the annual number of FSIs respectively estimated by ViDA for the *WP* and *WP after RSA scenarios* of section1 and section 3, based on the crash data entered for the existing situation and the roadway characteristics of the design.

Table 6 – Estimated annual FSIs by road user type (ViDA) – Section 1 and Section 3 WP and WP after RSA scenarios

Section 1

Estimated annual fatalities					
Dataset	Vehicle Occupants	Motorcyclists	Pedestrians	Bicyclists	Total
WP option	29	192	42	6	269
WP after Audit	21	144	38	6	209
Variation (%): WP option/ WP after Audit	**-28%**	**-25%**	**-10%**	**0%**	**-22%**
Estimated annual serious injuries					
Dataset	Vehicle Occupants	Motorcyclists	Pedestrians	Bicyclists	Total
WP option	285	1,920	422	64	2,691
WP after Audit	208	1,438	384	64	2,094
Variation (%): WP option/ WP after Audit	**-27%**	**-25%**	**-9%**	**0%**	**-22%**

Section 3

Estimated annual fatalities					
Dataset	Vehicle Occupants	Motorcyclists	Pedestrians	Bicyclists	Total
WP option	7	51	3	1	62
WP after Audit	5	45	3	1	54
Variation (%): WP option/ WP after Audit	**-29%**	**-12%**	**0%**	**0%**	**-13%**
Estimated annual serious injuries					
Dataset	Vehicle Occupants	Motorcyclists	Pedestrians	Bicyclists	Total
WP option	70	507	29	9	615
WP after Audit	53	454	28	8	543
Variation (%): WP option/ WP after Audit	**-24%**	**-10%**	**-3%**	**-11%**	**-12%**

The implementation of the countermeasures proposed in the RSA would contribute in a significant way to the reduction of the FSIs along the road sections. On average, the *WP after RSA scenario* results in a 22% reduction in annual FSIs for section 1 and 13% for section 3.

3.6 Benefit-Cost Ratio (BCR) Analysis

The RSA was supplemented by an economic evaluation of the proposed measures, including an assessment of their effectiveness over a 20-year analysis period.

To estimate benefits of each countermeasure, the range of effectiveness in terms of casualty reduction available in the iRAP toolkit [5] was used.

Some of the recommendations proposed in the RSA were not included in the iRAP toolkit and thus not even in the iRAP assessment of the *WP after RSA scenario*. Their effectiveness was therefore estimated by comparing them with similar countermeasures.

It must be considered that when several road safety measures are implemented in combination, the expected reduction is not the simple algebraic sum of those given by the individual measures but is generally lower. To take into account this overlapping effect, the procedure for estimating victims saved was calibrated on the basis of the annual FSIs estimates obtained from ViDA. The difference between the estimates for the *WP* and *WP after RSA scenarios*, represents the reference number of victims saved by the implementation of the accepted recommendations.

For the economic calculation of the benefits, the cost of one crash fatality was taken as 70 times the Gross Domestic Product (GDP) per capita. The cost of a serious injury was calculated as 0.25 times the cost of a fatality. This estimate was used in the World Bank's Road Safety Screening and Assessment Tool (RSSAT) and is also the estimate recommended by iRAP. These calculations resulted in the following costs:

- Cost of a fatality: 27.9 million CFAF (42,500 EUR).
- Cost of a serious injury: 7.0 million CFAF (10,700 EUR).

Since the exact location of the crashes was not known, but only the total number over the entire section, it was assumed that they were equally distributed over the section considered, with some adjustments to take into account for certain particularities (e.g., crashes involving pedestrians were considered to have occurred mainly in urban areas). For each recommendation, the length of road that benefits from the implementation of countermeasures was calculated. The number of casualties per km per year and the length of road influenced by each countermeasure were used to estimate the number of FSIs saved by the implementation of countermeasures.

To estimate the costs for the benefit-cost analysis, the cost of implementing each recommendation, the annual maintenance costs (estimated at 10% of the initial cost), as well as the lifetime, at the end of which the investment must be renewed, were considered. The total cost of the proposed recommendations for section 1 was 12% of the total construction cost of this section, and for section 3, it was 10% of the total construction cost. For each countermeasure, the present value of the costs and benefits has been calculated and used to obtain the Benefit-Cost Ratio (BCR). This ratio is a useful indicator for defining investment priorities.

The recommendation with the lowest BCR is the construction of sidewalks on both sides in all settlements. This is due to the high cost of implementation. An alternative recommendation has been proposed to reduce the costs especially for small villages, i.e. the construction of a sidewalk on one side only or paved footpaths off the road. Both of these alternative recommendations would offer slightly lower benefits but much lower costs, leading to a higher BCR.

The result of this analysis is summarized in the Net Present Value (NPV) which compares the investment costs and the expected benefits in terms of casualty reduction over 20 years. The Net Present Value (NPV) for the accepted recommendations is:

- 39.4 billion CFAF (EUR 60.1 million) for section 1.
- 2.3 billion CFAF (EUR 3.5 million) for section 3.

4 DISCUSSION

The methodology presented in this paper makes it possible to assess the impact of a project on the existing safety situation of a road.

Two road sections along the N'Djamena - Moundou corridor have been assessed. An analysis of their current road safety situation was carried out and the detailed design to rehabilitate them was assessed.

In the different steps of the procedure, the iRAP methodology and its tools were used. In particular, through the use of ViDA, quantitative comparisons of the different scenarios created were made.

The Star Rating of the *existing situation*, *WOP*, *WP* and *WP after RSA* scenarios was obtained for the two sections. The Star Rating results show a relatively high level of risk for all road user categories, in the *existing situation* and *WOP scenarios*, but also in the *WP scenario*.

Among the main causes of the road's poor safety level in the current condition, and thus also in the *WOP scenario* are the poor pavement and signage status, the presence of dangerous obstacles along the road and the absence of facilities for pedestrians and bicyclists. iRAP assessment of the design also did not provide the minimum 3-star required rating results for all user groups. This is due to the expected increase in operating speeds resulting from the resurfacing of the road. Only after the implementation of the recommendations proposed in the RSA, the star rating improved to 3-stars or better over the entire extent of the two sections for vehicle occupants, motorcyclists and bicyclists. For pedestrians, on the other hand, still a certain percentage remained rated 2-stars, mainly in rural stretches. The reason for this is the vulnerability of such users along roads without dedicated facilities for them where operating speeds are high.

In interpreting these results, it is worth emphasizing that pedestrian flow in rural stretches is not relevant. The iRAP assessment however estimates the star rating for pedestrian category, even if there is only one recorded.

Bicyclists are also included in the category of vulnerable users, but the addition of a shoulder in the design resulted in the improvement of their safety level since the shoulder represents a space out of the vehicular flow that can be used by bicyclists, which greatly reduces their interaction with motorized vehicles.

The Figure 11 and Figure 12 show the % of section 1 and section 3 roads reaching 3 stars or better for the four different scenarios.

Figure 11 –% of section 1 rated 3-stars or better in the four scenarios for the four road user groups

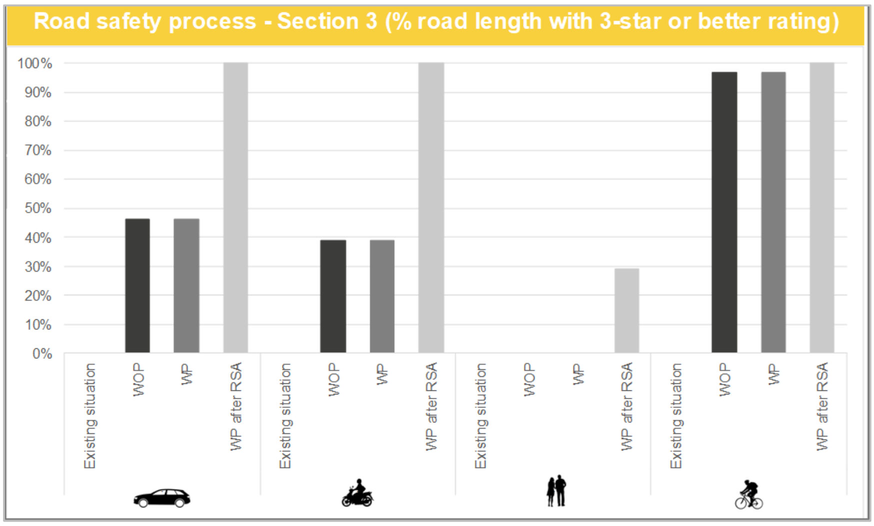

Figure 12 –% of section 3 rated 3-stars or better in the four scenarios for the four road user groups

Since there are remaining unsafe segments for pedestrians in both sections (rated 2-stars), it was studied the effect of the provision of informal paths (at least) in rural areas and a slightly lower operating speed in rural areas (reduction from 100 km/h to 90 km/h, being equivalent to the speed limit). An informal path refers to a safe space along the road but off the carriageway used by the pedestrians to move without conflicts with motorized vehicles, where there is no purpose-built sidewalk. These informal paths are commonly found in Africa as they are cost-effective and can be implemented in cases where there are not sufficient economical resources to build a proper sidewalk. With these two adjustments, the Section 1 and Section 3 would reach 100% of the segments rated 3-stars or better.

To ensure that the operating speed is at least equal to the speed limit, it is important to enforce users' respect for speed limits and to properly maintain signage, especially vertical speed limit signs.

The study shows how RSA makes an important contribution to improving road safety and that the benefit-cost analysis is an essential tool to support beneficiaries in making decisions on the prioritization of interventions.

The study revealed that some of the recommendations proposed in the RSA are not implementable in the iRAP methodology as there are no attributes reflecting them. Among them, the different performance classes of safety barriers are crucial to determine the level safety of a road section and it is something to be considered in future updates of the iRAP model. In addition, it might be useful to give different weight to urban versus rural environment for the calculation of star rating for pedestrians.

The methodology has been applied to a case study in the design phase, but it is also applicable to an existing road on which a RSI is being conducted and it is therefore possible to assess the impact of the proposed recommendations on the current situation.

A further development of the study could be to get the effectiveness, in terms of casualty reduction estimates, of a wider range of countermeasures and a method for estimating their combined benefit to take into account the overlapping effect could be developed.

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Directive 2008/96/EC on road infrastructure safety management.

4. iRAP website: https://irap.org/

5. iRAP Toolkit: free information on the causes and prevention of road crashes that result in death and injury (https://toolkit.irap.org/)

Paper 2:

The Role of Vehicular Mobility Performance on Road Surface Conditions

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ABSTRACT

Traffic mobility may be influenced by road surface conditions such as obstacles, surface quality, traffic control mechanism and interdependent vehicular motion. Its performance is influenced by level of vehicle mobility. Research on vehicular mobility mathematical quantification has been established for off-road factors but absent on on-road internal factors. The motivation of this work is to model the latter. The mathematical quantification describes the vehicular mobility performance as function of road surface conditions. Cracks and Potholes were quantified by making a rectangular shape within the area of cracks and potholes then finding the summation of each rectangular area you have and dividing by total areas of the road areas of the road width and length covered potholes and cracks. Results are obtained both analytical and numerical methods using Software simulation. For road surface conditions within cracks and potholes are rate in stipulated standard density value of % was determined in accordance with DIN-EN-12274-8 (2005). The roads mobility would be affected by the presence of the cracks and pothole exceeding the threshold. The results indicated the chosen road segment length and their corresponding cracks and potholes values as follows the road segment length of 2.7 km has a potholes value of 0 % and cracks value of 1.1 %. The road segment of length 2.6 km has a potholes value of 0 % and cracks value of 1.14 %. The segment length values 2.4 km of road has pothole 0.19 % and cracks value of 1.14 % are occurred. The results show that one road segment exceeded the stipulated threshold of 0.19% and 1.14 % for potholes and cracks. The occurrence results may make uncomfortable vehicle drive and unfavorable vehicle's dynamics. There is need to investigate the variables that affect dynamics and behavior of the motion.

Keywords: Vehicular Mobility Performance, Road surface conditions, Vehicle dynamics

1 INTRODUCTION

The vehicular mobility performance is dominated by the capacity of the vehicle to transmit the tractive force to the ground to overcome the road surface conditions. It can be influenced by off-road and on-road conditions both of which have external and internal factors. The off-road is the condition of road which provides the ability for a vehicle to operate on soft or deformable terrain is related to the wheel power management (Senatore, 2010). The mechanics of vehicle mobility for off-road conditions depend on soft or deformable terrain in which the soil strength, surface shape such as climb, bend and stench come to effect (Serban et al., 2019). Factors affecting field mobility, tractive efficiency, vehicle mobility and multi-wheel drive vehicles (Grantham et al., 2001, Vantsevich and Gray, 2009, Senatore and Sandu, 2011).

On the other hand, on-road conditions refer to the interaction of the vehicle tyre and the road surface making the grip surface, the vehicle speed, engine and mechanical characteristics of the vehicle. Characteristics on on-road conditions affect mobility via external and internal factors. The external factors include wheel interaction with road surface, interdependent vehicular motion, traffic flow, traffic control mechanism, road conditions such as potholes and cracks.

Cracks on road surfaces are non-internal factors; however, its information is important as cracks may affect mobility negatively. Cracks affect the vehicle mobility on the interaction of vehicle wheels with the road surface depending on the size of cracks in road surface. Cracks make travelling on the road to increase travel time leading to low mobility

Potholes are formed when water penetrates cracks in the road surface commonly caused by wear. This is making worse by extreme weather conditions, heavy traffic and poor drainage (Fosu et al 2022). Potholes cause traffic delays and accident (Ogundipe, 2008). It is important to consider the effect of potholes on traffic mobility (Ali et al., 2023).

In addition, poor road conditions lead to congestion and driver frustration which can result in dangerous driving behavior (Available online: https://ecogrit.co.uk/dangers-of-potholes/).

Realistic to investigate the effects of external factors for on-road conditions and to quantify the relationship between external factors with vehicular mobility under on-road conditions needed to alleviate these problems.

This paper focus on investigation to describe the inter relationship between road surface conditions with vehicle speed to identify the effect of road surface quality on vehicle mobility.

2 METHODOLOGY

The study site shall be on selected road segments which have severe degree of mobility (Ndume *et al.*, 2020). The selection was based on the segments with the following attributes; The standard attributes characteristics for studying mobility network segments was evoked from Ndume *et al*., (2020). These attributes are on; segment surface, segment capacity, segment length, segment traffic flow and obstacle. For each of these conditions a qualification for their suitability. The suitability is determined by measuring of the qualifiers as explained herein:

(i) Cracks quantification determination (%)

Cracks were quantified via a walk survey along the segment of the road by making a rectangular shape within the area of cracks then finding the summation of each rectangular areas you have and dividing by total area of the road width and length covered of cracks. Cracks qualification determined in accordance with the standard value of 0 %. Cracks qualification Determinations DIN-EN-12274-8 (2005)

$$Cracks = \frac{\sum_{ni}^{n} a_i}{A} * 100\% \quad (1)$$

where,

$\sum_{ni}^{n} a_i$ is summation of the area of rectangular shape within the area of cracks (mm²).

A is the total area of the road width and length covered of cracks (mm²).

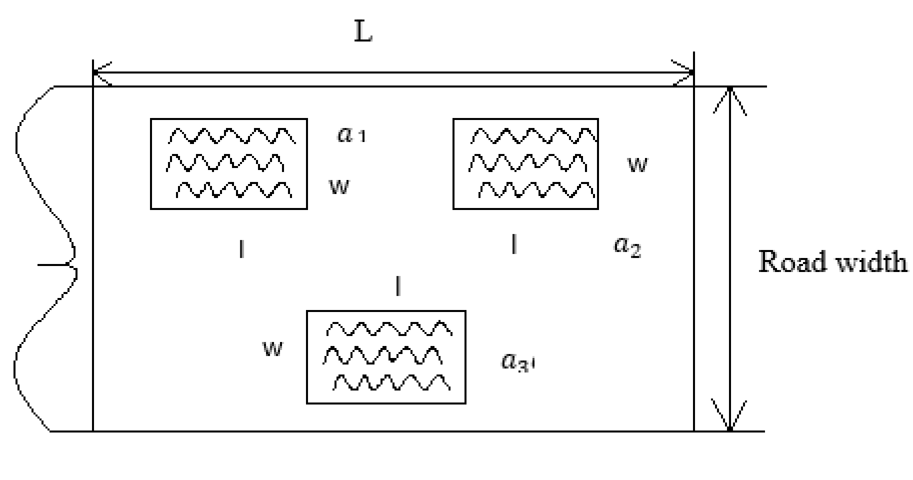

Figure I: Cracks study quantification on road segment

(ii) Potholes quantification determination (%)

Potholes were quantified via a walk survey along the segment of the road by making a rectangular shape within the area of potholes then finding the summation of each rectangular areas you have and dividing by total area of the road width and length covered of potholes. The standard threshold of pothole has a value of 0 % DIN-EN-12274-8 (2005).

Determination percentage of pothole

$$Pothole = \frac{\sum_{ni}^{n} a_i}{A} * 100\% \qquad (2)$$

where,

$\sum_{ni}^{n} a_i$ is the area of rectangular shape within the area of potholes (mm^2).

A is the total area of the road width and length covered of potholes (mm^2).

3 RESULT AND DISCUSSIONS

Cracks and potholes

Vehicle speed limit can be affected by the occurrence of road surface cracks and potholes, measured as occurrence density (Al-Qadi *et al.*, 2005). Cracks and potholes affect the dynamics of the vehicle suspension system and its stability of the movement and mobility Žuraulis *et al.*,(2014). Cracks occurrence density in % was determined in accordance with DIN-EN-12274-8 (2005) and evaluated by evoking the method given in Equation 1. Potholes qualification determined in accordance with the same standard. The parameters associated to these road conditions are shown to be cracks and potholes condition rating on the basis of the computed results presented in Table 1.

Table 1: Chosen Road Segments Lengths and their Corresponding Cracks and Potholes

S/N	Road	Selected Segments		Cracks	Potholes
		Segment Length (km)	Segments	%	%
			Standard Density value	0	0
1	A	2.7	Segment I	1.1	0
		2.6	Segment II	1.14	0
2	B	3.0	Segment III	1.0	0
		2.4	Segment IV	1.14	0.19
3	C	2.5	Segment V	1.0	0
4	D	1.9	Segment VI	0.4	0
5	E	1.1	Segment VII	0	0
6	F	1.0	Segment VIII	0	0

The results show that the road segment IV in B- road, exceeded the stipulated threshold of 0.19% of potholes. The occurrence results may make uncomfortable vehicle drive and unfavorable vehicle's dynamics Žuraulis *et al*.,(2014). When the critical speed intended for the condition increase, it dictates moving on low speeds for comfortability which consequently may affect mobility negatively.

The results show that the potholes condition rating for road segment I is only 0 % meaning adequate condition (sound). The road segment II show cracks of 1.14 % rated as adequate condition (sound). The road segment of II the results for potholes condition rating show that the value of 0 % with the meaning of the term sound meaning adequate condition. The road segment of III show cracks condition rating of 1.0 % rated as adequate condition (sound). The road segment of IV the potholes condition rating results show 0.19 % rated as uncertainty exists about the adequacy of the condition (warning). The road segment IV show cracks of 1.14 % rated as adequate condition (sound).

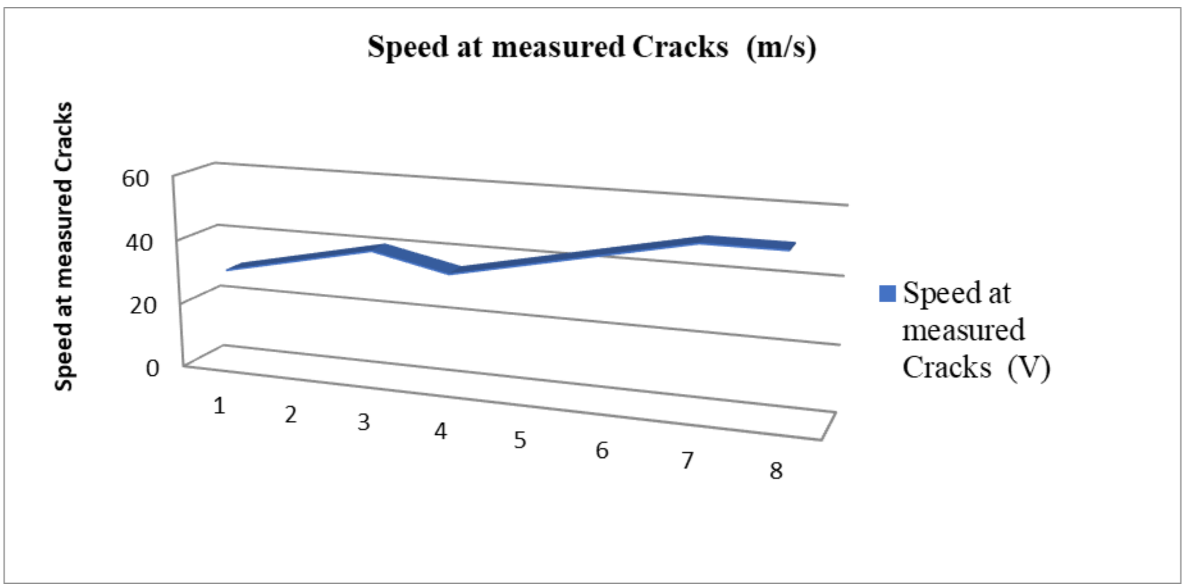

Figure 2: Vehicle speed limit as a function of road surface cracks

Figure 1 show that the parameters vehicle *speed* and cracks are essential to estimate the behaviour of vehicle in mobility conditions. The horizontal line with number 1 up to 8 indicates the road segments They signify the variables that affect dynamics and behaviour of the motion. With regard to the aforementioned distress criteria for use in pavement evaluation, both the cracks and potholes of a typical road segments are investigated.

4 CONCLUSION

This study successfully investigated to analyze the role of vehicle mobility on road surface conditions, specifically considering the cracks and potholes The findings reveal a clear relationship between road surface conditions and vehicle mobility, where increased road surface cracks correlate with smaller speed, reduced fuel efficiency, and lower engine revolution speed. This study also highlights the negative impacts of higher cracks values, such as discomfort, driver fatigue, increased risk of accidents, and overall reduced mobility due to the need to overcome *surface* irregularities. These outcomes emphasize the importance of maintaining road quality to enhance vehicle performance, reduce vehicle speed, and improve fuel efficiency, ultimately contributing to safer and more comfortable driving conditions. The insights gained from this research can inform road maintenance practices and vehicle operation strategies, aiming to optimize mobility and minimize the adverse effects of road cracks on vehicle performance.

5 RECOMMENDATIONS

This proactive approach will help mitigate the negative impacts of road cracks on vehicular performance and overall driving experience. It is suggested that this investigation be further extended and refined to explore *additional* factors influencing vehicular dynamics. By doing so, this work can serve as a foundation for the continued create of more advanced vehicular mobility investigation, potentially leading to significant improvements in road design, maintenance strategies, and vehicle performance.

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Paper 3:

Dynamic Influence of Wheel Polygon on Wheel Fatigue

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Abstract

Fatigue is regarded to be the main damage mechanism in railway wheels where mechanical and dynamic loads are imparted to wheels during their service life. This creates a multi-axial state of stresses leading to deformation and wear which significantly reduces the service life of wheels. This paper is aimed to analyse the effect of wheel polygon on the fatigue life of a high-speed railway wheel. One of the assumptions in the Hertz theory shows that the contact area should be small in comparison to the body dimensions and surface curvature, whereas for the wheel/rail contact problem, the surface curvature is comparable with the contact area when the contact area is near the wheel flange. As a result, the Hertz contact hypothesis may not be inapplicable. hence there is need to use a 3D FEM model for a practical method for fatigue analysis of wheel rolling contact which must also be in line with the mathematical analysis. With a CRH2 high-speed train as the research object, a three-dimensional finite element model of the wheel used to investigate the effect of the applied contact loading force due to wheel polygonization on the damage and life of the wheel component using the ncode simulation software. The interaction between the left and right wheels was considered using the MBS software and the obtained results of 172,337 and 3940 MPa, which resulted into damage of 107,105 and 105 respectively.

Key words: Finite element modelling, wheel-rail contact, contact force, stress and strain life, CRH2 high-speed train.

1 INTRODUCTION

Wheel fatigue is a term used to describe the damage that occurs on wheels or rails as a result of repeated loading and unloading when they come into contact with each other. This type of damage can be caused by a variety of factors, including heavy loads, high speeds, and sharp curves (Fu et al. 2016). Over time, this can lead to cracks and other forms of damage to the wheel, which can ultimately result in catastrophic failures, increased operating costs, and a decrease in overall safety if left unchecked. It is important to note that the weakest section of a wheel is typically found on the curved track, where larger centrifugal and creep forces are present. This can lead to a greater amount of creep force moment, particularly when compared to the tangent section of the track (Akeel, Sajuri, and Ariffin 2011).

Technological improvements in the railway industry have allowed for significant increases in the fatigue life of wheels. At the same time, current economic and logistical restrictions necessitate increased train speeds and load capacities, which result in greater contact forces on wheels. As a result of longer wear durations, faster speeds, and heavier loads, fatigue has become the leading cause of railway wheel replacement and reengineering (Ekberg and Marais 2000).According to the Union Pacific Railroad wheel fracture database, 65% of railroad wheel failures are caused by shattered rims, a form of subsurface initiated rolling-contact fatigue (RCF) (Liu, Stratman, and Mahadevan 2006).

Recently, a lot of literatures have studied the problems of wheel contact fatigue particularly. Fatigue strength can be analyzed in different ways such as analytical methods, experimental methods and numerical simulations. The approaches to evaluate the fatigue life of wheels have been presented widely by (Thesis 2019). Liu, Stratman, Mahadevan (Liu et al. 2006) reviewed the latest developments in the studies of the problems of wheel/rail rolling contact fatigue. Ding et al (Ding et al. 2012)predicted the rolling contact fatigue of different profiles of wheels. Q. Xiao (Xiao 2012) investigated the angle and fatigue life of crack initiation on the rail surface by developing a wheel/rail rolling contact model that included ratcheting and the functional friction coefficient. J.J. Ding (J. J. Ding, S. L. Sun, F. Li 2012) Based on the "layer" fatigue failure model of wheel/rail rolling contact, he investigated the effects of contact circumstances and wheel material on wheel/rail rolling contact fatigue.. X. Li (Li, Wen, and Jin 2011) applied the Non-Hertz contact theory to study the effects of axle load and wheel hardness to the rolling contact fatigue of wheel. And C. G. He (He et al. 2014)applied the Hertz contact theory to study the effects of curvature radius to the rolling contact fatigue performance of wheel under wet conditions.. J. W. Ringsberg (Ringsberg 2001; Ringsberg, Loo-morrey, and Josefson 2000) proposed a fatigue life prediction method of crack initiation which caused by the failure of low cycle fatigue and ratcheting. A. Ekberg (Testing 2002) established an engineering model of wheel rolling contact fatigue which can be expressed as an analytical form with three parameters, namely the surface fatigue, the subsurface fatigue and the deep fatigue. C. Richard Liu (Liu and Choi 2008) added the residual stress to the wheel/rolling contact fatigue model, results show that fatigue model which contains residual stress is more close to the experiment results. Ref.(Franklin, Widiyarta, and Kapoor 2001; Ringsberg 2001; Ringsberg et al. 2000)conducted correlation theory researches about fatigue crack initiation process as well.

In the field of railway wheel fatigue life prediction, the S-N method has been widely adopted by researchers. This is due to the fact that the S-N method is a simpler approach that can provide accurate predictions for high cycle fatigue, eliminating the need for more complex methods. Additionally, Dowling (Thesis 2019)has noted that for high cycle fatigue lives, where elastic strain is dominant, both the ϵ-N and S-N based approaches can be considered equivalent. One effective way of utilizing the S-N method is to take into account the endurance limit of the material. The mean stress and fatigue cycle amplitude can be compared with the fatigue limit of the material using a specified failure criterion, but it cannot predict the number of cycles to failure. Miner's rule is the simplest cumulative damage theory, being a linear damage rule.

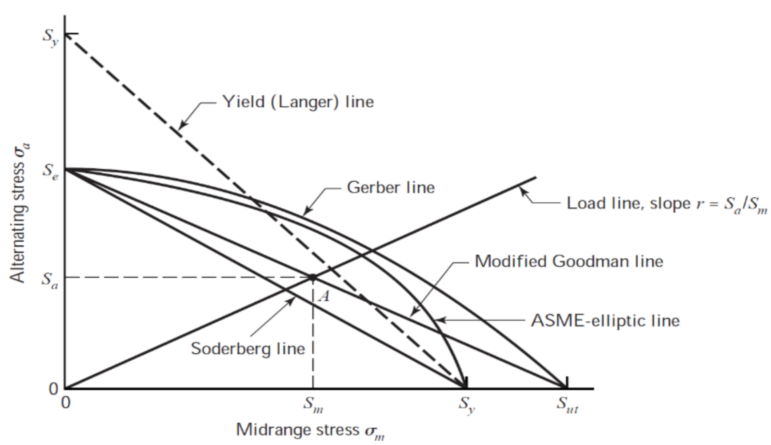

Figure 1: S-N curve

2 MATERIALS AND METHODOLOGY

2.1 Prediction Theory of Wheel Contact Fatigue

The three-dimensional (3D) FE model of wheel is based on the CRH2 EMU vehicle on the Beijing-Shanghai high-speed line of China. In this model, the actual structure parameters of wheel are included. The simulation is a set of the element size and the quasi-static loads on the wheel created with a library of ANSYS. This model can accurately simulate actual wheel contact behaviors considering wheel/rail contact parameters, such as longitudinal and lateral creep force, and the damage function(Xiao et al. 2017) to analyzed the status and fatigue damage distribution of wheels.

Force is applied on the wheel which has contact with the rail. The shape of wheel generated with a standard mathematical model is described by several key points. The Goodman approach in ANSYS via the FEM is used in all simulations to predict the mean stress effects. The detail drawing the wheel model is presented the 3D geometric model of the wheel is generated by revolving the 3D curves that describe the profile of the wheel tread as shown in figure

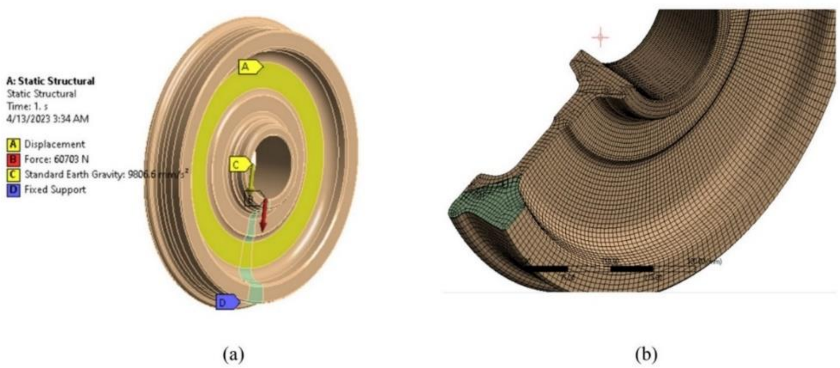

Figure 2: Wheel boundary conditions

The model is meshed to predict a reasonable model configuration, the wheel is spatially oriented relative to the rail according to the quasi-static state calculated by FEM. A geometric shape, a material model, a value for the coefficient of friction, and knowledge about the contact forces are required to produce a model of the wheel(Xiao et al. 2017)

2.2 Condition of Wheel Interface

The different polygon wheels of different length are simulated and compared with the numerical methods and the typical wheel contact solving process includes calculating the initial pre-loading (the static deformation and stress of equilibrium state) of wheel rolling contact under gravity. And initializing the initial pre-loading including the deformation and stress (calculated above and then explicitly solving the transient wheel contact process. Note that the initial pre-loading calculated above is to ensure the wheelset achieves a steady-state rolling.

2.3 Vehicle system dynamics modelling

To study the influence of wheel polygon on wheel-rail dynamics, a vehicle system dynamics model was established according to the actual structural parameters of high-speed trains, as shown in Figure 3. In the model, the positioning mode of high-speed train's revolving arm and the joint stiffness of shock absorber were considered (Cui et al. 2015).The normal force of wheel and rail is considered as the Hertz spring. Fastsim was used to solve the tangential force of wheel-rail. When solving the transient contact of wheel-rail, the difference of contact geometry caused by the 3D wear profile is considered, and the change of the creep rate/force of wheel-rail is also considered. Due to the main purpose of this paper is to discuss the effects of wheel polygonization on the wheel, the rail and the structure under the rail are regarded as rigid bodies to simplify the calculation.

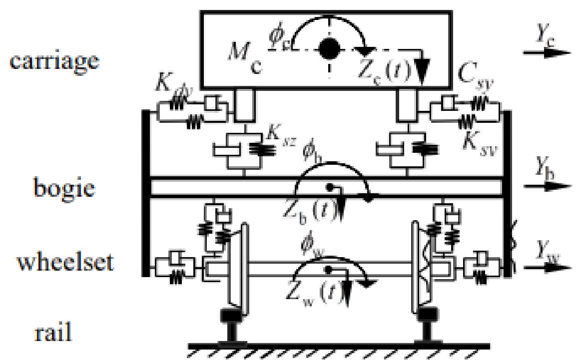

Figure 3: Dynamic model of passenger car [17]

3 RESULTS AND DISCUSSION

3.1 Dynamic Response

Figure 4, 5 and 6 show the response of longitudinal and lateral creep force of wheel-rail under the influence of wheel polygon. The wheel-rail creep force has some difference between Case1, Case2 and case 3. The maximum force of longitudinal creep is 164,330 and 383KN for the right pair of the wheel. The peak value of wheel-rail creep force is increased significantly which also has a significant increase in the damage of the wheel.

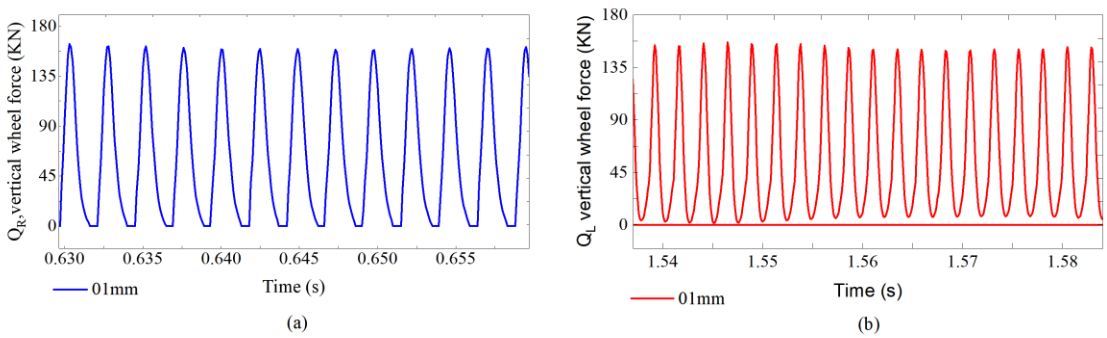

Figure 3: Dynamic response due to 0.1mm wheel polygon

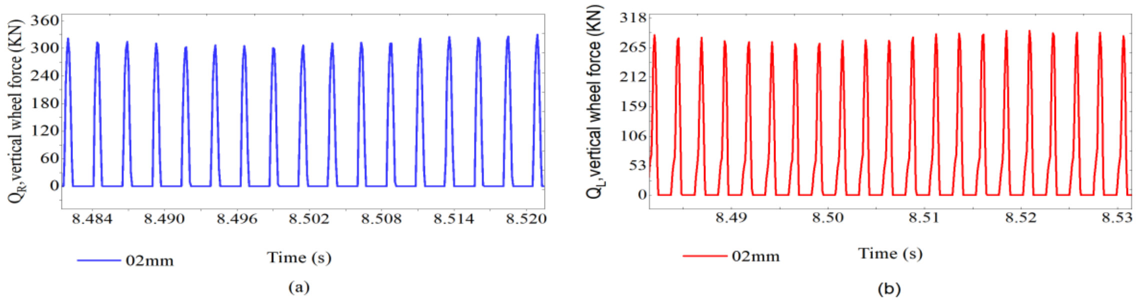

Figure 4: Dynamic response due to 0.2mm wheel polygon

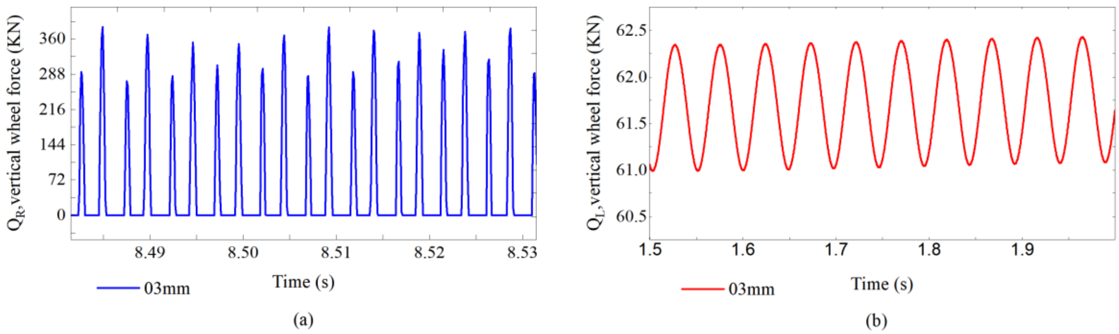

Figure 5: Dynamic response due to 0.3mm wheel polygon

3.2 FEA Model Construction and Stress Analysis

The establishment of the FEA model of the wheel is one of the prerequisites for fatigue analysis, which has a direct impact on the accuracy of fatigue simulation. The modeling of the wheel is carried out by CAD software, and the static strength analysis is performed by ANSYS software using the standard parameters. The FEA model of the wheel is shown in Figure 2 above. The element size is 8mm. According to the stress contour, the maximum stress exists at the wheel rail head contact, and the maximum stress value is 64.776 MPa.

Table 1: *Parameters of the Chinese model*

Parameter	Value
Mass of car (M_c)	35067kg
Mass of bogie frame (M_b)	3630kg
Mass of wheelset (M_w)	1794kg

Load Calculation under Simulated Operating Condition

Vertical loading

The vertical load acts on both the left and right wheels, and the static calculation formula is as follows

F_v= (M_c+2M_b+4M_B) g (1)

F = (35067+2×3630) +(4×1794) (2)

F_v/8= 60.703KN (3)

3.3 Fatigue Analysis

In this paper, the fatigue analysis software n Code is used to simulate the fatigue life of the wheel using the nominal stress method, which is an empirical method to predict the fatigue damage and life of the structure. This method is based on the S-N characteristics of the material which is suitable for high cycle fatigue failure (Qin et al. 2021)

The fatigue simulation is carried out based on the previously obtained load for the three cases i.e.,0.1,0.2 and 0.3mm of the wheel polygon depth, the n code results containing the life are simulated including the S-N curve of the material. The flow of the fatigue simulation is shown in Figure 4. The fatigue crack initiation life prediction and stress distribution under different vertical loading is calculated using the wheel model. The vertical static load is assumed to be the maximum load, which is $60.703KN$. It is necessary to input the S-N curve of the material before fatigue simulation with the nominal stress method. The wheel material is SAE Steel Grade 1090M_Rc29, with a tensile limit of 75MPa, an ultimate limit of 920MPa. In this paper, the S-N curve is fitted by n Code.

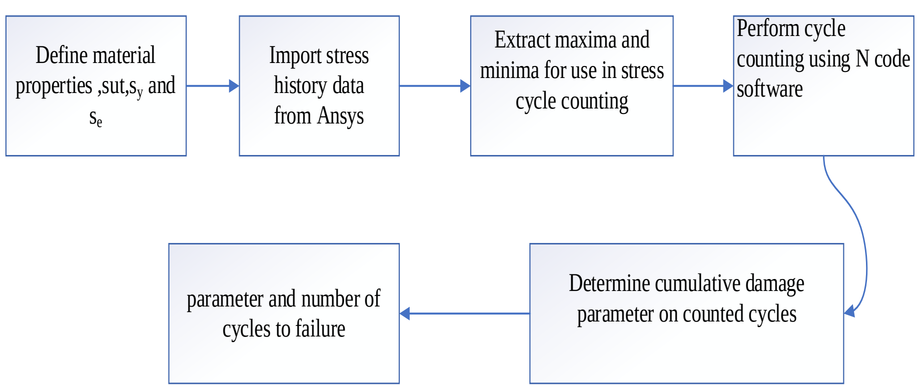

Figure 6: Fatigue analysis process

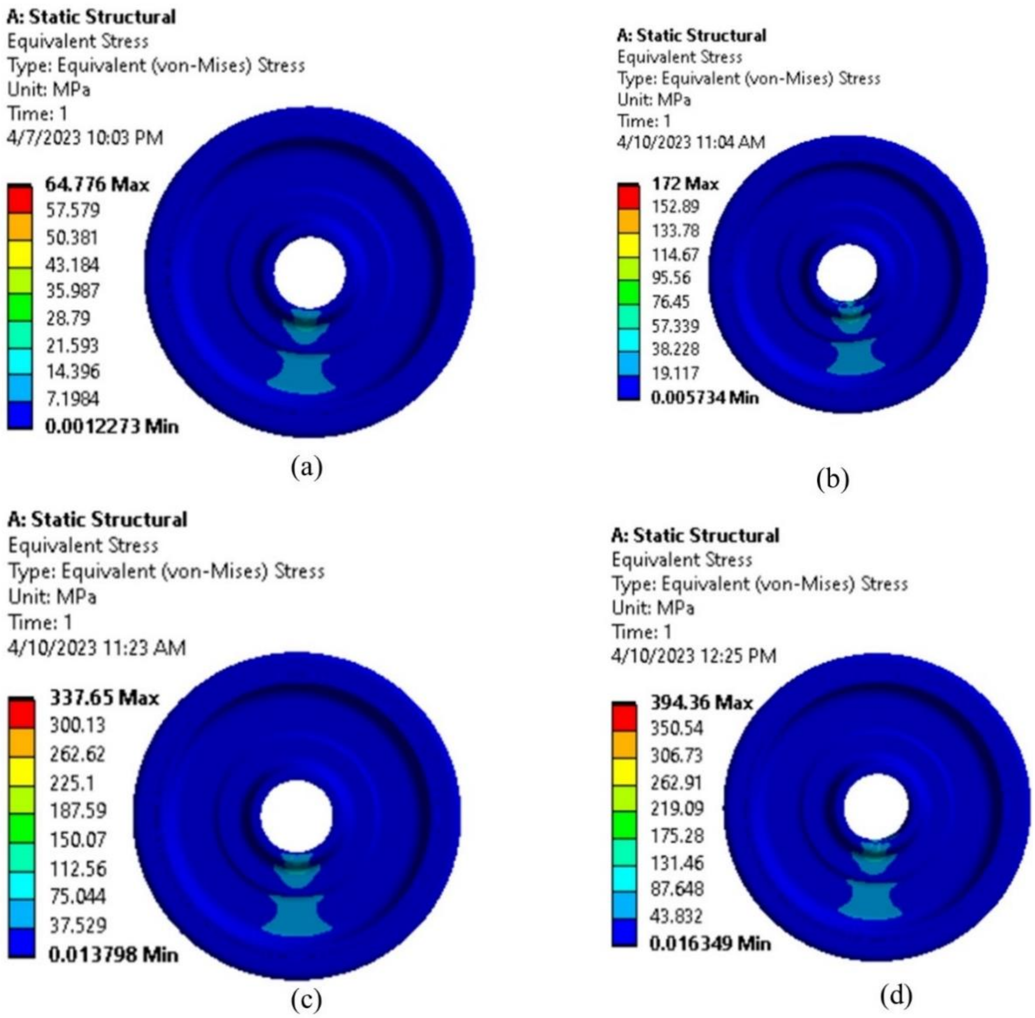

Figure 7: Equivalent stresses (von mises) vertical loads for the three load cases

Figure 8 shows the von-misses tress of the 3 load cases i.e., 0.1,0.2, and 0.3 mm and its evident that increase in the polygon depth has a direct impact on the stress on the wheel which also has a direct impact on the life of the wheel. The FEA analysis results file, and material S-N curve are input into n Code software to analyze the fatigue life of the wheel. The analysis results are shown table 2.

Table 2: Fatigue life table from n code simulation

No	Polygon size	Damage	Life(cycles)
1	0.1mm	2.339E-8	9.24E8
2	0.2mm	2.159E-6	8.18E5
3	0.3mm	6.117E-6	2.15E5

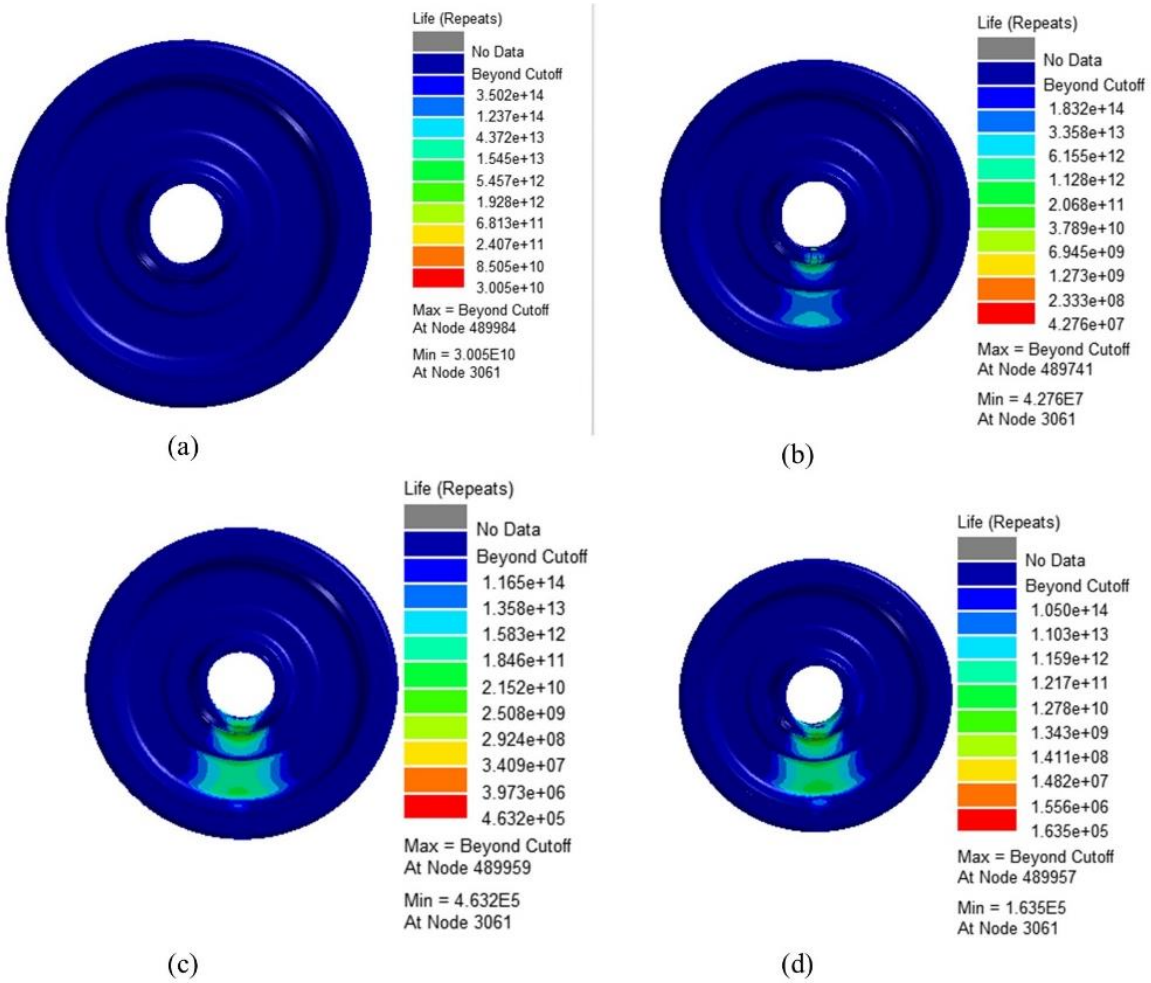

Figure 8: ncode Life prediction Results for the three load cases

3.4 Numerical Analysis Method of Fatigue Life in Terms of Strain

The initial contact point is assumed to occur at the wheel tread center and the contact force is assumed at the maximum value based on the over loading of passengers on the train. The design load of the model is applied on the wheel tread on the running surface of railhead (Akama 2007).Damage tolerance on the wheel-rail interface is defined by the following equation:

$$\sigma_{n,\max}\frac{\Delta\varepsilon_1}{2}=\frac{\sigma_f'^2}{E}\left(2N_f\right)^{2b}+\sigma_f'\varepsilon_f'\left(2N_f\right)^{b+c} \quad (4)$$

where $\sigma_{n,\max}$ is the maximum normal stress in the wheel with normal n, σ_f' and ε_f' represent the fatigue strength coefficient and fatigue ductility coefficient respectively, E is Young's modulus, b and c are the fatigue strength exponent and the fatigue ductility exponent, and N_f is the number of cycles to failure. Using the strain simulated from the three load cases fatigue life is calculated and compared with the simulated software results above.

Using the Smith-Watson-Topper/Bannantine ((0=90 degrees only)(Heyes et al. 1999)

Material properties for fatigue analysis

Table 3: Material properties for fatigue analysis

$\sigma^{i}_{f}(Mpa)$	v	$\varepsilon^{i}_{f}(\%)$	$E(Gpa)$	b	c
840Mpa	0.3	0.304	210×10^{3}	-0.18	-0.65

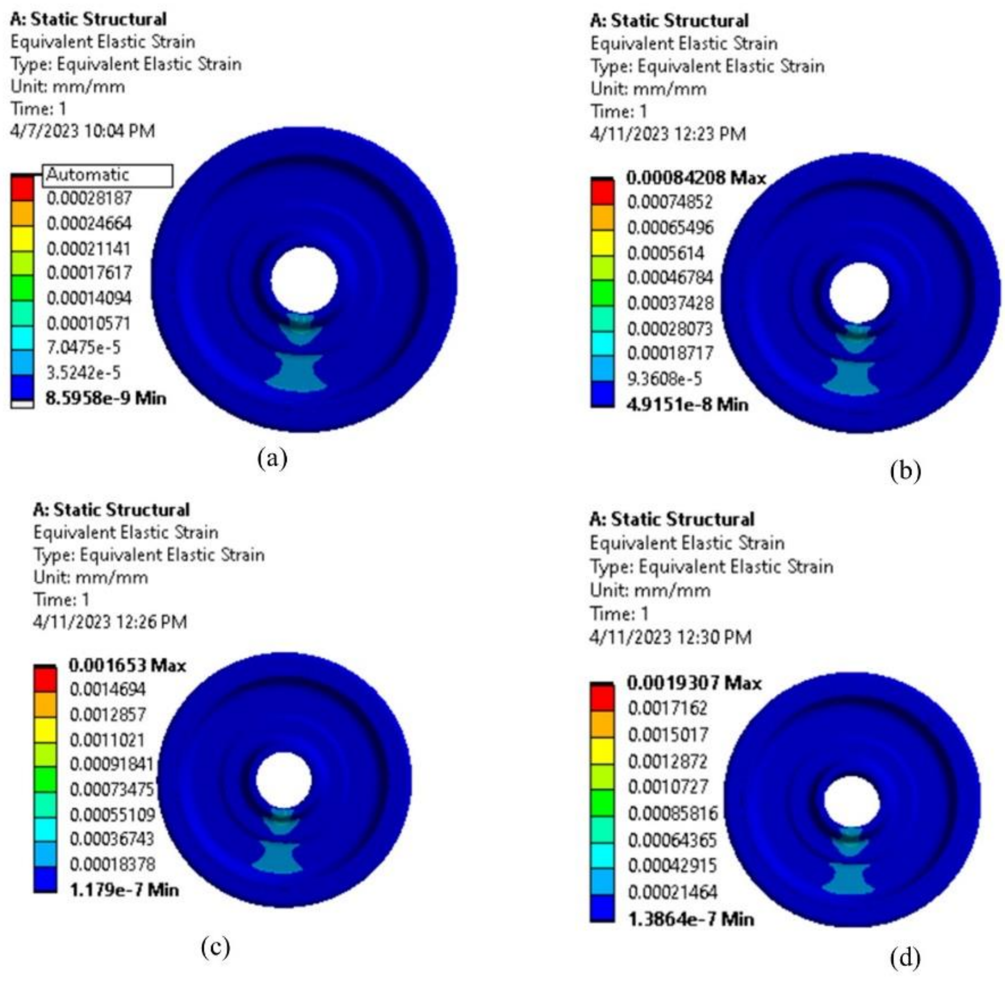

Figure 9: Strain simulated Results from ANSYS

Dynamic loads calculations

Case 1 0.1mm,

Using mansion coffin coefficient

$\sigma_{\max} = 172Mpa$

$\Delta\varepsilon = 0.00084208\text{Mpa}$

$$\sigma_{\max}\frac{\Delta\varepsilon}{2} = \left(\frac{(\sigma^{i}{}_{f})^{2}}{E}\right)(2n_f)^{2b} + \sigma^{i}{}_{f}\varepsilon^{i}{}_{f}(2n_f)^{(b+c)}$$

$$172\,\frac{0.0008420}{2} = \left(\frac{(840)^2}{210\times10^3}\right)(2\times10^6)^{-0.18} + 840\times0.304(2\times10^6)^{-0.65}$$

$n_f = 4.276 \times 10^8$

Case 2 0.2mm

$\sigma_{\max} = 337.65Mpa$

$\Delta\varepsilon = 0.001653\text{Mpa}$

$$\sigma_{\max}\frac{\Delta\varepsilon}{2} = \left(\frac{(\sigma^{i}{}_{f})^{2}}{E}\right)(2n_f)^{2b} + \sigma^{i}{}_{f}\varepsilon^{i}{}_{f}(2n_f)^{(b+c)}$$

$$337.65\,\frac{0.001653}{2} = \left(\frac{(840)^2}{210\times10^3}\right)(2\times10^6)^{-0.18} + 840\times0.304(2\times10^6)^{-0.65}$$

$n_f = 8.187 \times 10^5$

Case 3 0.3mm

$\sigma_{\max} = 3940.36Mpa$

$\Delta\varepsilon = 0.0019307\text{Mpa}$

$$\sigma_{\max}\frac{\Delta\varepsilon}{2} = \left(\frac{(\sigma^{i}{}_{f})^{2}}{E}\right)(2n_f)^{2b} + \sigma^{i}{}_{f}\varepsilon^{i}{}_{f}(2n_f)^{(b+c)}$$

$$3940.36\,\frac{0.0019307\text{Mpa}}{2} = \left(\frac{(840)^2}{210\times10^3}\right)(2\times10^6)^{-0.18} + 840\times0.304(2\times10^6)^{-0.65}$$

$n_f = 2.15624 \times 10^5$

Parametric studies

In this section, the influence of several factors like polygon depth and vertical loads on the fatigue damage of the wheels is studied.

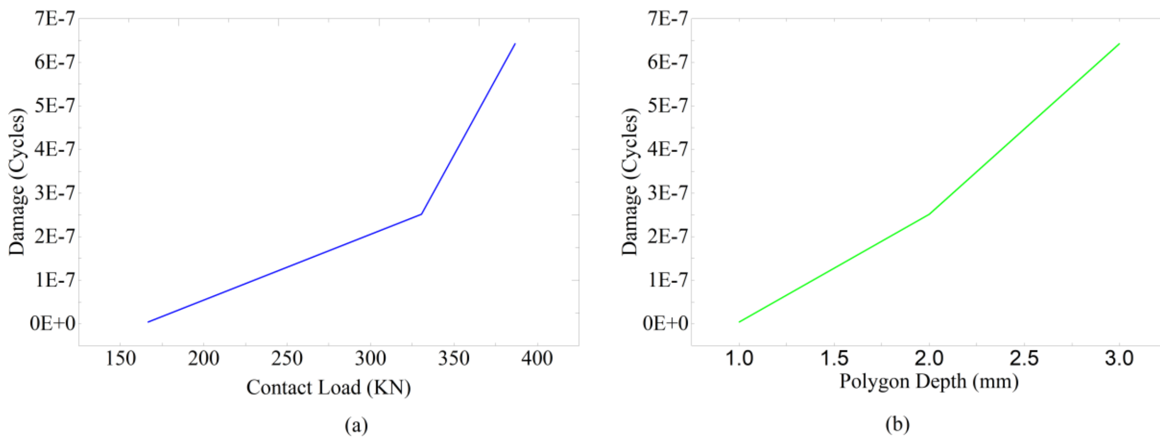

Figure 10: *Relationship between contact load, polygon Depth and Damage*

Vertical Loads

The damage accumulation rate on the wheel section for the wheel under different vertical loads (166.751KN, 330.571 KN and 386.656 KN) are calculated and plotted in Fig.(8a) As expected, the damage accumulation rate increases as the vertical load increases.

Polygon depth

The increase in polygon depth leads to an increase in surface contact between the wheel rail contact which also increases the contact forces as seen from 166.751KN, 330.571 KN and 386.656 KN therefore increasing the contact stressed hence reducing the wheel life.

4 CONCLUSION

The effect of the von mises stress on fatigue damage life initiation is demonstrated by the wheel contact model. The results of the investigations in the current study can be summarized as follows.

1. An increasing contact loading force results in more damage in the wheel interface.

2. The von mises stress increase as the polygon depth increase which has an impact on the life and damage of the wheel.
3. The effect of fatigue damage life initiation increases at the high polygon depth because there is a corresponding increase in the contact load.
4. The maximum value of fatigue life prediction at the straight area is approximately 924000000 cycles.

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Paper 4:

Implementing the Safety System Approach: A Pathway to Zero Road Facilities in Tanzania.

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Abstract

African Road safety remains a critical challenge, particularly in low- and middle-income countries like Tanzania, where traffic-related fatalities are alarmingly high. This presentation explores the Safe System Approach, which prioritizes the elimination of fatalities and serious injuries through a holistic framework that accommodates human errors and vulnerabilities. By shifting the focus from individual responsibility to shared accountability among all stakeholders—including road users, designers, and policymakers—this approach advocates for proactive measures that enhance road safety. Key principles such as designing for human tolerance, implementing safe speeds, and ensuring robust post-crash care will be discussed. Additionally, the study examines successful case studies from countries that have adopted this methodology, showcasing significant reductions in road deaths. The presentation will highlight practical strategies for integrating the Safe System Approach into Tanzania's transportation planning, aiming to foster a safer environment for all road users. Ultimately, this initiative aligns with global efforts to achieve zero fatalities on the roads, emphasizing the necessity of systemic change in traffic safety management.

Paper 5:

Vehicle Technologies and Road Financing Challenges

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Abstract

Over the decades, fuel levies, government central budget allocations, and private financing mechanisms have been a reliant source of financing for road maintenance, upgrades, and road infrastructure and development construction in most countries globally. To meet users ' needs and benefits, sustainable road financing is fundamental for roads. In recent years, the development of Electric technology and highly efficient fuel vehicles have significantly reduced the income generated from the fuel levy. The uptake in EV development, including plug-in hybrids (PHEVs) and full batteries (BEVs), has been tremendously noted to increase in most developed countries, including Europe, South America, China, the United States, and the rest part of the world, including South Africa. In this context, this research study aimed to discuss the impact of road funds on the transition to EVs while attempting to seek appropriate road financing alongside the traditional financing mechanisms that heavily rely on fuel levies to accommodate the uptake of EV technologies. The methodology of this research primarily based on identifying road financing mechanisms in range of countries focusing on the traditional road financing mechanism that mostly rely on the fuel taxations while attempting to present a proposal for road fund recovery to accommodate the uptake of the Electric and highly efficient vehicles by considering future technology trends, social and environmental impacts, in developing and developed countries. This study considered analyzing the potential impact of declining fuel levies by considering road charging policy, road generated revenue and expenditures that mostly relies on fuel taxation. The study findings strongly encourage a call for better options to improve traditional funding mechanisms while considering the pace of EV uptake and technological and cultural social trends and interventions. The study provides concise recommendations on road funding mechanisms and best practices for enhancing the sustainability of road maintenance and upgrades.

Session Two: Development of Maritime and Air Transport for Sustainable Economic Development

Paper 6:

Impacts of Covid-19 Pandemic to the Container Terminal Performance using Malmquist Productivity Index

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ABSTRACT

Covid- 19 Pandemic is another global catastrophe after the financial crisis of 2008-2009. To reduce the effects of an outbreak to the national economy, many countries adopted restriction measures including isolation and blockade. However, the impacts of covid-19 to the economic system, industries supply chain and transportation system cannot be ignored. In particular ports as a key node in the cross- border supply chain connecting shipping and land transportation their production and operations were severely affected. From such a background, this paper analyzes the impact of covid-19 outbreak towards container terminal performance specifically at Dar es Salaam port. The Malmquist Productivity Index -DEA approach was employed to determine the driver of port productivity and to measure the efficiency level and change at 2012-2022. The findings revealed that there is a drastic reduction of 2.28% of container cargo throughput at 2019-2020 while ship calls decreased by 33% to the same year and 9% by 2020-2021. Also, the results indicated the drivers of container terminal efficiency are both technical and technology (MPI=1). The container terminal remained to be consistent in efficiency level despite the covid-19 pandemic. Accordingly, this study is useful to both port authority, port operators and industry practitioners since it provides valuable insights for better equipping the ports to handle risks, prepare for and plan ahead of disruptive events like pandemics, environmental issues and security problems. Ultimately, this paper provides a valuable contribution to the scholarly community mainly related to maritime industry.

Key words: Covid-19 Pandemic, Container Terminal Performance, Malmquist Productivity Index, Efficiency

1 INTRODUCTION

The COVID-19 pandemic has profoundly disrupted global supply chains, with container terminals emerging as critical nodes heavily impacted by the ensuing economic and operational challenges. Container terminals play a pivotal role in facilitating the flow of goods between producers and consumers, making their efficiency crucial for maintaining supply chain resilience and economic stability (Notteboom & Pallis, 2020). The pandemic-induced disruptions, ranging from reduced demand and workforce shortages to operational restrictions and logistical bottlenecks, have tested the adaptive capacities of container terminal operations worldwide (Wang et al., 2021).

According to IAPH survey (2021), throughout the first phase in early 2020, China experienced a supply shock due to lockdown measures, which de facto prolonged the country's severely reduced output throughout the New Year period. The majority of the workforce was impacted by the lockdown, which reduced the industrial base between mid-January and early March 2020. The last stage of the global economy, which includes a distinct and steady recovery and a return to typical demand patterns, is still ahead of sight. When a period of recovery resembling such initiates, there may be a greater chance of protectionism to boost domestic manufacturing. Restoring and near shoring are also being explored as ways to strengthen supply chains, lessen reliance on foreign production, and foster vital regional and regional economies.

Ports are vital economic hubs that connect sea and land supply chains. Estimated at over 11 billion tons, the cargoes enter and leave ports. The role of ports in ensuring the continued supply of food, fuel, raw materials, and medical supplies as well as essential manufactured goods (Notteboom&Pallis, 2020). The terminal plays an integral role in the logistics chain by providing cargo handling services to a wide spectrum of customers, including shipping lines, freight forwarders and various types of organizations. Adeola et al (2018). The concept of port performance is formed by two interconnected components include efficiency, effectiveness while resilience to disruptions emerged as additional third component, (Notteboom &Pallis 2022).

As governments' implemented lockdowns and travel restrictions to curb the spread of the virus, global trade volumes plummeted, triggering a cascade of repercussions throughout the maritime logistics sector (UNCTAD, 2020). The demand for and freight rates for commodity vessels, such as dry bulk and tanker vessels, have decreased. Extremely Large Containership Vessels (VLCVs) are reportedly only carrying 10% of their capacity when they depart Chinese ports. (EABC, 2020). Container terminals faced unprecedented fluctuations in cargo volumes and vessel calls, exacerbating congestion and operational inefficiencies (Ng & Ducruet, 2021). Moreover, stringent health protocols and social distancing measures further strained terminal operations, leading to delays in vessel turnaround times and increased dwell times for containers (Brooks et al., 2020).

The impact is also noticed from many large ports with a strong gateway role which saw their container throughput drop. For example, Rotterdam (-7%), Shanghai (-6.8%), Los Angeles (-17.1%), Hamburg (-14.7%), Le Havre (-29%), Barcelona (-20.5%), and Valencia (-9.1). Only four large ports showed an increase in volume: Gioia Tauro (+52.5

%), Tangier Med (+22%), Port Said-SCCT (+23.5 %), and Antwerp (+0.4%). The world experienced a minor drop in global export in 2019 while in 2020 the huge decrease was experienced from merchandise export in which a drop is approximately to reach about -

7.5%. In case of Africa, the continent experiences a -10.18 30 % reduction in vessel calls, surpassing the global drop of -9.65% by 2020. (Cullinane & Haralambides, 2021)

COVID-19 is having a significant impact on Tanzania's transportation sector and economy. Limitations on passenger movements by road and rail, transportation and logistics capacity has been underutilized as a result of the pandemic. There was a shock in trade flows due to transport and logistics disruptions. Because of an outbreak, there has been a reduction in the usage of the workers for cargo loading and unloading. South Sudan, Uganda, Rwanda, and Zambia have all had transportation and travel restrictions imposed on them. (Wilhelmsen, 2020). The borders were opened; however, there are some delays in clearing trucks crossing the border due to imposed curfews. This has an impact on deliveries of exports & picking up of import cargo from the ports.

(EABC,2020). Following the COVID-19 outbreak (i.e. week 15 and week 16) more than 40% of ports were in a precarious position, reporting delays (6-24 hours) or heavy delays (> 24 hours) in cross-border trucking activities compared to normal conditions (IAPH,2021). At the maritime transport, in Tanzania all nationalities were free to change crews. If all control measures and preventative regulations are followed (no indications of disease, PPE prescribed by WHO), there are no limits for ships and crews. (Wilhelmsen, 2020). The expected disruption at Dare s Salaam Port is slower clearance of cargo at sea (EABC,2020).

This research aims to investigate the multifaceted impacts of the COVID-19 pandemic on container terminal efficiency specifically at Dar es Salaam Port. By analyzing empirical data and case studies from this port. This study seeks to elucidate how container terminals have adapted their operations, technology adoption, and workforce management strategies in response to the crisis. Additionally, it will examine the trends of cargo throughput and ship calls at 2012 - 2022, it will determine the drivers of port productivity and measure the efficiency level and change between 2012-2022. Lastly, it will describe the measures used by Port Authority to mitigate the impacts of Covid-19

Pandemic.

2 BRIEF BACKGROUND OF DAR ES SALAAM PORT

Dar es Salaam port is the Tanzania principal port with a total capacity of 4.1 million (dwt) dry cargo and 6.0 million (dwt) bulk liquid cargoes. The Port has a total quay length of about 2,600 meters with eleven deep-water berths. Dar es Salaam port handles about 95% of the Tanzania international trade. The port serves the landlocked countries of Malawi, Zambia, Democratic Republic of Congo, Burundi, Rwanda and Uganda. The port is strategically placed to serve as a convenient freight linkage not only to and from East and Central Africa countries but also to the Middle and Far East, Europe, Australia and America. (TPA HANDBOOK, 2020). Governments throughout the region recognize that the performance of Tanzania's ports, in combination with road and rail transportation and other logistic services, is important to the country's economic success.

Facilities available to support operations of Dar es salaam port are: -General cargo Berth (0-5) for break bulk, dry bulk and one RORO berth to handle vehicles. Container Terminal Berths (Berth 5 -11) Grain Terminal facility (silos with storage capacity of 30,000 tons). Inland Container Deposits (ICDs) facilities with the capacity of 24,300

TEUs and CFs with the capacity of holding 6,000 vehicles at once. A 150,000 MT Single Point Mooring (SPM) – for handling refined and crude oil and Kurasini oil Jetty (KOJ) for handling refined products (tanker size 45,000MT for KOJ1 and 5,000 tons for KOJ2). Generally, the intrinsic capacity of the port of Dar es salaam is to handle more than 18 million tons of cargo as follows: -General cargo 5.2 million tons, Container yard 6.8 million tons, Liquid bulk 6.0 million tons. (TPA HANDBOOK, 2020).

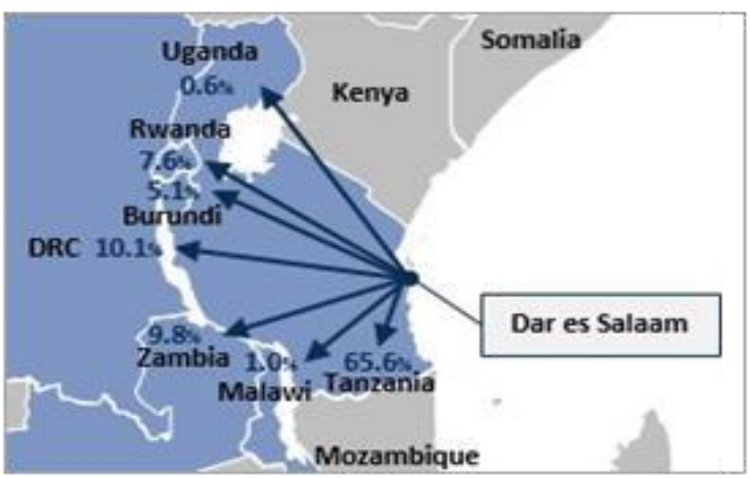

Figure 1. Port of Dar Es Salaam (*World Bank Database, 2021)*

3 LITERATURE REVIEW

The academic community has given considerable attention to the study of the effects of COVID-19 on port performance, demonstrating the topic's complexity and continued significance in today's discussion. The purpose of this literature review is to provide a thorough overview of the field's development in order to synthesize existing research, theories, and approaches relevant to the topic.

Since the outbreak of Covid-19 pandemic some scholars have studied the impact of Covid-19 on the port economy, environment and operations. For example, Hajar et al (2021), use Autoregressive Distributed Lag (ARDL) cointegration technique to measure the impacts of covid- 19 on the port environment at Tengar port of Morocco. They tried to show the relationship between the number of TEUs, cumulative number of new covid-

19 cases and the cumulative number of covid 19 cases of death. Their findings revealed that there is a negative and significant impact of the coronavirus crisis on container transport operations at Tengar Port.

The study of Osundiran, O et al (2021) added knowledge towards the impacts of covid - 19 to the port productivity. They sampled Singapore port as a case study. Lang Xu, et al (2021) undertook the study on the effect of COVID-19 pandemic on port performance. They have taken evidence from 14 ports of China. Their study used a panel regression model to determine key factors affecting port operations in the context of COVID-19. They use export and import cargo as dependent variables. Their findings showed that the severity of the epidemic has a significant negative effect on both import and export cargo throughputs. Likewise, that study depicted that at the macroeconomic level, the industrial added value above the designated size has a significant positive correlation with import throughput but has no significant impact on the export throughput.

IAPH- WPSP (2021), A survey-based analysis of the impact of COVID-19 on world ports in the period of April 2020 to April 2021. The study measures the impacts of covid – 19 to the different scenarios related to the port environment. For example, the impacts of crisis on vessel calls, the impacts of extra restrictions on vessels, extra delays due to changes in port call procedures, impact of crisis on hinterland transport and truck operations. The study surveyed different vessel markets include (i.e., container, other cargo and passenger). The findings revealed that, on a global level, about 29% of the ports faced a drop of more than 5% in the number of container vessel calls compared to a normal situation, The regional results demonstrate that the crisis in Europe peaked in week 19 and has shown gradual improvement since then, the blank sailing to the trade route mainly to the Far East countries led to a drop of the container market for more than 5%. While other cargo vessels experienced the reduction of more than 25% of vessel calls. However, the report depicted that, cruise/ passenger market affected more compared to other markets. The market declined for more than 50%. The study of Ayekola about the perspectives on the impact of the COVID-19 pandemic on the global and African maritime transport sectors, and the potential implications for Africa's maritime governance. The study depicted the short-term effects include drop in the volume of trade transported by maritime shipping; disruptions due to rerouted shipments; maritime defaults and bankruptcies; and stranded seafarers. However, In the African context, the paper highlighted that with a mere 4% share of global container port traffic and a 7% and 5% share, respectively, of international maritime exports and imports (measured by tonnage), Africa's significance to the global MTS is not huge.

Jagan, J. et al (2020) indicated the impact of covid-19 in the maritime sector in Malaysia. The study is based specifically in shipping, fisheries, maritime tourism, and the oil and gas sector. Likewise (Yin Ming et al, 2021) wrote on influences and response measures of COVID-19 epidemic on shipping and port industry in China. Their study focuses on evaluating different market segments, the different impacts on ports, containers, tankers, dry bulk cargoes, cruise ships and other subdivisions. Narasimha et al (2021) assessed the impact of COVID-19 on the Indian seaport transportation and maritime supply chain in India. The results on the quantitative performance of Indian major seaports during the COVID-19 indicate a negative growth in the cargo traffic and a decrease in the number of vessel traffic compared to pre COVID-19. Also, the paper of Anas, A et al (2022) investigates COVID-19's immediate impact and the ensuing issues for ports, shipping, and the maritime supply chains and industry under the exploratory review at the Port of Aqaba/ Jordan. In summary, in the research of measuring port performance in the context of covid-19 pandemic, those reviewed studies explicitly revealed that there are few papers that used Malmquist Productivity Index- DEA to study the impact of the Covid-19 pandemic on the port performance.

According to the literature reviewed, there is a shortage of paperwork, especially in Tanzanian sea ports, about the effects of COVID-19 on port performance. Therefore, this study fills the gap by analysing how the COVID-19 pandemic has affected container terminals.

4 METHODOLOGY

For the purpose of analyzing the port data under this study, two methods were adopted. The researcher used the Malmquist Productivity Index-DEA model to determine the efficiency of Dar es Salaam Port from 2012 – 2022, that is pre pandemic and after the eruption of Covid-19 diseases which is almost 11 years. MPI-DEA used because it is a proven and useful tool for the analyzing the efficiency level of ports as well as determination of the drivers of port productivity, (Osundiran,2020) However, the researcher was employed descriptive statistics techniques to assess the trends of the ship calls and cargo throughput at Dar es Salaam port at the same years.

4.1 Efficiency Measurement Concept

There are many methods which can be used to measure the efficiency of a firm. The two methods are the main and are modern ones; these are stochastic frontier Analysis (SFA) and Data Envelopment Analysis. From these methods DEA has gained the priorities and a huge importance in recent study which combines many inputs and outputs with various DMUs. Hence this study based on DEA-MPI.

DEA is a method for measuring comparative or relative efficiency. It is a non-DDD \ parametric method in operation research and economics for the estimation of production frontiers. It is used to empirically measure productive efficiency of decision- making units (DMUs) (Charnes A., W. Cooper and E. Rhodes 1978) The Malmquist Productivity Index is the standard approach for measuring productivity change over time. The Malmquist total factor productivity index was first introduced by the researcher Malmquist before being further developed in the context of DEA. Hence, Malmquist Productivity Index is useful in identifying trends and patterns in the industry (technological change). The output-based Malmquist productivity change index is defined by Fare et al (1994) which is used by the researcher under this study.

The Malmquist index is a geometric average of two indices that can be measured between period t and period t+1 technology (Osundiran et al 2020). The period t acts as the base year while t+1 is the coming one. The frontier shift as a result of technological change is graphically depicted in the following figure. This represents a change from frontier a to frontier b. On the frontier, C1 and C2 show an upward movement. This is due to a change in efficiency

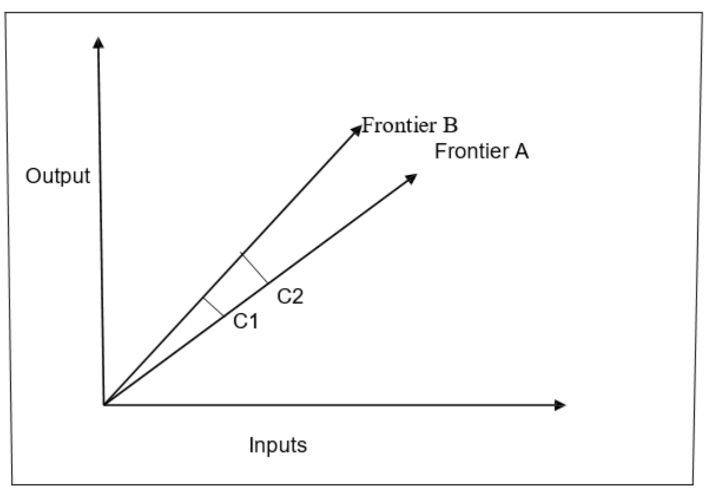

Figure 2. Decomposition of Malmquist Productivity Index

Source: Adapted from Osundiran (2021) Malmquist equation, which is used to calculate efficiency and determine the drivers of port productivity, is constructed as follow:

$$M(Y_{t+1}X_{t+1},Y_t,X_t) = \left[\underbrace{\frac{D^t\,(Y_{t+1}X_{t+1})}{D^t(Y_t,X_t)}} \times \underbrace{\frac{D^t\,(Y_{t+1}X_{t+1})}{D^{t+1}(Y_t,X_t)} \times \frac{D^t\,(Y_{t+1}X_{t+1})}{D^{t+1}(Y_t,X_t)}}\right]^{\frac{1}{2}} \qquad \text{Eqn (1)}$$

Where:

Efficiency change Technological change

X_t and X_{t+1} input vectors of dimension at time t and t +1

Y_t and Y_{t+1} corresponding k- output vectors

D_t and D_{t+1} denote an input

$$D(x, y) = \max(p : (s / \rho\ s \in L(y)) \qquad . \qquad \text{Eqn (2)}$$

Hence,

The interpretation is as follow:

where L(y) represents the number of all input vectors with which a certain output vector y can be produced, that is L(y) = (x: y can be produced with x).

ρ in equation (5) can be understood as a reciprocal value of the factor by which the

total inputs could be maximally reduced without reducing output.

Hence, M= Measures the productivity change between periods t and t+1. Productivity declines if M<1, remains unchanged if M=1 and improves if M>1.

4.2 Data Selection

Since the main function of container port is to handle containers and its ship, hence two outputs were selected, and eight variable inputs were considered by the author. After reviewing different studies of various scholars, the same factors/ variables are highly recommended to measure the efficiency and productivity change example (Joanna D, 2015), (Zhang, 2021), (Makiri M, 2019) (Ian M, 2021) and (IDB, 2015). Hence the same kinds of variables were used in this paper to analyze the impact of covid-19 pandemic to the container port of Dar es Salaam region as whole. Or to determine efficiency level of Dar es Salaam port in the context of Covid-19.

Table 1 Data of the Study

Input	**Output**
Input X1 – quay length (total quay length in (m)	Output Y1 – annual throughput in TEU
Input X2 – terminal area (total terminal area in (m^2)	Output Y2 - ship calls (number of ship visits annually)
Input X3 – ship to shore gantry crane (SSG)	
Input X4 – Rubber tyred Gantry Cranes (RTG)	
Input X5 – Reach Stacker	
Input X6 – Fork Lifts	
Input X7- Empty Handler	
Input X8 – Terminal Tractor	

5 RESULTS AND DISCUSSION

This section presents the data obtained from the field and respective Organizations, analysis and interpretation of data done through descriptive statistics and DEA-Malmquist productivity index. The data range is from 2012-2022. Table 2 Depicts the Inputs and Outputs variables used in this study, which are the data directly obtained from the respective organization (TPA and UNCTAD, 2024). It combines two outputs and 8 inputs variables.

Table 2. Outputs and Inputs Variables of the Study

Year	Through put	Ship Calls	Quay Length (M)	Terminal Area	SSG	RTG	Reach Stacker	Fork Lift	Empty Handler	Terminal Tractor
2012	507185	339	725	18.8	4	11	7	13	9	42
2013	553940	323	725	18.8	5	12	7	13	8	42
2014	612551	343	725	18.8	5	12	7	13	8	49
2015	639230	357	725	18.8	6	19	9	13	6	49
2016	630290	355	725	18.8	6	19	8	16	6	43
2017	617266	367	725	18.8	6	17	8	18	7	44
2018	705231	403	725	18.8	6	17	8	21	7	44
2019	726431	270	725	18.8	6	20	7	23	7	48
2020	709881	244	725	18.8	6	20	7	23	7	48
2021	700000		725	18.8	6	20	7	23	7	48
2022	700000		725	18.8	6	20	7	23	7	48

5.1 Trends of Container Throughput at Dar es salaam Port

This part examines the trends of container cargo at Dar es Salaam port from 2012-2022 years. Figure 2 shows the graphical presentation of annual container throughput at the Dar es Salaam port. The results revealed that there is a decline of 2.28 % between the years of 2019 and 2020. While between the years of 2020-2021 the decrease reached about 1.39%. This decline was noticed because at the end of 2019 is where the covid-

19 began and caused a lot of shock to supply chain activities. Different initiatives implemented including lockdown policy were the reason behind; hence many operations were stopped. This decline was slightly contributed by the covid-19 pandemic. From the year of 2018-2019 the Dar es Salaam container terminal experiences a gradual increase of its cargo throughput by 3.01%

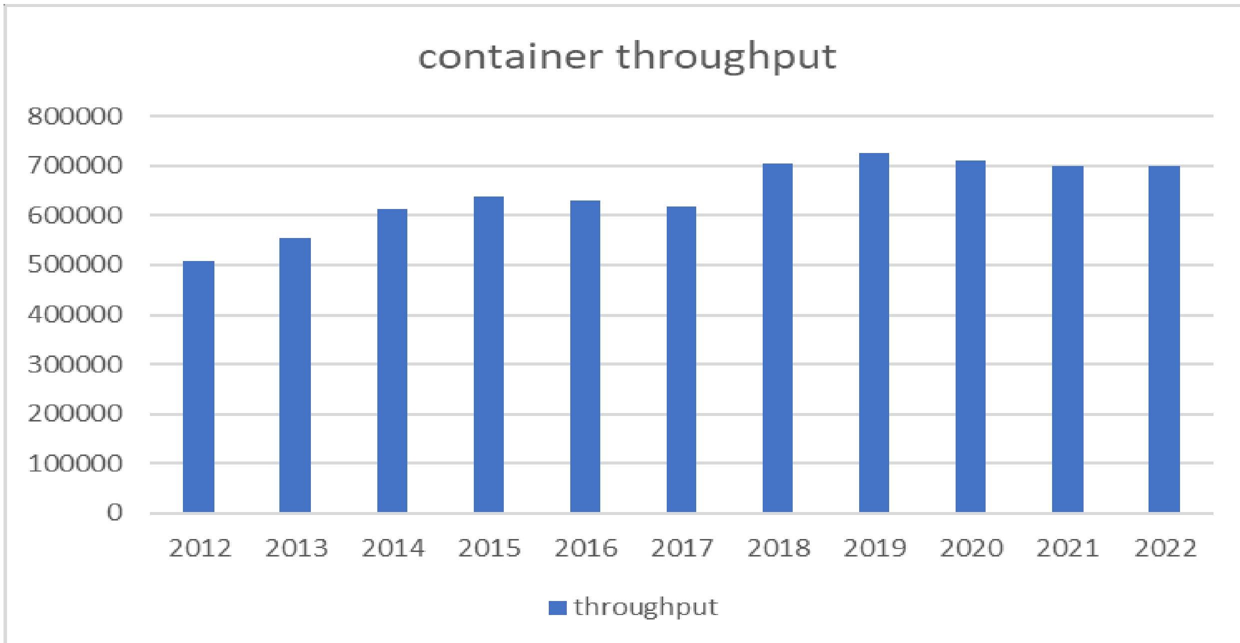

Figure 3: Container Throughput at Dar Es Salaam Port (Source: Author's Representation)

5.2 Trends on Vessel Visit at Dar es Salaam Port

The figure 3 depicts the trends of vessel visits to the port at Dar es Salaam. An analysis of the data shown that during the pandemic, fewer container vessels visited the port. Significantly lower ship calls were made in 2019 and 2020 than in 2018 and 2019, a fall of 33.02% while a fall of -9.63% noticed in 2020-2021. Tanzania imports the majority of its cargo from China, where restrictions have been put in place, many enterprises have been forced to close, and exports have somehow decreased. Numerous shipments remained in the storage place unshipped. The container crisis is another issue that COVID-19 brought up, which is why many ships are unable to function effectively. Thus, it affects a container terminal at the Dar es Salaam Port.

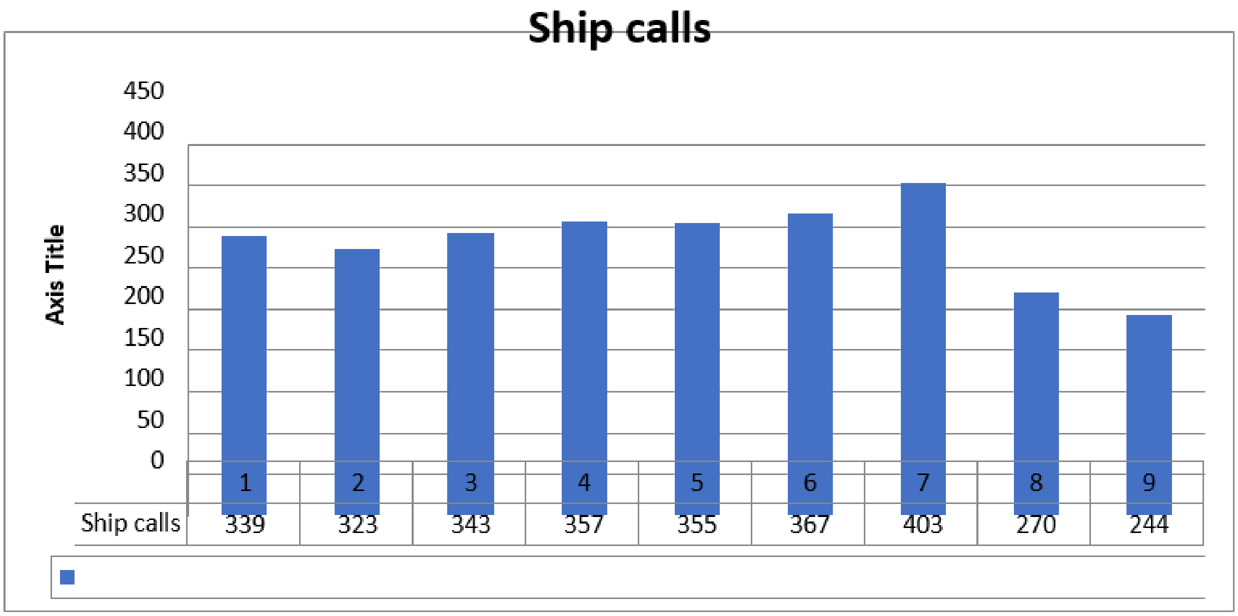

Figure 4: Ship Calls at Dar Es Salaam Port Source: Author's Representation

5.3 Malmquist Productivity Index-DEA Calculations

Another aspect of this thesis is to examine whether there is change of port efficiency and productivity level at Dar es Salaam Port onset the covid-19 pandemic. The output-oriented DEA- Malmquist Productivity Index was applied to measure the efficiency of container terminals at Dar es Salaam port from 2012-2022. The time frame work is pre-pandemic and during the pandemic. The software used is DEAP 2.1 version developed by Ocelli (1996). This software is used for the analysis of port data. Under DEA MPI two aspects are mainly considered which are technical efficiency (efficiency catch-up) and technological change (boundary shift). Hence the product of these two aspects is known Malmquist Productivity Index (MPI)

5.3.1 Technological Change

This is the one aspect of the Malmquist Productivity Index. Hence the container Port of Dar es Salaam was examined for its technological change over 11 years. Normally Technological change TC leads outward shift in the production frontier. Over the 11 years of analysis, under the technological aspect the Dar es salaam Port continues to be constant = 1 or by approximation. Under the technological base, the port shows stagnant condition. That is not increasing any reduction on a large scale. Though during covid-19 this container port had shown a slight decrease

Table 3. Technological Change for Dar es Salaam Container Terminal

Port of Dar es salaam	2012-2013	2013-2014	2014-2015	2015-2916	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022
Technological Change	1.04	1.02	0.96	0.95	0.96	1.06	1.02	0.98	0.99	1

Source: Author’s Calculation

5.3.2 Efficiency Change

The efficiency changes of container terminals at Dar es Salaam port did not decline during the pandemic period. This was attributed for a large amount as Dar es Salaam Port did not close its border during covid-19 era. Hence the port did not seize its operations. Efficiency Change for one way is connected to managerial efficiency that may lead the movement either to be downward or upward on the production frontier. Hence the container port of Dar es Salaam shown EC=1 over the years, so its efficiency level remains to be constant. Table below show the results.

Table 4. Efficiency Change for Dar es Salaam Container Terminal

Port of Dar es Salaam	2012 - 2013	2013 - 2014	2014 - 2015	2015 - 2916	2016 - 2017	2017 - 2018	2018 - 2019	2019 - 2020	2020 - 2021	2021 - 2022
Efficiency Change	1	1	1	1	1	1	1	1	1	1

Source: Author’s Calculation

5.4 Malmquist Productivity Index

This aspect determines the driver of port productivity at the container port of Dar es Salaam. The driver of port productivity at the container terminal of Dar es Salaam port indicated both efficiency and technology. Hence the product of efficiency changes and technological change is MPI. When MPI= 1 indicates consistency, when MPI < 1 show decline of productivity and when MP1 > 1 signifies there is a progress in productivity. From this analysis the year 2012-2013,2013-2014, 2017-2018, 2018-2019 shown there is a is a progress in productivity at the dare s Salaam container port, since the value is

> 1 while 2019-2020 and 2020-2021 the MPI indicates some decline of productivity, in this time it is where covid-19 declared and restrictions measures started to be implemented around the whole world.

Table 5. Malmquist Productivity Index for Dar es Salaam Container Terminal.

Year	Efficiency Change	Technological	MPI
2012-2013	1	1.04	1.04
2013-2014	1	1.02	1.02
2014-2015	1	0.96	0.96
2015-2016	1	0.95	0.95
2016-2017	1	0.96	0.96
2017-2018	1	1.06	1.06
2018-2019	1	1.02	1.02
2019-2020	1	0.98	0.98
2020-2021	1	0.99	0.99
2021-2022	1	1	1

Source: Author’s Calculation

5.5 Effective Strategies Used by Port to Reduce the Impact of Covid- 19 Pandemic

Another aspect of this research was exploring measures or strategies that port authority used to combat against the spread of covid-19 pandemic and to improve the efficiency where the port is under threat of pandemic.

A survey-based analysis of the impact of COVID-19 carried out. In order to address the COVID-19 epidemic, Dar es Salaam Port has put in place a number of strategic initiatives centered on health and business continuity. Establishing strict health and safety regulations, such as requiring health tests and requiring personal protective equipment (PPE) for all employees, were important tactics. Priorities were also set for improved sanitary practices, such as installing hand sanitizing stations and routinely disinfecting facilities. The port embraced digitalization by encouraging contactless transactions and electronic paperwork, which reduced in-person encounters. On-site traffic was lessened by flexible work schedules, such as alternating shifts and remote work for non-essential employees.

Additionally, proactive stakeholder engagement ensured clear communication regarding operational changes and health guidelines. These comprehensive strategies not only safeguarded the health of workers and visitors but also ensured the Dar es Salaam port's operational resilience during a challenging time.

7. CONCLUSION

This paper was analyzing the impact of covid-19 pandemic to the container port performance. The study area was container terminal at Dar es Salaam port in Tanzania. Dar es salaam Port is the main port in Tanzania with a lot of freight for export, import and transit for the landlocked countries like Zambia and DRC. The study is output oriented and adopts variable return to scale. Eleven years of analysis of the port had shown the consistency of its efficiency. Though there are some decreases of vessel call/ ship visit and cargo throughput especially when the covid -19 disease erupted. For example, from 2019-2020, the container throughput was decreased by 2.28% while shp calls falls for 33.02%This was slightly contributed by the eruption of the pandemic which led the disruptions to the entire supply chain network around all over the world. Sometimes the port declares a container crisis whereby many cargoes which are expected to be exported remain at the port. Even though the Dar es Salaam port, especially at the container terminal shows the decrease of its cargo, the port manages to ensure that technological and efficiency remains stable. This was proven by the method of DEA-MPI which results = 1. The Dar es Salaam port has achieved DEA- Malmquist Productivity index effectiveness despite the pandemic. The whole 11 years of analysis revealed there is consistency. This is contributed by technological progress done from year to year. Hence the empirical study revealed that technological progress plays an important role to Dar es Salaam port despite the entire operations being disrupted by Covid-19 disease. Those years of analysis the technology remains to be 1.

In addition, this study revealed that Dar es Salaam Port has put forward a number of measures to combat against the Covid-19 around the port and to reduce the speed of its spreading. Dar es Salaam Port prioritized the health and safety of its employees, stakeholders, and the general public while putting in place a number of successful measures to lessen the effects of COVID-19 and guarantee the continuous operation of its facilities. Important tactics comprised: application of stringent health screening procedures, such as temperature checks and health surveys, for port employees and guests. All personnel were required to wear personal protection equipment (PPE), such as masks and gloves. All communal areas and high-touch surfaces in the port facilities are routinely disinfected. Hand sanitizing stations installed in key areas to promote good hygiene. However, a greater reliance on digital channels for communication and paperwork in order to reduce in-person contacts; examples include electronic customs processing and electronic cargo tracking were used. Adoption of policies allowing non-essential employees to work remotely, which keeps operations running while lowering the number of employees present to keep stakeholders aware about port operations and health regulations, there were regular updates and communication with them. This includes shipping businesses and customs authorities' cooperation with health authorities to guarantee adherence to international and national health laws.

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Paper 7:

Passenger Satisfaction with Airport Service Quality: Insights from Julius Nyerere International Airport in Tanzania

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ABSTRACT

In today's increasingly competitive world, offering high-quality service to customers can be critical to an airport's competitiveness and profitability. The current study examined the influence of airport service quality on passenger satisfaction at Julius Nyerere International Airport in Tanzania terminal three. It applied the Hierarchical Service Quality Model to meet the study objective. A total 335 samples were collected from international passengers departing from Julius Nyerere International Airports - Dar es salaam using 7 points Likert-scale considering convenience sampling. The result of the Confirmatory Composite Analysis and PLS -SEM using three high order constructs confirmed that there is the positive influence airport service quality on passenger satisfaction. The airport service quality positively influences passenger satisfaction. Furthermore, the result showed that airport service quality is the most influential predictor of passenger satisfaction. In addition, these results have significant implications in practical, theoretical, and methodology. It makes a distinctive contribution to the Hierarchical Service Quality Model by testing its applicability in the airport context. Methodological implementations of partial least squares (PLS) research, particularly in relation to its utilization within the framework of high-order constructs, were implemented using two disjoint approaches. The current study provides a significant practical contribution to Airport authorities by emphasizing the significance of airport service quality in enhancing passenger satisfaction.

Keywords: Hierarchical Service Quality Model, PLS-SEM, High order Constructs, Two disjoint approach

1 INTRODUCTION

The airport provides the facilities, formalities, and procedures necessary for the efficient boarding and departure of aircraft (Kankaew, 2020). More advanced airport infrastructure is appealing to passengers since it increases the level of satisfaction experienced by passengers (Saut & Song, 2022). Modern airports have become more sophisticated because their terminal buildings contain shopping centers and movie theatres, allowing passengers to spend their time in the waiting lounge for shopping and entertainment (Bezerra & Gomes, 2020). From the passenger's perspective, the airport terminal can be divided into two major categories of activities: process and discretionary (Bezerra & Gomes, 2016). Passengers can shop, dine, rest, exchange currency, or engage in any other airport-provided activity during their downtime in the terminal, called discretionary activities (Bezerra & Gomes, 2016; Saut & Song, 2022). Normally, passengers undergo various procedures and discretionary activities within the airport terminal due to the extended waiting period before their flight (Prentice & Kadan, 2019). Also, studies show that passengers spend 20% of their time at the airport completing required procedures, and 80% participate in discretionary activities, such as shopping and retail (Wattanacharoensil et al., 2016). Airports possess characteristics that render them akin to shopping paradises, as they offer a variety of trendy and duty-free merchandise (Saut & Song, 2022).

Including a shopping and retail market within an airport, offering a variety of goods and services such as food and beverages, clothing, souvenirs, and other things, contributes to enhanced passenger satisfaction (Saut & Song, 2022). Airport operators recognize that travelers', particularly international air passengers waiting for their flights, are significant contributors to the growth of retail revenue at airport duty-free stores (Han & Hyun, 2018). Passengers are more inclined towards airports with enhanced infrastructure, and evaluating their perspectives on services can aid in improving the quality of services provided (Saut & Song, 2022).

The air transport industry has experienced significant changes, including positive growth in passengers and cargo (Bezerra & Gomes, 2020). Airports Council International (ACI) forecasts a 5.2% annual growth in global air traffic until 2029 (Hussain, 2010; Sgueglia et al., 2018). In East Africa, the survey report shows that passenger arrivals were 2.1 Million in Kenya, 1.9 Million in Uganda and 1.65 Million in Tanzania (KCAA, 2019; UCAA, 2021; URT, 2019). In Tanzania, between 2010 and 2019, the total number of passengers grew by 88.2% from 3.2 million to 6.2 million (Prakash & Barua, 2016). This growth mainly comes from the leisure and tourism sector and innovations in the travel industry (Prakash & Barua, 2016).

2 LITERATURE REVIEW

2.1 Theoretical Framework

The link between passenger satisfaction and service quality has been established by different researchers (Bezerra & Gomes, 2020; Seth et al., 2005). Various theories and models were used to study this relationship. However, most theories used in service quality studies to explain customer satisfaction were based on first-order variables; this study used second-order constructs that cover more variables and can identify problems from low levels to high levels in airport operations, The Hierarchical Service Quality Model (HSQM) was developed by (Brady & Cronin, 2001) as a framework for the evaluation of service quality. In this model, Brady and Cronin (2001) proposed this service quality framework and resolved the stalemate of the previous service quality models. Furthermore, it demonstrates the customer experience across multiple dimensions and service levels (Bezerra & Gomes, 2016). Using the HSQM approach, certain conventional SERVQUAL or SERVPERF model deficiencies are surmounted (Bezerra & Gomes, 2016). Due to its robust framework and precise definition of customer-centric criteria, the model offers a more accurate tool for evaluating service quality in the air travel industry. In addition, Hierarchical measurement considers service outcomes, which were not included in SERVQUAL.

2.2 Empirical Review and Hypotheses Development

Studies indicate that airport service quality (ASQ) influences passenger satisfaction (PS) (Adeniran & Fadare, 2018; Bezerra & Gomes, 2016; Bogicevic et al., 2013). Passengers play a critical role in evaluating the quality of airport services (Saut & Song, 2022). Service quality is a significant determinant of passenger satisfaction, and it is the primary evaluator that significantly impacts service quality assessment. Evaluating airport users' perceptions improves the airport's service quality (Bezerra & Gomes, 2020).. Passenger behavior and expectations surrounding the airport experience can differ depending on the traveler's circumstances, purpose, and traveler’s type. Regardless of their features, all of these travelers are at the airport to transfer from land to air transportation (Bezerra & Gomes, 2020). Satisfaction is achieved by assessing the services utilized (Saut & Song, 2022). Many studies on satisfaction are based on various evaluation methodologies (Saut & Song, 2022). It is an important measure of service quality for airport operations, in which operators of airports decide to provide a varied range of airport services, which can have a significant impact (Brida et al., 2016). Passengers can assess the quality of the services after utilizing them and, based on that evaluation, will express their satisfaction or dissatisfaction with the services. Airports aiming to increase their competitive advantage have made the provision of comfortable and convenient services through the delivery of an exceptional passenger experience a strategic priority (Martín-Cejas, 2006).

Airport Interaction Quality and Passenger Satisfaction

Airport interaction quality (AIQ)concerns the interactions between airport staff and passengers during service delivery(Wu & Cheng, 2013). It is determined by the extent of satisfaction expressed by passengers on the services provided by airport staff. (Bakır et al., 2022). Passengers anticipate that their needs at the airport will be met delightfully and courteously by qualified personnel (Bakır et al., 2022). Intensive interaction between the frontline airport personnel and passengers characterizes services (Gouthier & Rhein, 2011). The airport staff's motivation to address passengers' challenges has a favorable impact on passenger satisfaction (Balinado et al., 2021). Airport staff gains profound insight into passengers' wishes, needs, and problems through interaction. The airport staff's attitude, behavior, and expertise sub-dimensions in interaction quality are vital influencers of passenger satisfaction (Brady & Cronin, 2001; Wu & Cheng, 2013).

Airport service quality consists of numerous interactions between passengers and airport staff in which employees attempt to improve the airport's image and form passengers' perceptions (Pappachan, 2020). The service quality of airports likely influences a passenger's decision to return to the destination and constitutes both the initial and final impressions of their journey (Prentice & Kadan, 2019). For example, airport staff should smile while interacting with passengers, resulting in passengers' satisfaction and a positive impression (Trischler & Lohmann, 2018). The study conducted by Mansor et al. (2012) observed a favorable and significant link between interaction quality and customer satisfaction. Bezerra and Gomes (2016) asserted that passenger satisfaction is affected by the quality of involvement at the airport, particularly when airport staff are involved in resolving issues. In a service setting, perceptions of service quality occur at multiple levels. Several researchers have pointed out the significance of airport interaction quality on passenger satisfaction and identified it as having the most significant impact on perceptions of service quality, either positively or negatively (Bezerra & Gomes, 2016; Halpern & Mwesiumo, 2021; Wu & Cheng, 2013). Again, the main problem is to determine whether these established relationships are negative or positive because passengers and staff interact closely in the airport environment, this factor is crucial to passenger satisfaction. Therefore, it is hypothesized that:

H_1: Airport interaction quality has a positive influence on passenger satisfaction.

Airport Outcome Quality and Passenger Satisfaction

Airport outcome quality (AOQ) affects the service delivery outcome and incorporates consumer benefits (Wu & Cheng, 2013). The literature measured the AOQ by waiting time, tangibility and valance, contributing to customer satisfaction (Brady & Cronin, 2001; Wu & Cheng, 2013). Research has suggested that minimizing waiting time during airport processes is important since any extra time spent waiting in lineups diminishes passengers' free time and impacts their view of the quality of airport services (Prentice & Kadan, 2019). For example, passengers frequently perceive waiting in lines as an unproductive use of their time, worsening their level of satisfaction. The outcome quality denotes the benefits that passengers obtain from the service; that is, it indicates whether the service meets the requirements and desires of passengers (Wu & Cheng, 2013). Another attribute of outcome quality relates to tangibles, the physical resources airports employ to facilitate passenger service. Better service is proportional to the quality of tangibles supplied by an airport (Bezerra & Gomes, 2020). The appearance of supporting equipment used in the service to save passengers has the potential to make a lasting impression on passengers. The influence of the outcome quality component of service quality on passengers' overall satisfaction has been demonstrated in a number of studies (Bezerra & Gomes, 2016; Caro & Garcia, 2008; Wu & Cheng, 2013).

Additionally, evidence indicates that when customers are presented with multiple services, overall satisfaction is more significantly impacted by process dimensions than outcomes (Howat & Assaker, 2013). The primary objective of airport operators is thus the monitoring and enhancement of passenger satisfaction and airport outcome quality. Aspects such as extended queueing times negatively affect passenger satisfaction. The preceding literature supported the subsequent hypothesis:

H2: Airport outcome quality has a positive influence on passenger satisfaction

Airport Environmental Quality and Passenger Satisfaction

The influence of the physical environment on human behavior has received increased academic and managerial attention over the past several decades in the marketing discipline (Bitner, 1992; Smith, 2018). The factors contributing to a pleasant environment and excellent service in a service setting are the ambient conditions, spatial arrangement and Functionality, and the presence of signs, symbols, and artefacts (Batouei et al., 2020; Soe, 2022).

Ambient conditions are background circumstances linked to design factors, the visible part of the physical environment, containing an esthetic and functional element (Batouei et al., 2020; Moon et al., 2016). It comprises a variety of physical environment attributes, including but not limited to temperature, light, volume, scent, and sound.

Although invisible and intangible, these can stimulate the five human senses (Moon et al., 2016). The terms Spatial layout and Functionality pertain to the design and arrangement of seats, aisles, corridors, walkways, food service lines, restrooms, entrances, and exits in leisure service environments (Hong et al., 2020; Moon et al., 2016). Environmental artefacts, signs, and symbols may be explicit or implicit. They symbolize or aesthetically communicate to consumers information regarding the environment and its proper functioning and the degree to which a customer evaluates a service outcome as positive or negative (Liou et al., 2011; Moon et al., 2016).

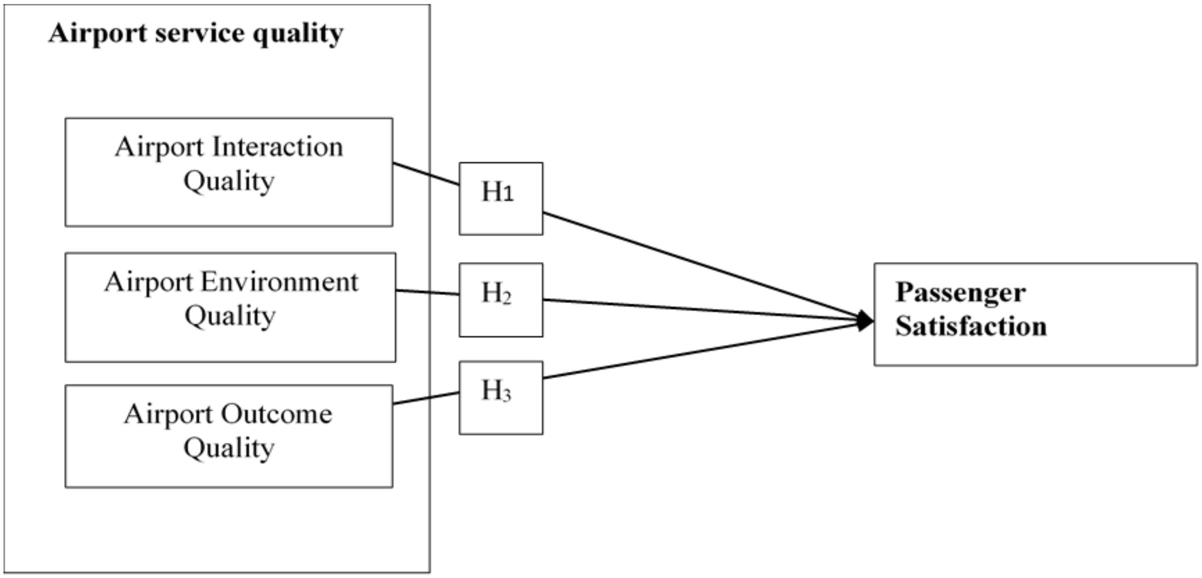
The airport environment, including layout, ambient and conspicuous signage, and accessibility and accuracy of signage are particularly significant in an airport environment where satisfaction must be achieved (Brida et al., 2016; Soe, 2022). Further, aesthetic aspects of airport physical design can improve customer satisfaction. Therefore, the airport's ambience, furnishings, and overall appeal have impacted customers' evaluations of its standard (Alfakhri et al., 2018).

In addition to providing appropriate service, airport operators have begun to consider artificial physical and atmospheric elements as factors in enhancing traveler satisfaction (Moon et al., 2016). Several researchers have found that the airport's physical environment is one of the most critical aspects of evaluating customer service. Most research has focused on three key characteristics or sub-dimensions: ambience, spatial arrangement, functionality, design, artefacts, signs, and symbols. (Bitner, 1992; Brady & Cronin, 2001; Liou et al., 2011). An airport's physical environment is important in increasing passenger satisfaction (Bogicevic et al., 2013). Technology and exposure to numerous service attributes enable passengers to distinguish between various airports in different perceptions (Smith, 2018). Therefore, it is hypothesized that:

H3: Airport Environmental Quality has a positive influence on passenger satisfaction

2.3 The Conceptual Model

The conceptual model illustrates the relationship between predictor factors, namely airport interaction quality (AIQ), airport environmental quality (AEQ), airport outcome quality (AOQ), and passenger satisfaction (PS), the resulting variable. According to The Hierarchical Service Quality Model by Brady and Cronin (2001), airport service quality is a multidimensional constructs comprising AOQ, AEQ and AIQ.



3 RESEARCH METHODOLOGY

3.1 Data

This paper is based on the ontology of objectivism and seeks to verify a theory (Ragab & Arisha, 2018; Saunders et al., 2019) and hold fast to the positivist view of knowledge that the truth is waiting to be found (Ragab & Arisha, 2018; Saunders et al., 2019). The study used a cross-sectional design because the date were collected once. The population was 1,649,500 international departing passengers travelling through Julius Nyerere International Airport (JKIA) (URT, 2023). In this study, the sample size was determined using the Yamane formula, which is stated as follows: n = N / [1 + N (e) 2], in which N= population of the study, n = sample size, e = the acceptable sampling error (Yamane, 1967). In light of the study's rationale, we allowed a 95% confidence interval and estimated a 5% margin of error. Most studies aim for a 95% confidence interval, which means that out of 100 random samples, at least 95% would be representative of the population of interest (Saunders et al., 2016). Thus, the sample size is n= 1,649,500 / [1+1,649,500 (0.05)2] = 399 The convenience sampling technique was used to pick study participants from the target population based on their availability, willingness to participate, and other practical considerations. (Etikan et al., 2016; Saunders et al., 2012).

3.2 Operationalization of the Variables

The independent variable was adopted from (Brady & Cronin, 2001), who operationalized the service quality in three hierarchical levels: Interaction, Physical environment and airport outcome quality. Based on their airport experiences, respondents rated airport result quality elements on a seven-point Likert scale.

(Bogicevic et al., 2013; Wu & Cheng, 2013). Valence is the primary feature that decides if customers are satisfied with the final service (Brady & Cronin, 2001; Wu & Cheng, 2013).

Passenger satisfaction (PS) was conceptualized as a low-order construct measured with four items; PS is achieved by providing the optimum level of services that passengers expect, particularly the highly-valued ones (Zidarova & Zografos, 2011). This was assessed using validated scales utilizing a seven-point Likert scale, with 1 representing strongly disagree and 7 representing strongly agree. It was operationalized as a dependent variable (Brady & Cronin, 2001; Wu & Cheng, 2013).

4 RESULTS

4.1 Data Screening

Data screening is required when conducting structural equation modeling research. SEM needs meticulous data collection and analysis. This SEM demands quantitative data, particularly primary data. The researcher ensures that the data meets the criteria of the analytic technique by overcoming the limitations of the research instrument (Hair et al., 2017).

According to Hair et al. (2010), data analysis becomes reasonably simple if clean data is collected. Of the 399 distributed questionnaires, 345 (86.5 %) were returned, 10 questionnaires were eliminated (335 remaining). Only 10 cases were eliminated from the data set due to missing data, while three cases with suspicious response patterns were identified and removed. Due to an error in data entry, two outliers were discovered and corrected. Finally, researchers followed experts' guidance and investigated the likelihood of common procedure bias (Hair et al., 2017; Pallant, 2020).

4.2 Demographic Statistics

The sample's descriptive statistics showed 57.2% males and 42.8% females. The sample included 12.1% of respondents with a certificate, 11.1% with a diploma, 47.6% with a bachelor's degree, 2.61% with a postgraduate diploma, 27.2% with master's degrees, and 2.1% with doctorates.

Furthermore, intercepted passengers revealed that 23.5% were 55 years or older, 41.2% were 45 to 54 years old, 12.9% were 34 to 44 years old, 11.7% were 25 to 34 years old, and 10.8% were between the ages of 15 and 24. According to the findings, 34.8% of passengers traveled through airports for the first time, 55.7% traveled 2-3 times, and 9.5% visited the airport 4 times or more. This suggests that most international travelers that visit these airports have used a variety of services.

4.3 Measurement Model Evaluation

The study employed SmartPLS4 software to perform partial least squares structural equation modeling (PLS-SEM) (Ringle et al., 2015). When analyzing reflective measurement models, it is required to assess the construct and indicator levels of measure reliability (including internal consistency, construct and indicator reliability) (Becker et al., 2023; Matthews et al., 2018; Ringle et al., 2015). The extracted mean-variance (AVE) is used to evaluate the convergent validity of each measure. Furthermore, one can successfully test the discriminant validity of a reflectively assessed concept by comparing the Heterotrait-Monotrait (HTMT) correlation ratio to other construct measures within the same model.

This study assesses AEQ, AIQ and AOQ as second-order components, and PS as first-order components. To reduce model complexity, researchers can use second-order structures like the hierarchical component model in the PLS-SEM (Becker et al., 2023; Hair et al., 2017). According to Sarstedt et al. (2019), using higher-order constructs has numerous benefits, including making PLS route models clearer, correcting accuracy inconsistencies, and minimizing collinearity issues (Becker et al., 2023). The figure 1 show measurement model result I which all indicators are reflective to first order constructs.

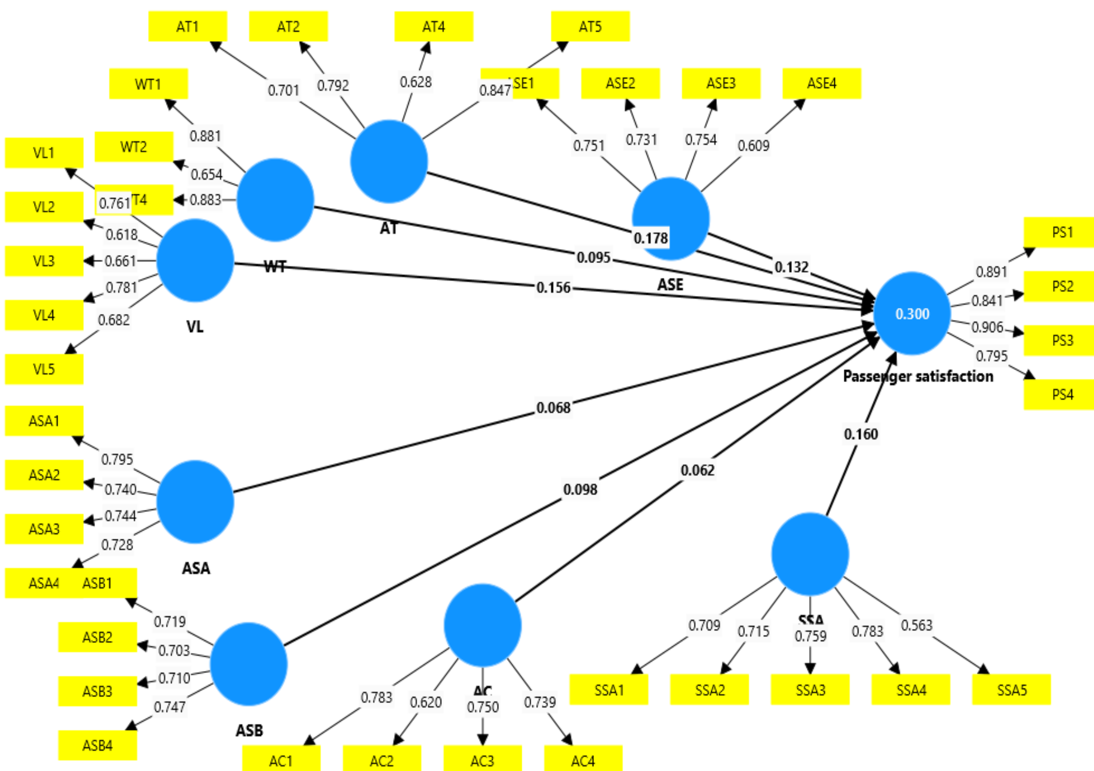


Figure 1. First order measurement model result

Table 1. Convergent validity and Reliability First-Order Construct Outcomes

1st order construct	Items	Loading	CR	AVE
Airport Staff Attitude (ASA)	ASA1	0.795	0.839	0.566
	ASA2	0.740		
	ASA3	0.744		
	ASA4	0.728		
Airport Staff Behaviour (ASB)	ASB1	0.719	0.811	0.509
	ASB2	0.703		
	ASB3	0.710		
	ASB4	0.747		
Airport Staff Expertise (ASE)	ASE1	0.751	0.805	0.582
	ASE2	0.731		
	ASE3	0.754		
	ASE4	0.609		
	SS5	0.751		
Airport Tangibles (AT)	AT1	0.701	0.833	0.558
	AT2	0.792		
	AT4	0.628		
	AT5	0.847		
Waiting Time (WT)	WT1	0.881	0.816	0.535
	WT2	0.654		
	WT3	0.883		
	WT4	0.881		
Valence (VL)	VL1	0.761	0.821	0.598
	VL3	0.618		
	VL4	0.661		
	VL5	0.781		
Ambient Conditions (AC)	AC1	0.783	0.818	0.530
	AC2	0.620		
	AC3	0.750		
	AC4	0.739		
Spatial Layout and Functionality (SLF)	SLF1	0.776	0.881	0.598
	SLF2	0.768		
	SLF3	0.743		
	SLF4	0.809		
	SLF5	0.769		
Signs, Symbols and Artifacts (SSA)	ASA1	0.709	0.834	0.504
	ASA2	0.715		
	ASA3	0.759		
	ASA4	0.783		
	ASA5	0.562		
Passenger Satisfaction (PS)	PS1	0.892	0.918	0738
	PS2	0.841		
	PS3	0.905		
	PS4	0.794		

Source: Field data 2024

Using the Heterotrait-Monotrait ratio of correlation (HTMT) proposed by Henseler et al. (2015), this study examined the discriminant validity. When the HTMT value is less than 0.85, discriminant validity between reflective constructs is unaffected. Discriminant validity problems occur with high HTMT values, with a recommended limit of 0.90 (Sarstedt et al., 2019). According to Table 2, 0.812 is the highest HTMT value in this investigation. This indicates that the measurement model quality is adequate and explicit, and the discriminant validity of the latent variables is acceptable.

Table 2: Heterotrait-Monotrait Ratio of Correlation (HTMT) for Discriminant Validity

	AC	ASA	ASB	ASE	AT	PS	SLF	SSA	VL	WT
AC										
ASA	0.152									
ASB	0.157	0.781								
ASE	0.325	0.715	0.812							
AT	0.274	0.295	0.266	0.252						
PS	0.291	0.337	0.399	0.409	0.443					
SLF	0.546	0.080	0.109	0.157	0.227	0.273				
SSA	0.664	0.069	0.114	0.147	0.169	0.306	0.513			
VL	0.174	0.259	0.291	0.276	0.674	0.419	0.145	0.191		
WT	0.164	0.259	0.274	0.248	0.519	0.345	0.058	0.089	0.418	

Source: Field data 2024

4.4 Structural Model Assessments

The hypotheses were tested by analyzing the structural model once the measurement model's reliability and validity had been tested (Hair et al., 2019). Before going to the next stage, the VIF (Variance-Inflation-Factor) was calculated to test the multi-collinearity of the model (Kock, 2015). All tolerance values are below the threshold of 3.3, as indicated by the results (Kock, 2015). The structural model displays the results of hypothesis testing in Table 3. A strong positive link exists between ASQ and PS has found. Table 5 shows a significant positive relationship between ASQ and PS (β = 0.218, β =0.246, β =0.331 at $p < 0.001$). Figure 1 shows the model of the second order constructs.

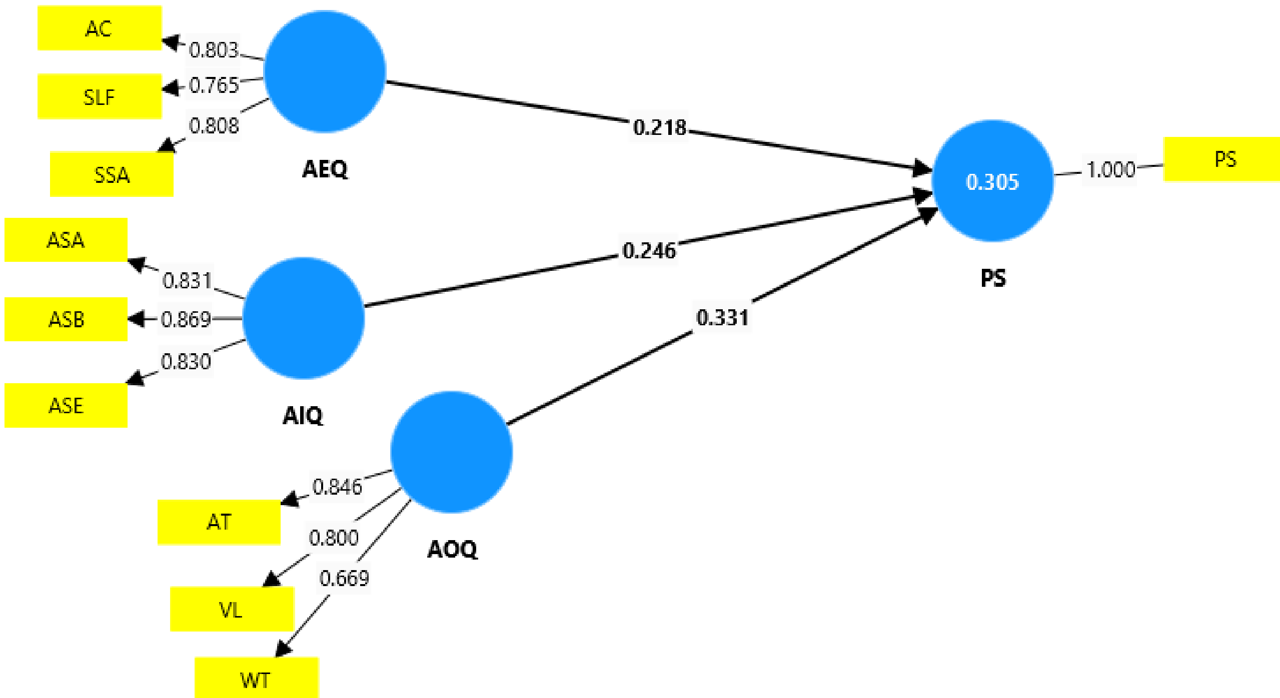


Figure 2: Second order structural model result

The bootstrap was carried out, specifically looking at the confidence interval for the coefficient estimate (0.123;0.304), (0.146;0.333), (0.225;0.422) suggesting a significant influence between ASQ and PS. The effect size (f2) must be calculated to prove the relationship. Table 5 shows that the f2 value of 0.646 was acceptable and above the 0.02 minimal requirement. This satisfactory f2 value demonstrated a substantial relationship between ASQ and PS.

Table 3: Multi-Collinearity Issue: Variance Inflation Factors (VIF)

Hypothesis	VIF	CMB Problem
AIQ ->PS	1.117	Not an issue
AEQ ->PS	1.125	Not an issue
AOQ ->PS	1.241	Not an issue

Source: Field data 2024

The validity, predictive power, explanatory power and predictive power of the structural model were assessed by calculating the effect size (f2), coefficient of determination (R2) and predictive relevance (Q2 predict) (Hair et al., 2019). As indicated in Table 4, the f2 value of 0.165, above the small effective size threshold, was considered acceptable. This acceptable value of f2 suggested that the size or magnitude of the influence of ASQ on PS has been confirmed to be within the acceptable threshold. An R2 value of 0.305 suggests that this model has a moderate value of predictive accuracy. More than

30.5 % of the passenger satisfaction was explained by endogenous variables (R2 = 0.305). The path models are relevant and meaningful, as seen below. Table 4 shows that the route model's predictive relevance for each endogenous latent variable is demonstrated by a Q2 greater than zero.

Additionally, the f2 value has sufficient predictive relevance, as it exceeds the 0.15 and 0.35 thresholds, respectively (Hair et al., 2019).

Table 4: Hypotheses Test Results-

Hypotheses	Std Error	t-value	95% Confidence Intervals	f^2	R^2	Q^2
H1	0.046	4.772	[0.123;0.304]	0.165	0.305	0.283
H2	0.047	5.191	[0.146;0.333]	0.179		
H3	0.050	6.622	[0.225;0.422]	0.240		

Source: Field data 2024

The results of the structural model are displayed in Table 4. In order to determine the structural model's prediction accuracy for a specific endogenous construct, Q2 value is 0.283 and is significant having a value of great than zero (Hair et al., 2019).

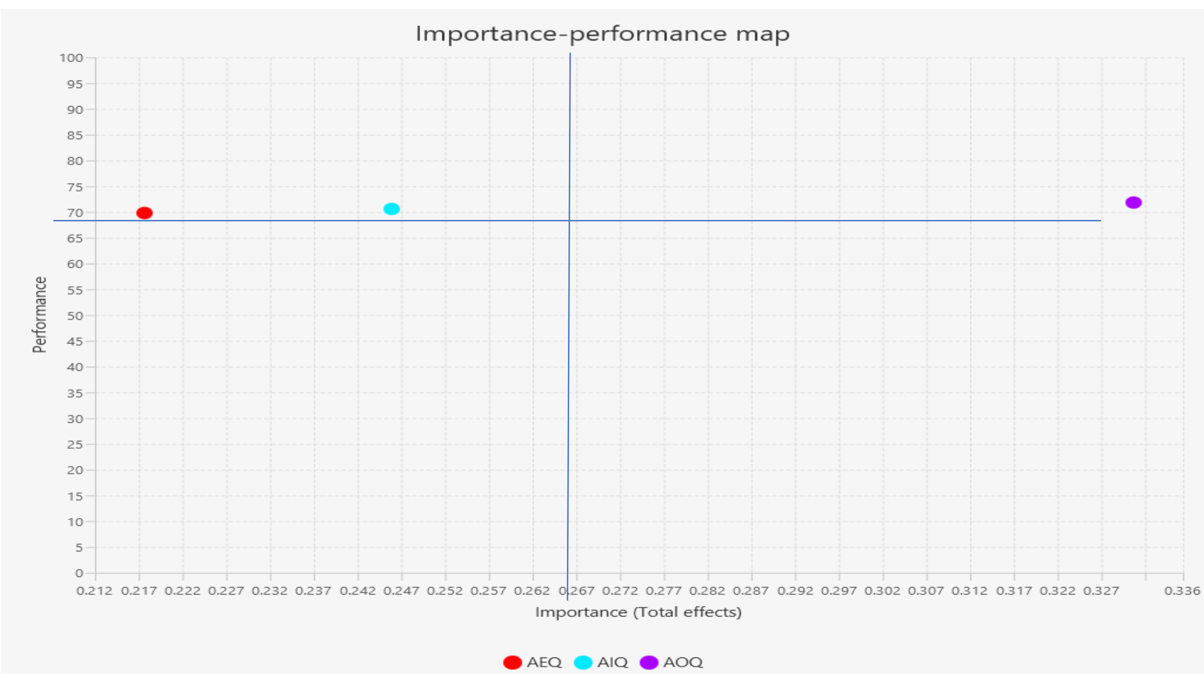


Figure 3: Importance Performance Map

4.5 Importance Performance Map Analysis (IPMA)

In order to improve certain target constructs, the IPMA recommends arranging latent variables (Ringle & Sarstedt, 2016; Wyród-Wróbel & Biesok, 2017). An IPMA carried out at the variable level to identify certain areas for improvement is shown in Figure 1. IPMA is useful for drawing further inferences and insights (Ringle & Sarstedt, 2016). Using the IPMA, low-order constructs (AEQ, AIQ, and AOQ) were assessed in relation to the target variable (PS). The high importance and performance of airport service quality indicate the good execution their mean values for performance and their importance are indicated in the Table 5. Despite its high-performance airport interaction quality demonstrated to be highly significant. Airport environment quality is another variable of poor performance and low priority.

Table 5: Importance Performance Map for Predecessor of Passenger Satisfaction

Variable	Importance	Performance
Airport Environment Quality	0.218	69.808
Airport Interaction Quality	0.246	70.596
Airport Outcome Quality	0.331	71.845
Mean Value	0.265	70.759

Source: Field data 2024

5 DISCUSSION

The first objective of this research was to ascertain the extent to which the airport interaction quality has an impact on the level of satisfaction experienced by passengers. The findings from the study supported hypotheses number one (H1) by validating that "There is a positive influence of airport interaction quality on passenger satisfaction." The results imply that the higher the airport interaction quality relationship, the higher the passenger satisfaction. The airport interaction quality relates to the employees' attitude, behaviour and expertise, when dealing with passengers' queries. These findings indicate that passengers value feeling valued as a customer. When utilizing airport services, their satisfaction increases if they receive prompt action and consideration from airport staff. A similar study demonstrates that airport interactions substantially impact overall passenger satisfaction (Farooq et al., 2018).

The aforementioned finding concerning airport staff brings to light the significance of front-line staff in the context of airport service encounter. It thus has management implications, for instance, the necessity of providing customer service training to the employees. Also stated was that interaction with airport personnel positively impacts service quality. The findings support the assertion that this dimension is crucial to customer satisfaction due to the direct interaction between passengers and service airport staff (Brady & Cronin, 2001; Wu & Cheng, 2013). For example, a study by Wu and Cheng (2013) indicated that a passenger's subjective inclination or disinclination is discernible from their observable actions. The findings are in line with the previous research (Bezerra & Gomes, 2016), demonstrated a significant beneficial relationship between the quality of airport interactions and passenger satisfaction.

The study also upholds the application of HSQM in the developing country, specifically in the airport context. Evaluation of the measurement model using the PLS algorithm indicates that all three low-order constructs passed the reliability and validity test. These are airport staff attitude (ASA), airport staff behaviour (ASB) and airport staff expertise (ASE). This result implies that satisfaction in these areas enhances passenger satisfaction; these results also align with the findings of (Yang et al., 2015; Zidarova & Zografos, 2011).

The second objective of this research was to ascertain the extent to which the airport environment quality has an impact on the level of satisfaction experienced by passengers. The findings from the study supported hypotheses number two (H2) by validating that “There is a positive influence of airport environment quality on passenger satisfaction.” The empirical findings indicated that the airport environment quality has a positive influence on passenger satisfaction. The findings support the prior work of Bitner (1992) and Wu and Cheng (2013), who reported that the physical setting influences passengers. Also, this view is supported by (Mansor et al., 2012) underlined that physical environment of the airport can have a substantial impact on how passengers perceive the quality of the service encounter, which in turn affects how satisfied passengers are with the service they receive.

The third objective was to examine the influence of airport outcome quality on passenger satisfaction. The study's conclusions were confirmed. ‘There is a significant positive influence of airport outcome quality on passenger satisfaction.’ supporting hypothesis three (H3). This implies that the higher the airport outcome quality experienced by passengers, the higher the passengers’ satisfaction; airport outcome quality was found to have the most significant effect on satisfaction. Passenger satisfaction is influenced by waiting time, tangibles, and valance under airport outcome quality. The research findings are similar to (Smith, 2018); Wu and Cheng (2013), discovered a notable positive impact on the relationship between the quality of airport access and passenger satisfaction. Many studies have shown that the quality of airport service quality has had a substantial impact on the overall service quality as perceived by travelers (Bezerra & Gomes, 2016; Guimarans et al., 2019). The airport service quality indicates what passengers obtain from the service, in whether the outcome quality meets the passenger's needs.

5 CONCLUSION

Airport service quality plays an important role in passenger satisfaction, particularly in the airport context. The study examined how airport service quality affects passenger satisfaction at Julius Nyerere International airport. The findings revealed that there is a significant effect of airport service quality on passenger satisfaction. This study generally has added to the body of knowledge the hierarchical nature of the service quality in the air transport context. Since the application of hierarchical service quality model shows the great effect on passenger satisfaction, furthermore, physical environment quality has a great impact and this prompts airport designers and architecture to develop more impressive airport designs as it demonstrated by this study to enhance passengers' satisfaction. Despite the wealth of airport service quality research, this study made two significant theoretical contributions. Firstly, applying high-order constructs in the airport context was important because the previous studies had limited to first order constructs. Secondly, the study used two disjoint approaches to reduce the problem of model complexity and collinearity issues. Again, this study holds significant practical implications regarding to the airport authorities in developing nations, including the Ministry of transport and Tanzania Airport Authorities (TAA). These implications specifically target the management and staff responsible for authority' operations and services. The developed hierarchical structure allows practitioners to determine the most and least crucial elements that underlie passengers' judgements of service quality. The results of this study indicate that TAA should prioritise improving airport interaction quality and airport outcome quality in order to provide excellent service. This framework allows managers to assess service quality at different levels, depending on reporting needs or the level of specificity necessary for decision-making.

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Paper 8:

International Tourists' Satisfaction on the Arrival Non-Processing Service Performance at Julius Nyerere International Airport

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ABSTRACT

This paper assesses the relationship between airport arrival non-processing service performance and international tourist satisfaction. The study was conducted at the Julius Nyerere International Airport in Tanzania. A quantitative research design was used to analyze 218 international tourists. Smart PLS 3 and SPSS were used to analyze data collected through questionnaires and documentary reviews. The results confirmed that airport arrival facilities and retail areas directly and significantly relate to international tourists' satisfaction. This implies that any attempt to ignore the assessment of these facilities and retail areas may affect international tourist satisfaction and lead to poor loyalty. The study further showed that arrival airport accessibility has no relationship with international tourist satisfaction, implying that excluding airport accessibility cannot affect tourists visiting various attractions. Airport operators should monitor service performance in all three constructs equally, as any service compromise can disturb tourists' satisfaction.

Keywords: Airport Arrival Facilities, Airport Arrival Retail Area, Airport Arrival Accessibility.

1 INTRODUCTION

Airports play a significant role by providing accessibility to potential tourism markets (Soshkin et al., 2019). Current statistics show that approximately 3,759 airports serve more than 1,303 airlines operating nearly 31,717 airplanes worldwide (Liu et al., 2019). For example, in 2018, more than 1.4 billion tourists arrived at different tourist destinations globally by airplane. The same report revealed that more than 91.99 million and 1.5 million tourists visited Africa and Tanzania, respectively (Berthe, 2019). According to recent research in the tourism industry, many airports struggle to deliver good services to attract travelers and maintain loyalty (Moeun et al., 2022).

Airports spend a lot of money to attract rivals and consumers (Gupta and Venkaiah, 2018) and have incorporated cutting-edge technology into their strategic plans to lure tourists who intend to visit many places in a single country. However, investing in advanced airport service performance does not go hand in hand with service delivery (Saayman, 2018). Also, it is hard to assess the effect of failure once a particular service is compromised. Nevertheless, researchers have outlined many strategies and methods to prevent service providers from entering the trap of compromising the quality of any airport service. Failure to adhere to those key indicators has caused many tourists to cancel trips or visit other countries (Anton *et al*., 2021).

The wind of international tourists visiting destinations in African countries has significantly been limited after the Covid-19 pandemic (Ruwan *et al*., 2020). The consequences of the pandemic stopped almost all tourism operations and transportation, particularly air transport. Besides the challenges encountered during the pandemic, tourists have complained about the poor performance of airport services in African countries. For example, reports by Ovuorie (2022), McSherry, (2020), Makoye (2014), Maestro, (2017) Amara, (2020), and Benson, (2022) established that airport infrastructures in Africa are not promising in terms of maintenance and cleanliness. Suarez and Jimenez (2016), African countries should improve their airport infrastructures to win tourists and make tourism a hub.

Some researchers argue about tourists' satisfaction by observing the quality-of-service performance at the airport. For instance, Ben (2019) investigated tourist satisfaction at the Nigerian Airport terminal and found that tourists' first impressions tend to change their minds about the destinations. According to Frunueth and October (2019), Adetayo et al. (2020), and Abdullahi *et al.* (2018), once airport service performance is good, the flow of tourists in a country can be apparent, resulting in enormous income earnings. Other researchers like Adeniran and Fadare (2018) included demographic characteristics and nationalities to understand the feelings of tourists about the destinations once arriving at African airports. In the present study, the Passenger Centered Airport Model (PCAM) by Wiredja *et al.* (2019) has been adopted with minor modifications to analyze the relationship between airport arrival non-processing services performance and international tourists' satisfaction.

2 RESEARCH PROBLEM AND HYPOTHESIS

2.1 Research Problem

Tourists visiting various destinations for leisure and relaxation cherish their arrival at the airport terminal (Chi *et al.,* 2018). This strategy has existed for many years because experience sharing by tourists tends to attract others to visit or themselves to revisit (Graham *et al.,* 2015, Jamkatel, 2018). Lohmann and Trischler (2018) and Adeniran (2018) have extensively researched tourists' views of locations after landing at a particular airport. Similarly, tourism specialists and stakeholders are constantly informed to invest in airports to attract and retain tourists (Chi *et al*.,2018). Contrasting departure processing, studies on arrival non-processing domains at airports in Tanzania to measure service performance and visitor satisfaction are limited.

Much research has been undertaken in developed nations or disregarded to include the arrival of non-processing domains. Interested readers can visit the studies of Zhang and Jiang (2016), Popovic *et al.* (2009), Park *et al.* (2011), Popovic *et al. (*2010) and Wiredja *et al. (*2017 and 2019), Yavuz et al. (2021), Bakır *et al. (*2022) and Chi *et al*. (2022). Similarly, despite the popularity of the Julius Nyerere International Airport (JNIA) in serving passengers and international tourists visiting tourist destinations, there has been a concern regarding the performance of the airport's services. Such complaints have harmed the tourist industry and the economy of Tanzania. Unconvincing airport service performance has received specific attention in Tanzania (Benson, 2022; Amara, 2020; McSherry, 2019; McSherry, 2017; Maestro, 2017). According to Makoye (2014) and McSherry (2017), maltreatment of passengers, limited amenities, and poor sanitation in the airport contributed to tourist dissatisfaction. Therefore, the present study was designed to assess the relationship between airport arrival non-processing service performance and international tourist satisfaction at JNIA.

2.2 Research Hypothesis

The study formulated three hypotheses while considering the activities after tourists have passed through arrival processing domains. The three arrival non-processing domains in airport studies often include airport facilities, retail areas, and airport accessibility (Wiredja et al., 2019). Each domain is regarded as a construct with indicators and the level of satisfaction or dissatisfaction among tourists depends on who offers the service (Bakır *et al.,* 2022). According to Kirk (2013), airport arrival facilities influence tourists' satisfaction. Further studies concerning the arrival facilities and their impacts on international tourists' satisfaction have been conducted by Yavuz *et al.* (2021), Smith (2018), and Prentice and Kadan (2019). Further relationship between arrival facilities and tourist satisfaction was studied by Sumanasiri and Dambagola (2020), Mwesiumo and Halpern (2021), and the references therein. In contrast, Chen and Chang (2012) assessed the performance of airport accessibility and established that tourists were dissatisfied with the facilities at the airport terminal. Adeniran et al. (2018) documented tourists' satisfaction with the quality of airport facilities and services. Cognizant of this, the present study formulated the following hypothesis to determine the relationship between airport arrival accessibility and facilities to international tourists' satisfaction;

H_1: Services at the airport arrival accessibility have a positive relationship with international tourist satisfaction.

H_2: Services at the airport arrival facilities have a positive relationship with international tourist satisfaction.

The arrival retail area is another arrival non-processing domain where tourists perform unrestricted activities. The domain has various shops, cafes, and food and beverage centres where tourists can enjoy available decorations, attractions, and value-for-money products before getting off the airport (Wiredja et al., 2017). Services offered in this domain are another source deterring airport performance and intention to reuse the airport (Wiredja, 2017). The friendliness and attention of service providers are crucial to satisfying tourists (Wiredja et al., 2019). However, there are limited studies on arrival retail areas as reported by Correia *et al.* (2008), Kramer (2013), Wiredja et al. (2017, 2019), and the references therein. The unavailability of quality shops, cafes, snack bars, restaurants, value-for-money products, variety of food and beverages in many airports has changed tourist satisfaction (Mwesiumo and Halpern, 2021; Hajez and Fawzy, 2021). Putra *et al.* (2021), and Ansari and Agarwah (2020) stress that unfriendly staff interactions in retail areas and readiness to assist tourists can affect tourists' perceptions. The present study formulated the following hypothesis to assess the relationship between airport arrival retail area services and international tourists' satisfaction;

H_3: Services at the airport arrival retail area have a positive relationship with international tourist satisfaction.

2.3 Significance of the Study

The airport is among the substantial factors of air transport and the tourism industry which handles hundreds of flights daily to allow tourists to access diverse inaccessible areas for tourism purposes (Jasrotia et al., 2020; Gupta and Venkaiah 2018; Calderwood, 2019; Jasrotia et al., 2020). Based on that fact, the significance of taking into consideration the tourists' expectations during airport design and renovation should not be weakened. Nevertheless, several tourism studies have disregarded the airport as a significant area that creates positive impressions on tourists (Marchalina and Dewantara, 2018). Currently, competition in the tourism industry is very high since many countries rely on their airports as brand ambassadors for tourists (Cristina, 2017; Saadat et al., 2018; Nugraha, 2017). Hence, in today's tourism industry, airports have become dynamic areas for tourists to engage in shopping, leisure, stayover, and other entertaining activities that generate income and contribute to economic growth (Gupta and Venkaiah, 2018). This study can benefit the tourism industry and airport authority because Tanzania did not clearly state the link between airport service performance and its relationship toward international tourist satisfaction. Since the findings had political and economic stuff on tourism industries, airport management, particularly JNIA, is expected to use it for service improvement.

3 LITERATURE REVIEW

3.1 Theoretical Framework

The Expectancy Disconfirmation Theory (EDT) was adopted in this study to examine the association between international tourists' satisfaction and arrival non-processing service performance at the airport terminal. Through disconfirmation, the theory describes how contentment is formed by contrasting perceived services (Patterson *et al.*, 1997). Oliver (1980) and Tse et al. (1988) were the first pioneers to use the theory in their studies. Since then, many researchers have modified the theory to suit their studies and subjects. Ryzin and Gregg (2006) and Zhang et al. (2022) applied the theory to assess community satisfaction with the services provided by local governments and private sectors. Elaine (2013) used the theory to analyze customer satisfaction regarding perceived service quality in health care. Fisun and Atila (2001) also used the theory to assess tourists' perceptions of the tourism and hospitality industry. Cheng (2019) similarly integrated Herzberg's two-factor theory and EDT before analyzing tourist satisfaction. Likewise, this study adopted two constructs from the same theory (perceived service performance and satisfaction) by integrating with the PCAM developed by Wiredja *et al.* (2019) to assess the relationship between airport arrival non-processing service performance and international tourists' satisfaction. The model contains domains/constructs and indicators that this study addressed as perceived services at the airport terminal.

3.2 Theoretical Gap

This study extended the theory by integrating with the PCAM because the general theory overlooked arrival airport facilities, arrival retail areas, and arrival airport accessibility in assessing tourist satisfaction (Wiredja et al., 2019). To meet the study objectives, constructs and indicators from the PCAM were adopted to support the theory. Thus, based on the fact that Wiredja *et al.* (2019) separated the arrival non-processing domain into arrival facilities, arrival retail area, and arrival airport access, the perceived service performance construct in the theory has also been segmented into a similar way. According to Wiredja et al. (2019), researchers can add indicators to improve airport service performance. All indicators were processed through EDT before determining international tourists' satisfaction. Thus, the PCAM can be modified to reflect all indicators. Figure 1 illustrates the actual model of EDT and Figure 2 shows the actual PCAM (see the highlighted section).

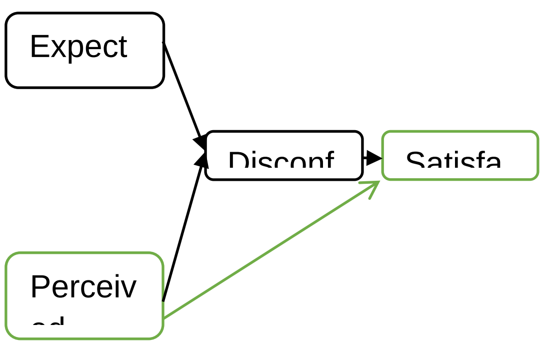

Figure 1: Expectance disconfirmation theory

Source: Oliver (1980)

Key: ———— Adopted construct

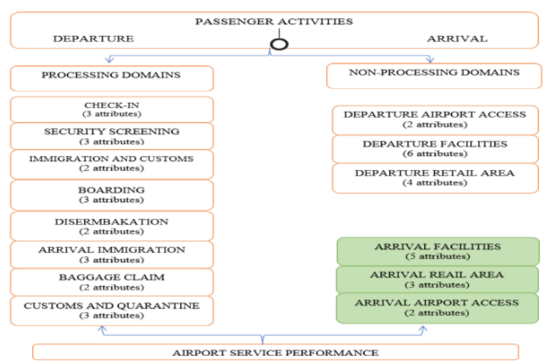

Figure 2: Passenger-centred airport model Source: Wiredje et al. (2019)

Indicators in the three constructs, as adopted from PCAM, were considered as perceived service performance by international tourists. Thus, tourists had to rate their level of satisfaction by comparing the perceived and expected services. Table 1 shows the link between EDT and PCAM.

Table 1: The link between expectance disconfirmation theory and passenger centered airport model

A	B
a. Indicators at the airport arrival facilities (serviceable ATM and money changer, the good sanitary condition of the restroom, clear information desk, display and signs, the conditions of baggage trolley, the convenient location of baggage trolley, internet or wi-fi is available and provided for free, cleanliness of the terminal floor, facilities, and public areas cleanliness, the terminal physical environment is good and comfortable) b. Indicators at the arrival retail area (variety of retail shops, value for money for the shops and cafes, availability of a variety of food and beverages, clear tourism information, and reasonable COVID-19 precaution and safety protocol) c. Indicators of the arrival airport accessibility (availability of transport option, satisfactory tax fare, and easy access to public transport)	International tourist Satisfaction

Source: Researcher (2023)

[A] Perceived service performance constructs, [B] Satisfaction

3.3 Empirical Literature Review

Services attained at airport arrival facilities have been reported to affect tourists' satisfaction (Kirk, 2012). Therefore, it is essential to determine travelers' satisfaction with airport service improvements. According to Tsai *et al.* (2011), the domain gives the first impression of a country to tourists regardless of the time spent in the environment. The condition of baggage trolleys and their convenient location, the availability of Wi-Fi, money exchanging sections or ATM facilities and information desks are among the valuable factors for international tourists (Yavuz et al., 2021; Smith, 2018; Prentice and Kadan, 2019). The cleanliness of washrooms and the friendliness of restaurant attendants also significantly contribute to the overall satisfaction of international tourists (Sumanasiri and Dambagola, 2020). The physical ambiance and shopping area during arrival have recently been reported by Mwesiumo and Halpern (2021) to have the slightest impact on satisfaction. According to Bakır *et al.* (2022), airport shopping and reliable Wi-Fi connectivity tend to have an insignificant influence on tourist satisfaction. Further studies concerning airport facilities have been conducted by Bellizzi *et al.* (2018), and Aydoğan (2021), Nadim et al. (2024), Madhushanka et al. (2023), Pivac et al. (2022), and the references therein. Wiredja *et al.* (2017) propound that many researchers have missed the inclusion of the domain without any genuine reason. However, some airports pay more attention to this domain by providing free services to incoming passengers to give them a first impression regardless of the time spent in the area (Riyas and Anand, 2020). Therefore, assessing the impacts of these services on tourists' satisfaction can help to improve tourism performance.

After completing all mandatory arrival activities at the airport, tourists can hire transport or pick up already-prepared vehicles for their tourism activities. A study about airport accessibility has also been described by Adeniran *et al.* (2018), which had a weak impact due to low-efficiency transport to satisfy passengers. Sumanasiri and Dambagola (2020) have reported on the same. However, many researchers have overlooked the inclusion of arrival accessibility in assessing airport service performance and tourist satisfaction (Wiredja et al., 2017).

The airport arrival retail area is mainly made up of numerous stores and cafes and a range of food and beverages from which tourists may enjoy value-for-money items before departing the airport. However, there is scanty literature on this since most researchers consider this domain unimportant in influencing tourist satisfaction (Wiredja et al., 2017). For instance, Mwesiumo and Halpern (2021) propound that service failure in shopping and cafes has little effect on tourists' satisfaction but according to Yavuz *et al.* (2021) and Hajez and Fawzy (2021), the eminence of the airport snack bar, restaurant, and cleanliness influence tourists' satisfaction. The nature of service providers during shopping and their friendliness takes a portion to attract repeat visitors (Putra et al., 2021; Ansari and Agarwah, 2020). Despite the efforts and investments by the government to promote the tourism industry in Tanzania, more workers are needed to improve service quality at the airport and destinations. When non-processing domains are not given priority in airport services, poor performance can lead to tourist dissatisfaction. This is because as tourists need to wait for their hosts, they can visit a café or sit in the waiting area and relax. Therefore, when such a service is unavailable, tourists may be discouraged and cancel the route to their destinations or become negative ambassadors.

3.4 Conceptual Model

Based on the research hypothesis, theoretical framework, and empirical literature review, the conceptual model with independent and dependent variables has been formulated as shown in Figure 3:

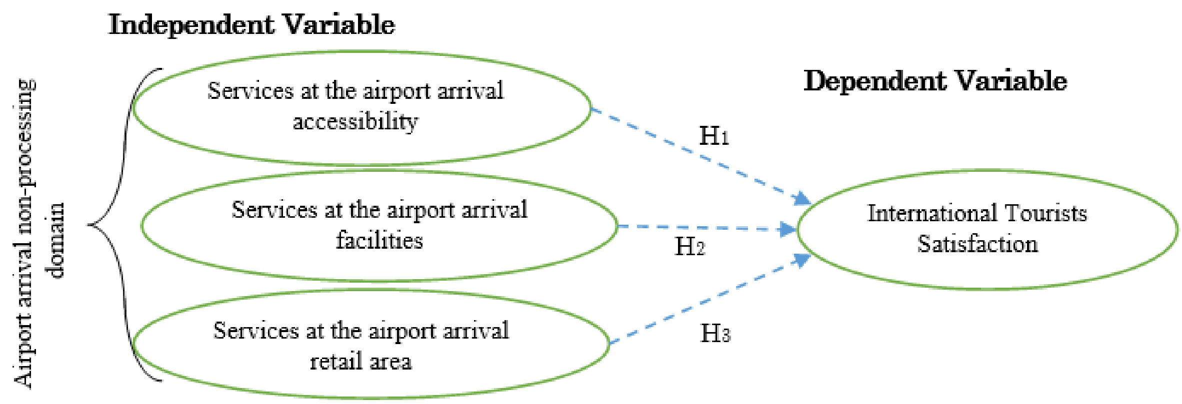

Figure 3: Conceptual Model, Source (Researcher, 2023)

The used indicators in the three constructs as adopted from the PCAM and those added from the literature are shown in Table 2.

Table 2: Indicators used in the study

S/N	C	D	E	F
	Arrival Airport facilities			
1.	Baggage trolleys are in good condition	AAF4	0.595	Added
2.	The internet or Wi-Fi is available	AAF6	0.669	PCAM
3.	The internet or Wi-Fi is provided for free	AAF7	0.695	Added
4.	The terminal floor, facilities, and public areas are well-cleaned	AAF8	0.777 3	Added
5.	The terminal physical environment is good	AAF9	0.832	Added
6.	Generally, the airport terminal is comfortable	AAF10	0.748	Added
	Arrival Retail Area			
7.	There is a variety of retail shops on arrivals	ARA1	0.759	PCAM
8.	Prices at shops and cafes are valued for money on arrival	ARA2	0.719	PCAM
9.	A variety of foods and beverages are available on arrival	ARA3	0.796	PCAM
10.	I can get clear tourism information at the Airport upon arrival	ARA4	0.773	Added
11.	There is good COVID-19 precaution and safety protocol	ARA5	0.707	Added
	Arrival Airport accessibility			
12.	There is an availability of transport options from the Airport to the city	AAA1	0.837	PCAM
13.	The tax fare is satisfactory	AAA2	0.810	Added
14.	There is easy access to public transport from the Airport	AAA3	0.875	Added
	International Tourists Satisfaction			

15.	I will communicate positively about Tanzania to fellow people in my country	ITS1	0.577	Added
16.	The good services at the Airport made me plan another trip to Tanzania	ITS2	0.810	Added
17.	Employees at the airport terminal are customer-focused	ITS3	0.834	Added
18.	The overall services performed at the Airport were satisfactory	ITS4	0.853	Added
19.	I will recommend others in my country to visit Tanzania	ITS5	0.812	Added

Source: Author 2023

[C] Arrival non-processing domain, [D] code, [E] indicator reliability, and [F] remark

4 METHODOLOGY AND DATA ANALYSIS

4.1 Methodology

This study used the quantitative research design to assess the relationship between airport non-processing service performance and international tourists' satisfaction. Using stratified sampling, 218 tourists were sampled. The sample size used in this study was acceptable as explained by Hair et al. (2018). Many researchers, for instance, Hair et al. (2018), suggested applying this sampling approach to manage data quality and interpretation. Quantitative data were collected using a structured questionnaire with closed-ended questions. The designed questionnaire included demographic information such as education, respondent's travel experience, sex, and age to suffice the purpose of the study. Both dependent and independent variables were non-parametric and did not need to satisfy the assumptions of parametric data. The five Likert scales were employed, and data were coded to simplify the analysis and interpretation.

4.2 Data analysis

The Partial Least Square - Semi Equation Modelling (PLS-SEM) was executed in two stages with the aid of SmartPLS3 software. The first stage thoroughly analyzed the evaluation of measurement models containing convergent validity, indicator reliability, internal consistency reliability, and discriminant validity. In the second stage, a structural measurement model containing coefficients of determination (R^2), predictive relevance (Q^2), collinearity, significance, and relevance of path coefficients (P- value), f^2- effects size of path coefficients were analyzed as described by Hair et al., (2018). The reflective measurement model was suitable for assessing the process because the construct influenced service indicators. Based on the nature of the study and data, an advanced method embedded in SmartPLS 3 software was suitable for the data analysis (Sartedt et al., 2017). Also, the PLS algorithm, Bootstrapping, and Blindfolding were executed using the same software to assess the fitness of the proposed model.

5 FINDINGS

5.1 Demographic Profile of the Respondents

Descriptive analysis showed that the respondents aged between 18 and 35 years were 50%, while those between 36 and 50 years were 33.8%, and those above 50 years constituted 16.2%. The findings disclosed that males were dominant (68.2%), while females constituted only 38.1% of the participants. Notably, those with a first degree were 51.6%, while those with Masters and PhD degrees constituted 37.6%, and those with secondary school education were 10.8%. These results imply that the respondents had significant knowledge about the industry and were mature enough to analyze the asked questions. For tourists visiting Tanzania, the study found that 51.8 % visited for leisure, 20.2% for conferences, 27.5% for business, and 0.5% for other purposes. Regarding the frequency of visits to Tanzania, 35.9% visited the country for the first time, 12.9% for the second time, 6% for the third time, and 45% more than three times. These findings imply that the tourists provided correct information based on their experiences because a large proportion of them had visited Tanzania more than three times.

5.2 Reflective and Structural Measurement Model

The findings showed that the reliability of the indicators was between 0.4 and 0.875. As Hair et al. (2018) recommended, the values were acceptable as shown in Figure 4. The composite reliability values were above 0.708 but below 0.95. Also, convergent validity which measures the Average Variance Extracted (AVE) was above 0.5. This signifies that every construct contributed more than 50% of the variance items making up the construct. The discriminant validity measured by the Heterotrait-Monotrait Ratio of Correlation (HTMT) was below 0.85 for all the study constructs. The result for the f^2 effect size was 0.004, which is below the f^2 effect size value. The values higher than 0.02 depict a small effect, 0.15 shows a medium effect, and 0.35 represents a significant f^2 effect. Thus, the f^2 value of 0.004 obtained from this study for the relationships between Arrival Airport Accessibility (AAA) and International Tourists Satisfaction (ITS) implies no relationship effect. Hence, the association can be dropped or mediated.

5.3 Relevance of Path Coefficient and Statistical Significance of The Hypothesized Relationship

The proposed model determined the path coefficient which was found to be positive for all the hypothesized relationships. The two direct hypothesized relationships (ARA and ITS, AAF and ITS) were statistically significant with a P-value less than 0.05. One direct hypothesized relationship (AAA and ITS) was statistically insignificant, with P-values of 0.429 higher than the recommended P-value of 0.05. Figure 4 presents the relevance of the path coefficient, indicator loading, and average variance extracted (AVE), while Figure 5 shows the statistical significance of the hypothesized relationship and the P-values.

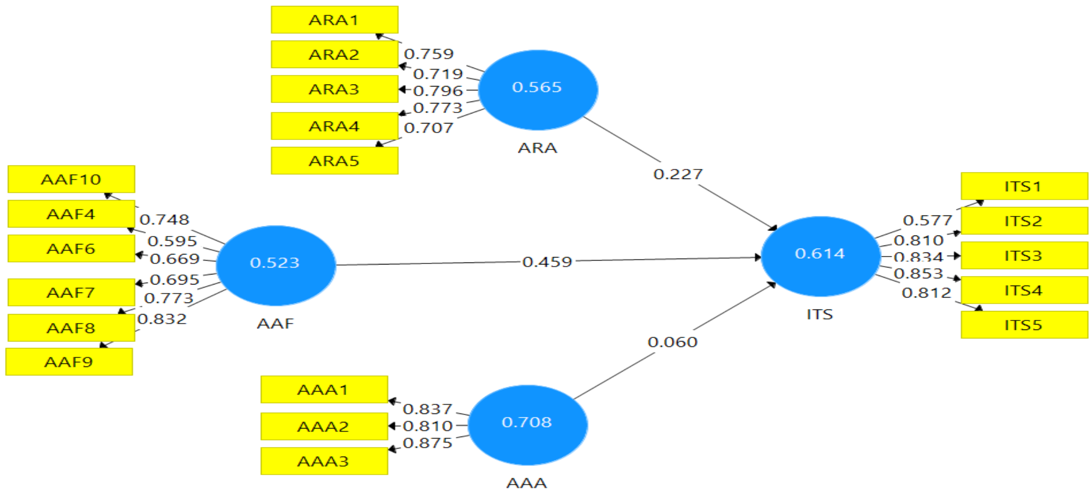

Figure 4: Relevance of the path coefficient

Source: Author, 2023

Key: Arrival Airport Accessibility (AAA), Arrival Airport Facilities (AAF), Arrival Retail Area (ARA)

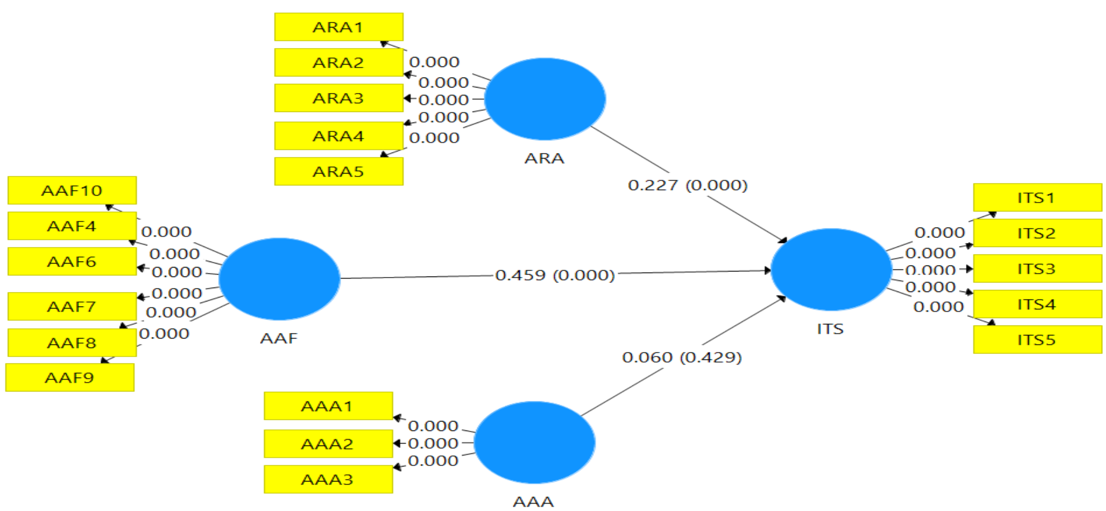

Figure 5: Statistical significance of the hypothesized relationship

Source: Author, 2023

Key: Arrival Airport Accessibility (AAA), Arrival Airport Facilities (AAF), Arrival Retail Area (ARA)

Table 3: Tested hypothesis

	G	H	I
Arrival Airport Accessibility **(AAA) ->** International Tourists Satisfaction **(ITS)**	0.716	0.429	Not supported
Arrival Airport Facilities **(AAF) ->** International Tourists Satisfaction **(ITS)**	5.421	0.000	Supported
Arrival Retail Area **(ARA) ->** International Tourists Satisfaction **(ITS)**	3.351	0.000	Supported

Source: Author, (2023)

[G] T Statistics (|O/STDEV|), [H] P Values, [I] Remark

After running the PLS algorithm, the result for the discriminant validity as per the HTMT report was less than the 0.85 value in all the constructs as recommended for structural models with conceptually distinct constructs. Table 4 shows the discriminant validity of this study.

Table 4: Heterotrait-Monotrait Ratio (HTMT)

	J	K	L
Arrival Airport Accessibility (AAA)			
Arrival Airport Facilities (AAF)	0.437		
Arrival Retail Areas (ARA)	0.668	0.473	
International Tourists Satisfaction (ITS)	0.416	0.682	0.507

[J] Arrival Airport Accessibility (AAA), [K] Arrival Airport Facilities (AAF), [L] Arrival Retail Areas (ARA).

5.4 Theoretical implications of the study findings

The study used three constructs with indicators adopted from PCAM as proposed by Wiredje et al. (2019). Each construct had a list of indicators to assess tourists' experiences at the airport terminal. Through these indicators, tourists rated their levels of satisfaction. The study added more indicators to all the constructs from the literature which significantly affected the actual number of indicators to the PCAM proposed by Wiredje et al. (2019). Cognizant of this, the model, specifically the arrival non-processing domain, has been validated to suit Tanzania airport service performance studies. Figure 7 demonstrates the validated PCAM (see the highlighted sections) compared to Figure 2 with genuine PCAM domain indicators proposed by Wiredje et al. (2019.

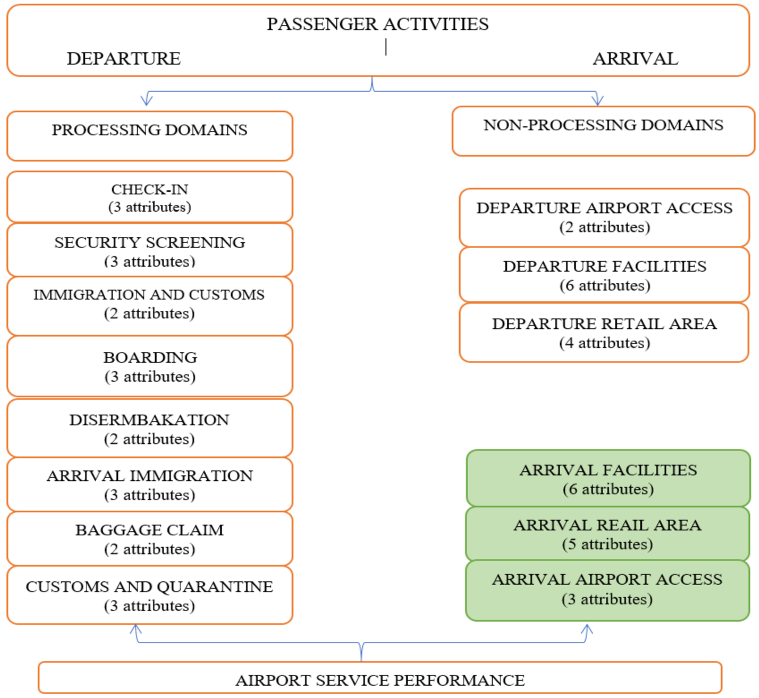

Figure 7: Validated PCAM

Source: Wiredje et al. (2019), Researcher, (2023)

6 DISCUSSION AND CONCLUSION

6.1 Discussion

The proposed model hypothesized that Airport Arrival Accessibility, Airport Arrival Facilities, and airport Arrival Retail Area had a direct and positive relationship with international tourist satisfaction. The findings revealed that two hypothesized relationships (arrival retail area with international tourists' satisfaction and arrival airport facilities with international tourists' satisfaction) were statistically significant with P-value<0.05. This indicates that the relationship between arrival retail area (a variety of retail shops, value for money in shops and cafes, a variety of foods and beverages, clear tourism information and reasonable COVID-19 precautions and safety protocols) and arrival airport facilities (conditions of baggage trolley, internet or Wi-Fi availability and provided for free, cleanliness of the terminal floor, facilities and public areas, comfortability of airport terminal and terminal physical environment) toward international tourists satisfaction exists in real life. The discriminant validity was below 0.85 for all the study constructs implying that the constructs used in the study were not interrelated. Hair et al. (2018) recommended that values less than five mean collinearity affect the interpretation of the overall model. Thus, the obtained collinearity statistics (VIF) value was less than 3, implying no multicollinearity problems among the predictor constructs

Results for the two relationships concur with those of Venkaiah and Gupta (2015), Prentice and Kadan (2019), and Aydoğan (2021), which also showed the existence of the relationship between airport facilities, services, and their charges with tourists' satisfaction. Similarly, the findings of Mwesiumo and Halpern (2021) showed that the unavailability of Wi-Fi and shopping at the airport led to dissatisfaction among tourists. On the other hand, Ansari and Agarwah (2020), Jasrotia et al. (2020), Nadim et al. (2024), Madhushanka et al. (2023), Pivac et al. (2022), Yavuz et al., 2021, Ma and Ma (2022), Smith, 2018 and Bellizzi et al. (2018) revealed that sanitation of washrooms, Baggage handling, shopping facilities, airport physical ambiance, car parking areas and comfortability, airport cleanliness and staff willingness to assist promote tourist re-visitation and lead to satisfaction. According to Hajez and Fawzy (2021), the eminence of snack bars and restaurants influences international tourists' satisfaction. Contrary to the study by Bakır et al. (2022), showing that airport shopping and Wi-Fi connectivity have little influence on tourists' satisfaction.

Furthermore, arrival airport accessibility (availability of transport options, satisfactory taxi fares, and ease of access to public transport) was hypothesized to have a direct and significant relationship with international tourist satisfaction. The findings were dissimilar as the direct relationship was statistically insignificant, with a P-value of 0.429 which is more than the recommended value (P-value<0.05) by Hair et al. (2018). This infers that a direct relationship does not exist between the constructs. These results contradict those of Adeniran et al. (2018), Sumanasiri and Dambagola (2020), Ansari and Agarwal (2020) who showed that airport services like transfer services, staff attitude, and efficiency in this domain influence tourists' satisfaction. Likewise, Adeniran et al. (2018) showed a weak direct relationship between public transport options and tourist satisfaction. However, the present study found no direct relationship between airport arrival accessibility and international tourist satisfaction.

6.2 Conclusion

The present study evaluated the connection between arrival non-processing service performance and international tourists' satisfaction. The study merged the expectancy disconfirmation theory and passenger centered airport model. Only two constructs from the theory that is perceived service performance and satisfaction were used in this study. The perceived service performance was segmented into three constructs based on the three domains forming the airport arrival non-processing domain in the passenger centered airport model. The theory missed service indicators for assessing customer satisfaction at the airport terminals; hence it was supported by the passenger centered airport model with service indicators in each domain. As recommended by

Wiredja et al. (2019), other indicators were borrowed from the literature and tested their significance in influencing international tourists' satisfaction. Two of the adopted constructs influenced international tourists' satisfaction directly and significantly while one construct had an insignificant direct relationship. Hence, passenger centered airport model has been validated based on the additional indicators from the literature. For outstanding airport performance, airport operators should strictly and closely monitor the airport services performed in these domains/constructs, starting with constructs having direct and then indirect relationships. Furthermore, many precautions must be taken when offering services in the domains with direct relationship to avoid unnecessary complaints that may result in losing return tourists. For the indirect relationship, airport operators/management should not compromise construct service quality as it may affect tourist satisfaction negatively. Generally, service quality should sustainably be retained and improved to surpass international tourists' expectations. This can seriously be done by assessing and auditing each indicator independently and regularly. The present study was restricted to three constructs (airport arrival facilities, arrival accessibility, and arrival retail area) of the airport arrival non-processing domain. Researchers can extend the model with other indicators to improve airport service performance to attract tourists. Also, future studies should integrate local and international tourists into their assessment. Since this study was grounded on the reflective measurement model, further research can use the formative measurement model to assess the relationship.

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Session Three: Application of ICT on Transport and Supply Chain Management in the New Era of Operations

Paper 9:

A Review of Wireless Magnetic Sensor Network Processes for Real0Time Vehicular Traffic Flow Monitoring

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ABSTRACT

One of the fundamental problems facing the road transportation system in the large cities of developing countries is the lack of adequate traffic monitoring and control systems that may lead to emergent traffic congestion. Traffic congestion in urban areas such as Dar es Salaam presents a complex dynamic problem that influences transportation efficiency and performance, increases fuel consumption and travel time, and causes discomfort to commuters. Its formation represents a combination of many complex processes and elements interacting with each other, such as roadside frictions, poor driving behaviours, number and type of vehicles, road capacity, condition, structure, geometry and speed bumps, traffic signals and lousy weather conditions. Traffic flow monitoring encompasses detecting, collecting, and disseminating traffic information, such as the congestion states of a road network, that facilitates traffic control and management. Magnetic-based wireless sensor networks have been deployed for traffic flow monitoring in many developed countries, but they are a novel phenomenon in most developing countries. Its adoption requires redesigning and alternative deployment strategies. This work was carried out to review the four fundamental processes in redesigning and deploying wireless magnetic sensor networks for traffic flow monitoring for deployment in developing countries' road networks. The literature review method was used in this study. The four fundamental processes of sensing, localization, energy source, and wireless communication were reviewed. The study surveyed the Dar es Salaam City Road networks and emphasized deployment strategies of wireless magnetic sensor networks for traffic flow monitoring.

Keywords: Wireless Sensor Networks, KILINODE, Magnetometer, Localization, Maximum Power-Point Tracking, MPPT, Traffic flow monitoring.

INTRODUCTION

Traffic flow monitoring collects and disseminates traffic flow information to road users, traffic control and management centres in real-time (Quinn & Nakibuule, 2010). Magnetic-based wireless sensor networks (wireless magnetic sensor networks) are among the current methods to collect traffic flow information directly from road networks (Runyoro, Zlotnikova, & Ko, 2014). The networks have been successfully implemented in developed countries. Its adoption in developing countries requires redesigning based on the economic, technological and local road network shortfalls (Quinn & Nakibuule, 2010; Runyoro & Ko, 2013). This study reviewed four fundamental processes for deploying magnetic Wireless Sensor Networks (WSNs) for traffic flow monitoring in developing countries.

A wireless magnetic sensor network consists of sensor nodes connected wirelessly and installed along a road infrastructure to collect traffic flow information over the passing vehicles. In most developed countries, the sensor nodes were buried under the road surface to monitor the passing vehicles. This intrusive implementation strategy requires a hole in the road surface to deploy or maintain a buried sensor node (Collotta et al., 2015). Hence, the overall cost of implementation and maintenance is high and requires road closure during the process. The non-intrusive implementation strategy is to alter the sensor node location to the roadsides. Therefore, redeveloping the signal detection and processing algorithm due to the increased proximity distance between the sensor node and the vehicular targets is necessary (Fimbombaya et al., 2020; Pascale et al., 2012). This work was carried out in Dar es Salaam City. The road network, travel corridors, and main geographical features were studied based on the city's road networks, literature review and physical observation.

MATERIALS AND METHODS

This study used the literature review method to survey the four essential processes that influence the implementation of a wireless magnetic sensor network for traffic flow in Dar es Salaam. The processes are localization, sensing, energy source and wireless communication media. Wireless magnetic sensor network architecture for Dar es Salaam city was also studied.

Localization

Localization is the selection of a deployment zone for the sensor nodes of wireless sensor networks to monitor the desired targets. Sensor nodes should communicate with the sink node for data forwarding and aggregation (Joseph & Xavier, 2014; Networks et al., 2016). When sensor nodes are deployed at fixed positions on the roadsides, as shown in Figures 4, and 5, various localization techniques are considered, such as pre-localization and self-localization (Dagher & Quilez, 2014); (Ngabas & Abdullah, 2014). The geographical information of every sensor node location in the wireless network is essential for managing and collecting data.

The study by (Kang et al., 2017) proposed the target localization based on the total geomagnetic field. In this method, the measurement of the total magnetic field is not affected by the total field sensors. The detection range is large due to its high sensitivity. The study by ((Mao, Klinger, Coulson, & Fidan, 2009) discusses localization techniques used to estimate the sensor node locations with unknown positions in a network. They used the available a priori knowledge of the locations of a few specific sensor nodes in the network and inter-sensor measurements such as distance, time difference of arrival, angle of arrival and connectivity. Further challenges influencing localization include measurements, environments, limited processing power, minimum hardware investment, multi-hop routing topology, and trade-offs regarding cost, size, and accuracy to suit required applications.

The study by ((Li & Li, 2012) shows that there are mainly two localization approaches for wireless sensor networks: pre-localization and self-localization. In the pre-localization approach, the sensor node location point is measured once and stored in the sensor memory during deployment. Any movement of the sensor node after deployment will result in errors in location information. In self-localization, the position of the sensor node is measured continuously in real-time after the deployment stage. Devices such as GPS are used for self-localization when embedded with the sensor node. However, the additional cost and energy consumption of GPS is expected if equipped on every sensor node. To overcome the cost implication of using a GPS device on every sensor node, GPS can be fitted with selected sensor nodes as beacons, and triangulation or trilateration techniques can be used to measure the neighbor sensor node positions.

Another self-localization technique, which does not require additional hardware, is Received Signal Strength (RSS) (Haferkamp et al., 2018); (Von Zengen, Baumstark, Willecke, Kulau, & Wolf, 2018). In this technique, the distance between neighbouring sensor nodes is estimated based on the signal strength of a received signal. Range-free localization is a promising self-localization technique that depends only on connectivity information. Hence, the sensor only needs to know its neighbours (Jurdak, Corke, Dharman, & Salagnac, 2010).

Energy Source

The WSNs should operate without depending on external energy sources to deliver the desired traffic flow information (Nayyar & Singh, 2015). Researchers have highlighted the possible sources of Energy (M. A. Matin & Islam, 2012); (Pinto, Bolzani, Montez, & Vargas, 2012) for WSNs, including primary batteries, rechargeable batteries, supercapacitors and energy harvesting (collecting energy from the surrounding environment) (Collotta, Denaro, Scatà, & Messineo, 2014). Others are the combination of rechargeable batteries and energy harvesting and a combination of supercapacitors with energy harvesting. The main criteria for evaluating energy source characteristics for WSNs include lifespan, duty cycle, energy density, charging time, self-discharging rate, and operating temperature (Simjee & Chou, 2006).

The study by (Marin & James, 2006) on energy storage elements for WSNs investigated capacitors, supercapacitors, batteries and fuel cells. They realized that supercapacitors have several advantages over batteries and fuel cells, including higher power density, shorter charging times, longer cycle and shelf life. Despite greater capacitances than capacitors, supercapacitors have yet to match the energy densities of mid to high-end batteries and fuel cells, as illustrated in Figure 1.**Error! Reference source not found.**Sensors Selection

Sensors are essential for the WSNs to collect desired physical information from the surroundings. The sensor type selection should be based on the available resources, including energy, processing power, and resolution of the analogue-to-digital converter (ADC) and amplifier. The current sensing technologies for traffic monitoring embedded in WSNs are based on magnetometers, acoustic, Bluetooth and passive infrared sensors (Daubaras & Zilys, 2012).

In recent years, magnetometers have been one of the most promising WSNs-based traffic flow monitoring sensors. When moving near the sensor, they measure the Earth's magnetic field distortions in either 1-, 2- or 3-axes caused by a metallic object such as a vehicle. The distortions carry the vehicular signature of a moving vehicle. The signature contains vehicular information such as its speed, type, direction and position (Palhinha et al., 2014). Magnetometers have replaced other older technologies in traffic flow monitoring, such as inductive loops, by showing better performance, tolerance and low cost (Pascale et al., 2012).

HMC1052 is a 2-axis magnetometer integrated circuit from Honeywell for sensing Earth's magnetic field. It has a sensitivity of 1 mV/V/Gauss and a resolution of 120nT. Due to its specifications, HMC1052 was recommended for traffic flow monitoring in Dar es Salaam. The Earth's magnetic field in Dar es Salaam is approximately 30,000nT (NOAA National Centers for Environmental Information, 2020); (H.S. Fimbombaya, Mvungi, Hamisi, & Iddi, 2018).

Wireless Communication

In WSNs, two types of wireless communication are present. First is short-range communication between sensor-node to sensor-node, and second is sensor-node to sink-node. The Current off-the-shelf short-range communication is based on the IEEE 802.15.4 standard (ZigBee or 6LowPAN) wireless technologies (Networks et al., 2016) and operates on the unlicensed 2.4 GHz band, with a bit-rate up to 250 kbps. Secondly, long-range wireless communication between sink-node to Traffic Management Center (TMC) includes GPRS, EDGE, UMTS, WiMAX, LTE or Wi-Fi evolutions (Kafi et al., 2013).

The study by (Karpis, 2013) showed that trade-offs between sensor-node power, communication range, data rate and transmitter/ receiver power sensitivity influence the transceiver capability. Based on the Friis transmission (Equation (1)), increasing communication range requires increasing transmitting power/receiver sensitivity; hence, high-energy consumption is needed.

$$\frac{P_R}{P_T} = G_T G_R \left(\frac{\lambda}{4\pi d}\right)^2 \qquad (1)$$

GT and GR are the antenna gain of the transmitting and receiving antennas, respectively
λ is the wavelength
d is the distance
PR is power available at the receiver antenna terminals and
PT is the power delivered by the transmit antenna
The antenna gains are with respect to isotropic.

The study by (Wang, (Wang, 2010) showed that wireless network communication dominates energy consumption over sensing and computation in the sensor node. Thus, optimizing its operations is essential to relieve the energy constraint in WSN. They summarized five emphases on optimizing energy consumption by wireless network communication: energy-efficient routing design, MAC design, in-network processing, load balancing and resource allocation.

Many routing algorithms are proposed for WSN. The shortest path (minimum hops-MH) algorithm is proposed to minimize energy consumption. The Ad-hoc On-Demand Distance Vector (AODV) routing is an example of using the number of link hops as its routing metric (Nikodem, Woda, & Nikodem, 2012). However, energy limitation is one of the most fundamental aspects of sensor networks. Routing algorithms for sensor networks generally attempt to minimize this resource's utilization. The design of MAC protocols for WSNs focuses on reducing energy consumption.

Under in-network processing, the raw data collected by the sensor are processed locally at the node to extract designated traffic flow information such as vehicular speed, location and classification. In-network processing eliminates the need to transmit raw data to a central point, significantly reducing the energy consumed by communication resources.

To alleviate unnecessary energy consumption from an uneven traffic load distribution, many researchers have focused their attention on the problem of load balancing. The researchers (Chang & Tassiulas, 2000) (Shih-Chang Huang & Rong-Hong Jan, 2004); (Teixeira, De Rezende, & Pedroza, 2004) (Tang & Li, 2006) showed that the imbalanced traffic load distribution could cause one part of nodes to die earlier than the others, thus degrading the network performance. The new routing algorithms proposed to counter the effect of the imbalanced traffic load distribution on network performance, which resorts to measuring the remaining energy reserves and other kinds of path capacity measurements.

WSNs Architecture for Traffic Flow Monitoring in Dar es Salaam

Dar es Salaam is Tanzania's commercial city and main port, with approximately 5.4 million people (National Bureau of Statistics, 2022). The Dar es Salaam urban structure is mono-centric as it has only one Central Business District (CBD) comprising the City Center and Kariakoo area (Kiunsi, 2013). The city is influenced by increasing traffic congestion (Mpogole & Msangi, 2016). This section reviews the Dar es Salaam City Road networks, the choice of wireless sensor-node for deployment in the city, and the WSN architecture suitable for city implementation.

The surface transport in Dar es Salaam mainly depends on road traffic (Kusyama & Machuve, 2013); (Sumatra, 2011). Major main roads and arterials converge in the city centre, where most of the traffic end and originate. Collectors and local streets connect to these main roads and arterials to form the city road network. Traffic facilities in Dar-es-Salaam are categorized into four main types: road links, roundabouts, and signalized and un-signalized intersections (Dar es Salaam City Council, 2004) (Ministry of Lands, 2013). Flyovers have been built in Dar es Salaam recently, such as Kijazi and Mfugale, adding the fifth category. Figure shows the road infrastructure converging to the Dar es Salaam City Centre.

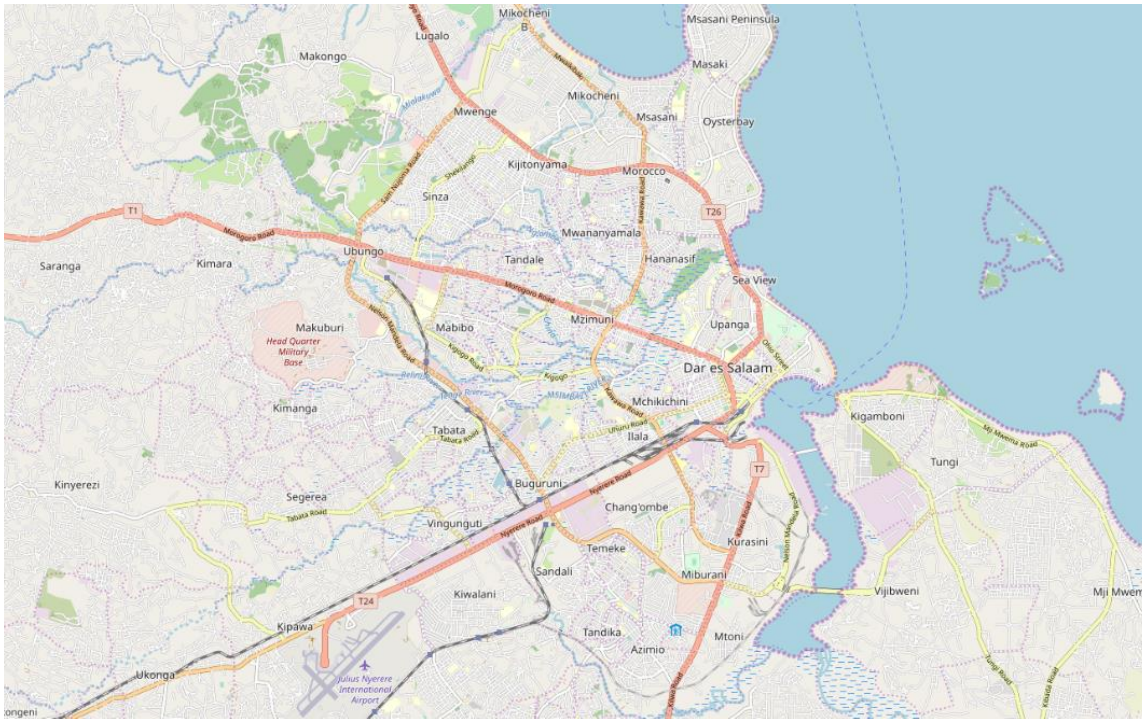
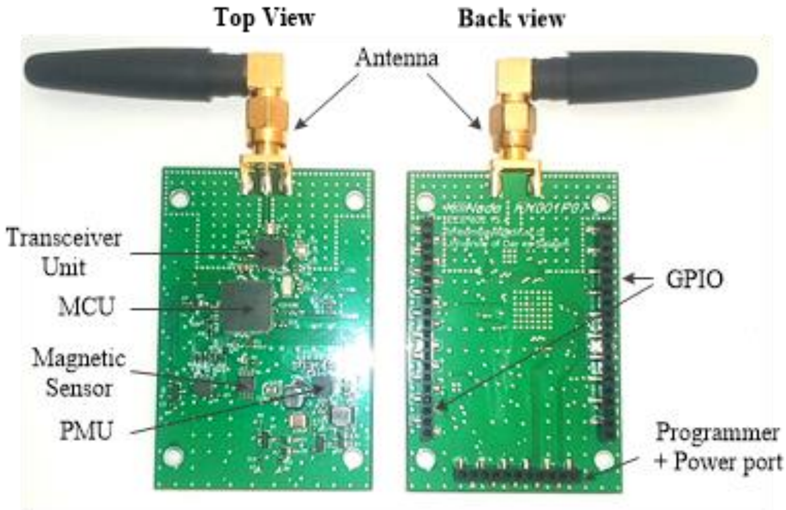
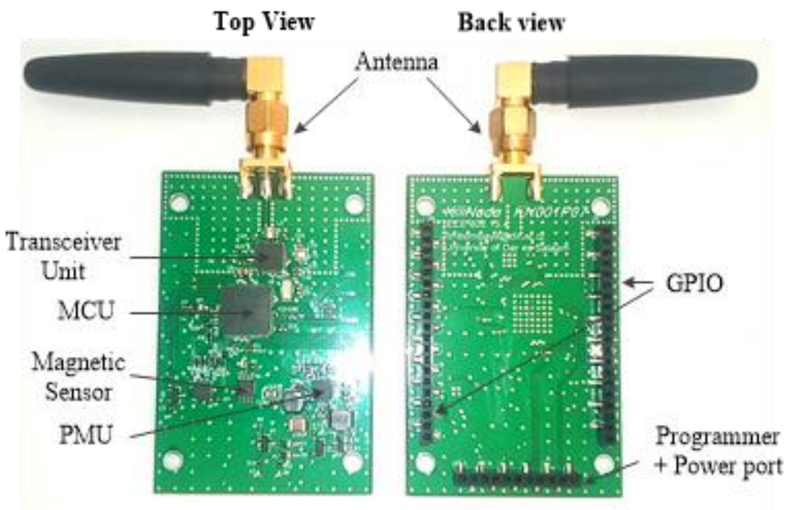


Figure 1: Dar es Salaam City map shows the main road infrastructure converging towards the City Centre

Sensor-node is a central electronic device within a WSN. The form factor of sensor-node includes a Processing Unit (microprocessor, microcontroller, or digital signal processor, Sensing Unit, Transceiver Unit and Power Management Unit (PMU) (Daubaras & Zilys, 2012). The selection of a sensor-node depends on the road network's various criteria. The trade-offs between sensing, processing and transceiver power and the available power at PMU must be maintained, ensuring an ever-last operation without disruption (Daubaras & Zilys, 2012); (Markevicius et al., 2016). The primary constraint of the sensor node is when the power source is depleted. In this case, the node is said to be dead. Energy-efficient algorithm implementation maintains low power consumption. The algorithm should keep the node in idle mode during low-power conditions.

KILINODE (Haji Said Fimbombaya, Hamisi, Mvungi, & Uledi, 2018) is a low-cost magnetic-based sensor node that targets traffic flow monitoring deployment in developing country cities. Its localization is based on sensor-nodes deployment on the roadside. It is composed of a powerful 16-bit MCU (PIC24FJ128GC006), a Transceiver Unit (CC2520), a Honeywell 2-axis Magnetometer (HMC1052) and a PMU that can integrate energy storage with an energy harvesting source such as a solar cell in Figure 2.





Figure

Figure 2: KILINODE top and back views show essential hardware components, the GPIO, programming and power interfacing ports

WSNs consist of many sensor nodes and at least one sink node installed on the roadsides and connected wirelessly by a radio frequency (RF) signal.

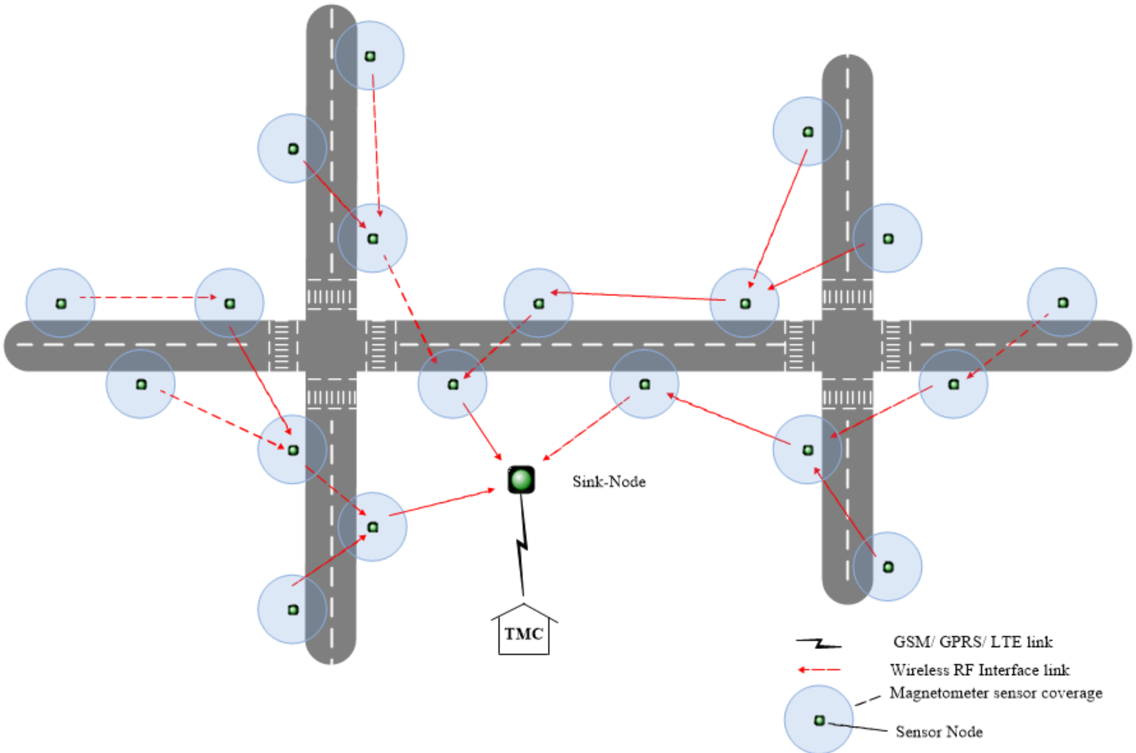


Figure 3 shows a WSN deployment for traffic flow monitoring with sensor nodes deployed on the roadsides. Each sensor node monitors a section of the road segment, processes the data locally and then transmits traffic flow information to the Traffic Management Center (TMC) through the sink nodes (H.S. Fimbombaya et al., 2018). The transceiver unit has a limited range that allows the node to transmit and receive data between short communication ranges. The sensor nodes create a peer network and act as routers to communicate with the sink node. Sensor nodes are equipped with limited computational, memory and energy resources. Dar es Salaam City is characterized by sunny days and high temperatures throughout the year (Akyildiz, Su, Sankarasubramaniam, & Cayirci, 2002). The most promising source of energy is harvesting from solar.

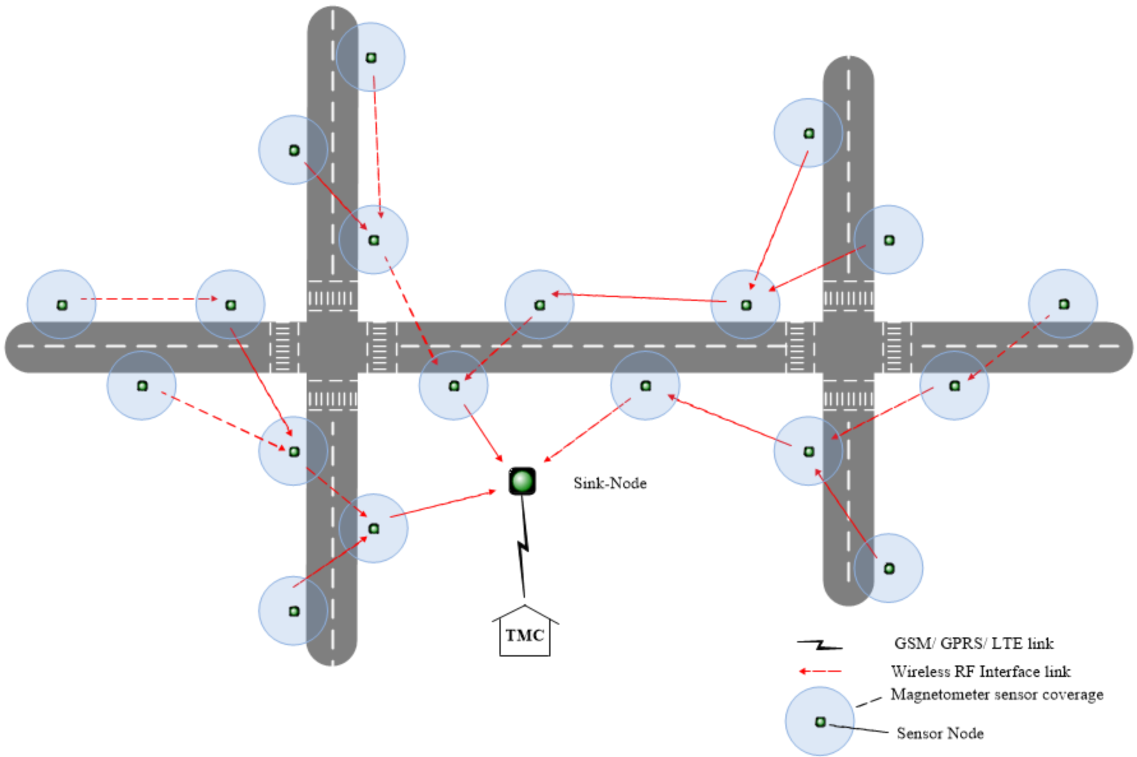


Figure 3: A road network installed with a Wireless Sensor Network for traffic flow monitoring

As depicted in

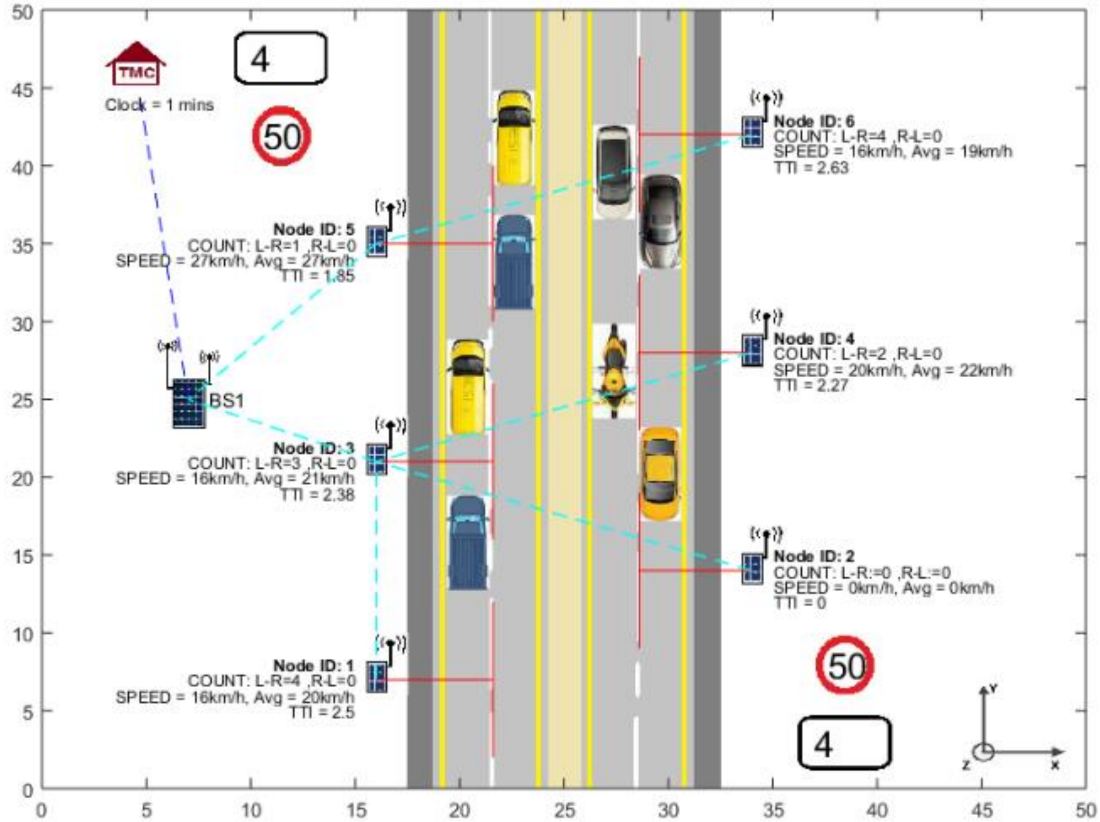


Figure4, each sensor node is operating independently. The distance between the sensor nodes depends on the transceiver sensor-nodes RF power (less than 400 meters). Sensor-node processes the sensed signal to extract the desired traffic information of vehicular count, type, and speed and then calculates the Travel-Time Index (TTI). The local traffic flow information from the individual sensor node is sent to TMC via the sink node. TMC have enough computational and storage facilities. Therefore, the average count and TTI per separate road network are calculated.

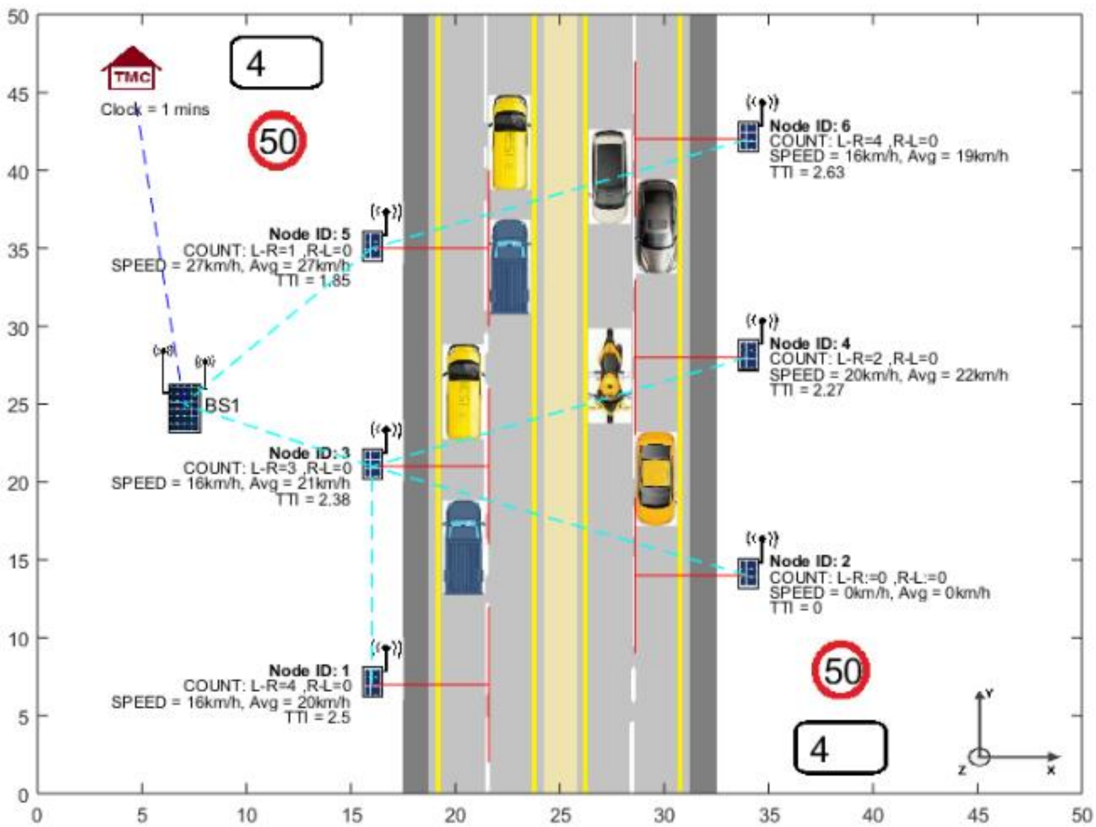


Figure 4: A Typical wireless magnetic sensor network configuration for traffic flow monitoring. Sensor nodes installed on the roadside

DISCUSSION

WSNs for traffic flow monitoring applications are categorized according to sensing type, sensor-node localization, and network architecture. The sensor-node placement can be either within the road surface or on the roadside. Due to the high installation and maintenance cost in most developing countries, installing the sensor nodes on the roadsides is preferable. Roadside wireless magnetic sensor networks have proved to be a reliable and better choice for traffic flow monitoring in cities of developing countries and beyond. Its main advantages include low installation and maintenance cost, local availability of the technology, sparsely covered area, no traffic destruction during installation and maintenance, energy-dependent and long operation life. The fundamentals of any successful wireless magnetic sensor network for traffic flow monitoring applications must ensure security, end-to-end reliability, privacy, real-time traffic flow detection, and mobility support. Traffic flow data available at TMC is disseminated to the commuters.

CONCLUSION

The importance of traffic flow monitoring, control and management in developing countries is a must due to the rapid increase in vehicles. The rapid growth in vehicular traffic makes traditional Intelligent Transportation System methods such as inductive loops out of scalability and real-time responding. Wireless magnetic sensor networks help to join the classical ITS system drawbacks due to their cheapness and scalability. Much research is essential to make wireless magnetic sensor networks a suitable partner. This research reviewed the four important processes in a magnetic wireless sensor network that must be considered for traffic flow monitoring. An additional review is required for other processes in designing and deploying wireless magnetic sensor networks in developing country cities such as Dar es Salaam. Roadside friction and chaotic and non-lane driving behaviours influence the traffic flow. This review of Dar es Salaam Road networks suggests the localization of roadside sensor-nodes.

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Paper 10:

Non-Invasive Vehicular Count and Travel Time Index Detection Based on Wireless Magnetic Sensor Networks

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Abstract

Vehicle count and travel time are vital traffic data in traffic flow monitoring, control, and road infrastructure management. The technological shortfall, high cost, and complexity during the deployment and implementation of most existing traffic monitoring systems make them out of choice for most developing countries. The deployment of non-intrusive, energy-independent, and cost-effective emerging wireless magnetic sensor networks is highly recommendable for traffic flow monitoring in most developing countries. This work studied vehicular count and travel time index detection based on non-invasive wireless magnetic sensor networks. The work used KILINODE as a wireless magnetic sensor node to evaluate its performance for detecting traffic count and travel time index. KILINODE deploys a scanning and decision algorithm to detect traffic data. The study was carried out in Dar es Salaam, where a designated road segment was deployed with wireless magnetic sensor nodes to experiment during the peak hours of the morning and off-peak hours of the afternoon. Results showed an efficiency of 98% and 71% success rates on vehicular counts in off-peak and peak hours, respectively, and an efficiency of 73% and 65% on vehicular travel time index in peak hours.

Keywords: Localization, KILINODE, Magnetometer, Machine Learning, ML, Scanning and Decision Algorithm, SDA, Traffic Management, Travel Time Index, TTI, Wireless Sensor Networks, Vehicular Count.

INTRODUCTION

Traffic flow information such as vehicular count and travel time index (TTI) (Balid, Tafish, & Refai, 2018) (Ester et al., 1998) plays a crucial role in traffic infrastructure management such as road design, safety, congestion management (Karimzadeh & Shoghli, 2020; Yahaya Hamisi, 2014), traffic control, statistics and air quality control. Road agencies such as TANROADS and TARURA set several criteria, such as controlling, monitoring and maintaining a particular road segment depending on its usage and occupation. Wireless magnetic sensor networks have been used for traffic flow management in many countries worldwide. They have shown many advantages compared to their counterparts (Wang et al., 2020). They proved cost-effective, have sparse deployment, and are unaffected by environmental changes.

This work used KILINODE, a wireless magnetic sensor node designed for non-invasive deployment to detect vehicular count, type identification and TTI (Mouapi & Hakem, 2018) (Jogschies et al., 2015). The technology uses a magnetometer sensor embedded with a powerful, energy-efficient microcontroller deployed on the roadside. KILINODE energy depends on solar energy harnessing. Its construction enables prolonged operations without relying on external power (Fimbombaya, Hamisi, et al., 2018). KILINODE deploys the Scanning and Decision Algorithm (SDA) (Fimbombaya et al., 2020; Fimbombaya, Mvungi, et al., 2018). The model extracts traffic data from Earth's magnetic distortions based on non-intrusive localization of the sensor node on the roadside.

Related Works

Most intrusive systems, such as inductive loops, cause high implementation and maintenance costs, making road closures during system repair and maintenance. The emergence of video-image processing techniques has shown promising vehicular counting and travel time detection methods. The implementation costs trade-off makes them less selective for the vehicular count, type identification and TTI deployment.

Factors Influencing Vehicular Detection

Several significant factors influence vehicular detection using non-intrusive wireless magnetic sensor networks, such as localization, interference, earth magnetic field fluctuations and energy dependency (Alsheikh et al., 2015; Ngabas & Abdullah, 2014). The location of the sensor node from the vehicular target impacts its operations. The detection quality is high when the target is close to the sensor node. It is vice versa when the target is away from the sensor node. When sensor nodes are localized on the roadsides, the distance to the vehicular target increases, resulting in poor detection. This problem is reduced by using a high-sensitivity magnetometer sensor and a designated detection model that amplifies the deteriorated magnetic distortion field due to increased distance from the target (Alsheikh et al., 2014; Soon et al., 2021).

Earth's Magnetic interference is caused by large metallic objects residing or moving near the wireless magnetic sensor node. The intrinsic intelligence of the detection model differentiates the actual vehicle from the false alarm. Hence, the false alarm due to interference is tremendously reduced. Vehicular detection depends on the Earth's magnetic field, which faces various challenges and fluctuations due to magnetic storms and temperature drifts. Most fluctuations occur in a very short time, resulting in a minor impact. The intelligent part of the modal detection discards the false distortions once detected (Markevicius et al., 2016, 2017). Wireless magnetic sensors operate continuously without depending on external power. The primary energy source relies on either batteries, supercapacitors, or harvesting. The built-in power management unit (PMU) helps balance consumption by harvesting from the environment (Kafi et al., 2013; Li et al., 2020).

System Model

This work studied wireless magnetic sensor networks for traffic detection of vehicular count and TTI at a designated road segment in Dar es Salaam. The work deployed KILINODE, a wireless magnetic sensor node that deploys a Scanning and Decision Algorithm (SDA). The SDA model performs three main activities on the captured Earth's magnetic field: conditioning, scanning, and decision, as depicted in Figure. The output data from the SDA model includes vehicular count, type, and travel time index (TTI) (Wang et al., 2020). The output data from the node are classified into primary (count and type identification) and secondary (TTI) (Mpogole & Msangi, 2016) (Prateek, Rajkumar, Nijil, & Hari, 2012). Primary data are extracted directly from distorted earth magnetic fields, while secondary data are calculated based on primary data. Figure 1 shows a typical raw distorted earth's magnetic field of moving vehicles detected by a roadside wireless magnetic sensor node. Figure 2 also shows how traffic flow data are extracted using an SDA model.

Figure 1: The SDA model's main activities on the captured distorted earth magnetic field are signal conditioning, scanning for vehicular detection and making the decision on the detected data

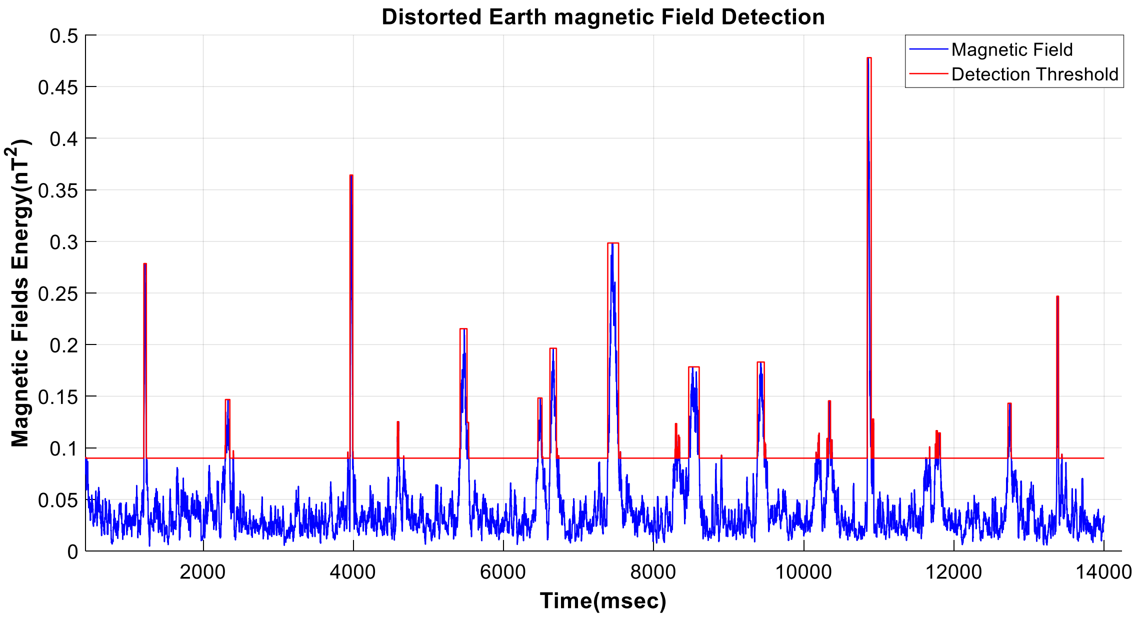

Figure 2: Distorted Earth magnetic field by moving vehicles. A roadside wireless magnetic sensor detects the field.

Figure 3 and Figure 4 show the experimental design comprising a road segment in Dar es Salaam deployed with wireless magnetic sensor nodes and a video camera. The typical wireless magnetic sensor node deployment indicates a wireless sensor network comprising one sink and three sensor nodes based on IEEE 802.15.4 specifications (Djahel et al., 2015). They are connected wirelessly using the 6lowPan protocol in a full-mesh topology (Maria et al., 2016). The sink node acts as an edge router, communicating directly to the remote server through the internet. Each sensor node operates autonomously by detecting the passing vehicle to get flow information. The road link is also deployed with the video camera to record the traffic flow manually during the experiment. The vehicular count and travel time are extracted manually (real) from the raw video by slow playback to collect the data. The raw traffic flow data extracted from the video was used as a benchmark counts and TTI.

Other traffic flow data were extracted from three wireless magnetic sensor nodes. The ratio between the data is used to evaluate the Efficiency of the KILINODE, a wireless magnetic sensor node (Zhu & Yu, 2015). The evaluation performance efficiency was calculated based on Equation 1 and Equation 2. A measure of Efficiency is the ratio of the theoretically minimal variance to the actual variance of the estimator (N. Damilola et al., 2014).

$$E_c(\%) = \frac{(C_{s1} + C_{s2} + C_{s3})\ /\ 3}{C_v} x100 \tag{1}$$

$$E_{TTI}(\%) = \frac{(TTI_{s1} + TTI_{s2} + TTI_{s3})\ /\ 3}{TTI_v} x100 \qquad (2)$$

Where:

E_c	= Efficiency of KILINODE on the vehicular count (%)
E_{TTI}	= Efficiency of KILINODE on the vehicular TTI (%)
C_{s1}	= Cumulative vehicular count by sensor node 1
C_{s2}	= Cumulative vehicular count by sensor node 2
C_{s3}	= Cumulative vehicular count by sensor node 3
TTI_{s1}	= Mean vehicular TTI by sensor node 1
TTI_{s2}	= Mean vehicular TTI by sensor node 2
TTI_{s3}	= Mean vehicular TTI by sensor node 3
C_v	= Cumulative manual vehicular count
TTI_v	= Mean manual vehicular TTI

Experimental Design

Two vigorous experiments were carried out in a single day during the morning's peak hours and the afternoon's off-peak hours. Each experiment was conducted for 30 minutes. Figure 3 and Figure 4 show the experiment setups at a designated road segment in Dar es Salaam.

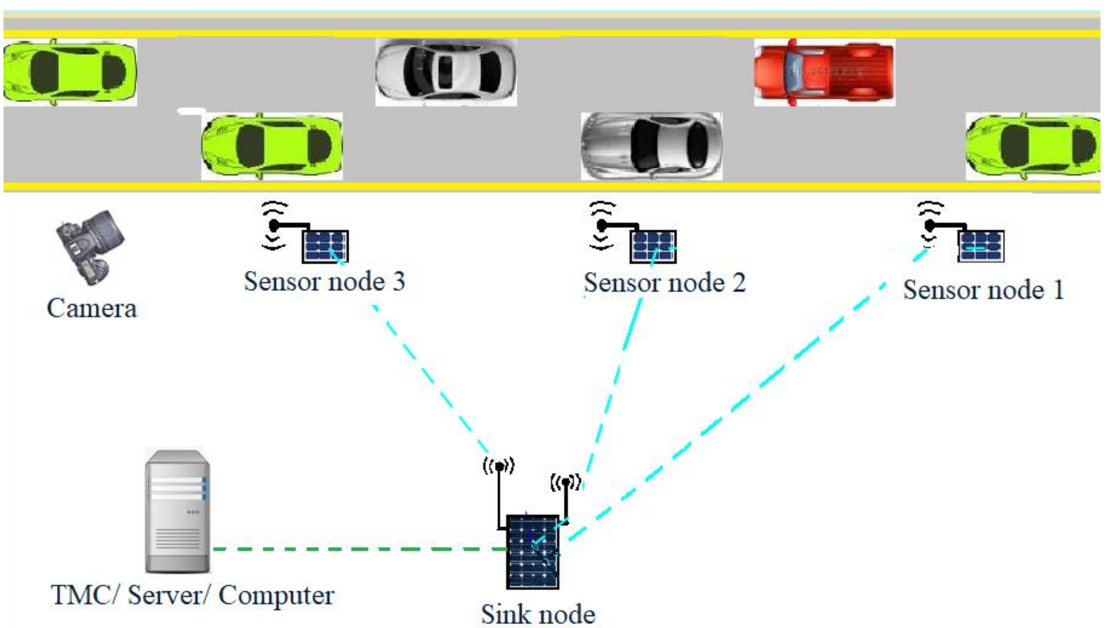

Figure 3: Experimental setup showing a video camera and three sensor nodes deployed on the roadside during off-peak hours

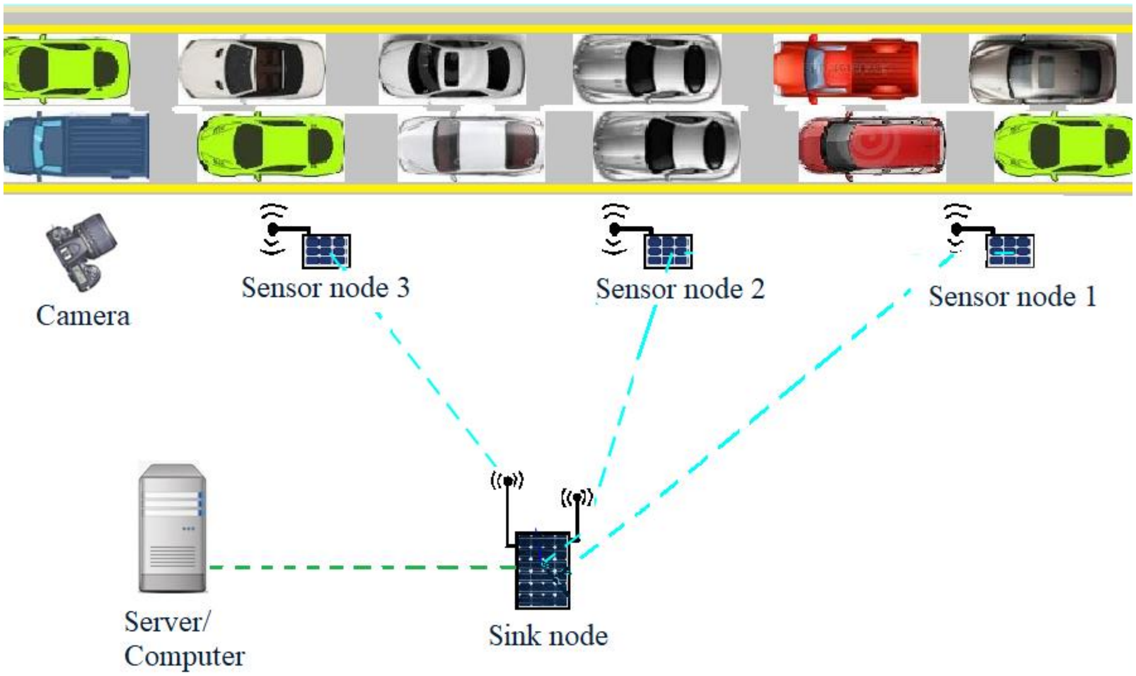

Figure 4: Experimental setup showing a video camera and three sensor nodes deployed on the roadside during peak hours

Table 1 and Table 2 show the traffic flow data collected from each wireless magnetic sensor node and sent to the Traffic Management Centre (TMC) (Djahel et al., 2015). At the TMC, the average vehicular count type and TTI were calculated. The performance of the wireless magnetic sensor nodes was calculated. It was experienced that few vehicles were passing the road segment during off-peak hours. During peak hours, vehicles passing the same road segment increased. The vehicular travel time was affected by the number of vehicles passing the road segment at a particular time. The raw videos captured during the experiment were used to generate the cumulative manual count and manual TTI.

Table 1: Experiment 1 Data Collection During Off-Peak Hours

Time(min)		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Cummulative vehicle counts	Manual	0	8	16	25	34	41	51	60	68	79	89	99	108	121	129	136	145	157	166	178	187	197	207	213	226	233	243	252	262	272	282
	Sensor-1	0	8	16	25	34	41	50	59	67	78	88	98	106	119	127	134	143	155	164	175	184	194	203	209	221	228	238	247	257	267	277
	Sensor-2	0	6	14	24	33	40	49	59	66	77	88	97	107	119	126	133	141	152	163	174	183	192	200	206	218	226	236	245	255	265	275
	Sensor-3	0	7	14	25	34	41	49	57	66	76	88	96	107	119	127	135	143	154	165	175	184	193	202	209	220	227	236	246	256	267	276
Travel Time index	Manual	1	0.9	0.9	0.8	0.9	0.9	0.8	0.7	0.7	0.7	0.7	0.9	0.8	0.9	0.7	0.7	0.9	0.8	0.9	0.8	0.9	0.9	0.9	0.9	0.9	0.8	0.9	0.7	0.8	0.9	0.9
	Sensor-1	0	0.9	0.8	0.4	0.8	1.1	0.7	0.5	0.6	0.6	0.6	0.6	0.8	0.4	0.8	1.0	0.6	0.4	0.4	0.3	0.5	0.4	0.7	0.6	0.2	0.9	0.6	0.7	0.9	0.4	0.5
	Sensor-2	0	1.0	0.9	0.4	0.8	1.1	0.6	0.5	0.3	0.3	0.6	0.5	0.5	0.4	0.8	0.8	0.5	0.4	0.3	0.3	0.5	0.6	0.8	0.6	0.3	0.9	0.4	0.7	0.8	0.5	0.3
	Sensor-3	0	0.8	1.0	0.4	0.8	1.1	0.5	0.7	0.4	0.4	0.5	0.4	0.5	0.3	0.9	0.9	0.7	0.4	0.3	0.3	0.3	0.5	0.4	0.5	0.4	0.8	0.5	0.5	0.7	0.5	0.4

Table 2: Experiment 2 Data Collection During Peak Hours

Time(min)		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Cummulative vehicle counts	Manual	0	12	27	37	47	57	71	92	109	127	145	166	187	205	220	237	257	276	292	309	327	342	359	376	393	413	429	444	463	481	499
	Sensor-1	0	8	17	26	36	45	57	70	80	93	103	119	130	143	154	168	182	195	208	219	234	249	265	279	293	306	315	329	344	358	369
	Sensor-2	0	7	17	25	34	43	55	68	81	93	104	116	129	142	155	168	178	192	206	217	232	247	262	276	289	303	313	328	341	356	368
	Sensor-3	0	5	15	24	34	44	55	65	77	91	102	117	130	143	155	166	178	191	203	215	229	241	257	270	283	297	307	322	335	349	360
Travel Time index	Manual	2.9	3.1	4.6	2.4	2.8	2.8	2.6	2.4	2.9	2.4	3.1	2.1	2.4	2.9	3.1	2.6	4.2	2.5	2.9	2.8	2.6	2.9	2.8	3.9	3.6	2.6	3.9	2.5	2.5	2.6	3.3
	Sensor-1	0.0	3.9	2.2	1.4	1.6	1.5	1.9	2.9	1.8	2.2	1.4	1.9	2.8	1.9	1.6	1.7	1.6	2.0	1.5	2.8	1.9	1.6	1.8	1.9	2.3	2.2	1.6	1.6	1.9	1.9	2.4
	Sensor-2	0.0	3.6	3.6	2.0	1.6	1.5	2.0	1.7	2.5	2.0	1.9	1.8	1.9	2.0	1.5	1.6	1.9	1.9	2.2	2.4	1.9	1.7	1.5	2.3	1.9	1.6	2.0	1.9	1.6	2.0	1.9
	Sensor-3	0.0	3.1	2.6	1.6	1.3	1.1	2.1	2.8	1.9	2.3	2.2	1.4	1.6	1.7	1.8	2.0	1.5	1.5	1.9	1.6	2.2	2.3	1.6	1.9	1.3	1.9	2.8	1.9	1.4	1.7	2.1

The Evaluation was based on the experiments conducted during the off-peak and peak hours. The manual counts and TTI were treated as the benchmark to assess the performance of the wireless magnetic sensor node, KILINODE, deployed on the roadside. Figure 5 and Figure 6 show the graphs of cumulative vehicular counts and TTIs during off-peak hours, respectively. The graphs contained the plots of both manual counts and counts done by both three sensors. Nevertheless, the TTI graphs show manual TTI and TTI calculated and generated by three KILINODEs. The general observation of the experiments performed during the off-peak hours is that the performance achieved by the sensor node is high.

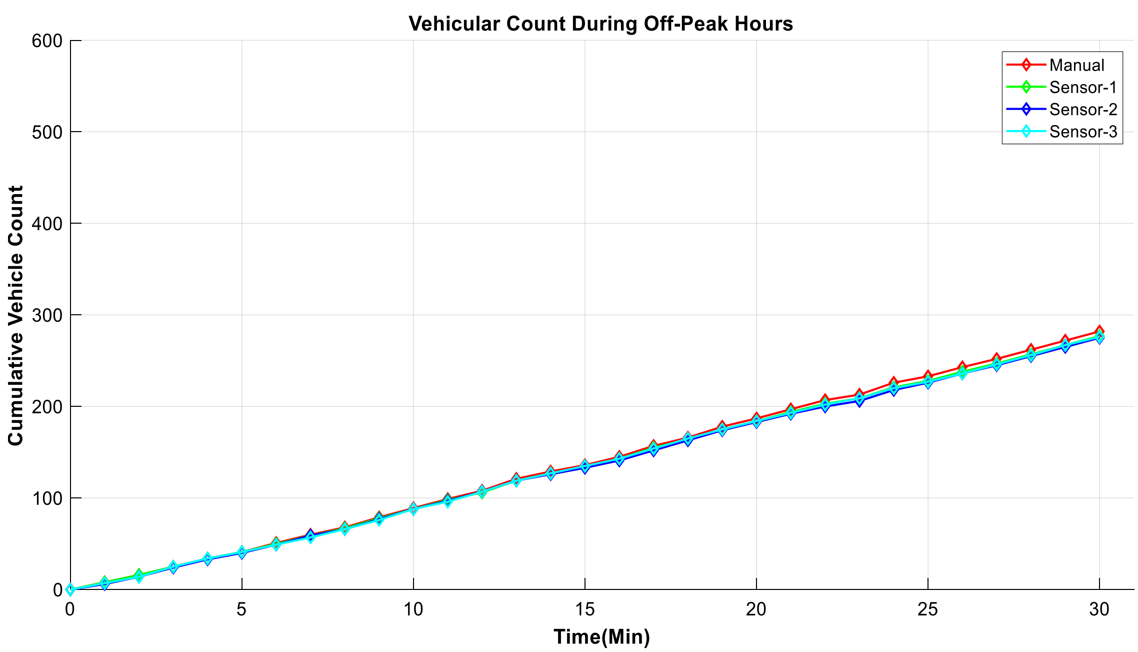

Figure 5: Vehicular counts during off-peak hours done by manual count and by three roadside wireless magnetic sensor nodes

Figure 7 and Figure 8 show the graphs of cumulative vehicular count and TTI during peak hours, respectively. The general observation shows that the number of vehicles passing a road link increases during peak hours. As a result, the traffic speed at the road segment is reduced. During this time, the vehicles were moving very close to each other. The general observation of the experiment done during the peak hours was that the performance achieved by the sensor node was moderate.

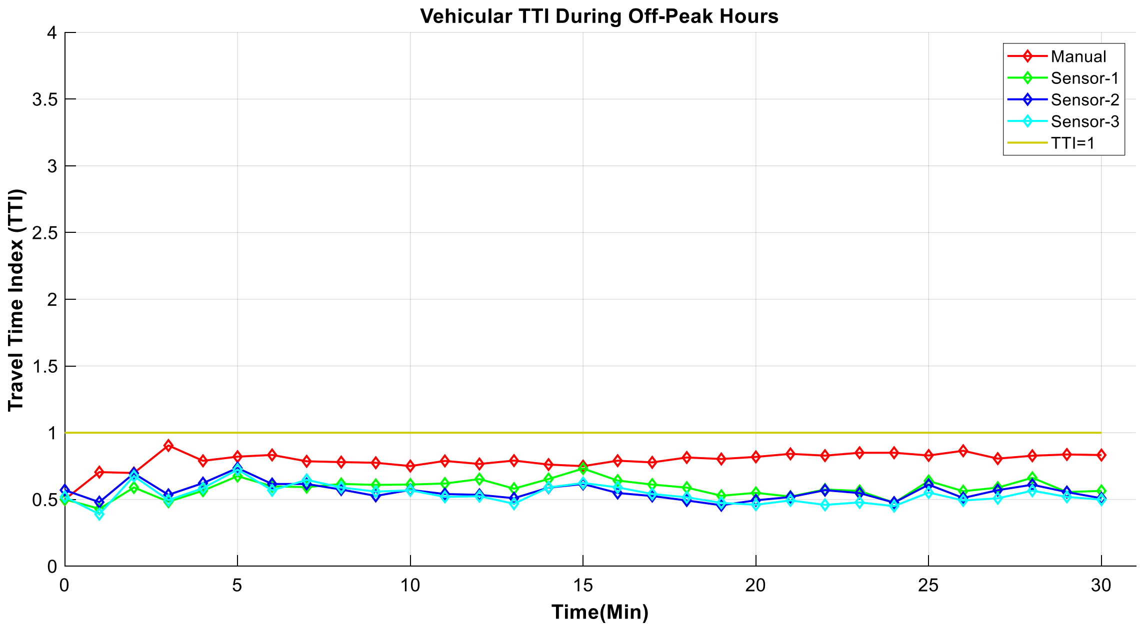

Figure 6: Vehicular TTI during off-peak hours done manually and by three roadside wireless magnetic sensor nodes

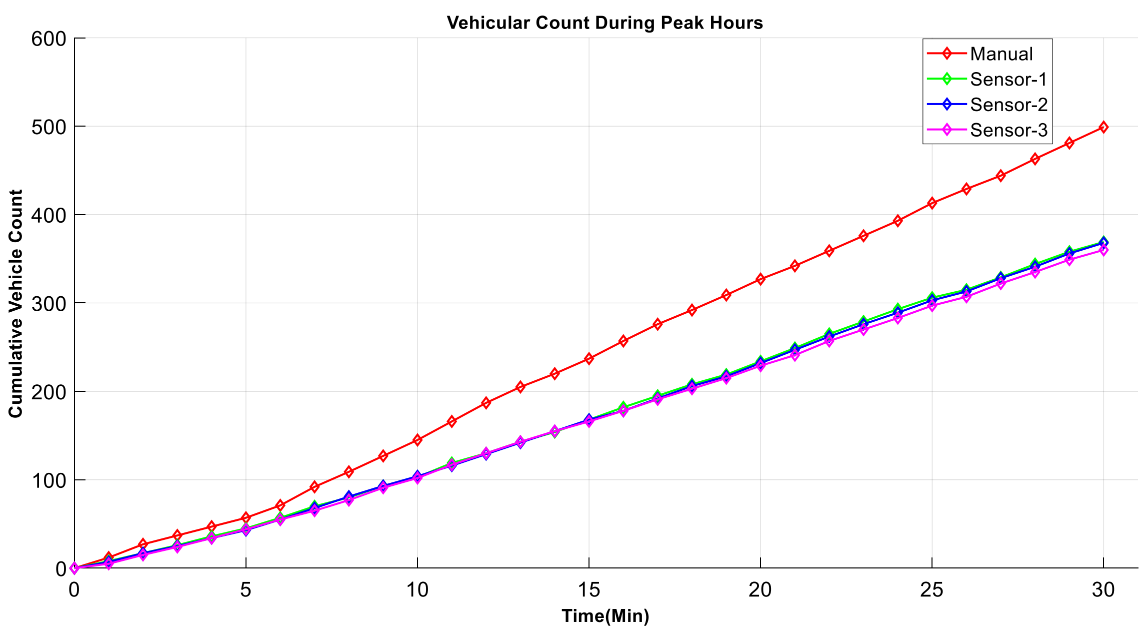

Figure 7: Vehicular count during peak hours done by manual count and by three roadside wireless magnetic sensor nodes

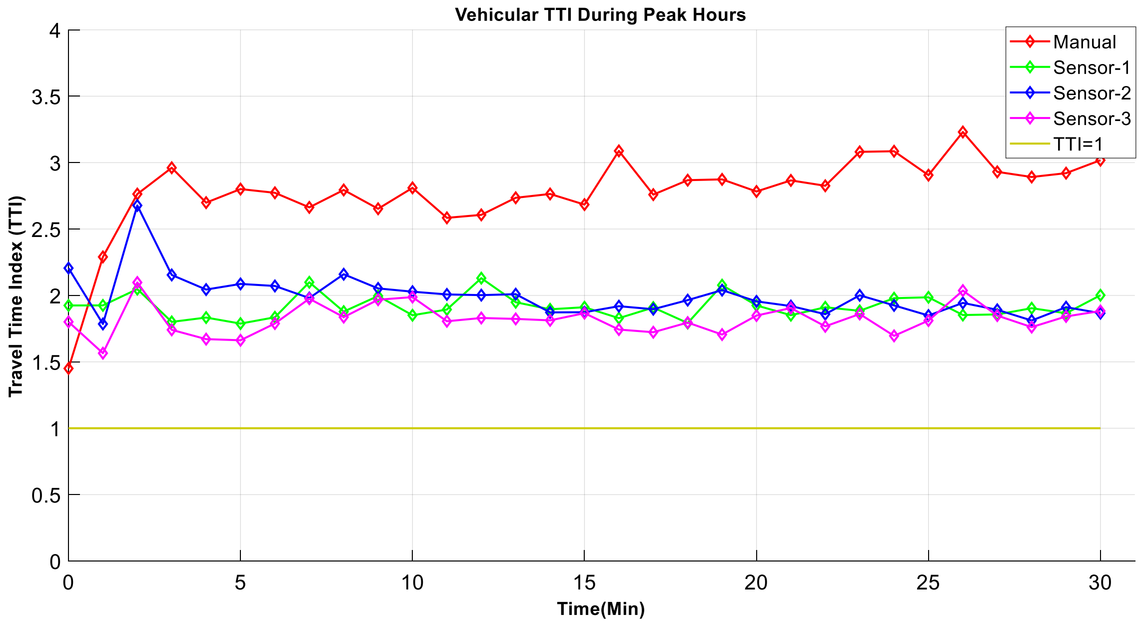

Figure 8: Vehicular TTI during peak hours done manually and by three roadside magnetic sensor nodes

The performance efficiency of the wireless magnetic sensor when used for traffic count detection during peak hours was calculated as shown in Equations 3 and 4.

$$E_c(\%) = \frac{(369 + 368 + 360)\ /\ 3}{499} x100 \ = \ 97.8\% \tag{3}$$

$$E_{TTI}(\%) \ = \frac{(1.9 + 1.9 + 1.8)\ /\ 3}{2.9} x100 \ = \ 70.9\% \tag{4}$$

Moreover, the performance efficiency of the wireless magnetic sensor when used for TTI detection during peak hours was calculated as shown in Equation 5 and Equation 6

$$E_c(\%) = \frac{(369 + 368 + 360)\ /\ 3}{499} x100 \ = \ 73.3\% \tag{5}$$

$$E_{TTI}(\%) \ = \frac{(1.9 + 1.9 + 1.8)\ /\ 3}{2.9} x100 \ = \ 64.5\% \tag{6}$$

RESULTS AND DISCUSSIONS

The high performance of the wireless magnetic sensor nodes during the off-peak hours is evident. The traffic counts during off-peak hours showed a high Efficiency of 98% success rate. The experiments were conducted on a road with two lanes in one direction. The general observation showed that the distance between successive vehicles is maintained sufficiently during off-peak hours. This is due to the fewer number of vehicles present at the road link. Magnetic wireless sensors show good detection results when the target successive vehicles are apart. Hence, the vehicles' speed and location in the two lanes have less impact on the vehicular count. Another cause of successful vehicular count during an off-peak hour is the video recorded to extract the benchmark manual vehicular count. After the video was recorded during the experiment, it was played back in slow motion to count the passing vehicles manually. The accurate number of vehicles that passed the designated road link was recorded. However, the detection efficiency is low during peak hours, when the road link is crowded with many vehicles. The performance of the wireless magnetic sensor nodes showed an efficiency of 73% success rate. One of the causes of this problem is the interference in the magnetic field of successive vehicles. The interference may cause a false alarm that impairs the detection of two or more successive vehicles as one. The current fundamental principle of operation of the SDA model is based on the time domain. The future enhancement of operating in the frequency domain will ensure the addition of filters to improve and reduce interference issues.

The general observation of the TTI during off-peak and peak hours showed performance efficiencies of 71% and 65%, respectively. The basic principle of how a wireless sensor node (KILINODE) extracts the travel time from the distorted magnetic field may impact the calculation of its TTI (Fimbombaya, Mvungi, et al., 2018). However, the manual method used to record manual travel time from a playback video in slow motion is assumed to contribute to the low-efficiency results of TTI. Its future improvement with a better application is a must in conjunction with a frequency domain operation and machine learning algorithm.

CONCLUSION AND RECOMMENDATION

Traffic count and TTI detection have shown great importance in traffic infrastructure design, safety and planning, congestion management, traffic control systems, traffic statistics, air quality, and information for economic development. The non-intrusive deployment method for Wireless magnetic sensor networks has shown outstanding achievement and prosperity when used for traffic data detection of count and TTI. Future works may operate in the frequency domain, incorporating machine learning algorithms to account for additional data output, such as vehicular classification. Compared to its counterpart invasive technologies such as loop counters, the cost-effectiveness makes wireless magnetic sensor networks the premier choice for most developing countries. Moreover, the technology ensures no road closure during its implementation or maintenance stages that may cause temporal traffic congestion.

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Session Four: Gas Transport, Energy and the Environment

Paper 11:

Characterization of Motor Vehicles' Exhaust Emissions and the Potential Impact to Ambient Air Quality, The Case of Dar es Salaam City.

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Abstract

Motor vehicles are the most useful, flexible and low-cost means of transport. However, increased number of motor vehicles has become the largest source of urban air pollution in major cities in the world. Vehicles' exhaust emissions contribute air pollutants including oxides of nitrogen (NO_x), oxides of Sulphur (SO_x), carbon monoxide (CO), hydrocarbons (HC), particulate matter (PM_{10} and $PM_{2.5}$) and photochemical oxidants. Regular monitoring of motor vehicles could control vehicular emissions, but in Tanzania vehicle emission testing is only done during registration process to enable the owner to acquire road worthiness certification and no further emission monitoring thereafter. The study aimed to characterize motor vehicles' emissions for the selected air pollutants and determine the associated impact to ambient air quality in Dar es Salaam city. Motor vehicles were randomly sampled along the busy roads for testing of exhaust gas emissions. A total of 258 motor vehicles were tested among which 198 had petrol and 60 had diesel engines. NOx, HC, and CO were tested using Eco gas 100 for petrol engines vehicles, while opacity was tested for diesel engines vehicles using Eco smoke 100. The results showed that, concentrations of pollutants in vehicular emissions were above the permissible emission standards for most (70%) of the tested motor vehicles. The average concentrations of CO, NOx, and HC were 4.67 ± 8.52 g/km, 0.43 ± 0.47 g/km, and 2.3 ± 0.21 g/km respectively. Nevertheless, compliance for individual vehicles was high at 52% for HC, 73% for CO, and none for NO_X, since its values were above the limits for all motor vehicles tested. For Diesel engines vehicles, 90% of tested vehicles failed on opacity test implying that majority of diesel engines pollute ambient air. The study findings indicate that emissions from motor vehicles in operation contain high concentrations of NOx, HC, and CO contributing to ambient air pollution. Mandatory testing and compliance of vehicular exhaust emissions to air quality regulations is suggested.

Key words: ambient air, emissions, vehicles, air pollution.

1 INTRODUCTION

Motor vehicles are the most useful, flexible and low-cost means of transport. They dominate the market for passengers and freight transport throughout the developing country (Garcia *et al.,* 2013). Use of motor vehicles for transport has triggered economic growth in most developing countries (Gwilliam and Kojima, 2012). Due to rapid increase of motor vehicles and limited control of vehicular emissions, they have become the largest source of urban air pollution in many major cities in the world (Schwela *et al.,* 1997). Vehicle traffic contribute to higher concentrations of air pollutants including oxides of nitrogen (NO_x), oxides of Sulphur (SO_x), carbon monoxide (CO), hydrocarbons (HC), particulate matter (PM_{10} and $PM_{2.5}$), and photochemical oxidants (Lary, 2000). These air pollutants are sited for environmental and social effects including respiratory diseases and cancer cases, increased energy consumption, and greenhouse gas emissions (Vaitiekūnas and Banaityte, 2007). Studies show that approximately 50% of deaths in European Union countries are caused by particulate matter from road transport (Amato *et al.,* 2014).

The study on the Global Burden of Diseases of 2013 indicated that Tanzania reported 39,825 premature deaths from the year 1990-2013 due to air pollution from particulate matter (Roy, 2016). People along the road sides in towns and cities like Dar es Salaam are exposed to vehicle related pollutants such as SO_x, CO, NO_x, HC, and PM which are above the acceptable levels specified by the World Health Organization (WHO) standards (El Haddad *et al.,* 2009; Henricson, 1999; Jackson, 2005). Despite the present and potential effects associated with air pollution, there are no sound measures taken to control air pollution from automobile sources to safeguard human health and the environment (Wilson and Gashaza, 2004). Jackson (2005) suggested the need for timely and effective measures to alleviate adverse impacts of air pollution from motor vehicles to avoid continuous deterioration of human health and environment in urban areas.

According to Tanzania Bureau of Standards (TBS) 3,300 used motor vehicles are imported per month of which two-third remain in Dar es Salaam (Henricson, 2009). Motor vehicle testing and inspection is mandatory according to Pre-Shipment Verification of Conformity (PVoC) program. Besides PVoC, the Environmental Management (Air Quality Standard) Regulation of 2007, requires owners of a motor vehicles to ensure emissions from their vehicles comply with emission guidelines. However, there is no regular inspection of vehicles for compliance with emission guideline. Lack of this inspection has caused many vehicle owners to pay less attention on the repair of exhaust emissions control devices during regular services of their vehicles.

2 MATERIALS AND METHOD

2.1 Study Area

This study was conducted in Dar es Salaam City. The City is located between latitudes 6.83° and 6.89°S and longitudes 39.24° and 39.30° E. Dar es Salaam is the largest City in East Africa and the seventh largest in Africa with approximate population of 5.3 million (Tanzania census of 2022). The city is an important economic hub and one of the fastest growing Cities in the world. It is a point of entry for vehicle importation and hosts about two thirds of all motor vehicles imported in Tanzania (Henricson, 2009; Shewere, 2013).

2.2 Sampling Site Selection

The exercise was conducted at five places including National Institute of Transport, where motor vehicles owned by staff members and some clients coming at Vehicle inspection center were tested. Ubungo Bus Terminal was another point where buses travelling from Dar es Salaam to other regions are available, and three fuel filling stations Oil Com-Mabibo near bus stand, BP gas station located at Ubungo External, Oil Com gas station at Manzese Big Brother were sampling points as presented in Figure 3.1. These points were Chosen because they represent busy roads of Dares Salaam City, having heavy traffic jams during morning and evening and remain busy for the rest of the day. Other reasons were conformability of gas analyzer to get power supply and also willingness of people to volunteer for their motor vehicles to be used in the study.

2.3 Sample Size and Sampling of Motor Vehicles for Testing

The sample size was determined based on the average number of motor vehicles attending the filling stations for fuel service. A total of 258 motor vehicles were tested, among which 198 were petrol motor vehicles and 60 were diesel motor vehicles. The study used systematic random sampling for motor vehicles at the filling stations using a random number of 4, meaning that every fourth vehicle was sampled for testing. Before testing process, the owner of the vehicle was requested for consent for his/her vehicle to be tested. For the motor vehicles which the consent was granted, they were assessed for inclusion in the study using three prescribed criteria namely: type of engine, whereby used motor vehicles with petrol or diesel engine were included, along with motor vehicles that had not undergone replacement of engine, and motor vehicles that had not undergone replacement of exhaust emission control system. The study considered motor vehicles of all categories ranging from small motor vehicles, light duty motor vehicles, passenger service motor vehicles and heavy-duty motor vehicles.

Motor vehicles were divided in four strata: the first strata consisted of motor vehicles with less than 2.5 tones from which petrol emissions was measured. The second strata consisted of motor vehicles of more than 2.5 tones from which diesel and petrol emissions were measured; the third strata consisted of motor vehicles with weight between 1.3 to 1.7 tones and the last strata consisted of motor vehicles with weight between 1.3 to 1.7 tones.

2.4 Emission Testing

The instruments used in petrol and diesel emissions testing were Gas Analyzer (Eco Gas 100) and smoke meter (Eco Smock 100). Gas analyzer gives the results of gases in parts per million (ppm) and the parameters recorded were CO, NO_X, HC, and CO_2. The emissions measured were compared with specifications directed in TZS 698:2012, the Tanzanian standard for inspection and testing of used motor vehicles for road worthiness.

2.5 Procedures

Private and light duty motor vehicles were selected in this category. Emission data was collected directly from exhaust pipe of the motor vehicles. The Gas Analyzer (Eco Gas 100) was used, the results of exhaust emissions are given parts per million (ppm). Parameters recorded were CO, NO_X, HC, and CO_2 procedures were followed according to TZS 698:2012, the Tanzanian standard for inspection and testing of used motor vehicles for road worthiness. Before taking measurement, the vehicle was left for five minutes in idle condition before placing the probe so as to warm-up of the exhaust system. After 5 minutes of the idle period and placing of the probe the results appeared on the analyzer display and was commanded to print. During measurement the engine speed was increased to 1200 rpm and kept constant for

5 minutes while the gas analyzer was set to sample the exhaust gas. The reason for increasing the speed was to enable the analyzer to sample gases which are produced when the vehicle is at 50km/hr and to create imaginary driving condition so as to know at allowed driving speed how much pollutants are emitted; for example, CO, CO_2 and HC emissions are produced more during low speed while NOx is produced more during high speed (Faiz *et al.,* 1996).

The results were converted from ppm to g/km as per required standards. According to Alkama *et al.,* (2006); Pilusa *et al.,* (2012) concentrations in ppm may be converted into g/km using following equations;

$$CO\ (g/km) = 9.66\times10^{-3} \times CO\ (ppm) \quad (i)$$

$$NO_X\ (g/km) = 28.26\times10^{-3} \times NO_X\ (ppm) \quad (ii)$$

$$HC\ (g/km) = 5.71\times10^{-3} \times HC\ (ppm) \quad (iii)$$

$$CO_2\ (g/km) = 166.3\times10^{-3} \times CO_2\ (Vol\%) \quad (iv)$$

The data obtained were recorded to a computer and exported to Microsoft Excel spread sheet for evaluation.

2.6 Parameters Analyzed in the Exhaust Emissions

In this study the parameters analyzed in the exhaust emissions of motor vehicles were: CO, NO_X, HC, and CO_2. These parameters were purposefully selected because they are common air pollutants emitted from exhausts of motor vehicles. Additionally, the pollutants have significant effects to human health and environment (Ristovski et al., 2005), (Zhang et al., 2021).

2.6.1 Emission Measurement from Diesel Engine

According to directives from TBS, emissions testing from diesel engine were done using two methods, namely Percentage Opacity method and Visual Inspection method. The Visual Inspection method is normally used for motor vehicles manufactured before the year 1990. From 1992 the Opacity method was adopted till now. However, there is a possibility of changing this method due to its weaknesses which will be discussed in result section.

2.6.2 Percentage Opacity Method

Opacity is optical term for the property for stopping light from being transmitted and when comes to exhaust gases, it corresponds to how opaque they were (Malka and Bidaj, 2015). The analyzer used for measuring opacity is known as smoke meter and it works under the principle of absorption of light through unheated sample chamber. It measures how much of specific wavelengths were absorbed by the sample. The amount of light absorbed is proportional to the concentration of the fluid which is absorbed. The model of smoke meter used in this study is Eco Smoke 100 and the emission standard used to determine compliancy was TZS 674:2001. Since opacity is measured in percentage, 0% means that all light is transmitted through the media (smoke) which indicates absence of particulate matter while 100% means that no transmission of light through the media indicating very high concentration of particulate matter in the smoke. The values between 0% and 100% imply the extent of particulate matter in the media. Figure 3.6 shows the working mechanism of the smoke meter.

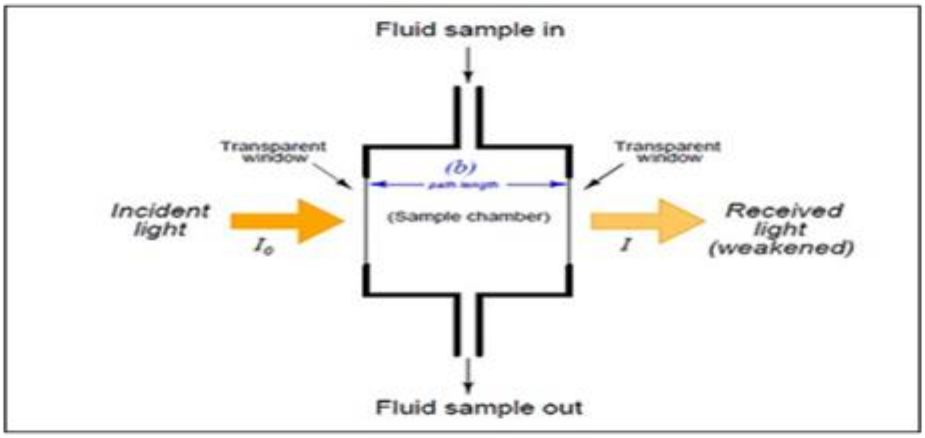

Figure 3.1 Working principle of smoke meter for opacity: $A = abc = \log\left(\frac{I_0}{I}\right)$

Where '**A**' is absorbance, '**a'** is extinction coefficient for photon-absorbing substance(s), **'b'** is path length of light travelling through the sample, '**c'** is concentration of the photon-absorbing substance in the sample, **I_0** is intensity of source (incident) light and **'I'** is intensity of received light after passing through the sample (Malka and Bidaj, 2015).

Evaluation of opacity involves another property known as light absorption coefficient. This property refers to ability to absorb light for homogenous matter, the relationship between the light transmission and the light absorption coefficient is described according to Beer-Lambert law as presented in the following equation.

$$K = \frac{1}{L_A} \ln\left(\frac{\tau}{100}\right)$$

Where K is the light absorption coefficient, L_A is the effective optical path length and τ is the ratio of transmitted light in percent (Malka and Bidaj, 2015).

2.6.3 Visual Inspection for Some of Diesel Motor Vehicles

This kind of inspection is done to motor vehicles manufactured before 1990. The color of the smoke indicates what is wrong with the vehicle. This method is used by Vehicle Inspectors in Tanzania till now; the judgment of the results depends on one's observation. The study aimed at comparing its results to that of opacity method. More detailed discussion is presented below:

2.6.4 Black Smoke

Vehicle engines are designed to run with the right combination of fuel and air to create the most efficient conditions for combustion when spark is introduced. When the fuel-air ratio skews to too much air, it is said to be lean. Smoke color is an indication of malfunction of the whole engine. One of the defaults is occurrence of black smoke which may indicate that air- fuel mixture is running rich. When there is more fuel than is optimal, it is called rich (Müller et al., 2006).

2.6.5 Blue or Grayish Smoke

This happens when oil is escaping from intended passage ways within the engine and being burned along with fuel. When there is leaking of valve seals, "blow-by" caused by worn piston rings or cylinder walls and excessive clearance around valve guides then oil creeps occur. One could always keep adding engine oil to the crankcase to prevent it from being all burned up which risks serious engine damage (Chaloulakou et al., 2005).

2.6.6 White Smoke

White smoke from exhaust occurs when the coolant made its way into the combustion chamber, this is a serious problem that needs to be addressed immediately to avoid overheating and major damage of the engine. The possible culprits for this may be a damaged cylinder head that needs to be overhauled, cracked engine block which needs engine replacement or blow cylinder head gasket. In any case, persistent, thick or white smoke out of the tailpiece indicates a problem with the engine and causes air pollution (Müller et al., 2006).

3 RESULTS AND DISCUSSION

3.1 Compliance of Motor vehicles Exhaust Emissions to Co limits (g/km)

Results on the concentration of CO in the exhaust emissions as measured directly from the exhaust pipe are presented in Figure 4.1. It was found that the minimum concentration was

1.53 g/km from motor vehicles with weight category of 1300 kg-1500 kg. The maximum CO concentration was 12 g/km from the motor vehicles with weight between 900 kg - 1300 kg. The average CO concentration for all sampled motor vehicles was 4.67 ± 8.52 g/km. It was observed that there was no defined relationship between the size of the vehicle and the amount of CO emissions, since the results show that motor vehicles from low weight motor vehicles (900 kg - 1100 kg) category and high with weight between motor vehicles (20000 kg - 3100 kg) did not comply with the permissible CO emission standard of 2.72 g/km. CO concentrations in the exhaust emissions of motor vehicles showed that 143 (72.2%) of sampled motor vehicles complied with CO emission standard while 54 (27%) did not comply.

According to Ristovski et al (2005) excessive emissions of CO may be attributed to poor servicing of the engine and the emission purification systems. The number of motor vehicles which did not comply with emission standard seems low but study by Othman (2010) showed that sites with high congestion of motor vehicles experience CO concentration above WHO, and the sites include Karikoo and Gerezani which had concentrations of CO about 15.3 μg/m^3 and 18 μg/m^3 respectively while the recommended value for exposure is 10μg/m^3, the study also went father by reporting symptoms of CO exposure to street vendors who stay for more than 10 hours along the roadside such as headache, mental dullness, dizziness, body weakness, irregular pulse and respiratory rates, again Mbuligwe and Kassenga, 1997 reported CO along roads sides in Dar es Salaam being ten times higher than recommended by EPA. Results obtained from this study as well as of the mentioned scholars show the need to control sources of CO emissions, one of them being vehicle exhaust emissions.

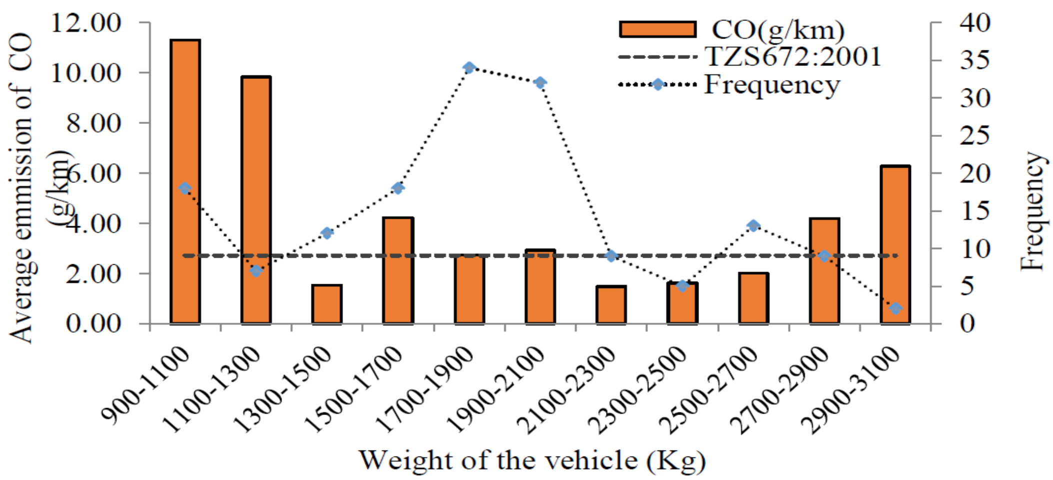

Figure 4.1 Average CO emissions for petrol motor vehicles with weight between 900 to 3100 kg

3.2 Compliance of Motor Vehicles Exhaust Emissions to NOx Limits (g/km)

Results on the concentration of NOx in the exhaust emissions are presented in Figure 4.2. It was observed that the minimum NOx concentration was 0.30g /km from motor vehicles category with weight between 1500 kg – 1700 kg. The maximum NOx concentration was 0.60 g/km from motor vehicles with weight between 2700 kg -2900 kg. The average concentration for all sampled motor vehicles was 0.43 ± 0.47 g/km. Comparison of exhaust concentrations with emission standard revealed that all sampled motor vehicles (100%) failed to comply with the emission standard of 0.15 kg/km. Failure of all sampled motor vehicles to NOx emission standard is an indicator that the emission control devices especially catalytic converters in the motor vehicles are not working properly (Carslaw *et al.,* 2011). Further comparison was made on the combined HC and NOx standard (Tables 2.2 and Table 2.6.) and Figure 4.4 which revealed that only 19.5 % complied and this may be attributed to low HC emission levels in the exhausts complied motor vehicles. This result of NO_X emissions being high can be supported by various results from NEMC (1992), (Mbuligwe & Kassenga, 1997; Othman, 2010) which indicated sites near roadside having NO_X concentration exceeding acceptable limit of 200 µg/m^3 set by WHO.

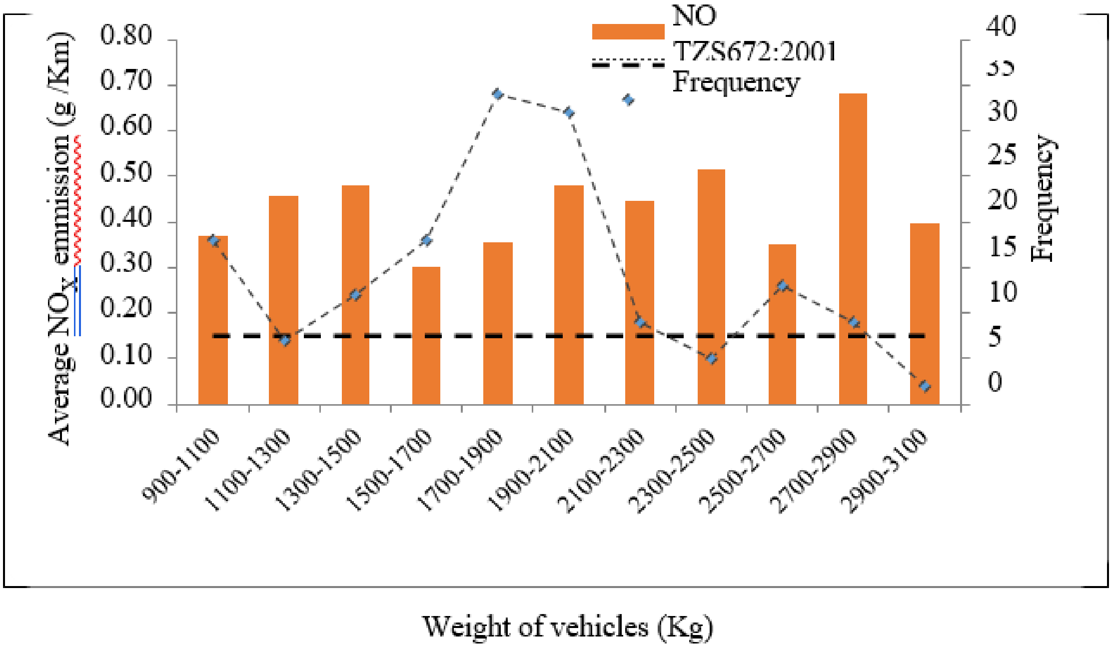

Figure 4.2 Average NOX emissions for petrol motor vehicles with weight between 900 to 3100kg

3.3 Compliance of motor vehicles exhaust emissions to HC limits (g/km)

Results on the concentration of HC in exhaust emissions are presented in Figure 4.3. It was found that the minimum HC concentration was 1.23 g/km from motor vehicles category with weight between 2100 kg to 2300 kg. The maximum HC concentration was 2.21 g/km from the motor vehicles category with weight between 1900 kg to 2100 kg. The average HC concentrations for all sampled motor vehicles was 2.3 ± 0.21 g/km. Comparison with NO_X emission standard revealed that 102 motor vehicles (52 %) complied with the HC emission standard of 1.7 g/km while 96 (48 %) did not comply and these were from the group category ranging from 1300 kg to 2100 kg.

High concentrations of HC in the exhaust emissions are an indicator of poor performance of the internal combustion system of the engine and the pollutants are considered to be the product of incomplete combustion (Laskowski *et al.*, 2019). However, comparison between HC standard with combined NO_X + HC standard revealed that 80.5% of the sampled motor vehicles did not comply with this standard which may be attributed to high content of NO_X in the exhaust emission boosting the combined effect of HC + NO_X.

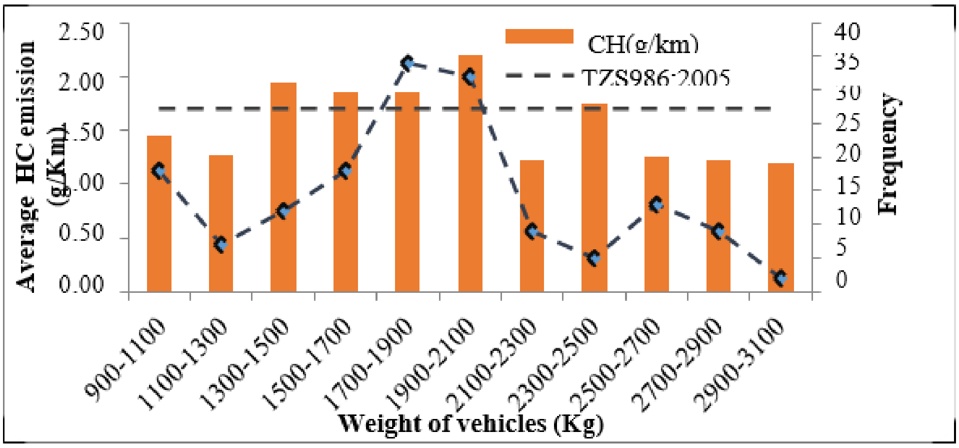

Figure 4.3 Average HC emissions for petrol motor vehicles with weight between 900 to 3100Kg

3.4 Compliance of Motor Vehicles Exhaust Emissions to HC + NOx Limits (g/km)

Results on the concentration of HC and NOx in the exhaust emissions were combined by summing up to determine the compliance with the HC + NOx emission standard and the results are presented in Figure 4.5. It was found that the minimum HC + NOx concentration was 1.6 g/km from motor vehicles category with weight between 2500 kg to 2700 kg. The maximum HC + NOx concentration was 2.69 g/km from the motor vehicles with weight in the category ranging from 1900 kg to 2100 kg. The average HC + NOx concentrations for all sampled motor vehicles were 2.0 ± 0.57 g/km. Comparison with HC + NOx emission standard revealed that 31 (19.5 %) complied with HC + NOx emission standard of 1.7 g/km while 128 (80.5 %) did not comply. Non-compliance for majority of motor vehicles to this standard may be attributed to high concentrations of NOx exhaust emissions as presented in Section 4.1.2 above.

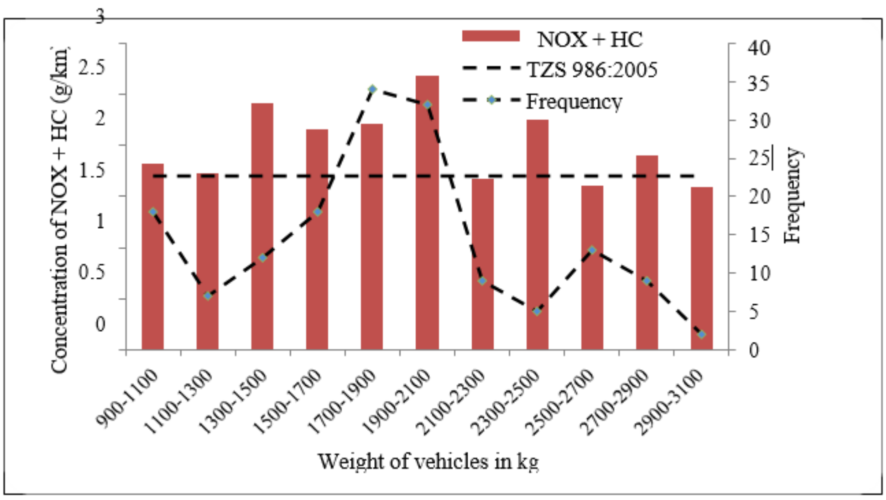

Figure 4.4 HC + NOX in exhaust emissions for motor vehicles with weight between 900 kg to 3100 kg

3.5 Compliance of opacity of the exhaust emissions with air quality standards

Data on the opacity of the exhaust emissions was collected for motor vehicles with diesel engines and the results were compared with Tanzanian standard (TZS 698:2012) as presented in Figure 4.5. The results are presented according to the group categories of motor vehicles by weights ranging from 5000 kg to 30000 kg. The types of motor vehicles under this category were those transporting goods and passengers. The results showed that the minimum opacity was 4% and the maximum opacity was 12.5%. Majority of the motor vehicles (40%) with opacity of 12% were from the group category of motor vehicles with weight between 2100 kg to 2500 kg. On comparison of the results to the Tanzanian standard, only 10 % of the sampled motor vehicles complied with opacity standard of 5 %.

The complied motor vehicles were only from the weight category of 5000 kg to 10,000 kg while the remaining 90 % of the tested motor vehicles failed. From the results it may be deduced that motor vehicles with diesel engines contribute more to the pollution of ambient air in Dar es Salaam City. The results of the current study were not in agreement with that reported by Wenzel (2000) who observed that increase in weights and engine size of the motor vehicles increases the likelihood of the vehicle to fail on opacity, it is observed that weight of the vehicle or engine does not have effect on emission, one may conclude that maintenance condition probably have effect on level of exhaust emission from the vehicle. Since HGV transport heavy and dangerous goods like fuel and other products upcountry (within the country) and nearby countries, many owners tend to do proper maintenance timely to avoid breakdown during transportation, more than 80% HGVs emitted within required limit.

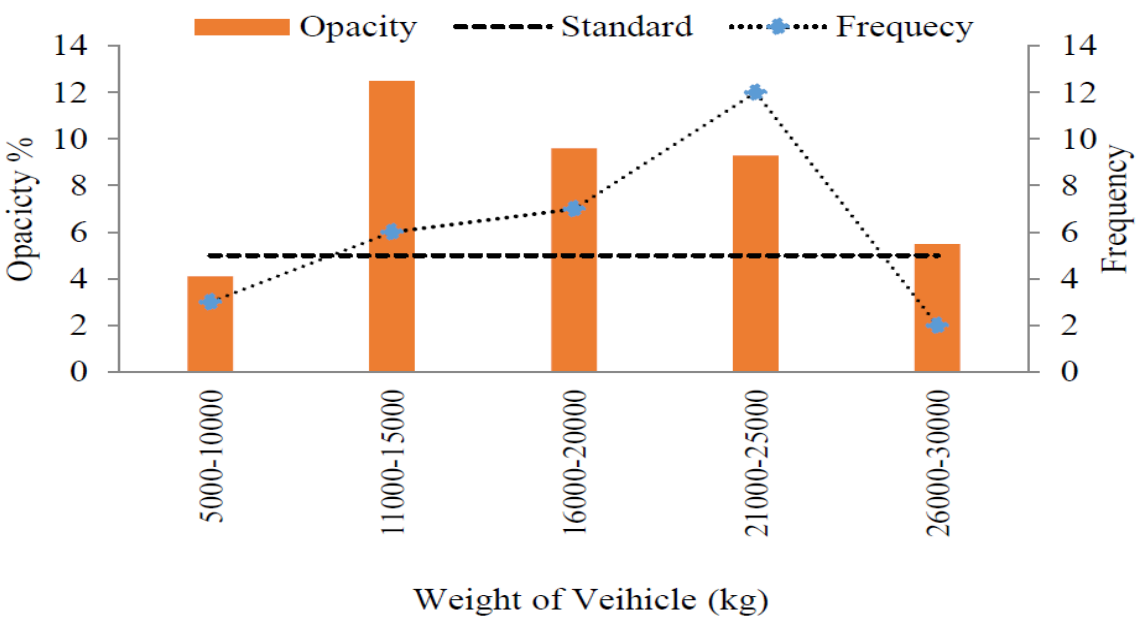

Figure 4.5 Opacity value from diesel motor vehicles

3.6 Compliance of Color of Exhaust Emissions

The available smoke testing devices do not analyze opacity for diesel motor vehicles manufactured before 1990, thus visual inspection of the color of smoke emitted was used, and the results are presented in Appendix A. The results show that 86.6 % (26) of the sampled motor vehicles passed while 13.4 % (4) failed. Pass on visual inspection for majority of sampled motor vehicles means that they did not produce colored smoke which may indicate that the engine and air control systems were in good condition. On the other hand, the failed motor vehicles produced colored smoke of black, blue, grayish or white which may indicate malfunctioning of the engine or emission purification system. However, although visual inspection is used, it may not be a reliable technical method to determine compliance to emission standard since it may entail some degree of subjectivity by the observer. During this study the influence of fuel quality was not considered.

4. CONCLUSIONS AND RECOMMENDATION

4.1 Conclusion

The quality of exhaust emissions from majority of used motor vehicles in Dar es Salaam do not comply with the permissible standard; the study revealed that air pollutants in the exhaust emissions including NO_X, CO, and HC were above required limit for most of the tested motor vehicles. This situation increases the susceptibility of ambient air to pollution due to vehicular exhaust emissions. The air quality along the busy roads in Dar es Salaam City is highly vulnerable to pollution due emissions from motor vehicles. The results from prediction model revealed that, increase in number of emitting motor vehicles contributes to the increased gas pollutants in the ambient air. This situation may endanger public health and environment especially in major cities like Dar es Salaam. Tanzania has legal and institutional frameworks for protection of environment but they lack clear demarcation of responsibilities and legal mandate to control vehicle emissions. Public awareness campaign is still poor as vehicle owners were observed to have low awareness on the compliance with exhaust emission standard and control of exhaust emissions.

4.2 Recommendations

The government needs to revise the whole program of vehicle inspection by introducing exhaust emission testing into the routine Vehicle inspection done by the responsible authority. Emission testing is required to ensure motor vehicles on road are not contributing to air pollution.

The government organ responsible for vehicle inspection should be strengthened in terms of technical capacity and equipment for monitoring and testing of exhaust emissions as strategy to control air pollution from motor vehicles.

Community awareness campaigns need to be established and strengthened by informing the public on the effects of air pollution from vehicular emissions on public health and their roles on air pollution prevention and control.

Regulations and Acts should state specific government institution mandated to conduct emission testing regularly and if feasible, penalty should be imposed to non-compliance for protection of the ambient air quality.

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Paper 12:

Performance of a Fuel Level Monitoring System Based on Savitzky-Golay (SG) Filter Smoothing Technique

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ABSTRACT

Accurate information about fuel level and fuel consumption is important for trip planning. Currently, most vehicles use conventional fuel level sensors with a floater arm attached to the discrete potentiometer (variable resistor). This system provides noisy and sometimes inaccurate information due to the driving profile and other mechanical structures of the fuel tank. This research intends to investigate the alternative methods where the Savitzky–Golay (SG) smoothing filter-based algorithm estimator is developed and tested to monitor the fuel level on a real-time basis. This fuel level is incorporated with telematics to obtain the location of vehicle information using the Global Positioning System (GPS) technology through telematics. In this paper, the performance of the fuel level SG filter-based estimator is compared to the noninvasive ultrasonic fuel level sensor (more accurate and well-positioned), the Kalman filter-based algorithm, and the conventional method. Matlab® simulation tool is used to analyze data obtained through a data acquisition system from conventional and noninvasive (NI) capacitive ultrasonic fuel sensors. The quality of the estimators is measured based on the standard deviation, margin of error, and signal-to-noise ratio (SNR). The results presented show that the SG filter-based estimator provides a better (lowest) standard deviation as well as a margin of error. Similarly, the SNR provided by the SG filter-based estimator is the best (highest).

Keywords: Accuracy; estimator; fuel level; GPS; Kalman filter; margin of error; Savitzky–Golay filter; SNR; standard deviation; telematics

1 INTRODUCTION

The vehicle fuel tank is a storage of fuel used by the engine of the vehicle. The knowledge of the fuel level in the field of transportation is one of the foundations when planning for driving. This information is later processed and displayed on the dashboard of the vehicle. Accurate information on the fuel level can be used on the fueling budget and the vehicle's fuel consumption rate (Ping et al., 2019). The reasons for the difference in vehicles' fuel consumption vary from many external factors such as driving profile, traffic conditions, weather conditions, excessive use of air conditioners, unnecessary loading of cargo, four-wheel drive, status of the vehicle, fuel quality, etc. (Jim et al., 2018).

Currently, the most popular, conventional, and economically viable fuel level sensors consist of a floater arm attached to the discrete variable resistor. The resistance of the fuel level is proportional to the fuel volume or position of the arm. Typically, vehicle tanks of various types and sizes come with a standardized mathematical model, a look-up table that transforms resistance into fuel-level volumes (Timu and Dinesh, 2022), Fackrell et al., 2003). This system provides highly noisy and sometimes slightly inaccurate information due to the driving profiles, mechanical disturbances, and uncertainties that affect the physical limitation of the arm positioning. Moreover, the sloshing phenomena of the fuel in the tank as the car accelerates or decelerates, and angular vehicle orientation may affect the position of the floater's arm and change the readings of the fuel level (Yu et al., 2020). Sloshing of fuel, the free surface motion of the fuel in a partially filled container due to external excitation, inside the tank can affect the level measurement of the fuel (Frosina et al., 2018). Sloshing normally occurs during acceleration, turning maneuvers, braking of the vehicle, and traveling in rough terrain (Rajagounder et al., 2016). The non-uniform nature of slosh will cause level sensing to be extremely inaccurate.

Therefore, the need for the investigation of an alternative method that may provide accurate information is necessary. Removing noise from statistical data can be realized using many different techniques, including filtering using lowpass or custom filters (Bellanger, 2024), additive smoothing (Valcarce et al., 2016, Sadhanala and Tibshirani, 2017), kernel smoothing (Friedman et al., 2001), and Poisson Principal Component Analysis (PCA), and Nonlocal-PCA (Kipele and Greyson, 2023).

In this research, the Savitzky–Golay (SG) filter-based estimator is used as an alternative method to measure the fuel level in the tank of the vehicle. The performance of this method is analyzed.

2 RELATED WORKS

There are various techniques used to design fuel management systems intended for fuel level estimation and monitoring. Candidly, there is no unique system used to monitor the fuel level or fuel consumption (Al-Chalabi et al., 2021). The work in (Al-Chalabi et al., 2021) suggests the algorithms by calibrating the flowmeter sensors separately to reduce the manufacturing error rate. This proposal found that the fuel consumed in the generator is more accurate and produced more security for fuel from leakage or pilfering. The abnormal behavior of the generator can be reached immediately by monitoring the voltage and ampere in real-time mode. The proposed techniques by the researchers include the Kalman filter-based algorithm. This technique is used to remove noise (Putra and Agoes, 2021; Park et al., 2016; Oonsivilai and Greyson, 2009; Becker, 2023).

Kalman filter-based optimization technique has been proposed by various researchers. Researchers in (Putra and Agoes, 2021) proposed a Kalman filter-based method that reduces data noise that occurs in the fuel sensor. This is implemented by changing the process error covariance and measurement error. Similarly, fuel capacity measurement is proposed by researchers in (Park et al., 2016) where the algorithm for measuring the capacity was created with a complementary filter using a Kalman filter where the results showed that the measurement of the fuel capacity was improved. Although the Kalman filter is a powerful tool for estimation, its estimates may be biased or inaccurate (Becker, 2023; Drécourt et al., 2006; Zanetti and Bishop, 2012). Moreover, it is sensitive to initial conditions or the accuracy of the initial state estimate.

An optical sensor based on Surface Plasmon Resonance (SPR) composed of a hemispherical glass prism, a magnesium fluoride layer, and a gold layer is proposed by Pozo et al., in the estimation of a real-time fuel level (Pozo et al., 2016). Principles, design, and applications of SPR are presented by Gupta and Verma (Gupta and Verma, 2009). Devi et al., (Devi et al., 2023) introduce a fuel theft detection and fuel monitoring system utilizing IoT technology to address the rising concern of fuel theft and enhance fuel management practices. Other models developed to predict fuel consumption rates include models based on machine learning and mathematical models intended to improve the prediction accuracy proposed by Xie et al. (Xie et al., 2023). In this paper, the Savitzky–Golay (SG) filter method is used to remove noise from the fuel level transmitter sensor. The estimation performance is measured using the standard deviation which describes how far or dispersed the estimator is from the true value, margin of the error, and respective signal-to-noise ratio (SNR). The Particle Electron

3G-270 cellular IoT, STM32F205RGT6 ARM Cortex M3 processor-based microcontroller, is used as a telematics cellular communication link. Newer versions such as B Series SoM and Boron can also be used (Greyson, 2023). Matlab® simulation tool is used to analyze data obtained through a data acquisition system from conventional and noninvasive (NI) capacitive ultrasonic fuel sensors. Kalman filter-based algorithm and SG filter algorithm methods are used to estimate the data from conventional sensors and performances are compared.

3 SAVITZKY-GOLAY FILTER TECHNIQUE

The Savitzky-Golay filter is a digital filter widely used in signal processing aimed at noise reduction and enhancing the smoothness of time-series data. SG filter is a low-pass filter whose structure is similar to a finite impulse response (FIR) filter (De Oliveira et al., 2018; Savitzky and Golay, 1964; Schmid et al., 2022; Hossea and Greyson, 2024). The smoothing points are found by replacing each data point with the value of its fitted polynomial. The process of SG is to find the polynomial coefficients that are linearly related to the data values (Staggs, 2005; Haider et al., 2018).

The filtering process forms the least squares polynomials fitting the data where the number of sampling points considered in a group is defined by the window size parameter while controlling the order of the used polynomial (Savitzky and Golay, 1964; Schmid et al., 2022). The mathematical description of the smoothing process implemented by Savitzky-Golay filtering is expressed by Eq. (1) (Liu et al., 2016; Chen et al., 2004; Brian et al., 2010; Li and Liu, 2011).

$$s^*_j = \sum_{x=-m}^{m} c_x s_{j+x} / N \tag{1}$$

where s is the original signal, s^* is the smoothed signal, c_x is the coefficient for the x^{th} smoothing, N is the number of data points in the smoothing window equal to $2m+1$, and m is the half-width of the smoothing window. The index j represents the running index of the ordinate data in the original data table.

The essence of SG filtering is adopting a polynomial in a sliding window to fit the original signal piece-by-piece depending on the least-squares estimation algorithm. The polynomial can be modeled as shown in Eq. (2) (Liu et al., 2016). Given a set of $2m+1$ data values, the polynomial of n degree that satisfies the least squares fit of these values is expressed as (Ruffin et al., 2008).

$$f(x) = b_0 + b_1 x + b_2 x^2 + \ldots + b_k x^k = \sum_{n=0}^{k} b_n x^k \tag{2}$$

where b_n is the coefficient of the polynomial, k is the polynomial degree.

The coefficient of the polynomial, b_n is obtained by applying the least-squares criterion expressed by Eq. (3).

$$\frac{\partial}{\partial b_n}\left\{\sum_{x=-m}^{m}\left[f_k(x) - s_x\right]^2\right\} = 0 \tag{3}$$

The b_0 is obtained by evaluating the Eq. (2) at x = 0, then b_n is obtained by computing the n^{th} differential of Eq. (2) at x = 0. Hence,

$$f_k^n(0) = \sum_{x=-m}^{m} c_x^n s_x \tag{4}$$

where n is the derivative order, c_x^n is the convolution weight, and s_x is the value of the x^{th} point.

4 EXPERIMENTAL SETUP AND PROCEDURES

4.1 Experimental Setup

Both accuracy and connectivity are considered when considering a fuel level sensor with telematics capability. The preinstalled conventional fuel transmitter and the more accurate NI capacitive ultrasonic fuel sensor with 98-99% accuracy as a standard fuel level measuring unit were used to collect data. Sensors, Particle Electron 3G-270 cellular IoT, GPS module, and display are installed to form IoT-based telematics for remote data logger as shown in Figure 1.

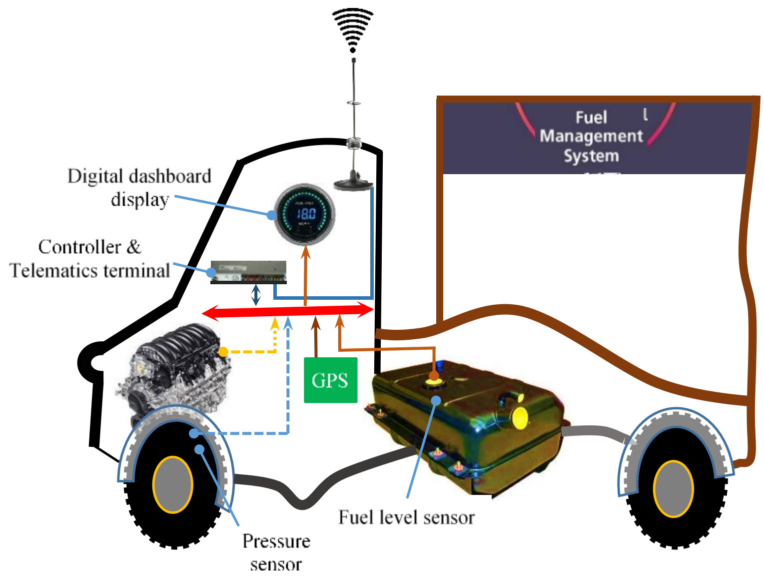


Figure 1: System components

4.2 Experimental Procedure

The NI ultrasonic fuel level sensor and conventional fuel level sensor were used to measure the real-time fuel level in the Suzuki Grand Escudo 2.7 V6 engine operated with gasoline with specifications shown in Table 1. Initially, the workbench experiment was carried out where the voltage (volts) and volume of gasoline (liters) in the Suzuki fuel tank. A Resistor of 309 Ω, E96 series (tolerance 1%) as per standard IEC (International Electrotechnical Commission) 60063:2015 (a series with a recommended tolerance of ±1%) is connected in series with the conventional fuel transmitter (IEC, 2015). The schematic circuit diagram to measure the voltage is shown in Figure 2. IEC 60063:2015 provides a series of preferred values for the resistance of resistors and the capacitance of capacitors.

Table 1: Vehicle specifications

Type	Suzuki Grand Escudo 2.7 V6 Engine
Engine	Water cooling 4 cycle V-type 6-cylinder DOHC24 valve
Fuel tank capacity	66 L
Fuel Consumption (JC08 cycle)	11.4 L/100 km

Firstly, based on the geometry of the tank, the mathematical model for the volume of the fuel that defines the geometry of the tank is developed for both fuel sensors. With the high-precision voltmeter, the voltage across the fuel transmitter (setup in Figure 2) is recorded when the fuel tank is empty. The fuel volume interval of 0.5 liters (0.5 L, 1.0 L, 1.5, etc.) was filled in the tank and the voltage was recorded as shown in Table 2. The data pattern in Table 2 is statically analyzed to form a regression function of the volume (in liters)/voltage (in volts).

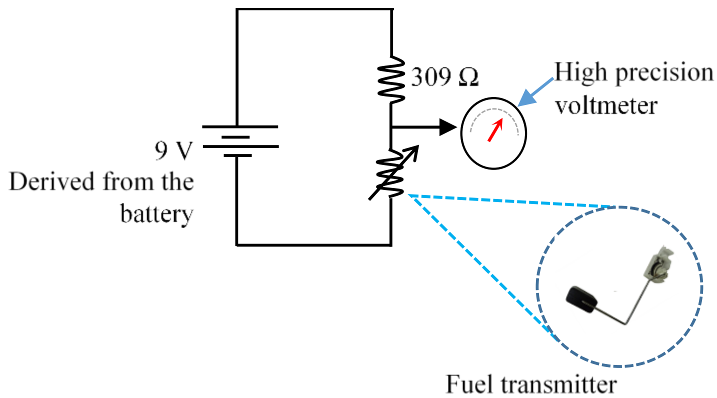


Figure 2: Schematic circuit diagram used to map voltage and fuel volume of a developed fuel transmitter

Table 2: Conventional fuel sensor volume (liters)/voltage (volts) mapped data

Trial#	Volume	Voltage
1	0.0	0.00
2	0.5	0.11
3	1.0	0.30
4	1.5	0.46
5	2.0	0.60
6	2.5	0.72
7	3.0	0.83
8	3.5	0.93
9	4.0	1.02
10	4.5	1.11
…	…	…
N-1	55.5	4.96
N	66	4.99

We specify the trend as a particular function of fuel volume, with the means of estimating polynomial time trends. This polynomial regression model, as shown in Eq. (5), is approached by considering the problem of approximating a function whose values at the fuel volume points $(x_0,...,x_n)$ 0.0, 0.5, 1.0, etc., are known only via the observations of voltage levels $(y_0,...,y_n)$ which are subject to error (Pollock, 1999).

$$y = \beta_0 + \beta_1 x + \beta_2 x^2 + ... + \beta_q x^q + \varepsilon \tag{5}$$

This can be expressed in matrix notation in Eq. (6)

$$y = X\beta + \varepsilon \tag{6}$$

where output and input parameters are $y = [y_o,...,y_n]'$, and $X = [x_q^j]$, respectively. Coefficients and errors are $\beta = [\beta_o,...,\beta_q]'$, and $\varepsilon = [\varepsilon_o,...,\varepsilon_n]'$, respectively.

In this study, investigation of the fuel level sensors performances was done along Bagamoyo road from Dar es Salaam Institute of Dar es Salaam (6°48'53.6" S 39°16'48.5" E) to Bagamoyo secondary school (6°27'18.8" S 38°55'39.0" E), a distance of ~68 km. The map of the route is shown in Figure 3.

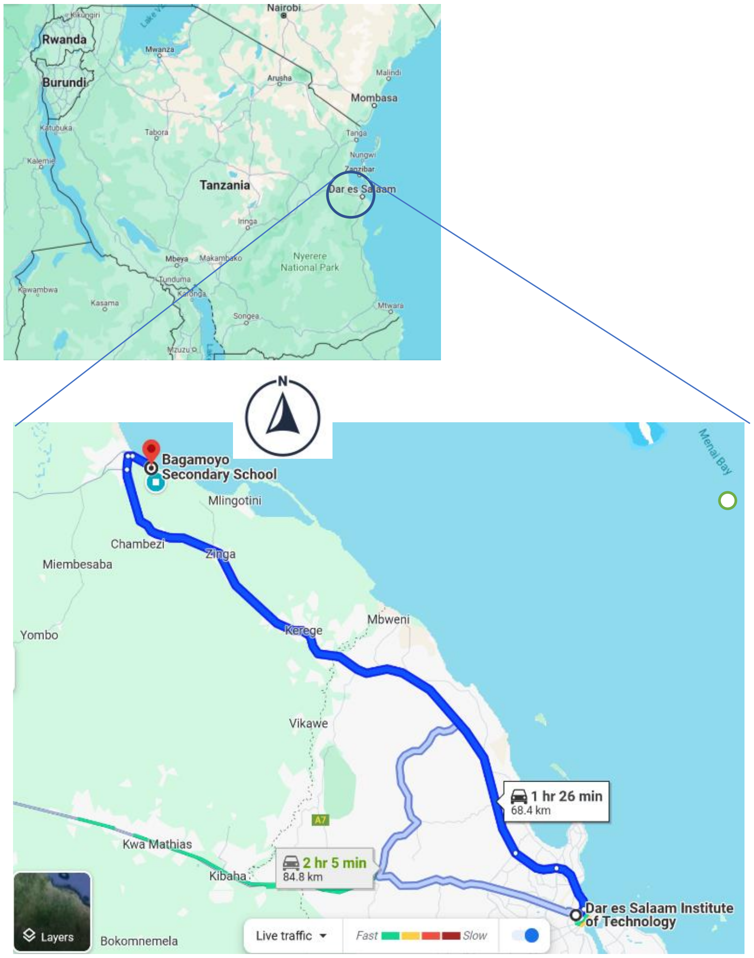
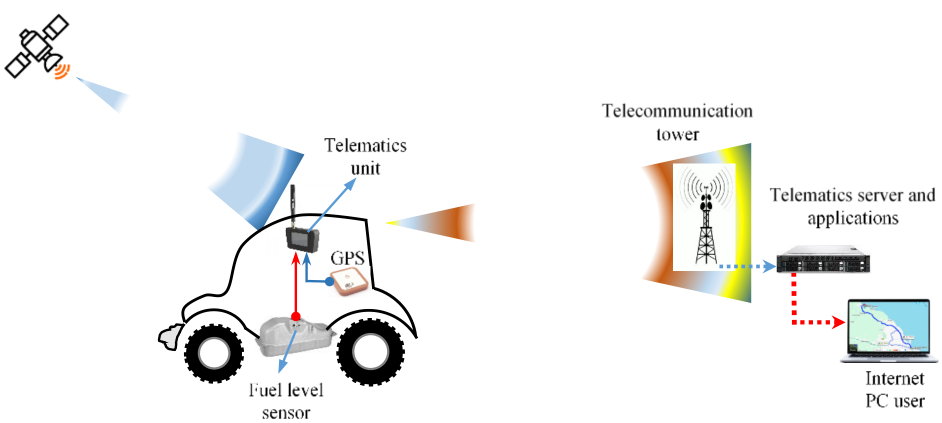
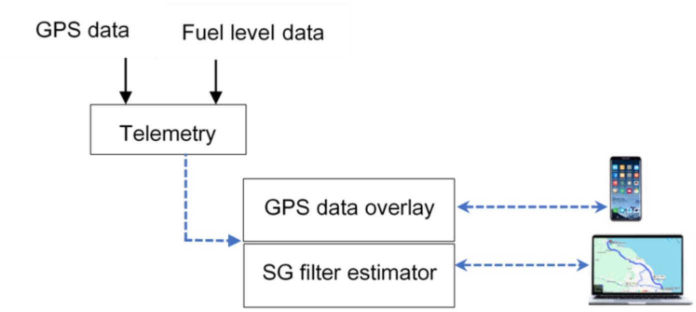


Figure 3: Route for the experiment



(a)



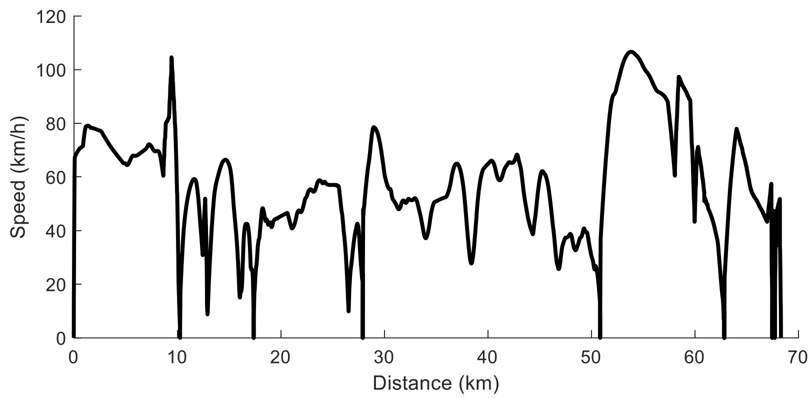
(b)

Figure 4: (a) the structure of the fuel estimator system (b) the block diagram of the system

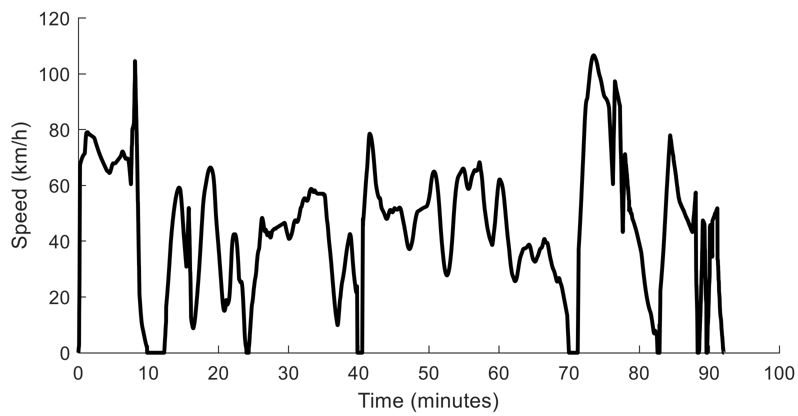
The fuel volume within the vehicle tank is recorded at the rate of 0.5 Hz and the NI ultrasonic sensor data were samples at the same frequency. The volumes of the fuel were calculated using the developed regression model of the conventional fuel level sensor. The telematics terminal records and processes the sensor data for further transmission using a local telecommunication operator through the gateway to the telematics server as depicted in Figure 4 (a) and the block diagram of the is as shown in Fig 4 (b). Server application (developed to accept data GPS and noisy fuel level data). The application overlays the GPS data on the Google map to show the location of the vehicle and applies the SG filter method to estimate the fuel level. The application processes and analyzes the received data to generate analytical reports for a selected period. More sophisticated systems may include other sensors such as an accelerometer and gyroscope to acquire other dynamic parameters of the vehicle. A filter is deployed to remove noises generated due to the sensor errors.

5 RESULTS AND DISCUSSION

The input fuel volume (L) and output voltage (V) mapped model for the conventional fuel level sensor was developed to obtain the fuel level. The observed fuel volume from the outside non-invasive tank fuel level ultrasonic sensor with high accuracy is compared with the proposed system along the route shown in Figure 3. The driving profiles are shown in Figure 5 and Figure 6.



(a)



(b)

Figure 5: Driving profiles (a) speed versus distance and (b) speed versus time

The speed of the vehicle along the route related to time and distance are depicted in Figure 5(a) and (b), respectively. Similarly, the time taken per distance is shown in Figure 6. It is also observed that the fuel levels recorded by both installed fuel level sensors have noise caused by vehicle movement and other mechanical disturbances. Therefore, the Kalman filter (KF) method and the SG filter technique are applied to remove the noise from the conventional fuel sensor. The standard deviation of the mean, margin of error, and signal-to-noise level are used to measure the noise level as shown in Table 3 with a given level of confidence. The fuel level data collected by the NI ultrasonic sensor and the conventional sensor is presented in Figure 7. Table 3 compares the fuel level data collected from both the NI ultrasonic sensor and the conventional sensor. The SNR estimate is computed as the ratio of the estimate of the variance of the signal to the variance of the noise. More details on SNR can be obtained in (Czanner et al., 2008).

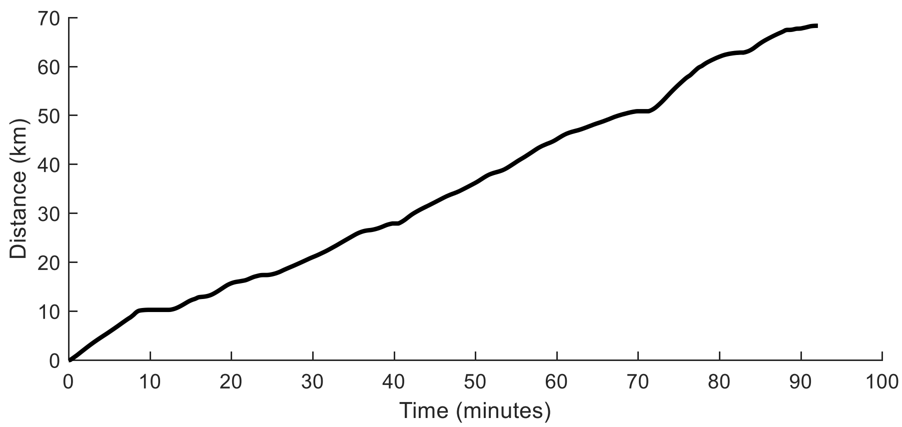


Figure 6: Driving profiles, distance versus time

Table 3: Comparison (95% confidence level C) of fuel level data from NI ultrasonic and conventional fuel level sensors

Signal measure	NI ultrasonic sensor	Conventional sensor
Standard deviation	0.1178	0.1191
Margin of error (95% Confident)	0.2308	0.2334
SNR (dB)	27.5888	27.3229

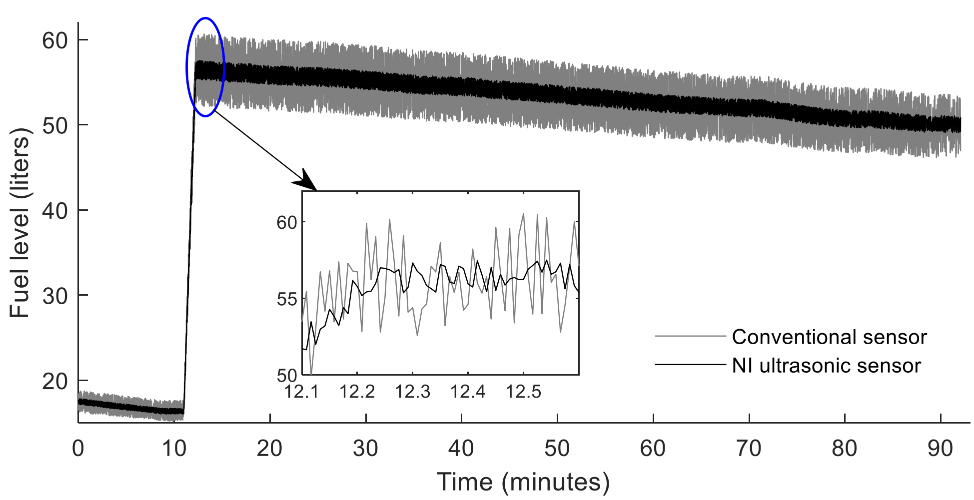


Figure 7: Fuel level data from NI ultrasonic sensor and conventional sensor

The noise is caused by vehicle movement and other mechanical disturbances. Therefore, the Kalman filter method and the SG filter technique are applied to remove the noise. Both SG filter and Kalman filter algorithm were implemented using Matlab® simulation software. The performance of the Kalman filter and SG filter estimators on the conventional fuel level sensor data are analyzed and shown in Table 4. It is observed that the SG filter's performance is better than the NI ultrasonic fuel level sensor shown in Table 3. Figure 8 shows the expected records from the Kalman and SG filters compared to the NI ultrasonic and conventional fuel level sensors. The performance of the SG filter estimator can be compared with the Kalman filter estimator during the fueling process as shown in Figure 9 where the SG filter performs well.

Table 4: The KF and SGFs algorithms performance (95% confidence level C) of fuel level data from the conventional fuel level sensor

Signal measure	Kalman filter	SG filter
Standard deviation	0.1179	0.1176
Margin of error (95% Confident)	0.2310	0.2305
SNR (dB)	27.4912	27.6157

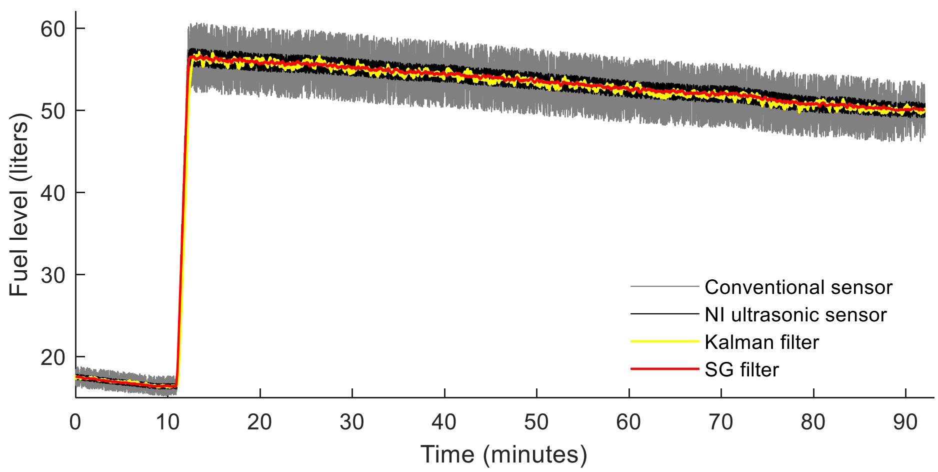


Figure 8: Fuel estimation performance of conventional fuel level sensor, NI ultrasonic fuel level sensor, Kalman filter, and Savitzky–Golay filter

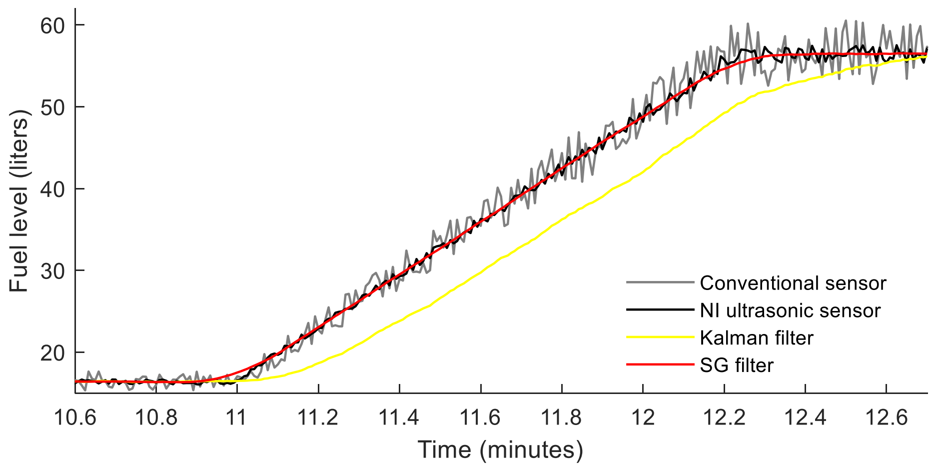


Figure 9: Performance of Kalman filter estimator and SG filter estimator during the fueling process

6 CONCLUSION

In this paper, fuel level data from the conventional sensor, noninvasive ultrasonic sensor, Kalman filter-based estimator, and SG filter-based estimator are quantitatively analyzed. The demonstration is done using the MATLAB® simulation tool. The performance of the SG filter-based estimator is compared to the other methods based on the standard deviation, margin of error, and SNR. A fuel measurement system based on the SG filter method can determine the fuel level in a vehicle fuel tank, even when the fuel is sloshing, or experiencing other dynamic conditions. The system based on SG filter estimation can address different fuel tank dynamic conditions including vehicle acceleration, maneuvering, and inclination. Results show that the SG filter-based estimator provides a more accurate track deviation from the smooth background of the given conventional data. The quality of the estimator evaluated using standard deviations for a normal distribution show that the number of standard deviations and the margin of error of the SG filter-based estimator proportional to the probability of getting an observation at least as far from the mean are the lowest. On the other hand, the SNR of the SG filter-based estimator is the highest among other methods. Hence the performance of the SG filter estimator is the best option compared to other methods used in this work.

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Author Contributions: The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

Availability of Data and Materials: All data generated or analyzed during this study are included in this published article.

Conflicts of Interest: The author declares that they have no conflicts of interest to report regarding the present study.

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Paper 13:

Pipeline Transportation: Unveiling Future Opportunities and Sustainability Challenges.

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ABSTRACT

This study examines the current state of pipeline transportation infrastructure in Tanzania, focusing on its role in facilitating national and regional logistics and supply chain management. Through a comprehensive analysis, the research identifies emerging opportunities within the sector that could enhance operational efficiency and contribute to the country's economic growth, particularly through significant projects like the East African Crude Oil Pipeline (EACOP) and the Tanzania Zambia Mafuta Pipeline (TAZAMA). Furthermore, the study investigates key sustainability challenges, including environmental impacts, social considerations, and regulatory factors that may hinder the effective implementation of these projects. Utilizing a mixed-methods approach that includes semi-structured interviews with stakeholders and a thorough document analysis, the findings reveal critical gaps in infrastructure, technological integration, and compliance with safety and environmental standards. The results suggest that while there are promising opportunities for development, addressing these sustainability challenges is essential for the long-term success of pipeline transportation in Tanzania. This study provides valuable insights and recommendations aimed at policymakers, industry stakeholders, and community representatives, fostering a more integrated and sustainable approach to pipeline infrastructure development in the region.

Keywords: Pipeline transportation, EACOP, TAZAMA, sustainability challenges, logistics, economic growth.

1. INTRODUCTION

Pipeline transportation plays a crucial role in the logistics infrastructure of resource-rich countries like Tanzania, where efficient movement of goods is essential for national and regional development. Projects such as the East African Crude Oil Pipeline (EACOP), the Tanzania Zambia Mafuta Pipeline (TAZAMA), and water pipelines for urban and agricultural needs are central to advancing Tanzania's logistics and supply chain management. These pipeline networks underscore the importance of integrating pipeline transportation into broader economic strategies. However, significant challenges persist, particularly in terms of sustainability, operational efficiency, and regulatory compliance, which limit the potential of these projects.

Despite ongoing efforts, the current literature does not sufficiently address the opportunities for enhancing operational efficiency or the sustainability challenges within Tanzania’s pipeline infrastructure. This paper seeks to bridge that gap by providing a comprehensive analysis of the state of pipeline transportation in Tanzania. The study will explore emerging opportunities that can improve operational efficiency and contribute to economic growth, while also identifying the sustainability challenges including environmental, social, and regulatory issues—that need to be addressed. By doing so, the research offers insights into how Tanzania can optimize its pipeline systems for long-term success within the framework of sustainable logistics.

The article is structured as follows, the first section reviews the current state of pipeline infrastructure, supported by insights from Morash and Clinton (1997) and Wang et al. (2022). The methodology outlines the research design used to gather data on pipeline operations, followed by a discussion of emerging opportunities and sustainability challenges. This discussion draws on sources such as Closs and Bolumole (2015) and Msimangira and Tesha (2014). Finally, the paper offers strategic recommendations for improving pipeline infrastructure, informed by global best practices as highlighted by Adewole (2019) and Kunaka et al. (2016).

This paper specifically has the following Objectives.

To explore the current state of pipeline transportation infrastructure in Tanzania and its role in supporting national and regional logistics and supply chain management.

To identify emerging opportunities in pipeline transportation in Tanzania that can enhance operational efficiency and contribute to the country's economic growth within the framework of sustainable logistics.

To examine the key sustainability challenges facing pipeline transportation in Tanzania, including environmental impacts, social considerations, and regulatory factors.

2. LITERATURE REVIEW

Pipeline transportation plays a crucial role in logistics and supply chain management, especially in developing economies like Tanzania. The literature on pipeline transportation in Tanzania highlights both the infrastructure's potential and its associated challenges. According to Morash and Clinton (1997), transportation capabilities are integral to international supply chain management, with pipelines being one of the most efficient means of transporting goods, especially in the oil and gas sectors. The role of transportation in facilitating global logistics is further emphasized by Mangan and Lalwani (2016), who assert that efficient logistics infrastructure is key to maintaining a competitive edge in global supply chains. However, despite its importance, Tanzania's pipeline infrastructure faces numerous challenges that hinder its full potential.

2.1 Theoretical Literature Review

The theoretical literature review explores key frameworks and concepts relevant to understanding pipeline transportation and its impacts. By analyzing established theories, this section provides insights into the interplay between infrastructure, operational efficiency, sustainability challenges, and economic implications. These theoretical perspectives form the foundation for examining pipeline projects like EACOP, TAZAMA, and others, within the context of sustainability and logistics development in Tanzania.

In this study researcher adopted a Sustainability Theory established by John Elkington (1994) introduced the Triple Bottom Line (TBL) framework, which emphasizes the integration of economic, environmental, and social dimensions in decision-making processes. This theory highlights the importance of balancing these three aspects to achieve sustainability. In pipeline transportation, the TBL framework is adopted to address critical challenges such as environmental risks, including oil spills, social displacement of communities, and compliance with regulatory frameworks. For example, projects like the EACOP must incorporate environmental protections, equitable social measures, and economic viability during their planning and execution phases to ensure long-term success.

2.2 Empirical Literature Review

Pipeline transportation is essential for Tanzania's logistics and supply chain management, particularly in the oil, gas, and water sectors. Key infrastructure includes the **Tanzania Zambia** Mafuta (TAZAMA) pipeline and the East African Crude Oil Pipeline (EACOP), which are critical for reducing transportation costs and supporting regional trade.

Despite its potential, Tanzania faces significant challenges in expanding and maintaining pipeline infrastructure. Issues such as underinvestment, inadequate maintenance, and limited coordination between public and private sectors hinder efficiency. Researchers like Msimangira and Tesha (2014) and Kunaka et al. (2016) emphasize the need for substantial investments to modernize infrastructure and align regulatory frameworks with international standards.

Opportunities exist in leveraging strategic partnerships, innovative financing models, and technological advancements to improve pipeline transport capacity. Projects like EACOP offer potential for economic growth, enhanced supply chain reliability, and regional integration. However, challenges such as political, economic, and environmental factors, alongside insufficient maintenance, must be addressed for long-term success.

In conclusion, while pipeline infrastructure in Tanzania plays a pivotal role in logistics, significant efforts are required to overcome existing challenges. Prioritizing investments, sustainability, and collaboration with stakeholders can help optimize pipeline networks and strengthen Tanzania's role as a regional logistics hub.

The development of pipeline transportation infrastructure in Tanzania presents numerous emerging opportunities that can significantly enhance operational efficiency and contribute to the country's economic growth, particularly within the framework of sustainable logistics. As Tanzania seeks to optimize its natural resource transport, particularly oil, gas, and water, the country has the potential to leverage these pipelines for greater integration into the regional and global economy.

The East African Crude Oil Pipeline (EACOP) and the Tanzania Zambia Mafuta (TAZAMA) pipeline are key examples of such infrastructure, representing not only a critical element of Tanzania's logistical network but also an opportunity for economic expansion and regional integration. According to Straube (2024), the future of logistics networks in sub-Saharan Africa lies in the strategic use of infrastructure like pipelines to reduce transport costs and increase efficiency in the movement of goods. Pipelines offer a more sustainable and cost-effective alternative to road or rail transportation, particularly for bulk resources like oil and gas, thus providing an opportunity for Tanzania to enhance its operational efficiency.

A major opportunity for Tanzania lies in the utilization of natural gas resources, as highlighted by Demierre et al. (2015), who discuss the potential for regional use of East Africa's natural gas. Tanzania is one of the leading countries in East Africa with substantial natural gas reserves. The pipeline infrastructure offers an efficient method to transport these resources not only for export but also for domestic energy development. The strategic use of pipelines could help Tanzania meet its energy needs more sustainably while generating revenue from exports, especially through the EACOP project, which is expected to facilitate oil exports via Uganda to international markets.

However, as Deus (2024) points out, the Tanzanian government has prioritized natural gas exportation over domestic energy development, raising questions about whether these opportunities are being fully exploited for local economic growth. By enhancing operational efficiency in pipeline transportation, Tanzania could balance the export of natural gas with the development of domestic energy infrastructure, thus ensuring that both local and regional needs are met in a sustainable manner.

Tanzania's pipeline infrastructure offers significant opportunities to reduce costs, streamline logistics, and boost regional and global trade by enhancing oil and gas transport efficiency (Adewole, 2019). Improved pipeline networks can create jobs, attract investments, and drive economic growth. The global energy transition further amplifies this potential, as natural gas serves as a cleaner alternative to coal and oil, positioning Tanzania to benefit if its pipeline networks are modernized (Nalule et al., 2022).

Incorporating pipelines into East Africa's development corridor strategies could facilitate trade and regional integration, increasing market opportunities (Ong'anya, 2024). However, sustainable planning is vital to balance economic growth with environmental protection, requiring careful management of pipeline projects (Mpapalika & Mmari, 2023). To maximize these benefits, Tanzania must invest in efficient, sustainable pipeline systems and align projects with global trends in energy and logistics.

Tanzania's natural gas reserves present significant opportunities for economic growth and energy sustainability. Pipeline infrastructure, such as the East African Crude Oil Pipeline (EACOP) and others, facilitates resource distribution for both export and domestic use. However, the government's focus on exportation raises concerns about underutilizing these resources for local development (Deus, 2024). Enhancing pipeline efficiency could support regional trade, lower costs, and attract investment, benefiting both domestic and regional stakeholders (Adewole, 2019).

Key projects like the Mkuranga-Dar es Salaam Gas Pipeline and TPDC Residential Gas Supply Initiative aim to expand household access to natural gas in Dar es Salaam. Stakeholders include the Tanzania Petroleum Development Corporation (TPDC), Energy and Water Utilities Regulatory Authority (EWURA), private contractors (e.g., China Petroleum Pipeline Engineering Co. Ltd.), and residential consumers, while environmental advocacy groups ensure sustainability compliance. Strategic investments and stakeholder collaboration can optimize Tanzania's pipeline networks to meet local and global energy demands sustainably (Nalule et al., 2022; Mpapalika & Mmari, 2023).

Pipeline transportation in Tanzania, including projects like EACOP and TAZAMA, is vital for economic development but faces significant sustainability challenges. Environmental impacts, such as oil spills, habitat disruption, and carbon emissions, are major concerns, particularly as pipelines traverse sensitive ecosystems (Bhattacharyay, 2012). Stronger environmental regulations and enforcement are essential to mitigate these risks (TEITI, 2024).

Social considerations, including displacement of communities and gender inequities, also pose challenges. Ensuring community consultation, fair compensation, and gender-sensitive policies is crucial for fostering social inclusion (Choumert-Nkolo, 2018; Busingye, 2019). Regulatory weaknesses, such as inadequate oversight and political instability, further undermine project sustainability and public trust (Eickhoff, 2023; Rognerud, 2012).

Achieving a Social License to Operate (SLO) through stakeholder engagement and sustainable practices is critical for project success (Karanja & Njenga, 2021). Balancing economic growth with environmental stewardship and social inclusion is key to ensuring pipeline projects contribute to long-term development. Addressing these challenges will require robust regulatory reforms, inclusive social policies, and adherence to international sustainability standards.

In conclusion, the literature on pipeline transportation highlights both opportunities and challenges for Tanzania. While projects like EACOP and TAZAMA present significant potential for enhancing logistics efficiency and contributing to economic growth, the sustainability challenges particularly in terms of environmental impact and regulatory compliance must be addressed to ensure long-term viability. By examining these factors, this study aims to contribute to the broader discourse on pipeline transportation in Tanzania, offering insights into how the country can optimize its pipeline infrastructure for sustainable logistics. Future research should focus on addressing the identified knowledge gaps, particularly in relation to the integration of sustainable practices in pipeline operations and the development of more robust regulatory frameworks.

3. METHODOLOGY

This section outlines the research methods employed in the study, Pipeline Transportation Unveiling Future Opportunities and Sustainability Challenges through Projects like EACOP, TAZAMA. The methodology is designed to ensure a comprehensive and systematic exploration of the objectives. The components include the study area, research design, research approach, targeted population, sample size, sampling techniques, data collection methods, data analysis, and ethical considerations, each of which is justified below.

3.1 Study Area

The study focuses on regions in Tanzania directly impacted by major pipeline projects, such as the East African Crude Oil Pipeline (EACOP), the Tanzania Zambia Mafuta Pipeline (TAZAMA). The EACOP impacts the Kagera, Geita, Shinyanga, Tabora, Singida, Manyara, and Tanga regions, while the TAZAMA pipeline affects the Dar es Salaam, Pwani, Morogoro, and Mbeya regions, all selected for their strategic roles in logistics and the associated environmental and social impacts. These regions were selected due to their significant role in national and regional logistics, as well as the environmental and social impacts of pipeline infrastructure in those areas.

3.2 Research Design

A case study research design was utilized to conduct an in-depth exploration of pipeline transportation infrastructure in Tanzania, focusing on projects like the East African Crude Oil Pipeline (EACOP) and the Tanzania Zambia Mafuta Pipeline (TAZAMA). This design was chosen as it provides a detailed investigation into the current state of these pipeline projects, emerging opportunities for enhancing operational efficiency, and the sustainability challenges they face. This approach is particularly suited to this study as it allows for a comprehensive analysis of how these pipelines support national and regional logistics and supply chain management, contribute to Tanzania's economic growth, and address critical environmental, social, and regulatory factors.

3.3 Research Approach

This study employs a qualitative research approach to gather comprehensive and detailed data on pipeline transportation in Tanzania, specifically focusing on projects such as the East African Crude Oil Pipeline (EACOP) and the Tanzania Zambia Mafuta Pipeline (TAZAMA). This approach facilitates an in-depth understanding of the perspectives of various stakeholders involved in these pipeline projects, aligning with the study's objectives of exploring the current state of infrastructure, identifying opportunities for operational efficiency, and examining the sustainability challenges, including environmental, social, and regulatory issues. By adopting a qualitative approach, the study aims to uncover valuable insights into how these pipelines support national and regional logistics and contribute to Tanzania's economic growth within a sustainable framework.

3.4 Targeted Population, Sample size and Sampling Techniques

The targeted population for this study includes individuals and organizations directly involved in pipeline transportation in Tanzania. These participants encompass a broad range of stakeholders, such as logistics managers from companies engaged in major pipeline projects like EACOP and TAZAMA, environmentalists, and community representatives from regions impacted by these pipelines. Given the focus on capturing specialized insights regarding logistics operations, sustainability challenges, and community impacts, a purposive sampling technique was employed to select participants based on their expertise and relevance to the research objectives.

A total of 25 participants were selected, representing key stakeholders including private sector logistics managers, environmental advocacy groups, and local community leaders. This sampling method allowed the study to focus on individuals with significant experience and knowledge related to pipeline transportation, ensuring that the data collected would be both comprehensive and relevant to the research questions.

Table: 1.0 Population Sample Size

Stakeholder Group	Number of Participants
Logistics Managers (Private Sector)	5
Environmental Advocacy Representative	8
Community Representatives (Affected Regions)	12
Total	25

This table illustrates the distribution of participants, ensuring a balanced representation of perspectives from different sectors directly involved or affected by pipeline transportation projects in Tanzania.

3.5 Data Collection Methods

The data collection methods employed in this study were designed to ensure a comprehensive understanding of pipeline transportation in Tanzania, particularly concerning the East African Crude Oil Pipeline (EACOP) and the Tanzania Zambia Mafuta Pipeline (TAZAMA). To capture rich and nuanced insights, a combination of documentary review and semi-structured interviews was utilized.

3.6 Document Analysis

The study adopted a content-based analysis approach combined with interviews to review relevant literature, policy documents, and reports on pipeline projects in Tanzania. Key sources included the Tanzania Extractive Industries Transparency Initiative (TEITI) reports, environmental assessments, and national accounts statistics, notably *"NATIONAL ACCOUNTS STATISTICS: Sources and Methods.* The *Social Report 2024* and interviews with stakeholders provided insights into social implications, community impacts, and engagement strategies. Additionally, the *Tanzania - Transport Sector Review, 2023* detailed transport integration, socio-economic benefits, and sustainability challenges. Findings from interviews enriched the analysis, offering nuanced perspectives on regulatory, logistical, and human rights dynamics. This approach provided a comprehensive understanding of pipeline transportation and its role in national economic development.

3.7 Ethical Considerations

Ethical principles were strictly adhered to throughout the research process. Participants were informed about the study's objectives, and their consent was obtained before participation. Confidentiality and anonymity were ensured, with participants' identities and responses being protected. Moreover, the study ensured that no harm would come to participants as a result of their involvement, particularly in discussions regarding sensitive topics such as environmental and social impacts of pipeline projects.

4. FINDINGS

This part highlights the findings on Tanzania's pipeline transportation, focusing on infrastructure assessment, emerging opportunities for operational efficiency and economic growth, and sustainability challenges such as environmental, social, and regulatory issues. Using document analysis and stakeholder interviews, it reveals the sector's strengths, limitations, and potential for innovation. The analysis addresses the research objectives, offering insights for future development.

4.1 Finding on the Current State of Pipeline Transportation Infrastructure in Tanzania

The data analysis indicates that pipeline transportation plays a crucial role in supporting both national and regional logistics and supply chain management in Tanzania. Major projects such as EACOP and TAZAMA contribute significantly to the movement of oil and gas, while water pipelines serve critical urban and agricultural needs. However, several infrastructure gaps remain, particularly in terms of maintenance and capacity expansion. These gaps hinder the optimal performance of the existing pipeline network, leading to inefficiencies in logistics operations and limiting the sector's potential in fully supporting Tanzania's economic growth.

As the study aimed to explore the current state of pipeline transportation infrastructure in Tanzania and its role in supporting national and regional logistics and supply chain management. A total of 25 participants were interviewed, comprising 5 logistics managers from the private sector, 8 environmental advocacy representatives, and 12 community representatives from affected regions. This diverse range of stakeholders provided valuable insights into various aspects of pipeline infrastructure.

The aging infrastructure of pipelines, particularly TAZAMA, poses significant risks, with urgent repairs needed to prevent leaks and ruptures. Participants emphasized the importance of modernizing outdated systems to avoid operational failures with environmental and social repercussions. Proactive measures for new projects like EACOP were also highlighted, ensuring adherence to high standards from the outset. These insights underline the critical need for maintenance and modernization to enhance safety and sustainability.

Maintenance practices for Tanzania's pipeline infrastructure face critical challenges, including infrequent overhauls and limited visibility of maintenance crews, which diminish public confidence in pipeline safety. The primary obstacle is inadequate funding, as maintenance budgets are often the first to be cut during economic downturns. This highlights the need for consistent financial support to ensure operational reliability.

Capacity issues also emerged, with TAZAMA operating at 70% capacity and demands increasing as EACOP comes online. While EACOP is expected to expand transport capacity and modernize infrastructure, concerns remain about whether these benefits will extend to local communities. Equitable development and local inclusion are key priorities for stakeholders.

Geographical coverage of the pipeline network is extensive but uneven, leaving resource-rich rural areas underserved. These gaps limit economic growth in regions with significant resource potential. EACOP's strategic connections to major markets offer opportunities for enhanced logistics and regional trade. However, stakeholders stress the importance of ensuring local benefits and addressing environmental concerns to build public trust and ensure sustainable development. Improved regional connectivity and cross-border integration are also needed to optimize trade and economic growth.

Technological Integration**,** the use of modern technology in pipeline infrastructure was another focus area. A logistics manager noted, "*Most pipelines are lacking in modern technology; we still rely on outdated monitoring systems.*" This observation reflects a critical weakness in current pipeline management. There are plans for advanced technologies with EACOP, as one logistics manager pointed out, "*With EACOP, there are plans for advanced monitoring technologies, but implementation is key.*" This anticipation suggests that EACOP could set a new standard for technological integration in the industry.

Environmental advocates emphasized that "*currently, AI-powered tools are not widely adopted. EACOP offers a chance to implement these systems effectively*". This potential for technological advancement is seen as a positive development, but stakeholders emphasize the need for effective implementation to realize these benefits.

A community representative stressed, "*Without proper monitoring, we cannot ensure safety. The technology used needs to be reliable*." This highlights the critical role of technology in ensuring operational safety and efficiency.

The flow rates were also a concern, with one logistics manager stating, "*We experience inconsistent flow rates on TAZAMA, often leading to delays*." These interruptions can severely impact local economies reliant on timely resource delivery. In terms of cost-effectiveness, a logistics manager remarked, "*Operating costs are too high for TAZAMA. We need to find ways to cut costs without sacrificing safety".* This acknowledgment of cost issues underscores the financial challenges facing pipeline operations. The interviews reveal that operational inefficiencies are a significant challenge in the current pipeline system, primarily due to maintenance backlogs. The anticipated introduction of EACOP is seen as a crucial step toward enhancing operational efficiency, but stakeholders acknowledge the need to address existing cost issues.

Pipelines play a vital role in facilitating trade, but challenges such as inadequate integration with other transport modes and insufficient investment hinder their efficiency. EACOP presents an opportunity to address these gaps. Participants highlighted the lack of funding for pipeline maintenance, particularly for TAZAMA, and inadequate resources for environmental protections. Dependence on foreign investment further complicates financial sustainability. While recent improvements in government policies were noted, bureaucratic delays continue to hinder project progress, underscoring the need for streamlined regulations to support sustainable development and growth in the sector.

The data collected from the semi-structured interviews reveals that while there are substantial advantages anticipated from the EACOP project, significant challenges remain with the current pipeline infrastructure in Tanzania. Stakeholders expressed optimism about EACOP's potential to enhance operational efficiency, regional connectivity, and economic growth. However, concerns regarding maintenance, capacity, technological integration, and compliance with safety and environmental standards must be addressed to maximize the benefits of both EACOP and existing pipelines like TAZAMA. Ultimately, effective implementation, community engagement, and investment in technology and infrastructure will be essential for the success of pipeline transportation in Tanzania.

The document analysis for the study revealed key insights into Tanzania's pipeline infrastructure and its role in logistics and supply chain management. The analysis highlighted the economic contributions of projects like TAZAMA and EACOP through royalties and taxes, but stressed the need for better fund management. Social concerns, including land acquisition and community displacement, were raised, with calls for improved stakeholder engagement and compensation practices. Logistical challenges, such as gaps in pipeline integration with other transport modes and aging infrastructure, were emphasized, along with the need for modernization. Human rights and environmental risks, including displacement and ecosystem disruption, were noted, requiring stronger regulatory oversight. The EACOP project presents significant economic opportunities, but environmental sustainability and equitable community benefits must be prioritized. Overall, while the pipeline network is critical to Tanzania's economic growth, the analysis identified areas for improvement in infrastructure, sustainability, and stakeholder engagement.

4.2 Finding on the Emerging Opportunities in Pipeline Transportation

The data gathered through semi-structured interviews revealed several emerging opportunities within Tanzania's pipeline transportation sector that could significantly enhance operational efficiency and contribute to national economic growth, particularly in alignment with sustainable logistics practices.

Technological Advancements, Participants identified the introduction of modern technology as a critical opportunity for improving the operational efficiency of pipeline transportation. A logistics manager stated, *"With EACOP, we are looking at advanced monitoring technologies, including real-time surveillance and AI-based systems. These will significantly reduce human errors and enhance operational efficiency."* This highlights the potential for automation and digital tools in streamlining operations and ensuring safe, efficient transport of resources.

An environmental advocate noted that "current pipelines lack technological integration, but EACOP offers the chance to implement cutting-edge technology that can improve both efficiency and environmental protection." This demonstrates that technology not only offers operational benefits but also addresses environmental concerns by reducing the likelihood of incidents such as leaks or spills.

Expansion of Pipeline Network and Capacity, another emerging opportunity discussed was the expansion of the pipeline network to underserved regions and increasing the capacity of existing pipelines. A logistics manager commented, *"TAZAMA is currently operating below capacity, and with upgrades, we can transport larger volumes more efficiently. EACOP will also help by introducing a new route with higher capacity, which is crucial for both domestic and export purposes."* This indicates that capacity expansion can directly contribute to boosting Tanzania's energy exports, thereby driving economic growth.

A community representative added, "EACOP will connect new regions that were previously cut off from such infrastructure. This will not only improve resource transport but also open up those areas for more economic activities." This suggests that expanding the pipeline network could lead to broader regional development by facilitating access to resources and improving infrastructure.

Regional Integration and Cross-Border Trade**,** Participants also saw an opportunity for strengthening regional integration through pipeline transportation. A logistics manager explained, *“EACOP creates a direct link between Uganda and Tanzania, which strengthens regional trade. This will streamline the movement of crude oil and reduce dependency on more expensive transport modes like trucking.”* This demonstrates the pipeline's potential to enhance cross-border trade efficiency by reducing costs and transit times, which are crucial for regional economic integration.

Additionally, an environmental advocate highlighted the importance of planning for future regional integration: “By establishing pipelines that can connect to neighboring countries, we can position Tanzania as a key energy hub in East Africa, boosting economic growth and fostering regional cooperation.” This emphasizes the strategic value of pipeline infrastructure in promoting Tanzania's role in regional energy markets.

Public-Private Partnerships and Investment Opportunities**,** the participants also discussed the potential for increased public-private partnerships (PPPs) and foreign investments in pipeline infrastructure. A logistics manager shared, *“EACOP has attracted significant foreign direct investment (FDI), and this is an opportunity we should leverage to improve other parts of the pipeline network.”* This shows that FDI can be a catalyst for modernizing infrastructure and ensuring efficient operation.

A community representative echoed this sentiment: “The government needs to create more favorable conditions for investment, which can help us address some of the logistical and environmental challenges we currently face.” This implies that fostering an investor-friendly environment will be crucial in unlocking the full potential of pipeline projects.

Sustainable Logistics Practices, Sustainability was a key theme, with participants identifying opportunities to integrate greener practices in pipeline operations. An environmental advocate noted, *“There’s a growing focus on minimizing the environmental footprint of pipeline projects. EACOP, for instance, includes provisions for habitat restoration and pollution control, which can set a new standard for future projects.”* This underscores the importance of adopting environmentally conscious practices as part of sustainable logistics, which can enhance the long-term viability of pipeline infrastructure.

A logistics manager also added, “By aligning our pipeline projects with global sustainability standards, we can not only attract more investment but also ensure that the benefits of these projects are long-lasting and not harmful to the environment.” This illustrates the link between sustainable practices and economic growth, as adherence to environmental standards attracts investors who are increasingly prioritizing sustainability.

Emerging opportunities in Tanzania's pipeline sector include integrating advanced technologies like AI for enhanced efficiency and safety, expanding networks to meet energy demands, and fostering regional trade through EACOP. Foreign investments and public-private partnerships provide avenues for modernization and job creation. Sustainable logistics practices align with global standards, promoting environmental sustainability and community engagement. These developments collectively drive economic growth and operational improvements.

Finding on the Sustainability Challenges Facing Pipeline Transportation

The semi-structured interviews with logistics managers, environmental advocates, and community representatives revealed a number of sustainability challenges associated with pipeline transportation in Tanzania. These challenges are primarily linked to environmental impacts, social considerations, and the regulatory framework that governs pipeline projects such as EACOP and TAZAMA.

Environmental Impacts**,** Participants consistently raised concerns about the environmental risks associated with pipeline transportation, especially in relation to potential oil spills, soil degradation, and the disruption of ecosystems. An environmental advocate mentioned, *“We’re particularly worried about oil spills, which could severely damage water sources and the surrounding biodiversity.”* This sentiment was echoed by a community representative who stated, *“In our region, we depend on agriculture, and we fear that any pipeline incident could contaminate the soil, which would affect our livelihoods.”*

Additionally, participants highlighted the lack of sufficient measures to prevent or mitigate environmental degradation. As noted by a logistics manager, *“The pipelines, especially the older ones, lack modern monitoring systems to quickly detect and respond to environmental hazards.”* Environmental sustainability is a critical challenge facing pipeline transportation in Tanzania. The risk of oil spills, contamination of water sources, and disruption of ecosystems poses significant threats, particularly for regions reliant on agriculture. The lack of adequate monitoring and response systems exacerbates these risks, highlighting the need for better environmental safeguards, particularly in projects like EACOP that traverse ecologically sensitive areas.

Social Considerations, another prominent theme that emerged was the social impact of pipeline projects on local communities, particularly with regard to land acquisition and displacement. A community representative remarked, *“Many people are being displaced from their land to make way for the pipelines, and the compensation they’re receiving* *isn't enough to rebuild their lives."* Another participant echoed this concern, noting, *"The compensation process lacks transparency, and many of us feel like we weren't adequately consulted before the projects began."*

Participants also mentioned the long-term social impacts, particularly the disruption to traditional livelihoods. As an environmental advocate stated, *"Some communities are losing farmland, which is their primary source of income. These projects need to account for long-term social welfare, not just immediate compensation."*

Social sustainability challenges in Tanzania's pipeline transportation are primarily related to displacement, inadequate compensation, and the lack of community engagement. While pipeline projects promise economic benefits, they often overlook the long-term welfare of affected populations. Addressing these social concerns will require greater transparency in compensation processes and a stronger commitment to community consultation and involvement.

Regulatory Challenges**,** Participants identified weaknesses in the regulatory framework governing pipeline transportation in Tanzania, which often results in poor enforcement of environmental and social protections. A logistics manager noted, *"The current regulations are there, but enforcement is inconsistent. This creates loopholes that companies can exploit to cut corners on safety and environmental standards."* Similarly, an environmental advocate commented, *"The government needs to strengthen the regulatory framework to ensure that these projects comply with international standards. Right now, there are too many gaps."*

Another challenge highlighted was the bureaucratic delays in securing necessary permits and approvals. A participant from the private sector remarked, *"The process to obtain permits is slow, which affects the timeline of our projects. But once we get the permit, there's minimal follow-up on compliance."*

Regulatory challenges are undermining the sustainability of pipeline transportation in Tanzania. The weak enforcement of environmental and social standards allows for exploitation, particularly by companies aiming to reduce costs. Additionally, the inefficiencies in the permitting process create delays and contribute to a lack of accountability once projects are underway. Strengthening the regulatory framework and improving enforcement are crucial for ensuring the sustainability of future pipeline projects.

A comprehensive review of various reports and policy documents revealed key sustainability challenges in Tanzania's pipeline transportation sector. Environmental concerns, such as the risk of oil spills, water pollution, and soil degradation, were prominent in the 2023 Human Rights Report and the report of the East African Crude Oil Pipeline (EACOP) in the year of 2019 related infrastructure. These challenges are exacerbated by the lack of modern leak detection systems in older pipelines like TAZAMA. Social issues, highlighted in the Social Report 2024 and 2023 Human Rights Report, include inadequate compensation for land acquisition and insufficient community engagement, leading to discontent and mistrust among affected populations. Regulatory challenges were also noted, with weak enforcement of environmental and social laws, as well as bureaucratic delays in project approvals, undermining the effectiveness of Tanzania's pipeline regulations. Strengthening enforcement mechanisms, improving community involvement, and adopting modern environmental safeguards are critical for ensuring the sustainability of pipeline operations in Tanzania.

The regulatory framework for pipeline transportation in Tanzania faces significant enforcement challenges. While regulations exist, the failure to enforce them consistently undermines their effectiveness. Additionally, bureaucratic inefficiencies slow down pipeline project approvals, leading to delays and creating loopholes that may be exploited. Strengthening enforcement mechanisms and streamlining the regulatory process are crucial for improving compliance and ensuring the sustainability of pipeline operations.

5. DISCUSSIONS

The study examined Tanzania's pipeline transportation infrastructure, highlighting its current state, emerging opportunities, and sustainability challenges. Findings revealed that while aging infrastructure like the TAZAMA pipeline faces maintenance and operational challenges, new projects like EACOP offer opportunities for modernization with advanced technologies. Technological innovations, such as real-time monitoring and AI-powered tools, along with integration of transport modes, can enhance efficiency and economic growth. However, sustainability challenges, including environmental risks, inadequate community compensation, and weak regulatory enforcement, threaten long-term viability. Addressing these issues through modernization, robust regulations, and community engagement is essential for fostering operational efficiency, sustainability, and regional connectivity. Tanzania’s pipeline sector has significant potential for driving economic development if these priorities are met.

6. CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

In conclusion, this study highlights the essential role of pipeline transportation in Tanzania's logistics and supply chain management, while identifying significant opportunities for operational efficiency and economic growth. However, sustainability challenges, including environmental concerns and regulatory factors, must be addressed to fully realize the benefits of pipeline transportation. Limitations of the study include the potential for bias in stakeholder responses and the focus on specific projects, which may not represent the entire landscape of pipeline transportation in Tanzania.

7. Recommendations

The study offers several key recommendations to enhance the effectiveness and sustainability of pipeline transportation in Tanzania. These include urgently modernizing aging infrastructures, particularly the TAZAMA pipeline, and leveraging the EACOP project to implement advanced technologies. It emphasizes the adoption of modern technologies, such as real-time monitoring and AI tools, along with training programs for local workers to ensure they can operate and maintain these systems effectively. Improved intermodal connectivity with other transport modes is recommended to facilitate seamless movement of goods, while community engagement initiatives should prioritize stakeholder involvement and fair compensation for affected populations. Strengthening regulatory frameworks to enhance the enforcement of environmental and safety standards, developing comprehensive environmental management plans, and focusing on sustainability initiatives, including ecological preservation and regional cooperation, are also crucial. Finally, establishing a monitoring and evaluation framework will help continuously assess the impacts of pipeline projects on local communities and the environment, ensuring accountability and transparency in operations.

Future research should explore the long-term impacts of pipeline projects on local communities and the environment. Additionally, stakeholders are encouraged to collaborate on developing comprehensive regulatory frameworks that address sustainability challenges. Investments in technology and infrastructure improvements are recommended to enhance operational efficiency within Tanzania's pipeline transportation sector.

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Paper 14:

Analysis of Logistics Performance in Developing Countries, The Case of Tanzania

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ABSTRACT

Logistics is becoming a major issue and an increasingly important part in the realization of the socio-economic development of many cities in the world. Logistics performance in Tanzania is growing today onwards where ports are constructed to easily facilitate movements of freights from origin to destination through different modes of transport (road, maritime, rail, air and multimodal transport). The main objective of this study was on Analysis of Logistics Performance in developing countries, the case was Tanzania. The study used case study research design and the mix of both quantitative and qualitative approaches in data collection. Results from data collections were analyzed by using the descriptive analysis for SPSS version 22 for quantitative data and content analysis for qualitative data and then discussed in relation to reviewed empirical studies. Also, the study developed the sampling technique to review and understand the current situation of logistic performance in Tanzania, to investigate the problems because Tanzania is ranked downward than others by running a comparative analysis. The findings of the study indicated the port operations were organized before, but gradually, there have been many complaints regarding its performance in transit time, customs processes and infrastructures that facilitates the operations at Dar es Salaam Port and other logistics areas in the country. The study recommends provision of adequate modern instruments in maritime industry of which smoothly would easily reduce the burden of congestion at ports and increase easily movements of goods or freights from one place to another. The findings of the study indicated that Logistics performance in Tanzania as a developing country has to take measures on regulating the logistics performance in different stakeholders or authorities given mandate to operate and regulate so as to avoid downward of Tanzania in logistics industry.

Keywords: Logistics Performance, Ports, Freights, Logistics Industry, LPI

1 INTRODUCTION

Within the African Great Lakes region, in East Africa, is the United Republic of Tanzania. To the north, it shares a border with Uganda; to the northeast, with Kenya; to the east, with the Comoro Islands and the Indian Ocean; to the south, with Mozambique and Malawi; to the southwest, with Zambia; and to the west, with Rwanda, Burundi, and the Democratic Republic of the Congo. Northeastern Tanzania is home to Mount Kilimanjaro, Africa's highest summit (Wikipedia, 2022).

Dar es Salaam is a prominent regional maritime hub that competes with Mombasa in East Africa community. Dar es Salaam port, receives approximately 4.1 million tonnes of dry cargo and 6 million tonnes of bulk liquid cargo annually. Democratic Republic of the Congo, Malawi, Uganda, Burundi, Rwanda, and Zambia are the landlocked countries that Dar es Salaam port serve. The performance indicators of Dar es Salaam are comparable to those of other eastern and southern African ports. It has a short container dwell time, a quick truck turnaround time, and excellent crane productivity. As an outcome, the port is the most productive in Sub-Saharan Africa for container handling and is among the best for general logistics operations (PWC, 2022).

However, according to the European Union (EU), Dar es Salaam's shipping prices are among the highest in the world. Utilizing the port will cost you 24% more than that of other port equipment in Sub-Saharan Africa. The Dar es Salaam port is more expensive than others because it has substantial capacity limits caused by congestion strong traffic growth and insufficient backward links with inland transport networks. After Mombasa, it has the highest demand-to-capacity ratio in Africa. Dar es Salaam is also responsible for transshipments that Mombasa is unable to handle due to significant capacity limits and operational inefficiencies (PWC, 2022).

In 2018, high-income nations took up eight of the top ten spots, along with Japan and Singapore, two nations that have historically dominated the supply chain sector.

Germany is in first place with a 4.20 rating. The scores of the next nine nations are quite close together, with Finland coming in at number 10 with a score of 3.97 and Sweden coming in at number 2 with a score of 4.05. Tanzania rank is 67th with 2.88 mean LPI (World bank,2018).

According to the World Bank's report, high-income nations have historically dominated the supply chain sector holding the top 10 spots in the LPI rankings for a number of years. (AIRCARGO NEWS, 2018). Tanzania officially transitioned from a low-income country to a lower-middle- income country in July 2020, marking the culmination of two decades of consistent growth (World bank, 2022).

A study conducted by Franceschetti (2015) on the causes for running downward ranking of Tanzania in comparative analysis for the performance of cargo Transportation companies; the findings revealed that fleet management systems, Timeless of delivery, Poor infrastructures especially rural logistics services and financial capacity have greatest influence on distribution.

The logistic performance in developing countries is often poorly maintained and managed and brings insufficient to support advanced logistics performance and normal activities. Although some governments of these developing countries are aware of these shortcomings and tend to have insufficient capital expertise to make improvements. Indeed, few performances significant improvements in logistics performance in developing countries have witnessed over the past five years. Further it remains uncertain according to which business indicators for developed and developing economies have common significant differences (Yildiz, 2014).

Logistic performance is the most difficult responsibility in any developing country without stable key performance indicators; these indicators are constantly pushing or pulling to many directions, both internal and external. Sales, Accounting, Operations, Purchasing, Customers, Vendors and Carriers. These make the challenge even more complicated in logistic responsibilities, control costs and maximize services. Many developing countries do not actually understand the core value of logistics in increasing the economic stability (Li, 2014).

Therefore, the researcher has to review by analyzing the logistics performance in developing countries specifically in Tanzania. The analysis focused on availability of wide area of logistic operations such as ports, despite of having wide range of logistic operations but is underrated one among developing countries whose logistic performance is too low and is not convincing compared to other countries.

Tanzania's logistics performance has changed over time, in line with its efforts to upgrade its trade facilitation and infrastructure. Tanzania is an East African developing nation that is strategically located to act as a transit hub for numerous landlocked neighbors, including Zambia, Burundi, Uganda, and Rwanda. Infrastructure, the effectiveness of customs, and the caliber of logistics services all affect the nation's logistical performance. Tanzania still has a long way to go before reaching better levels of logistical performance, nevertheless, regardless of recent advances.

Tanzania received a score of 2.89, placing it 96th out of 160 nations in the World Bank's 2018 LPI assessment. Despite having a higher score than the average for low-income nations, Tanzania trails behind rivals in the region like South Africa and Kenya.

Therefore, the researcher had to review by analyzing the logistics performance in developing countries specifically in Tanzania. The analysis focused on availability of wide area of logistic operations such as ports, despite of having wide range of logistic operations but is underrated one among developing countries whose logistic performance is too low and is not convincing compared to other countries.

General objectives

The main aim of the study was to Analyse the Logistics Performance in developing countries, taking Tanzania as a case study. And had three Specific objectives which were; To review and understand the current situation of logistic performance in Tanzania, to investigate the problems because Tanzania is ranked downward than others by running a comparative analysis and to discuss the findings and evaluate them and finally recommend the solutions to be implemented in the case study area.

2 LITERATURE REVIEW

Since 2007, the LPI has been released by the World Bank every two years. The goal of the proposal is to list the logistical challenges and opportunities each country faces when engaging in international trade. Consequently, LPI aids in understanding the difficulties that nations, along with their trading partners, confront in improving the performance of their national logistics systems (World Bank, 2014). According to six characteristics or indexes customs, infrastructure, international shipping, logistics quality and competence, tracking and tracing, and timeliness the World Bank LPI summarises how well each country is performing (World Bank, 2007, 2010 in Faria et al., 2014).

The significance of effective logistics is now generally recognized by policymakers all around the world. Private entrepreneurs move trade and business both inside and beyond borders. The Logistics Performance Index (LPI) and its components measure the efficiency of certain supply chains, or logistics performance. This performance is highly dependent on the policy environment: regulation and development services, infrastructure provision, or trade facilitation through friendly border procedures all contribute significantly to logistics performance when measured by individual countries or regional economic groups (WTO, 2014).

Core Components of Logistics Performance

Table 1; *Core Components of Logistics Performance (World bank, 2014)*

Component	Description
Customs	The efficiency of customs and border management clearing
infrastructure	The quality of trade and transport infrastructure
Services	The competence and quality of logistics service
Timeliness	The frequency with which shipments reach the consignee within expected delivery times
Tracking and tracing	The ability to track and trace consignments
International shipments	The ease of arranging competitively priced shipments.

The global survey of the international freight forwarders and the major express carriers, which oversee transporting goods and enabling trade around the world, yielded the data used to build the Logistics Performance Index and its indicators. It depends on the expertise and knowledge of experts (Avis et al., 2007).

The World Bank created a benchmarking tool in 2007 that compares and measures the performance of 150 nations' logistics systems based on an index of six parameters. The index enables a nation to pinpoint the advantages and disadvantages of its logistical partners as well as its own, and to set goals for improvement. Countries that can successfully connect to the global logistics network have better access to the markets, which is crucial for economic development. An international survey of forwarders and express carriers served as the basis for the estimation of the index and its indicators (d'Alene, 2015).

A network of services known as logistics is used to facilitate the physical transportation of commodities, international trade, and domestic commerce. In addition to transportation, it also includes a variety of other tasks like warehousing, brokerage, express delivery, terminal operations, and information and data management (World Bank, 2018).

Understanding how these networks function is important since they generate more than US$4.3 trillion in worldwide revenue annually. Performance in logistics is crucial for economic development and competitiveness in each nation. Ineffective logistics increase operating costs and limit opportunities for domestic and international integration. For poor nations trying to compete in the global economy, the cost might be especially high (World Bank, 2018).

Since the first LPI report was released in 2007, the emphasis on policy has changed. At first, logistics policy tended to focus on easing trade restrictions and clearing congestion at the borders. Today, domestic and international logistics are becoming more and more entwined. Stakeholders and policymakers deal with a variety of policies. Growing issues include supply chain resilience to disturbance or disaster, skills and training resources, environmental, social, and economic sustainability, and spatial planning (physical or digital) (World bank,2018).

Research Gap

The Dar es Salaam port's congestion has been a serious pressing and difficult issue. Due to the dispersion of some shipping lines and clients, this issue has had negative consequences on port operations and performance, which has led to falling revenue collections. This outcome might reflect port operators' inadequate operational performance, where one contributing element is late departure from the port (Meersman et al. 2012). To increase ports' effectiveness, solution for numerous port information systems have been created during the past few decades (Mlimbila and Mbamba, 2018).

The paper examines the examination of the logistic performance index on port logistics performance at the Dar es Salaam port, which remains a major concern for numerous port players due to the difficulties and competitions of logistics performance in Tanzania.

The study intended to reveal the fact on logistic performance to developing countries, in Tanzania there is a big challenge in running the logistics operations as the key performance indicator so as to dedicate the full mandatory of logistics performance in developing countries especially Tanzania as the part and parcel of its economic development. Tanzania is ranked as downward among developing countries operating logistics that its operations are actually effectives and efficiency, this is a reason to review its logistics performance operations by making a comparison to other nations operating logistics too. Taking a case study in TPA, Logistics companies and other sources concerning logistics and transport operations.

3 MATERIALS AND METHODS

Research Design

The nature of this study is descriptive research design, descriptive survey design is a technique for gathering data concerned with explaining relationships amongst variables (Saunders, 2019). Therefore, this tactic was suitable for this study, as the researcher anticipated to gather in depth information through descriptions and is beneficial for identifying variables. The design was considered suitable since the chief interest was to explore the possible association and define on the logistics performance situations in developing countries.

Sampling

The data of this study has been obtained through online questionnaires, online interviews, and documentary review. The study deployed purposive sampling so as to meet valid data.

Data Collection

The study has used three methods for this part of which are questionnaires, interview, and documentary review to spot out the logistics performances in developing countries and the problems associating with comparative analysis.

Questionnaire

An appropriate technique in analyzing the research problem that a researcher adopted was to administer questionnaires. Well prepared online questionnaires were distributed to the respondents. The respondents who were required to answer those questionnaires were drawn at TRA, TPA and private logistics companies. The study used both Open-ended and closed -ended questions. Questions were asked to respondents pertaining to the logistics performances based on the components of logistics performances, including timeliness, infrastructures, and customs. Government Authorities used here were Tanzania Ports Authority and Tanzania Revenue Authority.

Interview

This study employed the online interview method because it allowed the researcher to probed and asked Asking follow-up questions will help you better grasp the interviewee's viewpoints, feelings, and experiences with the subject of your research.

Documentary Review

This is another method which was used for the purpose of collecting secondary data to supplement the primary data. The information collected by other researchers and may or may not be necessarily analyzed or published. The study consulted various documents which included reports by and or for the World Bank, WCO, Tanzania Revenue Authority, and the East African Community Customs Management Act of 2004 and Tanzania Port Authority annual reports. Additionally, consulted other studies and publications containing the relevant study information. For example files, circulars, journals, manuals, websites and pamphlets.

Data Analysis

The content analysis method was used to analyse the qualitative data obtained, and the results were then presented thematically in accordance with the study's goals. Identification of opinions, ideas, and perceptions for analysing logistic performance in Tanzania was made easier by the segmentation of data into themes.

The quantitative information gathered from the open-ended questions was categorized and coded before being placed into the version 22 of the SPSS programme for analysis to draw quantitative conclusions about the study's subjects. Additionally, frequencies, percentages, and mean were calculated using the descriptive analysis.

Presentation and Discussion of Research Findings

This section is devoted to data presentation and analysis that the study collected from the respondents of Customs, importers (Logistics Companies) and TPA. The response was found from targeted groups through online questionnaires, online interviews and different documents of the authority guided by the research problem, research objectives, and research questions.

Characteristics of Respondents

The respondents who were involved in the study were asked to provide information in terms of age, as well as gender. Therefore, the findings, analysis and discussion are presented in the context of these variables.

Respondent’s Age

It was very important to know the age of each respondent involved or participated in the study. Each respondent was asked to mention his/her age when filling in the questionnaires.

A total of 3 (17.6%) respondents were aged between 18 and 25 years and the results were accurately true. Respondents whose age were between 26 and 33 were 6(35.2%), respondents aged 34 to 41 were 4 (23.5%), 2 (11.7%) were aged between 42 to 49 years and 50 and above were 2 (11.7%) these respondents were from Logistics companies, TPA and TRA.

Respondents Sex

The respondents who participated in the study were Government Employees (TPA and TRA) and Private Companies Employees; the respondents were both male and female. There is a total of 17 respondents who participated in the study whereby 13(76%) respondents were male and 4(24%) respondents were female.

Level of Education of Respondents

10 (58%) of the respondents had obtained a degree as their level of education. However, 4 (25%) respondents obtained certificate, 2 (11%) respondents obtained Diploma and 1 (6%) respondent obtained master’s degree as a highest level of education. Thus it can be revealed that most officials were educated but serving most uneducated society. That can be one of the factors keeping the transfer of goods because some people in this industry are ineffective and unprofessional.

The current situation of logistic performance in Tanzania

The current situation of logistics performance in Tanzania was discussed between researcher and respondents, and the first question was intended to understand the logistics structure based on customs, infrastructures and timeliness.

Infrastructure

Mode of transport typically deal with in your work.

Based on infrastructures, the questionnaires were distributed to both genders, and the modes of transport discussed here were road, rail, air, and marine. 11 (42.3%) respondents incurred using road transport and commented that there is a good infrastructures and direct access from the point of origin to point of destination. 10 (38.4%) respondents preferred to use maritime mode during the movement of freight. 3(11.5%) respondents use rail mode of transport in their logistics services simply because it carries a huge tonnage. 2(7.6 %) respondents use Air as a mode of transport during transportation of freights.

***Table 2**; preferred mode of Transport*

Mode of Transport	Frequency	Percent
Road	11	42.3
Maritime	10	38.4
Rail	3	11.5
Air	2	7.6
Total	26	100.0

Source: (Own work, 2022).

Most Suitable Mode of Transport for Freight Transportation

The most suitable mode of transport in freight transport is Maritime as respondents data deployed into the table below. 8(47%) respondents incurred using Maritime transport and direct access from the point of origin to point of destination. 4(23.5%) respondents preferred to use road mode during the movement of freight. 3(17.6 %) respondents use rail mode of transport in their logistics services simply because it carries a huge tonnage. 1(5.8%) respondent use Air and Multimodal respectively as a mode(s) of transport during transportation of freights.

***Table 3**: Most suitable mode of transport for Freight Transportation*

Mode of Transport	Frequency	Percent
Road	4	23.5
Maritime	8	47
Rail	3	17.6
Air	1	5.8
Multimodal	1	5.8
Total	17	100.0

Source: (Own work, 2022).

Rate of Quality Transport Related Infrastructures

The questionnaires were distributed to both genders and the rate of quality transport related infrastructures were road, rail, air, marine and multimodal transport, rating were given to acknowledge the quality of transport basing on the modes of transport. The table below indicates the frequency on the quality transport according to mode of transport.

Table 4: *Rate of Quality transport related infrastructures*

Mode of Transport	Very Low	Low	Average	High	Very High
Road			12	2	2
Maritime		1	5	7	2
Rail		4	7	3	
Air		1	8	5	1
Multimodal	1		4		2

Source: (Own work, 2022).

Problems Facing Logistics Performances in Tanzania

Problems encountered during freight transportation from the point of origin to destination

Ports Congestion

The today world's logistics is growing, and a lot of freights are moved from different origins to different destinations compared to previous years when developing countries were not considering logistics performance as key of their economy and now days, implementation are done to consider logistics operation as rated in national economic contribution. Respondents that tackled problems facing logistics performance in Tanzania mentioned ports to be congested, so it's difficult to meet time delivery, the agents or transporters ends up paying demurrages and storages for delaying moving their freights or containers from ports.

Safety and security

The respondents stated that the communities and organisations conducting mapping activities should develop contingency plans to deal with the various types of security incidents that may occur, even though it is challenging to make specific recommendations for safety and security in logistics performance. It was also mentioned that team members should integrate all responses to such incidents to protect the rights and wellbeing of local community members and make sure that employees and volunteers are not put in danger. For operations, the creation of a security- conscious culture is the key to efficient safety and security management. Logistics performance requires high attention to enhance the flow of operations per international standards meeting the specific requirements as it stands with (ISO).

Policy Constraints

Policy is among the problems facing the logistics industry which hinders the operations and complicates the customs processes at ports, and other government systems organs that are mandated to fulfill customs and flow of logistics activities. The respondents recommended on the policies guiding logistics operations that are not friendly compared to other developing countries, and the government has to review its policies in order to smooth up the logistics industry to be of high quality.

“the policies in Tanzania are much complicated as we speak now and are making the organs that are mandated to look over or supervise the logistics companies and other stakeholders underperform and others to do not meet customer’s requirements, when you look on the policies guiding the logistics industry all seem to resemble do not provide the solutions of what to be done in case of emergencies and others slow down the logistics performance”.

Low level of Technology

Tanzania is implementing the use of technology so as to match with other ports or logistics facilities, but in reality, the level of technology in Tanzania is still very low compared to developed nations thus underrated in logistics performance. Even though numerous logistics sectors suffer from an increasing shortage of competent labour and specialized experts to operate the advancement of modern technology, there is an increased demand for technically trained manpower to operate the cranes and other specialized equipment to facilitate logistics performance to meet today's economic stability.

Respondent interviewed about level of technology said;

“it is difficult to state on technology level in developing countries but Tanzania is trying increase its logistics operations through technology to smooth the operations to meet timeliness, though we lack much on modern technological equipment’s that operates in ports and other areas of logistics operations, this is a big challenge in our country where most of laborers are unqualified, overworked and lack the necessary skills sets to ensure the process is efficient, as the results logistics companies confront significant workforce turnover, increasing training expenditures, and underperforming human resource departments”.

Financial Constraints

As part of the functions of operations management, logistics plays an important role in transporting the flow of goods in and out of the country. The companies need to facilitate the smooth flow of incoming raw materials (inbound) to the company with the aim to facilitate the operations. The proper inbound management will impact several aspects in the company, such as production schedules, distribution effectiveness, customer satisfaction and firm performance. Despite of the role of logistics facilitating the incoming flows, logistics is also facilitating the outcome delivery. The role of logistics is expected to provide a better improvement of the quality of logistics performance and the accuracy of the amount of import and export from different companies (Tracey, 2005).

Therefore, in Tanzania, financial constraint hinder the logistics operations, thus read to the underperformance of government organs and other logistics companies, budgets provided by the government to support organs is not enough to make companies generate their revenues to level logistics operations.

Transit time

This is encountered for the transit time delays due to lack of cargo handling equipment's at ports which incurred many costs for the companies to move their cargos/frights from point of origin to point of destination where all respondents were the questionnaires were distributed mentioned transit time as a problem facing them, and cause logistics performance to be underrated.

One among the respondents that were requested to state on transit time recommended that;

“It is difficult to meet customer requirements because freights do delay at ports and increase transit time to deliver the goods or containers to final consumer whose freights are transported”.

Another respondent commented that;

“There is border delay due to slow network which cause traffic congestion of trucks that needs to cross borders from Dar Port to neighboring countries (Rwanda, Burundi, Uganda, Zambia and DRC), all these depend on Dar es Salaam Port to transship freights and containers, the government under the mandated organs like TPA, TRA and TASAC has to make sure are improving efficiency and developing strong systems to reduce delays and transit time".

Documentation Procedures

The respondents elaborated on documentations that in order to facilitate a smooth discharge of the containers at the terminal, a discharge list containing all containers on board a named vessel to be discharged at this port, must be prepared and submitted to the Terminal authorities, these documents must reach the terminal at least 24 hours prior arrival of the vessel. This serves as a notification to the Terminal on all containers to be discharged from a named vessel. Currently the discharge list is being prepared manually by just extracting information from the hard copy manifest. Complete discharge list is subsequently sent to the container terminal to facilitate discharge of containers. The discharge list is always prepared in accordance to the local terminal requirements, this slows down documentation process at port especially TANCIS systems.

Measures Used to Combat Problems so as to Ensure Clear Movement of Cargo

To ensure timely Documentation clearance; it is necessary to make sure the documentation is done prior to avoid long processes clearing the containers at port. To select good logistics company with good reputation; good selection on Logistics Company dealing with Dry port activities and transportation is another measure in order to avoid a necessary delay and for the sake of security and safety, some stakeholder are conscious with Maersk line as the shipping line.

Railway development-SGR; some respondents especially from TPA recommended on the introduction of Standard Gauge Railway (SGR) which is direct connected to port of Dar es Salaam, the movements of cargo would be easily transferred either to Inland Container Deports (ICDs) or to final destination due to nomination of cargo concern. For example Dar es Salaam to Morogoro or Dodoma where Phase I and II are obviously done.

To reduce customs procedures; it is important for the government under its organ Tanzania Revenue Authority (TRA) to reduce customs procedures and at least to link the systems to avoid wastage of time on customs processes and improving the customs experts that run the systems.

The extent a government is responsible in facilitating the movements of freights and overall logistics businesses

Providing Security assistance by police

Security from insurance companies

Building and maintaining quality infrastructures (ports and railways)

Cooperating with stakeholders to create a good environment for logistics development like making laws and maintaining them

Improvement on container transfers facilities to ICD which are taking long time due to procedures adhered.

Customs

Evaluate the efficiency of customs processes in the country

Based on Customs, there are 86 customs stations scattered all over the United Republic of Tanzania, of which 25 are seaports, 8 airports, 8 zonal offices, 9 main border stations, 6 Transit monitoring stations, 18 Post Parcel offices and 12 minor border stations. The first question in this study was to understand the customs responsible in facilitating logistics operations and the efficiency of customs in Tanzania. The custom involved here is known as TRA (Tanzania Revenue Authority). The respondents were requested to answer the questions requiring to evaluate the efficiency of the following processes in the country as given the ratings (Hardly Ever, Rarely, Sometimes, Often and Nearly Always). These findings show how unprepared employees are in operation and illustrate that effort to provide modern customs training courses need to be stepped up so as to speed up customs processes.

Table 5: *evaluate the efficiency of customs processes in the country*

Customs processes	Hardly Ever	Rarely	Sometimes	Often	Nearly Always
The clearance procedures		2	4	3	8
The transparent of clearance procedures of other border agencies		2	4	6	5
Import cleared and delivered scheduled		1	8	4	4
Export cleared shipped scheduled		2	7	4	4
Receive and information					

regulation changes	3	1	3	5	5

Source; (Own work, 2022).

Methods for determining whether shipments are physically inspected by customs

The respondents analysed their comments on the questionnaires distributed for them and the results are displayed on the below table. 13 respondents recommended using automated risk assessment and 12 use inspector direction method which some of them use both methods, 3 did not know the methods required in shipment whether it’s automated risk assessment or inspector direction.

Table 6*; Methods for determining whether shipments are physically inspected by customs*

Responses	Automated Risk Assessment	Inspector Direction
Yes	13	12
No		
N/A	1	
Do not Know	2	1

Source: (Own work, 2022).

Tanzania Customs and Declarations

The respondents analysed their comments on the questionnaires distributed for them, and the results are displayed in the below table. 12 respondents agreed that customs codes require to use importer licence customs broker to clear goods, 4 respondents disagreed customs codes do not require to use importer licence customs broker to clear goods, and 1 did not know the exactly the answer. Also, 14 agreed whether the organization or their customers are able to choose the location of the final clearance of the goods for imports, 1 said no, and only 2 did not know the whether choose the location for the final clearance of the goods for imports. 9 respondents agreed that goods be released pending final clearance against an accepted guarantee, 4 disagreed with the statement, 2 declared that it is not even applicable and 2 didn't know the exactly response.16 said yes on customs declarations be submitted and processed electronically and online, only 1 respondent didn't know what to recommend. Therefore, the respondents were conscious with the customs declaration available in Tanzania.

Table 7; Tanzania Customs and Declarations

Responses	Yes	No	N/A	Do not know
Does customs codes require to use importer licence customs broker to clear goods	12	4		1
Are you or your customers able to choose the location of the final clearance of the goods for imports	14	1		2
Can goods be released pending final clearance against an accepted guarantee	9	4	2	2
Can customs declarations be submitted and processed electronically and online	16			1

Source: (Own work, 2022).

Timeliness

The questions were asked based on the frequency with which shipments reach consignees within scheduled or expected delivery times (score and rank).

The ability to conduct an effective day to day logistics operation is highly dependent on receiving goods on time. Operational risks are reduced if transportation of goods is received in near real- time, especially when managing exceptions. The cost is even higher if the goods are being received at a late time.

According to respondent's perceptions, commented that

"The load reaches the customer at the right time, but it depends on the type of mode, the policy of the country and the weather of the area where the load is going. Also, the load may be delayed if there are challenges on the road such as accidents, road conditions, etc. The duration of the system as a whole should be taken into account in time-based competition. The general opinion in time research is to reduce the amount of time spent on things like product design, acquisition, production, assembly, distribution, and human resources. This does not imply that every location's logistics flow time must be equally significant. Although different links' time compression can benefit a corporation, the impact's size varies greatly".

Some of the respondents argued that there are many reasons for the time bottlenecks in the logistics performance, which can be summarized as follows: (a)Resource factors. The output rate of the entire logistics system will be constrained by those resources possibly talents, facilities, and equipment, or funds whose production capacity does not match that of other links and whose actual production capacity is lower than or equal to their production load or their demand. Unavoidably, it will develop into a time bottleneck that slows down the logistical performance response time. (b) Quality factors. In logistics performance, failure to discover unqualified personnel Time is wasted if nonconforming facilities or equipment must be reworked or scrapped in order to stop them from moving on to the next step. Therefore, a significant contributing factor to time constraints is quality issues. (c) Facilities layout factors. One of the key factors affecting time is the arrangement of facilities. Improper arrangement of facilities will lead to inefficient workflows and time bottlenecks. (d) Process setting factors. Many time bottlenecks in the logistics flow are caused by improper process settings. The above factors are the main causes of time bottlenecks in the logistics performance.

Time for Physical Inspection

For import, estimate the average time taken between the submission of an accepted customs declaration and notification of clearance in your country of work. According to the below table, it shows respondents were there is a delay in physical inspection of freights/ containers at ports of which it take one up to four days to do physical inspection and an average of 1 to 4 hours without physical inspection due to collected data.

Table 8: *Timeliness*

Without Physical Inspection	Average 1- 4 hours
With Physical inspection	Average 1- 3 days

Source: (Own work, 2022).

To how often the consignments reach within scheduled time due to mode of transport

The respondents analysed their comments on the questionnaires distributed for them, and the results are displayed in the below table. Many respondents are highly using multimodal transport for their shipments and other modes follow apart according to researcher's results as collected from specific areas such Tanzania Port Authority (TPA) and Logistics Companies. Therefore, the respondents were conscious with the customs declaration available in Tanzania.

Table 9; to how often the consignments reach within scheduled time due to mode of transport

	Hardly Ever	Rarely	Sometimes	Often	Nearly always
Road	2	2	5	4	3
Maritime		4	4	4	4
Rail	1	4	5	1	4
Air	2	1	2		9
Multimodal			9	2	2

Source; (Own work, 2022).

Average time from Tanzania to other countries

The respondents stated on the average time that freights move from Tanzania to other countries, some respondents from Superstar forwarders Co.Ltd said that;

“the average time taken to export cargo from port of Dar es Salaam to the destination point is not regularly because of some circumstances for example the distance of final destination, availability of direct vessel which do not transship to some port, (Dar port to China we normally take one month while South Africa it takes a week for direct vessel”.

Other respondents from TPA stated that;

“the average time taken to export cargo from port of Dar es Salaam to the destination point is not regularly because depends to the nature of the cargo and internal speed in documents processing otherwise always loading meet the established timeliness Cargo takes 21 to 30 days to reach destination again by making sure that every documentation procedure, logistics procedures and finance is well allocated, monitored and maintained”.

CONCLUSION AND RECOMMENDATION

Conclusion

A combination of factors applied by different stakeholders playing in logistics performance to the developing countries which are infrastructures, customs, timeliness on shipments, all these are in play of increasing the logistics performance according to world bank report and Tanzanian country different studies.

However, these indicators have reviewed and shown that Tanzania is underrated to developing countries which its operations are less to its marginal breakeven point and logistics performance decrease accordingly, the findings reviewed that in order the organization to win competitively must first focus on making these indicators in practice and operate under effective supervision and management has to be stable to come out with positive results.

The indicator's that expected as analysis of logistics performance in developing countries Tanzania focusing on Tanzania Port Authority, Logistics companies, Tanzania Revenue Authority, Tanzania Shipping Agency Corporation, these organizations basically on logistics gave their opinions on the status of logistics performance operations and the reasons Tanzania is underrated as downward considering of has Ports and manufacturing industries. As the respondents commented that, exactly these indicators mostly affect operations of logistics performance in Tanzania under its management umbrellas which develop some strong rules and regulations so as to double its operations and increase the performance. Also respondents agreed with World Bank report under these mentioned indicators that are not well managed which reveal the exactly performance to be of low quality.

The findings from the respondents, reveal that in order to improve their services Tanzania must hire or educate experts of logistics and transport which are good and can reform the logistics systems so as to meet logistics performances indicators perfections, Tanzania government might rethink to constantly accept customers, other logistics players complaints and claims that are to rebuild the logistics industry and take appropriate actions to tackle current situation of logistics operations performance. This will actually enable the stakeholders available in logistics industry that are direct concern to be active and make operations to be of effectives and efficiency.

Less initial investment and immediate benefits are suggested by the change of the customs features. Therefore, since initial infrastructure investments are substantial and the advantages are typically long-term, an approach that could improve Tanzania's logistic performance would be to concentrate on reforms. We can draw the conclusion that even while these investments are

necessary, they might not be adequate because alone the infrastructure investment might not guarantee the gains in logistic performance (Faria et al, 2014).

Recommendations

The results show that Logistics performance is part and parcel of today's world economic and fall on performance indicators that influence the stability of positive outcome, this is through the timeliness or reduction in transit time, congestion at ports and container terminal when is under control. Logistics systems in Tanzania depend on established authorities which are given exclusive mandate to manage the all logistics activities for example Tanzania Port Authority (TPA) for port operations and Tanzania Revenue Authority (TRA) for customs and declarations, these gave the overview on the current situation of logistics performance in Tanzania.

The findings of the study indicated that Logistics performance in Tanzania as a developing country has to take measures on regulating the logistics performance in different stakeholders or authorities given mandate to operate and regulate so as to avoid downward of Tanzania in logistics industry.

Tanzania serves as the international entry point for a number of its landlocked neighbours; Zambia, Uganda, Rwanda, Malawi, Burundi and the Democratic Republic of the Congo all rely to some extent on the country's transportation infrastructure for access to international markets. Both TPA and development partners keep a close eye on the functioning of the ports; inefficient port operations are a major factor in total delays for shipments in the logistics chain. Due to the elimination of the exclusivity provision in the TICTS concession, there are now more berths available to handle the container traffic, which has resulted in a major improvement in ship turnaround time over time. There are some issues that rely on them for international trade access, of which were recommended by respondents; the requirement to enhance the private sector's involvement in port operations, the creation of a new port at Bagamoyo to provide for long-term capacity building and the substantial investments needed in the sector to enhance capacity and boost productivity.

Additional help will be suggested to enhance container handling and storage at the dockside and at ICDs outside the port gate, as well as the intermodal juncture between the port, road, and rail services. The initiative, which is being put together with aid from Trademark, is also anticipated to address processing protocols and port sector improvements to shorten the time needed for cargo processing.

Government through the ministry of works and transportation has made and still makes several efforts to make improvements on our infrastructure country wise by building and repairing roads and railways to accommodate the increasing demand of cargo passing through Dar es Salaam Port.

Reducing custom clearance and storage times will improve dwell time at the port of Dar es Salaam, but doing so will also need supply chain and consumer behaviour changes because many customers import relatively tiny quantities (AFDB,2014).

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Paper 15:

Challenges of Supply Chain for Essential Health Commodities in Tanzania: A Case of Medical Stores Department's Regional Headquarters in Tanzania

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ABSTRACT

This study aimed to assess the challenges of the supply chain for essential health commodities in Tanzania, focusing on the Medical Stores Department (MSD) Headquarters and selected zones: Mwanza, Kilimanjaro, and Dar es Salaam. A semi-structured questionnaire was used to gather both quantitative and qualitative data. The results showed several major issues, including insufficient funds for medicine procurement, restrictive public procurement regulations, inadequate automated systems to monitor demand variations, inadequate data quality from health facilities, and a lack of accountability structure within the supply chain. To enhance efficiency and sustainability, this study suggests the establishment of a procurement guiding document for health commodities. Furthermore, the government needs to support local pharmaceutical manufacturing and offer financial assistance to industrial pharmacists to engage in local production to lessen dependency on imported medicine as well as timely disbursement of funds for the procurement of essential medicines. Also, the study hinted that fund is a key for MSD's operations and the steady flow of it directly affects the supply chain's efficiency of essential health commodities within the country. The study found that only 52.5% of the budget for medicines was made available, resulting in an unreliable supply of medicines. The interventions in this study are essential for ensuring an efficient supply chain and a means to tackle challenges for essential health commodities supply chains in Tanzania.

Keywords: supply chain, essential medicine, health facilities, challenges, public procurement regulations

1.0 INTRODUCTION

in Tanzania, like many low- and middle-income countries (LMICs), there are significant supply chain challenges that undermine the availability of essential medicines. The availability of essential medicines in public health facilities in LMICs ranges from 17.9% to 87.1%, while in low-income countries, this fluctuates from 7.7% to 67.6% (WHO, 2014; Lu et al., 2011). These differences reflect inefficiencies and weaknesses in the health supply chain management system. Several key supply chain challenges have been identified as contributors to the inefficiency of supply chain management for essential health commodities in low-income countries like Tanzania. For instance, inefficient procurement processes, inadequate quantification practices, inadequate warehousing capacity, and insufficient transportation and distribution systems severely limit the timely supply of medicines (Yale, 2011; Chen et al., 2014). These challenges, combined with weak inventory management and frequent delays in replenishment, result in stockouts that disrupt the sustainability of supply chain management. Moreover, these supply chain challenges lead to significant public health risks. The shortage of medicines often forces patients to resort to over-the-counter medicines or products from unregulated sources, exposing them to counterfeit or substandard products (Jia et al., 2016). Additionally, out-of-pocket payments for essential medicines as part of the supply chain challenge place a financial strain on households, further exacerbating healthcare access inequities (Luiza et al., 2016). Luan et al. (2014) have also noted that the inability to consistently supply essential medicines can drive up prices, creating affordability issues in low-resource settings. Tanzania's supply chain for health commodities faces similar challenges. Despite the government's efforts to reform the health supply chain for more than five decades, including a review of the supply chain system and a bottom-up quantification approach, the redesigned system to improve demand forecasting and align procurement with actual needs at the facility level, still essential medicines remained in short supply (MoH, 2018). The introduction of technologies such as the National e-Procurement System as a means to tackle supply chain challenges was expected to enhance the procurement efficiency of essential health commodities, but the health facilities continue to experience shortages of essential medicines (Binyaruka and Borghi, 2017). It is therefore this study aims to assess the key challenges affecting the supply chain for essential health commodities in Tanzania, focusing on MSD headquarters and three key zones: Dar es Salaam, Kilimanjaro, and Mwanza. By identifying the bottlenecks in the supply chain, the findings of this research will provide valuable insights for decision-makers to develop strategic interventions that can tackle these challenges and improve the supply of essential medicines.

2.0 MATERIALS AND METHODS

2.1 Study Area

The study was conducted at the Medical Stores Department headquarters and in three zones; Dar es Salaam, Kilimanjaro, and Mwanza. These are among the regions in Tanzania where the demand for essential medicines is high due to high population and urbanization (Administrative Units Population Distribution Report n.d.).The geographical characteristics and the availability of Zonal Referal and Specialized Hospitized Hospitals such as Muhimbili National Hospital, Muhimbili Orthopedic Institute (MOI), Jakaya Kikwete Cardiac Institute (JKCI) in Dar es Salaam, Kilimanjaro Christian Medical Center (KCMC), Mawenzi Hospital, Mount Meru Hospital in Kilimanjaro and Arusha region as well as Bugando Medical Center and referral Hospitals in Mwanza have been attracting patients from other regions. Dar es Salaam zone is located in Tanzania's Mainland, lying between 5°30' and 7° Latitude and 36° Longitude. It serves the Dar es Salaam region, the coast region, the Morogoro region, Zanzibar and Mafia Island. On the other hand, Dar es Salam Zone serves Comoro country through the SADC pooled procurement system. Kilimanjaro zone is located on Tanzania's Mainland between 5°30' and 7° Latitude and 36° Longitude. It comprised the Kilimanjaro region, Arusha region, and Manyara region. Mwanza zone is located in Tanzania's Mainland, between 5°30' and 7° Latitude and the 36° Longitude zone, representing the Mwanza region, Geita region, Mara region, Shinyanga region, and Simiyu region.

***Figure 1**: MSD Zones and distribution centers*: Adapted from URTI. (2021)

2.2 Research Design

2.2.1 Philosophy of the study

This study follows a pragmatic research philosophy, combining both quantitative and qualitative methods to assess the challenges of the supply chain for essential health commodities in Tanzania. The pragmatic method was selected to allow for an adaptable review of real-life problems, utilizing both quantifiable information and the insights of individuals involved

2.2.2 Study design

A descriptive cross-sectional survey was carried out in the MSD headquarters and chosen zones, using both quantitative and qualitative data collection methods. The quantitative and qualitative data were collected from key informants using a semi-structured questionnaire. After carefully checking for completeness, the data was recorded and analyzed with SPSS version 21. The quantitative data were presented using descriptive statistics such as frequency, percentage, and standard deviation. The qualitative data analysis included a thorough reading of the responses from the interview and summarized the results. The National Institute of Transport's Ethics Review Board granted ethical permission, and all subjects provided verbal agreement before data collection began. Confidentiality and anonymity were maintained.

2.3 Data Collection Methods

This study used primary and secondary methods to assess the challenges facing the supply chain of essential medicine in Tanzania. Primary data were collected using semi-structured questionnaires. The questionnaire was administered to respondents using the online platform through emails and WhatsApp links, and each respondent was requested to fill it. Secondary data was extracted from different datasets found in the Ministry of Health and Medical Store Department to complement the missing information in the primary data.

2.3.1 Validity and Reliability of the Data Collection Methods:

To ensure the validity and reliability of the findings, the identified challenges, such as inadequate procurement systems and stockouts were taken from key informants who are in operations of the supply chain activities and the same information was taken from different respondents to minimize the risk of bias. The researcher also established a trust relationship with respondents to ensure that the information provided was correct. On the other hand, the data collection tool was carefully designed to capture the information correctly. The results obtained were compared with other evidence to support findings. On the other hand, the selection of the study areas (Dar es Salaam, Kilimanjaro, and Mwanza) was designed to ensure that the findings are generalizable to other regions within Tanzania. The diversity of the selected zones enhances the external validity of the results. Key indicators such as procurement efficiency, and warehouse management practices were operationalized using established literature and validated by expert feedback. This ensured that the measurements accurately reflected the underlying constructs of supply chain challenges. The study instruments, including surveys and interview guides, were reviewed by stakeholders such as MSD officers and healthcare providers to confirm that they adequately captured the most relevant supply chain issues. Quantitative data were collected at different time points to ensure consistency in the reported challenges over time. The survey instrument used in the study was assessed for internal consistency using Cronbach's alpha through SPPS software which yielded a value greater than 0.7. This indicates that the items in the survey measured the same underlying dimensions of supply chain challenges consistently.

2.4 Sample Size and Sample Unit

2.4.1 Purposive Sampling for Qualitative Study

For this study, participants were selected based on their specific knowledge and experience in key areas relevant to the supply chain of essential health commodities. Only participants with more than five years of experience in procurement, demand and supply planning, warehouse operations, distribution, and finance were considered.

A total of 15 participants were selected and coded to complete the qualitative study, ensuring that their insights were directly related to the research questions. This purposive sampling method was ideal for gathering relevant and in-depth insights from individuals who are well-versed in the core operations of the supply chain, ensuring the richness of the data collected.

2.4.2 Sampling for Quantitative

The study population consisted of all employees involved in the pharmaceutical supply chain at the Medical Stores Department (MSD), including those working in procurement, logistics and distribution, demand and supply planning, and finance.

A stratified sampling method was used to make sure each subgroup was properly represented. The population was split into strata according to their functions in procurement, distribution, and finance, which allowed for choosing a sample that mirrors the different areas within the MSD supply chain. Yamane's formula was applied to find the right sample size. A confidence level of 90% was chosen, with a margin of error set at 10%. This guarantees that the sample is statistically enough to represent the whole population, with good confidence that the results will stay within the allowed margin of error. 80 respondents were computed using Yamane's formula (Yamane, 1973). This formula provided a quick and easy way to calculate the sample size based on the population size and provided a reasonable estimate for sample size. The sample size obtained was sufficient to explain the challenges facing the supply chains of essential medicine in Tanzania through the medical stores department.

For sample size computation;

Formula

$$n = \frac{N}{1 + N(e)^2}$$

where

n= Sample size, N= Total population (422) and e= Acceptable error value (10%)

Therefore:

$$n = \frac{N}{1 + N(e)^2} = \frac{422}{1 + 422(0.1)^2} = \frac{422}{1 + 4.22} = \frac{422}{5.22} = 80.842 \approx 80$$

Table 1 shows the distribution of sample size based on zones. The departments selected were Procurement, Customer Services, Logistics and Operations, Finance, ICT and Warehouse, and Director General Office.

Table 1: Distribution of Sample Size by Zones

Location	Population	Number of Samples
Mwanza zone	55	10
Kilimanjaro zone	49	9
Dar es Salaam zone and HQ	318	61
Total	422	80

Source: MSD Internal Reports and Staff Regulations

However, the study used only 50 respondents because some of the respondents were unwilling to participate in the study, and others were unavailable due to various reasons. Such limitation did not affect the analysis because (Draugalis, Coons, and Plaza 2008) said that a response rate of 50% or higher is sufficient for researchers to proceed with the analysis. Therefore, the sample size used to analyze the problem under study was 62.5% of the total population which is acceptable.

3 FINDINGS AND DISCUSSIONS

3.1 Findings for Qualitative data

The findings were presented in key themes and sub-themes to comprehensively capture the complexities of supply chain challenges. By organizing the qualitative data into these structured categories, a deeper understanding of the various factors affecting the supply chain and its implications for the procurement of essential health commodities was achieved. The findings are summarized below into main themes and their respective sub-themes.

Theme 1: Long Procurement Process for Essential Health Commodities

The long procurement process was identified by participants as a significant challenge in the supply chain for essential health commodities in Tanzania. Participants emphasized that the bureaucratic nature of public procurement regulations led to significant delays in the acquisition and distribution of essential medicines. The challenges associated with the long procurement process are divided into two key sub-themes: delays in approval and inefficient tendering processes.

Sub-theme 1: Delays in Approval

Participants pointed to delays in approval as one of the primary causes of inefficiencies in the supply chain. According to regulations, for procurement to proceed, the tender board must hold meetings, but sometimes, the members of the tender board are unavailable to meet the quorum needed to approve tenders. Participants noted that the board typically meets twice a month, and during each meeting, a maximum of 5 evaluation reports can be approved or sent back for corrections. Additionally, the procurement process involves multiple layers of authorization, further extending the time required for approvals. This results in essential medicines being ordered and delivered long after they are needed.

One respondent explained the limitations of the public procurement process: “According to the Public Procurement Act, the tender validity is 120 days, which is equivalent to four months. But in reality, it goes beyond four months due to multiple layers of authorizations.” (Respondent 2)

Another respondent commented on the structural issues with the procurement system: “The problem with public procurement is that it assumes all members needed for approvals are always available in the office, waiting for authorization. In reality, this is not the case, and the delay in approvals leads to receiving medicines with a low shelf life, which increases the risk of expiration.” (Respondent 6)

A similar experience was shared by another respondent: "Public procurement is slow and over-regulated, with too many layers of approvals. And since most medicines are coming from overseas, the delays in approvals, combined with this over-regulated process, lead to even more delays in the delivery of medicines. I think the public procurement system doesn't fit well with the needs of the health supply chain." (Respondent 10)

Sub-theme 2: Inefficient Tendering Process

Participants also highlighted the **inefficient tendering process** as a critical factor contributing to the long procurement timeline and as a significant challenge within the supply chain for essential health commodities. The stringent regulations governing public procurement require a series of complex actions from the moment a tender is advertised.

These processes can often last **more than four months** to complete, resulting in significant delays in securing essential medicines from manufacturers.

One respondent explained the complications involved in the evaluation process: *"Nowadays, we are conducting evaluations through a system managed by the Public Procurement Regulatory Authority (PPRA). Sometimes, technical errors during evaluation arise that need to be resolved by PPRA, and waiting for these issues to be addressed can take a long time, affecting the evaluation process. And that's just for evaluation; there are still so many other steps in the procurement process."* (Respondent 5)

"The tendering process can take so long that sometimes the tender validity period expires. When that happens, we have to extend the tender validity, but some suppliers refuse to extend their offers, which complicates things even further." (Respondent 8)

"For the procurement of pharmaceuticals, I believe we should have a separate guiding procurement document with minimal procedures to speed up the process and tackle this supply chain challenges effectively." (Respondent 11)

Summary Discussion

The findings reveal that the **inefficient tendering process and delay in approvals** significantly contribute to delays in the procurement of essential health commodities. The extensive procedural requirements and potential for technical issues within the evaluation system hinder timely acquisition, leading to stockouts a. Addressing these inefficiencies through streamlined procurement guidelines and processes could help mitigate the challenges faced in the pharmaceutical supply chain.

Theme 2: Funds to Procure Essential Health Commodities

Participants consistently identified the availability of funds to procure essential health commodities as a critical challenge in the supply chain. Insufficient funding, budget constraints, and unpredictable financial resources significantly hinder the procurement process and affect the overall supply of essential medicines in healthcare facilities.

Sub-theme 1: Budget Constraints

Many respondents expressed concern over **budget constraints** that limit the ability of the Medical Stores Department (MSD) to procure necessary medicines. The fixed budgets allocated for pharmaceuticals often do not account for fluctuating prices and the increasing demand for essential health commodities. This situation results in an inability to purchase enough stock to meet the needs of health facilities.

One respondent noted:
"Every year, the government pledges a budget for health commodities, but hardly does the fund get disbursed as it was budgeted. This creates a financial burden for MSD and forces us to make tough choices about which items to prioritize." (Respondent 3)

Another participant highlighted the consequences of budget limitations: *"Sometimes, especially with manufacturers from overseas, they require a commitment of 80% of the total value before production. If there's no commitment, the manufacturers will not produce the medicines. For local suppliers, some demand payment upfront before proceeding with deliveries, which makes it difficult for us to buy in bulk. This leads to stockouts and increased prices when we have to make emergency purchases."* (Respondent 6)

Summary discussion

The findings reveal that the challenges associated with **funds to procure essential health commodities** specifically, budget constraints and unpredictable funding sources significantly impact the procurement process within the pharmaceutical supply chain. These financial limitations hinder the ability to maintain adequate stocks of essential medicines, leading to frequent shortages that compromise patient care. Addressing these funding challenges is crucial for enhancing the efficiency and reliability of the supply chain for essential health commodities in Tanzania.

Theme 3: Inventory Management System

Participants identified **the inventory management system** as a significant challenge in the supply chain for essential health commodities. This includes inefficient inventory practices and tracking mechanisms that contribute to the difficulties faced in supply chain management.

Sub-theme 1: Inefficient Inventory Tracking

Respondents expressed concerns about the **inefficient tracking system** currently in place. The existing system is not fully automated, limiting its ability to assist in managing different aspects of inventory effectively.

One respondent explained:

"The system does not restrict me from allocating any item. For example, if I have two identical items with different expiration dates and batches, I expect the system to prevent me from allocating the item with the longer expiration batch and only allow allocation for items nearing their expiration date. However, that is not the case here. I can allocate any batch as much as I want, regardless of the expiration date. This creates a potential risk for stock expiration." (Respondent 5)

Another respondent commented on the physical constraints of the warehouse: *"The warehouse space does not allow us to practice proper inventory management. You might find that items nearing their expiration date are stored far back, surrounded by many boxes, while items with a longer shelf life are right in front of me. What do you do when you have many orders to attend to?"* (Respondent 8)

Summary discussion

The findings reveal that **the inventory management system** poses significant challenges to the effective supply of essential health commodities. Inefficient inventory practices and inadequate tracking mechanisms not only complicate inventory management but also increase the risk of stock expiration. Addressing these issues is crucial for enhancing the reliability of inventory management and ensuring the availability of essential medicines in healthcare facilities.

Theme 4: Local Manufacturers within the Country

Participants highlighted the role of **local manufacturers** as both a potential solution and a challenge within the supply chain for essential health commodities in Tanzania. While local manufacturing offers the possibility of reducing dependency on imported medicines, there are significant challenges that affect the reliability and scale of production, contributing to supply chain inefficiencies.

Sub-theme 1: Limited Production Capacity

One of the major challenges raised by participants was the **limited production capacity** of local manufacturers. Many manufacturers within the country struggle to meet the growing demand for essential health commodities due to outdated infrastructure, insufficient resources, and limited access to raw materials.

One respondent explained:

"Local manufacturers often cannot meet the high demand for essential medicines. Their production capacity is limited, and they also lack access to certain raw materials, which delays the entire process." (Respondent 7)

Another respondent emphasized the consequences of these limitations: *"Even though we have local manufacturers, the volume they produce is not enough to cover the needs of the healthcare facilities. We still have to rely heavily on imports to fill the gap."* (Respondent 2)

Sub-theme 2: Prices of Medicines from Local Manufacturers

Another challenge identified by participants was the **high prices of medicines** produced by local manufacturers. Although producing medicines locally could reduce reliance on imports, participants noted that the prices of locally manufactured medicines are often not competitive. This poses a significant challenge for the procurement process and the sustainability of relying on local manufacturers for essential health commodities.

One respondent highlighted the pricing issue:

"The prices of medicines from local manufacturers are often higher compared to imported medicines. This makes it difficult for us to justify purchasing locally when we can get the same products from abroad at a lower cost." (Respondent 4)

Another participant commented on the factors driving up local prices: *"Local manufacturers face higher production costs due to the lack of economies of scale and expensive raw materials, which are often imported. These costs are passed on to us, making locally produced medicines more expensive."* (Respondent 9)

Additionally, some respondents pointed out that despite the higher prices, local manufacturers sometimes cannot guarantee a consistent supply of medicines, further complicating procurement decisions.

One respondent explained:

"Even though local manufacturers charge more, they can't always guarantee a steady supply. So, we end up paying more for less reliable deliveries." (Respondent 7)

Summary Discussion

The **prices of medicines from local manufacturers** present a significant challenge for the procurement of essential health commodities. Higher production costs and limited economies of scale result in prices that are often not competitive with imported medicines. This makes it difficult for the healthcare system to rely on local manufacturers, despite the potential benefits of reducing dependency on external sources.

3.2 Findings for Quantitative data

Reliability table using Cronbach Alpha showing the internal consistency of the questionnaire. A value above 0.7 is acceptable reliability

Variable	**Number of Items**	**Cronbach's Alpha**	**Interpretation**
Procurement Challenges	5	0.85	High Reliability
Inventory Management	6	0.78	Acceptable Reliability
Supply Chain Coordination	4	0.81	High Reliability
Financial Challenges	5	0.74	Acceptable Reliability
Overall Reliability	20	0.82	High Reliability

Source. SPPS Version 2020

Validity table using experts' Content Validity Index used to assess how well the items covered the construct being measured, **CVI** scores are typically above **0.80** to indicate good content validity

Item	Expert 1	Expert 2	**E**xpert 3	**C**VI Score
Procurement issue	4	3	4	0.83
Inventory Management	4	4	3	0.92
Supply chain coordination	3	4	4	0.92
Financial challenges	3	3	4	0.75
CVI overall				0.86

Source. SPPS Version 2020

3.2 Challenges for the Supply Chain of Essential Health Commodities in Tanzania

3.2.1 Funds to procure essential medicines

The respondents were requested to provide their opinions on inadequate funds for procuring medicines. Table 2 shows that 2 (4%) respondents enormously disagreed, 3 (6%) disagreed, 8 (16%) were neutral, 11 (22%) agreed, and 26 (52%) highly agreed. The findings agree with the Government Audit Report for the financial year 2018/19, the CAG revealed irregularities in the procurement process due to an insufficient budget from the Ministry of Finance as well as the severe delay of fund disbursement to MSD. The CAG elaborated that in the financial year 2018/2019 the budget set for procurement of medicines, medical equipment, and laboratory reagents was TZS 251,500,000,000 while the fund disbursed by the government was 130,417,000,000 equivalents to 52.5% of the total budget. The performance of the MSD is constantly affected by fund availability which in turn affects the implementation of MSD strategic plans and the availability of medicines at the central level, hence affecting the efficiency of the supply chain. These findings are also supported by Woodburn (2013), who identified that inadequate budget planning and allocation of financial resources were compromising the supply chain of essential medicine in sub-Saharan countries. Similar findings were presented by Mtama (2015), who conducted the study in Malawi's central medical stores and found that insufficient funds allocated to purchase essential medicine were among the most significant challenges affecting the supply chains. The Government needs to allocate more funds, as suggested in the findings because the underfunding remains a supply chain challenge and severely affects the performance of the Medical Stores Department (MSD), impeding the implementation of strategic plans and diminishing the availability of medicines at the central level.

Table 2: Insufficient Funds to Procure Medicines

Ranking category	Frequencies	Percent
Extremely Disagree	2	4
Disagree	3	6
Neutral	8	16
Agree	11	22
Extremely Agree	26	52
Total	50	100

Source: Fieldwork survey, 2022

3.2.2 Public Procurement Regulations

The contribution of public procurement regulations to stock out of essential medicines was also studied. Table 3 reveals that 6(12%) of the respondents enormously disagreed with the argument, 4 (8%) disagreed, 12 (25%) were neutral, 11 (22%) agreed, and 17 (34%) highly agreed. These findings support the results presented by Amemba *et al.* (2013). The study found that complexity in the procurement process and regulations governing the procurement were affecting the supply chain of essential medicine in Kenya. For the case of Tanzania, particularly MSD, the same findings were noticed and called for countermeasures to overcome the identified challenge. (Wales et al. 2014)

The results from this study have key implications for those in policy, health management, and the pharmaceutical supply chain. A large number of respondents indicated that public procurement rules lead to stockouts, suggesting that the Tanzanian government and MSD should assess and simplify current procurement processes. Making these rules easier to navigate could improve efficiency and cut down delays in obtaining essential medicines. Additionally, providing training for procurement staff on best practices and technology use could enhance how the procurement process is managed, resulting in better inventory oversight and fewer stockouts.

Table 3: Public Procurement Regulations

Ranking category	Frequencies	Percent
Extremely Disagree	6	12
Disagree	4	8
Neutral	12	24
Agree	11	22
Extremely Agree	17	34
Total	50	100

Source: Fieldwork survey, 2022

3.2.3 MSD I Inventory Management system

The study analyzed MSD's inventory management system in terms of value, movement, risk of expiration, and importance. Table 4 provides the feedback of respondents where 12 (24%) enormously disagreed with the statement, 9 (18%) disagreed, 10 (20%) were neutral, 7 (14%) agreed, and 12 (24%) highly agreed. these findings from the analysis show significant concerns about how inventory is managed, especially regarding value, movement, expiration risks, and overall significance. About 24% of people surveyed strongly disagreed while another 24% strongly agreed about how well the inventory system works, showing a clear split in views on its effectiveness. This aligns with findings from Nieuwoudt (2010), which stated that inadequate inventory management negatively the pharmaceutical supply chain. Having too much stock and the risk that some items will expire not only threatens the MSD’s financial sustainability but also leads to an unreliable supply chain. This situation may cause shortages of essential medicines and more waste, putting extra pressure on resources.

To fix these problems, MSD must improve its inventory management methods. This could include using better inventory tracking systems, adopting just-in-time strategies, and providing proper training for staff handling inventory. these improvements can support the MSD's financial sustainability, allowing for better resource use and ultimately enhancing healthcare delivery throughout Tanzania

Table 4: MSD Inventory Management Systems

Ranking category	Frequencies	Percent
Extremely Disagree	12	24
Disagree	9	18
Neutral	10	20
Agree	7	14
Extremely Agree	12	24
Total	50	100

Source: Fieldwork survey, 2022

3.2.4 Inventory control practices

The study assessed whether MSD used scientific approaches like FEFO and FIFO to manage its inventory. Figure 1 gives the feedback from respondents which 32 (64%) of respondents enormously disagreed with the statement, 7 (14%) disagreed, 6 (12%) were neutral and 5 (10%) highly agreed.

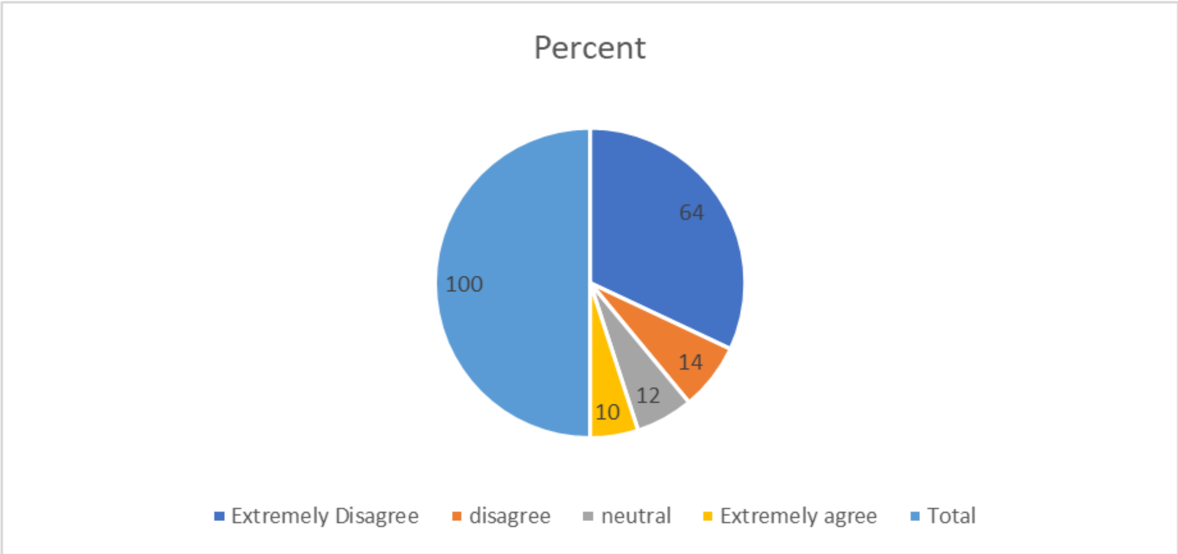

Figure 1: Inventory control practices

Source: Fieldwork survey, 2022

It is worth noting that MSDs follow the FEFO and FIFO to control the inventory of essential medicine in zones. However, sometimes the application of FIFO and FEFO becomes difficult in some zones due to warehouse layout design and space constraints that impede the proper application of FEFO, this was noted in MSD Central Warehouse. These results contradicted the findings reported in Nieuwoudt (2010) that poor FEFO and FIFO tends to affect the supply chains of essential medicine.

3.2.5 Product Knowledge for Warehouse Officers

Also, the knowledge of warehouse officers on furnishing the supply chains of essential medicine was assessed accordingly at the MSD. Table 5 shows that 10 (20%) respondents enormously disagreed with the argument, 6 (12%) disagreed, 11 (22%) were neutral, 7 (14%) agreed and 16 (32%) highly agreed. These findings are also supported by (X. Tang and J. Huang, 2016) emphasizing that Warehouse officers managing medicine logistics require pharmaceutical knowledge for accurate inventory and outbound management.

The assessment of this study shows a notable 32% of respondents strongly believe these officers have enough product knowledge. However, 20% of respondents disagreed strongly, suggesting that some warehouse officers might lack the needed expertise. This indicates that while many are trained in product knowledge, those without pharmaceutical training may struggle to effectively engage in supply chain management for essential medicines. Tang and Huang (2016) pointed out that warehouse officers in medicine logistics need solid pharmaceutical knowledge for accurate inventory control and good outbound management. By focusing on specific training for warehouse personnel, MSD can close knowledge gaps and improve its inventory management system. This would enhance the reliability of the supply chain and reduce supply chain challenges, which can lead to better healthcare results in Tanzania.

Table 5: Product knowledge for warehouse officers

Ranking category	Frequencies	Percent
Extremely Disagree	10	20
Disagree	6	12
Neutral	11	22
Agree	7	14
Extremely Agree	16	32
Total	50	100

Source: Fieldwork survey, 2022

3.2.6 Tendering Processes

Figure 2 presents the feedback from respondents about the tendering process. About 5 (10%) of the respondents enormously disagreed with the argument, 6 (12%) disagreed, 3 (6%) were neutral, 11 (22%) agreed and 25(50%) extremely agreed. Overall findings show that tendering processes compromised the supply chains of essential medicine at MSD. The respondents narrated that it is not surprising to see essential medicine expire before supplying to respective health facilities. This is consonant with the study conducted by (Yadav and Yadav 2015) pointing out that a long procurement cycle through the tendering process creates a cycle of uncertainty in the system of the supply chain leading to stockouts of health commodities. On the other hand, the Tanzania Government Audit Report for the financial year 2018/19 published on its website revealed that the delivery of medicines from international pharmaceutical manufacturing to MSD takes too long due to tendering processes as compliance with public procurement regulations leads to frequent stock-outs affecting the reliability of the health supply chain.

this call for the urgent establishment of a procurement guiding document that fits procurement of health commodities with minimal procedures to ensure timely delivery of health commodities

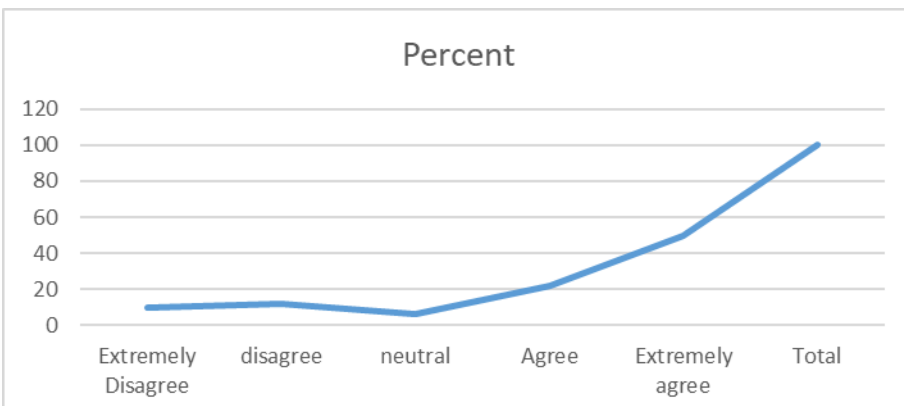

Figure 2: Tendering processes of medicine

Source: Fieldwork survey, 2022

3.2.7 Mechanism to monitor demand for essential medicine

Table 6 shows the feedback obtained from respondents about the mechanisms for controlling demand variation at MSD. 8 (16%) of respondents extremely disagreed with the argument, 5 (10%) disagreed, 7 (14%) were neutral, 7 (14%) agreed and 23 (46%) extremely agreed. This implies that MSD does not have the best mechanism control system to monitor demand variation and oversee demand fluctuation. The findings are supported by Dave *et al,* (2022) who stipulated that demand variation in the pharmaceutical supply chain can be effectively achieved through a blockchain network leading to reliability and transparency.

Overall findings indicate that the poor mechanism to monitor the demand variation and the lack of the best mechanism for controlling the fluctuation of the demand were among the challenges found to affect the supply chains of essential medicine in Tanzania.

Table 6: Mechanism to control system of essential medicine

Ranking category	Frequencies	Percent
Extremely Disagree	8	16
Disagree	5	10
Neutral	7	14
Agree	7	14
Extremely Agree	23	46
Total	50	100

Source: Fieldwork survey, 2022

3.2.8 Automated system at MSD

The study analyzed the feedback from the respondents on the automated system at MSD. Figure 3 presents the feedback from respondents on whether MSD had an automated system to ensure supply chains of essential medicines are done. About 8 (16%) of respondents extremely disagreed with the argument, 6 (12%) disagreed, 10 (20%) were neutral, 10 (20%) agreed and 16 (32%) extremely agreed. MSD does not possess an automated system to monitor dormant medicines and obsolete and slow-moving items. Findings are in the same line to Nieuwoudt's (2010) results, which found that the lack of an automated system to monitor dormant, obsolete, and slow-moving items affects the parts of the supply chain.

It implies that to enhance the efficiency and reliability of the supply chain, MSD must invest in the development and implementation of an automated inventory management system. Such a system would facilitate real-time monitoring of stock levels, improve decision-making regarding procurement and distribution, and ultimately ensure a more streamlined supply chain for essential health commodities. By embracing automation, MSD can better respond to the dynamic needs of the healthcare sector, leading to improved patient outcomes and more effective management of resources.

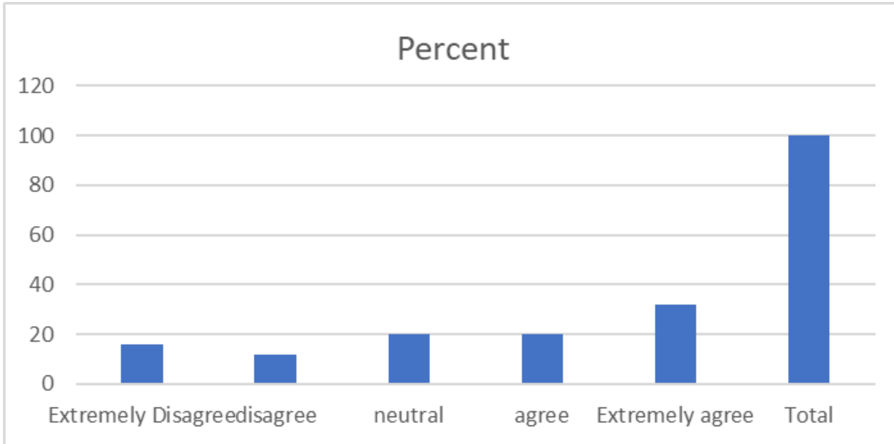

Figure 3: Automated system at MSD's zones

Source: Fieldwork survey, 2022

3.2.9 Shelf life

The study analyzed the feedback from the respondents about shelf life. Figure 4 shows that 5 (10%) extremely disagreed, 6 (12%) disagreed, 3 (6%) were neutral, 11 (22%) agreed and 25 (50%) extremely agreed. This implies that delivering items with a low shelf life is among the reasons for expiries in MSD. The findings about shelf life show important effects on supply chain management. With half of the surveyed individuals strongly agreeing that the delivery of items with short shelf lives leads to expiries, it is clear this presents a serious problem in pharmaceutical supply chain management. The Government Audit Report for the financial year 2018/19 backs up this concern, stating that the lengthy procurement process which includes preparing solicitation documents, advertising tenders, evaluating bids, negotiating prices, and preparing contracts takes at least three months. In addition, getting medicines from overseas producers can take another six to nine months, leading to long wait times and delivering products that might expire before they get to health facilities.

To solve this problem, MSD needs to simplify its procurement methods and enhance coordination with suppliers, making sure that medicines with sufficient shelf lives are prioritized for prompt delivery. Tackling these issues will not only cut down waste but also improve the efficiency and reliability of the pharmaceutical supply chain in Tanzania

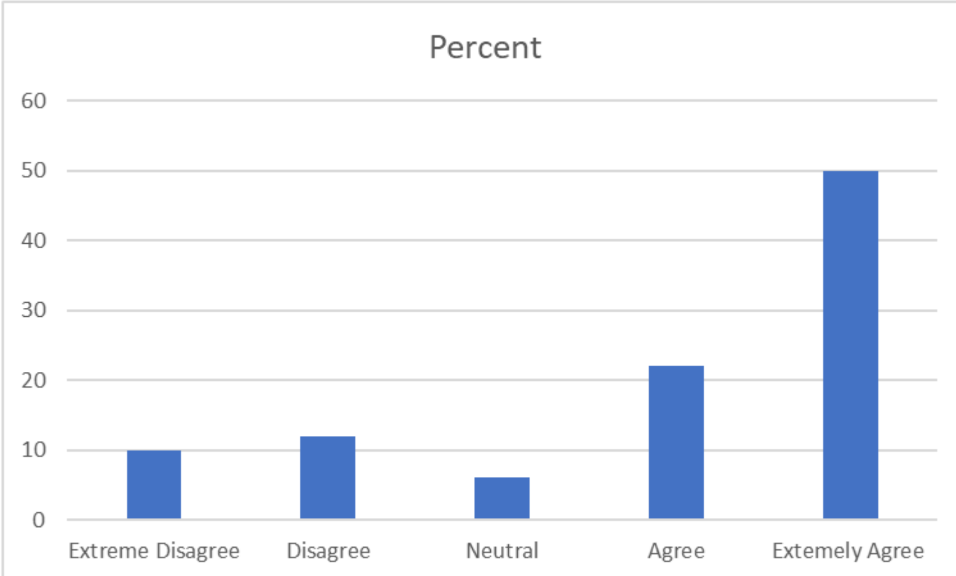

Figure 4 Shelf life

Source; Field Work Survey, 2022

3.2.10 Local pharmaceutical manufacturers within the country

The study analyzed the feedback from the respondents on the local pharmaceutical manufacturers within the country. Showing that 6 (12%) were neutral, 13 (26%) agreed, and 31 (62%) extremely agreed. This implies an insufficient supply of medicine due to an insufficient number of local pharmaceutical manufacturers within the country creates a weak link in essential medicines availability. The results about local manufacturers in Tanzania show important issues for the supply chain of essential medicines. A significant 62% of the participants strongly agree that the low number of local pharmaceutical producers leads to a poor supply of medicines. This situation creates a major hurdle in making sure essential health products are available. The Ministry of Health's Health Sector Strategic Plan 2021-2026 (HSSP V) supports this issue, stating that by the end of 2018, only 13 drug manufacturing companies were registered, producing just 25% of the nation's medical needs. This indicates that a large 75% of medicines, medical supplies, lab tools, and reagents have to be imported, which puts the country at risk of supply interruptions. Furthermore, Mwilongo (2021) backs this up, noting that local manufacturers can satisfy only 30% of essential medicine demands.

To tackle these issues, the Tanzanian government and other concerned parties need to put resources into and encourage local manufacturing production. Boosting local manufacturers' capabilities can improve the supply chain by lessening dependence on imports and raising the availability of vital medicines. This could include offering incentives for local production, enhancing regulations, and supporting research and development in the drug industry. By establishing a strong local manufacturing sector, Tanzania can achieve more independence in essential medicines, leading to better health results and increased resilience to supply chain challenges

3.1.11 Expiries of medicine at MSD

The study analyzed the feedback from the respondents on the expiries in MSD due to poor inventory control. The findings showed that 7 (14%) were extremely disagreed, 7 (14%) disagreed, 16 (32%) were neutral, 6 (12%) agreed and 14 (28%) extremely agreed. The results show that just 28% of those asked strongly agreed that expired products happen because of inadequate inventory control, while a significant 32% were neutral, indicating they are unsure about how inventory practices affect this problem. This suggests that medicine expirations are tied to factors beyond just the inventory system, like MSD’s procurement process, the delivery of items with short shelf lives, and the lack of a strong accountability system. These results point to the need for a thorough review of MSD's supply chain processes. Improvements must also be made in procurement strategies and supplier partnerships to ensure that medicines delivered to MSD have adequate shelf lives. Furthermore, creating a clear accountability system will improve oversight and responsibility in managing inventory, which will help decrease the chance of expiries.

The difference between these results and Mtama’s (2015) findings, who attributed increased expiries to inadequate inventory control, suggests that a multifaceted approach is required to address the complexities of inventory management. To effectively mitigate the issue of expired medicines, MSD should consider implementing integrated solutions that enhance both inventory management and procurement processes, ensuring a reliable supply of essential medicines and minimizing waste.

5 CONCLUSIONS AND RECOMMENDATIONS

This study assessed the challenges of the supply chain for essential health commodities in Tanzania through the Medical Stores Department (MSD). It pointed out several key issues that affect the supply chain's effectiveness, such as inadequate funds for procurement, a lack of automated systems to forecast demand, public procurement regulations that slow down the procurement process, inadequate inventory management practices, and limited product knowledge among warehouse staff. Further, issues with tendering and receiving medicines with short shelf life lead to financial burden for MSD.

The results showed that 34% of respondents strongly believed public procurement rules were a barrier to quick procurement, while 50% felt that insufficient funds hindered the efficient procurement of necessary medicines. To tackle these issues and enhance the sustainability of the supply chain for essential medicines in Tanzania, the following recommendations are suggested:

i. Timely disbursement of funds:

The government, through the Ministry of Health, should guarantee that funds for the procurement of essential health products are released promptly as per projections. This is key for MSD's operations because a steady flow of funds directly affects medicine availability and the supply chain's efficiency. The study found that only 52.5% of the budget for medicines was made available, resulting in critical shortages.

ii. Simplified Procurement Process:

The government should develop separate procurement guidelines for essential health commodities that minimize bureaucratic procedures. Since over 50% of respondents were concerned about current procurement rules, these new guidelines should enable MSD to speed up procurement processes and respond faster to immediate healthcare needs. Simplifying these procedures could help reduce the long delays tied to tendering, as shown by the study's findings pointing out procurement slowdowns from regulatory compliance.

iii. Further Research on Procurement Regulations:

Further research is necessary to explore how public procurement regulations affect stock levels at MSD. Such studies will offer useful insights into how to refine these regulations to fit the procurement of health commodities. The study pointed out the importance of continuously evaluating how these regulations impact procurement efficiency of health commodities.

iv. Support for Local manufacturers:

The government should encourage local pharmaceutical companies by offering financial incentives, like tax reductions on imported raw materials. The study indicated that merely 13 pharmaceutical companies operate in Tanzania, producing only 25% of the needed medicines. This support could boost local production and lessen the dependence on imports. Furthermore, the government should empower industrial pharmacists by providing financial assistance for them to organize and develop production facilities at low interest rates. This strategy will boost the number of pharmaceutical industries and improve stock availability.

v. Focus on Automated Systems:

MSD should prioritize the implementation of automated inventory management systems to better monitor stock levels, including dormant and slow-moving items. Utilizing technologies like the Internet of Things (IoT) and data analytics can help MSD anticipate demand changes, minimize expiry risks, and ensure timely medicine deliveries. The study showed that the absence of an automated system significantly contributed to inventory problems, with 32% of respondents expressing concerns about this issue.

vi. Training for Warehouse Staff:

A thorough training program for warehouse staff should be created to improve their knowledge of inventory control and product handling. Knowledge is important. By giving staff the right skills and knowledge, MSD can make its operations better and make sure that essential medicines are stored and managed properly. The study showed that ongoing training for warehouse staff is key for keeping the supply chain working well.

By taking these basic steps, the Tanzanian government and MSD can greatly improve the efficiency and strength of the supply chain for essential health supplies. Tackling these issues will not only help with the availability of medicines but also lead to better health for the people, helping to achieve the overall aim of universal health coverage in Tanzania. The study's results highlight the immediate need for planned actions to strengthen the pharmaceutical supply chain, ensuring that essential health products are regularly available to meet the healthcare needs of the Tanzanian people

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Paper 16:

Gender Disparities in the Transport Sector: Focus on the Maritime Sector in Tanzania

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ABSTRACT

This study examined the current state of gender disparities in the Tanzanian maritime sector. Secondary data were obtained through institutional reports conducting short courses in cargo tallying for international shipping and folk lift operators' courses. Findings shows a clear and statistically significant gender imbalance favoring male participation The sector faces challenges in achieving gender equality, and more targeted efforts may be needed to encourage and support female participation in maritime education and careers. The study recommends that to foster gender parity in the Tanzanian maritime sector, it is essential to implement gender-inclusive policies. Besides reforming maritime education to be more inclusive is crucial by recruiting female students and provide training that accommodates their needs. (For example, offering flexible schedules and on-campus childcare can help women balance their family responsibilities). Additionally collaborating with community leaders and organizations to promote gender equality can also foster a more supportive environment for women pursuing maritime careers.

Key words: Maritime, Gender disparity, Transport sector.

1 INTRODUCTION

Gender disparities continue to exist in various sectors on a global scale, encompassing health, education, employment, and notably, transportation (World Bank, 2019; United Nations, 2020). Within the maritime sector, which has traditionally been male-dominated, there are evident gender imbalances (IMO, 2019; ILO, 2018). The maritime industry faces persistent gender disparities globally, with women representing just about 2% of the seafaring workforce (BIMCO and ICS, 2015; UNCTAD, 2020). **Policies in countries like Norway and the Philippines aim to close these gaps with varying degrees of success (ILO, 2021).** Despite the significant role that the maritime sector plays in the economic advancement of nations worldwide, gender disparities persist within the sector, thereby hindering the complete utilization of women's contributions.

Gender role theory (Eagly, 1987) delineates how societal norms describe distinct roles for men and women. Structural functionalism (Parsons, 1951) posits that societal structures inherently favour male dominance in specific sectors. In the maritime sector context, gender disparities materialize through discrimination, harassment, limited training, and resource access, as well as unequal compensation and benefits (ILO, 2018; IMO, 2019). Resolving gender disparities is critical for optimizing human resource deployment and fostering sectoral development (World Bank, 2019; UNCTAD, 2020). Maritime positions were historically deemed unsuitable for women due to perceived physical and mental demands (Gordon, 1997). The comprehension of gender disparities in the maritime sector is based on the acknowledgment that women's roles and contributions have been systematically undervalued and underrepresented (Kitada, 2013). Women working in the maritime field commonly encounter feelings of isolation, loneliness, safety apprehensions, as well as obstacles related to maintaining a work-life balance and maternity rights (Belcher et al., 2003; Thomas, 2004). Women encounter substantial barriers to engagement in the maritime field, particularly in training and operational positions (Kitada**,** 2013; IMO, 2019). The impediments they face include gender prejudices, absence of mentorship, and restricted access to training (Gibbs & Monro, 2012; McKay & Doyle, 2013).

In Tanzania, the maritime sector plays a crucial role in the economy by facilitating trade, transportation, and employment (Tanzania Ports Authority, 2020). Nevertheless, female participation in the industry, particularly in training and operational capacities, remains minimal. This is attributed to a blend of cultural, social, and institutional obstacles such as gender stereotypes, discrimination, and absence of tailored policies and initiatives to bolster women's progress (ILO, 2018; UN Women, 2019). The enduring gender disparities within the maritime industry of Tanzania serve to restrict the access of women to opportunities for education, work, and progression in their careers. Systematic review of workforce demographics reveals less than 5% female participation (Tanzania Ports Authority, 2020). The situation caused by barriers include gender biases, lack of mentoring, and limited access to training (Maseko, 2018). Addressing gender disparities is crucial for optimizing human resource utilization and enhancing sectorial growth (ILO, 2021). This article seeks to evaluate the current status of women's engagement in the Tanzanian maritime sector, particularly the involvement in short course training.

LITERATURE REVIEW

2.1 Overview of Maritime Sector

The transport sector includes all forms of transportation—land, air, and sea—and is vital for economic development and connectivity. It encompasses various modes such as road transport, aviation, railways, and maritime transport (World Bank, 2019). Maritime sector encompasses industries involved in the transportation of goods and people via sea routes. This includes shipping companies, port operations, and maritime logistics. The sector plays a crucial role in global trade, with approximately 12 billion tons of goods transported by sea annually (IMO, 2019).

Gender disparities refer to the differences in treatment or outcomes between men and women across various contexts, including employment, education, and health. In the maritime sector, these disparities manifest in various forms, such as unequal pay, limited career advancement opportunities, and lack of representation in leadership roles (UN Women, 2020).

2.2 Overview of Global Research on Gender Disparities in Maritime Sectors

Global studies reveal that women constitute only about 29% of the workforce in the maritime industry, with even fewer serving as seafarers (approximately 2%) (IMO, 2019). Countries like Norway has seen increased female representation in shipping companies due to targeted training programs and gender-inclusive policies (ILO, 2021). In contrast, Tanzania still faces challenges such as gender stereotypes and cultural barriers that hinder women's full participation Study conducted by (Iakovaki and Gota, 2023) on gender diversity in maritime sector indicated that among the root causes of the low participation of women in shipping is male domination. According to the European Community Ship Owners' Associations (ECSA). Since there are so few women working in the industry, work at sea is often perceived as a job for boys and men. Ships are closed communities and, in most cases, serve as a seafarer's home as well as a workplace. Similarly, Fidan et al (2020) study on gender discrimination among maritime students shows that the maritime sector is one of the sectors considered to be more prevalent in stereotypes of gender roles. Hence highlights a significant gender gap that needs addressing through policy reforms and focused initiatives.

2.3 Scope and Significance of Women's Involvement in maritime sector

Training programs aimed at enhancing women's skills in the maritime industry are essential for promoting gender equality. Initiatives like the "Mentors to Mentees" program in Tanzania provide mentorship and training to women seeking careers in maritime fields. Such programs have shown effectiveness in increasing women's participation and leadership within the sector (Pike et al., 2015; International Day for Women in Maritime). Research indicates that women in Tanzania's maritime sector face significant challenges in accessing education and training opportunities. According to Mkama (2016), maritime education institutions in Tanzania have historically been male-dominated, with limited enrollment of female students. This gender imbalance is evident in the low number of female graduates from maritime academies. For example, the Dar es Salaam Maritime Institute reported that less than 10% of its students were female in 2018 (Dar es Salaam Maritime Institute, 2018). In operational roles, women are also underrepresented in the Tanzanian maritime sector. The International Labour Organization (2021) highlights that women occupy less than 5% of seafaring positions. This underrepresentation extends to leadership roles, with very few women holding senior positions in maritime companies. A study by Kitada (2013) found that cultural norms and gender biases contribute to the limited presence of women in operational capacities. Women have begun to occupy leadership and operational roles within the maritime industry; however, significant gaps remain. Case studies highlight successful female leaders who have navigated challenges to achieve prominent positions. For instance, women in Tanzania have contributed significantly to maritime safety and security initiatives through their involvement in various training programs (Kitada, 2013).

2.4 Main Obstacles and Hindrances Encountered by Women

The first barrier for women seafarers is culture embedded in occupation. Kitada (2020) studied the occupational culture of seafaring and concluded that masculine norms and values are reflected in the work culture on board ships. Seafaring jobs are often assumed to require muscles to operate equipment on board. According to the research (Kitada 2010; Chan 2019), women seafarers noted that even though technology is advanced, using muscle power demonstrates the traditional masculine value of labour and privileges the employment of strong and tough men.

Cultural norms in Tanzania significantly impact women's participation in the maritime sector. Gender stereotypes and societal expectations often discourage women from pursuing careers in this field. According to Mkama (2016), there is a prevailing belief that maritime jobs are too demanding for women, which limits their participation. Additionally, family responsibilities and traditional gender roles further restrict women's ability to engage in maritime professions (Pike et al., 2015).

Institutional barriers also play a critical role in hindering women's participation. A lack of gender-inclusive policies and mentorship programs in maritime institutions exacerbates the gender disparity. The International Maritime Organization (2019) reports that maritime training programs often lack provisions to support female students, such as scholarships and flexible training schedules. Furthermore, harassment and discrimination in the workplace create an unwelcoming environment for women (ILO, 2021). Kormych (2020) study revealed that "Specific, obligatory agreements on work in maritime industries do not provide sufficient regulation environment for achieving the aim of integration of women, as evidenced by women's' low percentage in the industry. Study by Grimett (2024) exposed the overwhelming influence of gender stereotypes on the ability of women to progress within male-dominated sectors and the prevalence of gender-based placement within maritime roles, where women were still primarily lowered to support and junior positions, despite their dedication to their careers.

2.5 Specific Studies Focusing on Tanzania and Similar Contexts

Research specific to Tanzania indicates that female seafarers face numerous challenges, including inadequate maternity rights, pay gaps, and limited career advancement opportunities (Mkama, 2016).

These studies emphasize the need for further investigation into regional disparities within East Africa. Despite some progress, significant gaps remain in understanding how gender-inclusive policies impact women's participation in the maritime sector. Future research should focus on evaluating the effectiveness of current training programs and policies aimed at promoting gender equality within Tanzanian maritime contexts (UNCTAD, 2020). Additionally, exploring the socio-cultural barriers that persist will provide further insights into enhancing women's roles within this industry.

3 RESEARCH METHODOLOGY

Data were obtained from National Institute of Transport cargo tallying for international shipping and Bandari College folk-lift operators' short courses 2018 to 2023. The aim is to spot if there was existence of gender disparities in the maritime sector on aforementioned courses. The data were analysed using both descriptive and inferential Analysis such as Z-Scores and T-Test and visualization of result trend.

4 STUDY FINDINGS

4.1 Analysis of Gender Disparity in Folk-lift Operators Student Enrolment

This analysis examines the gender disparity in student enrolment for fork lift operators short courses over the academic years from 2018-2019 to 2022-2023. The data indicates significant differences in the number of male and female students enrolled each year.

4. 1.1 Descriptive Statistics

The statistics as shown in table 1 indicates that: Overall Enrolment: Male students consistently outnumber female students in all academic years. There was a significant increase in female enrolment in 2022-2023 compared to previous years. Male enrollment peaked in 2022-2023, showing a consistent upward trend over the years.

Table1: Fork lift Operators participant statistics

Academic Year	Female	Male	Male-to-Female Ratio
2018-2019	12	272	22.67
2019-2020	56	289	5.16
2020-2021	41	634	15.46
2021-2022	34	582	17.12
2022-2023	115	1033	8.98

Summary Statistics 2024

Descriptive statistics shown in table 2 and figure1 indicates that, the mean number of female participants is 51.6, while the mean for male participants is 562. The total average number of trainees is 613.6. The standard deviation indicates variability in the number of participants, with males showing greater variability.

Table 2: Descriptive statistics for folk lift operators' courses 2018-2023

CATEGORY	Female Participants:	Male Participants:	Male-to-Female Ratio:
Mean:	1.6	562	13.88
Median	41	582	15.46
Standard Deviation:	7.86	308.39	7.23

Summary Descriptive statistics 2024

Figure 1: Descriptive Fork lift operators courses 2018-2023 visual presentation

Inferential Analysis for forklift operator's gender disparity

The data reveals a consistent gender disparity in the maritime sector, with significantly more male participants than female across all years. The male-to-female ratio highlights this disparity, with ratios consistently favouring males.

The inferential analysis supports these findings, showing statistically significant differences between male and female participation rates.

T-Test:

T-statistic: Indicates the difference between male and female groups.

P-value: Determines statistical significance (typically $p < 0.05$).

Visualization of Variance and Skewness

Variance: The variance for female participants is significantly lower than that for male participants, indicating that the number of male participants fluctuates more across the years. Higher variance in male participants indicates greater variability compared to females

Skewness: The skewness values suggest that the distribution of participants is positively skewed, particularly for females, indicating a longer tail on the right side of the distribution. Positive skewness in male-to-female ratio suggests a longer tail on the right, indicating more years with higher ratios.

The t-test results indicate a statistically significant difference in the means of male and female participants, with a p-value of 0.020728952051337485

and a mean difference of 510.4. The 95% confidence interval for the difference in means is (235.9708815449789, 784.829118455021), suggesting that male participation is significantly higher than female participation in the maritime sector

The visualizations for variance, skewness, and the normal and t-distributions have been successfully generated. Let's review these visualizations to understand the data better:

Variance and Skewness: These bar plots illustrate the variability and distribution shape of the number of participants.

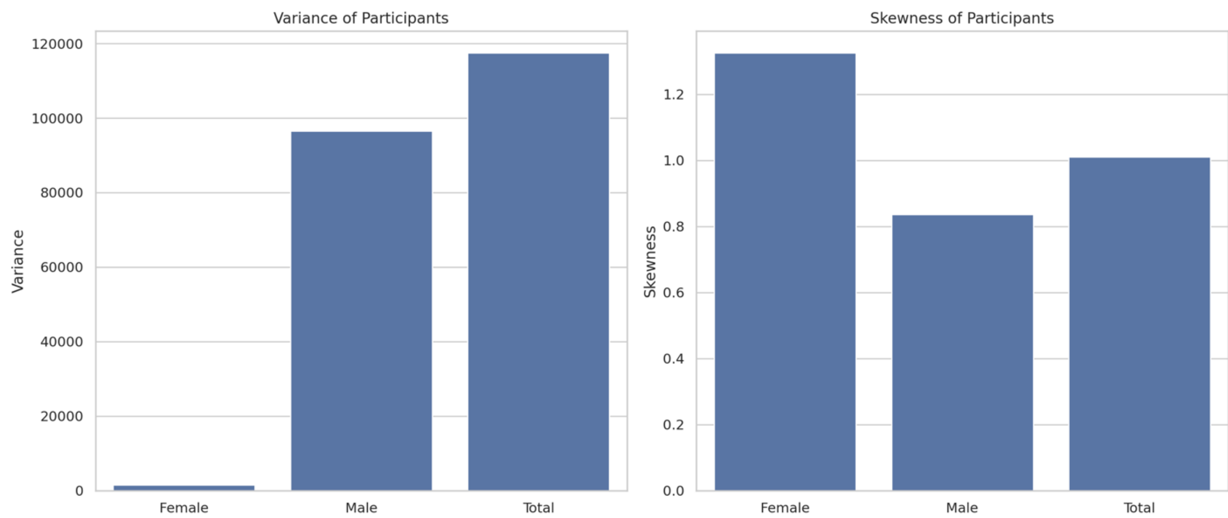

Figure 2: visual presentation of fork lift operators courses inferential results

Normal Distribution (Z-table): This plot shows the standard normal distribution, highlighting the critical region for a 95% confidence interval.

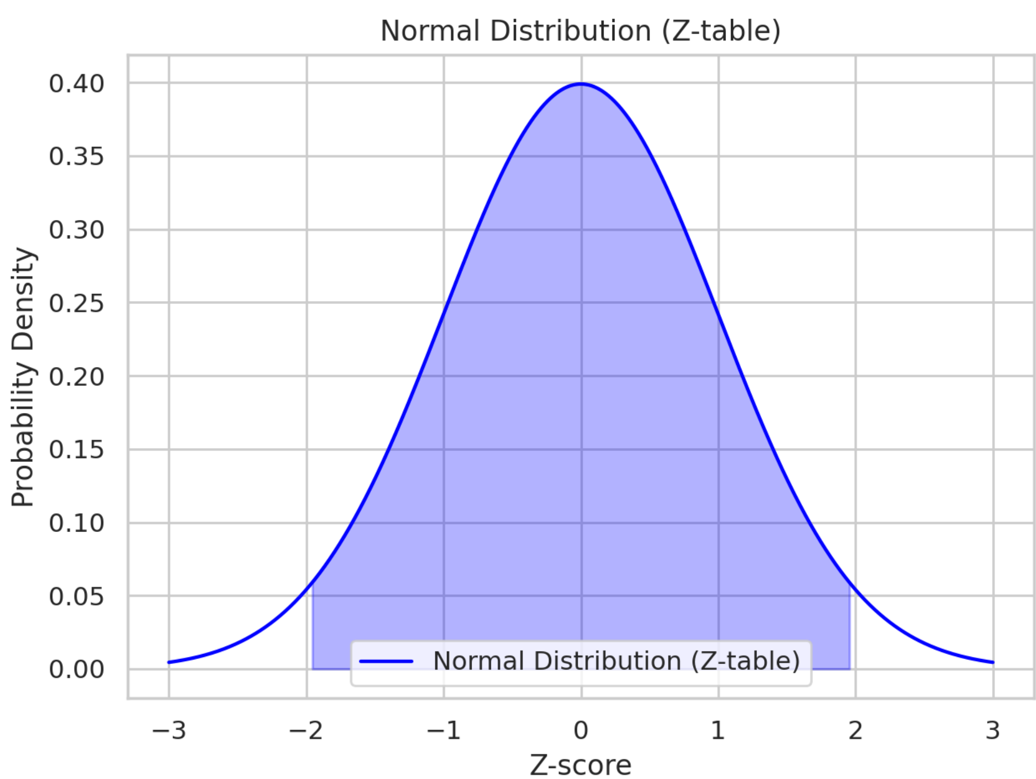

Figure 3: Normal distribution Z-score for fork lift operator's course 2018-2023

T Distribution (T-table): This plot represents the t-distribution, which is used for small sample sizes and unknown population standard deviations.

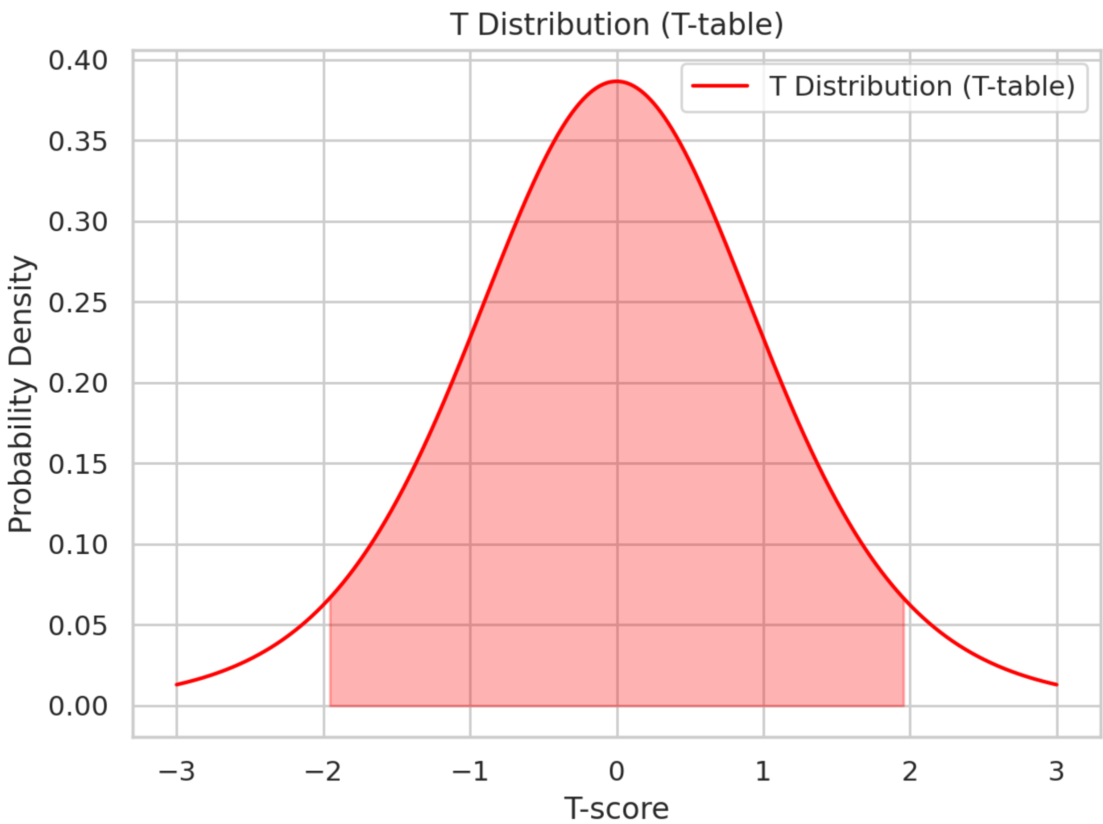

Figure 4: T-distribution for Forklift operator course 2018-2023

The analysis as presented in figure 2-4 reveals a persistent gender disparity in student enrollments for fork lift operator's short courses, with male students significantly outnumbering female students. However, the gap appears to be narrowing slightly, particularly with the noticeable increase in female enrollment in the 2022-2023 academic year. Continued monitoring and targeted interventions may be required to achieve a more balanced gender representation: There is a significant gender imbalance in the maritime sector across all academic years. The average percentage of female students is only 8.41%, indicating a male-dominated field.

Trend in Female Participation: While the number of female students fluctuates over the years, there's a notable increase from 12 in 2018-2019 to 115 in 2022-2023. This suggests some progress in female representation, albeit slow.

Male-to-Female Ratio: The male-to-female ratio varies considerably across years, from a high of 22.67 in 2018-2019 to a low of 5.16 in 2019-2020. The average ratio is 13.878, meaning for every female student, there are about 14 male students.

Overall Growth: Both male and female student numbers have generally increased over the years, with 2022-2023 showing the highest numbers for both genders. This indicates overall growth in the maritime education sector.

Statistical Significance: The t-test results (t-statistic: -3.645, p-value: 0.0065) indicate a statistically significant difference between the number of male and female students. The low p-value (< 0.05) suggests that this gender disparity is unlikely to be due to chance.

Variability: There's considerable variability in the data, especially for male students (std dev: 310.67) compared to female students (std dev: 38.82). This suggests more consistent, albeit lower, female participation rates

4.2 Analysis of Gender Disparity in cargo tallying Student Enrollment

4.2.1 Descriptive Statistics

The calculated cargo tallying student enrolment descriptive statistics were calculated and the results are presented in table 3:

Table 3: Descriptive statistics for cargo tallying student's enrolment 2018-2023

Statistic	Number of Trainees	Male	Female
Count	5	5	5
Mean	163.4	101.8	61.6
Standard Deviation	122.22	83.38	40.07
Minimum	55	28	27
25th Percentile	104	50	40
Median	111	71	54
75th Percentile	180	123	57
Maximum	367	237	130

Summary Statistics 2024

4.2 2 Inferential Statistics for cargo tallying enrolment

Z-Scores for cargo tallying enrolment

The z-scores for the number of trainees, male, and female participants in cargo tallying course 2018-2023 presented in Table 4.

Table 4: Z-scores for cargo tallying enrolment 2018-2023

Category	Z-Score Values
Number of Trainees	[0.15, 1.86, -0.54, -0.48, -0.99]
Male	[0.28, 1.81, -0.69, -0.41, -0.99]
Female	[-0.13, 1.91, -0.21, -0.60, -0.97]

T-Values for cargo tallying enrolment

The t-values for comparisons between groups are presented in table 5.

Table 5: T-values for cargo tallying enrolment 2018-2023

Comparison	T-Value
Male vs Female	[0.97, 0.36]
Number of Trainees vs Male	[0.93, 0.38]
Number of Trainees vs Female	[1.77, 0.11]

Summary Statistics 2024

4.2.3 Visualizations for cargo tallying enrolment

The following visualizations in figure 5 present the variance and skewness of the data for cargo tallying 2018-2023.

Variance: Indicates how much the data points differ from the mean; higher variance in "Number of Trainees" suggests greater variability compared to gender-specific counts.

Skewness: A positive skewness indicates that there are lower values (i.e., fewer females), while negative skewness indicates a tail on the left side.

Variance and Skewness: Trainees: 14938.30, Male: 6951.70, Female: 1605.30

Trainees: 1.04, Male: 0.92, Female: 1.16

Inferential Analysis: 0.9717404680371136, 0.35963979935805784

Visualization: The data shows considerable variability in trainee numbers across years, with male participants generally outnumbering females. However, the t-test (p-value > 0.05) suggests no statistically significant gender disparity.

Visualizations: Variance and skewness are visualized in the chart below:

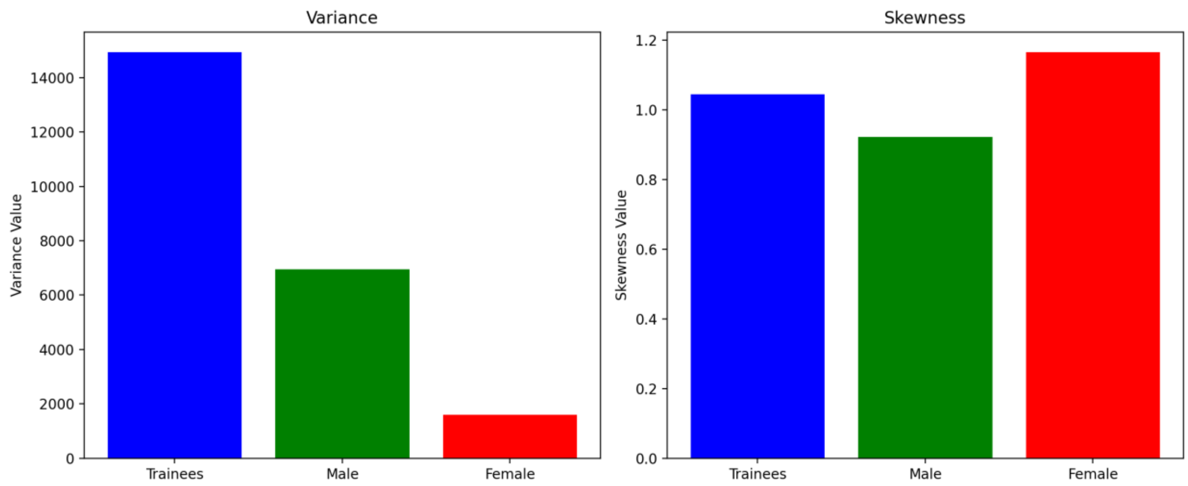

Figure 5: variance and skewness for cargo tallying student's enrollment 2018-2023

The data indicates a consistent gender disparity in the maritime sector, with males generally outnumbering females. However, the lack of statistical significance in the t-test suggests that this disparity may not be as pronounced as it appears. Further investigation with a larger dataset could provide more insights.

The analysis provides insights into gender disparities in the maritime sector's training programs in Tanzania, highlighting significant differences in participation rates between male and female trainee.

5 CONCLUSION

The maritime sector, as represented by this data, shows a clear and statistically significant gender imbalance favoring male participation *such as folk lift operators' courses which are male-dominated careers.* While there are signs of improvement in female representation in cargo tallying courses, particularly in the most recent academic year, the disparity remains substantial. The difference may be due to the fact that forklift operators considered to be men's job while cargo tallying considered to be lesser men's job. The sector faces challenges in achieving gender equality, and more targeted efforts may be needed to encourage and support female participation in maritime education and careers. The overall growth in student numbers suggests an expanding field, which could present opportunities for improving gender balance in the future

6 RECOMMENDATIONS

For the maritime sector to foster gender parity and inclusiveness

Policy Interventions

To foster gender parity in the Tanzanian maritime sector, it is essential to implement gender-inclusive policies. The government and maritime institutions should establish scholarships specifically for women and create mentorship programs to support female students and professionals (UNCTAD, 2020). Additionally, policies addressing harassment and discrimination in the workplace should be enforced to ensure a safe and supportive environment for women (ILO, 2021).

Educational Reforms

Reforming maritime education to be more inclusive is crucial. Maritime academies should actively recruit female students and provide training that accommodates their needs. For example, offering flexible schedules and on-campus childcare can help women balance their family responsibilities with their education (Kitada, 2013). Furthermore, incorporating gender studies into the maritime curriculum can raise awareness about gender issues and promote a more inclusive culture (Pike et al., 2015).

Community and Cultural Engagement

Engaging with communities to challenge and change cultural norms is essential for increasing women's participation in the maritime sector. Awareness campaigns that highlight the contributions of women in maritime roles can help shift societal attitudes (Mkama, 2016). Collaborating with community leaders and organizations to promote gender equality can also foster a more supportive environment for women pursuing maritime careers (WIMA, 2020).

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Paper 17:

Save Life! Optimization of Dynamics for Pharmaceutical Distribution Performance

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ABSTRACT

Optimization of dynamics determining distribution performance of pharmaceuticals is vital in realizing Sustainable Development Goal (SDG) number 3 which insists on provision of good health and well- being to the society. This study was designed at unfolding diverse factors that influence the distribution performance of pharmaceuticals in the Medical Stores Department (MSD) of Tanzania. This study utilized cross-sectional survey strategy in gathering data from 67 staff members working in the MSD using census approach. A structured questionnaire facilitated the collection of quantitative data which were later analyzed using ordinal logistic regression. The results disclosed that all variables of inventory management, information management system and facility location positively and significantly govern the distribution performance and henceforth rejection of the foreseen null hypothesis. This study realized dynamics inducing distribution performance of pharmaceuticals but did not cover the role of 3PLS and 4PLS in enhancing the same, and hence, an imminent study ought to seal this gap. Also, having grasped management information system is of strategic pillar, then it would sound imperative to analyze the application of artificial intelligence in distribution system performance. This paper assimilates the concept of sub aspects of supply chain management in footings of distribution management and that of pharmaceuticals and hence multidisciplinary value addition. Also, this study illustrates the applicability of strategic choice theory in strategic management in developing countries through pertinent choice of inventory management, information management system and facility location in triumphing SDGs.

1 INTRODUCTION

1.1 Background to the Problem

The pharmaceutical sector has grown for many years worldwide, and this has impacted the ever-growing accelerating distributions and logistics challenges (Aytekin et al., 2023; Wu and Dong, 2023; Yaroson et al., 2021). The distribution system of pharmaceutical items is featured by dynamics (Diaz et al., 2023). This intricacy is regarded one of the primary hurdles to the performance and efficiency of a pharmaceutical supply chain. Gruji c et al. (2020) revealed that glitches of procurement and distribution significantly contribute to the overall inefficiencies of health systems in different nations by reducing complaints of limited access to necessary medications (Mackintosh et al., 2018). Increased customers' needs force most of the business and non-business sector to optimize distribution process in order to mend customer service through product quality and availability while minimizing the logistics-related costs (Purvis et al., 2021; Tukamuhabwa et al., 2011). United Nations Sustainable Development Goal No 3 emphasized on the need to ensure good health and well-being to the public through accessibility of health supplies (Zimon et al., 2020). Globally, a well-planned and executed distribution system keeps medicines in good condition throughout the distribution process, minimizes losses from spoiling and expiration, maintains accurate inventory records, keeps medicines in a steady supply, rationalizes medicine storage locations and guarantees that transportation facilities are used (Supply, 2012). On the other hand, effective and efficient flow of pharmaceuticals depends on the distribution management for ensuring the key objective of distribution management of maintaining a steady supply of pharmaceuticals (Hou et al., 2017; Supply, 2012). The World Health Organization has primary functions that include increasing access to key pharmaceuticals and other medical developments as well as collecting, evaluating and using critical information (Githendu et al., 2020).

In developed countries, effective distribution of pharmaceuticals depends on several dynamics, including logistics system in place, good inventory management, effective communication and coordination between the pharmaceutical manufacturers, distributors and health centers (Gruji c et al., 2020). The proper medications may be made available at the optimal time, in the optimal quantity and at the right place with the help of effective management information system (Wang et al., 2024). This helps to prevent stock outs and overstocking, which can lead to wasted resources and decreased patient access to necessary medications. Good inventory management allows the pharmaceutical distribution system to run more successfully and efficiently (Volland et al., 2017). Equally important, a reliable information management system is vital for coordinating the distribution network (Aytekin et al., 2023). The information system tracks inventory levels, buy and sale prices and the distribution and reception of medications using forms and procedures. The system could be manual, automated or both (Supply, 2012). Effective information management systems can track the movement of drugs from different distribution centers, monitor their storage and handling and ensure that they are not expired or contaminated. Optimal information management practices can improve the safety, efficacy and efficiency of pharmaceutical distribution (Yousefi and Alibabaei, 2015).

Also, the location of the facility should be strategically chosen to minimize transportation costs and time while also ensuring that the facility is easily accessible to the target customer base (Savadkoohi et al., 2018). Having multiple facilities in different locations can also help to ensure continuity of supply in the event of disruptions at a single facility. Finally, the efficiency and efficacy of pharmaceutical distribution can be greatly impacted by the placement of distribution centers (Jung et al., 2021). Therefore, important distribution components are optimized to boost cross-regional commerce growth, establish material time- space matching, increase flowing material values and implement data collection and information management systems. A sustainable material flow system that accommodates competition enhances social and economic development in a community (Hou et al., 2017). Adopting system inventory management best practices in the health sector can enhance donor collections, component manufacturing and the inventory that a hospital and blood supplier must maintain on hand in order to satisfy patient requirements through real-time inventory management, information management systems and demand forecasting. The majority of Canadian public sectors struggle with inventory control (Stanger et al., 2012).

Despite major international finance efforts, emerging African countries, particularly those in sub-Saharan Africa, are concerned about their healthcare systems, notably the availability of pharmaceuticals (Yenet et al., 2023; Mackintosh et al., 2018). There are complaints that in Tanzania, the distribution of pharmaceuticals is not promising and hence leads to unsatisfactory customer satisfaction, contrary to the current global move of saving lives through proper medication (Masui, 2024; Ruhago et al., 2022). The current distribution networks in Tanzania and Kenya have negative impact on general community access to high- quality medications and subsequent health outcomes (Mackintosh et al., 2018). A study by Mahuwi and Israel (2024) conducted in Tanzania in other settings described the usage of electronic means in the management of pharmaceuticals as crucial. Tanzania established the Medical Stores Department (MSD) as an autonomous institution under Act of Parliament No. 13 of 1993 [CAP 70 R.E. 2002], which is in charge of, among other things, the distribution of health goods. The MSD aims at guaranteeing that medications and medical supplies of adequate quality are always available to all healthcare facilities in the entire nation (URT, 2023). The distribution process begins at MSD Headquarters Central Warehouse and extends to the last mile (individual health institutions) via MSD zonal stores and sales stations. It should be taken into note that the MSD in Tanzania is a giant organization which affects the global supply chain as the drugs are procured from different manufacturers and wholesalers located from different nations worldwide (URT, 2023).

Research has shown that most low- and middle-income countries' pharmaceutical and health commodity distribution systems face difficulties with inventory management, information management, projections and preservation (Githendu et al., 2020). Specifically in Tanzania, the MSD distribution system is featured with unsatisfactory performance with frequent stockouts in health facilities (HSSP, 2015). Inventory management, information management system and facility location are very vital for the distribution performance in supply chain management system (Meredith and Shafer, 2023; Rushton et al., 2022). Given that MSD is a life-saving organization that works to guarantee the timely distribution of medications throughout the nation, it is crucial to identify the precise cause of the subpar performance in the context of developing nations. This can be done by concentrating on the locations of facilities, information management systems and inventory management in Tanzania's pharmaceutical distribution system, as well as by setting a precedent for MSD users through this rigorous research. Therefore, based on the background of this study, the main objective was to establish the dynamics that need to be optimized for the distribution performance of pharmaceuticals in Tanzania. Moreover, in order to achieve the main objective, the following questions were addressed in this study;

RQ1. What are the inventory management dynamics that optimize distribution performance of pharmaceuticals?

RQ2. How do information management system dynamics optimize distribution performance of pharmaceuticals?

RQ3. Do facility location dynamics optimize distribution performance of pharmaceuticals?

1.2 Research gap

Pharmaceuticals are needed to treat and prevent human diseases (Ghadge et al., 2023). The challenge of drug stockout resulting from an unsatisfactory distribution management system has been persisting in Tanzania, leading to unnecessary deaths (Elias and Mushi, 2024; Mollel et al., 2024). Shortage of pharmaceutical requirements in healthcare facilities due to unsatisfactory distribution contravenes the UN SDG Number 3 which encourages good health and well-being of citizens. The Government of Tanzania took initiatives to establish MSD to ensure adequate distribution management of pharmaceuticals to health facilities (HSSP, 2015). Despite the adopted initiatives, the

Controller Auditor General (CAG) report of 2020/2022 noted the continuity of unsatisfactory supply to the health facilities featured with stock outs and slow moving of short-life-span drugs, which in turn affect the health of the public. It was also reported that MSD managed to fulfill only 34% of total customers' orders for 43,180,884 products, leaving 66% unfilled resulting into inadequate customer service (CAG Report, 2020/2021). The CAG report has recommended for the need to establish effective distribution management of pharmaceuticals. Moreover, inventory management and information management system are documented elsewhere as key dynamic factors for the distribution performance (Meredith and Shafer, 2023; Rushton et al., 2022). Furthermore, shortage of pharmaceuticals normally results in loss of life in Tanzania (Sequeira D'Mello et al., 2020; Kazibwe et al., 2022). Therefore, having unsatisfactory distribution performance of pharmaceuticals in Tanzania compelled for the need for scholarly studies on how to optimize dynamics for the distribution performance in the context of Tanzania.

2 LITERATURE REVIEW

2.1 Theoretical review

In the present inquiry, the strategic choice (SC) theory was used to shed light on the factors that influence pharmaceutical distribution. SC theory initially was proposed by Child (1972). According to Child, SC theory proposes that individuals' decisions such as those from top management about how to respond to external conditions like change in technology, location of facilities and availability of physical resources are key performance determinants. SC theory distinguishes one organization from another by emphasizing the significance of identifying, explaining and forecasting the factors of organizational success as well as understanding why some organizations outperform others (Bowersox et al., 2020). These strategic decisions were taken as part of a company-specific learning process. SC theory focuses on addressing strategic issues of the organizations (Luu, 2023). Furthermore, SC is documented as a tool for the success of the organization targets (Ali, 2024). Better planning is very important, but SC always demands re-examination (Born, 2024). Management of pharmaceuticals distribution involves strategic decisions in order to attain long-term plans of the firms especially in terms of customer satisfaction (Guru et al., 2023). Strategic decisions of pharmaceuticals distribution involve inventory management, information management system and facility location, which fall under strategic decision in terms of choice making while centering on the strategic orientation of the firms (Meredith and Shafer, 2023).

SC theory which specializes in best choice making is capable of elucidating the most suitable supply chain models that result in organizational performance (Tiwari et al., 2023). Furthermore, the theory holds that sustainability of the organizations relies on how decisions are strategically made while taking care of the surrounding business environmental dynamics (Malik and Bebenroth, 2022; Hitt et al., 2021). The theory has further proved to be relevant in determination of personal values (Lichtenstein et al., 2022) and hence had to be conducted and tested in the context of distribution performance of life-saving commodities with emphasis on inventory management, information management and distribution facility location using MSD.

2.2 Empirical literature review

In order to think of and come up with the proper direction of this academic investigation, diverse findings were empirically analyzed and the gaps gained were used as the basis of seeking answers to undressed concerns as follows:

2.2.1 Inventory management of pharmaceuticals.

Gabriel (2020) conducted a study on the rationale of inventory control systems in Tanzania's public health sector using descriptive research methodology and a purposive sample technique to identify representatives. Data were obtained via questionnaires. The findings suggest that there are weaknesses in the inventory management system utilized by the organization on the issues facing the system in MSD. In this study, issues concerning managing stock level and outbound operation in physical inventory management on performance of an organization were not covered, so this study intended to find more information on those indicators. The study of Gabriel (2020) was descriptive and hence failed to explain the root cause of the performance using cause–effect relationship for wide generalizability. Nkuba (2019) conducted a study on pharmaceutical inventory management practices on service delivery using qualitative research design aided by the interview method to collect data. The findings revealed that Nyamagana Hospital uses both manual and computerized inventory recording systems. Knowing that MSD supplies pharmaceuticals to the entire country prompted for survey design aided with the usage of a questionnaire for wide generalizability. Yornu and Ackah (2020) carried out a study on the affiliation of efficacy of Inventory and Stores Management on Turnover of Central Medical Stores and realized that inventory management strategies have a positive impact on inventory turnover. The study of Yornu and Ackah (2020) was conducted in Ghana while focusing on turnover. MSD as an institution specially designated to render service to the public of Tanzania, and it is more of service delivery rather than turnover concerns and hence prompted for the same aspects to be tested in the context of public service delivery in Tanzania while focusing on customer satisfaction of MSD distribution performance.

2.2.2 Information management system of pharmaceuticals.

Layti et al. (2020) conducted a study on logistics information systems versus traceability of pharmaceutical products hospitals. A questionnaire was used to collect data on reverse logistics traceability of pharmaceutical products. The results of analyzed data reveal that more than 90% of health institutions utilize basic/office automation combined manual systems for controlling their drug stockpiles, resulting in low traceability. Moreover, while the study of Layti et al. (2020) focused on reverse logistics, the undertaken study focused on the forward logistics movement of the drugs centered on order management during physical distribution management. Similarly, Yornu and Ackah (2020) found that inventory information management has a large effect on demand forecasting and a direct effect on turnover, but their study was done in the context of another developing country in Africa. Also, Oraini (2024) conducted a study on the role of information systems on performance in the pharmaceutical sector and revealed that the current information system directly effects the performance of pharmaceutical enterprises in the Middle East, which has eventually affected how decisions are made within the firms. The scope of the study focused on general contribution of information management on firm performance and not specifically on the effectiveness of distribution of pharmaceuticals toward firms' performance, and hence, the study aimed at filling this scholarly gap. Firms' performance is a function of both logistic input and output. Based on the contextualized problem of this study, it was specifically focused on analyzing distribution of pharmaceuticals and hence systematically stuck on logistic output as prompted by the study problem.

Sehrish (2020) conducted research on the impact of integrating information systems on firm performance by referring the Platinum Pharmaceuticals Ltd. as a study area. The study examined the impact of procurement criteria in regards to information systems on the corporation's overall performance. A combination of research methods was employed to steer the study, and data were gathered utilizing a questionnaire. The integration of the information system in the procurement department has a beneficial impact on the annual return on investment of Platinum Pharmaceuticals Ltd., according to the data system results. The study was limited on contribution of the information system in inbound logistics toward firm performance. This study aimed to cover the relationship between information management and outbound operation toward firm performance in terms of customer care.

Furthermore, the primary goal of the selected firm was manufacturing while MSD is a non- manufacturing organization and thus this study called for wide generalization of the findings.

2.2.3 Facility location for distribution performance of pharmaceuticals.

Onstein (2021) conducted a study on factors influencing physical distribution structure design. The study's findings revealed that the number of major facilities has increased over time, as has their contribution to the total developed surface area. As a result, large facilities play a significant role in developing spatial planning policies. Results also show factors that may contribute to the decision whether or not to relocate facility within the current region. The third question identifies three factors that determine companies' distribution structure design. The study explained factors influencing physical distribution structure design but did not state the contribution of location of distribution facility on the performance of a pharmaceutical industry. Furthermore, another scholar discovered an impractical warehouse site; the presence of redundant operations reduces distribution efficiency (Gabriel, 2020). Gabriel's (2020) study was observational, and thus, it failed to clarify the core cause of performance utilizing cause-and-effect relationship.

The study conducted by Kramer et al. (2019) on rich vehicle routing with due consideration to auxiliary depots and delivery speculations in pharmaceutical distribution attempted to show and clarify a routing challenge encountered by a 3PL provider in distribution of pharmaceutical supplies to health units. The study results reveal current routing decision resulted in unsatisfactory utilization of hospital medical warehouses, mismatch between demand quantity and supply quantity at the expense of distribution costs and unfair geographical proximity of the health centers and the distribution points. Routing is a subset of distribution management. Effective routing depends on the nature of facilities location and hence prompted for the need to look at the location of distribution facilities of MSD which serves as depots in Tanzania.

Sanchez-Sierra et al. (2018) conducted a study on facility location model with inventory transportation and management costs. The study's scope was to lay out an integrated inventory facility location model that minimized distance, transportation and inventory management expenses. Following analysis, the location of the suppliers and distribution facility was selected using only the basic model. By re-estimating (revising) the location of the distribution facility, it was found that the optimal location for distribution facility is minimized and also transportation cost in the revised location was minimized. The study covered effects of facility location on upstream transportation costs, but it did not explore downstream transportation costs.

2.3 Hypothesis formulation

Having reviewed theoretical and empirical literature reviews, it remained very important to postulate some hypotheses for scientific hypothetical deductive testing of the existing problem as follows while focusing on three key aspects.

Empirically, inventory management accounts for the firm's performance (Rashid and

Rasheed, 2023). Equally important inventory management is closely linked with total quality management and hence better performance of the firms (Mahajan et al., 2024). However, the study of Mahajan et al. (2024) focused on the overall performance of the firms in other countries apart from Tanzania, while this study is focused solely on the distribution performance. Focusing on the distribution performance might be of more advantage because in business management, there is a need for understanding the most beneficial area that contributes more to the performance. Furthermore, the limitations of the study area of Rashid and Rasheed (2023) called for the need of related studies to be conducted in other settings for wider generalizability. Equally important is the study of Mahajan et al. (2024) based on the systematic literature review and hence called for the need of quantitative study guided by positivism paradigm. Therefore, based on those arguments, this study postulated Ho 1 to underscore what persists in other context persists in the context of inventory management versus distribution performance of pharmaceuticals in Tanzania?

HO1. Inventory management is not one of the dynamics for distribution performance of pharmaceuticals.

Also, studies conducted in developed countries counted management information system as a key driver for the supply chain performance of firms (Naceur et al., 2024; Rold an Bravo et al., 2023; Harju et al., 2023; Kliestik et al., 2023). However, the level of adoption of technology determines the viability of the use of systems and automation for real-time information use in the business. African countries are lagging behind because of the associated cost (Mwakyusa and Ngwebeya, 2022; Changalima and Ismail, 2022; Smidt and Jokonya, 2022). Interestingly, Ade-Ibijola and Okonkwo (2023) argued that the information system should be adopted in Africa quickly as it is regarded as a tool for alleviating poverty. Due to this debate, the inventory management remained as one of the dynamics worth hypotheses testing for wide generalizability as follows:

HO2. Management information system is not one of the dynamics for distribution performance of pharmaceuticals.

Similarly, facility location is described as one of the key issues for management of activities (Taouktsis and Zikopoulos, 2024; Yunusoglu et al., 2024). However, with the invention of online services aided by Internet, facility location seems not to be a key issue (Rahman and Rahman, 2022). Arguably, facility location remains very vital in the distribution and marketing of physical goods from one point to another one for the accessibility to the user (Nazemi et al., 2022). With the close proximity of the facility location to the customers, there is reduction of transportation cost and hence enriched customer care (Rajak et al., 2018, 2021). Therefore, based on those mixed results, the following hypothesis was postulated:

HO3. Facility location is not one of the dynamics for distribution performance of pharmaceuticals.

2.4 Conceptual framework

Diagrammatic presentation of the relationship of variables showing dynamics that optimize distribution performance of pharmaceuticals was presented. Hereunder, inventory management, information management system and facility location were described as predictor variables assumed for the distribution performance measured in terms of customer care. See Figure 1 to see the relationship and HO1, HO2 and HO3.

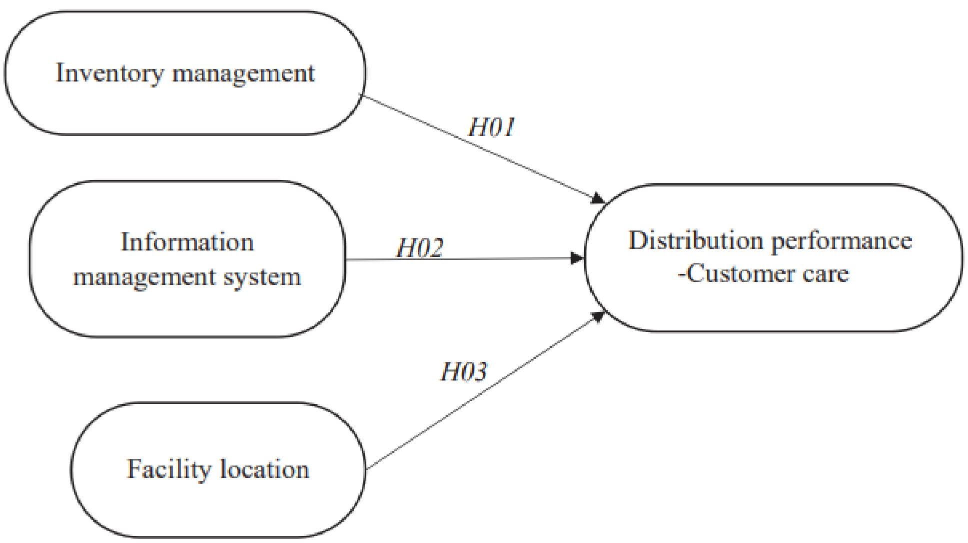


Figure 1. Conceptual framework

Source(s): Adopted from the literature review (2023

3. METHODOLOGY

3.1 Study area

The study was undertaken in Tanzania's regions of Dar es Salam, Dodoma, Mwanza, Mbeya, Kilimanjaro, Mtwara, Tanga and Kagera. The logic behind the choice of these regions is that MSD Headquarters Central Warehouse is located in Dar es salaam and Zonal Warehouses are placed in Mwanza, Iringa, Kilimanjaro, Mbeya, Tabora, Dodoma, Tanga, Mtwara and Kagera (Pyuza et al., 2023; Mbwasi et al., 2023). The operations found in the head quarter and zonal warehouses are the ones associated with physical management of inventories, information management system and facility location decisions accompanying with pharmaceutical distribution of MSD in Tanzania.

3.2 Research strategy

This study opted for a cross-sectional survey research design. In terms of time, data were gathered once there was no requirement for monitoring any temporal changes and therefore the cross-sectional approach. Geographically, the study covered different regions in Tanzania of the country, and hence the survey approach was aided by a structured questionnaire. This study was based on deductive quantitative methodologies due to the utilization of a survey approach. The logical method centered on employing SC theory. Quantitative approach aims to generate and analyze numerical data (Tashakkori and Teddlie, 2021). Furthermore, the quantitative method primarily involves a survey via questionnaires to collect data which are ultimately given in numbers for the application of statistical analysis tools (Creswell, 2021).

The need to study the cause–effect relationship of determination of contributing dynamics of pharmaceuticals distribution on the performance of MSD in Tanzania called for the explanatory-survey design by using those contributing dynamics as an explanatory variable to explain the distribution performance as an outcome variable. The strategy centered on collecting numerical data from the sampled personnel of the directorate of distribution management present in the MSD zonal offices across the country.

3.3 Sampling and data collection strategies

The researcher gathered information from the staff members who are working in the warehouses that facilitate distribution management of pharmaceuticals in MSD. Therefore, having a total population of 67, it is then realized that the target population of this study was 67 respondents. Having realized that, only 67 are available for inquiring information; the census method was espoused for complete enumeration as sample size. Census tends to be more representative and hence eliminates biasness (Walker, 2023). Other scholars in the discipline of supply chain management that utilized a small sample size and hence used a census methodology are Kimario and Mwagike (2024) with 55 enterprises, Kimario and Kira (2023) with 55 firms and Kamau (2013) with 56 firms. Moreover, three of the targeted respondents did not react. The reaction level obtained was adequate for this investigation as it has been highlighted as a reaction level of more than 70% is acceptable (Mugenda and Mugenda, 2003). Staff members from the warehouses falling in the physical distribution management were targeted because of being at the position to explain how inventory management, distribution information management system and facility location decision affect the performance of

MSD outbound logistic operations in terms of customer's satisfaction as they are the ones receiving complaints from the customers and handling them.

The usage of customer's complaints to index customer's satisfaction serves an extra advantage identifying the very specific concerns while providing prompt feedback for upgrading (Rane et al., 2023). Data for this study were primarily collected using the questionnaire. Furthermore, quantitative data were collected via a survey approach using standardized questionnaires. For reliability purposes, questionnaires were exposed to a pilot of 11 respondents, thereby meeting the minimum suggested sample size of 10 as proposed by Creswell (2021). This study focuses on collecting quantitative data from employees operating in warehouses of the physical distribution management of MSD.

3.4 Operationalization of variables and data analysis

The operationalization of variables has helped to understand the construct variables of the primary independent variables as well as assigning them numbers through coding so that they could be conveniently be processed by computer. The following builds were used to implement inventory management as the explanatory variable: inventory management in terms of issuing of stock (acceptance of customer requests, selecting what is under request and handing them to who has requested them), stock levels (indispensable inventory, which refers to the optimal quantity of items to be maintained for the smooth functioning of the firm) and safety stock (safety stock is a further quantity of items kept in the warehouse). The following components were used to operationalize the explanatory variable: inventory accessibility (access to each product's current location, available stock, relevant purchase and orders), order management (receiving, tracking, fulfilling and shipping an order to a customer), relationship (handling of different actors of distribution management of pharmaceuticals from headquarters down to the zonal warehouses and eventually the health facilities) and e-information sharing (sharing of inventory details via online system using electronic networked devices). Also, facility location was operationalized as proximity to the customers (nearness of the warehouse to the hospitals/health center), routing decisions (creation of the most cost-effective path whilst minimizing travel time to stretch on loading and offloading plugs) and cost (refers to both standing and operational expenses associated with positioning of the warehouse at a certain point). Furthermore, the designated constructs were hypothesized using a five-point ordinal scale. This facilitated the understanding of the attitudinal expression in the form of an ordinal scale reflecting how inventory management systems are embraced in the context of pharmaceutical distribution management in MSD

Tanzania. The five-point ordinal scale was coded under the following coding; 1-very low extent, 2-low extent, 3-ordinary extent, 4-great extent, and 5 very great extents.

This study's outcome variable is the distribution performance operationalized by customer satisfaction. The rationale behind the choice of customer satisfaction based on the usage of customer handling complaints arrangement which is an eye focus of all staff members of MSD involved in the distribution system of pharmaceuticals from the central warehouse down to the zonal warehouses. All complaints gathered through different means such as phone calls, emails, verbal communication and suggestion boxes are directly communicated to the staff involved in the distribution system. The usage of customer's complaints to index customer's satisfaction serves an extra advantage identifying the very specific concerns while providing prompt feedback for upgrading (Rane et al., 2023). Information was captured using an ordinal scale. The choice of five points in the ordinal scale is an insight from past scholars who studied the connection between cause and effect in social sciences disciplines. Other scholars who analyzed social science traits using an ordinal scale of 5 points are Magoma (2021), Kimario and Mwagike (2021) and Mwaiseje and Mwagike (2019).

The collected data were analyzed with the help of Statistical Package for Social Solution (SPPS) using ordinal logistic regression. Congruently, the cause–effect relationship that exists between distribution of pharmaceuticals and the performance of MSD was inexorable.

Traditionally the best way to capture data for quantitative analysis is through using continuous numbers. Cause–effect relationship studies call for regression analysis as a quantitative approach. Customer service as an outcome of the relationship seems qualitative in nature. Precisely, customer satisfaction is an attitudinal aspect apprehended expressively using an ordinal scale. The use of ordinal logistic regression in this investigation was extremely useful and included strategies for automatically reproducing the important ordinal variable (Fernandes et al., 2021). Tillmanns and Krafft (2021) use qualitative responses as an alternative for factors that cannot be described numerically using continuous numbers in multiple regression analysis. Thus, the alternative qualitative technique for assessing performance was chosen analogous to the practices of Chebichii et al. (2021), Kimario and Mwagike (2024), and Matimbwa and Masue (2019) who performed the same. Also, in order to enhance visual presentation of the findings, scatterplot graphs were used to show the relationship of the variables (Goh et al., 2024).

3.5 Flow chart of the methodology

In order to enhance audio visual presentation of the methodology, kindly see Figure 2 which shows the flow chart of the methodology.

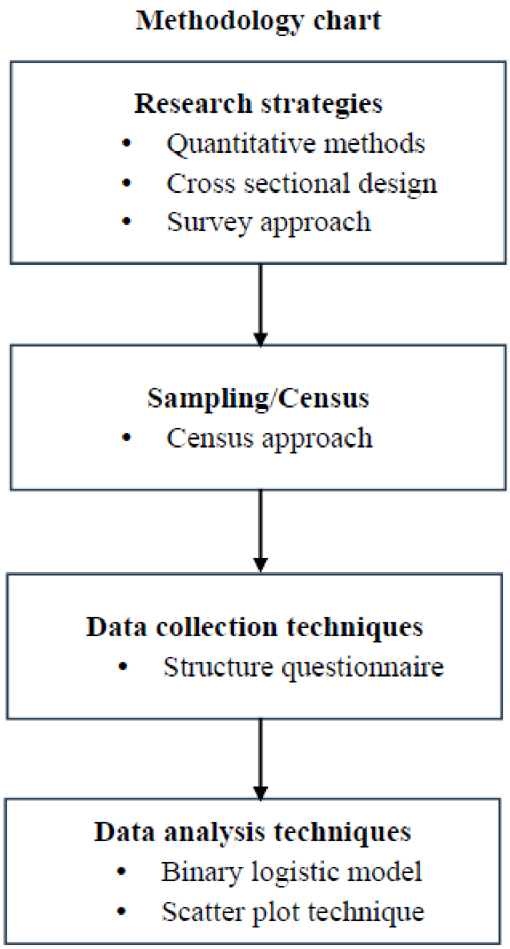


Figure 2. Methodology chart of the study

4. PRESENTATION AND DISCUSSION OF THE FINDINGS

4.1 Reliability tests

Reliability of the variables that were independent shown by the findings of coefficient of reliability was evaluated by Cronbach alpha approach, and the results were as follows:

inventory management (0.77), information management system (0.85) and facility location (0.77). Therefore, the data for this study were generalized to be reliable as the coefficient of reliability was above 0.7, as supported by Purwanto et al. (2020).

4.2 Diagnostic test of the findings

Based on the fact that it is recommended when conducting a parametric study, it is important to conduct diagnostic tests before embarking on inferential statistical analysis. Diagnostic tests of the parameters of the ordinal logistic regression model had been verified before performing deductive statistical evaluation (Garren and Osborne, 2021). Therefore, model fitness and multicollinearity of the data were all tested before running logistic regression. Findings indicate proportionality of the predictor factors to the resultant variables validated using Pseudo R square of 62.4% for the appropriateness of the data. The Nagelkerke value, together with inventory management, information management and facility decisions, explains 62.4% of the variation in the result for the variable of customer service in MSD. Despite of the fact that SPSS produces two outputs, i.e. Cox and Snell and Nagelkerke, the latter was chosen in preference to the other one due to its ability to reach maximum theoretical coefficient value of 1 (Field, 2024).

The multicollinearity tests were checked. The relationship between each of the variables predicted was verified using both the inter-item matrix of correlation and the variance inflation factor (VIF). The inter-item correlation matrix revealed that the value of the coefficients of correlations varied between 0.1 and 0.6. According to the rule of thumb, a coefficient of correlations less than 0.8 shows the lack of multicollinearity. As a result, it is safe for ruling out the absence of multicollinearity in this data because the coefficients of correlation of the variables that predicted controlling the dynamics of pharmaceutical distribution were all less than 0.8, as disclosed in Table 1. Furthermore, VIF collinearity statistics were as follows: inventory management (1.051), management information system (1.181) and facility location (1.192), and hence, there is an extension of the argument that there is no multicollinearity because the values were all less than 10 as ruled by Senaviratna and Cooray (2019). However, it should be understood that VIF is the most confirming technique for checking correlation of variables (Field, 2024). Other social science researchers employed VIF, including Magoma et al. (2024) and Shahanga and Kasambala (2023).

Table 1: Inter-item correlation matrix

		Inventory management	Information management	Facility location	Effective distribution
Inventory management	Pearson correlation	1	0.169	0.195	0.375**
	Sig. (2-tailed)		0.178	0.120	0.002
	N	65	65	65	65
Information management	Pearson correlation	0.169	1	0.379**	0.483**
	Sig. (2-tailed)	0.178		0.002	0.000
	N	65	65	65	65
Facility location	Pearson correlation	0.195	0.379**	1	0.630**
	Sig. (2-tailed)	0.120	0.002		0.000
	N	65	65	65	65
Effective distribution	Pearson correlation	0.375**	0.483**	0.630**	1
	Sig. (2-tailed)	0.002	0.000	0.000	
	N	65	65	65	65

Note(s): **Correlation is significant at the 0.01 level (2-tailed)
Source(s): Field data (2023)

Table 1. Inter-item correlation matrix

4.3 Presentation and discussion of the inferential statistical upshots

During the course of data interpretation dynamics that contributes to changes in pharmaceuticals, distribution effectiveness was analyzed using ordinal logistics regression analysis, and the P-value is considered significant when it is less than 0.05, implying the confidence interval of the results of this scholarly work is 95% (Di Leo and Sardanelli, 2020).

As a result, hypotheses with p-values below 0.05 were significantly rejected. After the ordinal regression assumptions had been verified, the researcher proceeded to perform the inferential statistical evaluation through actual testing of the given assumption (Fernandes et al., 2021). The regressions were conducted for every independent variable versus the dependent variables, as hypothesized. The inferential statistical results derived from ordinal logistics regressions are shown in Table 2.

HO1. Inventory management has no effect on distribution of pharmaceuticals. The HO1 having < p value of 0.012 and β coefficient of 0.237 was significantly rejected at $p < 0.05$. The findings in their first impression concur with those of Alam et al. (2024) who argued that inventory management is very useful. The research investigation of Alam et al. (2024) took place in a developing country of Asia, and strangely, the findings accord with our study, which was conducted in Africa, signaling that developing countries globally should strive for improved ways of managing their inventories.

A step further of analysis as shown in Table 3 aimed to understand the parameters of inventory management issuing of stock (p 5 0.041, β 5 0.6), stock levels (p 5 0.002, β 5

0.7), safety stock (p 5 0.027, β 5 0.1) and steady stock supply (p 5 0.005, β 5 0.3) categorically and significantly contributes to distribution management of pharmaceuticals that enhances customer care. Based on the findings, it has been noted that the distribution performance of pharmaceuticals is not promising because of failure to manage the safety stock properly in the distribution systems contrary to the expectations of the users. Interestingly, further analysis of the construct variables employed scatterplots to show the association of the independent variables to the dependent variables. In examining the influence of inventory management on the distribution of pharmaceuticals at the MSD, a scatterplot was employed (refer to Figure 3). The plot indicates a positive, although weak, connection between inventory management and effective distribution (R linear 5 0.141). This indicates that while enhanced inventory management practices influence more efficient distribution, there may be additional factors impacting distribution effectiveness. However, the extent of R2 does not necessarily matter and hence the described R2 value of 9% and above is regarded as reasonable for inferential analysis (Itaoka, 2012). Therefore, findings of the specific parameters concur with those of Gonçalves et al. (2020), Motla et al. (2023) and Delshad et al. (2024) who argues proper inventory management in either safety stock, the manner of issuing and the levels to be kept is of high stake for the performance of the operations but should be well managed so as to realize its benefit.

HO2. Information management has no effect on distribution of pharmaceuticals. The HO2 having a p value of 0.009 and β coefficient of 0.259 was significantly rejected at $p < 0.05$. The findings generally concur with those of Yang et al. (2021) who argued that information management systems should be well optimized in the distribution of medical materials for effective public health service in developed countries. Therefore, same findings concurred in developing countries using Tanzania medical supply system as a lesson. Detailed analysis as shown in Table 4 aimed to understand the parameters of information management system revealed inventory accessibility through tracing (p 5 0.043, β 5 0.8), order management system (p 5 0.002, β 5 0.95) as supported by Guo et al. (2023) from developed country, e-information sharing (p 5 0.006, β 5 0.4) as supported by Esmaeilzadeh (2023) and relationship management through electronic systems such as ERP (Enteprise Resource Planning) (p 5 0.021, β 5 0.15) by Kumar et al. (2023) significantly contributes to distribution performance of pharmaceuticals that enhances customer care. Figure 4 is the scatterplot that displays the connection between information management and the efficient distribution of pharmaceuticals in a medical store department. On the horizontal axis are the scores for information management, where higher scores indicate better practices in managing information. The vertical axis represents the scores for effective distribution, with higher scores indicating a more efficient distribution process. The line of best fit shows a positive slope, suggesting a positive correlation between information management and effective distribution. The R2 value, R 5 0.234, reveals that approximately 23.4% of the variation in effective distribution scores can be accounted for by the scores for information management and hence the model fitted the data as ruled by Itaoka (2012).

HO3. The location of distribution facilities has influence on distribution of pharmaceuticals. The HO3 having a p value of 0.001 and β coefficient of 0.485 was significantly rejected at $p < 0.05$. The findings concur with the argument of Hugos (2024) and Egri et al. (2023) that proper location of the distribution facilities ensures responsive distribution performance. A step further of analysis as shown in Table 5 aimed to understand the parameters of location of distribution facilities and revealed proximity to the customers (p 5 0.044, β 5 0.5) as supported by Loussaief et al. (2023) and Ouyang et al. (2024), routing decisions (p 5 0.002, β 5 0.8) as supported in related context by Ning and Du (2023), facility location costs (p 5 0.009, β 5 0.15) as supported Meneses et al. (2023) and accessibility of the location facilities (p 5 0.006, β 5 0.4) as supported by Koenig and Diarra (2023) categorically and significantly contribute to distribution performance of pharmaceuticals that enhances customer care. Figure 5 is the scatterplot that displays the connection between information management and the efficient distribution of pharmaceuticals in a medical store department. On the horizontal axis are the scores for information management, where higher scores indicate better practices in managing information. The vertical axis represents the scores for effective distribution, with higher scores indicating a more efficient distribution process. The line of best fit shows a positive slope, suggesting a positive correlation between information management and effective distribution. The R2 value, R 5 0.234, reveals that approximately 23.4% of the variation in effective distribution scores can be accounted for by the scores for information management.

Table 2.
Ordinal logistic regression results on overall dynamics influencing distribution performance of pharmaceuticals

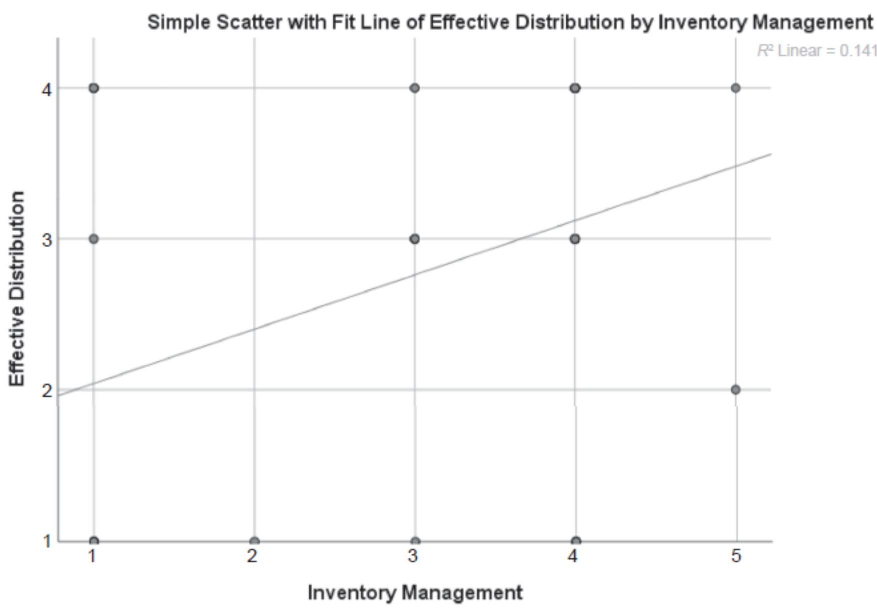
Model		Standardized coefficients Beta	Sig	95.0% confidence interval for B Lower bound	Upper bound
1	Constant		0.560	−1.026	0.561
	Inventory management	0.237	0.012	0.053	0.402
	Information management	0.259	0.009	0.075	0.512
	Facility location	0.485	0.001	0.305	0.712

Source(s): Field data (2023)

Table 3.
Ordinal logistic regression results of inventory management vs distribution performance of pharmaceuticals

Parameter	Estimate	Std. error	Wald	df	Sig	95% confidence interval Lower bound	Upper bound
Threshold							
Effective distribution = 1.00	2	0.5	6	1	0.014	1	3
Effective distribution = 2.00	1.5	0.7	5	1	0.025	0.1	2.9
Location							
Issues of stock	0.6	0.3	3.5	1	0.041	0.1	1.1
Stock level	0.7	0.12	10	1	0.002	0.46	0.94
Stock safety	0.1	0.08	0.4	1	0.027	0.05	0.25
Steady stock supply	0.3	0.06	8	1	0.005	0.18	0.42
Link function: logit							

Source(s): Field data (2023)



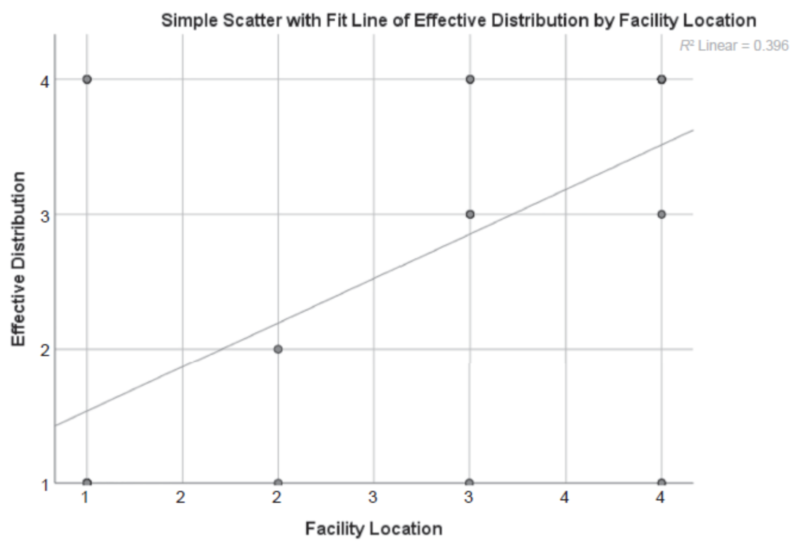
Source(s): Field Data (2023)

Figure 3.
Scatter plot for inventory management vs distribution performance

Parameter	Estimate	Std. Error	Wald	df	Sig	95% confidence interval Lower bound	Upper bound
Threshold							
Effective distribution = 1.00	1.8	0.52	5.2	1	0.022	0.8	2.8
Effective distribution = 2.00	1.2	0.69	4.5	1	0.034	0.2	2.2
Location							
Proximity	0.5	0.28	3.2	1	0.044	0.1	0.9
Routing	0.8	0.11	9.6	1	0.002	0.59	1.01
Cost	0.15	0.07	1.8	1	0.009	0.01	0.29
Accessibility	0.4	0.05	7.5	1	0.006	0.3	0.5
Link function: logit							

Source(s): Field data (2023)

Table 5. Ordinal logistic regression results of facility location vs distribution performance of pharmaceuticals



Source(s): Field Data (2023)

Figure 5. Scatter plot for facility location vs distribution performance

5 CONCLUSION AND RECOMMENDATION

5.1 Conclusions

This study examines dynamics determining the distribution of pharmaceuticals in Tanzania. The study concludes that inventory management in terms of issuing of stock, stock levels, safety stock and steady stock supply categorically and significantly contributes to distribution performance of pharmaceuticals that ultimately enhances customer care. On another hand, distribution management system in terms of accessibility through tracing, order management system and e-information sharing and relationship management through electronic systems contribute to distribution performance of pharmaceuticals that ultimately enhances customer care. Equally important, location of distribution facilities revealed that proximity to the customers, routing decisions, facility location costs and accessibility of the location facilities is of fundamental importance.

5.2 Implications

Distribution system of pharmaceuticals is supposed to be well optimized because it is a lifesaving bustle. Therefore, Tanzania, as a developing country, is recommended to optimize on this finding to revamp its current performance. Interestingly, this paper assimilates the concept of sub-aspects of supply chain management in footings of distribution management and that of pharmaceuticals and hence multidisciplinary value addition. Inventory management, management information system and facility location are both considered as the strategic supply chain dynamics which configure the future success of the distribution of pharmaceuticals in Tanzania. Thus, the study contributes to the thrilling literature on the debate of understanding dynamics that optimize distribution performance of pharmaceuticals in Tanzania. Also, while Tanzania is challenged by unsatisfactory customer care in health in terms of access of medicinal drugs, this study has filled the gap by identifying key factors to focus on while achieving SDG Number 3 which insists on equal opportunity of access to health services. Equally important, the Ministry of Health and Social Welfare of Tanzania through MSD is encouraged to re-organize its distribution system of pharmaceuticals in the country. Theoretically, the study contributes to SC theory by describing how SC is applicable to the distribution system of pharmaceuticals of developing countries through thought-out choice of inventory management, management information system and location optimization.

5.3 Limitation and areas for future studies

Despite the fact that this study accomplished the principal purpose, it went through some limits that merit future research to be conducted to bridge the gap. Knowing dynamics that determine the distribution system of pharmaceuticals, future can contemporarily be directed on the use of third- and fourth-party logistics given its trending worldwide application. Also, knowing distribution management system is a challenge, and future study should extend to the usage of artificial intelligence on distribution system and even more largely on supply chain performance of medical items. Equally important, since the three major dynamics studied were found significant, future study should be sequential quali-quanti so as to explore more dynamic factors that ultimately influence distribution performance of pharmaceuticals.

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Paper 18:

Reliability and Compliance of Imported Used Vehicles with Roadworthiness Standards: "A Case Study of Imported Used Vehicles in Tanzania"

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ABSTRACT

African countries import used vehicles from countries such as Japan, the United Kingdom (UK), Singapore, and the United Arab Emirates (UAE). These vehicles are imported in various conditions in terms of quality, depending on the first user. As a result, the Government of Tanzania has set standards that imported vehicles must comply with before being allowed on the road. This study aims to investigate the reliability and safety compliance of imported used vehicles (IUVs) based on data collected at the National Institute of Transport – Vehicle Inspection Centre (NIT-VIC) over five years (2016–2020). A total of 11,978 vehicles were inspected for roadworthiness compliance, of which 56.7% were heavy- duty vehicles and 43.3% were light-duty vehicles. Of all the vehicles tested, 57.82% passed, 42.05% failed, and 15 (0.13%) were rejected. The failures were due to various factors such as component or system failure or malfunction. Tyres ‘condition was the most common component contributing to vehicle failure at 42%, while brake system failures accounted for 41.5%, lighting systems 41%, safety systems 39%, and vehicle bodies for 40.6%. The test results indicate that a significant number of imported used vehicles do not comply with roadworthiness standards, raising road safety concerns if they are not properly repaired before use. Additionally, used vehicles have been found to contribute to environmental pollution through their exhaust gas emissions.

Keywords: Transport, imported used vehicles, roadworthiness, Pollution and Safety

1 INTRODUCTION

Transport has become one of the basic needs of human life to enhance mobility, stimulated by the great growth of social and economic activities in society. It is characterised by consuming mobility services offered by a transport mode in a given period (Cascetta, E. 2013) (P. Roman, S.Tom George, 2020). Various modes of transport such as air, water, rail pipe, cable and road are used to accomplish the need of transporting passengers and goods from one place to another. Among the modes, road transport is the oldest mode often used worldwide and mostly in developing countries Tanzania included. Motor vehicle production originated in Europe (German, France and United Kingdom) and North America in the 19th. In the 20th century, Japan was the leading country and by in 21st century, China became the World's largest vehicle producer with mass production of electric vehicles.

The emergence of modern technology in vehicles such as increased use of electronics in engine management, safety and entertainment systems, improved body style, fuel efficiency vehicles, high engine output and less emissions motivates the change of old vehicles with new modern vehicles. This results in an emerging trade market of used vehicles from developed countries to developing countries. Davis & Kahn (2010), Coffin et al. (2016) & P. Roman, S.Tom George, (2020), declares the existence of international trade of UVs from high-income countries especially Organization for Economic Cooperation and Development (EOCD) countries to low-income countries. The reason behind this is the difference in income level and depreciation cost and the low cost of purchase and repair of the vehicle (Coffin et al., 2016). The big market has been the developing countries, especially in Africa (BASKIN, A. 2018) (Ayetor, Mbonigaba, Sackey, et al., 2021a).

Tanzania a Southern Sub-Saharan country with 61.7 million people (URT, 2022) and projected to 89,204,781 by 2035 (United Republic of Tanzania, 2018) has no vehicle manufacturing industry and very few motor vehicle assembly plants. The lack of a motor vehicle manufacturing industry and inadequacy of vehicle assembly in the country results in the country accepting the importation of used vehicles to subsidize the need to acquire road transport vehicles to satisfy mobility. Used vehicles are more prone to faulty and can cause road crashes resulting in road traffic injuries, death and disability, with human, socio and economic burdens worldwide (Ghandour et al., 2020). Road crashes are defined as any abnormal incident that occurs on the road such as rolling or collision of the vehicle with other vehicle(s), or other road users or infrastructure and results in damage, loss, injury and death of occupants (Prices, 2004). Road crashes counted 1.35 million deaths by the year 2016 and projected to become fifth among the deaths caused by 2030 mostly been from developing countries (Boniface et al., 2013), WHO, V. (2018) (Magesa et al., 2023). According to Ayetor et al. (2021b), Tanzania imported an average of 61,167 used vehicles per year.

Therefore, this paper aims to analyse the customer choice of importing vehicles in Tanzania based on the 11978 units of IUV visited National Institute of Transport Vehicle Inspection Centre (NIT-VIC) for a period of five years (2016-2020). NIT-VIC is a state-of-the-art Vehicle Inspection Centre in Tanzania used to ascertain the quality of on-road vehicles based on roadworthiness standards. Imported Used Vehicles (IUVs) like any other imported commodities must be inspected for confinity to compliance (roadworthiness certificates) before being allowed to use public roads. Various vehicle systems and components were inspected and tested per TBS standards. The tests such as vehicle speed, brake imbalance and brake efficiency, headlight direction and intensity, noise level and emission level for both diesel and petrol engines are carried out and analyzed.

2 MATERIALS AND METHOD

The study was based on 11978 IUV of different types; cars, station wagon, min buses, buses, tractors and trucks imported to the country under the destination inspection (DI) programme and visited NIT-VIC for the year 2016 to 2020. Modern tools, equipment and machines were used during inspection to test for conformity of the vehicles on roadworthiness. The speed meter machine DENSO V 1.56555 made in South Africa was used to test the coloration of the wheel speed and tachometer reading. Millitron roller brake tester machine from South Africa measures brake efficiency and brake force imbalance. Emission testing headlamp testing, and noise level meter machines from MAHA German and Millitron SA were used to analyze exhaust gases, light intensity and direction, and level of noise produced respectively. Tyre pattern and crack checker, scurf gauge and play detector, were used during the inspection.

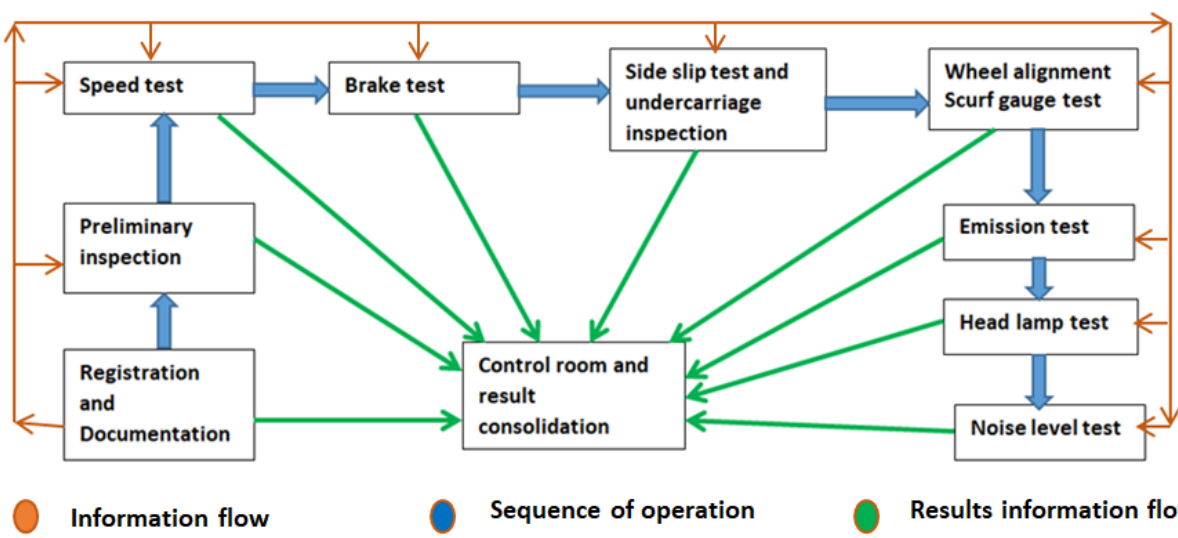

Figure 11: Vehicle inspection operation flow chart

2.1 Testing operations

The study was an experimental set-up in a lane fitted with various machines arranged in sequential order as described in **Figure 1.** Before the inspection, the vehicle owner submitted valid documents such as import duty clearance and bill of landing for vehicle registration. The information used in each machine to process findings/data for the particular vehicle.

2.2 Preliminary inspection

Preliminary inspection is carried out before the vehicle is allowed to enter machines. The aim is to identify any fault that can lead to the failure of the vehicle during inspection or has severe deterioration unsafe to operators, machines and the infrastructure. It includes tyre wear, cracks and pressure inflation. Furthermore, inspection on the vehicle operations including engine starting, vehicle controlling systems (steering, brakes), communication system (indicators, lighting), safety system (safety belts, seat belts, horns) and vehicle body just to mention few.

2.3 Speed meter test

The vehicle was tested using speed meter tester DENSO V 1.56555 a free roller type machine fitted with a sensor to count the revolution of the tyre. The metal rollers were driven by vehicle tyres as vehicle driven. The vehicle is driven at the intended speed range from 0km/hr to 100km/hr while capturing the reading of the speedometer at the vehicle's dashboard via a remote. The speed tested was 30, 50, 80 and 100 km/hr as per machine set-up. The aim was to compare the actual speedometer reading and the reading obtained at the wheel.

2.4 Brake test

Brake efficiency and brake force imbalance were measured using a roller brake tester machine. The machine is fitted with four rollers, two rollers (driver and driven) on each side as per vehicle axle. The rollers are coated with friction material, an electrically driven gear motor with a limit speed of 5m/s. Also, the machine was equipped with a weighing device to determine axle weight automatically, an electric sensor, a decelerator meter and a remote sensor to control motors. The vehicle axle is driven onto the rollers, and the motors are actuated to drive the wheels and allow the operator to apply the vehicle brake to stop the motors. The weight of the axle load, and force applied were used to calculate brake forces imbalance (kN) and efficiency (%) using eqn. 1&2.

$$brake\ force\ imbalance = Brake\ force\ in\ either\ side - brake\ force\ in\ other\ side \quad (1)$$

$$Brake\ efficiecy\ = \frac{axle\ weight\ kN}{force\ applied\ N}\, x\ 100\% \quad (2)$$

2.5 Side slip test

A side slip or scurf gauge device is a metal plate installed along the lane equipped with a potential meter sensor and connected to a roller brake tester machine to measure tyre dynamic toe. It is electrically powered device with carrying capacity of 10 tons able to measure both toe in or out up to 15mm from the tyre track.

2.6 Play detector test

The play detector was a mechanical hydraulic operated device made of steel plate, cylinder piston, and pump from Millitron SA. The device has a carrying capacity was 10 tons per axle, installed on each side of the inspection pit used to test the suspension and steering system linkages of the vehicle.

2.7 Emission test

The vehicle exhaust emission level was tested using a gas analyzer MDO 2 LON for petrol engines and a smoke meter MGT 5 for diesel engines made in MAHA Germany. The vehicle engine was accelerated to 2400 rpm to warm the engine; the exhaust probe was fitted into the exhaust tail pipe connected to the emission test. The vehicle was accelerated to full throttle for 5 seconds and released. The probe sucks the exhausted gas for analysis. The experiment was repeated thrice to find the average value. The results are quantified into %volume for CO, CO2, and N_{Ox} while suit (opacity) from diesel engine quantified in ppm. According to (Tanzania Bureau of Standard, 2011) the allowable levels of emitted gases are described in Table1.

Table 4: Emission Limits for petrol and diesel vehicles in Tanzania

Engine type	CO (% by V conc)	Opacity (m^{-1})	HC (PPM)	References
Petrol	4.5	na	1200	TZS 698:2013
Diesel	4.5	2.5	1200	

2.8 Headlight beam test

The vehicle headlight beam for fluorescent, light emitting diode LED, halogen, and xenon was tested using Technolux and MLT 3000 MAHA made in Italy and Germany respectively. The parameters measured were intensity lux (Lx) or Candela (cd) and direction/optical angle in degrees. The device was set 30 cm in front of the secured vehicle and placed on a levelled surface area facing the headlamp of the vehicle at the focal point of the headlamp. The angles tested were horizontal and vertical direction. The horizontal direction of the light beam depends on the regulations of the country that guide the placement of the vehicle on the driving lane. According to the Tanzania Road Traffic Act (1973), TBS used motor vehicle inspection standards (Tanzania Bureau of Standard, 2011) the optic light beam oriented to 15º toward the left heeding the driving lane. To provide clear visualization of road signs, marks, and other road users. The driving light intensity was measured at 12000 cd equivalent to (1.3 to 7.5 lux) (Tanzania Bureau of Standard, 2011) (Kevin J. Gaston, 2018).

3 RESULTS AND DISCUSSION

3.1 Status of Vehicle importation under DIP as per NIT-VIC report 2016-2020

In Tanzania, the experience shows that most of the imported vehicles into the country are used vehicles. For the years 2016 to 2020, a total of 11978 vehicles were inspected at NIT-VIC under the Destination Inspection Programme (DIP) where 57% were HDVs and 43% were LDVs as shown in Figure 2(a). Figure (2b), shows a progressive increase of IUVs in the country, and the year 2018 has the highest number of IUVs by 29.8% inspected at the Centre. The trend concurs with (Davis & Kahn, 2010, Coffin et al., 2016, P. Roman & S. George, 2020, Ayetor et al., 2021a&b) that there is a vast existence and growth of international trade of used vehicles in developing countries, particularly Tanzania. Ayetor et al., 2021a mentioned Tanzania with 61,167 vehicles 6th after Ghana (76,011), Ethiopia (81,259), Kenya (89,616), Libya (148,668), and Nigeria (171,248) in the importation of used vehicles in 2019. The data shows that there was a dramatic drop in vehicle importation in the year 2019 and 2020 preferably due to covid-19 pandemic disease.

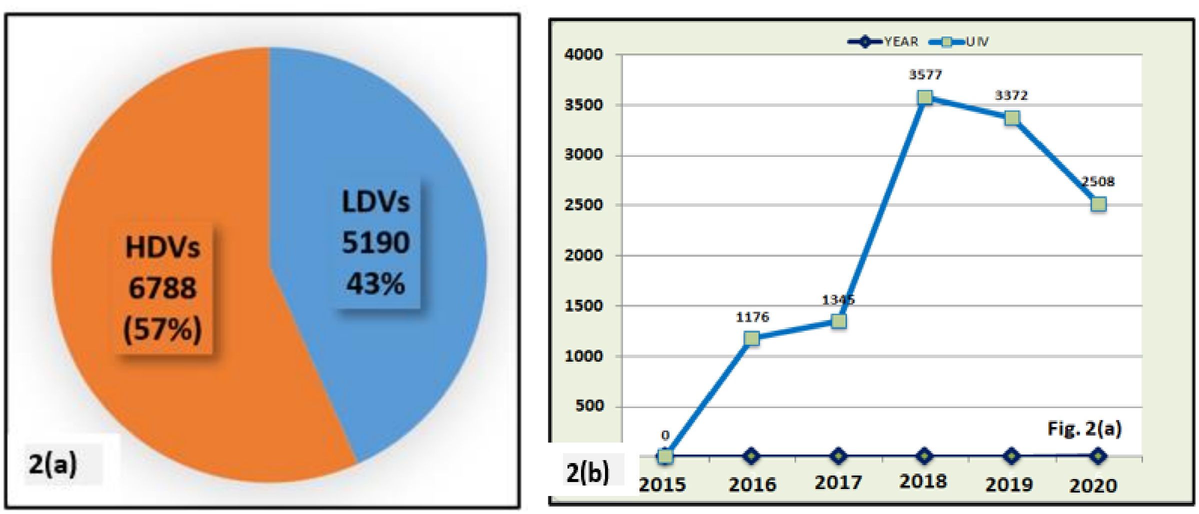

Figure 12: (a) Imported HDVs Vs LDVs at NIT-VIC for the year 2016-2020; (b) A trend of imported used vehicles at NIT-VIC for the year 2016-2020

3.2 Prevalence of IUVs in the country as per NIT-VIC Report 2016-2020

Generally, vehicles can be classified based on; type of use, size, fuel used, engine, or body type. According to the Tanzania Revenue Authority (TRA), vehicles are categorized into heavy-duty vehicles (HDVs) or light-duty vehicles (LDVs) and further classified into light passengers' vehicles (LPVs), light load vehicles (LLVs), heavy passengers' vehicles (HPVs) and heavy loading vehicles (HLVs) as described in table 2.

HLVs are the most imported used vehicles by fifty-three per cent (53%), followed by LLVs (32%), LPVs (11%) and HPVs the least IUVs by 4% as shown in Figure 3(a). Based on fuel type, currently, vehicles are categorized based on power source petrol or diesel. Figure 3(b) shows that diesel-powered vehicles (68%) are the most IUVs compared to 32% of petrol vehicles. Ninety per cent (90%) of vehicles inspected use conventional fuels (diesel 70% and petrol 20%) and two per cent (2%) were hybrid vehicles powered by conventional fuel and alternative fuels (LPG 1.2%, CNG 0.6%) and electric vehicles (0.2%). Hybrid vehicles were among the 0.3% of untested alternative-fuelled vehicles.

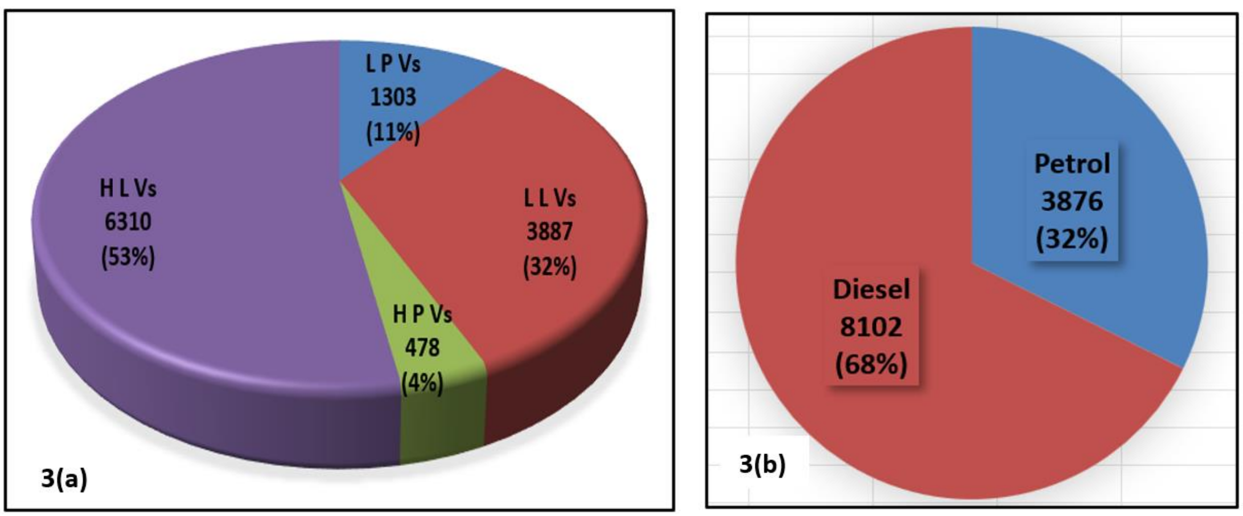

Figure 13: (a) Vehicles tested based on vehicle classes (b) Vehicles tested based on fuel type

Table 2: Classification of vehicle classes based on carrying capacity

Item	Group	Classes	Carrying capacity	Fuel used	Example	References
Vehicle	Light Duty Vehicles	Light Passenger Vehicles	Less than 12 passengers	Mostly Petrol	Sedan, saloon, station wagon, Hatchback, pickup double cabin	(Ayetor, Mbonigaba, Sackey, et al., 2021a) (Shokravi et al., 2020) (Turap et al., 2020) (Coffin et al., 2016) (Z. Chen et al., 2009)
		Light Load Vehicles	Less than 3500 Kg	Petrol and diesel	Pickup single cabin, carry	
	Heavy-Duty Vehicles	Heavy Passenger Vehicles	More than 12 passengers	Mostly diesel	Van, min buses and buses	(Turap et al., 2020), (Anumita Roychowdhury, 2018) (Coffin et al., 2016) (Z. Chen et al., 2009)
		Heavy Load Vehicles	More than 3500 kg	Mostly diesel	Canters, lorries, tractors and trucks,	

3.3 Vehicle inspection and testing

Vehicle inspection involves a thorough examination of the vehicle to ensure that it meets the basic standards of roadworthiness set by a regulatory body. Various systems, parts, and components in the vehicle are inspected to ensure are in accordance with manufacturer specifications. On the other hand, vehicle testing refers to a set of procedures and assessments conducted on a vehicle using proper tools, equipment, and machines to evaluate its performance, safety, durability, and compliance with various regulations or standards.

3.4 Vehicle inspection

Vehicle factor is among the major factors to cause accidents on the road, in workshops, or in vehicle inspection centres (Mohanty & Gupta, 2015). It is all about factors related to the vehicle's safety status (Liu et al., 2018). Preliminary vehicle inspection involves early vehicle checks carried out by the vehicle operator before running the vehicle on public roads. For the case of vehicle inspection centres, a preliminary or initial vehicle inspection is an inspection carried out to identify problems/failures/faults in the vehicle before subjection to testing machines.

Figure 4 shows the results of vehicle systems tested during the study. Tyres were seen to be the most significant component contributing to vehicle failure to comply by 42% due to crakes, sidewall cuts, tread wear, and age (more than 8 years as per TBS). Tyre crakes are caused by long-life exposure to ultraviolet sunlight, temperature, and humidity changes during disposal. Safety system 41% failures, it is all about the safety of the vehicle to mitigate crushes using passive and/or active vehicle safety systems (Jeong & Oh, 2017; Koopman & Wagner, 2017). It includes examining seat belts, head restraints warning signals and massages. Other miscellaneous 39.2%, are any part of the vehicle apart from major components or systems with fault and can which by one way hinders vehicle operation. This includes corrosion, bushes, leakages, mirrors, fitting, linkages, missing locks, and mismatching of parts, signals and gauges just to mention a few.

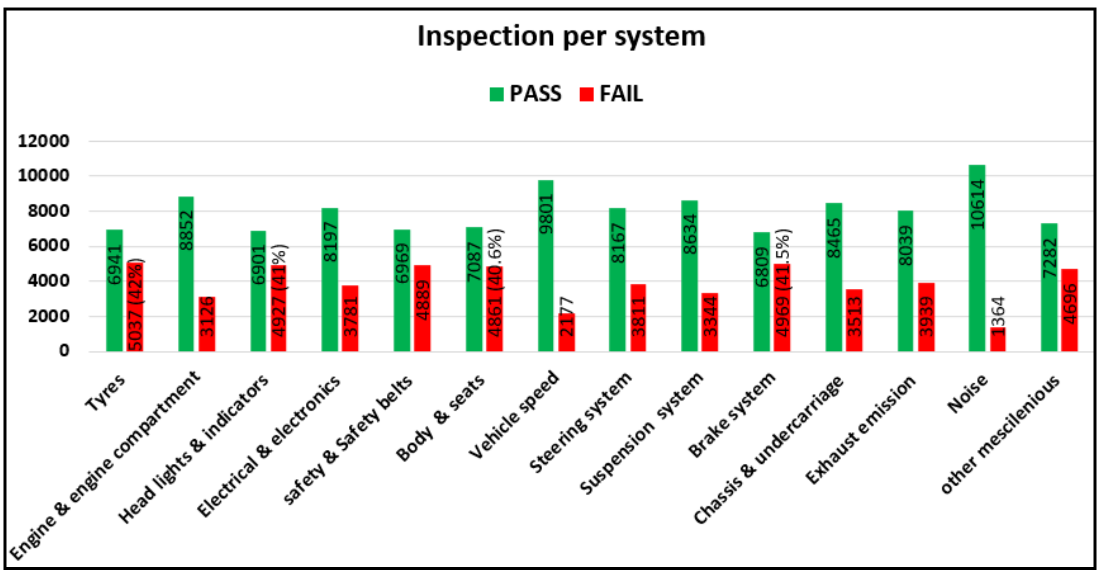

Figure 14: Test results per vehicle systems

3.4.1 Speed testing

Vehicular speed is among the major factors that cause human mistakes in the transport system causing vehicle crush results in injuries and fatalities (Adnan et al., 2013; Doecke et al., 2020; Goldenbeld & van Schagen, 2007; Jusuf et al., 2017; Nurprasetio et al., 2018; The & Versus, 2013). The speeds tested are 30km/hr, 50km/hr, 80km/hr, and 100km/hr as cruising speeds directed to be used in Tanzania roads. The speed of 30km/hr is used in restricted areas including city and town centers, 50km/hr is used in areas with high population density and pedestrians cross the roads, and 80km/hr for the highways and trunk roads with obstruction free. The results show that 2177 (16.7%) vehicles failed the test, the most vehicles that failed on speed test were light-duty passenger vehicles, light-duty load vehicles and heavy-duty passenger vehicles. The main reason was the use of tyre sizes different from manufacturers' specifications. That is using wheel rim of high diameter and low tyre profile.

3.4.2 Brake system testing

The brake system is a crucial safety and control system in the vehicle. The system is inspected its operation at the preliminary stage to ensure safety during machine testing and thereafter the brake performance during machine testing. According to the study, the brake system contributes 41.5% of vehicle failures mainly due to low brake efficiency, brake imbalance, hydraulic or pneumatic leakage, excessive free pedal play, sponge brake, noise, and ABS malfunction notification.

3.4.3 Emission testing

Vehicle emissions count for more than 80% of air quality pollution with saviour impact on human health and climate change effects (Adeyanju et al., 2003; Ayetor et al., 2021; Deshmukh et al., 2020; Faculty et al., 2017; Franco et al., 2013; Huang et al., 2018; Qin & Gao, 2022; Siskos & Moysoglou, 2019; Tiwari & Mandloi, 2019; Zhong & Bushell, 2017). It includes exhaust and crankcase gas emissions such as carbon monoxide, sulphur dioxide, nitrogen oxides, particulate matter (PMs) soot, hydrocarbons, fine particles from tyre and lining materials wear and acid vapour of batteries. In line with our previous study and in accordance with TBS, the emission parameters tested at NIT-VIC are Hydrocarbons, Carbon Monoxide, and Carbon Dioxide, for petrol engines and opacity (soot contents) for diesel engines. From the study, the vehicles visited the NIT-VIC were 75% diesel-powered vehicles, 23% petrol and 2% alternative fuels dedicated or dual-powered fuels LNG 1.5%, CNG 0.5% and hybrid electric vehicles 0.2% as shown in Figure 5(a). Out of 11978 visited the centre, 11025 (92%) vehicles tested for emission, 5,780 (52.4%) passed the test, 5245 (47.6%) failed the test and 953 (8%) vehicles were not tested see Figure 5(c). Petrol vehicles have a higher rate of failures by 50.8% of petrol vehicles tested compared to 42% of diesel vehicles as shown in Figure 5(b). In the case of alternative fuels, no vehicle fails the emission test, and the results concur with (Nabora et al., 2019)(Kalghatgi et al., 2018; Rhys-Tyler et al., 2011; Rossman, 2009) that alternative fuels have fewer Greenhouse gas emissions compared to petroleum fuels. Electric vehicles have zero GHG emissions (Tomlinson et al., 2018; Zhao et al., 2021).

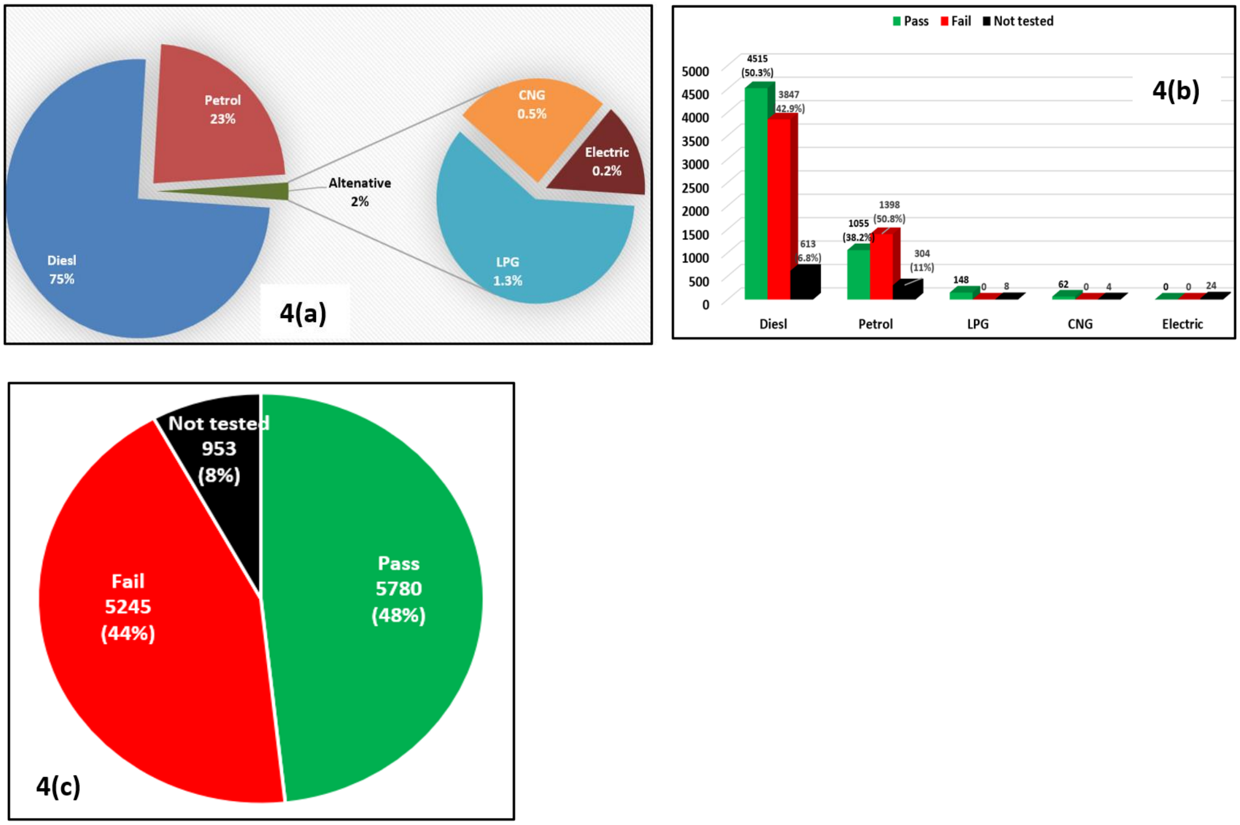

Figure 15: (a) Vehicles by fuel visited the centre (b) Results of emission tested by fuel type (c) General emission test results

3.4.4 Headlight testing

Poor vision results in difficult and unsafe driving. Properly designed headlights aim to assist drivers and other road users to see, be seen and help to evaluate road conditions for better driving judgment (Y. S. Chen & Chiu, 2018). According to the study, headlights contribute to 37.6% of vehicle failures. The main issues have been, nonworking headlights, light orientation and intensity, and broken headlight glasses which have direct cost implications to maintain them.

3.5 Effects of age and kilometres travelled on vehicle reliability

The age and kilometres travelled by the vehicle are among the many factors used to determine the reliability of the vehicle (Rush et al., 2022). As the vehicle ages, it is allied with tear and wear, components deterioration, outdated technology, high maintenance cost and diminishing vehicle value. The study shows that vehicles aged more than 11 years were more susceptible to failure by 49%, 7-10 years by 44% and 3 – 6 years by 36% as shown in Figure 6. Vehicles with 3 years or less are not tested as per TBS guidance. On the other side, vehicles that have been driven for many kilometres generally show more signs of wear and are likely to suffer from mechanical failures, impacting vehicle reliability. Fifty-two percent of the vehicles with 200,001 kilometres or more failed the inspection, whereas those vehicles with kilometres ranging from 100,001 to 200,000 km and 1 to 100,000 km failed the inspection by 44.1% and 34.2% respectively. The study revealed that vehicles with higher age and kilometres of travel are more prone to failure although vehicles that have been properly maintained remain more reliable longer than those that have been neglected.

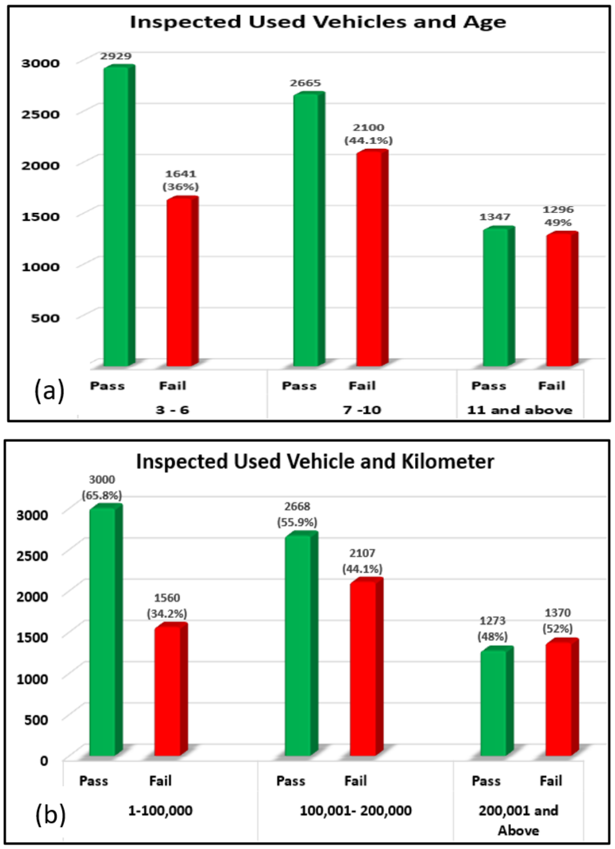

Figure 16: (a) Inspected vehicles and age (b) Inspected vehicles and kilometer

5 CONCLUSION

The emergence of modern technology in vehicles, the stylish and the need to own mobility motivates the change of old vehicles to new modern vehicles resulting in an emerging trade market of used vehicles from developed countries to developing countries. Used vehicles like any other imported commodity have to be inspected and tested on roadworthiness to conformity. A good number of the vehicles failed the test and few were rejected. Tyres, headlight, safety and brake systems have a higher rate of failures, while aged vehicles and vehicles with higher kilometres of travel have higher rates of failures. Also, petrol-fuelled vehicles were found to be air pollutants by releasing GHG that affect human health and the environment. The huge failure of the vehicles tested proves that, vehicles sold to developing countries have exhausted use and are of low value due to their tear and wear and depreciation, high cost to maintainability and failure to meet vehicle regulation standards in developed countries. Furthermore, vehicles with higher age and kilometre of travel are shown to have a higher rate of failures hence less reliability of the vehicle.

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