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DEVELOPMENT OF WEB AND ANDROID APPLICATIONS FOR MANAGEMENT OF RAILWAY DATA AGGREGATION AND ANALYSIS FOR TANZANIA RAILWAY CORPORATION

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A Dissertation Submitted in Partial Fulfilment of the Requirements for the Degree of Master's in Information and Communication Science and Engineering of the Nelson Mandela African Institute of Science and Technology

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ABSTRACT

Railway transportation is one of the oldest forms of transportation that created links to populated and unpopulated parts of the world with railway tracks constructed through remote areas in earlier days. The ever-growing utilization of science and technology has been implemented in railway transportation to reduce travel time and increase passenger comfortability. African countries such as Tanzania acquired a railway network during the colonial era with the government performing few modifications to cater to evolving passengers' needs. There are still setbacks in generating adequate information on how the railway sector progresses and how railway information is disseminated to the public. This study utilizes information technology and provides means for railway data collection, analysis, and information dissemination in Tanzania through the use of web and mobile applications. The study was conducted through the collection of data from Tanzania Railway Corporation (TRC) headquarters in Dar es Salaam intending to understand the overall performance of the railway sector in terms of data acquisition and information dissemination. The research looked into ways in which Tanzania differs from railway systems that are statistically improved with Great Britain being the casing point and found use of fewer railway attributes being collected and analyzed. This prompted the development of an improved railway information system which used mixed approach in data collection involving interviews with TRC staff, questionnaires distributed among passengers, and document reviews. From system requirements acquired, android and web applications were successfully developed which create a gateway to railway information, provide visual presentations of collected data from day-to-day railway operations, create up-to-date maps of the Tanzania railway network, and foster higher accuracy data collection.. The evaluation of the developed system showed great acceptance as a way forward for railway data capturing, analyzing and dissemination in the near future. Inclusion of GIS techniques proved to be of importance in creating awareness of Tanzania railway network to the public with participants having a higher percentage of agreement in the matter. In general acceptance, the system received more than 75% approval rating prompting more usage of railway data attributes as evaluation keypoint in railway transportation within Tanzania.

DECLARATION

I, Kitoi Elisha Adam do hereby declare to the senate of the Nelson Mandela African Institution of Science and Technology that this dissertation is my original work and that it has neither been submitted nor being currently submitted for degree award in any other institution.

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CERTIFICATION

The undersigned certify that they have read and, with this recommendation for acceptance by the Nelson Mandela African Institution of Science and Technology, a dissertation titled ***"Development of Web and Android Applications for Management of Railway Data Aggregation and Analysis for Tanzania Railway Corporation"*** in partial fulfilment of the requirements for the degree of Master's in Information and Communication Science and Engineering of the Nelson Mandela African Institution of Science and Technology.

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AU	African Union
CSS	Cascading Style Sheets
dLab	Tanzania Data Lab
DSRC	Dedicated Short-Range Communications
ECOWAS	Economic Community of West African States
eGA	e-Government Authority
GDP	Gross Domestic Product
GIS	Global Information System
GIS-T	Geographical Information System for Transportation
GPS	Global Positioning System
HTML	HyperText Markup Language
ICT	Information and Communication Technology
JNHP	Julius Nyerere Hydropower
LENNON	Latest Earnings Networked Nationally Over Night
NBS	National Bureau of Statistics
NSC	North-South Corridor
ORR	Office of Rail and Road
RFID	Radio Frequency Identification
SADC	Southern African Development Community
SGR	Standard Gauge Railway
TRC	Tanzania Railway Corporation

CHAPTER ONE

INTRODUCTION

1.1 Background of the Problem

Following a predicted growth of traffic in the global transportation sector of more than 80 passenger-kilometers by 2030, transportation has become an important sector towards development in any country regardless of its economic status. With transportation mainly seen through roads, other forms of travel such as railway transportation play a significant contribution towards increasing passenger-kilometers. Railway transportation has different reaches when displayed in terms of developing and developed nations due to the number of passengers and technology adopted within the sector in which developed nations seem to have the upper hand. Focusing on developing nations, Tanzania has been engaged in this form of transportation since the colonial era with its network reaching rural and urban areas intensively. Due to various economic setbacks, the Tanzanian government went from public ownership of the railway sector to privatization and back to total public ownership in almost a decade in the effort of increasing efficiency and revenue generation linked to railway transportation. As of 2016, a study by Masenya *et al.* (2018) showed that Tanzania had plans to raise its Gross Domestic Product (GDP) from 7% to 10% in 2021 which is to be achieved with collaborative efforts of all development sectors including transportation. With plans to increase its economic status, the railway sector was not left behind as the Government spearheaded the formation of Tanzania Railway Corporation (TRC) to take full responsibility of the railway network and its activities within the country. The TRC has been provided with full control of any business conducted through railway transportation which has led to the revival of train routes that were inoperable for a long time (such as Arusha to Dar es Salaam) and establishing commuter train routes in Dar es Salaam such as Kariakoo to Pugu paving way for congestion reduction within the growing business city (Alfred & Kaijage, 2019).

Before the establishment of TRC, the number of passenger journeys in railway transportation was recorded to be 683 861 in the year 2003 with the decline to 593 889 after 5 years (Kazi, 2016). With privatization proving inefficient as passenger journeys declined, TRC formation acted as a solution for future restoration of railway transportation with active government participation and support in which National Bureau of Statistics (NBS) recorded an increase of passenger journeys

to more than 3 million annually proving the solution to be working accordingly (National Bureau of Statistics, 2020). In terms of exportation of goods, NBS showed over 8 trillion Tanzanian shillings in annual revenue which link to increased business activities and with the establishment of broader and faster cellular networks such as 4G, trade activities have taken a huge turn through use of mobile payments and borderless communications making possible conduction of business with people all over the globe.

Not only has the former railway network been considered, but more plans have also been implemented by TRC considering the increase in the population of about 57 million people recorded by NBS as of 2020 with higher projections in the future (National Bureau of Statistics, 2020). This increase has been analyzed by the government and has established various projects such as Standard Gauge Railway Network to provide support to the current network and provide faster services as the nation aims higher in the transportation sector (Merkezi, 2019).

Standard Gauge Railway (SGR) network has been established by the government and implementation of the project is in five phases with the first and second phases being in effect. This leap into an advanced form of railway transportation goes hand in hand with the construction of Julius Nyerere Hydropower (JNHP) station in Rufiji which aims at eradicating electricity shortage in the country in the terms of providing enough electricity to meet daily requirements and supply more for new projects such as SGR as well as selling to other countries due to massive wattage supply of more than 2000 MW predicted after completion. SGR is linked to economic boost with expectations of higher speed leading to shorter travel time, more cargo tons per travel, and employment opportunities when fully operational (Wang *et al.,* 2021). With both projects under construction, a direct link has been established to enable Tanzania to prolong its fight for economic growth and at the same time contribute to the industry of transportation in a global context.

These two major projects have a broad view in terms of economic development as they will pave a way for Tanzania to utilize the growing demand of science and technology as a factor for economic boost but it depends on how accurate these projects are monitored and evaluated once they are operational.

Monitoring and evaluation requires significant amounts of data and specific data types collected for measuring various targets. Tanzania falls behind in this area as most data collected are through non-technological ways such as focus groups in which the amount of data collected is low leading to high discrepancies in the evaluation of progress. To-date, data collection has been based mostly on passenger and cargo transportation in which the number of users is used as a point of evaluation for growth while in developed nations, a broader view of railway transportation is evaluated by speculating different aspects such as passenger satisfaction and complaints handling percentage enabling responsible organs to gain higher accuracy during process evaluations. To aid in the field of data aggregation, Tanzania harbors several organizations such as Tanzania Data Lab (dLab) which deals with providing solutions in the field of data science taking a step closer towards national data aggregation.

In the 21st century, the internet has evolved and become a link to people in a global context making them engaged to their telecommunication devices at a higher rate even in developing countries. A study done by World Bank Group (2020) showed that of 57.6 million people, more than 40 million have engaged with telecommunication services such as internet connectivity and long-distance communications through the use of mobile phones . This has brought about a new context in terms of information dissemination with people engaging in internet techniques such as emails and social media more than physical newspapers and traditional media techniques such as televisions and radios giving the age of science and technology more power on how people receive and disperse information. In Tanzania, most government organs prefer the use of website creation as a way to share information to the public in the effort to engage in the digital era in which it provides general information of what the organ does and what services are available. This is evident as TRC has established an online train ticketing system in 2020 to facilitate paperless bookings, faster services and reduced booking queues.

With increasing techniques in data aggregation and Information and Communication Technology (ICT) service provision, data collection and analysis have higher chances of accuracy than ever before. In the aspect of railway transportation, accurate and well-presented data is a key towards increasing passenger engagement through the use of digital platforms as well as improving techniques of evaluating the progress of the form of transportation in question. Utilizing advanced railway network need to go hand in hand with advanced information dissemination techniques to

provide viable information on how the railway sector is progressing in the age of advanced railway network. As the number of people is growing in terms of telecommunication and internet service usage, these services are the focal point in data collection and analysis to provide visually understandable data to the public and through easier means.

This study was done to improve data aggregation techniques for the railway sector with the aim of improving passenger engagement in railway services by utilizing web and mobile applications as digitization techniques in use in today's world.

1.2 Statement of the Problem

The use of ICT has paved the way for public transportation to reach users at their fingertips with the speculated increase of users owning mobile devices that can interpret information through digital services offered. Process digitalization has become one of the factors for easier integration from manual to the technological transformation of various management systems aimed at simplifying transportation service provision in global context. As for transportation systems, this means integration of existing booking procedures, payment processes, and information dissemination through the use of ICT.

Long distance road transportation being highly used still has low engagement of passengers in acquisition of their services through digitalized processes according to a study done by Msigwa (2013) even though several transportation companies such as Shabiby and Tahmeed have existing digitalized booking systems. This has sparked a need for digitization of transportation services in which for the railway sector, it will pave a way for creation of datasets through data collected from the digitized processes and making improvements in service provision. This is to support future progress as railway transportation is going to be highly utilized due to many improvements done by the government and increase passenger involvement in railway services.

The research aims at increasing the engagement of passengers in railway transportation through process digitization by utilizing the use of mobile applications and at the same time provide TRC with data from their customers through the use of web application with the help of Global Information System (GIS) services. This is to contribute in the field of data science by improving data collection and promoting customer experience in railway transportation by generating data

that can be evaluated towards service improvements and establishing needs acquired from customers and boosting the creation of high accuracy datasets.

1.3 Rationale of the Study

As an African country and a member of the African Union (AU), Tanzania must follow goals stipulated in the AU and perform its duties to the utmost of its capability to ensure it joins hands with other African countries to engage in economic activities and drive the will towards developed status in terms of economy. As it has been seen throughout the initiation of various projects within the country such as the construction of the JNHP station and SGR network, there is a need to adopt modern management systems of these projects to be in the fast-paced global race of development and still offer support to pre-existing systems.

The use of data collected can help boost a nation's economy by pinpointing the areas under duress and those thriving hence getting a viable direction of how to increase productivity in given sectors. As for railway transportation, the study conducted speculates the ways TRC collects data and the types of data they deal with in the act of promoting their services and obtaining passengers as a way to increase their service provision.

This research gives a helping hand towards the use of information systems in the capacity of data collection and increasing customer engagement in railway transportation as the government has recently revived its transportation routes and has plans to promote further railway services in the future.

1.4 Research Objectives

1.4.1 General Objective

To develop web and android applications that capture, analyze and present railway data in visual aid presentations.

1.4.2 Specific Objectives

The study aimed to achieve the following specific objectives:

(i) To identify requirements for train travel planning and process digitalization.

(ii) To develop data sourcing and GIS modules for passengers' data compilation and better customer experience.

(iii) To test developed modules with data usability.

1.5 Research Questions

This research tends to answer the questions below:

(i) What are the requirements needed to evaluate the progress of activities involving transportation in the railway sector?

(ii) What is required to design a railway information with inclusion of data sourcing and GIS techniques in an effort to improve their experience?

(iii) Will the proposed system perform better than the existing ways used for data collection and increase customer satisfaction during the provision of railway services?

1.6 Significance of the Study

Public transport is the form of transport highly used in Tanzania in which being a third world country even with the recent achievement of reaching a lower-middle economy, still has a majority of people depending on public transport for their day-to-day activities. With the government's efforts in increasing the nation's economy, focus on the deployment of a vast network of infrastructure to facilitate further economic activities and attract more investors is in effect paving way for development sectors to thrive and have a hand towards increasing the national revenue.

With these efforts, the government will need larger manpower in ensuring tax collections are efficiently done and development sectors are deeply analyzed to see if there is any crack that brings down the effort for development. These efforts need to go hand in hand with internal analysis of the nation's development sector to give the government an overview of what has been done, what is currently in progress, and what can be done in the future to boost the effort for development.

This study has solely focused on the transportation sector by analyzing the railway services offered within Tanzania. The projected results provide an overview of railway services in terms of quality, the number of passengers, and decision making in terms of areas to boost services and where to establish new ones to reach and if possible, go beyond government aspects as the government is in the process of increasing efforts within railway transportation sectors through projects such as the Standard Gauge Railway.

1.7 Delineation of the Study

With the platforms developed as part of this study, railway data is aimed at making great changes in terms of aggregation, analysis and presentation. The developed system aimed at improving the methods in which TRC populates railway data on daily operations with higher accuracy projections in railway data analysis aimed at presenting the analyzed data with easy-to-understand visual depictations. With the attributes populated within the developed system, more railway data can be included to produce further meaningful projection on how railway sector is operating on daily basis.

CHAPTER TWO

LITERATURE REVIEW

2.1 Railway Transportation and Infrastructure in Africa

Following the existence of railway networks going back more than a century, African countries were not left behind as these networks started to exist during the colonial era. Many railway lines were constructed within African countries by colonialists to safeguard trade activities and maintain a military advantage over Africans (Jedwab & Moradi, 2012). After many African countries fought for their independence and managed to drive the colonialists away from their territory, it was the duty of African leaders to safeguard all resources and manage them towards African development. As a case for development, a study was conducted by Bayane *et al.* (2020) as part of analyzing the African Union vision for Agenda 2063 in the transportation sector. The study focused on the Economic Community of West African States (ECOWAS) and distinguished its data collection from 11 countries among them; Liberia and Burkina Faso. Railway infrastructure was found to be interlinked with mines and ports due to high exportation traffic from these areas with meter track gauge (1000 mm) being dominant while standard track gauge (1435 mm) is available in Ghana and Liberia only. In terms of rolling stock, 50.18% of wagons and 35% of passenger coaches were reported fit for use with an aging capacity of over 30 years. The use of mechanical signals and telecommunication technology dating back to the 1960s were reported as they fit the existing due to low traffic volume in existing networks. Even though there are few projects under construction but the study pinpointed the lack of interoperability and interconnectivity within the region as most projects focus on the national level hence exists inconsistency between present actions and future targets. Also, the study aimed at covering what ECOWAS goals for free mobility, business engagement in a peaceful environment, and improving regional transport system and the present undertaking have come to pass but a long road still needs to be covered. According to Deen-Swarray *et al.* (2014), most ECOWAS goals have hinted at infrastructure to facilitate development across the region which has led to cooperation with various African and international entities to ensure their vision is active and underway within their proposed time. But most of the railway networks seemed to be in the same conditions since the removal of colonialists and this has largely been so due to the case of increase poverty and large debt owed to developed countries as specified

by Mouhamed and Qiu (2020) hence making it difficult for ECOWAS to fulfil its goals within the amount of time they set out for themselves but they try harder to make ends meet as their agenda marks a milestone to development.

The colonial rule was largely occupied in Africa to the extent of reaching the southern zone of Africa. A railway network was built in South Africa connecting countries such as Zimbabwe, Mozambique, and the Democratic Republic of Congo (DRC). After independence, the Southern African Development Community (SADC) was formed and held the responsibility to oversee the railway network in collaboration with member states in which the network resides. It broke down the network into several corridors to facilitate easier management and policymaking. A study conducted by Sakanga *et al.* (2020) explores North-South Corridor (NSC) as one of the corridors in terms of its economic contribution to the SADC market. NSC links South Africa, Zambia, Botswana, Zimbabwe, and DRC where it faces multiple competitions from other corridors but has a regionally harmonized railway gauge. Despite being involved in the NSC corridor, South Africa has its core railway network within its borders in which according to DemmerezDeCharmoy and Grabe (2020), took advantage of the plans to convert it into a standard gauge railway network by 2050. The objective was to understand the impact of the new system and how other corridors can benefit from it through intervention by considering annual tonnage, line capacity, freight growth, and infrastructure conditions. The results stipulated that only three corridors were capable of utilizing the intervention by transporting enough cargo tones for efficient profit margin with regard to the construction cost planned.

There exist major companies that control railway networks in the Southern zone of Africa such as Transnet being TransNamib (DemmerezDeCharmoy & Grabe, 2020). Operating in Namibia, it has a fleet of locomotives considered to be more than 50 years of age making them utilize some of the oldest technological advancements in railway transportation since the colonial era. A study conducted by Engle *et al.* (2015) speculated the increased rate of train accidents and delays related to the TransNamib fleet which showed only 25% of the locomotives are in use. With old railway networks, untimely maintenance of locomotives, underfunding and long shifts for employees, the study showed how TransNamib made insufficient plans in ensuring safety while providing services leading to 90% of the accidents addressed to human errors. This study continues to show from a

long line of studies the situations with colonial-era railway infrastructure that is still in use with the African continent due to underdevelopment facing the continent (Blumenfeld *et al.*, 2019).

The extension of railway networks in the African continent can be seen as extensive through our own eyes but colonialists' plans were for business activities mostly and not for engaging in developing their colonial territories. Through the union of railway associations, many countries from all continents have come together to establish a similar goal of retaining the transportation power of railways by implementing goals linked to sustaining more effort in providing railway services. One of these bodies, the International Union of Railways (UIC) has speculated the implementation of railway goals towards a more advanced future in transportation and through frequently updated statistics, Africa has the least percentage of passenger kilometers, tonne-kilometers, and length of railway lines respectively from 2004 to 2019 making it the continent with low utilization of railway services and low contributor of economy in terms of railway services.

These studies focused solely on how railway infrastructure have been implemented by residential countries but have no footprint on how railway data is utilized in showing railway transportation projections within those countries.

2.2 Transportation Services Towards Customer Satisfaction

The use of any kind of service must link directly or indirectly to the customer to make the customer engage frequently with the service as that is one of the main goals when dealing with the provision of services (Meyer & Schwager, 2007). Knowing your customers can help to expand the business and receive criticism that can sky-rocket the business from where it currently is. From a study done by Kalangi *et al.* (2018), the researcher dived into the experience of customers as they got involved with a well-known mobile application from a company that provides a wide range of services. The results of the research portrayed the mobile application as user-friendly with most customers engaging with it daily. With services such as transportation and food delivery, most customers became engaged with the mobile application to make life a little bit easier which made the mobile application seem as a success to a higher remark in terms of its customer satisfaction and experience offered. Most customers prefer to engage in services when they have information beforehand of how, when, and where the service is to be delivered. Following the notion, Chan *et*

al. (2020) investigated how public transportation would be anticipated once the use of a real-time tracking system is introduced and made available to users. The study focused on attributes such as accessibility, safety, and reliability to boost the loyalty aspect of its users in public transportation. Deployed in Malaysia, the Global Positioning System (GPS) tracking system embedded in a mobile application saw a significant change in all its aspects researched with an increased percentage in every single aspect leading to increased customer loyalty and satisfaction in using public transport.

Management of the transportation sector mostly falls in the hands of its operators and with a large number of people acquiring public transport, understanding the needs of users of public transport can boost the quality and rate of service provision linking to further appreciation and engagement from passengers (Ojo, 2019).

In this section, the use of digital systems have been utilized by the various researches discussed making them favourable in increasing passenger involvement in transportation systems. Limitations within these studies lie on analyzing road public transportation without clear focus on railway transportation data acquisition and analysis within the areas studied on.

2.3 Railway Network Advancements

Developed countries played a large part in the colonization of Africa but had already enforced technological changes in their home countries before colonial rule started. This paved the way for them to acquire changes at a faster pace than developing countries at those times. From the times when trains were subjected to coal as a power source to the use of electricity, narrower track gauges and cellular networks such as Global System for Mobile communications (GSM) and Long-Term Evolution (LTE) for communication and management (Choi *et al.*, 2015). The evolution of train technology has been embraced positively leading to construction plans within developing countries to start bearing fruit.

Apart from ECOWAS, the Eastern part of Africa was not left behind during colonial rule in terms of railway transportation which contributed to goods and services around East Africa during those times. It made it easier for colonialists to transport materials from one area to another easier through trains at that time as advancements in science and technology were low compared to

today's world. For Kenya, the revolution of railway transportation goes back to 2009 when preparatory work and design were initiated which led to successful contract signing by 2014. A study conducted by Wissenbach and Wang (2017) was aimed at speculating the need that drove Kenya to engage earlier in advanced railway systems and the influence of Kenyan politics and Chinese government along the way as well as the impact the new railway network had on the local economy. The reign of President Uhuru Kenyatta showed interest in deploying the Standard Gauge railway network and by 2017, the dream finally became true by making Nairobi-Indian Ocean a Standard Gauge railway network. This network led to job creations, greater revenue generation, and increased customer engagement in railway services which gave Kenyan citizens a great deal of involvement in the project as they were more than 70% different from allegations pointing out that the Chinese used their people and few or none from Kenya. The study further speculated the accusations of corruption leading to presenting the construction contract to the Chinese company in which it was highly doubted from the study's point of view as the tender bidding was seen to be uncompetitive from the government's end according to procurement laws and lead to the Chinese company, China Roads and Bridges Corporation (CRBC) to acquire the contract and as of the result lead to negotiation breakdown of Uganda-Kenya oil pipeline. Also, the study found that tribal conflicts among Kenyan MPs led to delayed planning and financing of the project in which after the establishment of the project, land disputes emerged between citizens and the government with the government stipulating the land is owned by them as it was similarly speculated by Zhao (2020). The issue of debt came to light as the government had borrowed money from the Chinese government to finance the project leading to an increase in import tariffs from foreign countries to contribute to loan payments as well as the increase in debt-to-GDP ratio according to Githaiga and Bing (2019), similar to the situation in the construction of Ethiopia-Djibouti railway line (Mohapatra, 2017). The end of the study showed that Chinese companies in general experience many disputes with residents mostly due to imbalance between the governments and its people making China seem like the root of the problem during the construction phase even though they acted as technology transferors at that time and area.

These studies show how technological advancements can be implemented to ensure railway transportation is under proper utilization with ability to adapt to new era of science and technology. Even though these studies focus on African countries utilization of technological advancements in railway transportation, these studies fail to show how data that will be generated through the use

of advanced systems can be collected and analyzed for future use and projections on railway transportation.

2.4 Use of Datasets in the Transportation Sector

The flow of information has increased rapidly since the 1960s as the use of the information superhighway (now commonly known as the 'internet') came into existence (Mercer, 2000). This provided a way for individuals to present their information to anyone and in whatever way they wanted as long as it reaches the intended audience. As the internet grew, new networks such as social networks came into existence paving way for people from different angles of the world to interact and exchange ideas. The expansion created multiple flows of information globally enabling the process of data mining to process the data and produce meaningful information.

As networking increased so did the flow of information in which various companies engaged in the process of collecting the information and storing them in so-called datasets. These included any type of information related to that particular company to help in identifying their number of customers and different traits they possess that keep them engaged in the services provided. From schools to multi-billion dollar companies, the flow of information is increasing and proper analysis of information is needed to obtain valuable aspects of users and their behavioral traits towards the services provided. Even governments have interacted in the process of data mining to better visualize how their development sectors are progressing and what plans are needed to ensure the continuation of greater revenue generation and aiming high towards development. Others use this information to compare various aspects that exist in the transportation sector such as Morency *et al.* (2007) who speculated the existence of car-sharing systems in Montreal by analyzing the transaction datasets that were collected by one of the companies providing car-sharing services. The study aimed to analyze day to day usage of these services by passengers and find a link between trips by using the transaction datasets provided. The results displayed the pattern between frequent and occasional users as well as frequently used trips with their respective timestamps. This study helped to provide the company with deeper visualization of how their business can be enforced to other parts of Canada and make a profit out of it due to transaction datasets they collected.

Another study by Du and Aultman-Hall (2007) made the use of GPS receivers to obtain GPS data streams to identify trip length during service provision taking into consideration the amount of time the vehicle is stationary. It involved participants who were directed to record time when the vehicle was stationary and when in motion to distinguish the length of trips at higher accuracy. Equipping vehicles with GeoLoggers, the study resulted in the identification of 94% of the trips and made the data collected enable much higher accurate datasets through the use of trip dividing methods.

Apart from road transport, studies have been done in the air transport trying to understand the trends of its users as the services are ever-growing leading to Hess and Adler (2011) deducing small changes in user travel patterns with change in air travel conditions for United States of America (USA) from datasets collected between 2002 to 2005.

2.5 Transportation Services in the Digital Era

Science and technology advancements are hard to ignore in this day and age as they are portrayed in every aspect of our lives either in communication or our travels. With the management of major development sectors such as transportation, many countries try to engage in these advancements as they have shown that a load of management becomes lighter compared to the use of manual techniques. Many people engage in the world of smartphones which act as small information dissemination devices capable of transferring information globally without change in position.

With transportation, some have employed the use of these smartphones which use mobile applications that can be created by anyone hence reducing the restriction to a few developers. Anybody can create these applications and be a helping hand in turning around development status individually or nationally. As the number of public transport users does not seem to slow down, multiple applications have been created to help in managing information from transport service providers such as (Ghosal *et al.*, 2015; Sutar *et al.*, 2016) who have made online usage of transportation services possible in railways and road transportation across India. These studies have exploited the use of online storage, GPS, and GIS techniques to increase customer engagement and the in-depth flow of information related to their areas of study. Ghosal *et al.* (2015) contributed to the process of online ticket booking and the use of virtual money through smartphones giving way to reducing unnecessary queues during the booking process. Further Sutar

et al. (2016) engaged in the Internet of Things (IoT) which made possible the exploitation of mobile application development, Radio Frequency Identification (RFID), and existing wireless cellular networks to provide users with information on the nearest bus from the position of the user by utilizing the capability of mobile application to communicate with a microcontroller placed on the bus through RFID technology to determine the distance between the user and the nearest bus. For smaller cities, the use of mobile applications for simplifying public transportation has been seen as an effective solution as Aykurt *et al.* (2018) showed how mobile applications can be used to show various bus routes, bus boarding, and payment as well as a weather forecast on a particular day for users' decision when in Sivas province in Turkey.

Due to a variety of technological techniques, researchers such as Kamilakis *et al.* (2016) have gone to the extent of utilizing these features to showcase how users can interact with different features that portray the same kind of information and come with different user experiences. The study utilized the use of maps and mobile augmented reality (MAR) in which MAR uses real-life objects embedded with fictional objects describing the real-life objects. The two mobile applications were deployed to a sample population in Athens, Greece to anticipate which mobile application had a better reaction with the users. The results of the study yielded that MAR applications were seen as new and groundbreaking due to fewer people having direct engagement with them while the mapping feature on mobile applications seemed to be familiar and users were more comfortable using them.

Other technologies such as Bluetooth have played a big part in transforming transportation services into a data mining source that can help to make decisions based on data generated. A study done by Ahmed *et al.* (2016) exploited the use of Bluetooth and Dedicated Short Range Communications (DSRC) technologies as a way to predict real-time vehicle movements for taxis in New York, America, and displaying the results on Google Maps. It involved developing a mobile application with the capability of communicating with DSRC devices through Bluetooth devices embedded in the smartphone. The results showed the capability of the mobile application to obtain information communicated from DSRC device and meaningfully display it on a map giving further determination from the city to deploy the technology to other transportation utilities. More researchers utilized the power of machine learning and artificial intelligence to provide an understanding of the world of railway construction through the use of satellite imagery. The study

conducted by McCullough *et al.* (2020) inspected the possibility of attaining valuable information from photogrammetry reconstruction of railway lines in Ethiopia and representing it as geospatial data that was used to train a model for the prediction of transport routes construction to simplify planning processes for developing countries.

2.6 Impact of GIS in the Transportation Sector

The flow of information has been an important part of our world of today full of advancements in science and technology. Being a part of the development sector, the transportation sector has been involved in generating huge amounts of data due to the engagement of many people in this sector either through public or private transportation. The movement of people drives this sector to further heights as transportation is highly utilized and promotes interconnectivity as well as interoperability. It boosts other development sectors such as tourism and trade to a point where development without transportation is considered ambiguous.

Through advancements in science and technology, there exists a need to have information beforehand to make appropriate plans as to what services are lagging or need improvement for the provision of services to thrive. In the case of transportation, researchers have dived into the concept of unifying information as a whole leading to the creation of GIS and making things like Google Maps possible. With the introduction of GIS, some cities have taken into account the implementation into their transport sectors such as Almasri and Al-Jazzar (2013) who have performed trials in their transportation plans to speculate the flow of traffic in Gaza city. The study aimed at performing traffic estimations by taking data from 36 intersections within the city. With the use of ArcGIS software and TransCAD, the results showed a difference in actual (use of model) and estimated (traditional ways) is about 10% by the use of spatial analysis and that within the next 2 to 3 years there will be an increase in traffic. The study became a beacon to city planners by showing different gaps that emerge from the existing plans and urging new plans for smooth and futuristic control of traffic.

As most developing countries face restrictions in financial acquisitions, Agyemang (2013) tried to adopt a way to engage GIS into Transportation Information Systems (TIS) leading to the use of Geographical Information System for Transportation (GIS-T). The aim of the study conducted was to see the applicability of cost-effective ways to employ GIS techniques in developing countries

and obtain results that can help to boost transportation restructuring and data collection. Conducted in Ghana, the study focused on one of the highways in Accra due to the high population of people meaning high traffic flow and a huge amount of data to deal with. Traditional stopwatch and traffic congestion registration technique that uses GIS receiver was used to generate bus stop coordinates and time travel data along the highway at different times of the day which led to identifying peak hours and their traffic flow. The research concluded that it benefited in terms of costs and yielded better results compared to existing techniques used at that time. This showed that there are ways to implement GIS with minimal costs and training without relying on developed countries' assistance in performing their analysis in the transportation sector.

2.7 Study Gap

As much of the studies discussed above specified, the use of ICT in transportation is not a new concept and its continuation is highly projected. These studies talk about simplifying transportation services or analyzing the trend of customer engagement in the provided services but most studies have been done in developed countries. Developing countries were left out mostly due to poor infrastructure and lack of advanced transportation techniques making it difficult for researchers to show various trends of transportation services at adequate periods of time. For Tanzania, the studies focused mostly on the performance of the railway sector in economic development but failed to speculate the existing railway network practices collaborating in specifying the extent of performance through their collected data.

This study engaged in the growing use of ICT in Tanzania by utilizing the techniques available to promote broader data collection with higher accuracy as well as increasing the percentage of passengers' engagement with railway services. This aims to initiate a base for further incorporation of other techniques as the advancements continue through the construction of the SGR network. Utilization of mobile and web development as well as web mapping techniques has increased over the years with their usage being part of many companies' service provision techniques in which integration of these techniques can be utilized to create a functional system for improving data collection techniques and pave way for the corporation to benefit in the world of technological advancements. This will help TRC to have a platform for information dissemination that will

utilize global technological usage and reach an unlimited number of people giving power to TRC to brand themselves internationally and still provide services nationally.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Research Methodology

For the study conducted, the use of a mixed method approach was chosen. This research approach refers to the utilization of collected numerical and narrative data as well as observations from existing theories and deducing a pattern to whether the collected data corresponds to the theories or not (Williams, 2007). Assessment of railway information was deduced with comparisons from United Kingdom with those from the Tanzanian context which provided similarities and differences in data aggregation and analysis for decision-making practices concerning the railway sector. Numerical data was obtained from TRC contained in various datasheets which speculated statistics such as revenue and passenger movements while narrative data was obtained from questionnaires, interviews and further document reviews.

3.2 Study Area

Following the increasing number of people in Dar es Salaam, the government through TRC has implemented the use of commuter trains that provide railway services across the region with the target of reducing traffic congestion in road networks. As the railway network seems to start from Dar es Salaam branching to other regions (Fig. 1) and higher number of people acquiring commuter train services, the flow of information is highly achieved daily leading to most train travel information being collected at Dar es Salaam as it is the biggest city in terms of population and business activities (Collier & Jones, 2016). Tanzania Railway Corporation (TRC) controls a large part of the railway network as compared to Tanzania-Zambia Railway Authority (TAZARA) and its headquarters are still in Dar es Salaam making it easier to use the city as a study area due to necessary information concerning the movement of passengers and goods through trains being collected at their offices in the city.

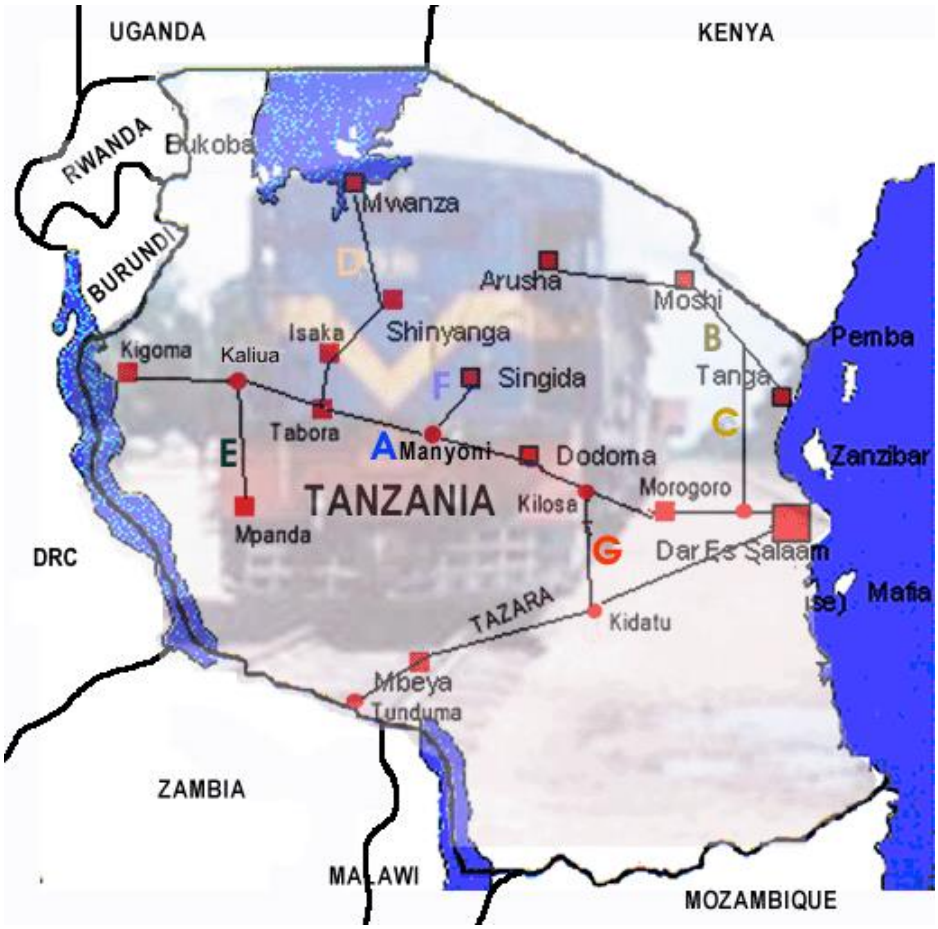

Figure 1: Existing railway network in Tanzania

The use of datasets is highly linked to developed countries and due to this, comparison with data collected by Tanzania was used to show the extent to which Tanzania has reached in terms of understanding various attributes needed to analyze the trend of railway transportation. With Europe having a vast network of railway lines, datasets from the United Kingdom were chosen for comparison as they are annually published with more content than other developed countries and are under the terms of Open Government License v3.0.

3.3 Data Collection

To achieve the process of identifying requirements; questionnaires, interviews, and document reviews were considered for data collection in this study (Hox & Boeije, 2005). The specified study has focused on the transportation sector targeting the railway sector to understand passengers' requirements and how to implement them in the process of digitalization as well as

deducing the pattern between Tanzania railway sector and developed countries' railway sector data collection. Questionnaires focused on passengers views and understanding on existing railway service provision while interviews focused on TRC efforts and challenges during service provision. Data collection based on primary data from questionnaires and interviews with secondary data uncovered from document reviews mostly railway transportation datasets from United Kingdom.

3.3.1 Interviews

This is more of a face-to-face conversation with the interviewee or through a communication device such as a mobile phone . This can be identified as mining information from the source in a very direct way. The use of interviews was proposed to attain information about various departments of the corporation with their daily tasks where questions were created through an online tool known as Google Forms for better error corrections and higher accuracy achievement.

With the available number of departments, it was reasonable to conduct unstructured interviews with the personnel concerned due to different approaches towards the provision of railway services within the corporation where valuable information was extracted concerning passengers, data collection, infrastructure, railway networks, and maintenance practices. Purposive sampling was used where the heads of departments such as safety, statistics, and business operations were interviewed to understand the depth of TRC operations by each department's effort in providing railway services. A total of 4 heads of department, 2 employees of the business department and one from statistics department were interviewed face-to-face according to the interview guide in Appendix 2. The selected staff were chosen for their roles in acquiring and storing railway data according to the study's requirements.

3.3.2 Questionnaires

This technique is used to give a respondent space to write their answers at their time with higher accuracy without the need for fast responses as the questions are simple and need no or very little elaboration . It is discrete hence providing the respondent with a sense of security while answering the questions without the worry of being pointed out due to the nature of the answers. With the use of online tools, Google Forms was used for creating, sending, and analyzing answers from

questionnaires at an easier pace than the use of printed paper forms. This helped to create more accurate questions and collect answers within a touch of a button simplifying the art of collecting answers from individuals physically. Random sampling was used to give each participant a chance to submit answers as much as required. Sixty five (65) questionnaires were distributed among passengers but only 48 were returned which results in 74% of distributed questionnaires.

3.3.3 Document Reviews

Information has been collected since the beginning of time and people have found ways to store information for future use in favor of themselves and others. Document review is the process of collecting and analyzing information stored at different times about a particular topic from various sources either be physical or electronic copies. Safeguarding of information has proven valuable for research purposes where researchers can use pre-existing information to create something new or improve it.

As the study focused on datasets, developed countries have been further steps ahead in terms of utilizing advanced technological practices as compared to developing countries in terms of datasets generation. This led to the use of United Kingdom datasets for railway transportation under the Department of Transport in which massive amounts of railway data are collected due to a large number of daily operational trains of about 24 000.

Attributes such as the number of public performance measures and passenger satisfaction surveys are conducted and analyzed and finally presented in a readable form with high accuracy giving the research room to compare various attributes of railway services as the datasets are published by the Office of Rail and Road (ORR) under the terms of Open Government License v3.0. This will be used to deduce various attributes by the United Kingdom in terms of the railway sector as compared to TRC collection attributes collected over the years.

As the research focused on the Tanzanian railway sector, TRC documents were reviewed to understand the evolution of railway transportation in Tanzania and to what extent the corporation has reached in terms of engaging in the ever-growing field of science and technology. Data from TRC documents and datasets from United Kingdom railway transportation were analyzed to

visualize the extent in which Tanzania railway sector has reached in terms of railway data as compared to developed countries railway data aggregation and analysis stretch.

3.4 Data Analysis

The research focused on utilizing information from the railway sector, the major plan was to understand various railway attributes collected by TRC within the country for trend analysis of the railway sector. United Kingdom's railway datasets were chosen and compared to Tanzania's railway data for better visualization of how these geographical areas operate their railway transportation systems by analyzing the content obtained from documents reviewed, questionnaires and interviews conducted. To achieve this, the analysis stage was conducted through the use of a data analysis tool known as R Studio. It is a free and open-source tool with various features such as code editor and advanced visualization tools giving users space to create unique and understandable visual-aid analysis through the use of R programming language suited for data science practices (Krotov, 2017).

3.5 System Design

The software development process relies on the design phase which helps to provide requirements for the system before actual coding is done. In this point of view, the study used collected data to produce these requirements by use of Unified Modeling Language (UML). It is a world-known language due to its use of graphical elements such as use cases and sequence diagrams which act as blueprints for system developers (Schmuller, 2004).

3.5.1 Functional Requirements

These are observable tasks or processes performed by the system. These are mostly noticed by the user of the system. For the proposed system, the functional requirements identified are described in Table 1.

(i) Functional requirements for web application

Table 1: Functional requirements for the proposed system

No.	Requirement	Description
1.	The system will allow the system administrator to log in	(i) System administrator gets access to the web application upon provision of correct credentials. (ii) Integration of two step-authentication during registration is implemented for better security measures towards accessing the web application. (iii) For security purposes, the system will provide the administrator chance to reset the password when necessary.
2.	The system will allow the system administrator to add and update information	(i) The system administrator will add new information or update the existing one when appropriate. (ii) Old and irrelevant information at that particular time can be deleted.
3.	The system will perform data review and analysis with the help of data visualization techniques through PHP and HTML manipulation	(i) Existing data will be reviewed and the system will help the system administrator to perform data analysis through PHP and HTML functions for data visualization. (ii) Charts and graphs will be generated for better visual data representation.
4.	The system will allow the system administrator to generate and upload reports	(i) Stored data will be used to generate railway reports showing data collected at each month of the populated year. (ii) Reports such as revenue and passenger journeys will be generated in pdf form for reviewing and in excel form for mathematical manipulations. (iii) Option for uploading important documents for passengers' reviewing will be provided by the system.
5.	The system will retrieve passengers' comments for review	Passengers' comments will be collected within the database and retrieved to the web application for further review.

(ii) Functional requirements for android application

Table 2: Functional requirements for android application

No.	Requirement	Description
1.	The system will allow passengers to make comments.	(i) Passengers will write and submit comments on specific train stations and areas of concern. (ii) The system will capture the date when each comment is submitted.
2.	The system will provide information on railway service provision.	(i) The system will provide train information in terms of train categories namely commuter, long-distance, and SGR. (ii) The system will contain the fare amount for each active train route with timelines for departure and arrival of the said route. (iii) Links to external systems created by TRC such as online ticketing will be embedded to enable further interaction of passengers with existing systems.
3.	The system will allow passengers to read documents.	Passengers will read documents that have been uploaded to the centralized database by the TRC system administrator.
4.	The system will allow passengers to access TRC progressive activities.	(i) Passengers access the latest information on the nature of railway services. (ii) The system will provide links to external sources of information for railway services such as social media accounts of TRC for further inquiries. (iii) Information on current management and board members will be portrayed for a better understanding of TRC's managerial roles.
5.	The system will provide GIS information of railway stations as well as its network in Tanzania	(i) Web maps created by use of QGIS will be embedded in the mobile application in pdf form. (ii) Each route active in Tanzania will be mapped and shown to passengers within the mobile application
6.	The system will provide visual presentations of data collected by TRC.	(i) Annual data collected by TRC will be stored in a centralized database for a simplified data analysis process. (ii) Stored data will be categorized in terms of train type such as commuter and long-distance with further categorization according to train wagons for long-distance trains.

	(iii) Graphs and charts will be presented to passengers on various attributes such as revenue for each year of successful train operation.

3.5.2 Non-Functional Requirements

These are requirements guiding the behavioral properties of the system. They describe the qualities of the developed system in completion. Table 2 describes the qualities of the proposed system.

Table 3: Non-functional requirements of the proposed system

Attribute	Constraints
Response time	Moving from one page to another should be within 5 seconds.
Security	All passwords will be encrypted within the database after a successful signup process.
Compatibility	The android application will be compatible with all smartphones and tablets capable of running android software.
Ease of use	The language and directory used should be understandable.

3.5.3 System Design Architecture

In the development of the proposed system, various components are entitled to connect to make a complete system that will deliver upon the requirements specified. These components can be linked to a specific structure that shows how the system works as compared to the connections that exist between components (Hasselbring, 2018). The proposed architecture of the developed system can be seen in Fig. 2.

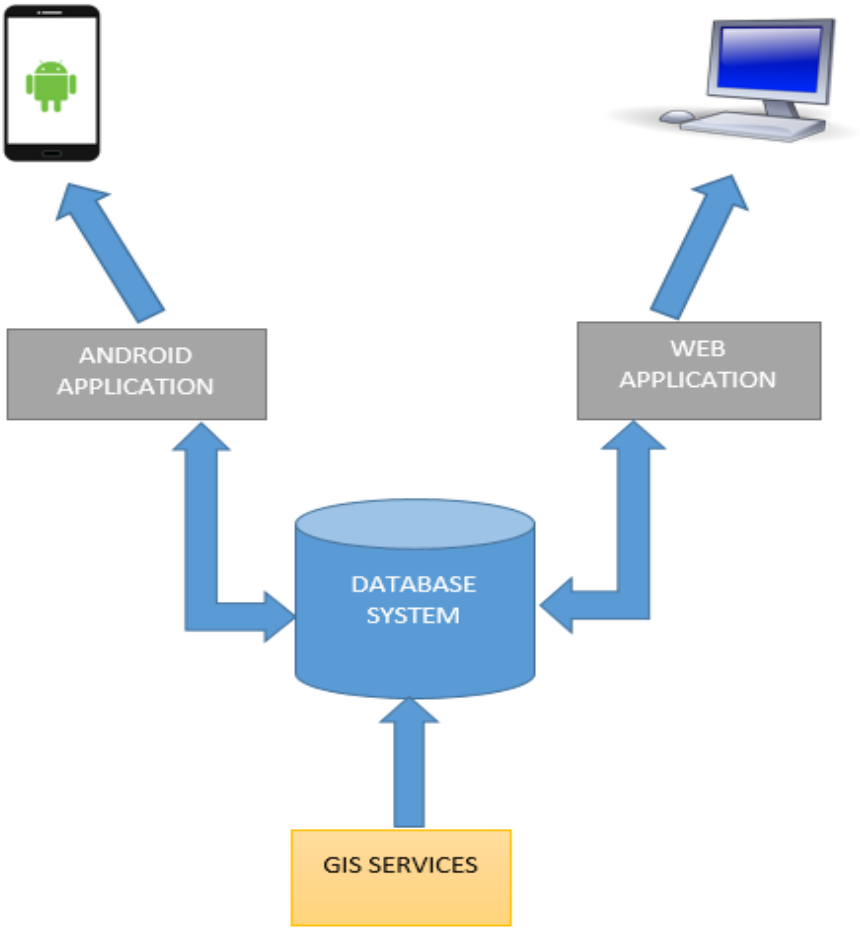

Figure 2: System architecture for the proposed system

For a clearer understanding of how the system works, a contextual diagram has been created to show the flow of data when the developed system is in operation. Figure 3 shows the integration of web and mobile applications accessed by system aadministrator and passengers respectively. With activities such as uploading train statistics and schedules as performed by system administrator through the web application, passengers get to access these statistics and schedules through the mobile application which is interlinked with the web application through the centralized database. Online train ticketing system and TRC website act as external systems due to being already established by the corporation hence the diagram shows how these external systems have been embedded within the integrated system and information passed through when these external systems are accessed.

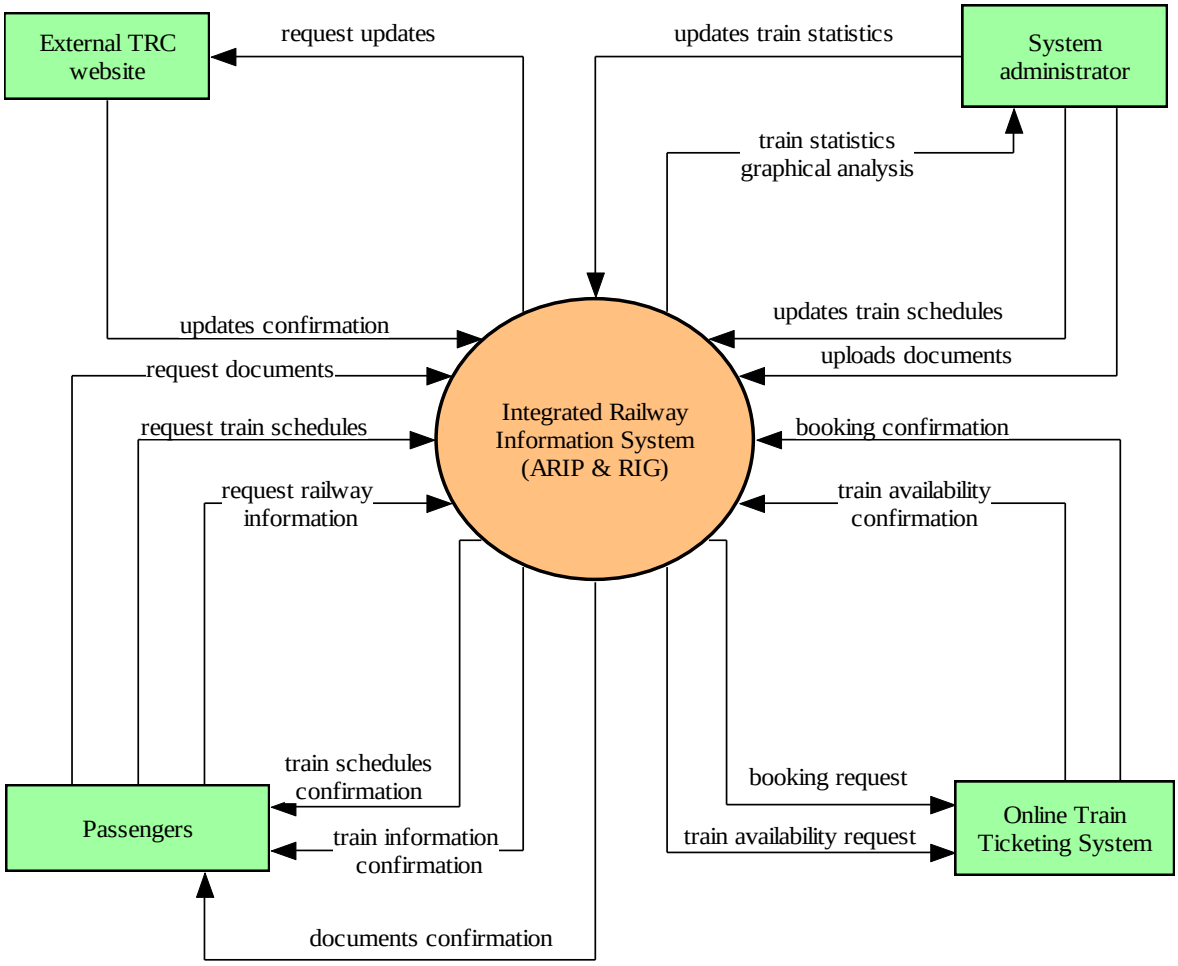

Figure 3: Contextual diagram of the developed system

3.6 System Modeling

After data analysis, the researcher needs to evaluate findings and come up with requirements. As the research stretches to the development of an information system, the requirements need to be modeled into a systematic flow and this will be achieved by the use of Unified Modeling Language or UML. Developed in the 1990s, this language creates a vision of the system according to the user's perspective and comes up with a blueprint of the system before development starts (Schmuller, 2004).

3.6.1 Data Flow Diagram

This is a visual presentation of the existing relationship between data and system entities. It shows the flow of data from one entity to the other when the system is in operation. This diagram enables the developer to understand how the system needs to interact with its user and provides a wide range of functionalities that need to be integrated into the system for smooth interaction. It is easy to understand in which it can be used to present the system to non-technical personnel without much difficulty.

3.6.2 Use Case Diagram

This mostly depicts who is to interact with the developed system and what activities they are to engage with when using the system. It describes how the system will work according to the user's view and access level to the system.

From the functional requirements specified for the system, use case diagrams created have adopted two actors namely system administrator and passenger in which Fig. 4 and Fig. 5 show various activities to be undertaken by passengers and system administrator when they interact with the developed system through the android application and web application respectively.

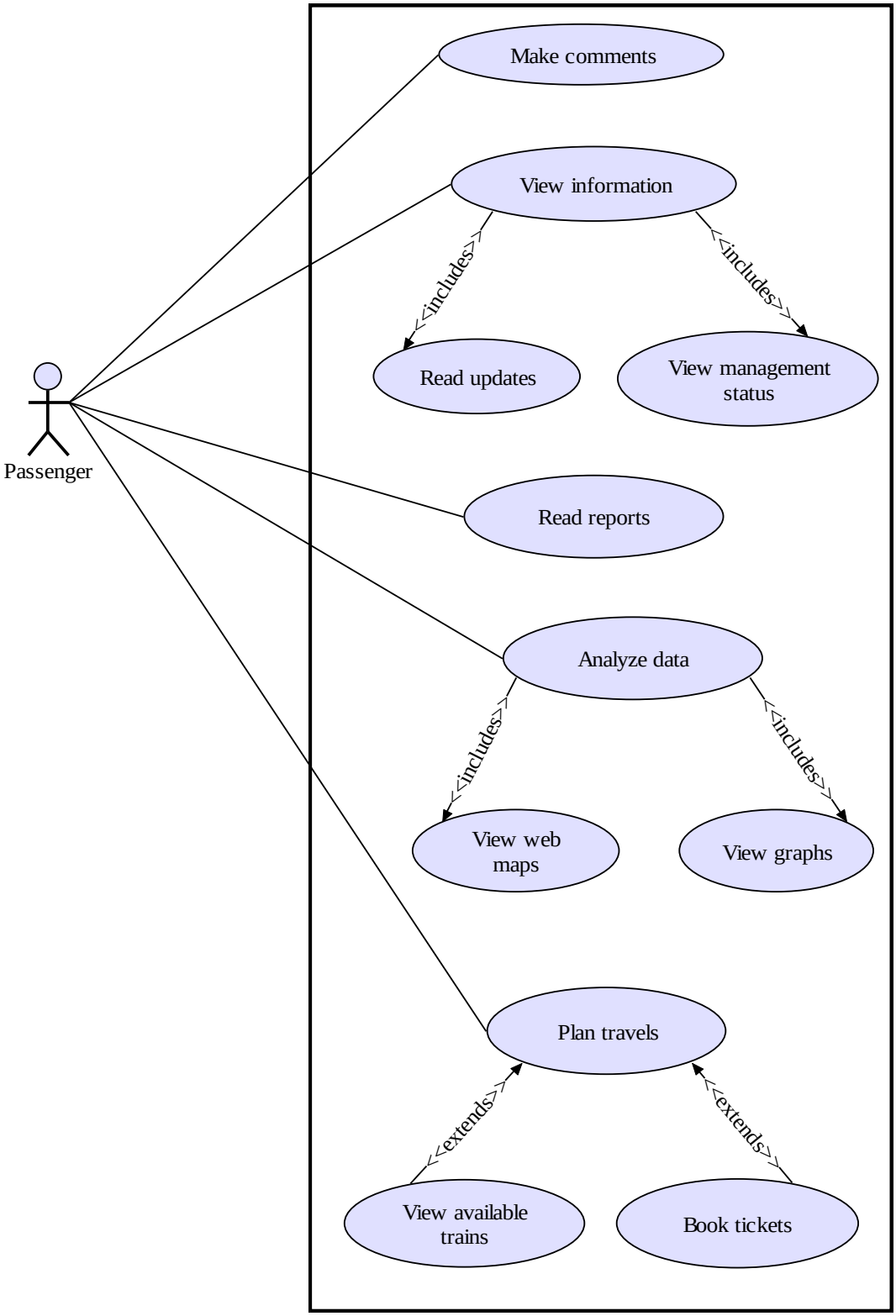

Figure 4: Use case diagram for passenger

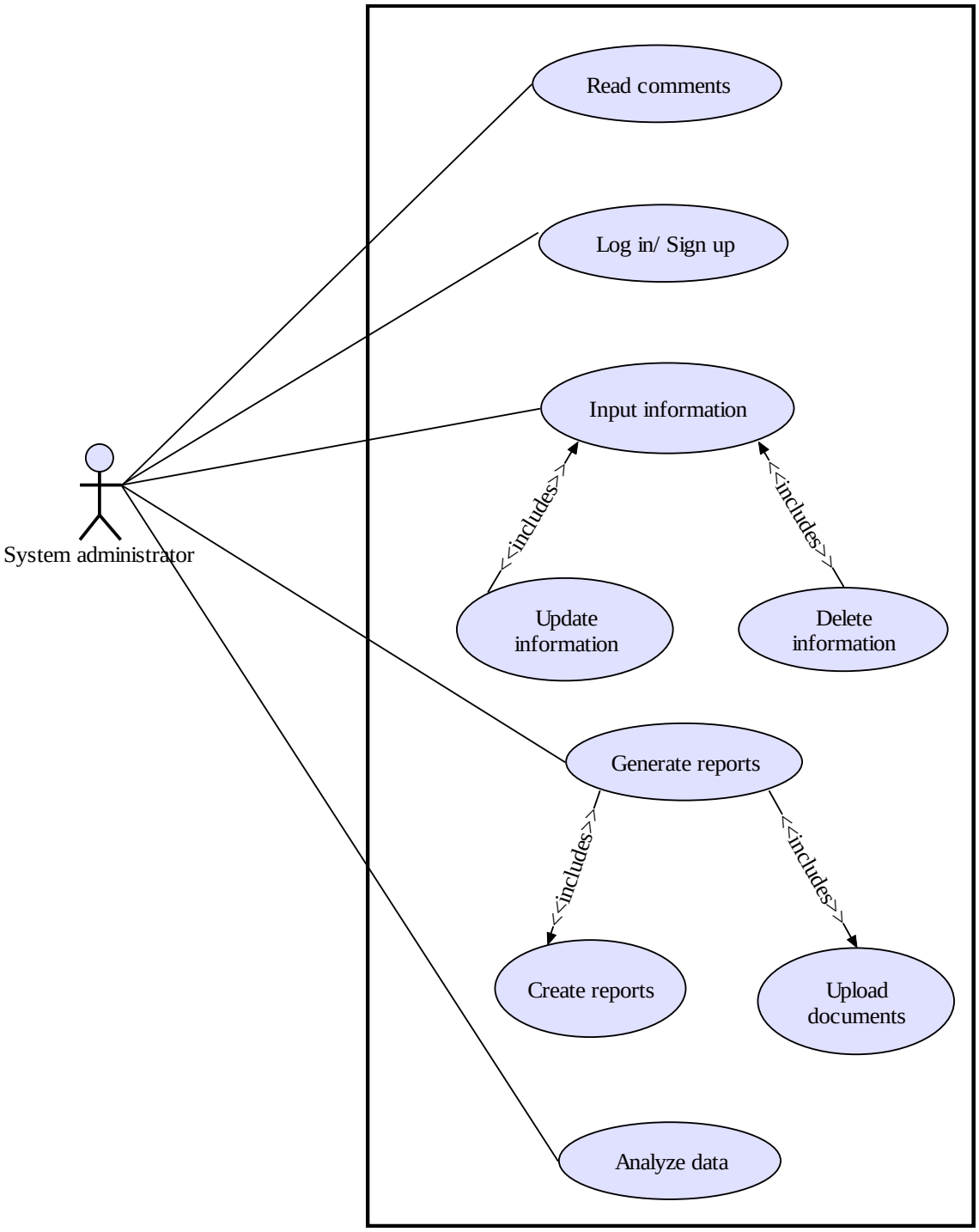

Figure 5: Use case diagram for system administrator

Each use case activity can be further explained through use case descriptions. These are used to show the detailed path the use case activity will take from who is involved with the use case to the flow of events. To showcase the use of use case description, Tables 3 and 4 provide explanations

on two use cases one for each actor respectively where the “Make Comments” use case has been used to show the interaction aspect between passengers and TRC through the mobile application. The “Generate Reports” use case has been used to show how data is placed in various file formats for better visualization through the web application when accurate data has been collected as the study focused on improving datasets generation.

Table 4: Detailed explanation of “Make Comments” use case for passenger

Use case	**Make comments**
Description	Passenger adds comments
Actors	Passenger
Pre-conditions	Passenger must be connected to the internet and has android application pre-installed
The basic flow of events	(i) Passenger accesses the android application (ii) The system prompts the homepage (iii) Passenger chooses comment section (iv) Passenger is guided by system to fill the required information (v) Passenger provides necessary information and submits a comment (vi) The android application sends the comment to the centralized database. (vii) Database acknowledges the added comment (viii) The system exits the comment section and prompts the homepage of the mobile application
Postconditions	A new comment is added
Special requirements	The user is connected to the internet and using an android enabled mobile phone

Table 5: Detailed explanation of "Generate Reports" use case for system administrator

Use case	**Generate reports**
Description	System administrator generates reports from railway data stored in the centralized database
Actors	System administrator
Pre-conditions	(i) The system administrator must be connected to the internet. (ii) The system administrator must establish a successful connection to the centralized database.
The basic flow of events	(i) System administrator accesses the web portal of the system. (ii) The system prompts the homepage of the system. (iii) The system administrator chooses the "Statistics" dropdown menu item. (iv) The system administrator chooses desired statistic option of the dropdown menu for report generation. (v) The system prompts the selected option page. (vi) The system administrator clicks the desired file format report generation download button. (vii) The system acknowledges the request and generated the appropriate report by compiling data from the centralized database.
Postconditions	Data is compiled and viewed in form of a file
Special requirements	The system administrator is using a web browser and has direct access to the server-side of the system

3.7 System Implementation

After identification of all requirements needed for the system development, implementation depicts the tools needed to make the system come to life. As the research deals with the utilization of ICT as the flow of information and data collection basis, the development of a mobile application and a web application has been considered as the best way to improve integration between railway services and its users. A detailed approach as to what is needed to bring this integration into life is explained in the categories.

3.7.1 Android Application Development

Being a free source operating system for mobile applications, the android mobile application has been chosen as the best solution for passenger side interaction (Holla & Katti, 2012). This is due to the increased number of android phone users as opposed to other mobile platforms such as iOS and KaiOS as a result of cheaper prices and familiarity of Android operating system in terms of use. To enable the development of an android mobile application, Android Studio software which is freely supplied by Google was be used due to its wide range of features making it possible for achieving development strategies with the help of Java programming language as seen in Appendix 1.

3.7.2 Web Application Development

The number of computers being produced has skyrocketed in the 21st century and with further functionalities being credited, the art of web development has evolved with developers trying to enter the speculated age of codeless web development. Web development is the process of creating a website or web application for the internet or intranet (Mikkonen & Taivalsaari, 2008). With the research being on information systems, implementation of a web application has been chosen as the best way to integrate with the android application as the two will be interlinked in the process of information transfer. Web technologies such as HyperText Markup Language (HTML), JavaScript, and Cascading Style Sheets (CSS) were utilized hand in hand with an open-source web development platform known as Visual Studio (VS) Code for the web application development process.

(i) HyperText Markup Language

This refers to the standard language used to create web pages. Over the years, it has been improved and newer versions have been released to cater to existing features and needs for developers. It contains all necessary content that needs to be seen within the web application for a user to interact with by specifying how text, graphics, video, and other files are organized and linked together . For the system to be developed, the HTML 5 version was used to utilize new and improved features as compared to older versions. .

(ii) Cascading Style Sheets

This deals with the visual aspect of the web application. It contains features such as color, font, and style which gives developers much room to work with depending on how the web application needs to appear visually to make the user more engaged with the web application. It promotes the ability of the developer to create a unique web application compared to others.

(iii) JavaScript

This is referred to as the programming language used for the manipulation of data inserted in webpages. It can manipulate HTML and CSS elements meaning it interacts with HTML and CSS to create interactive web pages for the user with most developers referring to it as a scripting language.

3.7.3 Web Mapping

This is the integration of maps within web pages to collect and analyze spatial data through the use of APIs and frameworks to boost integration of online cartography skills (Roth *et al.,* 2014). From the list of well-known GIS software, QGIS will be used for creating and deploying maps into the developed system due to it being open-source, having an existing working relationship with HTML and JavaScript as well as having a large community of developers for debugging and expert assistance. It also has a powerful plugin known as qgis2web which will be useful in deploying QGIS layers into HTML format.

3.7.4 Database Implementation

Data needs to be stored upon collection and database systems are what take the advantage of the situation (Coronel & Morris, 2016). With the development of mobile and web applications, information captured by these two systems needs to be stored in a database system to complete the back-end development process and create integration between them. With the research focusing on improving ways to populate datasets, the use of a database system is of utmost importance and with the evolving trend of technology, a structured query database was used to integrate the system. The use of XAMPP server, PHP and MySQL technologies will be utilized for a smooth transition of stored data.

The use of MySQL database was devised as a necessary method for the data storage mechanism for the system developed from the research under study. The use of the MySQL database proved to be useful due to the high integration of data types collected from the system as well as the large community of developers sharing and engaging in various problem-solving techniques through this type of database. Figure 6 shows various database tables that have relationships among each other within the MySQL database created for the developed system.

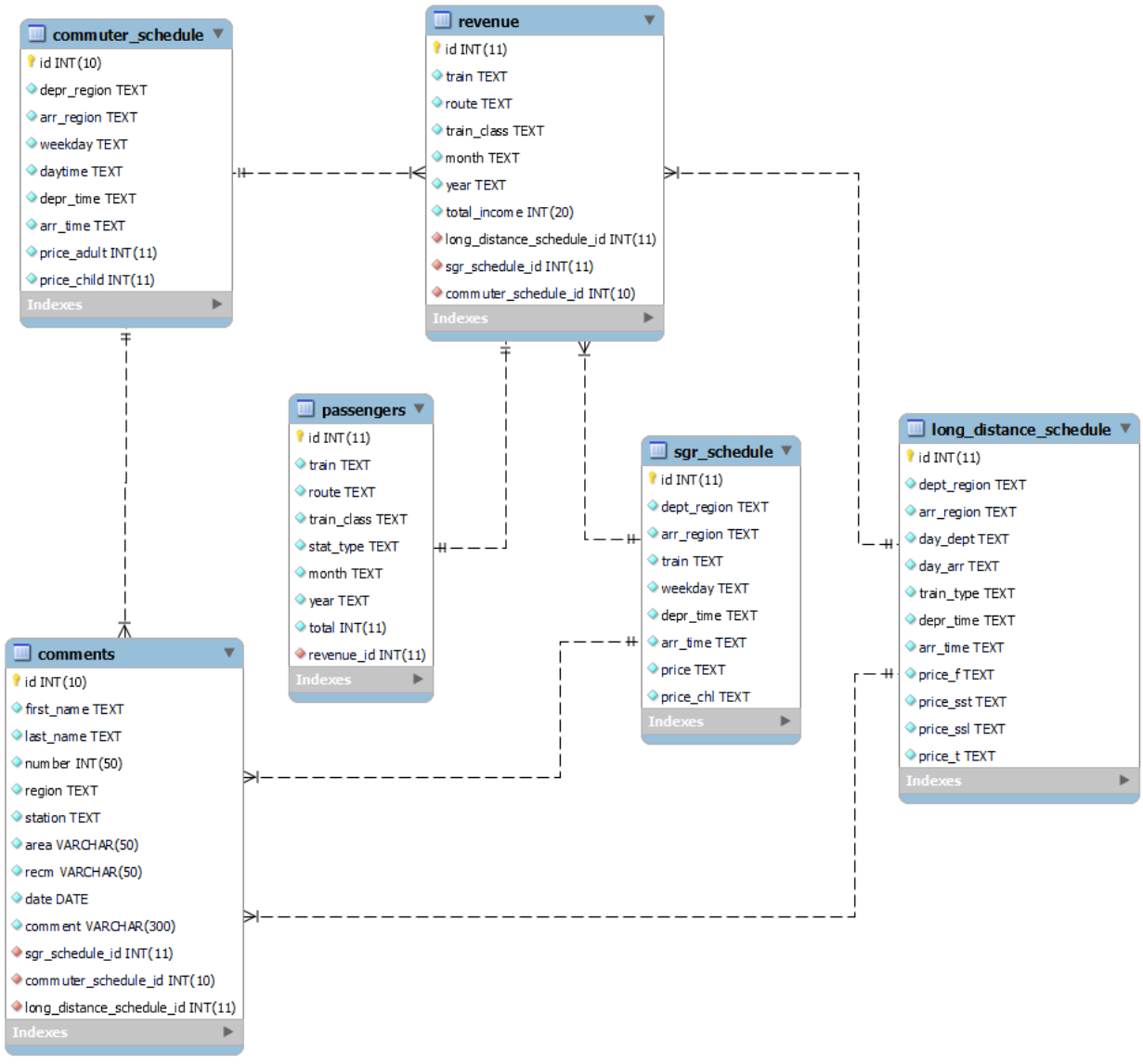

Figure 6: Relational schema of the centralized database

3.8 Software Testing and Validation

This is the last step after development in which the system will be tested to verify its capability to utilize all requirements specified after complete system development has been achieved. With the developed system, the tests were conducted to see if the individual attributes perform their functions effectively as well as interoperability among two or more functionalities.

A group of 28 people consisting of 6 TRC staff, 17 passengers and 3 NM-AIST students and 2 supervisors was selected at random to evaluate the usability and functionality of the developed system. The evaluation of the developed system was purposely targeted to different groups of people to ensure technical and non-technical sides of the developed system were covered.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Results and Discussions from the Study Area and Related Document Reviews

As a measure of development success, the research has managed to specify various areas concerning the railway sector as compared to developed countries such as Great Britain as a way of speculating what steps are needed to achieve further accomplishments in railway transport.

4.1.1 African Railway Network Statistics

Africa is a developing continent in many aspects including poverty reduction and infrastructure in which Tanzania is one of its members. In terms of transportation infrastructure, African countries have benefited in some ways during the colonial era and have since been managed and promoted according to each country's need and economic capability after independence. According to the analysis done by Counter Intelligence Agency (CIA) through their World fact-book publication in 2014, statistics revealed that the African continent is ranked behind Asia, the United States of America, and Europe in the terms of total available railway lines contributing about 6.7% of global railway lines in kilometers (Fig. 7) meaning that the utilization of railway networks was highly in need during the colonial era for business activities and local transport for colonialists. World fact-book has shown how strong Africa is in terms of railway facilities and provides African countries with in-depth knowledge of residing railway network paving way for speculations of future achievements with increasing use of science and technology and business activities in the global market as some countries such as Ethiopia and Kenya constructed SGR network in recent years to boost their economic progression.

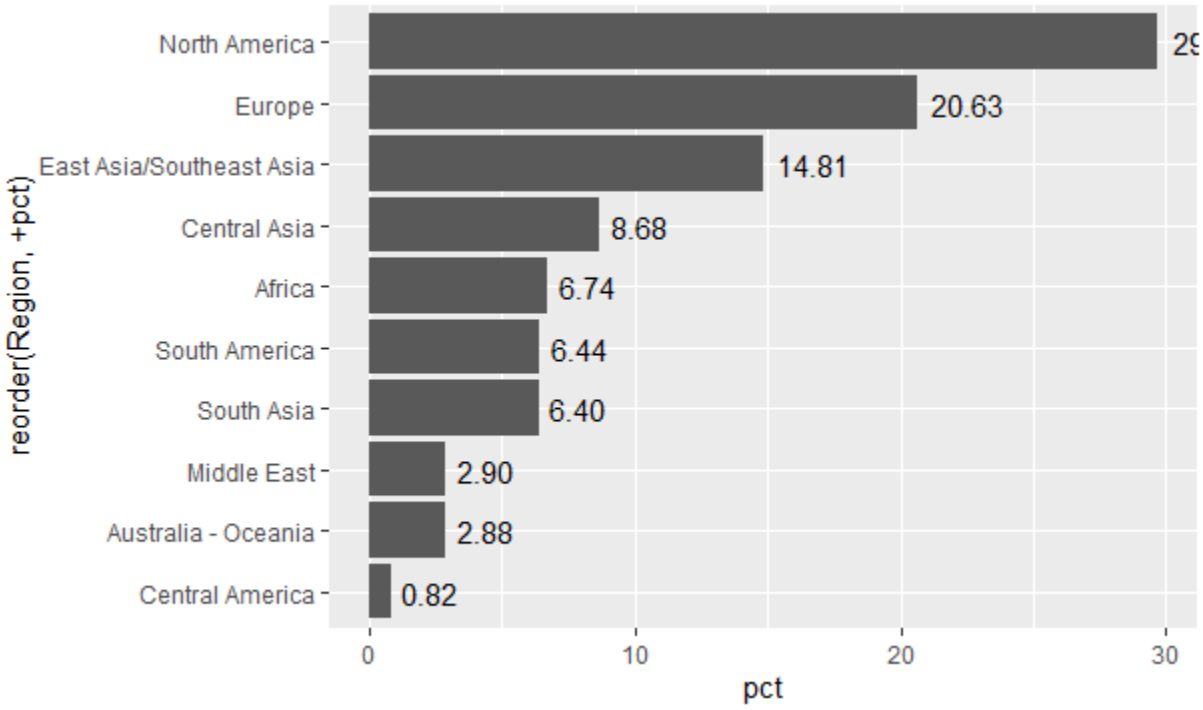

Figure 7: Global railway network distribution by percentage

With a higher percentage than most continents, the World fact-book further revealed rankings of African countries in which Tanzania was among the top 5 countries contributing about 5% of total African railway lines in kilometers (Fig. 8). World fact-book was published before the existence of the SGR project which is under construction speculating that Tanzania had higher hopes of railway transportation in earlier days. This shows that Tanzania plays a big part in Africa in terms of railway transportation with more networks to be added in the future. Although there is a higher railway network in Tanzania than most African countries, there has not been a smooth transition in terms of a financial undertaking which has been proven by an in-depth analysis of Tanzania's Meter Gauge Railway (MGR) status by Yapi Merkezi, a company under contract for construction of the new SGR network in which it uncovered more than 40% of railway track being in poor conditions that could lead to severe damages to human life and trains with their lifetime dating back to the colonial era. The addition of locomotives and wagons shortages led to economic and operational setbacks for the Tanzania railway sector for more than a decade leading to the Tanzanian government engaging in a privatization scheme with Rail India Technical and Economic Services (RITES) in 2007.

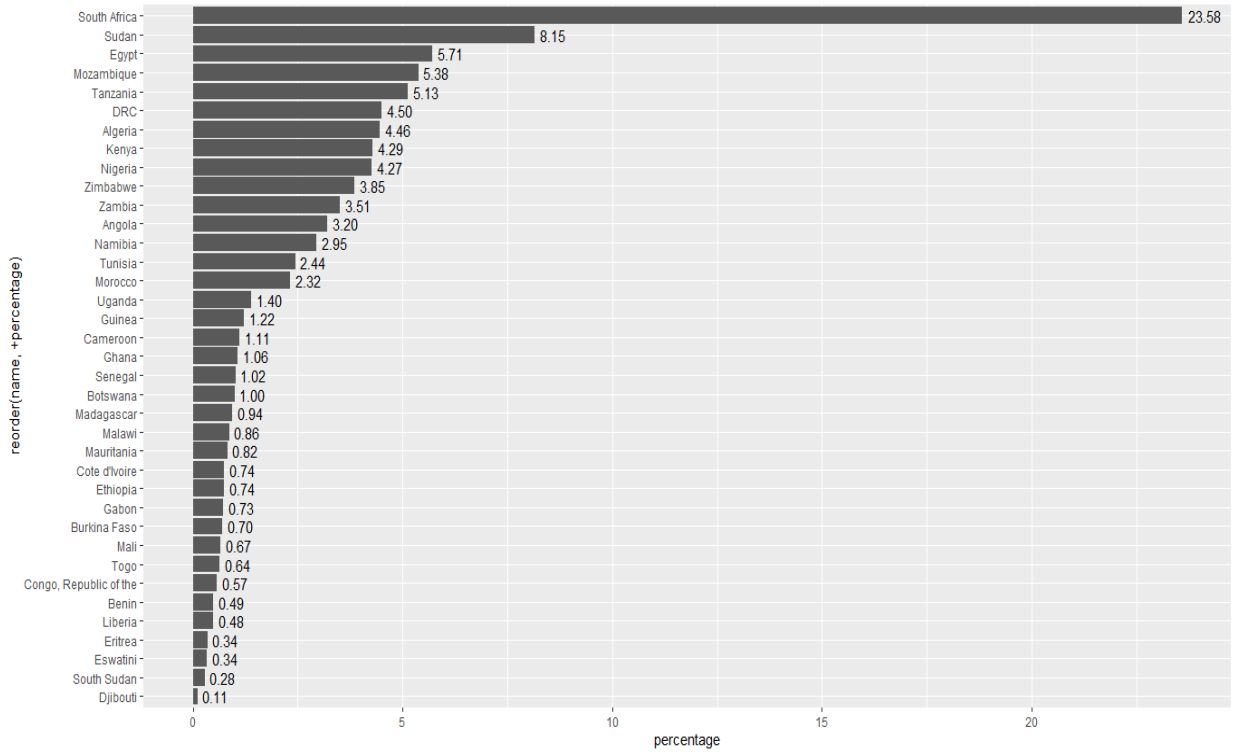

Figure 8: African railway network by percentage

4.1.2 Tanzania Trends in Railway Traffic Flow

Tanzania has engaged in long-distance and commuter train services across the country. Dar es Salaam is the only region that utilizes commuter train services due to its higher population and higher frequency of business activities than any other region with long-distance train travels stretching to various regions of Tanzania. Data collected from TRC shows that long-distance train travels have been revived with various routes such as Dar to Arusha and Dar to Kigoma being operational in light of providing energy in the railway transportation sector. As of recent revival, data collected from TRC concerning passenger journeys from mid-2019 to mid-2020 were analyzed (Fig. 9) and showed the existence of 15 000 average monthly passenger journeys with more than 80% of these journeys contributed by third-class seats due to lower costs.

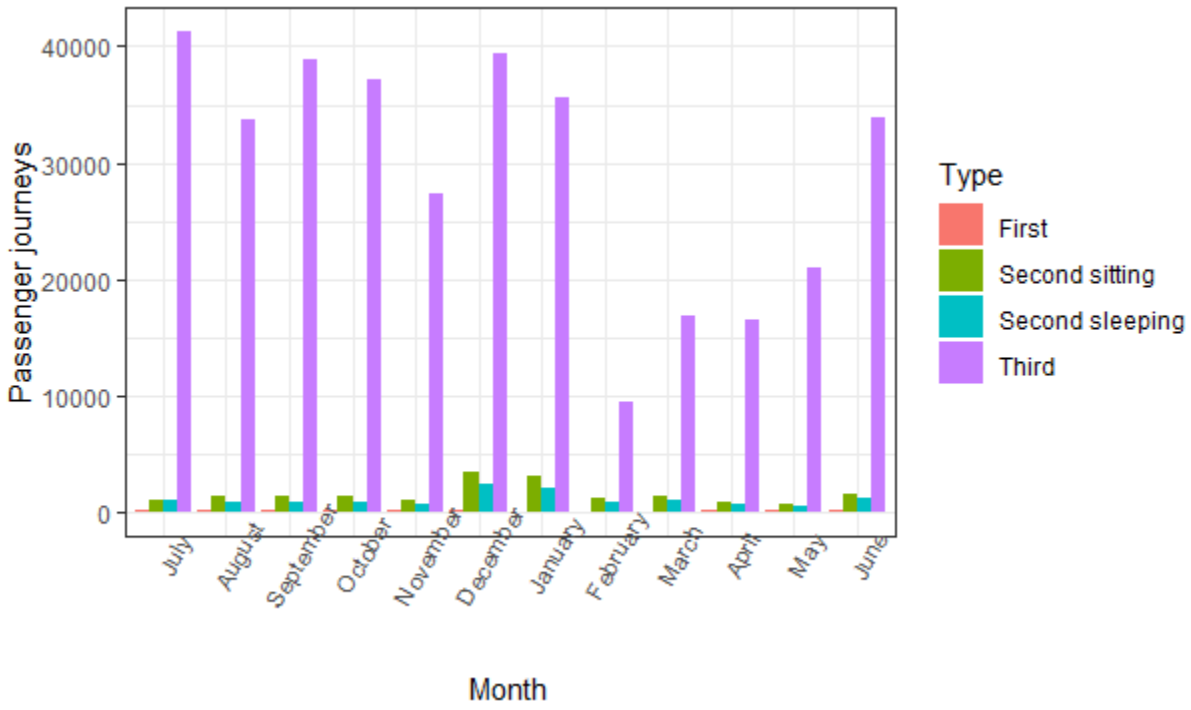

Figure 9: Passenger journeys of Tanzania railway network from July 2019 to June 2020

Establishment of commuter trains in Dar es Salaam aimed at promoting better city planning strategies in the effort of reducing road congestion by stretching city resources to more transportation schemes to support existing infrastructure and facilitate higher revenue generation. Data provided by TRC from mid-2017 to mid 2020 (Fig. 10) showed that mid 2017 to mid 2018 recorded 500 000 average passenger journeys, mid 2018 to mid 2019 recorded 300 000 average passenger journeys and mid-2019 to early 2020 recorded 300 000 average passenger journeys for both commuter routes with recorded sharp fall of 150 000 average passenger journeys from early-2020 to mid 2020 due to COVID-19 restrictions undertook by the government at that period. The overall analysis of passenger journeys through commuter services was recorded to be within 300 000 per month showing great effort made by TRC to support road transport with feasible economic progression projected shortly due to the high number of passengers. The great difference in average passenger journeys between long-distance train services and commuter train services is due to weekly schedules of long-distance travel as compared to daily travel of commuter services.

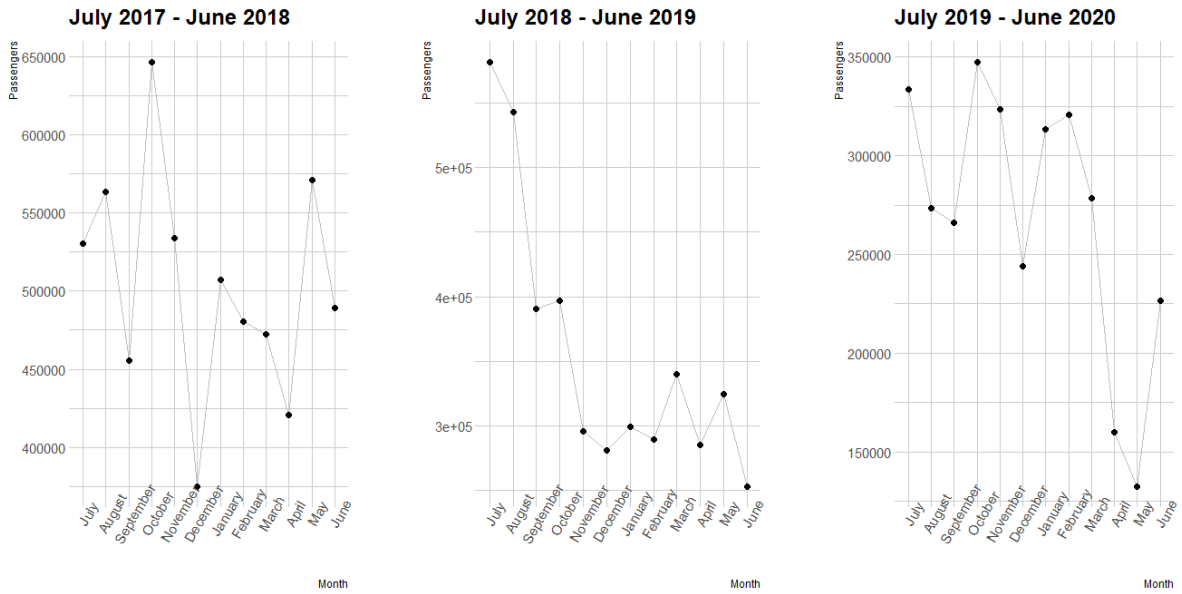

Figure 10: Passenger journeys through commuter trains in Dar es Salaam

Revenue data collected from TRC detailed in Table 5 in 3 years shows higher revenue generation with an average of 12 billion Tanzanian shillings collected annually proving efforts made since the establishment of TRC in 2017 paying off.

Table 6: Revenue generated (in Tanzanian shillings) by commuter and long-distance trains in Tanzania

Type	Year		
	2017-2018	**2018-2019**	**2019-2020**
Long distance	1 256 845 557	7 119 722 586	10 774 121 092
Commuter	2 420 929 260	1 443 449 500	1 968 474 300
Total	14 989 387 817	8 563 172 086	12 742 595 392

This is credited to efforts done by TRC to acquire more train wagons and reviving train routes such as Dar es Salaam to Arusha paving the way for more passengers to acquire railway services due to reduced costs as compared to bus transport. With recorded average passenger journeys increasing in 3 years since TRC has been in effect, further revenue prospects are projected in the

future with the SGR network projected to be operationally supporting the existing railway network resulting in higher passenger journeys leading to higher revenue generation.

4.1.3 Statistical Releases from NBS and Ministry of Works

The use of science and technology has branched out to many development sectors and transportation services have not been left behind. With the statistics obtained from NBS, Tanzania's population is increasing and with that population, many citizens engage with growing advancements of science and technology through telecommunication services with 89% of Tanzanians utilizing telecommunication services through a fixed or a mobile phone. Out of 89%, more than 49% are engaged in internet services (Fig. 11) that act as a gateway to global news and interactions signifying that almost half of the country interacts with global content and is aware of matters happening outside their borders.

Despite being in a developing state, these statistics show increasing interconnectivity with future projections linking more Tanzanians with mobile phones. These projections have increased government efforts to establish more ways to ensure higher interaction with its people and with global context to foster wider information dissemination tactics concerning the railway sector in ICT as evident through an online e-ticketing system established by TRC aimed at simplifying the acquisition of train tickets without the need of queueing at stations for service provision.

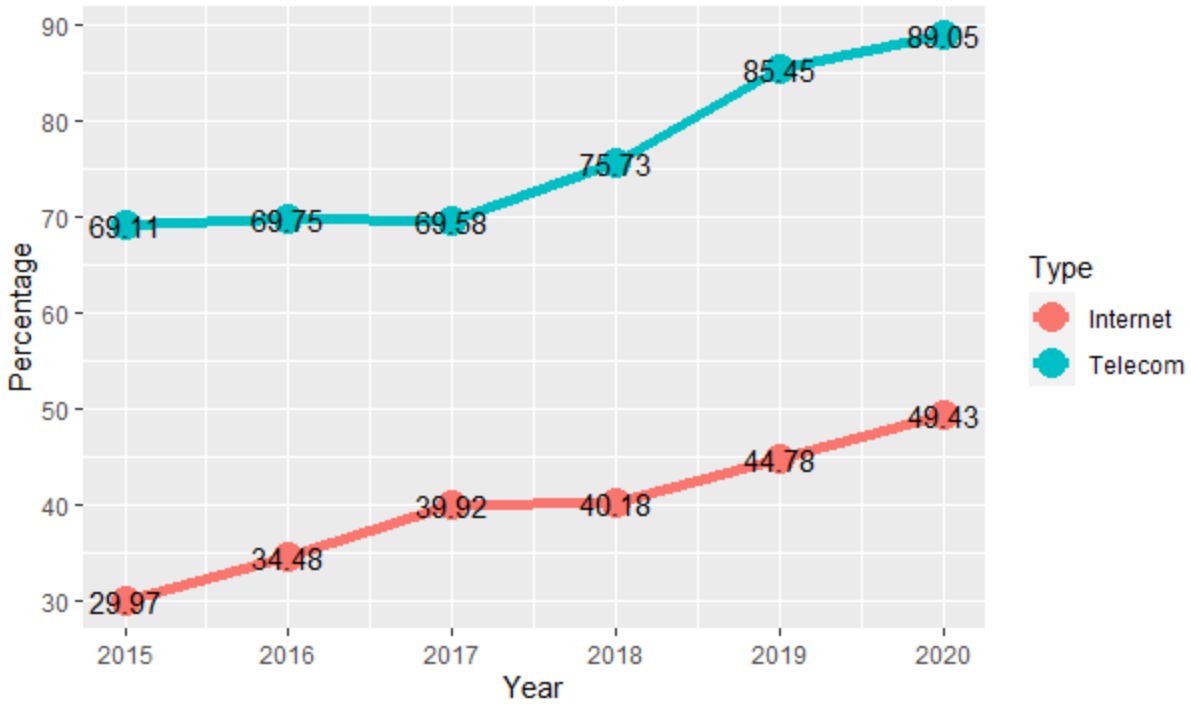

Figure 11: Telecommunication service and internet service users in Tanzania

Statistics from 2005 to 2010 have shown a decline in passenger traffic that lead to the Tanzanian government dismissing privatization schemes and opting for full control of the railway sector by 2011 without much traffic change either. As of 2017, new bills were formed by the parliament to establish TRC to take wholesome control of the sector through railway track maintenance and acquisition of new locomotives as envisioned by the government to uphold traffic flow. This led to an increase of up to 2 million annual average passenger journeys through railway transportation and created a change in traffic compared to a decade ago when 200 000 to 500 000 average passenger journeys were annually recorded (Fig. 12).

These statistics boosted government efforts in railway transportation paving way for the new and improved SGR network to be under construction with projections of higher speed and more cargo transport capabilities to be achieved.

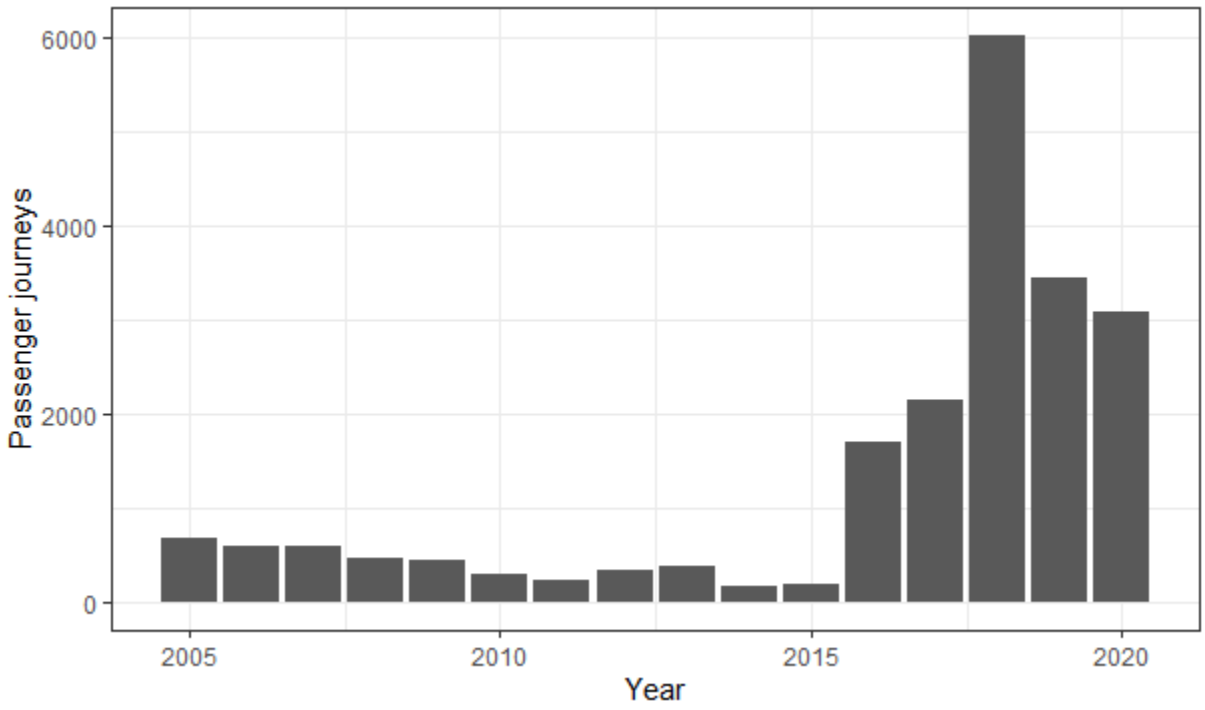

Figure 12: Tanzania passenger journeys from 2005 to 2020 (in 000')

4.1.4 Tanzania and United Kingdom Railway Data Comparison

United Kingdom datasets contain railway statistics from Great Britain, Wales, Scotland, and Northern Ireland. In this research study, data from Great Britain acquired from ORR statistical releases have been taken into consideration due to having most data collection from its vast railway network compared to other countries in the United Kingdom. With more than 15 000 km of railway lines of which about 6 000 km are electrified as of 2021, the network has acquired a reputation in its continuous use of railway services which contain mainline, non-mainline, and underground trains in London as well as the use of Latest Earnings Networked Nationally Over Night (LENNON) ticketing and revenue database which replaced Computer Analysis of Passenger Revenue Information (CAPRI) in 2003/04 which plays a major part in contributing information in the creation of these statistical releases or datasets. The database system is in use in more than 2000 train stations across the United Kingdom giving it massive capability to comprehend the amount of data injected into it leading to high accuracy information released quarterly.

As the means of transportation through trains involve passengers, one of the units of measurement is passenger-kilometers which describes the number of passengers transported over one kilometer.

According to ORR, the annual average passenger-kilometers recorded in Great Britain for a period of 4 years from 2016/17 to 2019/20 is 66 Billion which shows a huge difference from the average passenger-kilometers recorded in Tanzanian for the same period amounting to 338 million according to TRC. The annual average difference of 66 Billion passenger kilometers (Fig. 13) between these two countries is due to a large number of operational trains in Great Britain as compared to Tanzania, higher accuracy data collection techniques through the LENNON system, and the existence of train franchising techniques by Britain government.

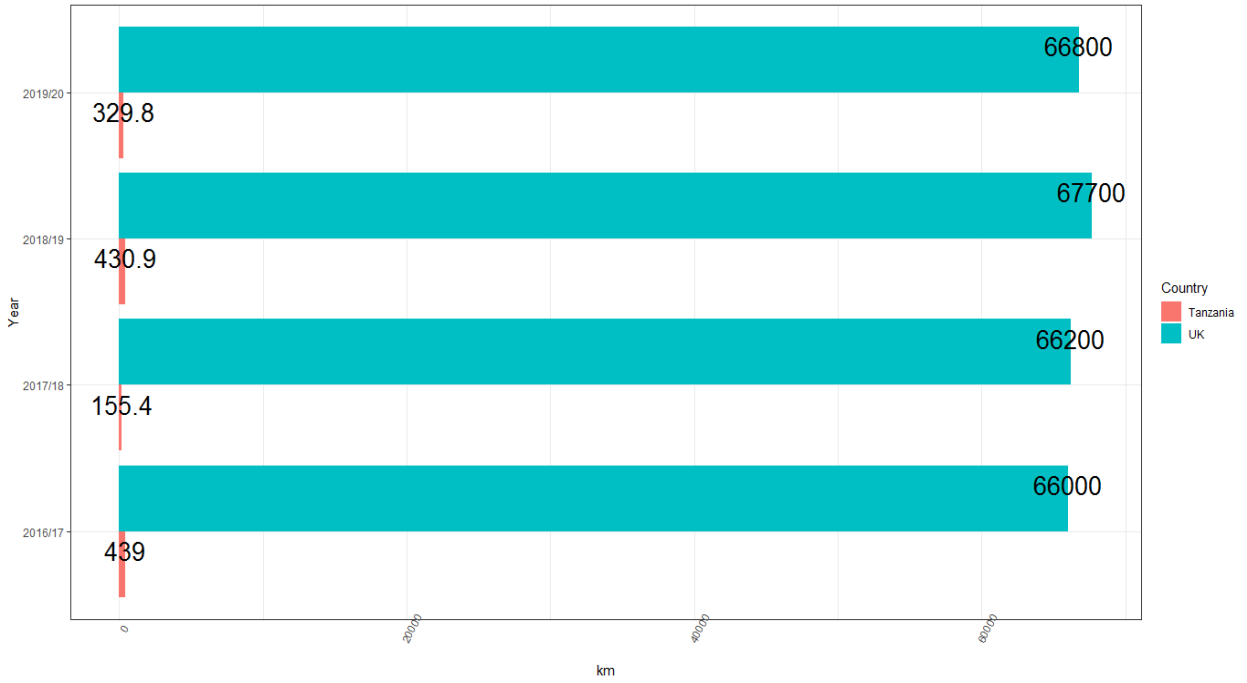

Figure 13: Comparison of passenger kilometers (in millions) between Great Britain and Tanzania railway networks

Another assessment was conducted to compare the revenue generated between these two geographical areas according to their statistics released. From 2016/17 to 2019/20, ORR recorded an estimated annual average of 31 trillion Tanzanian shillings collected from railway services while TRC recorded an estimated annual average of 13 billion Tanzanian shillings. The statistics show difference between revenue these two countries of about 31 trillion Tanzanian shillings (Fig. 14) depicting a huge gap in revenue generation between the two railway sectors.

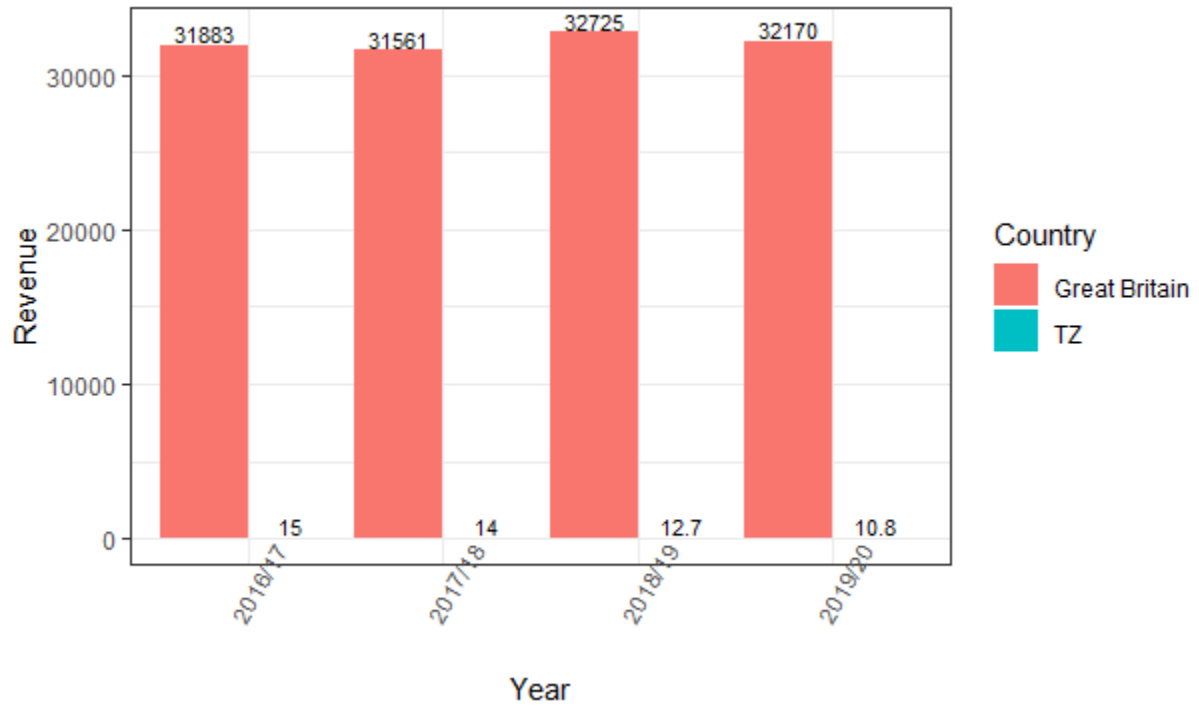

Figure 14: Comparison of revenue generated (in billions Tanzanian shillings) between Great Britain and Tanzania railway networks

With a comparable number of people between these two geographical areas, the number of passenger journeys still is of huge difference due to the higher number of railway lines in Great Britain compared to Tanzania. Passenger journeys are calculated as the distance from where the passenger boarded the train to where the passenger exited the train. For a period of 15 years from 2005 to 2020, each country has seen an increase in passenger journeys but at different rates. As of 2020, ORR showed that Great Britain had recorded 1.7 billion passenger journeys while NBS showed that Tanzania has recorded 3 million passenger journeys depicting a difference in 1.4 billion passenger journeys between the two countries (Fig. 15). This is highly due to the difference of about 12 000 kilometers of railway lines favoring Great Britain although Great Britain occupies one-quarter of Tanzania's geographical area and feasibly similar population statistics.

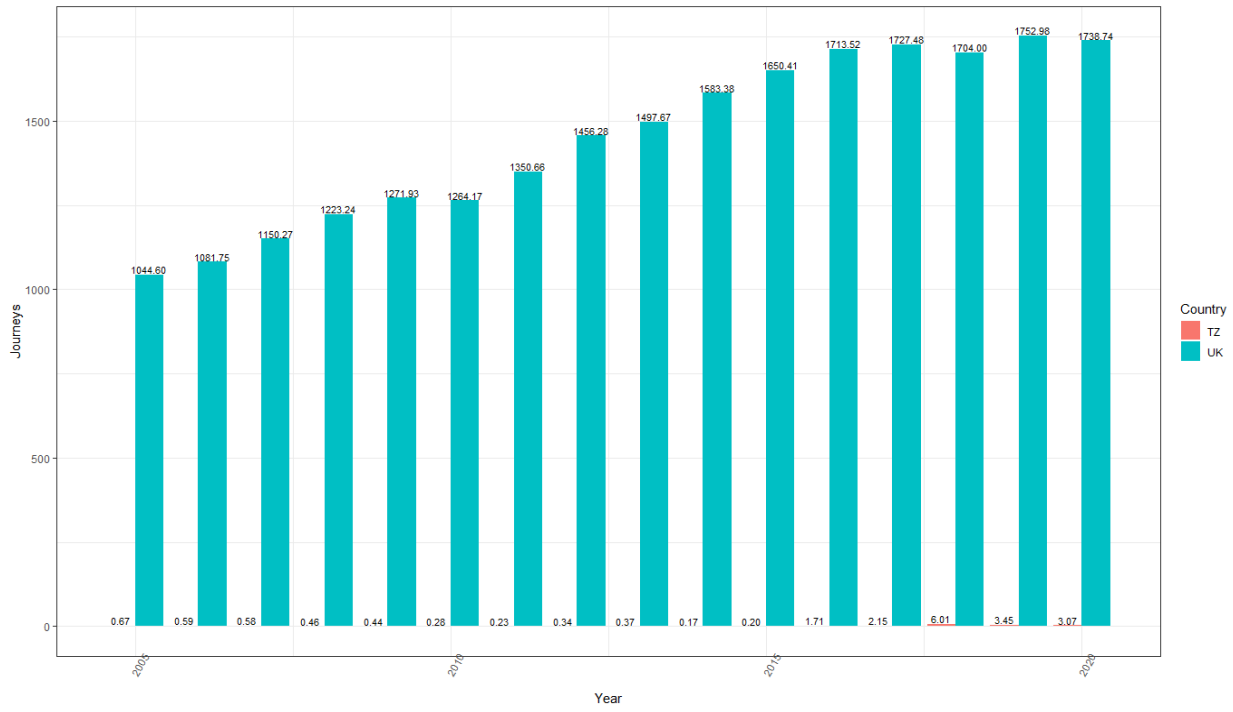

Figure 15: Comparison of passenger journeys (in millions) between Great Britain and Tanzania railway networks in 2020

In terms of understanding how these areas conduct railway services, some factors need to be analyzed to verify their breaking points in terms of service provision. One of these factors is the analysis of rail safety during the operation of trains. For accurate analysis, four aspects of rail safety were analyzed which include derailments, collisions, deaths or fatalities, and injuries.

Of all these aspects, Great Britain has shown higher numbers in terms of rail safety in which it surpassed Tanzania's rail safety statistics by thousands showing that more railway lines and operational trains have resulted in to increase in rail safety incidents involving human and non-human entities alike and in their moment of similarity, both geographical areas have shown that the number of injuries is higher than all 3 aspects combined (Fig. 16) according to statistics released by the Ministry of Works and Transportation of Tanzania and ORR.

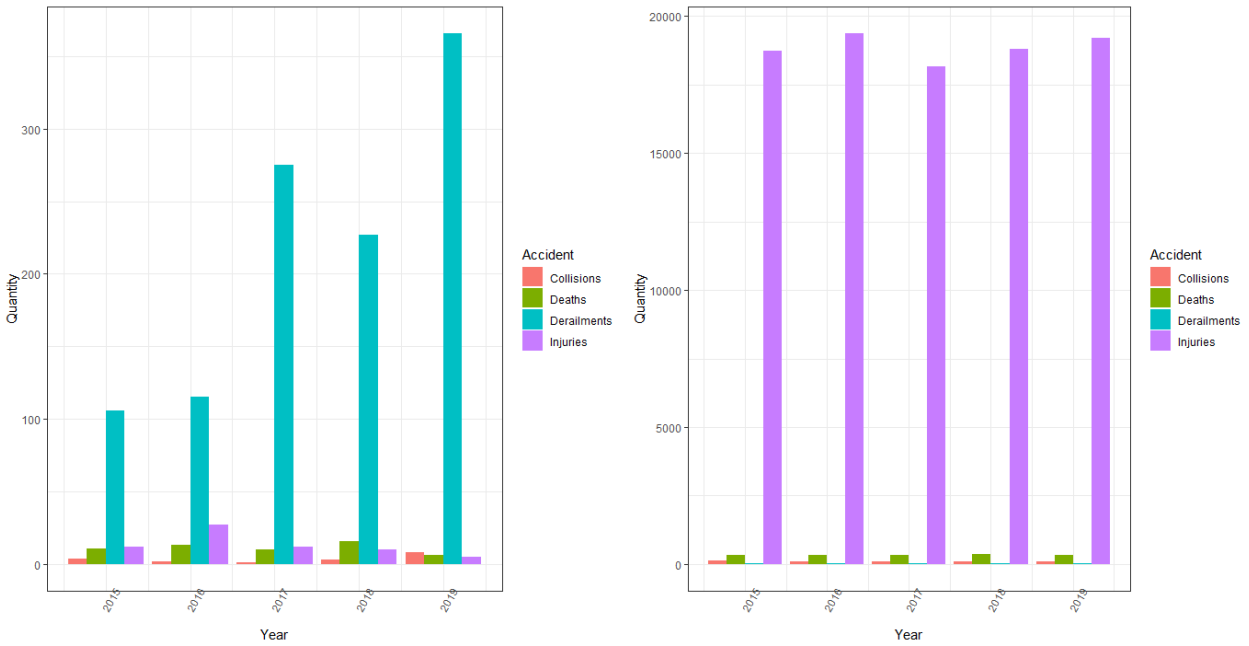

Figure 16: Comparison of Great Britain and Tanzania railway safety statistics

4.1.5 Methods Used to Acquire Railway Services

As a developing country with an existing railway network, TRC has engaged in the provision of railway services through the use of railway stations and a recent online train ticketing system. According to respondents of questionnaires, a high number of respondents know ticket bookings directly from train stations while few respondents admitted to the existence of an online booking system. This has shown that there is little to no use of an online booking system. As of 2020, an online booking system had been introduced by TRC to facilitate the use of ICT in the provision of tickets but still, the number of responses to the system has been low due to frequent maintenance of the system by TRC forcing passengers to rely on non-ICT methods of booking tickets straight from train stations.

4.1.6 Methods Used to Collect Data from Railway Services

Interviews conducted at TRC offices yield information about safety, passengers, revenue, and migration to ICT systems. According to one of the interviewees in the finance department specified the use of train operators as major players in collecting information about passengers. This was evident in the compilation of commuter train passengers as the number of passengers and revenue generated for the previous day was brought physically every morning to TRC offices by one of

their employees located at Kamata station in Kariakoo and was added to excel files in TRC offices for digital storage. The tiresome process of physical presentation of previous passenger data from commuter travels proved to be the existence of little use of ICT services in the compilation and analysis of information concerning railway services and their continuous progress.

4.2 System Implementation

After specifying requirements and creating the flow of data to be achieved through the functional requirements, the next step was to develop a functional system. The development process was achieved through four steps which were the development of the android application, development of the web application, web mapping, and development of database system. Each of these steps was achieved by the use of specific tools in which more explanation of the tools and the results from the development process are depicted below.

4.2.1 Android Application Development

Development of the android mobile application was devised as a solution for passengers' interaction with TRC services due to an increasing number of mobile phone users shown by Tanzania Communications Regulatory Authority (TCRA) data released by NBS (National Bureau of Statistics, 2020). The developed mobile application has been embedded with various functionalities to help passengers acquire as much information as possible about train services within Tanzania as well as create a link between TRC and passengers through views and opinions. The developed mobile application is named ARIP which stands for Advanced Railway Information Portal to give a sense of advancement in terms of relaying railway information to passengers.

(i) Homepage

The developed android application has its outlook as can be seen in Fig. 17. The design has been implemented to create an easy-to-understand scenario as the use of card view layout has been implemented to provide better visual aid presentation of features to be undertaken when using the mobile application.

Figure 17: The ARIP homepage

(ii) Railway Information

With the aim of disseminating as much information as possible to passengers about railway services, an android application was developed to provide up to date railway information as well as showcasing Tanzania's progression in the provision of railway services. Figure 18 shows multiple information disseminated by android application concerning TRC such as management roles, mission and vision directives as stipulated by TRC laws as well as up to date information which is linked with TRC official website to provide easy access to passengers without the need to search for the site on a web browser.

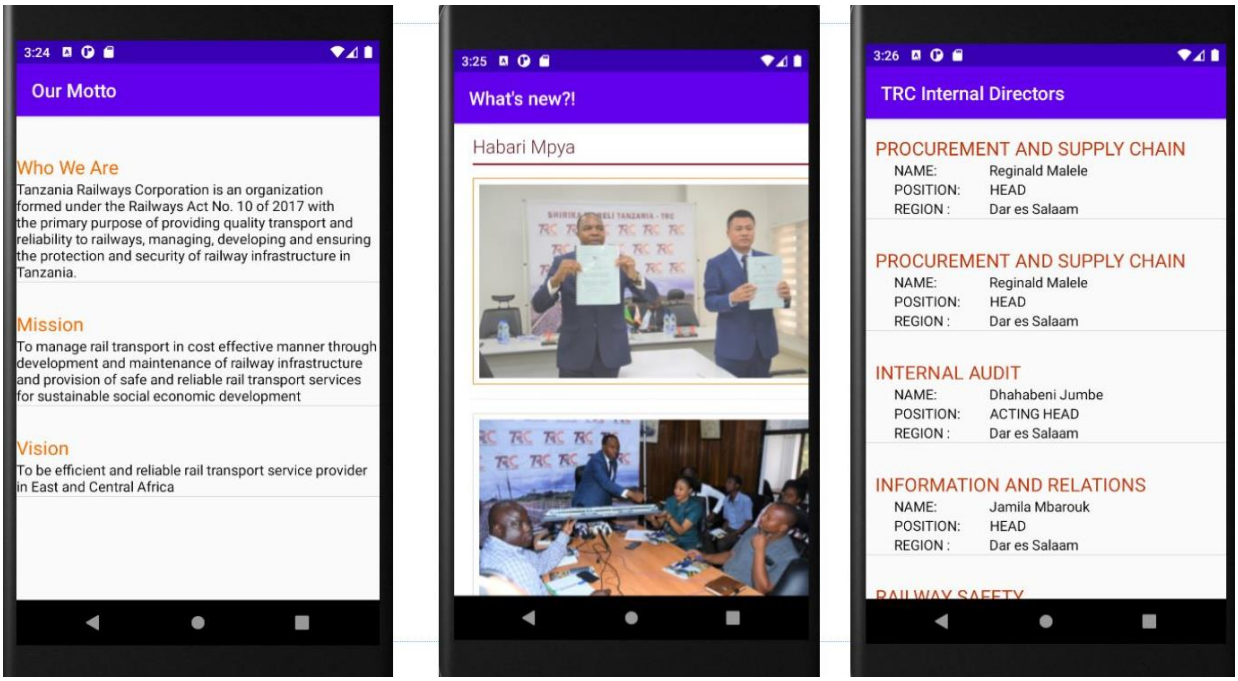

Figure 18: The TRC information through ARIP application

More information is accessible through the android application such as global ranking of railway lines as well as African ranking can be viewed in graphical presentation a shown in Fig. 19.

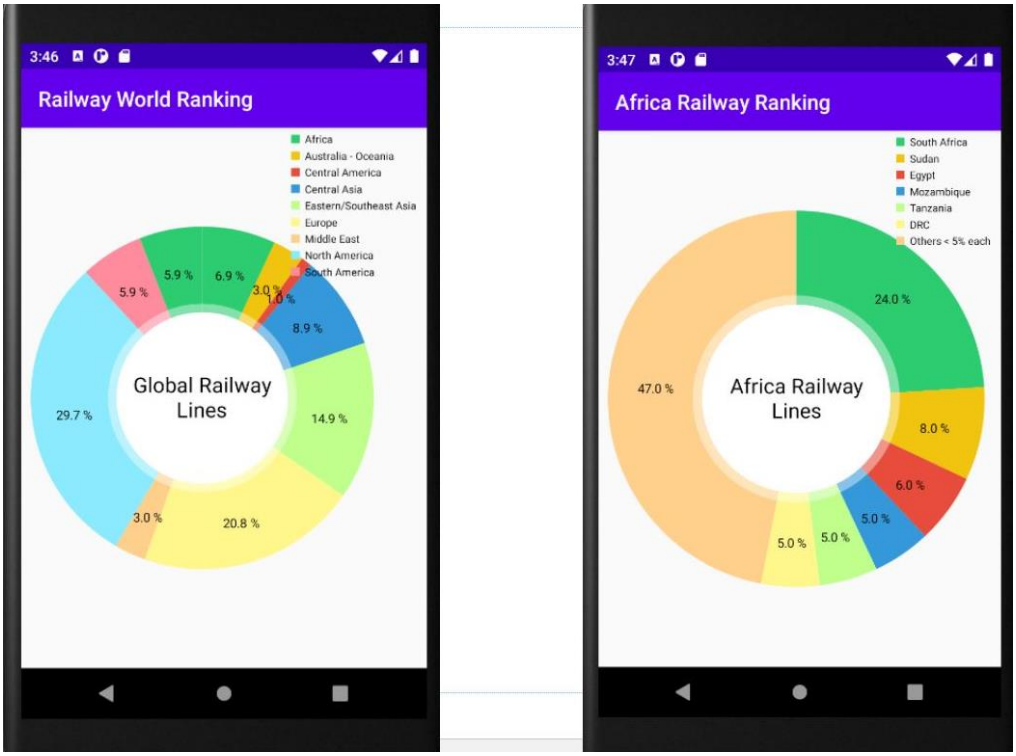

Figure 19: Railway lines statistics accessible through ARIP application

(iii) Train travel plans

The developed android application provides information on train schedules according to the types of trains available in Tanzania. The application provides commuter and long-distance train schedules with information acquired from TRC as well as the proposed SGR schedule for Dar es Salaam to Morogoro route. Figure 20 shows information about long-distance travel as accessible through the android application.

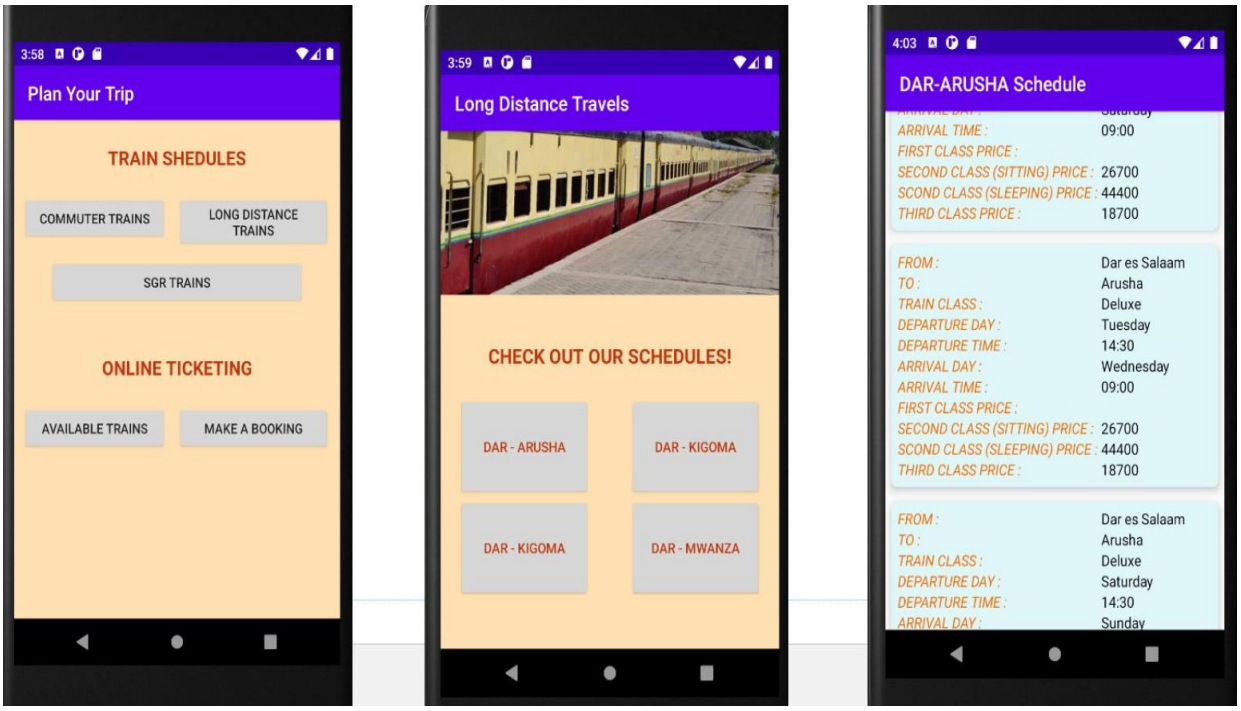

Figure 20: Long distance travels through ARIP application

In the light of technological advancements, TRC has been able to develop an online ticketing system through the use of a web application. As the ARIP application aims at increasing customer experience, the android application has been linked with the online ticketing system which will enable passengers to make their booking without the hustle of finding the Uniform Resource Locator (URL) or web address for the online train ticketing system or visit TRC official page to be linked to the online ticketing system. As shown in Fig. 21, the android application is linked to the online ticketing system where passengers can view available trains and train travels on that particular day and proceed to ticket booking when satisfied by the information provided through the application.

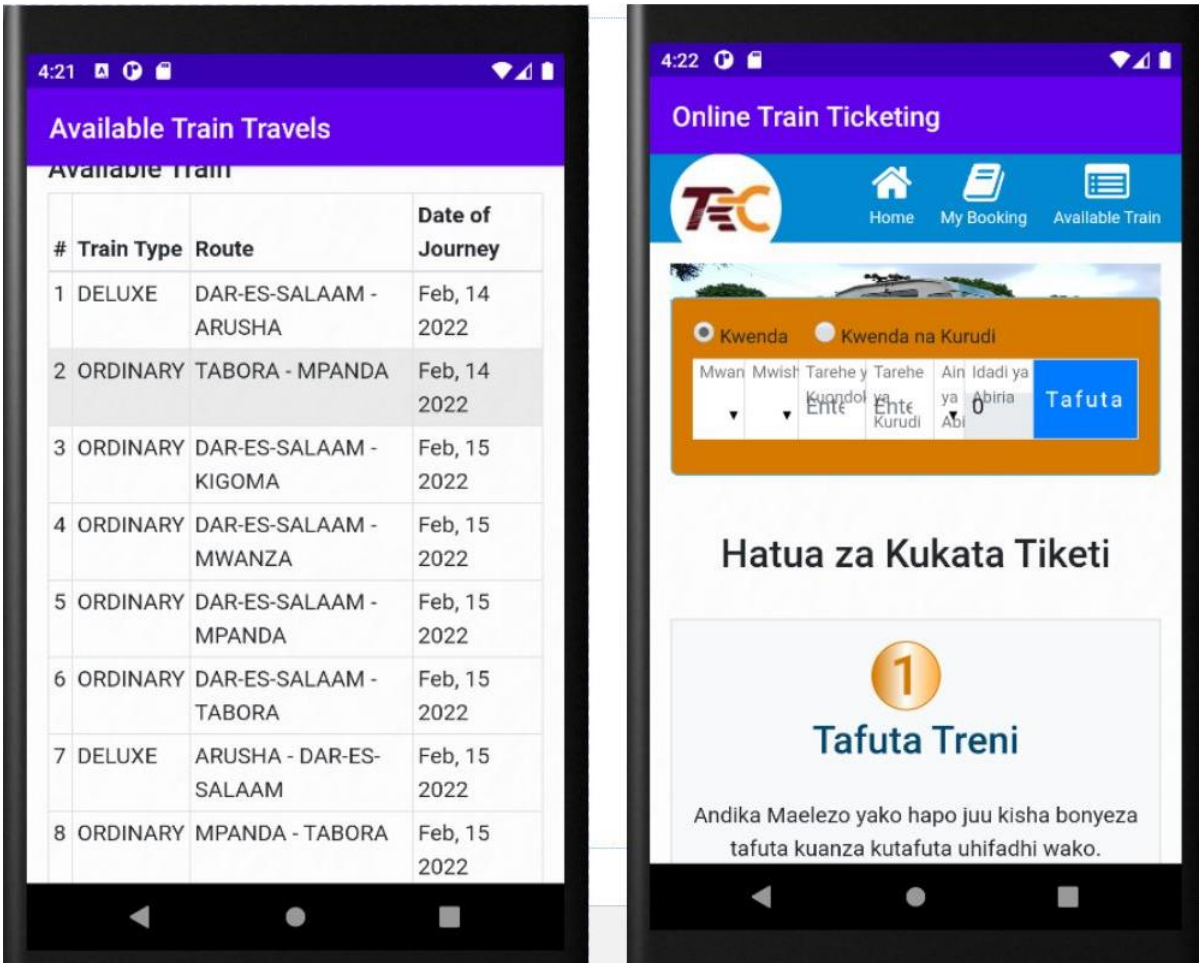

Figure 21: Online train ticketing system accessible through ARIP application

(iv) Views and opinions

As an integrated system, the vision for this application was to create a link between passengers and TRC through ICT without the need of face to face meetings. The developed application meets this criterion by having a section where passengers can air their complaints or praises to a particular station by stipulating a specific area of concern. The system also captures the date when the particular complaint or opinion was submitted to give TRC a timeline in terms of working on submitted comments as shown in Fig. 22. The application also provides passengers with links to external ICT resources such as social networks linked with TRC in case of any inquiries that need to be subjected to TRC and cannot be submitted through the comment section as shown in Fig. 22.

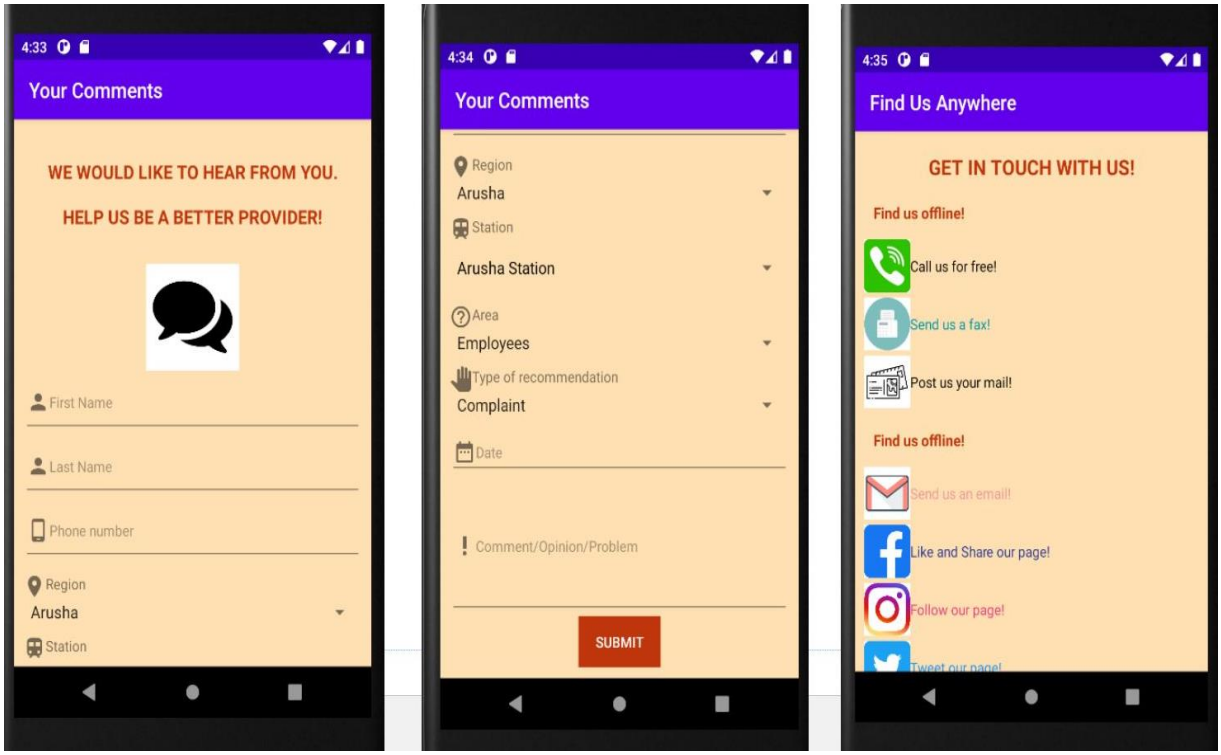

Figure 22: Comment and contact sections of ARIP application

(v) Document reviews

The android application has a link to a centralized database that enables uploaded documents through the web application to be fetched and viewed in their uploaded form. This function enables passengers to view important documents such as monthly magazines (Fig. 23) concerning railway services without the need of browsing to the official website.

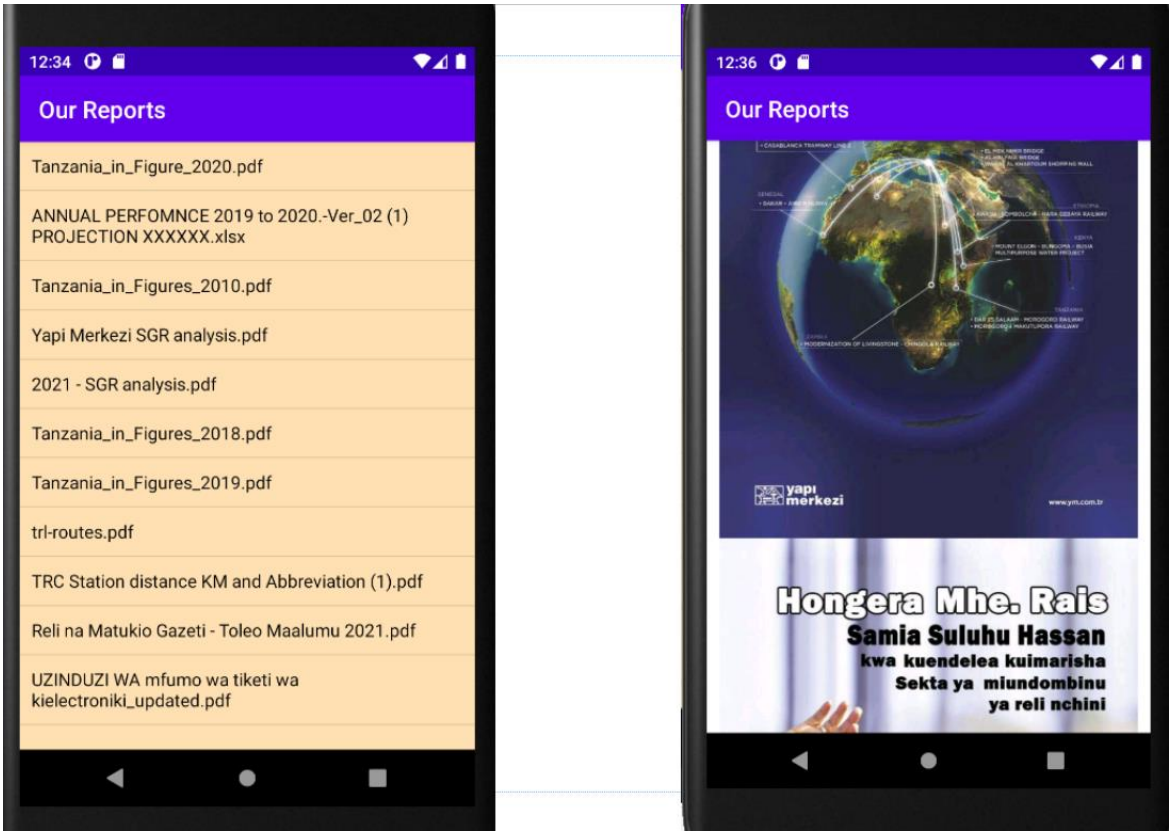

Figure 23: Railway magazine viewed in ARIP application

(vi) Railway Statistics

As one of the major features of developing this application, railway statistics are displayed in the form of graphs for better understanding and easier explanation. With revenue, passenger journeys and passenger kilometers, and safety being major attributes in the railway sector, the android application provides information about these attributes from 2017 to 2020 according to data collected from TRC. Each attribute except safety is analyzed independently in commuter and long-distance trains with long-distance trains further speculated in wagon categories which are first class, second class (sitting), second class (sleeping), and third-class wagons. An example of passenger journeys, passenger kilometers, and revenue statistics for long-distance trains in the year 2019 can be seen in Fig. 24 displayed respectively from left to right.

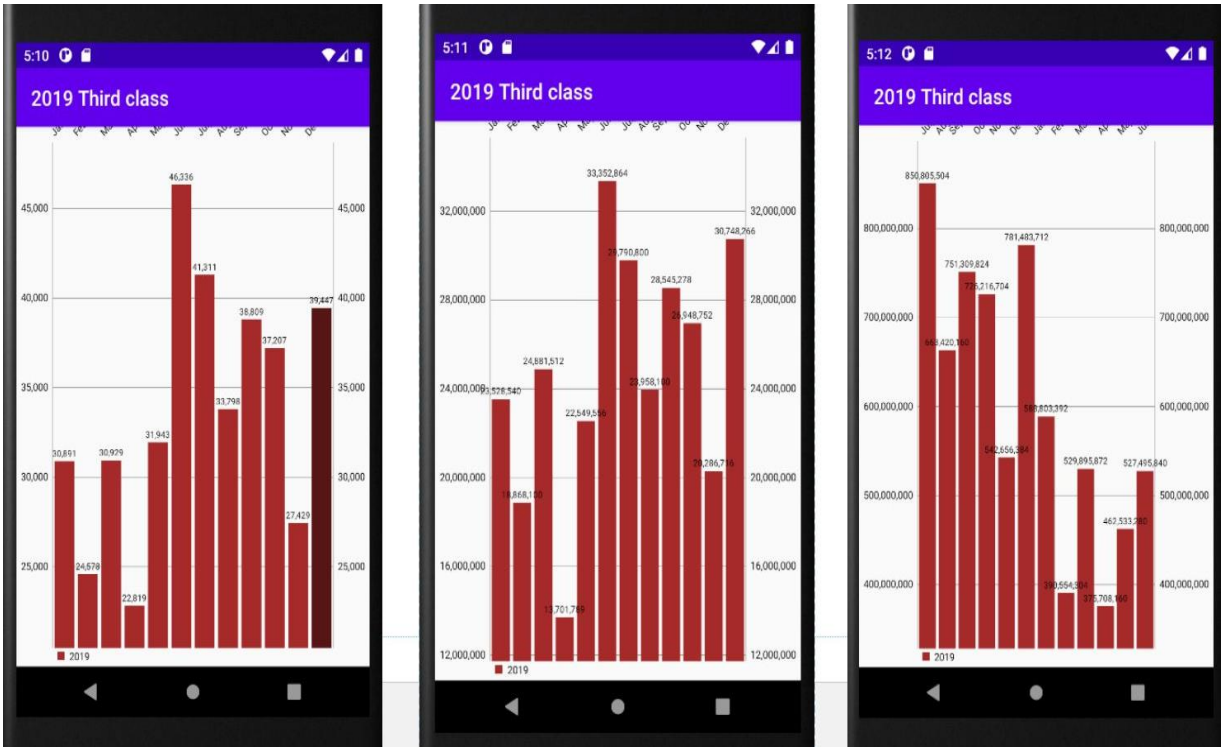

Figure 24: Railway statistics in 2019 for third class wagons in long distance trains through ARIP applications

Further statistics in the aspect of safety are graphically displayed to show the number of accidents that have occurred in a certain period. The android application displays information on safety attributes through data obtained from Ministry of Works and Transportation reports with Fig. 25 showing the number of derailments that have occurred in railway tracks from 2015 to 2019.

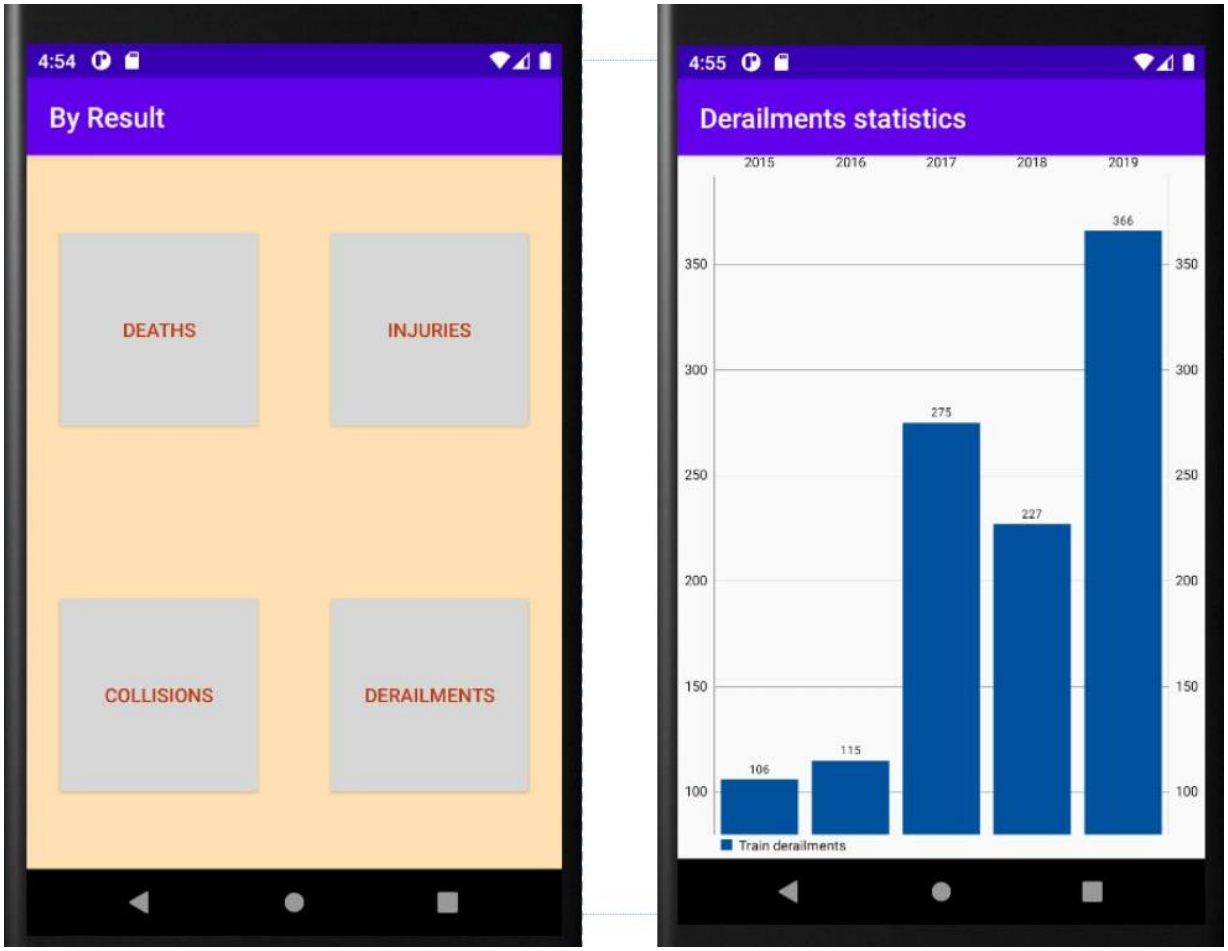

Figure 25: Derailments statistics as accessible through ARIP application

As the android application displays information about railway services, data concerning the distance of railway lines as well as railway stations is important to provide passengers with knowledge of the nearest train stations from their residential areas. To foster more knowledge on railway stations and their whereabouts, web mapping technology was used to display stations that are under TRC and where they are situated within a map to simplify passengers' curiosity and reduce ignorance when railway stations are concerned.

Loading of web maps within the android application was successful through the use of the PDF Viewer feature. The web maps were created and saved as pdf files which were then embedded into the android application. As can be seen in Fig. 26, web mapping was successful and pdf files can be viewed in the android application without much hustle to provide information on railway lines as well as railway stations. The application displays web maps for each route taken by long-distance and commuter trains respectively.

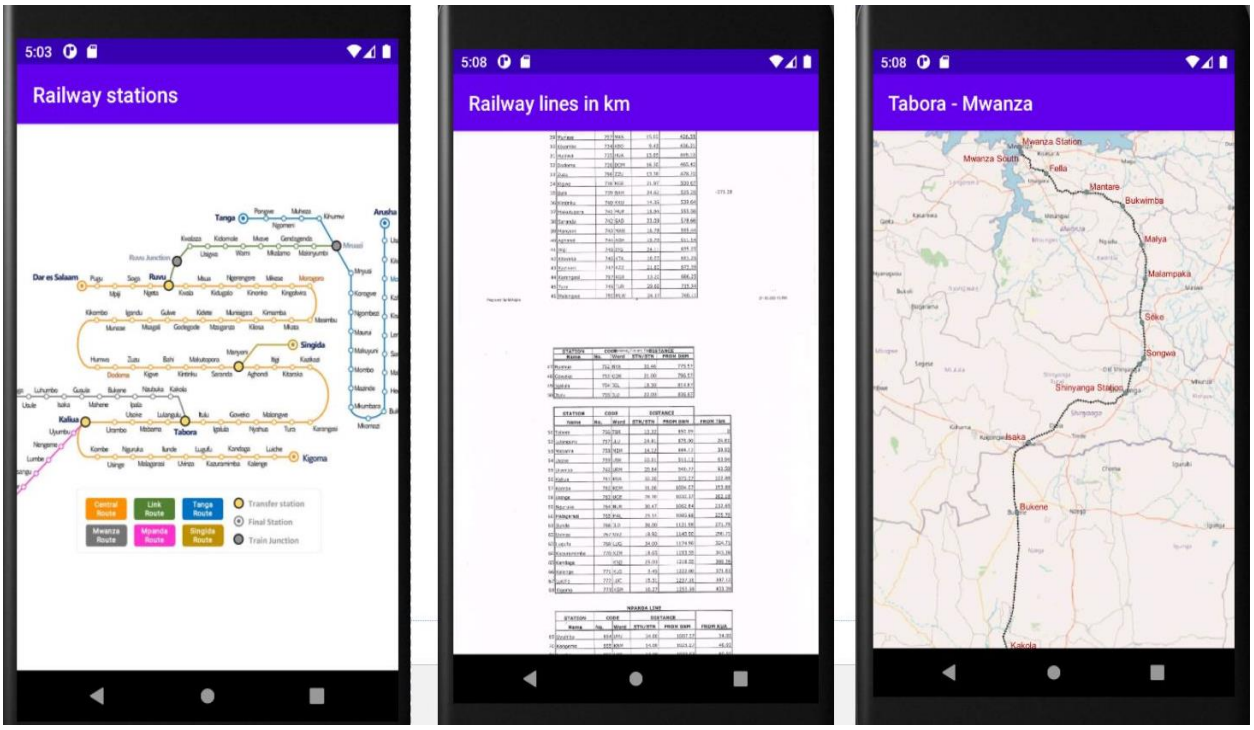

Figure 26: Railway lines and railway stations as accessible by ARIP application

4.2.2 Web Application Development

With the majority of employees stationed in offices, the development of a web application was devised as a solution for railway data aggregation and analysis problems. The integration of various departments in TRC could be linked through the system with each department's data encompassed within the system and reports generated could be linked to the effort of a specific department.

The developped web application is named RIG which stands for Railway Information Gateway as the web application is used to populate railway information before the information is displayed to passengers through the android application.

(i) Homepage

This is the main page of the web application. For security purposes of data collected within the system, a two-step verification process has been employed in which the signup process is enclosed with email verification making it more secure in preventing unauthorized access. After successful registration through email verification, the system administrator can log in to the system and has

the option of resetting the account password and the database will capture the changed password for successful login verification in the future. Fig. 27 shows the main page of the web application after successful login.

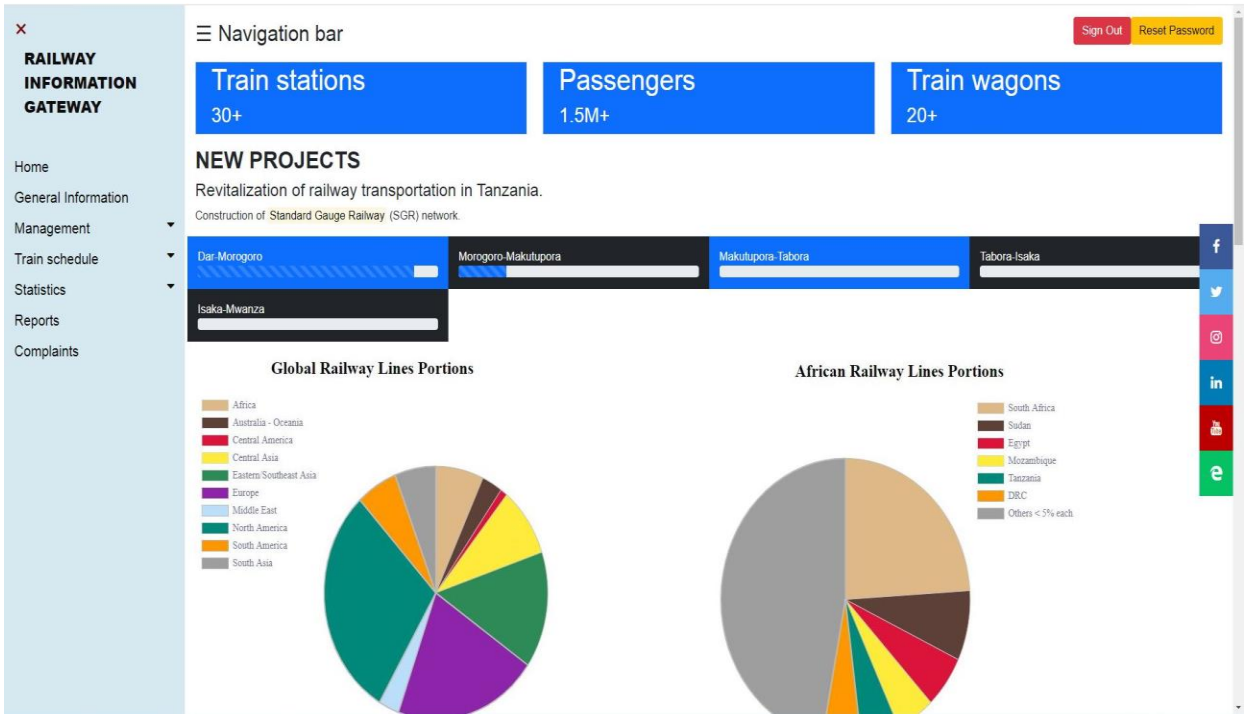

Figure 27: The RIG homepage

(ii) Train schedules

The web application uses CRUD operations to ensure submitted data can be edited or deleted in case of misinformation or human error respectively. This ensures that data entry is achieved at the higher accuracy possible to enable the system administrator to monitor the flow of data and ensure there is no duplication as well as reduce human errors as shown in Fig. 28. These operations are integrated into other data entry attributes such as management roles due to frequent leadership changes.

Figure 28: CRUD operations on train scheduling

(iii) Comments review

As a part of the integration, the web application provides an interface for TRC to engage with passengers by reviewing complaints which are submitted through the use of the android application. The web application gives access to viewing comments and not editing as they come from passengers and not TRC staff. This can be seen in Fig. 29 which shows a sample of comments as fetched from the database.

This gives TRC much information on how their stations operate in each region and how frequently they issue satisfying services to their passengers. Through this, the rate of information about problems arising during railway service provision increases giving room for TRC to act fast on rectifying these problems to promote better services and acquire more passengers in the future without depending on employees reports only.

OPINIONS AND COMPLAINTS

ID	Region	Station	Area of concern	Type of recommendation	Date	Action
1	Arusha	Arusha Station	Employees	Complaint	0000-00-00	
2	Tanga	Mnyusi	Train wagons	Opinion	2021-11-04	
3	Tanga	Mnyusi	Train wagons	Opinion	2021-11-04	
4	Kilimanjaro	Makanya	Station offices	Opinion	2021-11-05	
5	Morogoro	Mkata	Train schedule	Praise	2021-11-11	
6	Katavi	Ndui	Railway track	Complaint	2021-11-15	
7	Singida	Manyoni	Employees	Complaint	2021-11-15	
8	Dodoma	Bahi	Other	Complaint	2021-11-15	
9	Dodoma	Bahi	Other	Complaint	2021-11-15	
10	Mwanza	Bukwimba	Station offices	Opinion	2021-11-15	

Figure 29: Complaints review as seen in web application

(iv) Data visualization

With the use of Javascript, data visualization was made possible with statistical attributes such as revenue and passenger kilometers made easier to understand through bar graphs that show trends of data annually. Commuter statistics for revenue can be seen clearly as shown in Fig. 30 where two available routes are compared to show how each route performs in terms of revenue generation.

In the aspect of data visualization, the web application makes it easier for the system administrator to generate pdf files for publications on the TRC official website or for other office purposes as well as generating excel files for mathematical manipulation operations which can also be seen in Fig. 30 in the form of red and green buttons respectively. This saves time for the system administrator to input data manually in excel files when in need of mathematical information such as mean and variance of specific sets of data.

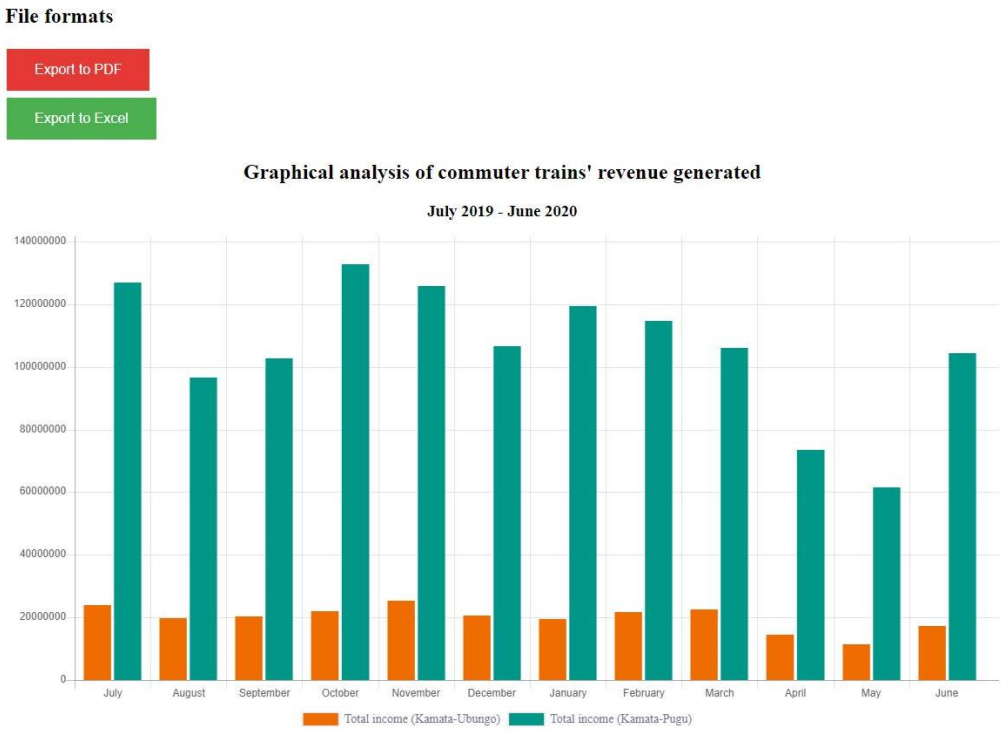

Figure 30: Data visualization through web application

(v) Uploading documents

As a link to passengers, the web application enables the system administrator to upload documents relevant to railway services that are important for passengers' engagement. This provides a simpler way for TRC to showcase its monthly reports and published magazines to its passengers without relying on them to visit the official website for updates through browsing at all times. For better quality of reports, the web application allows pdf and excel files only to be uploaded due to their popularity and a large number of software applications available for viewing these files (Fig. 31).

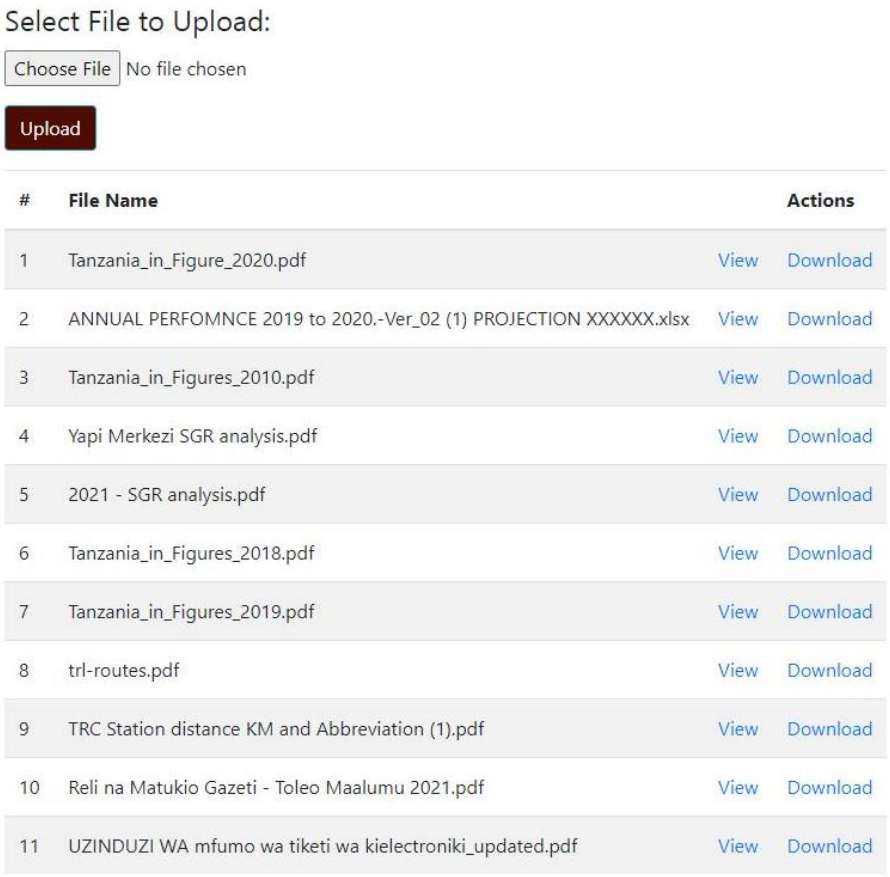

Figure 31: Uploading documents in web application

(vi) Other functionalities

The web application has made it easier for the system administrator to navigate through external TRC links such as its official website and social network accounts through the use of the HTML icon bar feature which contains multiple external links one click away.

There also exists a web map of Tanzania railway lines which is embedded in the homepage to provide a visual presentation of which stations are available and reside in which region to generate quick information to staff members when they do not know the specific location of railway stations when populating data. Also, a graphical presentation of railway lines ranking is included to provide global information on how far Tanzania has come in terms of railway service operations. All these features can be seen as shown in Fig. 32.

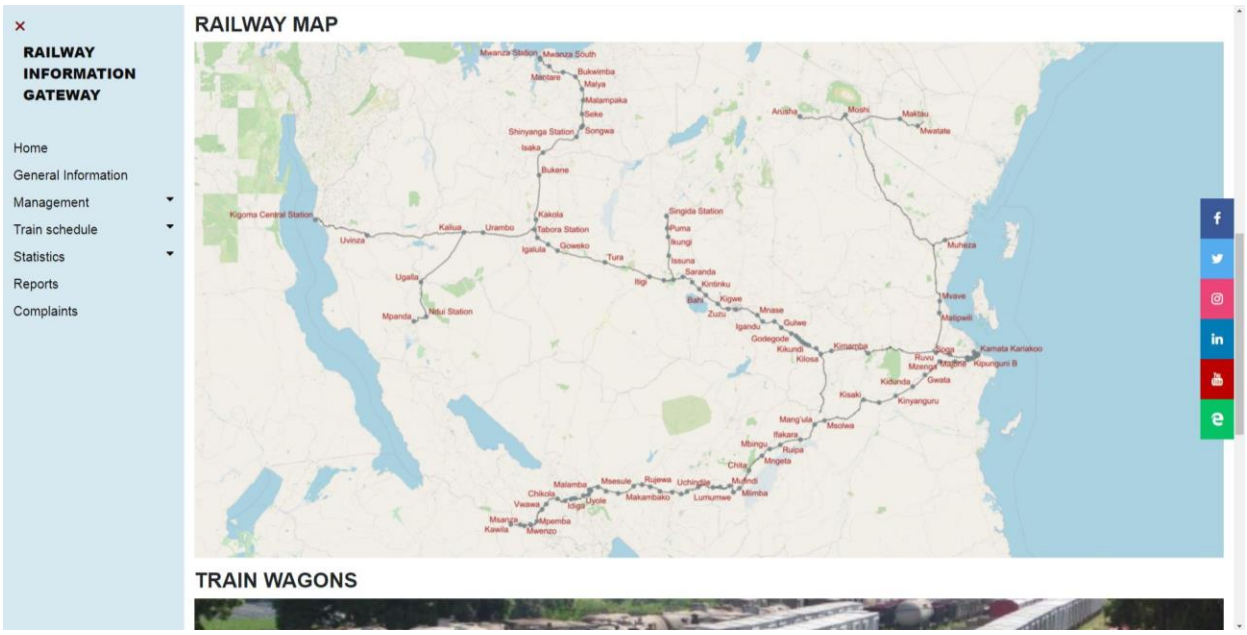

Figure 32: External links to TRC as seen to the right of the web application

4.2.3 Web Mapping

With the introduction of a new and improved railway network, there was a need to add better visual presentation of data to cater for improved use of science and technology in the railway sector. The introduction of a new SGR network means an increase in the number of railway stations and railway track length hence the use of web mapping has been used to facilitate better visual presentation of railway stations and railway tracks on the map and show the path railway network takes in all regions with active railway service operations.

With the help of QGIS software, both developed applications have been embedded with web maps to give a clear view of the Tanzania railway network with existing railway stations situated in their respective locations on the map (Fig. 33).

This process was made possible by the use of pre-existing CSV files of Tanzania railway stations which were uploaded into and modified within the QGIS software in terms of location and names to reduce ambiguity and generate higher accuracy.

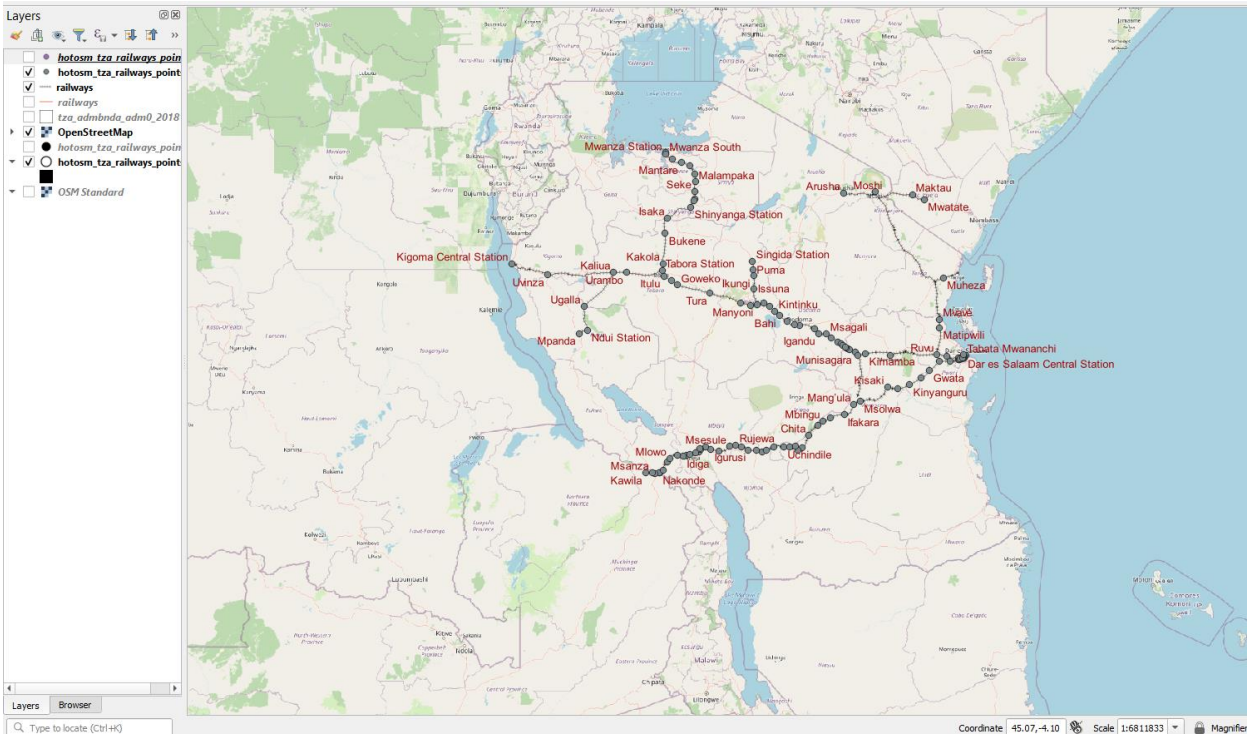

Figure 33: Web mapping through QGIS software

4.3 System Testing and Validation

With the developed system being complete, all requirements speculated within the study need to be integrated into the system in which software testing verifies if the system delivers what is required. This is a way of finding errors or faults within the developed system when in use as well as securing proper data flow among entities involved with the system (Jan *et al.*, 2016). Three types of software testing have been done to showcase the level of functionality the developd system maintains in which unit, integration, and system testing techniques have been used.

4.3.1 Unit Testing

Individual parts or components of the developed system are tested to verify their ability to perform according to their functionalities. This test is performed to see if the source code is written according to the functionality needed to be accomplished by the specified component by detecting and removing bugs within the source code. Various components have been tested and their results are specified in Table 7.

Table 7: Unit testing for the developed system

Unit description	Input	Output	Results
Entering statistical data for passengers	Non-numerical values for income statistics	Error message	PASS
	Complete and correct data	Data processed and stored in the centralized database	PASS
Login and registration forms	Click the registration page link on the login page	Directed to the registration form	PASS
	Click the login page link on the registration form	Directed to login page	PASS
Password encryption	Password using alpha-numeric values	Encrypted password stored in the centralized database	PASS
Logout session	Click sign out button	User removed from the active session and prompted to enter login credentials again	PASS
Navigation bar	Click the close icon on the navigation bar	Navigation bar collapses	PASS
Icon bar	Click an item on the icon bar of the web application	Directed to specific external link clicked on new tab	PASS
Card view layout	Click on an item of the main menu on the android application	Directed to specific class linked with the clicked card	PASS
Button layout	Clicking specific button	Directed to specific functionality	PASS
Comment submission	Incomplete credentials	Error message	PASS
	Complete and correct credentials	Data processed and stored in the centralized database	PASS

4.3.2 Integration Testing

Two or more individual components of the developed system that have a shared interaction are tested to verify proper functionality. This showcases how individual components interact with one another for the aim of achieving desired functionality. Table 8 provides further explanation on integration and specifies results achieved from the existing interaction of individual components.

Table 8: Integration testing for the developed system

Integration description	Input	Output	Results
User registration on web application	All required registration credentials	The email verification process is prompted	PASS
Data visualization on both systems	No data populated	No graphs are created	PASS
	Data populated within the centralized database	Bar graphs are created using populated data	PASS
CRUD operations on web application	Adding new data by clicking submit button	Data is populated and stored in the centralized database	PASS
	Modifying existing data by clicking the update button	Modified data stored in the centralized database	PASS
	Deleting existing data by clicking the delete button	Deleted data is removed from the centralized database	PASS

4.3.3 System Testing

This is where the flow of data is checked to see if it meets system requirements. The system is tested as a whole where it needs to show the proper flow of data from the point where the user accesses the system to the point where the user exits the system as can be expressed with some activities that can be achieved within the system (Table 9).

Another test conducted was compatibility testing in which web application was successfully accessed through multiple web browsers such as Google Chrome and Microsoft Edge.

Table 9: System testing of the developed system

Scenario description	Data flow		Results
Passengers creating and submitting comments to the centralized database	(i)	Passenger accesses the android application	PASS
	(ii)	The homepage is prompted and the passenger clicks the comment option of card view layout	
	(iii)	The comment submission form is prompted	
	(iv)	Passenger fills the form and clicks the 'submit' button	
	(v)	The android application processes data and transfers it to the centralized database	
	(vi)	The android application prompts passenger for successful submission and comment is populated in the centralized database	
	(vii)	The android application directs the passenger to the main menu to view other options	
System administrator generates pdf files for commuter passenger journeys data	(i)	The system administrator accesses the web application	PASS
	(ii)	The login page is prompted and the system administrator provides login credentials	
	(iii)	Upon successful verification of credentials stored in the centralized database, the web application homepage is prompted	
	(iv)	System administrator access navigation bar and clicks on 'Statistics' menu item	
	(v)	The drop-down list is prompted and the system administrator clicks 'Passenger journeys' sub-menu item	
	(vi)	The drop-down menu is prompted and the system administrator clicks 'Commuter' sub-menu item	
	(vii)	Web application prompts new page and fetches data from the centralized database	
	(viii)	After a short time, fetched data is presented in graphs, and file generation buttons are generated	
	(ix)	System administrator clicks on 'Export to pdf' button and pdf viewer opens with populated commuter data	
	(x)	System administrator clicks download icon and pdf file is downloaded in local machine	

With results specified from all types of software testing conducted, a high probability of functionality has been achieved paving way for the developed system to be utilized according to requirements specified within the study.

The results obtained from participants of the evaluation of the developed system showed higher percentage of user engagement in terms of technical and non-technical aspects. Technical aspects were evaluated by NM-AIST personnel together with TRC staff in which it received higher engagement rate with users complying with results in Table 9 for more than 75%. Few attributes such as displaying of revenue data made users question the display parameters used as being too raw and suggested use of percentage representations for easier understandings.

For non-technical side of the evaluation, all participants were targeted in which the results showed higher acceptance percentage in ease of use of the developed system. Further details of the evaluation have been expressed in the Table 10.

Table 10: System evaluation of the developed system by participants

Items	Strongly Agree (%)	Agree (%)	Strongly Disagree (%)	Disagree (%)	Not sure (%)
The system was easy to use	22	78	0	0	0
There is a need for expert help in accessing the system	0	2	21	72	5
The system has an interactive view and feel	27	70	0	0	3
The system can act be used as a gateway for railway information for anyone	13	73	0	7	7
The system contains more railway data than current data available	25	67	0	0	8
The system needs more railway data to be included	13	45	8	26	8
Graphical presentations are well understood	20	71	0	0	9
The system is useful for future railway statistical collection techniques	27	64	0	3	6
The use of maps create a better understanding of Tanzania railway network	24	72	0	0	4

4.4 Discussion

The developed system proved to be a step closer towards railway data aggregation and analysis with input data being visualized in easy-to-understand graphs making it easier for passengers to understand what data is being presented. The rate of attributes displayed show a significance improvement from known sources of railway data such as NBS yearly reports in which more attributes have been analyzed and visually presented apart from displaying data in numbers only.

The use of web and android applications gives space for staff and passengers to engage with data in their own categories respectively. This reduces the mismatch of data representation in which each individual reads the analyzed data in the way it was intended either as staff or passenger without the need of further explanation from the other.

The developed system has tried to bridge the gap of railway data presentation in terms of quantity and quality as compared to existing forms of railway data presentations. The research has found large number of railway data attributes that are not included with various reports generated at country level for analysis of railway transportation in Tanzania as compared to countries that have more railway usage statistics.

In terms of requirements needed to evaluate railway transportation in Tanzania, the research found that more railway data attributes are needed to be collected, analyzed and disseminated to the public in an effort to engage more passengers in understanding the road taken by Tanzania government in ensuring better railway transportation services are delivered across the country.

With the developed system, the research involved the use of web and android applications which act as tools for railway data capturing, analyzing and disseminating with the aim of increasing the number of railway attributes to foster higher number of attributes needed for evaluation of railway transportation in Tanzania.

The research dived into including railway transportation engagement by evaluating the developed system with passengers, railway transportation service providers as well as scholars. The use of broader number of railway data attributres proved to be of importance in evaluating railway transportation and boosting passenger engagement in terms of railway transportation service provision.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Population increase as seen in national survey statistics projects further use of transportation infrastructure in the future prompting further government efforts in light of future demands in public transport. The movement of goods and people promotes economic activities leading to development in the country and the construction of advanced infrastructure systems can boost further development activities that is why efforts in infrastructure are emphasized with more roads being reconstructed and SGR network being constructed to achieve better developmental results in the future in terms of transportation.

This research aimed at showcasing how developed and developing countries differ in terms of railway transportation and with the case study of Great Britain, it has been seen as if Tanzania is smaller compared to Great Britain in terms of the geographical area due to less railway network stretch and lower revenue generation statistics but appears to be incorrect according to the study. This has given a broader view of how much is needed to be done by the Tanzanian government in the effort of reaching higher economic status through the transportation sector. Utilization of geographical area available and concrete financial planning can bring about so much more in terms of transportation within the country and can take Tanzania one step closer to being a higher economy country with its people engaging in developmental activities and working together to foster a rise in national and individual economies.

5.1.1 Railway Services Through Information Systems

Throughout the research, the use of digital techniques has been analyzed and to some extent development sectors have managed to engage in these techniques to provide information to the people and cultivate in the digital era. As to the railway sector, TRC being the major player in its quest to greater success, the digital era has not passed them without involving themselves in one way or another through the development of their website with the following link: www.trc.co.tz which has been useful to show the day to day activities done by the corporation and how much further they are willing to go to ensure railway sector engages into the digital era.

Similar to the website, TRC has managed to establish an online train ticketing system that helps passengers to acquire train tickets through the internet to support physical appearance at train stations for ticket booking and processing. The process of digitization of railway information systems has been largely possible through the establishment of eGA by the Tanzanian government which has been given the power to perform a digital transformation of government services.

Since the 21st century came into existence, the world has been speculated as a village due to the high interconnectivity of people around the world mostly through social networks. Being a leader in railway development, TRC has engaged itself into social networks by creating official accounts on Facebook, Instagram, LinkedIn, and YouTube to mention a few which have helped the corporation to showcase its revival plans and services in operation. The corporation uses these platforms to disseminate information concerning the railway sector and create further attention to their services in a global context.

5.1.2 Modernization of Data Collection

The railway sector under TRC has seen some significant changes through statistical releases disseminated to the public by NBS and the Ministry of Works and Transportation. With yearly releases of national statistics from their database from 2010, NBS has been a leading organ in acquiring information about the progress of the country in all development sectors but with the railway sector, the information portrayed is limited to the number of annual passenger journeys and annual tons of cargo transported making it difficult to see the broader view in railway service progression.

With the latest statistical release of the Ministry Of Works and Transportation, the railway sector has been given a much broader information gateway with information such as railway safety and locomotive failure statistics being involved which shows that there is still a lot of information that can be dispersed to the public concerning this sector.

5.1.3 Challenges Experienced in TRC Digital Platforms

(i) The website created has a lot of missing information in some of its menu lists such as organizational structure which shows that the department dealing with the management of the website is unaware of these small details which can help broaden the public's

knowledge on how their corporation is run. Also, the map embedded into the website has not been working for a while which shows the decreased engagement of the department dealing with managing the website.

(ii) There is a high reliance on the TRC website to incorporate all information concerning the railway sector due to the non-existence of other platforms such as mobile applications. In the world of today, most people engage with mobile phones giving mobile applications higher power to be interacted with rather than websites.

5.1.4 Challenges Facing TRC In Delivering Railway Services

(i) Railway track maintenance and rehabilitation is still a challenge making some of the railway routes still inoperable.

(ii) Some of the train wagons are too old to be in use due to the risk of damage and accidents while in operation limiting the corporation in terms of service provision.

(iii) Little engagement of passengers in cities apart from Dar es Salaam due to little to no traffic congestion making it difficult to establish commuter train services due to higher operational costs that would bring about a small fortune in profits.

(iv) Frequent and undisclosed maintenance schedules of the online train ticketing system prompted passengers to physical ticket acquisition from train stations from time to time.

5.1.5 Challenges Faced in the Period of Conducting the Research

(i) Inability to convert web maps into HTML format due to multiple errors that evolved due to integration of different CSV files with different information which led to the creation of pdf files to be retrieved through android applications and generating jpeg files to showcase web maps through the web application.

(ii) Some categories of data about the railway sector such as safety statistics could not be acquired from TRC offices due to political and security purposes which were brought to light by the head of the department during the interview session. This created a setback but

eventually part of the information was acquired through the latest release of transport statistics from Ministry of Works and Transportation.

(iii) The latest statistics from the Ministry of Works and Transport were released in August 2020 describing data collected up to 2019 which shows a lack of information on timely basis due to unavailable data from 2020.

(iv) Most data collected from TRC were from 2017 onwards which showed little data aggregation before 2017 making it difficult for data to be attained, analyzed, and tested within the developed system for a broader view of the railway sector within the past decade.

5.2 Recommendations

(i) Exploration of more platforms such as mobile applications by TRC as a gateway in service provision and not depending on websites only due to the increasing number of mobile phone owners. This will enable more visits to digital platforms hence increasing passenger engagement through the touch of the mobile screen leading to better service provision techniques and further expansion of services that were never thought of.

(ii) Data is the major drive towards development and for the railway sector, Tanzanian government's hand in utilizing advanced data collection techniques can prove to be highly advantageous to enable thorough internal analysis of its services. Collaboration with data aggregation institutions such as dLab can help to boost data collection and analysis methods and provide higher accuracy and better visualization of railway data.

(iii) Further engagement of Tanzania government in the process of creating railway network shapefiles using available GIS software due to existing shapefiles being privately created and owned. Having national web maps can be useful in terms of displaying geographical information and facilitating research activities in the railway sector and further collaboration with institutions dealing with data aggregation such as dLab can help to achieve this need. This will help to generate information about our nation's railway infrastructure to showcase how far it has spread throughout the country and give a basis for further research to be conducted.

(iv) The integration of external systems within the developed web-mobile-based system has proven to be of greater importance for this study but encourage other researchers to implement standalone functionality for booking procedures and train availability status to reduce dependency of external systems created by TRC which have proven to be in maintenance mode from time to time. This will increase accessibility and reduce the load for the developed system to require connection of other systems for it to perform its functions.

(v) In the aspect of revenue data generation, the study prompts actual amounts which are in large sums. Other research studies are encouraged to facilitate the use of percentages so as to show the months that have higher earnings than others in a more understandable way.

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APPENDICES

Appendix 1: Sample Java codes for ARIP application main menu

```
package com.example.arip;
import androidx.appcompat.app.AppCompatActivity;
import androidx.appcompat.widget.AppCompatAutoCompleteTextView;
import androidx.cardview.widget.CardView;
import android.content.Intent;
import android.os.Bundle;
import android.view.View;
import android.widget.Switch;

public class MainActivity extends AppCompatActivity implements View.OnClickListener {
    public CardView card1, card2, card3, card4, card5, card6, card7, card8;
    @Override
    protected void onCreate(Bundle savedInstanceState) {
        super.onCreate(savedInstanceState);
        setContentView(R.layout.activity_main);

        card1 = findViewById(R.id.trip);
        card2 = findViewById(R.id.info);
        card3 = findViewById(R.id.report);
        card4 = findViewById(R.id.comment);
        card5 = findViewById(R.id.management);
        card6 = findViewById(R.id.analytics);
        card7 = findViewById(R.id.contacts);
        card8 = findViewById(R.id.general);

        card1.setOnClickListener(this);
```

```
    card2.setOnClickListener(this);
    card3.setOnClickListener(this);
    card4.setOnClickListener(this);
    card5.setOnClickListener(this);
    card6.setOnClickListener(this);
    card7.setOnClickListener(this);
    card8.setOnClickListener(this);
}

@Override
public void onClick(View view) {
    Intent i;
    switch (view.getId()){
        case R.id.trip:
            i = new Intent(this,Trip.class);
            startActivity(i);
            break;

        case R.id.info:
            i = new Intent(this,Info.class);
            startActivity(i);
            break;

        case R.id.report:
            i = new Intent(this,Report.class);
            startActivity(i);
            break;

        case R.id.comment:
            i = new Intent(this,Comment.class);
```

```
            startActivity(i);
            break;

        case R.id.management:
            i = new Intent(this,ViewManagement.class);
            startActivity(i);
            break;

        case R.id.analytics:
            i = new Intent(this,Analytics.class);
            startActivity(i);
            break;

        case R.id.contacts:
            i = new Intent(this,Contacts.class);
            startActivity(i);
            break;

        case R.id.general:
            i = new Intent(this,ViewGeneral.class);
            startActivity(i);
            break;
      }
   }
}
```

Appendix 2: Sample interview questions for TRC staff

Introduction

My name is Kitoi Elisha Adam. I am a Master's student from Nelson Mandela African Institute of Science and Technology. I would like to ask questions relating to railway transportation as part of my reseach studies concerning datasets and customer engagement related to the said transportation. The research bases on use of information systems to improve passenger engagement and datasets generation within Tanzania Railway Corporation. Information collected through these interview questions are solely for academic purposes and have no intention to be used otherwise. I thank you in advance for sparing your time to answering these questions and taking this research forward.

Questions

1. How stretched is the railway network?
2. What is the average number of passenger journeys for long distance travels recorded by the corporation? How does the corporation collect these numbers?
3. What is the daily average number of passenger journeys for commuter travels? How does the corporation collect these numbers?
4. How many train stations are available for long distance trains across the country? How many stations are there for commuter trains?
5. Does the corporation have fixed or changing train shedules? Do passengers get up-to-date train schedules? If yes, are the schedules updated in weekly or monthly intervals?
6. Is there a map for train stations across the country? If yes, where can one find it?
7. How frequent do passengers air their concerns about railway services being provided? Is there a platform where passengers make complaints? Do the complaints reach the corporation? If yes, how are they stored?
8. How frequent does the corporation receive reports of accidents related to railway transportation? Are the accident statistics collected and stored? Are they available to the public?

9. Are there any other types of data collected by the corporation? How are they collected and stored? Are they available to the public? How is the collected data used for progress evaluation?
10. Where does the corporation stand in terms of digitization of its services? Are there existing digital platforms concerned with railway transportation? How have they helped in the daily operations of service provision?
11. Are there strategies in place to improve the railway digital space in the growing use of digital technology in global service provision techniques?

Appendix 3: Sample questionnaire questions for TRC passengers

Introduction

My name is Kitoi Elisha Adam. I am a Master's student from Nelson Mandela African Institute of Science and Technology. I would like to ask questions relating to railway transportation as part of my reseach studies concerning datasets and customer engagement related to the said transportation. The research bases on use of information systems to improve passenger engagement and datasets generation within Tanzania Railway Corporation. Information collected through these questions are solely for academic purposes and have no intention to be used otherwise. I thank you in advance for sparing your time to answering these questions and taking this research forward.

Questions

1. Are you aware of the existence of information systems dealing with transportation in Tanzania?
2. If yes, have you used any of these systems to acquire services within the country?
3. If yes, please mention information systems used.
4. What platform was the information system created on?
5. Was the system you used easy to navigate tthrought the process of acquiring transportation services in the country?
6. If no, please mention reasons for discomfort with the said systems.
7. Does TRC use these information systems to provide train travel services to its customers?
8. If yes, what platform does TRC use to deliver its services?
9. Have you used TRC online systems to acquire train travel services within the country?
10. Does the use of information systems created by TRC simplify service acquisition compared to physical bookings from train stations or information dissemination from televisions and radios?
11. If no, please mention reasons for these systems to underperform.
12. Please mention overall challenges faced when acquiring train travel services in the country.
13. Please mention your opinions on what needs to be improved in providing train travel services.

Appendix 4: Evaluation questionnaire of the developed system

Introduction

My name is Kitoi Elisha Adam. I am a Master's student from Nelson Mandela African Institute of Science and Technology. I would like to have your opinions on how the developed system is accessible at your end. The developed system bases on use of information systems to improve passenger engagement and datasets generation within Tanzania Railway Corporation. Information collected through these questions are solely for academic purposes and have no intention to be used otherwise. I thank you in advance for sparing your time to answering these questions and taking this research forward.

	Strongly Agree (%)	Agree (%)	Strongly Disagree (%)	Disagree (%)	Not sure (%)
The system was easy to use					
There is a need for expert help in accessing the system					
The system has an interactive view and feel					
The system can act be used as a gateway for railway information for anyone					
The system contains more railway data than current data available					
The system needs more railway data to be included					
Graphical presentations are well understood					
The system is useful for future railway statistical collection techniques					
The use of maps create a better understanding of Tanzania railway network					

RESEARCH OUTPUTS

(i) Research Paper

Adam, K. E., Dida, M. A., & Nyambo, D. G. (2023). Development of Railway Information System to Improve Railway Data Aggregation and Analysis in Tanzania. *Mobile Information Systems*, *2023*.

(ii) Poster Presentation

Appendix 5: Poster Presenation

DEVELOPMENT OF WEB AND ANDROID APPLICATIONS FOR MANAGEMENT OF RAILWAY DATA AGGREGATION AND ANALYSIS FOR TANZANIA RAILWAY CORPORATION

Kitoi E. Adam, Dr. Devotha Nyambo and Dr. Mussa Ally Dida

ABSTRACT

The ever-growing utilization of science and technology has been implemented in railway transportation to reduce travel time and increase passenger comfortability. African countries such as Tanzania acquired a railway network during the colonial era with the government performing few modifications to cater to evolving passengers' needs. There are still setbacks in generating adequate information on how the railway sector progresses and how railway information is disseminated to the public.

This study utilizes information technology and provides means for railway data collection, analysis, and information dissemination in Tanzania through the use of web and mobile applications. The research looked into ways in which Tanzania differs from railway systems that are statistically improved with Great Britain being the casing point and found use of fewer railway attributes being collected and analyzed. This prompted the development of an improved railway information system which used mixed approach in data collection involving interviews with TRC staff, questionnaires distributed among passengers, and document reviews. From system requirements acquired, android and web applications were successfully developed which create a gateway to railway information, provide visual presentations of collected data from day-to-day railway operations, create up-to-date maps of the Tanzania railway network, and foster higher accuracy data collection.

INTRODUCTION

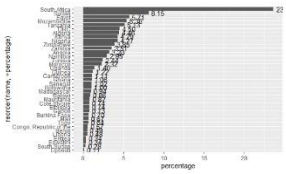
With data collection been based mostly on passenger and cargo transportation, number of users is used as a point of evaluation for growth while in developed nations, different aspects such as passenger satisfaction and complaints handling percentage enables responsible organs to gain higher accuracy during process evaluations. Tanzanian government has established various projects such as Standard Gauge Railway Network to provide support to the current network and provide faster services (Yapi Merkezi, 2019). With low passenger engagement (Msigwa, 2013), the research aims at increasing the engagement of passengers in railway transportation through process digitization.

MATERIALS AND METHODS

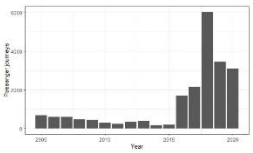
The use of a mixed method approach was chosen. Great Britain and Tanzanian railway information was deduced and provided similarities and differences in data aggregation and analysis for decision-making practices concerning the railway sector. Numerical data was obtained from TRC datasheets while narrative data was obtained from questionnaires, interviews and document reviews. The design phase utilized the Unified Modeling Language (UML) with use case diagrams, functional and non-functional requirements produced. Implementation of the digital tools was undertaken by utilizing Visual Studio Code and Android Studio, MySQL database as database system for the platforms. Web mapping was a feature utilized in this research study and was implemented through the use of QGIS software.

RESULTS

According to World fact-book publication in 2014, statistics revealed that the African continent is ranked behind Asia, the United States of America, and Europe in the terms of total available railway lines contributing about 6.7% of global railway lines in kilometers. The World fact-book further revealed rankings of African countries in which Tanzania was among the top 5 countries contributing about 5% of total African railway lines in kilometers.



Statistics from 2005 to 2010 have shown a decline in passenger traffic that lead to the Tanzanian government opting for full control from privatization of the railway sector by 2011. As of 2017, TRC was established to take wholesome control of the sector to uphold traffic flow. This led to an increase of up to 2 million annual average passenger journeys through railway transportation and created a change in traffic compared to a decade ago when 200 000 to 500 000 average passenger journeys were annually recorded.



Comparison of railway data from Great Britain with that of Tanzania showed huge differences in terms of passenger kilometers, passenger journeys, revenue generated. Further analysis showed lack of other railway data attributes such as passenger satisfactory and average rolling stock data which was observed in Great Britain only. The research made efforts to address how railway data can be collected, analyzed and disseminated through the digital tools created.

DISCUSSIONS

The developed system has tried to bridge the gap of railway data presentation in terms of quantity and quality as compared to existing forms of railway data presentations. The research has found large number of railway data attributes that are not included with various reports generated at country level for analysis of railway transportation in Tanzania as compared to countries that have more railway usage statistics. The use of broader number of railway data attributes proved to be of importance in evaluating railway transportation and boosting passenger engagement in terms of railway transportation service provision.

REFERENCES

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