

Public Bus Transportation System Network Analysis for Improved Accessibility in a South African City: A Case of Durban

by

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Abstract

A significant goal of developing cities in developing countries, particularly in South Africa, is to develop a sustainable public transportation infrastructure. Significant efforts have made to augment the public transportation system and provide greater accessibility to the people in several major cities in South Africa, including Johannesburg, Pretoria, Cape Town, and Durban. However, the public transport system, involving mainly bus transportation, remains secondary to predominantly private transportation by means of individually driven cars and public transportation by taxis operated by private agencies. Furthermore, the public transportation system has been observed to be under-utilised. It has been argued that the challenges include inadequate route networks, the configuration of the routes, frequency of buses, location of bus stops (nodes), availability of information, social inclusiveness and bus fare, which engender challenges of accessibility. Furthermore, numerous suburbs with a disproportionately lower socioeconomic profile have restricted access to public bus transit. In other words, due to inadequate route networks, the public bus transit system is insufficiently accessible.

Therefore, using the study context of the current public bus transportation system of Durban City of South Africa, the factors related to the route network which influence accessibility were examined in this study and how the accessibility of the public bus transportation system could be improved and become inclusive was explored. To achieve this, the spatial design of the current public transport network was evaluated, a network analysis of commuters' accessibility was performed, the social inclusiveness of commuters using the public bus network was examined, and a model was developed to simulate scenarios that would make it possible to improve the accessibility of the public bus network.

A field observation methodology was adopted to collect data about public transport and users. Further spatial and network-related data were collected by using a geographic information system. In addition, the eThekweni Transport Authority provided secondary data on both geographical land use and the public transit network. A geographic information system method was used to make spatial analyses of the public transportation system. The study was conducted using both spatial analysis and statistical methods. Both descriptive and inferential statistical methods were used to examine the relationship between various spatial, public bus transportation network and user factors. Relevant statistical modelling, such as the Negative Binomial Regression Model, was used to examine the influence of various parameters of public bus transportation accessibility on the model.

The findings revealed that the suburbs on the outskirts and townships on the city's outskirts lacked proper access to the city's public transit system. This implied that more infrastructure consisting of roads and nodes (bus stops) should be extended to those locations. The findings also confirmed that commuters from these locations combined walking, biking, and using lifts to reach their bus stops. The simulations showed further that positive increments in the parameters of accessibility (Bus usage, Frequency, Cost, walking time and social inclusivity) indicated improvement in the accessibility of public bus transportation, while negative values indicated no accessibility.

The study helps to a better knowledge of the numerous accessibility problems that residents in different suburbs of Durban, South Africa's eThekweni metropolis, encounter. The novelty of the study lies in the incorporation of social inclusivity in the public bus transportation accessibility model, specifically in the South African context of Durban. The findings are useful because they may be used to help reconfigure and upgrade the public transportation network in Durban, South Africa, to improve accessibility for individuals living in the city's outskirts.

Furthermore, public transportation companies can identify more efficient routes and send more of their vehicles to them.

The findings of the study can be utilized to help design policies and strategies for the positioning of bus stops in order to improve people's accessibility, as well as alternative and efficient public transportation routes.

In addition, the study used a geographic information system-based spatial methodology with probabilistic modeling to analyze the public transportation route network, providing an alternate method for assessing problems of public transportation accessibility.

Keywords: Public transport system, network analysis, improved accessibility, accessibility model, social inclusivity, geographic information system and negative binomial regression model.

Declaration

I, the undersigned, hereby declare that the work contained in this dissertation is my own independent work and that this dissertation, or any part thereof, has not previously been submitted by anyone or by me to another institution in order to obtain a degree.



Signature Date:01/04/2023.

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Chapter One: Overview of the Study

1.1. Introduction

Developing, or transforming existing cities into, smart and sustainable, inclusive cities is one of the main agendas in many countries around the world. While concerted efforts in this direction have been made in cities in the developed world with appropriate policy and strategic initiatives, for countries in the developing world, including Africa, initiatives in this direction are being made. The United Nations' Sustainable Development Goal 11 (UN SDG11) encourages sustainable cities and communities (Leal Filho et al., 2020). According to UNDP Africa, the fast growth in the population and size of African cities necessitates the implementation of programs that would make cities more inclusive and sustainable. In this context, arguments have evolved that creating job and business possibilities, safe and affordable housing, and building resilient societies and economies are all important for cities to be sustainable.

In addition, development should involve expanding and reinforcing public transport, establishing green public spaces, and enhancing urban planning and administration in participatory and inclusive ways (UNDP, n.d). Similarly, through its National Strategy for Sustainable Development and Action Plan (NSSD 1), South Africa's National Department of Environmental Affairs established the groundwork for long-term development (SA Cities Network, 2017).

The department pushed for a systematic approach to sustainability in which social, economic, political, infrastructural, and ecological systems are embedded within one

another and then integrated through a governance system that binds them together in a lawful regulatory framework (Dietz, 2018; SA Cities Network, 2017). Furthermore, in alignment with the function of transportation for the development of sustainable cities in the developed world, it has been stated that road transportation plays a critical part in the sustainable development of cities in South Africa (Das, 2020; Emuze & Das, 2015). (Das, 2020; Emuze & Das, 2015). Moreover, arguments have emerged that public transport is one of the major and essential aspects which needs augmentation or reinforcement that could lead to sustainable cities, not only in South Africa, but also in the cities of other developing nations, including those in Africa (Das, 2020; Emuze & Das, 2015; Dietz, 2018; SA Cities Network, 2017).

Public transportation is a challenge in major cities of the world. It might have both positive and negative implications. It provides opportunities for higher accessibility and affordable intracity movement, contributes to reduce traffic congestion, energy consumption, and air pollution, (Muhammad et al., 2011; Zhong-Ren et al., 2012). On the other hand, it might create economic challenges for automobile, specifically car industry and private taxi industry. Furthermore, it faces several sustainability challenges that includes economic and operation efficiency social acceptability and inclusivity. Social inclusivity is the process of making it easier for people and groups to participate in society (Boardman et al., 2022 & Fisk et al., 2018). Social Inclusivity will be a relevant concept in the context of this study, to help include the disadvantaged in the existing transport network, which will in turn boost public transportation.

Developing countries including South Africa also have their shares of the challenges that emanate from public transportation (Muhammad et. al., 2011). South Africa has its own unique challenges on public transportation found in their major cities. Despite the availability of public transportation system in several cities of South Africa such as Cape Town, Johannesburg, Pretoria and Durban, its use by people is argued to be low. Some of the reasons for the lesser use of public transportation system in these cities include inadequate quality of buses or lack of accessibility of many suburbs to bus services within a reasonable distance, safety and security concerns, reliability issues, and lack of affordability to a large segment of the population, particularly the disadvantaged section of the society (Findley, & Ogbu, 2011; Vilakazi & Govender 2014; Aropet, 2017). Also, the tension between public transportation and taxi operators is observed. As a result, public transit, particularly bus transportation, remains a major concern in South African cities, with accessibility and social inclusion posing major challenges.

Public transportation has various advantages over private/taxi transportation. It is less expensive for the less fortunate, fostering social inclusion; it takes up less urban space; it uses less energy; it pollutes the environment less; it is relatively safe; it encourages job accessibility; and it enables mobility for all. Many cities have invested in the construction, expansion, or modernization of public transportation systems in recent years (Gutiérrez-Jarpa et al., 2013).

1.2. General Background to Public Transportation System and Accessibility

Public transportation refers to the movement of people, commodities, services, information, and, in the event of an urgent need, troops through space to various destinations (Sheller, 2018). Evidence shows that public transportation reduces traffic congestion, lowers transit and business costs, lowers the average cost of basic commodities, and helps businesses grow (Claudia et al., 2017). It also enhances air quality by reducing several dangerous air contaminants (Ioannis et al., 2020).

Furthermore, people who do not own a car can use public transportation to go to their destinations for a reasonable price and in an acceptable amount of time.

More importantly, public transit facilitates access to residential areas, encourages new business initiatives and work zones, eliminates accidents, and lessens the need for additional infrastructure (Ragnar, 2017).

Road transportation, railway transportation, water transportation, air transportation, and pipeline transportation are all examples of transportation. While all the public transportation systems are important with significant implications at different spatial scales, road transportation is observed to be highly important and pervasive at the regional and city scale. Public road transportation includes both bus transportation and transportation by public taxis (mini combi buses). However, public bus transportation is the predominant mode of transportation in many cities and regions. The public bus transportation system is known in different forms such as Bus Rapid Transit (BRT), Integrated Road Transport Network (IRTN) (Viljoen, 2021). Since this study is focused on the accessibility challenges of public bus transportation network, the discussions will be limited to public bus transportation system.

1.2.1. Public Bus Transportation System

The growing population has necessitated the development of better public bus transit systems in cities and suburbs to meet people's everyday travel needs (Reza et. al., 2013).The public bus transportation system in a city runs through a route network system to offer people with access. Nodes and linkages make up the public transit system.

The location of these nodes, as well as the creation of routes that pass through them to pick up and drop off people, are crucial to a city's public transportation network's success and accessibility (Simone, 2010).

As a result, the route network that allows people to access public transportation determines its effectiveness. On the other hand, the route network for public bus transportation is an important part of the operational planning process for public transportation. The organizations of routes and scheduling, as well as the cost of public transportation, are all important aspects of the system (DoT, 2007; Shen et al., 2018). In other words, accessibility is not only dependent on the route network but also on planning and scheduling, costing, etc. Lu & Zhou, (2018).

1.2.2. Challenges of Public Bus Transportation in Global Cities

Public bus transportation systems experience several challenges across the world. Developed countries have significantly improved and have efficient public transportation systems but there are still challenges faced at one time or the other. The challenges faced are generally related to aging transport infrastructures and the

cost of transportation. However, many countries have subsidized the public transportation system to make them affordable to the public (Van Wee, 2011; Di Ciommo, 2017). Lack of adequate infrastructure, long lines at stations and terminals, overcrowded trains, buses, minibuses, vans, jeeps, and other public utility vehicles, and interminable traffic jams are all challenges in developing countries (Bannaga, 2018). Furthermore, physical challenges such as poor road network systems, nodes, parking system and traffic system, are experienced. Similarly, institutional challenges that include both structural and cultural aspects of the institutions or organizations responsible for the development and implementation and operation of public transportation, funding, budget, human resource, etc., are also experienced (Avelino, 2019). As a result, the majority of the issues can be traced back to economic viability, infrastructure, operational efficiency, and social acceptability.

Furthermore, the larger a city gets, the more intricate its public transportation network becomes. There is a risk of interruption, especially if the complexity isn't well controlled. However, in recent decades, roads in urban areas have been extended to ensure free access. The infrastructures were built for speed and capacity, yet urban circulation grew at a faster rate than many predicted Zavitsas, et. al., (2010).

Various levels of government made investments in order to improve accessibility in cities and regions (Rodrigue, 2020). Also, according to Luis and Daniel, (2018) local governments face the difficulty of making public transportation accessible to a substantial portion of the population who are impoverished in order to provide efficient and inclusive public transportation. To address these issues, a number of public transportation systems around the world have established targeted subsidies for specific social groups such as students, the elderly, and persons with limited

mobility, as well as the impoverished (Guzman & Oviedo, 2018). However, Reza et. al., (2013) argue that ultimately, it is the choice of the passenger to use private or public transport, though it is influenced by the government and community decisions.

1.2.3. Public Bus Transportation in South African Cities

According to Monirehalsadat et al. (2019), accessibility is defined as the ease with which one may reach desired destinations, activities, or services in a given location, and that accessibility has numerous benefits, albeit some have detrimental effects on local and global surroundings. The effects of public bus transit accessibility can be demonstrated in the study area of Durban, South Africa. The accessibility of South African public bus transport differs because of the influence of apartheid on transportation planning. This was one of the major challenges addressed in this study.

According to Louis et al. (2018), the necessity for accessibility-based transportation analysis is well known, given that the consequences of major transportation projects on land-use are commonly overlooked, and, as a result, accessibility is either not accounted for or assessed insufficiently. To comprehend transportation planning, an accessibility-based evaluation framework is required. The effects of induced land-use changes can be used to better understand the effects of travel time. The implications on land usage, on the other hand, indicate the transportation investment's accessibility benefits. The goal of this research was to see how some of the characteristics used to model accessibility affected the results.

Access to transportation amenities is thought to affect property prices, according to Linchuan et al. (2020). Furthermore, recent research on the impact of transit accessibility on property prices has primarily concentrated on rail and bus rapid transit systems. The latter category falls within the scope of this study, which supports the finding that transit infrastructure brings development and appreciated property prices where they are found. It will be an interest of future research to encourage rapid facility developments in the suburbs.

Changes in accessibility, according to Nahungu & Christo (2018), are driven by greater affordability rather than increased spatial coverage. Furthermore, Nahungu & Christo (2018) suggested that while public transportation is beneficial as a transportation project in some cities in South Africa (SA), it is not yet a general urban intervention that expands on wider improvements in life satisfaction within served communities, such as providing equitable access to the suburbs. Although Bus Rapid Transit (BRT) systems have been planned or implemented in South African cities, according to Bannister & Esteves (2017), challenges remain in providing affordable, reliable, and safe public transportation to address spatial patterns left over from apartheid while also providing economic benefits. According to Vilakazi & Govender (2014) they argued that, in public transportation in South Africa, taxis or mini-buses are patronized more although they are not as safe as public bus transportation. The important, identifiable challenges include the lack of accessibility to the suburbs, inadequate route networks, inadequate availability buses, poor operational efficiency, affordability of public bus transportation, the erection of shacks in cities for ease of access, and the preference for mini-buses and taxis over public buses.

1.2.4. Accessibility and Public Bus Transportation

The US Department of the Environment defines accessibility as "the ease and convenience of access to spatially distributed possibilities with a choice of route" (Widener et al., 2013). Accessibility is determined by transportation, time, and spatial constraints, all of which limit people's ability to participate in productive activities (Odoki et al., 2001).

Physical access to products, services, and objectives can also be characterized as accessibility in public transit. The ease with which individuals can travel from one location to another or within a location using public transportation refers to the ease with which they can arrive at a specific area, territory, or goal; the ease with which individuals can access any ideal facilities, items, and activities by traveling from one location to another or within a location using public transportation. The spatial distribution of prospective goals in respect to an individual's final destination determines accessibility. Accessibility is also determined by the transportation framework's ability to provide access to geographically separated locations and the willingness of persons to use it. Accessibility is also influenced by the scope, quality, and nature of the activity. As a result, examining accessibility in geospatial technical design, implementation, and development takes into account both geographical and financial considerations, necessitates a wide range of data, and includes route network analysis (Ajay & Bharti 2013; Liu, & Zhu, 2016).

The consequences of poor investigation of accessibility are evident in the existence of shacks and slum-like buildings within the cities in a bid to reduce the impacts of

lack of accessibility to public bus transport, which need to be addressed (Aropet, 2017; Ferranti et al., 2020; Mtizi, 2008; UN-Habitat 2003). Moreover, the impact is experienced as a result of the preference of some passengers to use taxis or mini buses, which are considered to be less safe than public bus transport.

1.2.5. Challenges of Public Transport Accessibility at Global Level and in South African Cities

The challenges of public transport accessibility are lost of attractiveness, concentration in the city centers (central business districts) and not to suburbs, experiencing lengthy business trips due to traffic, and preference of minibuses (Wachs, 2013; Cervero, 2013; Bouton et al., 2015; Joseph et al., 2020). According to Bert (2015) argued the reason why accessibility is a challenge at a global level and that research has not covered the impact of the integration of ICT. Other worldwide problems include including the transport system's robustness in indicators and comparing perceptions of accessibility to standard accessibility indicators.

1.2.6. Public Transportation Accessibility Challenges in South Africa

Challenges of accessibility have become apparent in South African cities, ranging from economic viability and infrastructural inadequacy to social acceptance. It has been observed that accessibility of public bus transport in most South African cities needs improvement to serve the larger population effectively. This is observed from the daily experience by passengers moving from the suburbs to the cities (Mtizi, 2008; Findley, & Ogbu, 2011; Aropet, 2017; Ferranti et al., 2020). Moreover, organizational challenges have been observed. It has been argued that many of the

poor suburbs in the cities of South Africa are less accessible to the public bus transportation system, specifically in terms of availability of bus routes, frequency of available buses and the walking distance from the bus stops. The majority of the bus stops, or bus terminals are located a long distance from the suburbs and require significant walking time, sometimes exceeding 30 minutes. Furthermore, many people in the economically weaker sections of society are not able to afford public buses. Thus, a large section of the population of the city is socially and economically excluded from accessing the public transportation system (Santos, 2010; Hernandez, 2016).

1.3. Problem Statement

The majority of South Africa's major cities have implemented public bus service in some manner. Johannesburg, Pretoria, Cape Town, Durban, and other cities have built public bus transportation networks. Some cities, like Cape Town, Johannesburg, and Pretoria, have updated their current public bus networks to Bus Rapid Transit (BRT) systems. Durban is working on an Integrated Rapid Transit System (IRTS) to increase public transportation options in and around the city. However, accessibility of the public bus transportation is argued to be a significant challenge experienced in these cities. It is argued that the bus network systems experience challenges related to lack of adequate accessibility to the suburbs, affordability of public bus transportation, the preference of minibuses and taxi over public bus transportation and safety and security concerns. In other words, three significant challenges emerge, first, the majority of the people do not use public buses because of lack of availability of buses and safety concerns, again, people

belonging to disadvantaged sections could not afford to use public buses and finally, operation of public bus transportation system by the bus services providers becomes economically unsustainable. The main research gap is social inclusivity in the public bus transportation system by the economically disadvantaged people.

As a result, it is necessary to investigate the accessibility problems that public transportation systems in South African cities face, as well as how socially inclusive they are and accessible public bus transportation system be developed. However, studies on these aspects in the South Africa context are scarce. Therefore, using the study context of the currently operated public bus transportation system of Durban, the study examined the accessibility challenges of Public Bus Route Network System and how socially inclusive and accessible public bus transportation can be created to provide improved accessibility to people.

1.4. Research Questions

The following research questions which are investigated in this study are:

1. How accessible and socially inclusive is the current public bus transportation?
2. What are the accessibility challenges of public bus transportation?
3. How can the public bus transportation be made more accessible and socially inclusive?

1.5. Aim and Objectives

The goal of this study is to use spatial network analysis to assess the accessibility of Durban's current public bus transportation route network and provide suggestions to make it more accessible and socially inclusive. To achieve this aim, the following objectives were developed for this study:

1. Examine the current public transportation system, and its route network in Durban City.
2. Perform a public bus route network analysis to examine the accessibility and social inclusiveness of the current public bus transportation system and the route network.
3. Identify the challenges of accessibility and social inclusivity of public bus transportation system.
4. Develop model estimations to examine the factors that influence accessibility and social inclusivity of Public Bus Transportation network and create simulated scenarios to develop strategies to improve accessibility and social inclusivity.
5. Propose guidelines to improve the accessibility and social inclusiveness of the Public Bus Transportation Network in Durban.

1.6. Methodology

The study was centered on the use of engineering approach to solve social challenges experienced in the public bus transport network of Durban. Observation

was carried out in the study area and compared with data collected from the eThekweni Transport Authority (ETA) in the form of a current public transport records (CPTR) shapefile (spatial data). GIS techniques were used to deduce spatial attributes such as distances from bus stops to suburbs. Ground truthing was done to verify the data acquired by visiting landmarks in the field. Some acquired maps were specifically digitized to extract information required for the study, considering map embellishment.

The related socioeconomic data of the study area were required to achieve a robust methodology. Considering the first identified challenge, which is lack of accessibility to the suburbs, transportation network analysis involving spatial and socioeconomic data with the primary data will be performed. It helped to understand the accessibility challenges of Durban. Social inclusivity will be included in the model to address the second concern- 'affordability of public bus transportation'. A proposed guideline will be established to address the third identified challenge of erection of shacks at the cities. The model is bid to improve the current public bus transportation to address the last identified challenge of preference of minibuses and taxi over public bus transportation. This research concerns understanding an existing spatial transportation network and how to improve its functionalities, which will require some spatial (count) data to create a model. Negative Binomial Regression Model was used because of its effectiveness to analyze count data. The methodology will be discussed in detail in chapter four of the thesis.

1.7. Justification of the Study

Public transportation in developed countries forms an important part of the solution to a nation's economic, energy and environmental challenges. The emphases justify the need for this study. According to Litman & Burwell, (2006), "The goal of sustainable transportation is to ensure that environment; social and economic considerations are factored into decisions affecting transportation activity." The current public bus transport scenario in South African cities does not uphold this view, also making it important to indulge in the research to improve the ailing public bus transport network. Several schools of thought have highlighted the challenges experienced by most South African cities including Durban, the study area (Mtizi, 2008; Findley, & Ogbu, 2011; Aropet, 2017; & Ferranti et. al 2020). The study has become very necessary to help alleviate the concerns identified, which include lack of accessibility to the suburbs, affordability of public bus transportation, and the preference of minibuses and taxi over public bus transportation. The rationale behind this research surrounds the gaps identified from the various literatures that were reviewed and the challenges that public transport network poses to the immediate neighbourhood of the study area.

1.8. Scope of the Study

The purpose of this study was to examine the current public transportation network in Durban, South Africa, for issues of accessibility and social inclusion. The route network encompassing the wider Durban area was evaluated in this regard. The spatial data, socio-economic data, and derived data from GIS analysis were all

obtained from the Department of Transport (DoT) eThekweni Transport Authority. Spatial and Route Network analyses by GIS and statistical methods were used for analyses and modelling. The study was undertaken also to propose guidelines to improve the accessibility and social inclusiveness of the Public Bus Transportation System in Durban (Cappo & Verity,2014).

1.9. Organization of Remaining Chapters

The thesis has been organized into seven chapters as follows:

Chapter One: Introduction, General Background of Public Transportation System and Accessibility, Challenges at the Global, National, and Local Levels, Problem Statement, Research Questions, Aims and Objectives, Methodology, Justification of the Study, Scope of the Study, Limitation of the Study, Thesis Organisation and Conclusion.

Chapter Two: Literature Review organised under several relevant aspects related to the investigation, including: Introduction, Sustainable Road Transportation, Sustainable Public Transportation, Factors Influencing Sustainable Public Transportation, Challenges of Public Bus Transportation System, Various Measures Undertaken for Sustainable Public Transportation, Accessibility of Public Transportation, Relationship between Route Network and Accessibility, Route Network Analysis, Methods and Models Used in Public Transportation Analysis, GIS and Other Different Statistical and Mathematical Models, Public Transportation

Scenario in South Africa, Synthesis, Summary Findings, Knowledge Gap and Summary/Conclusion.

Chapter Three: contains a discussion of the study context, including: Introduction, Durban City Profile, Transportation and Road Transportation Profile of Durban, Public Transportation in Durban, Accessibility and Mobility, General Accessibility Challenges, and Summary.

Chapter Four: contains an explanation of the Methodology used in the thesis, including: Introduction, Research Philosophy Adopted, Research Design, Research Methods, Planning Process, Modelling, Validation of Model, and Summary.

Chapter Five: Analyses and Results. The chapter contains a discussion of the following aspects: Introduction, Socio-Economic Scenario of the Study Area, Evaluation of Transportation System, Evaluation of Current Public Bus Transportation System, Analysis of Public Bus Transportation Network for Accessibility, Modelling for Sustainable Public Transportation System, Evaluation of Social Inclusivity Provisions for Social Inclusivity, Discussion/Synthesis of the Findings, Conclusion and Summary.

Chapter Six: Modelling and Simulations The sub-headings include: Introduction, The Poisson Model, Development and Application of Poisson Regression Model, Results, Summary of Critical Findings, Guidelines for Optimal Development of Public Bus Transport Network of Durban South Africa, and Conclusion.

Chapter Seven: Recommendations and Conclusion, with the following sub-headings: Findings, Strategies, Guidelines, Recommendations and Summary.

1.10. Summary

Chapter One is the introduction of the study in which the efforts made globally and locally to address the challenges that emanate from public transportation were identified. The background for the study was established, providing a picture of the current transport network, citing challenges faced globally and in Durban. The study's problem statement, research questions, targets, and objectives were also included. An outline of the methodology used was presented. Premised upon the problem identified in this chapter, theoretical background for the study, based on a literature review has been presented in the next chapter. The methodology that was followed was outlined. The theoretical framework for the investigation, based on a literature review, has been described in the next chapter, based on the problem outlined in this chapter.

Chapter Two: Literature Review

2.1. Introduction

Public transit accessibility is a well-known issue in major cities around the world.

It differs from one city to the next, from one region to the next, and from developed to developing countries around the world (Pojani & Stead, 2015).

Around the world, there have been concerted efforts to construct smart and sustainable public road transportation networks, both at the local and regional levels. To achieve sustainable public road transportation systems, various approaches have been adopted, such as transportation facilities using public buses, Bus Rapid Transit systems, Integrated Road Transportation Network systems, and Smart travel etc. (Anik et al., 2020). However, sustainability in the public transportation system has remained a serious challenge in many countries, including South Africa (Goebel, 2007). One of the major challenges is provision of adequate accessibility to different areas of a city or urban region, which is socially inclusive, in other words, provision of accessibility to the people belonging to all strata of society (Revi & Rosenzweig, 2013).

It is noted that greater levels of accessibility have been witnessed in modern cities, characterised by shorter commuting times, increased employment rates, and greater levels of economic and social activities, while reducing social isolation (Hu, 2015; Lucas, 2012). Public transportation promotes employment opportunities, that are the key component in evaluating the performance and social outcomes of any city transport network. Employment equity is central to preventing social exclusion as a

result of the financial support and stability and other areas of life. In other words, if there are lower levels of employment or retention in a particular area, lower levels of education and lower social networking will affect employment outcomes due to poor access to public transportation (Merlin et al., 2018).

Nevertheless, because of the distribution of land-use and transport networks within major urban centres in South Africa, access to destinations is never equal among urban consumer populations (Allen & Farber, 2019). As demand for public transportation grows in many developing countries, consumers face significant obstacles. As the demand for inter-city transportation increases, accessibility poses a challenge as availability of different modes of transport fail to meet transport needs.

Modes of transport used in inter-city movement include personal transport or privately operated/publicly operated vehicles, such mini-buses or buses. In a similar study, undertaken by Statistics South Africa (2021), it was identified that 39% of commuters use taxis which are privately operated compared with 38.4% who use privately-owned cars. In another study, taxis accounted for 80.2% of all workers' transportation, of which 16.6% used buses in 2020, while train transport accounted for 3.2% in 2020 compared with 12.9% in 2013 (Statistics South Africa, 2020). Nevertheless, despite these statistics regarding private and public transport, there is a significant number of people who use a combination of the modes listed above.

An accessibility problem is indicated when availability of public buses is absent such that not all routes are covered, which leaves commuters with options of walking

significant distances or using different modes of transport to reach their destinations (Washington et al., 2021). A primary function of the transport system should be to provide consumers an opportunity to participate in daily economic activities and make use of social and health facilities. This can only be assessed by evaluating the principles and concepts of accessibility in the distribution of public urban transport and accessibility (Papa et al., 2016, Merlin et al., 2018).

Rapid economic development and urbanisation increases urban population in major urban centres; hence it becomes necessary to redistribute the population of these centres by creating satellite metropolises and cities. This in turn increases accessibility challenges because the distances between these centres with amenities varies as a result of an irreversible mismatch of employment and housing (Zhou et al., 2016).

Public transport does not operate in isolation, as it is related to many aspects of public life, for example, location, cost affordability and social inclusivity (Seo & Nam, 2019). In other words, the principles of opportunity cost apply to consumers of public transport. For example, consumers can trade accessibility to reside in a more spacious house or in a safe neighborhood. Another important aspect of public transport is consumer behaviour based on economic power. Research has indicated that high-income households prefer more attractive residential comforts and vice versa, assuming all other conditions remain the same (Allen & Farber, 2019; Seo, 2016). This means that, despite reliance on public transport, many neighbourhoods are disadvantaged, as public transport fails to provide accessibility to destinations which give consumers opportunities for employment and amenities. Research in much literature surveyed indicated that poor public transport and accessibility

combines with other forms of social and economic determinants leading to more disadvantages or transport poverty (Lucas, 2012; Hine & Mitchell, 2017).

Transport poverty is compounded by two main factors, namely: lack of access to travel and activities. This leads to an increased general cost of accessibility to destinations, increased suppression of activities and, moreover, it perpetuates social exclusion (Pereira et al., 2017). However, sustainability in the public transportation system has remained a serious challenge in many countries, including South Africa which is discussed in the next sections. One of the major challenges is provision of adequate accessibility to different areas of a city or urban region as well as inclusivity, in other words, provision of accessibility to all the people, irrespective of social class in society.

It has been argued by many schools of thought that poor accessibility to public transport within sub-groups of all social classes is on the increase (Klein et al., 2018; Farber et al., 2018; Páez et al., 2013; Delbosc & Currie, 2011; Barnes et al., 2016; & Fan et al., 2012). Differing levels of accessibility for different classes and different social groups have been reported. However, other sources have agreed on the comparative socio-economic disparities as being a critical factor that influences accessibility but argued that the disparities are aligned with social needs (Fransen et al., 2015; Foth et al., 2013).

2.2. Sustainable Road Transportation

The 7th UN millennium development goal (MDG) emphasizes the need to promote environmental sustainability. This concerns modes of transportation that are “green” and have low impact on the environment, which are to balance our current and future needs of transportation sustainably. According to Szeto et al. (2015), Le-Blanc (2015) and Gudmundsson et al. (2016) argued that public transportation serves the purpose of the UN MDGs and should be upheld. Santos et al. (2010), Jain et al. (2014) and Pojani & Stead (2015) considered public transportation to be a safe, affordable, and preferable mode of transportation. According to Klopp and Petretta (2017) and Das et al. (2016), many recent studies have been focused on the problem of public transportation. Sustainable road transportation is a challenge at the international, state, and regional levels. This confirms the assertion by (Havenga et al., 2011, Thambiran and Diab, 2011, Msigwa, 2013) that the challenges are being experienced in sustainable road transportation in Durban. Since it has been established that the challenges have global and regional perspectives, it has become necessary to find a lasting solution to sustainable road transportation according to (Santos et al., 2010, Makarova et al., 2017), who consider it to be a safe and affordable mode of transportation, and a preferable mode in the future.

(According to Ali et al., 2021) Sustainable road transportation and light rail frameworks fundamentally produce 62% lower outflows of ozone-harming substance per traveller mile compared with private vehicle use for the same distance. Giving choices other than owning a private vehicle reduces vehicles on the streets, lessens congestion, eases pressure on the public roads, and promotes well-being. It can develop cargo effectiveness, improve framework of electric vehicles, use green

development, expand technology-driven development, co-ordinate and utilise land sustainably and advance green parkways. The goal of expanding sustainable road transportation is to increase public transit acceptability and use while concurrently reducing motor vehicle miles travelled and gridlock (Iclodean et al., 2020; Koslowsky et al., 2013; Hutton, 2013). It can save multiple times the cash used to drive a private or individual vehicle.

For road transport to be sustainable, it should include social, economic, and environmental aspects. This is informed by the reality that transport systems interact with other aspects, such as land-use, to achieve the desired objectives. For example, when a new road is constructed or widened, it decreases the cost of transport in those areas and, hence, accessibility and opportunities are increased (Wang, 2019). In turn, this increase leads to changes in population and employment opportunities or distribution, while establishing new travel demands (Szeto et al., 2015), which might lead to under-estimation or over-estimation of usage of transport infrastructure, as travel demand shifts according to changes in the distribution of space.

In the literature reviewed, several authors, such as Xu et al. (2016) and Soltani-Sobh et al. (2016), have explored this issue. However, in providing sustainable road transport, it is necessary to include data on changing demand and gradual network upgrades, which were still limited in the studies reviewed (Szeto et al., 2015). One of the glaring disparities in the literature reviewed was the exclusion of land-use in studying the impact of the design of sustainable road networks. Many researchers have focused on the effects of road network design without discussing sustainability

or studying changes in demand and network overtime in relation to land-use (Haque et al., 2021; Alireza Seyedvakili et al., 2020;Canca et al., 2019).

It is noted also that sustainability is not based mainly on threat analysis but is related more to transport analysis. Specifically, sustainability addresses the interaction between the environment and socio-economic factors in order to provide mutual advantage or disadvantage within the scales of public transport. For example, how does sustainability relate to inequity, social welfare, and air pollution? In other words, transport and city planners can no longer focus on congestion alone when transport issues are discussed or solved. This underscores the need for more efforts to create environmental awareness within the transport sector to address sustainability (Wang et al., 2018).

Additionally, transport systems require effective control and objectivity for sustenance. This will lead to equal sustenance of human life and economic growth. In other words, effective policy development is required which can enlarge or limit the effects of the transportation system (Sayyadi & Awasthi, 2018). For appropriate assessment of policy to be undertaken, indicators are required, which measure system responses and processes under particular sets of conditions. Indicators are critical in assisting city planners to make decisions and legislation to achieve sustainability. Economic, social, and environmental aspects are generally used as indicators of sustainability in the transportation sector. These indicators should be measurable, goal oriented and multi-faceted.

2.2.1. The Socio-Economic Role of Road Transport

Individual accessibility to products, services, and information, according to Hojeghan & Esfangareh (2011), Schiller & Kenworthy (2017), and Alpkokin (2012). It is a fundamental human action that contributes significantly to social activity as well as the public and global economies. The transportation industry has an impact on a region's socioeconomic development. As a result, all key players in the transportation sector play a critical role in ensuring that the most crucial transportation services for the economy and personal pleasure are given top priority.

According to the Asian Advancement Bank Foundation (ADB, 2010) interest in the extension of transport framework and exchange work together with decreases in public need and upgrades in socio-economic development. Additionally, these components decrease exchange and opportunity expenses and upgrade market infiltration with improved admittance and portability. An improved transportation foundation leads to complex financial communications, with the specific causal connection between monetary development and framework and transport venture being blurred. Be that as it may, the causal connections result in constructive outcomes. The advantages of enhanced transit accessibility and mobility are presented to businesses and individuals, along with proposals for poverty alleviation. Accessibility and mobility in rural areas are critical for all members of society to have access to the economy and a better quality of life, especially for those who cannot afford to travel to seek possibilities. However, there must be a balance made between demand, needs, priorities, and budgetary limits.

This issue should be investigated, and definitive guidelines on the socioeconomic significance of transportation in South Africa and its financial repercussions in the future should be supplied (Meijer et al., 2018).

2.3. Sustainable Public Transportation

Public transportation, according to (Miller et al., 2016, Sabeen et al., 2012, Hipogrosso & Nesmachnow, 2020), enhances the environment by reducing the number of people driving single-occupant vehicles. More fuel is saved, air pollution is reduced, and the carbon footprint of the area is reduced by increasing ridership on public transportation. The normal use of a private vehicle will require the expenses of maintenance and other extra charges like parking charges, outflow tickets, and speeding fines. A decent travel framework is both quick and regular and one approach to accomplish it is to beat congestion by making committed transport paths. Committed transport paths can double, even triple transport spaces, and move multiple travellers on numerous occasions each hour compared with normal path traffic.

Sustainability has become an overarching concern for transportation policy and planning around the world. A sustainable transportation system simply means balancing the current and future economic development happening in transportation. The aim of sustainable transportation is to control pollution, energy consumption and provide adequate accessibility Rajak et al., (2016). The benefits of public bus transportation include further development of local area well-being, financial advantages to the local area, eco-friendliness, decrease in air contamination, and further reduction of street congestion (Litman, 2013; 2015). Public bus transportation leads to further development of local area versatility, which

is recommended by this study. Public bus transportation offers a fair transportation framework to travelers, which is supported by this study, and enhances workers' usefulness. Public bus transportation does have disadvantages compared with private vehicles, such as being less adaptable, re-routes might be troublesome, route issues and being less accommodating, which confirm the claims of this study. Comparisons of long-term statistics are crucial for improving implementation in different nations. Nonetheless, because the mechanisms to do so are lacking in much of the work reviewed, it is difficult to quantify actual impacts (Naganathan & Chong, 2017).

2.3.1. The Challenges of Sustainable Public Transportation

According to (Jaafar et al., 2014, Miller et al., 2016, Pan et al., 2018), highways and parking capacity boost automobile travel per capita while reducing modes of mobility like walking, cycling, and public bus transportation. The difficulties of providing sustainable public transportation increase asset utilization, pollution, and land consumption, as well as the vehicle troubles that non-drivers face. In other words, the issues of sustainable public transportation result in increased traffic congestion, longer driving times, insufficient public transportation, difficulties for non-mechanized cars, and a loss of public space. High framework maintenance costs, natural consequences, energy consumption, and accidents are among the other challenges.

In Durban, poor accessibility to suburbs and regions of the city and environs and lack of interest by commuters in using the public bus transportation service were currently

a problem. It was simply because commuters could not reach their locations using the buses, so they looked for alternative means of transportation (Turok, 2014).

2.3.2. Procedure to Sustainable Public Transportation

According to recent studies by (Banach, 2019, Hipogrosso and Nesmachnow, 2020), sustainable public transportation is viewed generally as one of the better choices for reducing the negative, natural effects of metropolitan mobility. Recent studies on public transportation support the view that it reduces negative, natural effects (Banach, 2019, Hipogrosso & Nesmachnow, 2020).

Although private transport offers freedom and privacy, it leads to other challenges, which go beyond pollution, environmental degradation, congestion, accidents, a decline in public transportation and poor accessibility. However, in the last decade, solutions are being designed for sustainable public transportation in many countries and in major cities of the world. This has led to the creation of new transportation modes, creation of pedestrian zones and changing perceptions based on the dominance of private transportation (Miller et al., 2016).

To provide solutions to challenges in the transport sector, sustainable transportation systems should be revitalised. This would enable the movement of much more of the population compared with private transportation modes, especially considering that fewer vehicles would be employed. Greater use of public transportation would make it possible to reduce greenhouse gas (GHG) per passenger per kilometer compared

with private vehicle transportation (Hipogrosso & Nesmachnow, 2020). Sustainable public transportation not only improves economic growth, but also improves accessibility, which is a critical social issue. Figure 2.1 shows the interaction between economic, social and environmental aspects.

Figure 2.1: Main aspects related to sustainable mobility



Source: (Hipogrosso & Nesmachnow, 2020)

The shift to sustainable transportation has been a paradigm shift that integrates many concepts and solutions in much of the literature reviewed (Banach, 2019; Fournier, 2017; Banister, 2008; PadrónNápoles et al., 2020). Redesigning and planning public transportation system modes based on social processes, accessibility, reduction in motorized transportation, and integration of people and traffic, as well as social and environmental issues, have been advocated under this paradigm (Poxrucker et al., 2016). However, in the literature reviewed, research was

focused mainly on environmental impacts while ignoring important aspects such as equity, safety, health and impact on the economy and quality of life (Hipogrosso & Nesmachnow, 2020).

Technology has the capacity to provide tools for the development of new processes of data analysis. One of the solutions for urban planning, which has been proposed in many cities, is the transportation-oriented development model. This model can contribute towards long-term sustainability (C40 Cities Climate Leadership Group, 2016). This model helps to reduce carbon emissions, provide accessibility to services, and provide socio-economic benefits while expanding the connectivity of public transportation with residential houses and economic opportunities and services (Gudmundsson et al., 2016). In the literature reviewed, many other solutions have been identified by Sebhatu et al. (2016), who proposed a production, exchange, and consumption model. This is a thorough approach of modeling transportation impacts that must be incorporated into all integrated urban models. This model provides data on economic utilities such as household incomes, housing rentals and affordability. In another study by Seto et al. (2010) an index was developed for sustainable urban transportation based on data from planners, defined by experts. The third solution in the literature reviewed was offered by Magdalena (2016), who studied problems of public transport in Bucharest, Romania. In this research, many similar cities and challenges in the former Eastern European capitals were replicated, where there was a lack of policy to discourage private transport. Using indicators of accessibility, the public transportation was analysed in which fares and access to residential areas were considered in relation to transportation.

2.4. Various Types of Public Transportation System

Buses, trains, trams, trolleybuses, ferries, and rapid transit (e.g., light rail transit (LRT), bus rapid transit (BRT), and metro services) are among the several modes of public transportation utilized globally and locally. They are easily accessible to the general public and can run on a set schedule (Chakwizira, et al. 2011). The following sections go through the numerous sorts of public transportation systems. The BRT has been thoroughly discussed, while the others have been skimmed through. However, as recommended by Basnak et al. (2020) and depicted in Table 2.1, new classifications feature a 5-tier scale based on right-of-way (ROW) classification.

The terms used in Table 2.1 are explained below.

Table 2.1: Classification of public transport systems in cities

Class	Highest capacity public transport modes	Typical ROW*	Typical max. capacity (pphpd)**
I	(no public transport, private modes only)		
II	Demand-responsive (taxi)	"C" (mixed traffic)	-
III	Bus, tram, trolleybus	"C" (mixed traffic)	0–7,000
IV	BRT***, LRT****	"B" (partial priority)	5,000–30,000
V	Metro, HRT*****, BRT (high standard corridors)	"A" (full priority)	10,000–70,000
*ROW (right of way), **Pphpd (passenger per hour per direction), ***BRT (bus rapid transit), ****LRT (Light right transit), *****HRT (Hampton roads transit).			

Source: (Basnak et al., 2020)

ROW "C" corresponds to traffic circumstances that are mixed.

This covers regular bus services, trolleybuses, and trams with a maximum capacity of 7,000 pphpd and an average commercial speed of less than 20 km/h.

"B" ROW ": a partially separated right-of-way in which public transportation operates on segregated lanes but with level crossings, such as BRT and LRT lines, with commercial speeds of 20–40 km/h and typical maximum capacities of 5,000–30,000 pphpd. "A" ROW ": a fully separated right-of-way found on metro lines, regional trains, or high-capacity BRT corridors with dedicated infrastructure and separate-grade intersections. These systems' typical maximum capacity ranges from 10,000 to 70,000 pphpd, with average speeds exceeding 25 km/h.

2.4.1. Bus Rapid Transit System (BRT)

In comparison to light rail transit, the BRT system has risen swiftly to 163,3 million kilometers in over 200 countries (Li & Hensher, 2020, Institute for Transportation and Development Policy (ITDP), 2017).

Latin America, Asia, Europe, North America, Africa, and Oceania are among these countries. The Bus Rapid Transit System's key features are dedicated bus lanes that operate independently from all other types of transportation (Kwan, 2017, Respond, 2018, Meneguet et al., 2018) Because only professional drivers are permitted on the route, BRT permits the buses to run at a very high degree of reliability (given the traffic). Bus Rapid Transit (BRT) is a high-quality, bus-based transit system that provides metro-level services in a timely, pleasant, and cost-effective manner.

It accomplishes this by providing dedicated lanes, with bus ways and landmark stations often aligned to the road's center, off-board fare collecting, and quick and frequent service.

BRT has features similar to a light rail or metro system, and it is far more dependable, convenient, and rapid than traditional bus services. BRT, with the correct characteristics, can avoid the delays that plague ordinary bus services, such

as being trapped in traffic and having to wait in line, to pay on board (ITDP, 2014). The merits of BRT can be summarised as having minimal expense interests in framework, hardware, and functional enhancements, and innovation can give the establishment of Bus Rapid Transit considerably updated execution of transport frameworks. Considered as a co-ordinated, obvious framework, Bus Rapid Transit accommodates altogether quicker working velocities, more noteworthy assistance dependability, and expanded comfort, co-ordinating with the nature of rail travel when carried out in suitable operations (Hoque et al., 2020, Button, 2010).

According to Matthews, (2011), Gora and Rüb, (2016) & Suau-Sanchez et al., (2020) argued that BRT has its challenges globally and locally as a result of delays experienced, such as system integration, passenger stops, and negotiating right turns because of traffic signals and general congestion. The issues experienced generally were confirmed in this study and were related to their occurrence in the Durban study area. It had been argued that the BRT challenges could be addressed by increasing the speed limit, delays can be decreased if queue separating is expanded and the quantity of stops is diminished. The strategies require traffic to respect transport returning into the traffic stream from transport stops, which also could lessen delays related to general congestion (Hobbs, 2016, O'Flaherty, 2018).

Low cost, operating flexibility, rapid implementation, excellent performance, and environmental benefits are just a few of the benefits of BRT (Nikitas & Karlsson, 2015; Deng & Nelson, 2011). The ITDP's 2014 BRT standard system includes the following features (Institute for Transportation and Development Policy, 2014):

I BRT fundamentals (dedicated ROW, bus way alignment, off-board fare collection, intersection treatment, and platform-level boarding); (ii) Service planning (multi routes express, limited local devices, control centers located in top 10 corridors, demand profiles, hours of operation, multiple corridors network); (iii) BRT implementation (dedicated ROW, bus way alignment, off-board fare collection, intersection treatment, and platform-level boarding); (iv) BRT(iii) Infrastructure (passing lanes, bin emissions minimization, station setback from intersection, center stations, and pavement quality); (iv) Station (distance between stations, safe and comfortable stations, number of doors on the bus, docking bays and sub-stops, sliding doors in BRT stations); (v) Station (distance between stations, safe and comfortable stations, number of doors on the bus, docking bays and sub-stops, sliding doors in BRT stations);(vi) Access and integration (universal access, integration, with other public transportation, pedestrian access, secure bicycle parking, bicycle lanes, bicycle paths); (v) Communications (branding, passenger information); (vi) Access and integration (universal access, integration, with other public transportation, pedestrian access, secure bicycle parking, bicycle lanes, bicycle paths).

Bus Rapid Transport is one of the post-modern, dynamic transportation systems and it is a solution for, or method of controlling, congestion in crowded areas. However, despite its proven data about relieving congestion, BRT requires a scientific approach for its management, especially to keep BRT lines acceptable, using quantitative and qualitative criteria (Abbasi et al., 2020). Using technology to manage BRT has been proposed by many researchers, such as (Vilarinho et al., 2014), for vehicles with higher occupancy rates. The BRT system optimises fuel consumption

as it attracts more commuters, thus decreasing private car transit modes in crowded areas, hence reducing fuel consumption (Morten, 2020).

The consequences of BRT on social costs, air pollution, and fuel consumption were presented in other publications evaluated. The studies revealed that reduced traffic reduces societal costs and pollutant emissions, resulting in lower fuel consumption costs (Bigazzi & Rouleau, 2017). In comparison to fixed rail, the BRT system offers excellent service levels, segregated ROWs, station platforms, high-quality amenities, and sophisticated mobility support systems at a lower cost (Currie & Delbosc, 2014). In other words, BRT should not be viewed as the final solution, but rather as a means of creating a shift in the way public transportation is delivered. This combines the best light rail and bus systems to provide mass transportation systems that can adapt to changing mobility needs (Nikitas & Karlsson, 2015; Li & Hensher, 2020).

Investigations into BRT performance drivers have shown several key factors such as fare, service frequency, infrastructure, connectivity, and accessibility. By comparing the understanding of BRT across regions, best elements of practice in BRT systems can be defined. For example, in early BRT versions, only design features were considered compared with the latest or current systems, which incorporate operations (dynamics) and design features (statics) to obtain a full range of indicators (Li & Hensher, 2020). Besides improved accessibility, urban mobility, economic benefits, reduction in pollution etc., BRT has economic benefits for city growth and improved transportation by increasing accessibility, which increases property prices and can thus be used as a source of funding for transportation infrastructure through land value capture (LVC) (Smith & Gihring, 2006). The LVC

has been considered to be solely attributable to BRT systems in much of the studies reviewed (Mulley, 2014; Zhang & Wang, 2013).

Others, on the other hand, neglect to include actual research in which the LVC or depreciation due to BRT systems has been calculated (Salon et al., 2014; Ulloa, 2015; Zhang & Liu, 2015). This demonstrates that LVC varies between case studies, even when attempts have been taken to close gaps (Stokenberga, 2014; Higgins & Kanaroglou, 2016). As a result, the level to which these factors contribute to variances in land and property value is unknown because those that were investigated were focused on sub-sets without a comprehensive search of literature (Zhang & Yen, 2020). Because BRT was a relatively new concept in public transportation, several quantitative studies of its impact on land and property value began in the late 2000s. However, it is the new entrants into BRT systems, such as Columbia, Bogotá, China, and Beijing that have dominated empirical evidence in the literature reviewed (Zhang & Yen, 2020).

For example, in South America studies are dominated by Transmilenio in Bogotá, Columbia, including cross-sectional studies (Perdomo, 2011; Rodríguez & Targa, 2004; Targa, 2003). On the other hand, only one longitudinal study was conducted for South America (Rodríguez & Mojica, 2008). Only five BRT studies have been conducted in North America thus far: the BX12 Bus Service in New York City, the Franklin EmX Line in Eugene, Oregon, the Silver Line in Boston, Massachusetts, the Martin Luther King Jr East Busway in Pittsburg, Pennsylvania, and the RTC Rapid in Reno, Nevada (Perk & Catala, 2009; Curley, 2012; Hodel & Ickler, 2012; Perk et al., 2013; Ulloa, 2015). In six Australian studies, the benefits of BRT on land value are not significant when compared to North America and Asia (Mulley, 2014). However,

evidence of LVC in the neighborhood of stations was shown to be 11 percent greater in longitudinal research using the DID approach compared to control areas in a longitudinal study using the DID method (Mulley & Tsai, 2016). Nonetheless, negative effects on residential buildings were identified in a Brisbane South-East bus way study utilizing HPM (Zhang & Liu, 2015). The effects of BRT were mixed in these investigations and varied substantially between cases. They differed based on parameters like geographic location, socioeconomic status, and study techniques. As a result, there was no clear picture of variance or distinct trends in the literature evaluated in these investigations (Zhang & Yen, 2020).

2.4.2. Metro Rail Systems

Metro rail systems are defined by the International Association of Public Transportation (UITP) as urban passenger transportation systems that "run on their own right of way and are separated from general vehicle and pedestrian traffic."

The words "heavy rail" and "heavy urban rail" are essentially equivalent with the term "metro" (especially in North America) (Fantechi, 2013, Yin et al., 2017).

According to (Furlan et al., 2019), high fares and the time taken during the construction phase are the challenges facing the railway system. According to (Li, 2011) suggested that productivity could be increased, cost reduced, and risks mitigated by making a metro rail system stand-alone, without obstructing other public transport systems. Owing to the increase in the working population, greater numbers of city dwellers use urban transport. The relevance of urban transport systems, such

as rail transit, depends on various types of corridors in the same cities which need different public solutions according to demand (Patel et al., 2020).

2.4.3. Tram Systems

According to the Urban Electric Mobility Initiative (UEMI) launched by UN-Habitat, a tram system is made up of cars that move on tracks on city streets. They normally share the road with other road users (private cars, bikes, and pedestrians); however, some lines may have a separate right of way. Tramcars run on electricity-powered lines or networks, which are referred to as tramways. They are designed to be unobtrusive so that pedestrians, cyclists, and automobiles may freely travel around them and on the infrastructure while the trams aren't running. A tram is a train in response to a sudden spike in demand for a tramway track on open metropolitan roads. Some incorporate portions of isolated options to proceed (Dahl & Haug, 2020). The tramlines or organisations work with cable cars in open vehicles called tramways or cable car/trolley.

2.5. Components of Public Road Transportation

2.5.1. Road Network

A good public transportation system, according to Jean-Paul (2020), must be able to accommodate a high number of individual trips. It should be planned to build direct public transportation roads that suit all transportation needs. A good public

transportation system may be built by laying out a network of roadways that allows people to make complex journeys by combining routes.

Many transportation systems around the world are made up of roads that were built in isolation rather than as part of a network. These highways are frequently unsatisfactory in serving the needs of a large number of travelers. Poor road planning leads in insufficient route coverage, the need for unnecessary road interchange, and irregular frequency (Haas, 2019, Tolley & Turton, 2014). Road networks should be built to provide easy connections between all points where transportation is required. They should be built to meet certain standards or criteria, such as a maximum number of interchanges between routes on any given journey (Vuchic, 2017).

Cities are always growing and changing; therefore the best road pattern will not evolve. Even with sophisticated planning capabilities, demand for transportation services will fluctuate. Because of the quick pace of development in emerging countries, such as Africa, transportation planning is problematic. It is necessary to carry out routine road revisions regularly in cities (Hall et al., 2019). It has been proposed that road networks be structured to function entirely on a commercial basis, with each route generating a profit. In most cities, the primary public transportation routes should radiate outwards from the city center, with roads branching off to serve places on either side. The nature of the road system, as well as policy and economic considerations, would determine the number of these branches (Cervero, 2013a).

Public transport bus roads should penetrate further into residential areas and inner suburbs. This would leave travellers with an option to walk along the roads or use the bus. The first option would result in a higher frequency of service and, as a result, shorter passenger waiting time; but, it would also mean a longer average walking distance and maybe more traffic congestion. The second option would lead to fewer visits and greater average wait times, but shorter average walking distances (Hall et al., 2019). In a city with a population of 1 million or more, the center will often encompass a considerable region, allowing travelers to travel to a variety of places (Meyer and Gomez-Ibanez, 2013, Weiss et al., 2018). It is unacceptable for all routes to converge at a single focal point when the distances between them exceed tolerable walking distances.

As a result, there may be numerous sites, each of which would be the focus of several radial routes, requiring a separate sub-network of routes to connect them (Meyer & Gomez-Ibanez 2013). Allowing roadways to continue across the core area to destinations in the inner suburbs is critical. If the majority of people travel to and from the city center and only sometimes travel between outer suburbs, the decision whether or not roadways should finish at the city center is entirely operational (Vuchic, 2017).

Congestion created by buses when waiting between journeys and when turning are two examples of road network difficulties (buses being turned around wastes time). Buses frequently occupy terminal facilities, necessitating a large amount of area. Passengers traveling between city centers will be required to change buses or walk for portions of their route. Because there is time for recovery in the city center, schedules are less likely to be delayed by traffic (Litman, 2017). If the roads share a

common terminus, one solution to these problems is to provide a convenient interchange between them. The benefits of operating along city center roadways usually exceed the drawbacks, though each case must be evaluated on its own merits.

Several bus roads may exist in a transportation network, feeding passengers into trunk bus routes. These are an alternative of running many routes along the same corridor, each branching off to serve locations not served by the main route. Operating feeder services with smaller vehicles is often more cost-effective. Also, where road conditions restrict the operation of larger vehicles on a stretch of a route, it is normally preferred to operate small vehicles on that section, feeding into a larger bus service for the main section. On major urban routes, this eliminates the need for small buses to run alongside larger buses (Venter et al., 2018).

In particularly smaller towns, a route system might be appropriate. This means all roads meet at a central focal point, and passengers can travel between any two points in the town by transferring from one route to another, where journey times are relatively short, and service frequencies are high so that transfer times are minimised (Rathore et al., 2016; & Gong et al., 2012). Although convenient interchanges are often provided, the need to change vehicles increases journey times for passengers, and the additional turn-round times reduce vehicle utilisation (World Bank Group & PPIAF, 2006).

2.5.2. Route Network

A network, according to Jean-Paul (2020), is a collection of routes. Individual paths traveled by transit vehicles are referred to as routes. Routes have a geographical component that refers to the streets and stops served along the route, as well as a temporal component that refers to the time the bus will arrive and depart from each stop or station. Grid networks are widespread in major cities. The majority of these networks are focused on the central business district, with a few lines extending considerably outside it (CBD). Grid networks make extensive use of already-existing roadways. One or more dedicated bus lanes may be required when traffic is heavy, such as in the CBD, to allow buses to move freely. Although exclusive bus lanes boost system capacity by decreasing delays caused by interfering traffic, they also diminish the capacity of roadways to handle private traffic and parking (DiMento et al., 2012). In modern cities, radial networks are also common (McLeod et al., 2017). Linear pathways from the CBD to distant areas are included in these schemes.

Commuters who reside in the suburbs and work in the central business district benefit from radial networks, but inter-suburban transportation is not efficiently provided unless direct lines connect each of the suburbs. In some circumstances, radial routes also feature dedicated bus lanes (Iravani 2019; & Kelobonye, et al., 2021). Many modern cities' transit systems use a blend of grid and radial networks. Radial routes are used to transport people to and from the suburbs, and a grid network is used to transport people within the CBD. The route structure should meet the needs of the population; as a result, each community's needs must be considered independently (Scheurer et al., 2016; & Wang et al., 2020).

2.6. Accessibility and Mobility

Users choose mobility, so it may be used to assess the effects of infrastructure investment and related transportation policy on regional growth. High levels of accessibility are provided by well-developed and efficient transportation systems, whilst lesser levels of accessibility are provided by less-developed systems (Jean-Paul, 2020). Mobility refers to the ability and ease with which products and services can be moved (Hietanen, 2014). Interstate highways with designated truck lanes, which improve the overall volume of commodities transported, and Bus Rapid Transit (BRT) systems with bus-only lanes, which increase the efficiency of moving people while avoiding autos on the roadways, are two instances of mobility. Due to a shortage of funding and the inability to develop the transit system indefinitely, Congestion Management Systems have become the trend in transportation. These methods are used to manage travel demand by coming up with new ways to boost volume and capacity (Community-Planning-Zoning, 2019). Accessibility is thus linked to a slew of economic and social prospects, with traffic acting as a hindrance to mobility. Accessibility refers to a location's ability to be accessed from, or from which to reach, other areas. As a result, the capacity and layout of transportation infrastructure are critical factors in determining accessibility (Jean-Paul, 2020).

Accessibility is the quality of travel, according to Banister (2011a), Halden (2011), and Litman & Steele (2017), and it occurs on a community and individual level using Access Management approaches to give access to varied land uses. Access Management focuses on travel time, cost, alternatives, comfort, and danger, while also meeting the requirements of everyone in the community. Transportation is considered to be relevant in terms of mobility and accessibility. The goal is to expand

the transit system's overall capacity while maintaining efficiency and accessibility (Community-Planning-Zoning 2019).

Furthermore, accessibility is defined as the ease with which one may get to desired destinations from a specific location, based on the number of options available and the problems or impediments encountered (Venter & Cross, 2014). The benefits are quantified in terms of employment openings, whereas the downsides are calculated in terms of distance or time in this scenario. According to several experts, accessibility is usually linked to principles of equity and social justice. To put it another way, a lack of accessibility can lead to social isolation and denial of basic human rights (Jaramillo et al., 2012; Martens, 2006; Venter & Cross, 2014). Land use, transportation, commuter characteristics, and the availability of opportunities or barriers all contribute to accessibility, which is linked to fairness and social justice. Although there are several perspectives on how to measure accessibility in transportation, the availability of cumulative opportunities, such as the number of destinations within a given location and the availability of travel mode options, is usually used to analyze accessibility (Handy, 2002).

Gravity-type measures and threshold-type models are two sorts of methodologies that can be used to assess accessibility. In gravity-type measures, all potential options in a given location are totaled, but each is weighed according to the travel time required to access them. To put it another way, opportunities closest to the point of origin carry more weight than those farther away (Delmelle & Casas, 2012; Hansen, 1959; Venter & Cross, 2014; Venter & Mohammed, 2013). Gravity-type metrics offer the advantage of not requiring the analyst to supply an arbitrary cut-off

distance or travel duration, but their complexity makes them more difficult to grasp and articulate (Venter & Cross, 2014). Threshold measures, on the other hand, require the specification of a cut-off value and are used to count only the opportunities that fall inside that boundary (Venter & Cross, 2014).

Accessibility in transportation can be characterized as physical access to products, administrations, and goals. It relates to the ease with which one may go to a given location, territory, or goal (TCRP, 1996). The ease with which individuals may use optimal facilities, commodities, and activities by moving from one region to another or inside a single site via transportation is referred to as accessibility (TCRP, 1996).

The quality of travel that occurs on a community and individual level as a result of Access Management practices that allow people to access a variety of land uses and services is referred to as accessibility. Access Management focuses on travel time, cost, alternatives, comfort, and danger, while also meeting the requirements of everyone in the community. The availability of diverse infrastructure and facilities to enable people to access functions or land-uses is an indicator of accessibility (Handy, 2002). It is dependent on the spatial distribution of prospective goals as opposed to an individual's origin-destination. It also depends on the transportation framework's ability to access spatially isolated locations and the individual's willingness to use the transportation framework. Accessibility is also influenced by the scope, quality, and nature of the activity. As a result, investigating accessibility in geospatial technical design, implementation, and development takes into account both geographical and financial considerations, necessitates a wide range of data, and includes route network research (Ajay, Bharti 2013; Liu & Zhu, 2016). Accessibility can be accessed from a variety of angles, such as group, mode, place,

or activity (Litman, 2020). Based on this background, accessibility was evaluated in this study according to the number of people per number of trips.

2.6.1. General Accessibility Challenges

According to Banister (2011b), Miralles-Guasch et al. (2016), Das (2019). & Ajayi et al. (2020), operator impatience/discrimination, waiting time, and lack of support were key barriers to public transportation accessibility. Furthermore, the larger city is, the more complicated its accessibility becomes, and the greater the risk of disruption a, especially if this complexity is not adequately handled. The ability of a city's transportation infrastructure to move labor, consumers, and freight between many origins and destinations is critical to its productivity. It was also noted that parking and traffic are constant roadblocks to accessibility. According to Jean-Paul (2020), traffic congestion and parking difficulties, longer commutes, inadequacy of public transportation, difficulties for non-motorized transportation, impact on land, loss of public space, environmental impacts, and energy consumption are some of the major challenges of public transportation accessibility.

2.7. Factors Influencing Sustainable Public Bus Transportation Systems

According to Iclodean et al., (2020), Koslowsky et al., (2013) & Hutton, (2013), the goal of providing or expanding public transit is to enhance access to and use of public transportation while reducing motorized-vehicle miles travelled and gridlock. Public transport can save multiple times the cash used in driving private or individual vehicles. The normal use of a private vehicle will require the expenses of

maintenance and other charges such as parking charges, outflow tickets, and speeding fines, which favours sustainable public transportation. Established transport paths can create transport rates and move multiple travellers each hour compared with normal path traffic, which favour sustainable public transportation.

2.7.1. Land-Use

The goal of evaluating land-use in transportation, according to (Ustaoglu et al., 2018, Bocarejo et al., 2013), is to examine policy consequences in terms of the implications of future growth patterns. Vehicle trips are generated as a result of land use, resulting in traffic congestion and costly road capacity expansions. The implication is that transportation and land-use policies have a major influence on the built environment, i.e. (i) how we access road hazards or accidents, (ii) whether it is easy and safe, (iii) greenhouse emissions, and (iv) it eases access to facilities such as healthcare, police stations and fire stations. In Durban, land-use planning enhances the sustainability of public transportation.

Rapid growth has occurred in many peri-urban areas around the world in the last two decades, with substantial ramifications for the urban environment. Dispersed development (urban sprawl) has been recorded in numerous cities, as opposed to the compact development seen in the 1950s. This shift has had negative consequences for air quality, increased traffic and accessibility, and incurred unwelcome social justice costs (HABITAT, 2016). As a result, sustainable urban forms and efficient transportation are increasingly required. In other words, there is a strong link between transportation efficiency and changing land-use patterns in big

cities, since the degree of compactness and density influences commute distance and time, accessibility, transportation systems, travel energy consumption, and pollution (Ustaoglu et al., 2018; Hopkins, 2007).

In most of the material studied, scenario analysis via computer modeling was utilized as a platform to inspire alternative land-use and development patterns for land use analysis in actual applications. These patterns include anything from urban sprawl to compact or transportation-oriented corridor development (Mubareka et al., 2011).

Simulations have become more sophisticated in recent years, particularly for individual component behavior, while some expressly deal with agents such as people and cars, cellular automata, land, or plots for various purposes (Breuer et al., 2018; Batty, 2007).

Many studies exist with an increasing focus on land-use modelling to assess the impact on sustainability of different forms of urban development, for example, soil degradation (Boardman & Poesen, 2007), water supply (Choi & Deal, 2008), biomass energy (Daioglou et al., 2019) and urban sprawl (Rimal et al., 2018). Other researchers have focused on analysing the changes by pattern, while integrating socio-economic policies into simulation models. Other groups have used a conceptual framework to look at the environmental implications of urban land use (Bajocco et al., 2018; Nuisl et al., 2009).

Furthermore, a great number of researchers have focused on sustainability in land-use and transportation plans, the establishment of performance indicators,

accessibility measures, or socio-economic and environmental impact assessments in the literature evaluated (Geurs & Van Wee, 2004; Geurs et al., 2010; Waddell, 2016). Nonetheless, there is a scarcity of wider consequences on sustainability that alter economic linkages in any of this research. This is especially true when it comes to incorporating land development scenarios into impact assessment frameworks (Schroeder & Lambert, 2011; Hickman et al., 2012; Vermote et al., 2014).

2.7.2. Social Inclusivity (SI)

Social inclusivity promotes unity, efficiency, and robustness by decreasing modularity in public transportation (Gunaruwan & Jayasekera, 2015). According to Miller (2020), social inclusion encourages making cities places where residents can live without differentiating social classes and promotes public transportation. According to some scholars, social inclusion is the process of changing the terms on which individuals and groups participate in society by enhancing the ability, opportunity, and dignity of those who are disadvantaged due to their identity or social standing. They suggest further that no one should be disenfranchised because of their social identity in the case of public transportation (Bamberg et al., 2007; Afacan & Afacan, 2011; Preston & Rajé, 2007). Social inclusivity is relevant to people's dignity and security, and it helps people to feel connected in the society to which they belong; in other words, giving them a sense of belonging, membership, and relevance in their community (Roffey, 2013, Dattilo, 2017). According to Ainscow (2005), people want to enjoy relationships, shared experiences, advocacy, a sense of identity, and transparency in any society in which they find themselves, which are the components of social inclusivity. This can be achieved with a good public

transport network. According to Martens (2018), inclusiveness is the ability to access any destination safely and reliably by navigating in an environment in which individual needs are considered, this is one of the main purposes of public transportation. According to Okezie et al. (2021), inclusiveness is a challenge in the public bus transportation system in Durban.

2.7.3. Accessibility

According to Mościcka et al., (2019) argued that accessibility is a factor that influences public bus transportation. According to Santos et al. (2013), public bus transit is an environmentally, economically, and socially sustainable mode of transportation that is critical in the fight against climate change. Public transportation supports habitable environments and produces a viable economy, reduces traffic, and supports the health and wellness of the communities. According to Chu et al. (2012), there are challenges to the accessibility of sustainable public transportation. Seker and Aydin (2020) proposed that the environmental impacts of public bus transportation can be improved by reducing vehicle weight, sustainable driving, reducing tyre friction, encouraging electric and hybrid vehicles, and improving the walking and cycling environment in cities as solutions to sustainable public transportation. Tong et al. (2015) define accessibility as the ability or ease of traveling to a destination from a starting point utilizing public transit. High accessibility means that locations can be reached with reasonable ease, whereas low accessibility means that a desired destination cannot be reached. According to Ferrari et al. (2014), one of the issues facing public bus transit systems is accessibility. The goal of this research was to discover solution to these challenges.

2.7.4. Route Network

According to Soares et al. (2021), route network is the process of selecting a path for public transport in a network or between multiple networks. An effective route network permits even movement of vehicles from one point to another. According to Bast et al. (2016), route network is one of the challenges facing public bus transportation systems. According to Hahn et al. (2017) and Challa & Singh (2021), route network is a factor that influences sustainable public transportation. The influence is evident in the public transportation.

2.7.5. Affordability

According to Robin et al. (2005), affordability refers to the extent to which the financial expense of travel forces an individual or household to make compromises in order to travel, as opposed to the extent to which they can afford to travel as they choose. It is one of the challenges of public bus transportation systems (Ilahi et al., 2015).

2.7.6. Vehicle Types

Weng, et al. (2018) and Tirachini et al. (2020) agreed that vehicle types are one of the factors that influences sustainable public bus transportation. Buses, mini-bus taxis, and cars are used in public transportation. The number of people that buses carry at a time will reduce personal vehicle usage and promote green energy and public bus transportation. Buses are the main interest of this study.

2.7.7. Nodal Points/Bus Stops

Nodal points such as bus stations, frequency of service, and tariffs, according to Andreev & Terentyev (2019), determine the sustainability of public bus transit.

Successful public transportation systems typically travel through densely populated areas, provide synchronized connections, and provide quick and efficient service (Olla, 2014). Designing bus stops to be level with buses and walkways is a basic characteristic that ensures that boarding is easy and quick. Bus stops improve passenger safety in the following ways: Passengers are prevented from attempting to board or alight in potentially dangerous situations such as intersections or when a bus is turning and not using the curb lane. A bus driver cannot be expected to check for intended passengers all of the time (Berg Wincent, 2021).

2.8. Method Undertaken for Measures of Sustainable Public Bus Transportation

According to Lewis & Raulerson (2020) Sustainable transportation public bus means designing public transportation services that are attractive to the passengers who use them. Finding solutions that enhance equity and sustainability of public bus transportation is the task of transportation professionals. Some methods undertaken are leverage data to understand and improve public bus transport services, promote multimodal transportation to help passengers complete their trips and understand the connection between sustainable public transportation and healthy living. The course of action is aimed at promoting the use of sustainable public bus transportation. It is possible to cut greenhouse gas emissions by moving more people with fewer

automobiles. When compared to private automobiles, public bus transportation emits much less greenhouse gas per passenger mile.

2.8.1. Route Network Analysis

Route network analysis determines the optimal path or route, from one network location to another or multiple locations (Fischer, 2006, Mandloi and Thill, 2010). The principles of graph theory, linear algebra, and one-dimensional algebraic topology are all used in network analysis mathematics (Slepian, 2012). Route network analysis is defined as the process of "breaking down a complicated project's data into its elements (activities, events, durations, etc.) and displaying them to highlight their interdependencies and interrelationships," according to Business Analyst Learnings (2017). The procedure provides the foundation for a number of specialized analytical approaches that are utilized whenever a network has to be analyzed and improved. Project management, logistics, and transportation all use these strategies. Network analysis, according to Samiithamby (2013), is a significant quantitative tool in the process of effective management decision-making. Samiithamby (2013) suggested that network analysis is a skill that managers of projects must learn to be skillful enough to manage complex and complicated projects. Furthermore, Samiithamby (2013) agreed that network analysis can predict the duration and cost of a project to be implemented. (Samiithamby, 2013, Slepian, 2012) also agreed that the application of network analysis is vast, including transportation, which is the focus of this study. Moreover, network analysis contributes to managing projects effectively and efficiently to meet deadlines. A network service area has streets that are all accessible and can be reached within a defined time. These streets fall within known restrictions which help to evaluate accessibility. With this information it is possible to

know how much land, people, and the service area are involved in a locality or neighbourhood.

2.9. Network Analysis Challenges and Solutions

2.9.1. Challenges

According to Samiithamby (2013) & Slepian, (2012) observed that government did not apply network analysis in the process of infrastructural development and did not reap the benefits of the process, which has been proven to be effective. Network analysis has been reported to have connection issues as well as other challenges, such as requiring properly defined, autonomous, and stabilized project activities, considering just the previous activities of a project network formulation, and focusing on the project's essential route (Scott et al., 2008, Blakely and Leigh, 2013).

2.9.2. Solutions

Network Analysis has been identified as offering a vast range of solutions to complex transportation problems (Samiithamby, 2013, Ajay & Bharti 2013). In addition, Network Analysis can be utilized efficiently in an organization to plan, design, implement, and complete projects in accordance with the resources available and their associated costs. It can also be used to manage the implementation of projects effectively and efficiently (Scott et al., 2008, Slepian, 2012).

2.9.3. Geographical Information System (GIS)

According to Tache & Popescu (2015) GIS can be used to model the major transport ways on water, land, and in the air. This confirmed that GIS is a methodological tool to evaluate accessibility. They used GIS to evaluate travel costs to a few established destinations by air, land and water. GIS was used as a tool to monitor the indicators, identify spatial disparity (which was a concern for this study), and provided solutions that improved territorial development. This justified the use of GIS in public transport research O'Sullivan,(2000). According to Wachter & Ding (2016), enabling access to a variety of opportunities and services should be an aim of transportation planning and legislation. Lack of accessibility may result in a number of concerns, including a decrease in rural population, social marginalization, and a stifling of regional development and economic progress in both developing and established countries. While providing a basic degree of accessibility to all socioeconomic levels is critical, transportation expenditures should be cost-effective. This necessitates a thorough grasp of accessibility as well as the intricate link between equity and efficiency.

Accessibility has been used in sectors such as urban and land-use planning, transportation management, and public facility location analysis, according to (Sun et al., 2018). They agreed that obtaining basic data necessitates some technological input, such as the use of big data capture technologies and knowledge of the real times when passengers must arrive at their bus stops. Traditional accessibility research, according to Sun et al. (2018), employed a small traffic area or fixed grid as an analytical unit, and the results were more focused on macro space and may reflect micro traffic features. However, using a GIS space analysis tool to reflect the accessibility of every site in a city as well as the spatial arrangement of public

transportation stations is recommended. According to Yannis and Antoniou (2013), governmental entities, politicians, transportation operators, researchers, and user groups have been more focused on urban mobility in recent years. It has been recognised that resolving this issue will necessitate a concerted effort and cooperative measures.

Customer happiness and satisfaction is one of the most important elements influencing client loyalty, with the assumption that a satisfied consumer will always utilize the same service provider. Passengers' overall happiness with public transportation may be influenced by factors such as frequency, timeliness, vehicle cleanliness, proximity, speed, fare, accessibility, transportation safety, and information. Some of these criteria were taken into account in the current study to assess and simulate how they affect accessibility (Pavlna, 2015). According to Cantillo & Márquez (2015) suggested that the problem of urban road accidents is remarkable and of a significant magnitude. The quantitative techniques used in the study concurred with the current study.

2.10. Methods and Models Used in Public Bus Transportation Analysis

The results of this literature analysis revealed that the methodologies utilized to evaluate public transportation systems are qualitative. Zou et al. (2014) used fuzzy mathematics methods to quantitatively represent qualitative concerns, while AHP (analytic hierarchy process) was used to quantify expert subjective judgments. According to Wang et al. (2014), Negative Binomial Regression Models (NBRM) is appropriate for use in public transportation to predict the outcomes of events.

According to Gu et al. (2020), Negative Binomial Models (NBM) have been used in empirical analysis of crashes involving buses to create a database. According to Pulugurtha & Agurla (2012), Negative Binomial Models (NBM) have been proven to be relevant in improving the accessibility of public transportation. Other types of models that can be used are discussed below.

According to Menon & Lee (2017) used the Poisson Regression Model (PRM) to predict short-term satisfaction of demand of public transportation users accurately with a homogeneous Poisson process, using a neural network as the underlying intensity. According to Liu et al. (2018), the Bayesian Network (BN) technique might be used to estimate rationally the probabilities of various revenues from various route services, with the goal of meeting passenger demand while lowering bus operation costs. Existing bus routes in the study area could be optimized to generate the highest and most likely profits.

According to Ruqin et al. (2019), the most effective approach of easing urban congestion and promoting urban sustainability is to improve public transportation accessibility (PTA). PTA is divided into three categories: access to stations, network accessibility, and activity accessibility. Ruqin et al. (2019) evaluated public transportation service access (PTSA) at stations, taking into account walking time to stations and waiting time for services at stations. Studies are currently being conducted to assess the accessibility of public transportation terminals. Ruqin et al. (2019) developed an accessibility evaluation model (AEM) to evaluate various public transportation modes as a whole. Inturri et al. (2021) used a spatial and statistical method (SSM) to uncover meaningful and easy indicators for sustainable mobility

planning by looking at the association between PT use, user satisfaction, and PT accessibility. This revealed that in this investigation, a geographical and statistical strategy may be applied. Table 2.2 summarizes the result of models and methods used in public transportation analysis.

Table 2.2 Results of analysis on methods and models used

Author	Study type	Methods	Merits / Demerits
Zou et al. (2014)	Quantitative PT	fuzzy mathematics / AHP	Yes
Wang et al. (2014),	Predict PT	NBRM	Yes
Gu et al. (2020),	Crash empirical analysis	NBM	Yes
Pulugurtha & Agurla (2012)	Accessibility of PT	NBM	Yes
Menon & Lee (2017)	Prediction PT	PRM	Yes
Liu et al. (2018)	Estimation PT	BN	Yes
Ruqin et al. (2019)	public transportation accessibility (PTA)	(AEM)	Yes
Inturri et al. (2021)	PTA	SSM	Yes

Source: Researcher's own construct.

2.11. Synthesis of Findings

2.11.1. Methods

Network analysis was not performed with primary source, which was the gap identified in the study. Most researchers did not consider network analysis in their methodology to clearly show the various scenarios of the transportation routes.

Network Analysis was relevant in this study to ensure the use of robust methods (Tache & Popescu 2015).

2.11.2. Related Literature and Model Techniques

The studies by Sun et al., (2018), Adarkwa & Attoh-Okine (2013) & Liu et al., (2018) were unique in their types as they applied Bayesian Network to model public transportation, considering attributes/parameters in the model such as different stages of travel time and transit fares. The gap identified was that network analysis was not used in the previous studies to process data. The study considers using Negative Binomial Regression Model (NBRM).

2.11.3 . Accessibility

Pablo et al. (2016), Saghapour et al. (2016) and Liu et al. (2018) focused on accessibility and various inequality challenges seen in public bus transportation. They all considered accessibility parameters that would enhance the course of public transportation. Those studies were relevant to the current study although gaps were identified where most previous studies did not use NBRM methodology to do their analysis. The previous studies reviewed helped in evaluating current trends in transport research and providing information about methodologies that might benefit the current research. The study may consider using Negative Binomial Regression Model to model Accessibility.

2.12. Knowledge Gap and Justification for this Study

2.12.1. Knowledge Gap

Public transportation has been widely researched by notable authors around the world. Accessibility challenges are experienced in most cities of the world in developed, developing or under-developed countries. In this study, public bus transportation was used to solve accessibility problems. The knowledge gaps identified in the case of methodologies is that GIS, network analysis and NBRM were deficient in the literature reviewed. The methodological approach considered for this study was derived from the gaps identified in previous literatures that were reviewed.

In related literature and model the knowledge gap identified that, most previous literature reviewed did not use NBRM in modeling public bus transportation. In previous model of Accessibility models performed, the study identified gaps in the parameters used in the model. The study may consider introducing other parameters that influence public bus transportation accessibility for instance Social Inclusivity.

2.13. Summary

A vast amount of literature in the specific field of public transportation accessibility was reviewed. In each case, research methods, data collection methods and various methods of analysis were considered to resolve on the approach to be applied in this study. It was decided to use a research method in which quantitative analysis was applied using spatial data and the Negative Binomial Regression Model which

analyses count data. The data collection approach was to use GIS-deduced spatial data, and a demographic and socio-economic dataset. Finally, Statistical and GIS network analysis was used. In Chapter Three, the study area has been defined.

Chapter Three: Study Area Profile

3.1. Introduction

According to Jones (2014) and Elmes et al. (2020), study areas are generally the geographic boundaries used to define the extent for a research analysis. The purpose is to ensure that the data and analysis are confined to a specified area. The Durban City of eThekweni Municipality in South Africa's Kwazulu-Natal Province served as the research's focus. This chapter delves into the research area profile in depth as it relates to the study, including the historical, demographic, socioeconomic, and contemporary situation of Durban's public bus system.

Figure 3.1 depicts maps of the research area, including (a) a map of South Africa with Kwazulu-Natal; (b) a map of Kwazulu-Natal with eThekweni Municipality; and (c) a map of Kwazulu-Natal with eThekweni Municipality, and (c) is the map of eThekweni Municipality showing Durban, the study area, and the third largest city in South Africa.

Durban is a city in KwaZulu-Natal, South Africa.

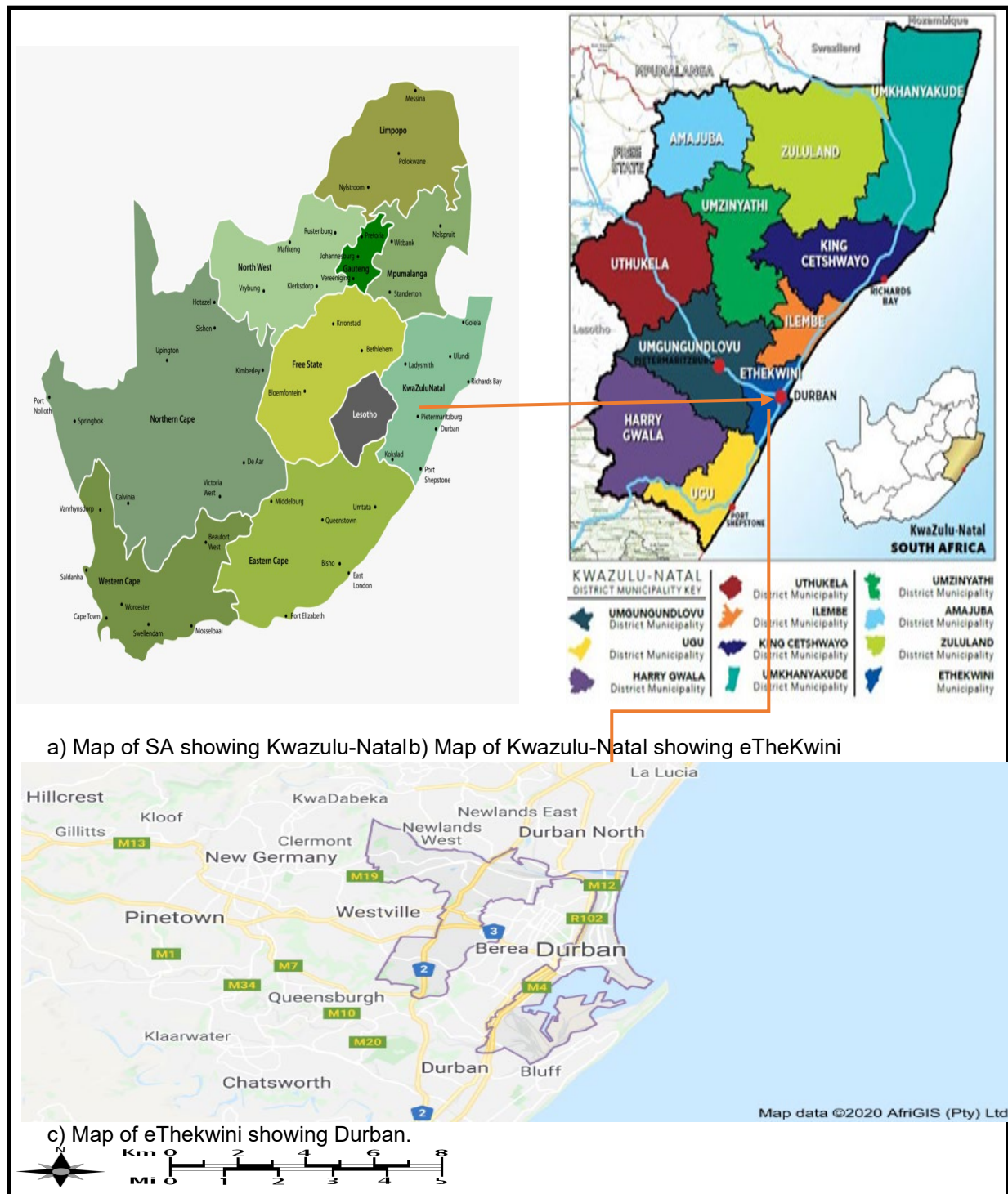
It is the province's largest and most populous city, as well as the country's third largest.

It is located on the country's eastern coast at 29°53' south latitude and 31°03' east longitude. The city is well recognized for being home to South Africa's busiest seaport.

Because of its sunny environment, gorgeous beaches, unique culture, and different attractions, it is also a major manufacturing base as well as a tourist draw.

According to Statistics SA, the city's population was little over 3,8 million in 2021.

Figure 3.1: The study area (not to scale)



Source: (<https://www.google.com/>)

Durban has a humid, sub-tropical climate, with hot, humid summers and pleasant, dry winters that are free of snow and frost.

Durban has an annual rainfall of 1,009 millimeters (39.7 in) with an average temperature of 24 degrees Celsius (75 degrees Fahrenheit) in the summer and 17 degrees Celsius (63 degrees Fahrenheit) in the winter.

3.2. Durban City Profile

Durban is regarded as an industrial centre that encompasses a wide range of socioeconomic and civic activities. Durban demography, city size and population density, total and gender population, spatial layout, and landuse were all examined in this section.

3.2.1. Durban Demographic Profile

The latest version of the UN World Urbanization Prospects (Meja-Guevara et al., 2019, Pillay & Maharaj, 2013) provided the population estimates and projections. These figures represent Durban's urban agglomeration, which comprises the city's population as well as nearby suburban districts.

According to Statistics SA (2011), the eThekweni population is projected to increase from 3 947 020 (2020) to 4 164 503 (2024). Based on gender, it is estimated that the total female population will increase from 1 983 620 (2020) to 2 086 241 (2024) and the overall male population will increase from 1 963 400 (2020) to 2 078 262 (2024).

According to Musvoto et al. (2016) and Willemse & Goble (2018), the distribution of races within the municipality is broken down per region. The central and northern regions have the highest population density. The municipality's urban core, the

central region, is home to around 1.18 million inhabitants (34.54 percent of the population). Following that is the northern area, which has a population of around 1.15 million people (33.61 percent of the population). The southern region houses roughly 758 000 people (22.03%), whereas the outer west region houses the fewest people, with a total population of approximately 338 000 (9.82%). (Census, 2011).

Table 3.1 shows the socio-economic status of the study area including details of the gender statistics, marital status, employment status, age, and income of the people of Durban, South Africa. The abbreviations used in the table are the following: M=Male, F=Female, M1= Married, LT= Living Together, NM= Never Married, W/W = Widow/Widower, S= Separated, D= Divorced, E= Employed, UE= Unemployed, LI= Lower Income, LMI= Lower-Middle Income, UMI= Upper-Middle Income and HI= High Income.

Table 3.1: Summary of socio-economic data for Durban

Gender (%)		Employment Status (%)	
M	F	E	UE
48.5	51.5	52.8	47.2
Age Span (% in Years)		Income (%)	
0- 16	19.4	LI	23.1
17- 40	49.6	LMI	22.8
41-64	24.1	UMI	39.2
65 & above	6.9	HI	14.9
Marital Status (%)			
M	31.5		
LT	6		
NM	55.8		
W/W	3.7		
S	0.8		
D	2.2		

Source: Statistics SA (2011),

3.2.2. City Size and Population Density

Section 3.1 paragraph 3 describes the overall area of Durban, which has a population density of 6,800 persons per square mile (2,600 per square kilometer).

3.2.3. Total and Gender Population

According to Statistics SA (2021), Durban's total population is growing at a 0.57 percent annual pace. Females make up 51.5 percent of the population, while males make up 48.5 percent. The city has had considerable growth over the last several decades, though it has recently slowed to little over 1%. Between 1990 and 2010, however, the city's population grew at a breakneck pace. Currently, the population density is roughly 6,800 people per square mile (2,600 per square kilometer).

Over 51% of residents are Black African, 25.1 percent are Indian or Asian, 15.3 percent are White, and 8.6 percent are Coloured, according to a racial profile of the city. Around 68 percent of the city's residents are under the age of 19, while another 68 percent are employed.

Table 3.2: The racial structure of Durban

S/No	Black	Indian/Asian	White	Coloured
1	51 %	25.1 %	15.3 %	8.6%

3.2.4. Spatial Structure

Durban's urban morphology includes beaches, a large port, botanical gardens, a complex-structured stadium, vibrant Zulu traditions, and a vibrant Indian/Asian community. As the largest city in the province of KwaZulu-Natal and the country's

economic core, it has the potential and capacity to become an African tourism destination of choice (Hoogendoorn et al., 2015, Rogerson & Rogerson, 2019).

3.2.5. Land-Use

Land-use, according to Rodrigue (2020), is primarily a socio-economic definition of space and is concerned with the economic nature of activities such as production, consumption, dwelling, and transportation. In urban areas, social, cultural, and economic activities take place at various locations, producing an activity system. Some activities, such as commuting and shopping, are considered routine because they occur frequently and are thus predictable. Durban land-use is shown in Figure 3.2. The details of the suburbs in the study area, listed in Table 3.3 below, are shown in Tables 3.4 to 3.6.

Table 3.3: Alphabetical list of Durban’s central suburbs

S/No	Suburbs	S/No	Suburbs
1	Asherville	16	Overport
2	Bellaire	17	Palmiet
3	Berea	18	Reservoir Hills
4	Bluff	19	Ridgeview
5	Cato Manor	20	Sherwood
6	Essenwood	21	South Beach
7	Glenwood	22	Stamford Hill
8	Greyville	23	Sydenham
9	Kenville	24	Umbilo
10	Mayville	25	uMkumbaan
11	Montclair	26	Wiggins
12	Morningside	27	Windermere
13	Mount Vernon	28	Woodhaven
14	Musgrave	29	Woodlands
15	North Beach	30	Yellowwood Park

Source: (Census, 2011)

Table 3.4: Alphabetical list of Durban's northern suburbs

1	Avoca	6	Mount Edgecombe
2	Broadway	7	Phoenix
3	Durban North	8	Sea Cow
4	KwaMashu	9	Lake Umgeni Park
5	La Lucia		

Source: (Census, 2011)

Table 3.5: Alphabetical list of Durban's western suburbs

1	Botha's Hills	6	New Germany
2	Cowies Hill	7	Queensburgh
3	Gillitts	8	Shallcross
4	Hillcrest	9	Westville
5	Kloof	10	Winston Park

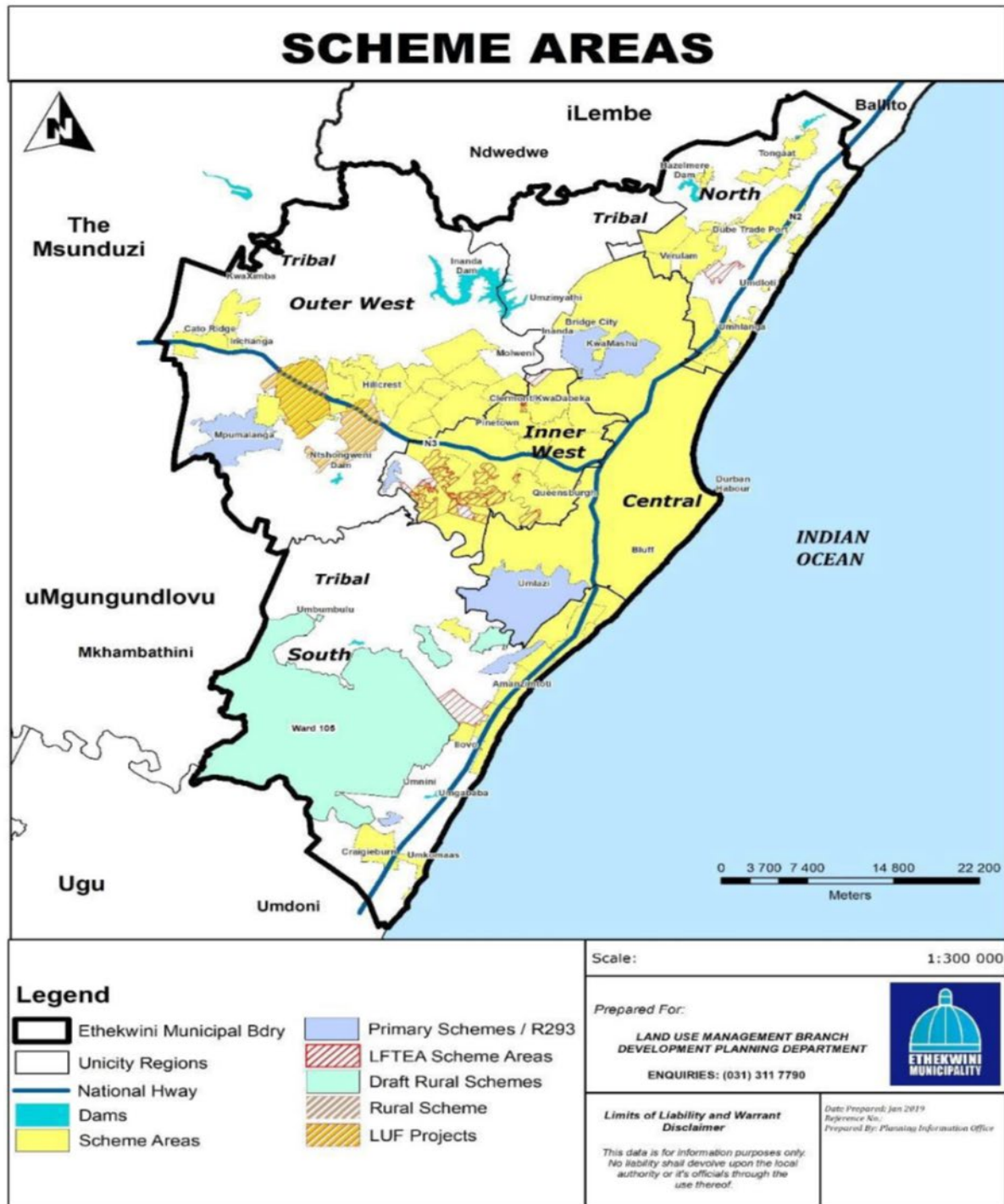
Source: (Census, 2011)

Table 3.6: Alphabetical list of Durban's southern suburbs

S/No	Suburbs
1	Amanzimtoti
2	AthlonePark
3	Isipingo
4	Lotus Park
5	Umlazi

Source: (Census, 2011)

Figure 3.2: eThekweni land-use map showing town planning scheme extension areas



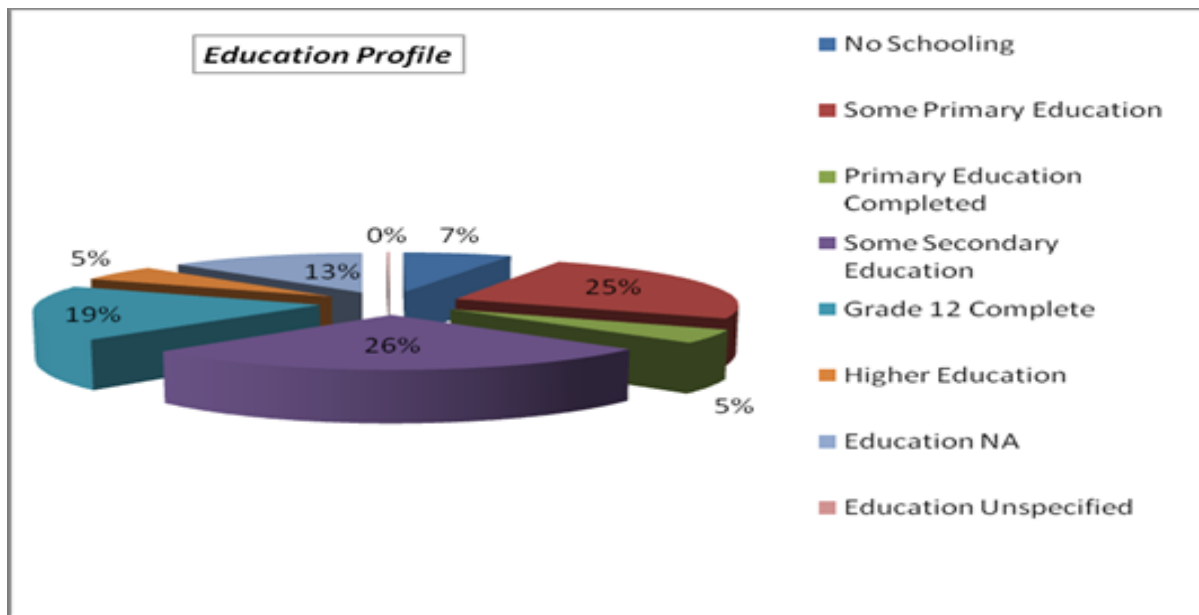
Source: www.cityofdurban.co.za

3.3. Social Profile

The social structure includes education infrastructure and education level, health infrastructure and general health of people, tourism, active and employable population, and people under social inclusivity. This is relevant because it adds to the general well-being of the people.

The education profile shows that 26% of the population in eThekweni Municipal has some secondary education, 25% has some elementary education, and 7% has no schooling; 26% of the population has secondary education (Grade 12/Standard 10) and only 5% has university education. Learners who went to school and took part in the government nutritional program made up 64% of the total, compared to a national average of 59 percent for metros. In 2016, 70% of learners aged 7 to 24 attended educational institutions in eThekweni Municipality, which was lower than the national average of 72 percent for metros. Only 7% of people between the ages of 18 and 29 were enrolled in a college or university.

Figure 3.3: Education profile of population



Source: (Stats SA, 2016)

3.3.1. Health Profile

In mid-year 2021, South Africa's population was predicted to be 60,14 million, up approximately 604281 (1.01 percent) from mid-year 2020. In Durban, there is an average spatial distribution of adequate health services. The health facilities in Durban are shown in Table 3.7 below.

Table 3.7: Health facilities and their numbers in Durban Metro

Health Facilities	Number
Hospitals	12
District Hospitals	2
Regional Hospitals	6
Tertiary Hospitals	1
Specialised Hospitals	3
Clinics	39
Community Health Centre	6
Mobile Hospitals	21

Source: www.iussonline.co.za

3.3.2. Social Grant

According to the Municipal Integrated Development Plan (IDP, 2020/21), the social grant system supports 26 percent of Durban's present population, while 36 percent of households in the municipality get some type of social grant.

3.3.3. Economic Profile

The South African economy grew by 1% in the first quarter of 2021 (January–March), resulting in an annualized growth rate of 4.6 percent. This comes after the fourth quarter of 2020 had a revised 1.4 percent increase in real gross domestic product (GDP) (annualized: 5.8 percent).

According to the Community Survey 2016, the main source of income is 70% from salaries, 10% from other sources, 10% from grants, with a further 2% from pensions, while 8% is unaccounted for. On the production side of the economy, the banking, mining, and trade industries were the key drivers of output, while household spending and inventory adjustments aided in spurring development on the expenditure side.

Despite the fact that the economy of South Africa has grown for the third quarter in a row, it is still 2.7% smaller than it was in the first quarter of 2020. Durban contributes approximately 9.6% of the total South African GDP (eThekweni Municipality, 2020a), implying a GDP per capita of approximately R8460 in 2019. Durban is home to the largest and busiest port in South Africa, with over 30,000 people dependent on its activities. Its economy comprises industry, mining, commercial activities, service activities, transportation, and tourism.

3.3.4. Tourism

International arrivals plummeted by 71 percent from a little over 15,8 million in 2019 to less than 5 million in 2020, according to Statistics South Africa's 2020 Tourism Report.

Because of the lockdown and travel restrictions imposed, the COVID-19 pandemic definitely had a significant impact on the tourism sector around the world, especially in South Africa. According to the data, the total number of travelers (arrivals and departures) decreased by 71% between 2019 and 2020. The total number of travelers fell by 50.7 percent during a 15-year period, from about 24.6 million in 2006 to 12.1 million in 2020.

3.3.5. Employment Profile

The following information regarding Durban employment at district level was obtained from Stats SA (2007) and Shisanya, (2015). According to the broad definition, Umzinyathi District Municipality had the highest unemployment rate (59.12%) followed by Zululand District Municipality (52.82%). According to the strict definition, the lowest unemployment rates were in Sisonke District Municipality (20.49%), Amajuba District Municipality had the highest unemployment rate (42.33%) followed by uThungulu District Municipality (36.06%). The employment statistics of Durban is shown in Table 3.8 below.

Table 3.8: Employment statistics

Status	Number
Employed	810761
Unemployed	612032
Not Working	771430
Unspecified	n/a

Source: (Durban metro statistics)

3.3.6. Inequality and Poverty

Male and female unemployment rates were 31.4 percent and 34.0 percent, respectively, according to Statistics SA's unemployment numbers from the QLFS Q1: 2021. Black African women were the most vulnerable, with a 38.3 percent jobless rate. Females accounted for 31.2 percent of individuals in management positions, according to gender and occupation disparities. Figure 3.4 shows a view of part of the popular Durban port, which is one the busiest ports in Africa. From a socio-economic perspective, the figure shows the beauty of Durban and its economic proficiency.

Figure 3.4: View of Durban port



Source: (<http://creativecommons.org>)

3.4. Public Road Transportation System in Durban

The IRPTN of eThekweni is linked with the Government's public transportation integration criteria, encompassing a variety of relevant public transportation modes such as Rail Rapid Transit (RRT), Bus Rapid Transit (BRT), Quality Bus and Minibus Services. The Durban eThekweni transport system is served by 337 bus routes and 203 bus stops in Durban. They are Appendix B, and are derivatives of the GIS input in transportation.

Table 5.6 lists the different types of buses, while Appendix C lists the schedule.

The public transportation system in Durban has gone through a series of phases since the apartheid era, when there was limited access from some suburbs to the city of Durban. During the post-apartheid era reasonable development has been experienced to curb the challenges for the public transportation system created during the apartheid era. The government has been committed to this project in different phases and planning to roll out Go! Durban as a solution to the challenges experienced. The goal is to implement measures that will result in a more efficient transportation network system that will reduce delays entering and leaving the city.

The government's plan for the IRPTN in all major cities was to make subsidised public transportation systems easier to use, with a focus on shorter journey times, spatial transformation, and addressing apartheid geography. This has been accomplished, and the following are examples of the IRPTN roll-out plan's successes: On the C3 Route, ten world-class stations with cutting-edge technology have been completed. These stations serve as recognizable landmarks for the city's appearance. The installation of the BRT in the Pinetown CBD will help to regenerate this highly populated area.

The BRT and precinct area's infrastructure accommodates non-motorized means of transportation, creates a safer environment, and promotes urbanity. This has resulted in a more livable, easily accessible CBD, demonstrating the BRT's capacity to alter commuters', business owners', and public life. The different economic opportunities generated by the new infrastructure's accessibility demonstrate the favorable impact on the economy. World-class design of two key bridges connecting the northern districts to the wider eThekweni Region (M25/Bhejane Underpass Bridge

and Cornubia Bridge). These bridges demonstrate the municipality's ability to overcome challenges in correcting historic spatial designs by forming creative linkages and collaborations to ensure service delivery. The municipality's internal team's participation on the Bhejane Underpass was commendable, demonstrating the municipality's commitment to technical excellence.

To ensure that a world-class system is delivered to the city, staying current with changes or improvements in technology is critical, and incorporating this into BRT implementation with the use of the latest pavement technologies, Kassel kerbs for bus docking at stations, tactile paving, universal access compliant stations, and unique bridge designs, to name a few. Partnerships between multiple levels of government, parastatal organizations, and the private sector have been critical in achieving public transportation goals. To accelerate infrastructure deployment in the city, large-scale intervention from both the public and private sectors is required.

The Bhejane Underpass and Cornubia Bridges were built in collaboration with a private developer and eThekweni Municipality, and the MR577 was built in collaboration with two realms of government, the KZN Department of Transport and eThekweni Municipality. The municipality used proactive planning, public-private partnerships, and inter-governmental partnerships to facilitate the building of inclusive, compact urban precincts, connect people to opportunities, and accelerate development in Cornubia and Pinetown to build new, mixed-use city centers. Transport demand and supply data generated from operators' internal systems, as well as broad surveys, can be used to develop public transportation profiles. Overall transportation plans and predictions, land-use plans, plans for private and public

sector initiatives, traffic demand forecasts, and economic forecasts are some of the other planning data available to transportation authorities.

3.5. Public Bus Transportation

Taxis are the most common mode of transportation in Durban, South Africa, with 51 percent of families who use public transportation (76.7%) relying on them, followed by buses (18.1%) and trains (7.6%), while 23.3 percent use a combination of walking and various modes of public transportation. In a technical analysis published by Statistics South Africa (2011), it was clear that the usual, per capita, monthly cost of family travel was greater for families in the highest pay quintile (R404) as compared to families in the lowest pay quintile (R136) values in Rand.

Furthermore, taxis were found to be the most expensive mode of transportation, with an average monthly cost of R254 per capita, followed by trains (R248) and other modes of transportation (R231). In comparison to families in the highest pay quintile, families in the lowest pay quintile spent a higher percentage of their income on open transportation. Over 66 percent of households in the lowest income quintile spent more than 20 percent of their monthly family pay per capita on public transportation (66.6 percent). Only 3% of households in the highest income quintile spent more than 20% of their monthly family pay per capita on transportation.

According to the report's findings, nearly 3.7 million students rely on public transportation as their primary mode of transportation. Taxis were the most popular mode of transportation in every geographic location. When compared to students from the lowest pay quintile (R447), students from the highest pay quintile (R447)

spent more on travel costs (R351). Trains appeared to be the most expensive mode of transportation, costing an average of R422 a month, followed by public transportation (R393) and taxis (R393) (R375) values in South African Rand.

Most students from low-income families spent more than 20% of their per capita, monthly family pay on open transportation (98.2%), followed by quintile 2 (88.7%) and quintile 3 (88.7%). (62.9 percent). Approximately four out of ten laborers used public transportation to get to work (39.1 percent). Taxis had the highest rate (26.5%), followed by other modes of transportation trains (7.6%) . Apart from public transportation, the majority of experts (30.8 percent) drove a vehicle/bakkie/truck to work, followed by those who walked to work (21 percent) and those who traveled in a vehicle/bakkie/truck (7.6 percent).

When comparing workers in the highest pay quintile to workers in the lowest pay quintile, workers in the highest pay quintile spend more on travel costs (R582 per capita) (R491). Taxis looked to be the most expensive mode of transportation, with a per capita norm of R561 per month, followed by other modes of transportation (R502) and railways (R402). The results showed that experts in the lowest pay quintile spent more than 20% of their monthly family pay per capita on open transportation (98.9 percent). Approximately 6% of workers in the top pay quintile were likely to spend more than 20% of their monthly family pay per capita on public transportation (5.6%). (SSA, 2015).

Buses, railroads, and other public transit vehicles are used to transfer large groups of people, products, and services from one location to another. Public transportation

carries more people than private cars. It makes it possible to control traffic congestion, reduce air pollution, and reduce personal driving for professional drivers which encourages a smaller number of accidents on roads.

Durban has a public transportation system that is operating but needs improvement to be effective in comparison with international standards. The system comprises mini-bus taxis, the Go! Durban Bus Rapid Transport (BRT), public buses and trains. The scope of this study was limited to discussion of public bus transportation in Durban only. Approximately 40 buses operate within the routes in Durban and serve mostly the suburbs within the city. The roads are structurally well built and serve the purpose of smooth riding, with seven-line networks connecting Cato Ridge, Durban, Kelso, kwaMashu, Pinetown, Stanger, and Umlazi (DoT., 2019).

Durban is a thriving tourist destination and is growing fast and becoming the most important gateway to Africa. There are countless business opportunities and experiences available for travellers and tourists visiting the popular sights. The most common challenges are inadequate accessibility to suburbs outside the city centre, and lack of patronage of the public bus transportation.

eThekweni Transport Authority (ETA) is making efforts to end the several challenges faced by public bus transportation in Durban. The most recent was the introduction of Go!Durban; which is a public bus transportation system that is gaining much attention. Table 3.9 shows the list of bus operators in Durban. Figures 3.5, 3.6 & 3.7 show the regions of eThekweni and the state of the public transportation network. These are map of Durban digitized and are inputs of GIS made for the purpose of

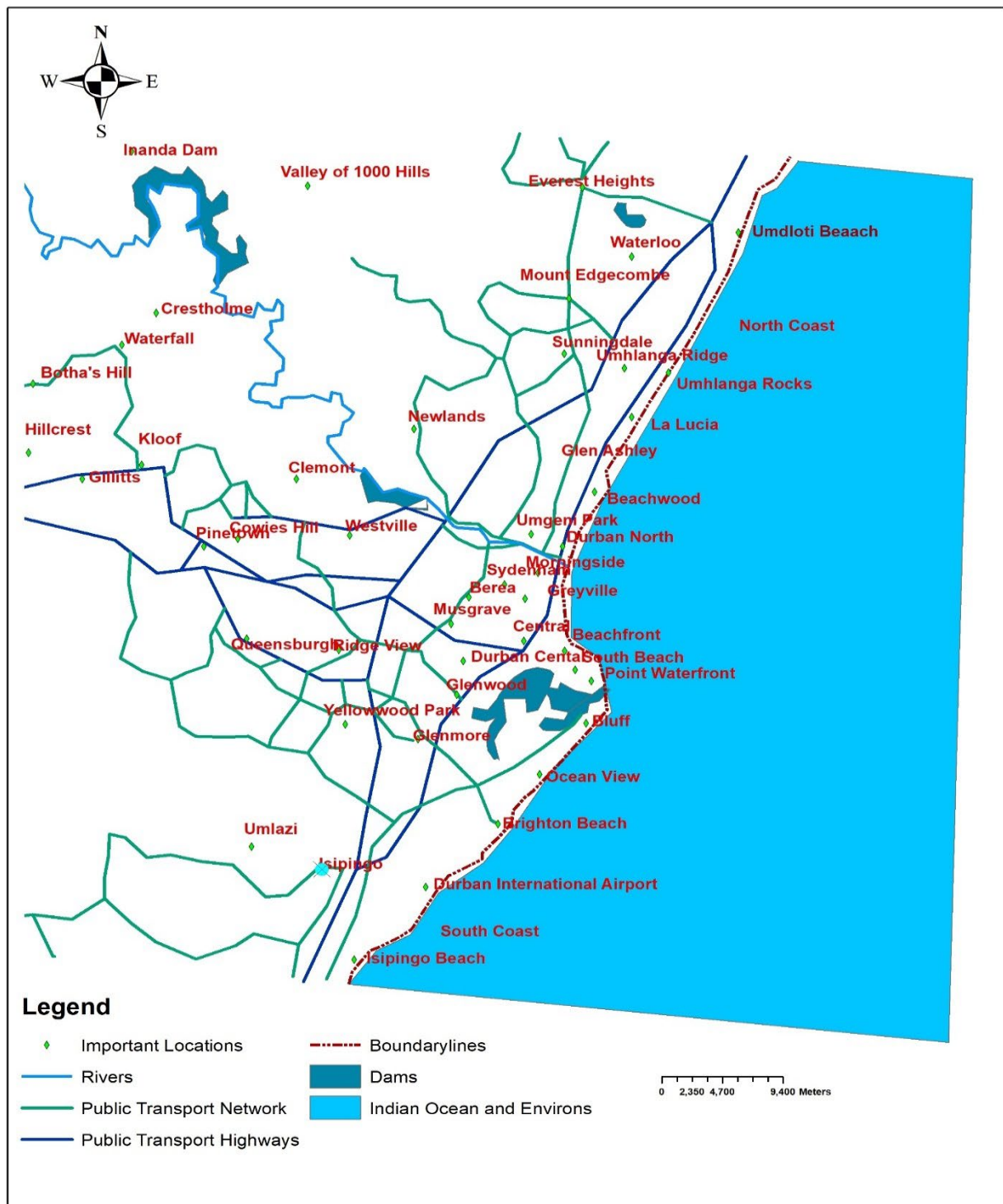
the study. The values as seen in figure 3.7 are the distances of the routes to the next bus stops in kilometers. ETA oversees the first three bus companies and subsidizes their operation. This is the gap; the other companies had to foot their entire operational cost. It gives Durban people movers, Mynah bus services and Aqualine more opportunities to patronage by the passengers.

Table 3.9: List of buses used in Durban, South Africa

S/No	Buses	S/No	Buses
1	Durban people mover	21	Lakehaven
2	Mynah bus service	22	Leesan's
3	Aqualine	23	Mac's
4	Durban Transportation	24	M.G.Hurdeen
5	City Transport	25	Megashlin's
6	Durban Ricksha Buses	26	MBT
7	AA Tours	27	N.R.Moses& Sons
8	Transnat	28	Newlands
9	AlmeerKaloo& Sons	29	Ngotshana Bus Serv.
10	Ashina's	30	Northway
11	CTS / Metro	31	Nikhiel's
12	Dehal's	32	Olyumpic Bus Lines
13	Deo's Coach Tours	33	Pra's Coaches
14	Diannes Coaches	34	Rama City Express
15	Eagle Star	35	Roselite
16	F.Saiub / Infan's	36	RSV Coaches
17	Kenfield	37	Sashvin's Tours
18	KKC	38	Springfiels Safari T.
19	KZN	39	Mariann Ridge Tr.
20	KZT	40	Metrobus

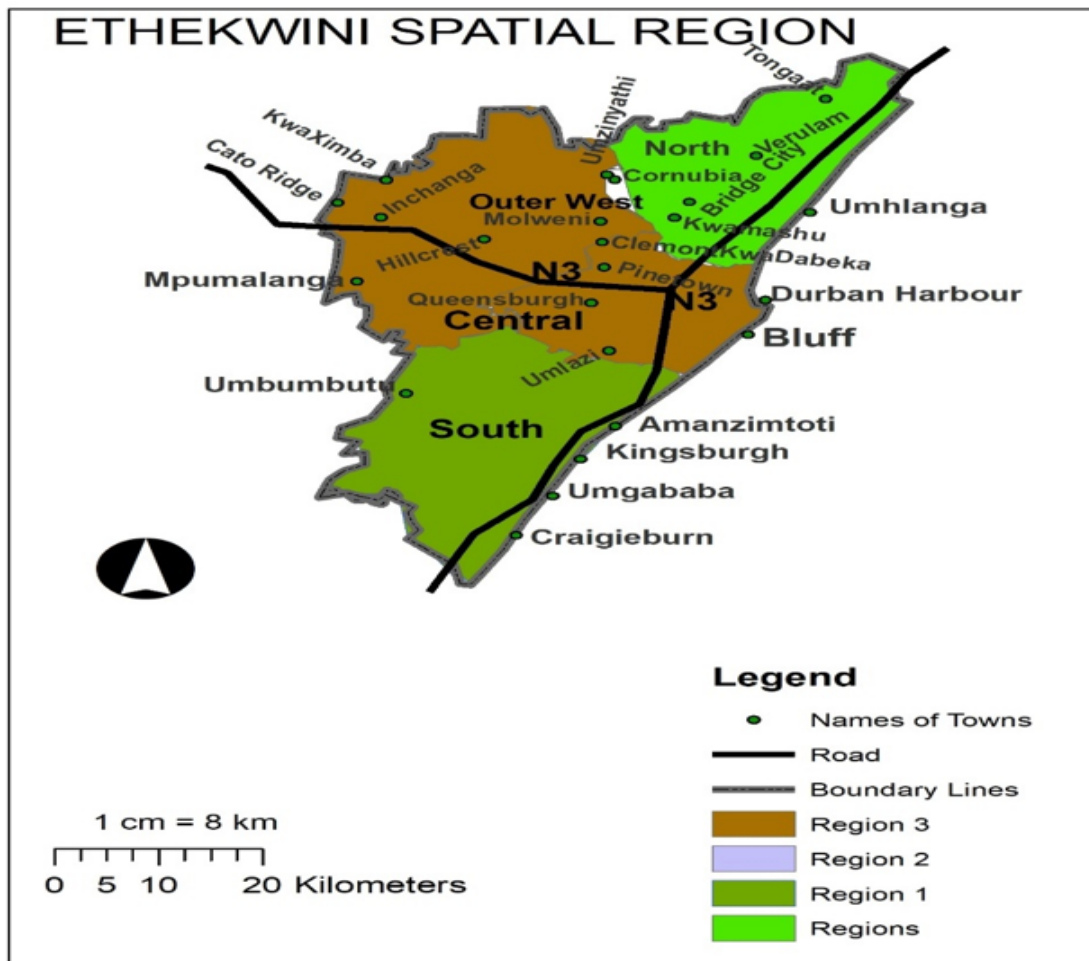
Source: (Durban metro statistics)

Figure 3.5: Map of Durban showing bus routes and locations in the study area



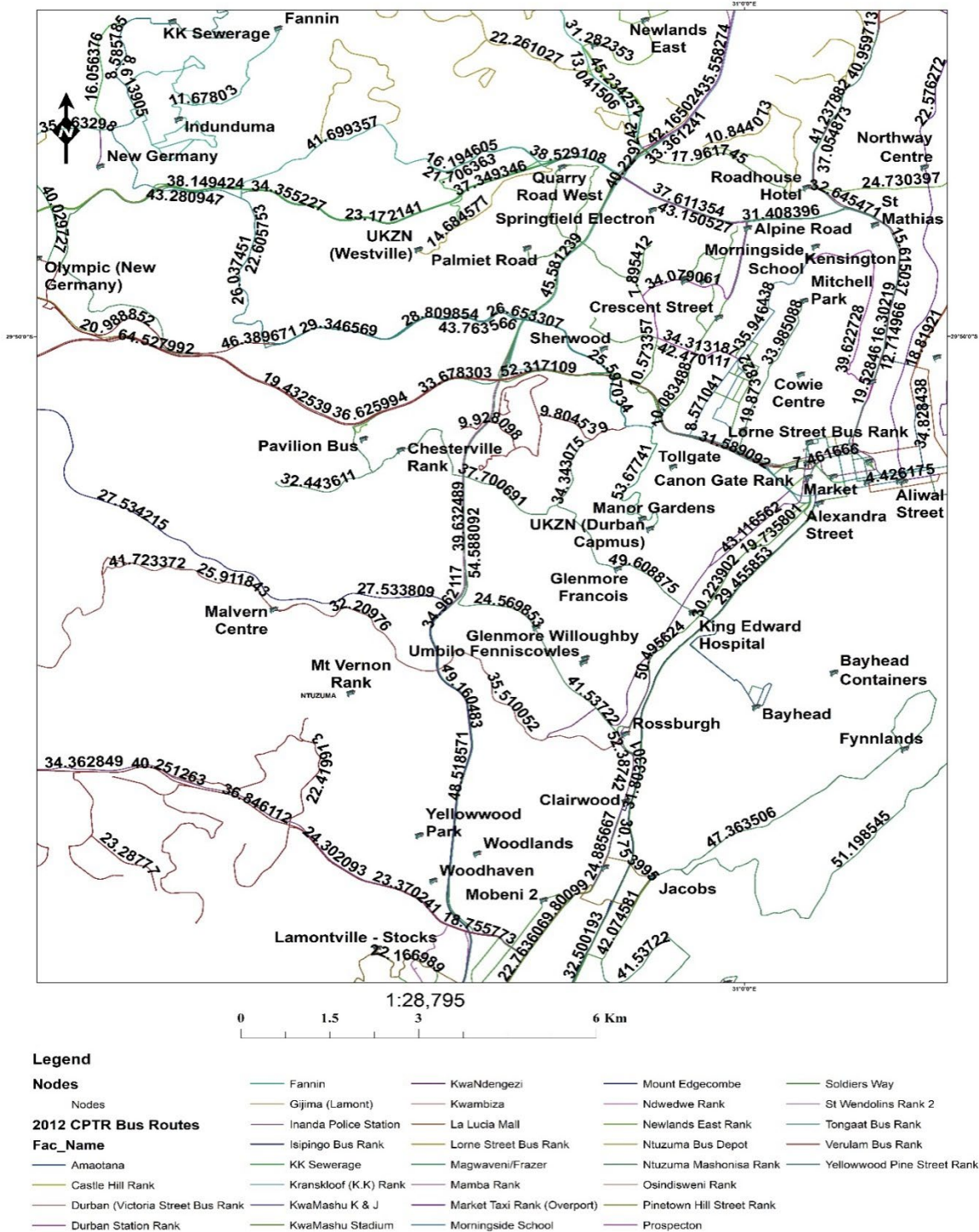
Source: Researcher's own construct

Figure 3.6: Map of eThekweni showing regions in the Durban study area



Source: Researcher's own construct

Figure 3.7: Current public transportation network of Durban



Source: Researcher's own construct

3.6. Summary

Durban, the study area, is a city with many beaches and clement weather that attracts several tourists a destination to spend vacations. This justifies the need for an effective and efficient public transportation system to enable the several tourists from different races and backgrounds to move around Durban with ease. The analysis shown in the study area indicates the current status of situation in Durban. In this chapter, several areas that concern the status of public transportation were identified, including demography, spatial distribution, socio-economic status, employment, and the general state of the study area. In Chapter Four, having reviewed the several challenges noted in Chapters one, two and three, the methodology that suited the study and would provide solutions to the challenges to improve the accessibility of public bus transportation in Durban, eThekwini, has been explained.

Chapter Four: Methodology

4.1. Introduction

The scientific justification for the procedures used in this study is presented in this chapter, which includes the philosophy, research design, data collecting, and data analysis. The reasoning includes the parameterisation and model estimation that aided in the resolution of the study's objectives. The difficulty of access to the suburbs was highlighted as one of the study's issues. This was resolved by performing Transportation Network Analysis (service area map) using spatial information in the data. This helped to understand the accessibility challenges of Durban. Social inclusivity was included in the model as the novelty of the study to resolve the second concern of affordability of public bus transportation as one of the parameters that influenced accessibility. The model was simulated to observed scenarios which could improve the current public bus transportation in the study area.

4.2. Research Philosophy Adopted

The research philosophy was centred on Epistemology (factual truth) and Positivism (factual knowledge). This determined the strategies that were used to acquire, process, analyse and present data (Scotland, 2012).

Epistemology is the theory of knowledge. It is about the mind's relation to reality. It evaluates the different psychological routes to knowledge, including different

processes of reasoning, logical and scientific introspection, perception, and intuition(Bromme et al., 2008, Sobel & Kushnir, 2013).

Count data/observations, socio-economic and GIS data can be evaluated according to Positivism, which helped in the various analyses (Hennink et al., 2020).The philosophy agrees with the empiricist view that knowledge emanates from human experience. Collins (2018), Crowther and Lancaster (2012) agreed with this assertion and, therefore, based on the literature reviewed, the approach was adopted for the study (Sandoval et al., 2016).

4.3. Research Design

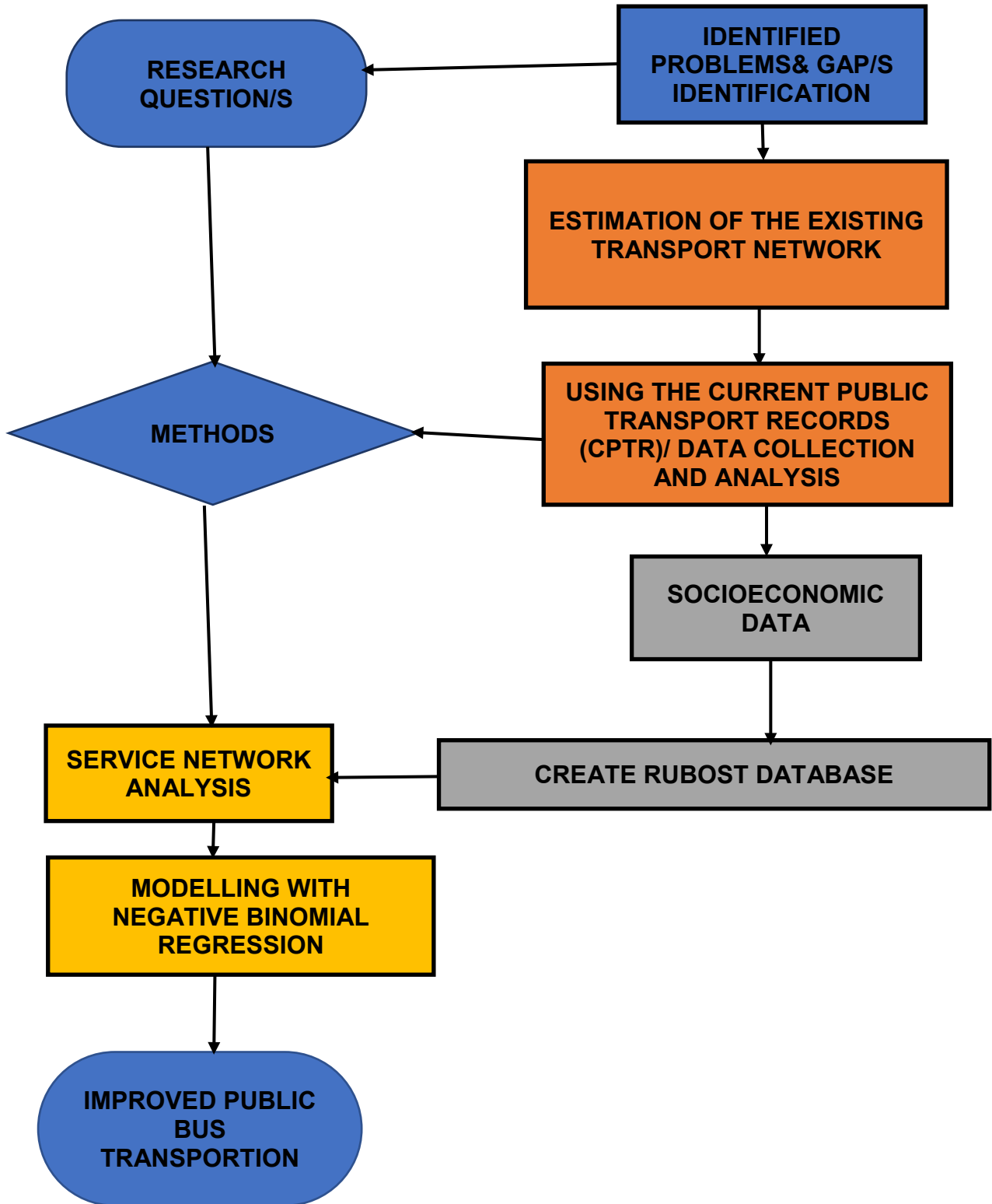
The research design represents the process that was employed to carry out the study to a conclusive end. The process started with a desire to enhance the public transportation of Durban after a difficult personal experience in reaching desired destinations. After consultation with research supervisors, the desire was transformed into research questions, defining the objectives, writing a research proposal and search for data. It followed the entire process of the research that include problem formulation, setting up research questions, ethics, data collection and analysis. The methodology required acquisition of data, processing data, analysis of the results and presentation of results (Tache & Popescu, 2015).

The gathered spatial data were utilized to conduct a Network Analysis of the study area (applying GIS), which revealed the areas with less accessibility, confirming the identified challenges of the study. With this known, further analysis was carried out to

give credibility to the study. Social inclusiveness was included as a novelty in the research and indicated that the areas with less accessibility were those where most of the disadvantaged people were living. Poisson distribution was used to perform the model analysis.

Figure 4.1 below shows the flow diagram of the research design, from research question to research objectives, from literature review to data search, and from the methodology to the various analyses performed.

Figure 4.1: Research design flowchart



Source: Researcher's own construct

4.3.1. Ethical Clearance

The research being an engineering study, all steps were taken to ensure that ethics were upheld. Care and caution were taken not to harm any living or non-living entities. The study did not involve in conducting interviews (Aguinis and Henle 2004, Wester 2011, and Hayward et al., 2021).

4.3.2. The Methodology

Figure 4.1 depicts the flow of the methodology implementation process, which included the research question, study objectives, gaps found through the literature evaluation, data collected and derived from field observations, CPTR, socioeconomic environment, and GIS. Following the consideration of the research questions, the research objectives were developed in order to determine the study's scope. Based on the reviewed literature, the research methods were derived and applied to the study. The method enhanced the quality of the analysis performed from data processing to presentation.

The intention of the study was to improve the existing transport network, which was the source of primary data. Coupled with other data sources, such as socio-economic statistics, Using CPTR and GIS data from the study area, a model was developed using the Negative Binomial Regression Model, which was then used to conduct the research. The model was created to help improve the study area's current public transportation system.

The flowchart also shows that data derived from GIS enabled the creation of a robust database on which to perform the service area network analysis of the shapefiles of the data acquired from the study area. This was the first stage of the analysis.

Several modelling methods were considered in the research, including Bayesian inference, Negative Binomial Regression, a Poisson regression model and complex theory. They were applied to the data to determine a suitable method. Negative Binomial Regression was employed to conduct the study investigation because to the type of the data, which was count data (Pei, 2011; Mehta, 2013). The conclusion was supported by several schools of thinking.

Furthermore, since one type of road was considered, the challenge of a multi-level problem with repeated measures did not exist. Therefore, on this account, instead of using the Poisson Distribution Model, the Negative Binomial Model was shown to be more appropriate. As a result, utilizing accessibility as the dependent variable and influential public bus transit characteristics as the independent variables, a Negative Binomial Regression Model was created. The study's model was created using a Geographic Information System (GIS) and web-based data. GIS techniques were used to calculate distances and road network data. Transportation analysis entails a great amount of computing and includes spatial and socioeconomic factors with precise data. The gathering, processing, and analysis of spatial and non-spatial data are all part of accessibility analysis.

This research required an understanding of the existing spatial transportation network and how to improve its functionalities with regards to areas with less access. It required some spatial data and socio-economic data to create a model. The model

was used with other factors to improve the transport network. However, the difficulties in assigning spatial features to socioeconomic data were overcome by employing the negative binomial regression model (NBRM) to source the accessibility modeling parameters (distance, time, walking time, etc.). GIS can be used to build models, analyse them, and make conclusions about a real-world situation. GIS can also be used to query the outcome of a design model in a database. That was the concept behind the Network Analysis, which assisted in identifying the known or existing problems and the gaps specified in the research, which suggested the use of spatial information to solve the problems since the approach to implementing policies had contributed positively and was not enough to solve the problems.

Tache & Popescu (2015) affirmed and concluded that GIS has the capacity to be used as a tool to measure transport accessibility. Accessibility Analysis is a GIS-based analysis tool for urban transportation planning. It has a number of benefits. Accessibility Analysis combines a number of well-known measures to determine the level of accessibility in a given area. Straight-line distances, shortest-path distances, three-part network distances, travel time, and expenses can all be measured using the Accessibility Analysis tools for quantifying trip impediment (Liu & Zhu, 2016). Ajay \$ Bharti (2013) used spatial data and socio-economic data in a study, similar to what were used in this study. Available current literature on the on-going spatial development framework (SDF) and Integrated Transportation Plan (ITP) set out by the eThekweni Municipality to promote public transportation was reviewed. Part of the literature reviewed included spatial public transportation modelling approaches around the globe. The existing transport network was the major primary dataset from

which a robust database was created on which Network Analysis was performed using ArcGIS software. A conceptual model was developed to assist in the process of modelling. The network could be improved (modelled giving easy access to areas with limited access) by considering the social inclusiveness factors. The outcome was a map showing Nodes (locations/facilities) and Links in an ArcGIS accessible format (shapefiles). ArcGIS software was used in analysing the data acquired and to perform Network Analysis, since it has been proven to be reliable in processing and analysing images. The different communities were depicted as nodes and their links/edges/lines showed proximity and efficient Transport Networks to the city. Accessibility was defined as the ease with which people can get to their selected activity sites thanks to transportation networks (Neutens, 2015). Using spatial data of the Transport Network made it possible to improve the Transport Network considering all the noted factors and scale. Part of the parameters used was the demographic statistics to design the model to target a reasonable population of the disadvantaged class. Satellite Bus Stations (facilities/small bus ranks) could be established to serve the inaccessible areas. People can decide to come to work from the rural areas if a functional public bus transportation network is available.

4.4. Data

The dataset used in this research has been presented in this section.

4.4.1. Data Collection

The primary data were acquired from observation in the field. The process involved visiting and also measuring parameters of Bus ranks, buses were followed from one destination to another to determine time, distances, frequency, and number of

passengers from the origin destination to the different nodes or stops along the route observed. The instruments used were field sheets, biro, stopwatch, and hand-held global positional system. The process followed the adopted methodology. Other relevant data are the socio-economic and demographic data for Durban, and the CPTR saved in the Hard disk from eThekwini Transport Authority were the data used in the study. The data covered the working class, social inclusivity (aged and retired, students and general disadvantaged populace), the underpaid and unemployed (people receiving social grants).

Records were kept during field observation of connecting public buses from an origin destination to the end of the route. This made it possible to acquire data such as real-time frequency, time, and distances of different routes. These data were compared with the secondary data (CPTR) acquired from ETA to reinforce the accuracy of the data. According to Morse et al. (2014) and Kaya et al. (2019), shapefiles are the data requirement for spatial transportation research. As a result, as recorded in current public transportation records, the study's shapefiles (secondary data) were collected on a hard drive from the Department of Transportation's eThekwini Transport Authority (CPTR, 2012). The spatial data helped in assessing the exact state of the public transportation network of Durban.

According to Tang and Waters (2005) it is recommended to use desktop research and GIS applications and affirmed that there was a promising future for the GIS community and researchers, suggesting that it enables users with no previous GIS software experience to visualise, share, and manage geographic data using an internet connection. Using GIS was a benefit to this study and justified its adoption.

GIS and internet research were determined to be relevant, and data acquired from websites was handled and organized to create a network dataset and execute network analyses, according to Tome et al. (2018). This also backed up the technique used in the study. Alistair et al. (2015) emphasised the use of GIS and publicly available data to address concerns in accessibility and public transportation. This affirmed further that the survey method of using GIS and internet research was relevant in public transportation. The distance-related data were deduced from the secondary data (CPTR) using GIS and serves as part of the contribution of GIS in this thesis. The hand-held GPS was used along the routes where necessary to acquire geodetic locations of public sites or landmarks. The eThekweni Transport Authority's Department of Transport (DoT) supplied data on current public transportation records (CPTR, 2012). The secondary data was used to double-check the primary data collected in the field. This increased the research's credibility in terms of the investigation's correctness. The spatial (secondary) data was collected in the form of a shapefile created from current imagery of the Durban study area, which was geo-referenced and ortho-rectified and served as a base map. The remote sensing data were processed using Google Earth Pro and ArcGIS Software to make them suitable with spatial network analysis (kml to shapefile). This produced the current public transport records (CPTR), which were obtained from the transport authority as a shapefile containing the details of the Durban Public Transport Network in softcopy, which constitute the secondary data. The data were adequately geo-referenced and processed. It was used to create a database which was used to perform the network analysis of Durban.

For data collection and analysis, this study used a systematic research strategy that included the use of GIS technology. The GIS approach was found to be appropriate due to the nature of the data and the needs for Network Analysis (O'Sullivan et al., 2000, Gigovi et al., 2017). A geographic information system (GIS) is computer software that collects, stores, manages, evaluates, and displays geographic data. Spatial position is the feature that distinguishes geographic data from all other types of data. The investigation's beginning point was spatial location because of the capacity of GIS products (maps/plans), measurements, and various types of data used together regarding a geographical area (Sara et al., 2011). The GIS step involved spanned from data acquisition to processing through presentation.

Data acquisition: GIS was applied in acquiring data for the study. The shapefile gotten from the department of transport were GIS based. The data were represented the real world in digital environment for spatial data. Data was also extracted from the CPTR for tables, and maps used in the study. Data Processing: Some of the data used in the study were processed using the GIS software e.g ArcGIS; it is another contribution of GIS in the study.

Data Presentations and maps: All the maps produced by the author are GIS based map produced via GIS software.

4.4.2. Tools and Techniques for Data Collection and Analysis

The following are the data collection tools and techniques:

- 1) A hand-held GPS;
- 2) Google Earth Pro Software;
- 3) ArcGIS 10.7.1 Software;
- 4) SPSS 26 IBM software;

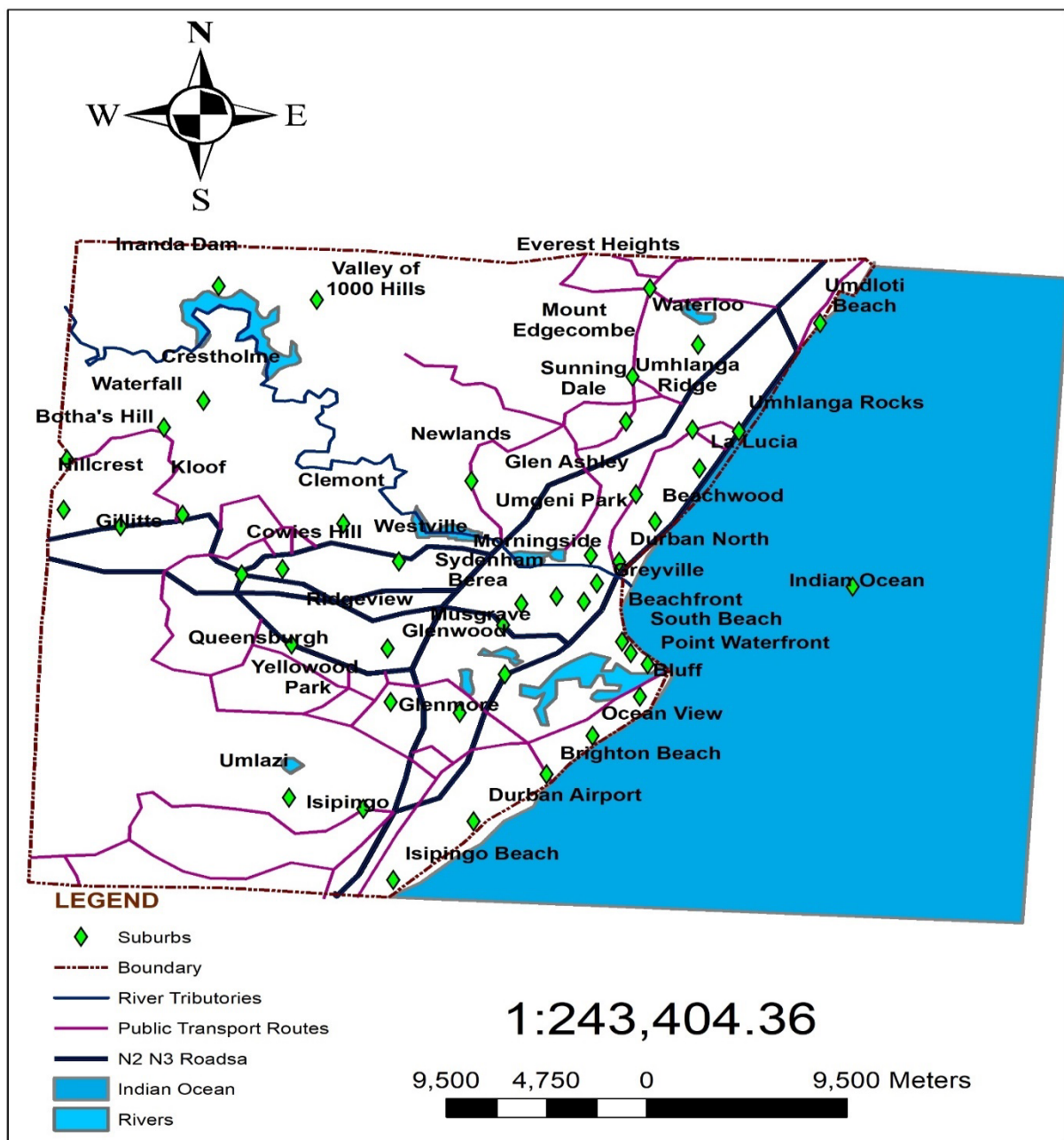
- 5) Microsoft Excel;
- 6) Global Mapper; and
- 7) El-Shayal Smart GIS.

The set of equipment and software were used to acquire the data used in the study, to process the data and to present the results. Summarily, the purpose of the tools, equipment's and software's and why they were used in the study is explained thus: The purpose of the handheld GPS was to pick coordinates of sites visited especially the landmarks. It is a tool suitable for acquisition of coordinates. It is used by putting a lithium battery in the battery compartment, by pressing the power button it can be put on. Pressing the menu button and navigating to satellite, where the device will acquire the satellites available at its position to acquire the coordinates of the current location. The google earth software is used to acquire data as imagery of any area of interest by opening the software, using the coordinates of the positions acquired with the GPS device. The satellite image acquired can be saved in the hard disk and used to digitize the features of interest. ArcGIS software is a global tool used to process and manipulate data acquired and present it in an acceptable format. It was used extensively in performing digitization exercised in the study. The IBM SPSS and Excel software are known software's used in processing and analysing data. They were used to perform analysis for the study. Global mapper and El-Shayal Smart GIS software's are tools used to acquire and process data. They were used in the study to acquire the open street maps of the suburbs in the study area.

4.4.3. Sample Selection

The sample collected included the areas of the suburbs in the Durban study area (Vandersteen, 2018). The sample comprised the city area of 225.91 km² (87,22 square miles) and Metro of 2,292 km² (885 square miles) of Durban. The geographical coordinates of the sample were 29°53' South and 31°03' East. Figure 4.2 shows the sample location of some suburbs in Durban and their transport routes.

Figure 4.2: Sample observation locations in the study area



Source: Researcher's own construct

This is relevant to the study as they represent the sample selection sites of the study (Lanza, 2008 & Mason, 2010).

4.4.4. Administration of the Survey

Zohrabi, (2013) and Vardaxis et al. (2018) did not use questionnaire surveys in their studies but, rather, field observation that was compared with the data acquired from the organisation. Therefore, this approach was applied to this study in which primary data obtained from the field were compared with secondary data obtained from DoT of ETA. Therefore, no questionnaire survey was done.

4.4.5. Secondary Data

Secondary data included a mix of GIS-derived data, socioeconomic, and demographic data from the study area that were judged to be appropriate for the research. The data was sourced from the internet and relative books. The CPTR (2012) shapefiles were obtained from the eThekweni Transport Authority's Department of Transportation.

The data was compared to data collected in the field.

4.5. Data Analyses

After entering the data into Microsoft Excel and cleaning it by deleting unnecessary spaces, duplication, and double-checking spellings and figures, it was compiled (Xu et al., 2016); data mistakes and bias returns were eliminated through cross-checking. Therefore, to ensure data accuracy it was compared with data sources from the organization (ETA), and the data accuracy improved. The consistency of the data was ascertained by using standard deviation. Outliers were removed,

variance helped to describe and represent the data. The Inferential statistics used are correlation, one sample statistics and variance inflation factors (VIF) of the data. The data passed the test for statistical significance and was found suitable for the research. To quantify the extremeness and outcome of the data, significance tests were performed (t-test for p values). The larger the absolute value of the t-value, the smaller the p-value, and the greater the evidence against the null hypothesis. The goal is backed up by (Washington et al., 2020, Grant et al., 2016). The results of all of the analyses are presented in full in Chapter 5. The estimated model of accessibility of public transportation was evaluated by considering certain influential parameters of the study. The model was analyzed and tested for goodness of fit and other analysis, it was satisfactory and presented in chapter six.

4.6. Conceptualisation Probe of the Model

To facilitate the process of analysing a problem to be solved with the model, some essentially basic questions were considered to avoid bias. The NBRM was used in the study, because it was found most suitable to the data. The relevance was to show variables and hypothesised relationships between variables. The questions raised were the following:

- 1) What is the goal of the investigation?
- 2) Is the analysis author qualified?
- 3) What is it necessary?
- 4) Which stakeholders are to make the decisions?
- 5) What is the timeframe of the decision?

- 6) Is there any omission in the model solving any of the problems?
- 7) What is the existing knowledge in the field of research, and its relationship with the solution the model is bringing?
- 8) Are the technological, economic, political, and social components of the model analysis feasible?
- 9) Does the analysis ignore any consequences of the solution that should be examined during the decision-making process?
- 10) Are the assumptions expressed clearly?
- 11) What are the preliminary criteria for weeding out poorer alternatives or outliers?
- 12) How was the final outcome presented?
- 13) Are the analyses' limitations and merits expressed clearly?
- 14) In what format was the result presented?
- 15) Are the limitations and the merits of the analysis clearly stated?
- 16) Are the factors appropriate for making a decision?
- 17) Are the conclusions intuitively satisfying?
- 18) What is the uniqueness of the deductions?
- 19) Did the model consider all the critical challenges?
- 20) What degree of uncertainties was permitted?
- 21) What are the considerations to fix uncertainties?
- 22) Are competitive or contentious replies taken into account?
- 23) Is the model sufficient, logical, systematic, and rational?
- 24) Did the study take into account a variety of modeling approaches?
- 25) Did the recommendations take into account the risks?
- 26) Did the model analysis meet the study's goals and objectives?

27) Did the model consider sensitive analysis, that will influence the recommendations?

4.7. Modelling

Models are representations of fields of study, according to (Barve et al., 2011), and should realistically mirror the purpose and function occurring in the field. In the example of Durban's public bus transit accessibility, the model depicted the current state of the bus system with the goal of improving it. The model is done to examine the influence of the parameters and simulate to improve the current challenges the accessibility of public bus transportation is experiencing. In public bus transportation, Poisson distribution model, Bayesian inference and Negative binomial regression models (NBRM) are mostly used. There are several others, but for this study NBRM was used. According to some academics, Negative Binomial Regression predicts the likelihood that an observation will fall into one of two categories of a dichotomous dependent variable based on one or more quantifiable or classifiable independent factors (Hilbe, 2011; Wang et al., 2020).

For over-dispersed count data, where the conditional variance exceeds the conditional mean, Negative Binomial Regression might be utilized.

Because it has the same mean structure as Poisson Regression and an extra parameter to describe over-dispersion, it can be regarded a generalization of Poisson Regression. The confidence intervals for the Negative Binomial Regression are likely to be shorter than those for a Poisson Regression Model if the conditional distribution of the outcome variable is over-dispersed (Chen et al., 2016, Payne et

al., 2018). Because the probabilities are successive terms in the binomial expansion of $(P+Q)^{-n}$, where $P=1/p$ and $Q=(1-p)/p$, the name "Negative Binomial" was coined (Zhou et al., 2016). The difference in the logs of expected counts of the response variable is expected to change by the relevant regression coefficient for a unit change in the predictor variable x assuming the other predictor variables in the model are held constant (Park, 2013; Cox et al., 2009). The model is similar to that of the Poisson Regression Model (Hayat & Higgins, 2014; Sáez-Castillo & Conde-Sánchez, 2013; Zamani & Ismail, 2012). The detail of the model has been discussed in Chapter Six.

4.7.1. Selection of the Model (Negative Binomial Regression Model)

Negative Binomial Regression is a refinement of Poisson Regression that relaxes the limiting requirement that variance equals mean in the Poisson Model. The classic negative binomial regression model is the NB2 (Hilbe, 2011). Poisson Regression Modeling is frequently used in count data analysis, but it has a flaw: it presupposes that the outcome variable's conditional distribution is Poisson, which necessitates that the mean and variance be identical. When the variance exceeds the mean, the data is said to be over-dispersed. For consecutive events, when the first occurrence makes a second occurrence more likely, albeit still random, over-dispersion is expected (Yang & Berdine, 2015). In Table 4.1 below the reason why NBRM was selected is explained, when the Goodness of Fit values were compared with the Poisson Distribution Model from the preliminary model analysis.

Table 4.1: Selection of model by Goodness of Fit comparison

S/No	Goodness of Fit	NBRM Value	Poisson Distribution Value
1	Akaike's Information Criterion (AIC)	852.432	5823.345
2	Finite Sample Corrected AIC (AICC)	853.682	5824.162
3	Deviance	1.069	105.636
4	Pearson Chi-Square	1.112	102.428

4.7.2. Model Assumptions

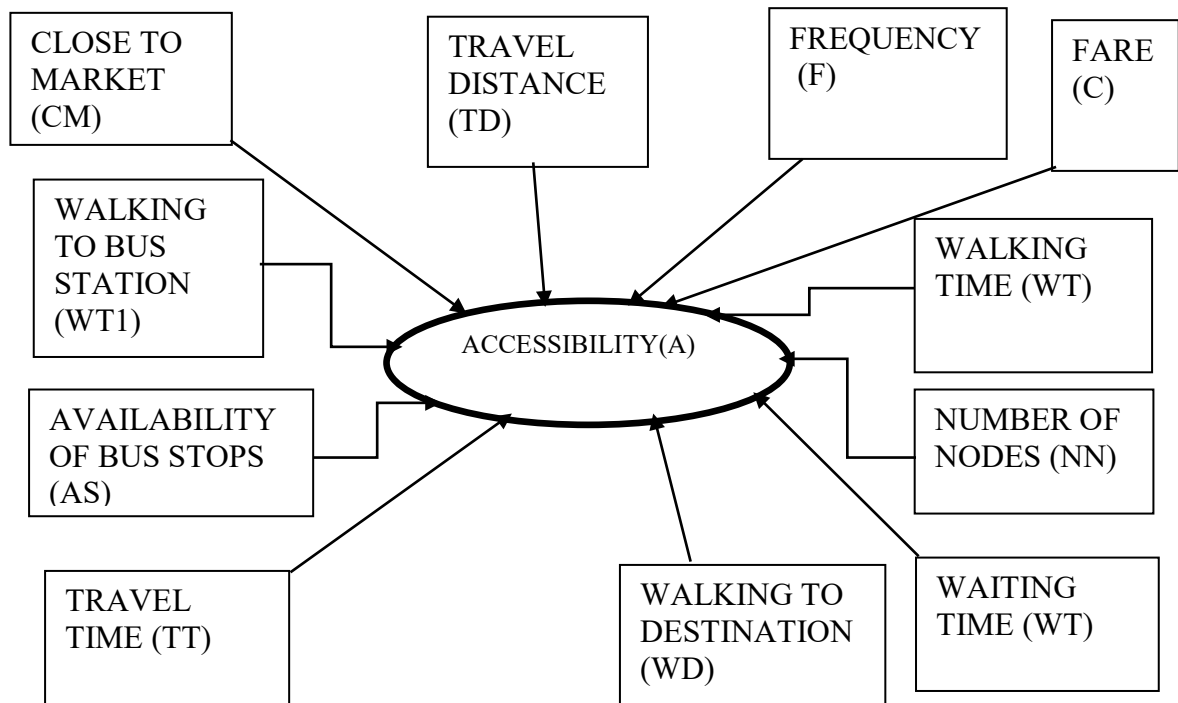
The accessibility of public bus transportation was considered in this study to be a function of frequency, fare, waiting time, bus usage and social inclusivity. This was supported by existing theories (Redman et al., 2013, Ford et al., 2015; Saif et al., 2019; Friman et al., 2020). The important model assumptions considered were that the dependent variable (accessibility) was based on count data. Further assumptions will be seen in chapter six in modeling and simulations.

4.7.2.1. Model Conceptualisation and Parameterisation

The parameters considered for the modelling of accessibility of public transportation are shown in Figure 4.3, which illustrates the conceptualisation of the Negative Binomial Regression Model, which includes the parameters considered before narrowing down to those that influenced the accessibility model. The major parameters that influenced the accessibility of public transportation were identified based on the evaluation of observations, correlation coefficients, and variance inflation tests (VIF). To establish the association between these independent variables, more significance tests were performed. After the analysis, the final result

was obtained (Soltani-Sobhet al., 2016). Thus, the model considered: waiting time, number of nodes, waiting time before the start of the trip by the bus (time between end of one trip and start of the other), bus occupancy (during the travel, getting in and getting out of the bus at different stations), cost of trips (fares), travel time, frequency, walking to destination, travel distance, availability of buses, closeness to market and offices, walking time to bus stations, and social inclusivity.

Figure 4.3: General conceptualisation of the model



Source: Researcher's own construct

In Table 4.2, the conceptualisation of the model is explained further.

Table 4.2: List of variables in the accessibility of PBTN

S/N	Important Variables of APBTN	Abbreviations
1	A	Accessibility (Dependent Variable)
2	F	Frequency (IV)
3	C	Fare (Independent Variable (IV))
4	WT	Waiting Time (IV)
5	WT1	Walking time to Bus Station (IV)
6	WD1	Walking to Destination (IV)
7	WD	Walking Distance (IV)
8	AS	Average Speed (IV)
9	CM	Close to Markets (IV)
10	NN	Number of Nodes (IV)
11	TD	Travel Distance (IV)
12	TT	Travelling Time (IV)

Source: Researcher's own construct

4.7.2.2. Conceptualisation of models

The accessibility model was conceptualised based on the outcome of the correlation coefficient, variance inflation factors and significance test. From Table 4.2 above, there were eleven parameters observed for the accessibility of public bus transportation.

4.7.2.3 Conceptual model for each Bus Usage (U)

Bus usage, "U", was a factor that influenced social inclusivity. Therefore, it is a regression model and a function of frequency divided by the reciprocal of cost (Avenali et al., 2020). Its equation can be seen in section 4.7.4.

4.7.2.4. Conceptual model for each Social Inclusivity

Social Inclusivity, “S”, was a factor which influenced accessibility of public transportation. Therefore, it was required to improve accessibility of public bus transportation in Durban. It is a function of population of the weaker section, distance travelled by the weaker section and the bus usage of the weaker section (Andreasen and Møller-Jensen, 2017). Its equation can be seen in section 4.7.4.

4.7.2.5 Conceptual model for each Accessibility

Conceptualisation of the accessibility model parameters are discussed below with respect to their influence on the model. Its equation can be seen in section 4.7.4.

4.7.3. Model Estimation of Negative Binomial Regression Model

Model estimate is commonly done when a dependent variable is stated as a function of independent variables, according to Honaker (2010). The model might then estimate missing values of the dependent variable under certain assumptions. The dependent variable, accessibility, was represented as a function of the independent variables of frequency, fare, social inclusivity, and walking time to estimate the accessibility of Durban's public bus transit. The model was estimated and justified using the data collected for several key parameters. To design and understand the effectiveness of public bus transportation, a Negative Binomial Regression Model (NBRM) was used. All of the variables that potentially affect public transportation accessibility were evaluated and quantitatively analyzed before the model was estimated utilizing those that were statistically significant. The model was developed

using just the most important and influential parameters. Accessibility was employed as the dependent variable, and the most influential, statistically significant factors were used as the independent variables while estimating the model. The Negative Binomial Model was used to assess the predictive ability of 11 independent factors on the dependent variable Y. (accessibility of number of people daily).The model assumptions were scrutinized for any flaws.

The variables were log-transformed, and the regressions were redone to account for the normality violations. The modifications were examined to see if they altered the model's interpretation or significance. Because log transformations make it more difficult to evaluate the coefficients (without adding value), the remaining regressions were performed without them. Although the NBR Model was used to design and conceptualize the model, the connections between the variables were linear. The following modelling parameters for the city of Durban were considered in the research in a bid to improve the existing transport scenario (Wang et al., 2011).

4.7.4. Model Development and Presentation

The Negative Binomial Regression Model (NBRM) was developed and presented, which made it possible to write logic that is completely independent of the perspectives used in creating the model. Before the model was built, correlation and significance tests (t-values and p-values) among the independent variables were used to examine co-linearity and the relationship between the independent components and the dependent variable. In addition, extreme outliers were removed from the models throughout development to improve their resilience and accuracy.

The Goodness of Fit (value/df near to 1.0), Omnibus test (p-values 0,05), and Chi-square test (p-values 0,05) were used to assess the models' validity. Based on the study, the model developed of accessibility of public bus transportation was the Negative Binomial Regression Model presented as follows:

$$\text{Log}(Y) = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \dots + \beta_nX_n \quad (1)$$

Where:

Y=Dependent Variable,

β_0 = Predicted number of events,

$\beta_1, \beta_2, \beta_3, \dots, \beta_n$ = Regression coefficients

$X_1, X_2, X_3, \dots, X_n$ = Independent parameter or predictor variables.

Model development for bus use (U):

Bus use (U)= (1/ α) Fare (Public bus use is inversely proportional to Fare (cost) and directly proportional to Frequency). U is required to complete the model for SI.

It is developed using regression modelling with the principle of solver.

$$U \propto 1/C \quad (2)$$

$$U \propto f \quad (3)$$

Which gives:

$$U = kf/C \quad (4)$$

Where U is public bus use

K is constant

F is Frequency and

C is Fare.

Model development for Social Inclusivity using regression modelling:

Social Inclusivity is a function of P_e , D_p and U .

Inputting the value of U , we now have:

$$S = aP_e + bD_p + mu + \mu \quad (5)$$

Where:

a , b & m are regression coefficients.

P_e is Population of people that are economically disadvantaged.

D_p is Distance travelled by people that are economically disadvantaged.

U is public bus use.

μ is intercept.

Model development for Accessibility of Public Bus Transportation without SI by using

NBRM:

Accessibility is defined as = Bus occupancy per day x no of trips per user.

$$\ln(A) = \alpha f + \beta C + \delta wt + \mu \quad (6)$$

Where the coefficients of

A = Accessibility of the public transportation without Social Inclusivity,

F =Frequency, C = Cost, WT =Walking Time and μ = intercept (model without Social

Inclusivity).

A = Current (Not adequate)

S = Current(Not Adequate)

$A(t)$ = Improve (Future)

$S(t)$ = Improve (Future)

$A(t)$ = Improve if $S(f)$ improves

$A = f$ [Frequency (f), Fare (C), walking time (wt)]

Model development for Accessibility of public bus transportation with SI by using NBRM:

Therefore, inputting the S in Equation (6) we have Equation (7)

$$\ln A = \alpha_1 f + \beta_1 C + \delta_1 wt + \gamma_s + \mu_1 \quad (7)$$

(Model in future with social inclusivity)

A= Accessibility of the public transportation with Social Inclusivity,

F=Frequency, C= Fare, WT = Walking Time, S is Social Inclusivity and

μ = intercept

Where: α , β , δ & γ are regression coefficients.

4.7.5. Validation of Model

Testing the Negative Binomial Model on public bus transit in Durban provided an indicator of its accuracy and trustworthiness for future improvement. The re-substituting approach was used. Re-substitution involves estimates that are derived by applying a model to the data from which it was learned (Webb, 2010). The validation was achieved for each of the model and is shown in Chapter six.

Table 4.3 Model validation parameters

S/No	Model validation parameters	Validation Value
1	Akaike's Information Criterion (AIC)	852.432
2	Finite Sample Corrected AIC (AICC)	853.682
3	Deviance	1.069
4	Pearson Chi-Square	1.112
5	Omnibus test p-value	0.000

Source: Researcher's own construct.

4.8. Summary

The Public Bus Transportation Network of Durban was obtained by applying the methodology from the research viewpoint of positivism/epistemology that is entrenched. Statistical analyses were done before modelling. The public bus transportation network was quantitatively analyzed, and its operation was better understood thanks to the technique used in this chapter, which focused on improving Durban's public bus transit. The next chapter contains a presentation and discussion of the data collected for this study, and an analysis of the processed data. Modelling will be discussed in detail in Chapter Six.

Chapter Five: Analyses and Results

5.1. Introduction

The study investigation is carried out in this chapter, and the results are provided.

GIS analysis is carried out, which entails examining the various suburbs in the study region, as well as network analysis and statistical analysis of the data. The findings of all analyses are presented in light of the study's aims. Data were collected from the field by observation and compared with the data obtained from DoT of eThekweni Transport Authority (ETA). Further data were sourced from GIS, and socio-economic data relevant for the study were obtained from desktop research. Therefore, there was no need for ethical clearance (Ozoekwe, 2015; Ahmed, et al., 2011).

The data were statistically analysed to derive the parameters that influenced the accessibility of public transportation in Durban. The relevant data for the study were verified for accuracy and consistency. The 2019 ortho-rectified photograph of the study area was acquired to serve as a base map and to verify data obtained to determine the extent of its consistency with existing landmark features. The unaligned features were verified during observation, using a hand-held GPS device during ground truthing (visiting landmarks and acquiring their coordinates with the GPS device). The verified and accurate data were transferred to an excel sheet for other statistical analyses to be performed. It is shown in Appendix G.

5.2. Socio-Economic Scenario of the Study Area

The entire socio-economic data were required to plan and improve the public transportation system in Durban. The parameters investigated are discussed under the following subheadings: population and population density, age-gender structure, occupation, income, number of people using public transportation, families depending on pay, financial and demographic status of the study area, and education. The findings are given under the examined subheadings, and their relevance is to improve public bus transportation in the study area.

5.2.1. Population and Population Density

The demographic characteristics of a city are an essential indicator of the development of a city. They provide an indication of the population profile of the city. Understanding a city's public transportation needs requires an understanding of its demographic characteristics. Table 5.1 shows the total population and population density of Durban City during the previous five decades (1971-2021). The table below illustrates Durban's gender statistics. The male population was estimated to be 1,93 million (48.8%), while the female population was estimated to be 2,02 million (51,2 percent). It's important to know how many people are expected in Durban.

Table 5.1: Percentage gender statistics of Durban population

S/No.	Male	Female
1	48.80 %	51.20 %

Source: (Stats SA, 2011)

Durban eThekweni is always the same size (2,291 km² or 885 square miles). The population density per square kilometer is 1723 persons .According to the IDP review 2020/21, the population is growing at a pace of 1.13 percent each year. Furthermore, a high population density (>1500 people/km²) has been found, which is steadily increasing. This suggests that public transit in Durban may be in increased demand, according to eTheKwini. Table 5.2 According to the IDP review 2020/21, the total population of Durban in 2020 is shown in the table.

Table 5.2: Total estimated population of Durban, eThekweni during 1971-2021 (5 decades)

Year	Population Estimated	Male 48,8%	Female 51,2%	Difference	Area	Population density in Sq. Km
1971	886,006	432,371	453,635	21,264	2,291	387
1981	1,257,352	613,588	643,764	30,176	2,291	549
1991	1,789,917	873,479	916,438	42,959	2,291	781
2001	2,730,483	1,332,476	1,398,007	65,531	2,291	1192
2011	2,971,536	1,450,110	1,521,426	71,316	2,291	1297
2021	3,176,254	1,550,012	1,626,242	76,230	2,291	1386

Source: (<https://worldpopulationreview.com/world-cities/durban-population>)

The total population and distribution of male and female population during the years 2020-2024 is shown in Table 5.2. It was found that the female population increased by 111 352 over the period and has increased on average compare with the male population. The population of the Durban, eThekweni study area was estimated at 3 947020 according to the (IDP review 2020/21. The entire population was targeted to patronise and bring improvement to the challenges of public bus transportation.

Table 5.3: Gender population distribution of Durban

Year	Male	Female	Difference	Total
2020	1,926,146	2,020,874	94,728	3,947,020
2021	1,954,245	2,050,357	96,112	4,004,603
2022	1,981,143	2,078,576	97,433	4,059,719
2023	2,006,958	2,105,690	98,732	4,112,675
2024	2,032,277	2,132,226	99,949	4,164,503

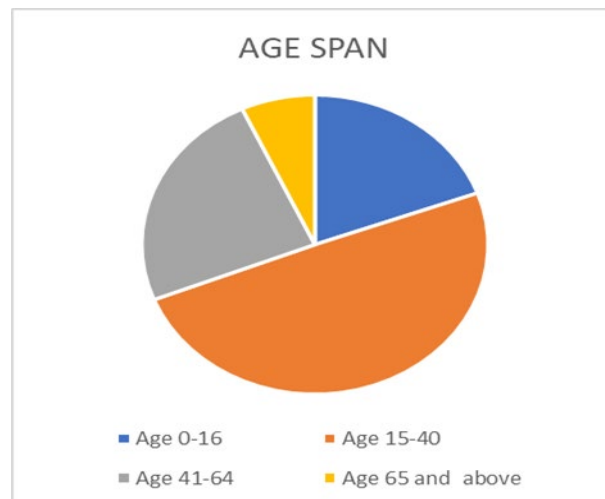
Source: (<https://worldpopulationreview.com/world-cities/durban-population>)

5.2.2. Age-Gender Structure

Figures 5.1 and 5.2 show the total population of South Africa by age and gender from 2009 to 2020. In 2019, the female population of Durban, South Africa was estimated to be 29,7 million, while the male population was estimated to be 28,86 million.

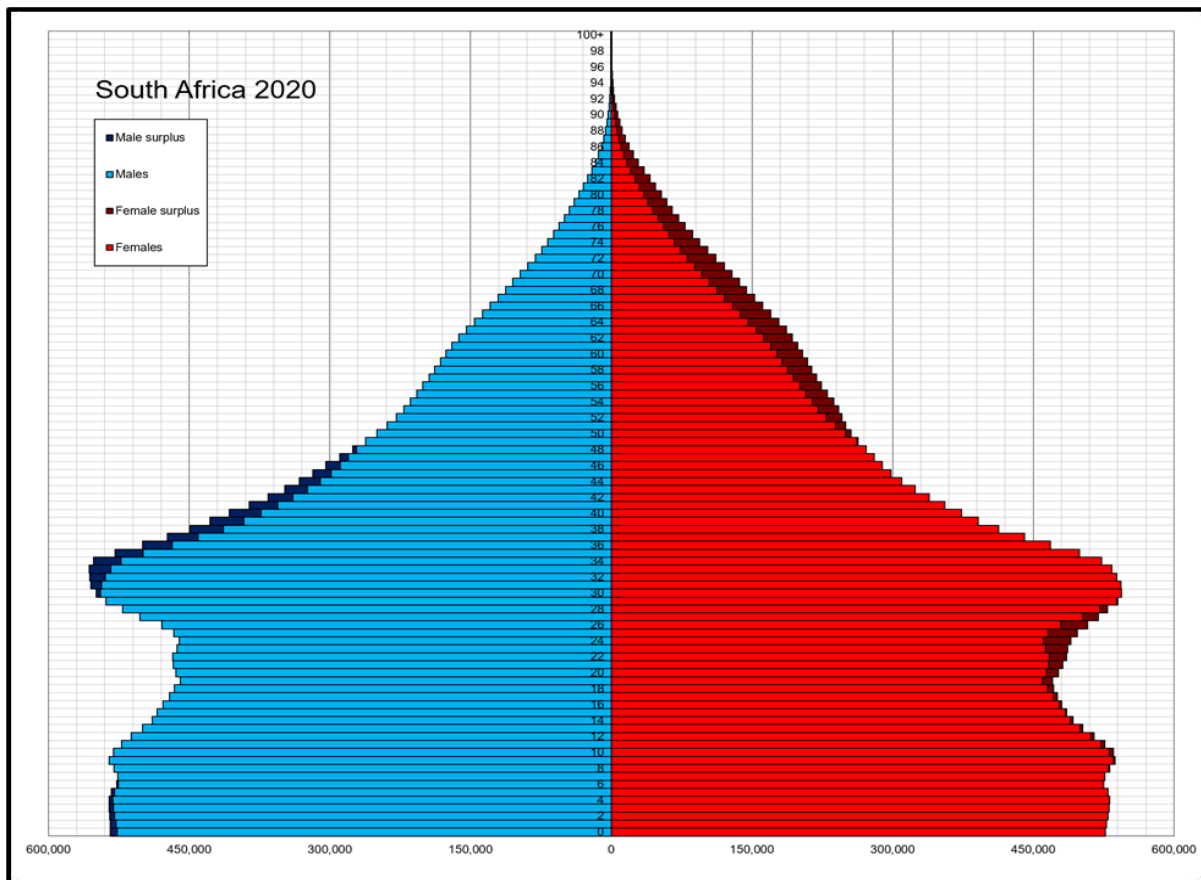
This indicates that there are more female South Africans in Durban than males.

Figure 5.1: Chart of age span socio-economic factor of the study area



Source: Researcher's own construct

Figure 5.2: Age-gender showing variance between male and female



Source: (Stats SA, 2020)

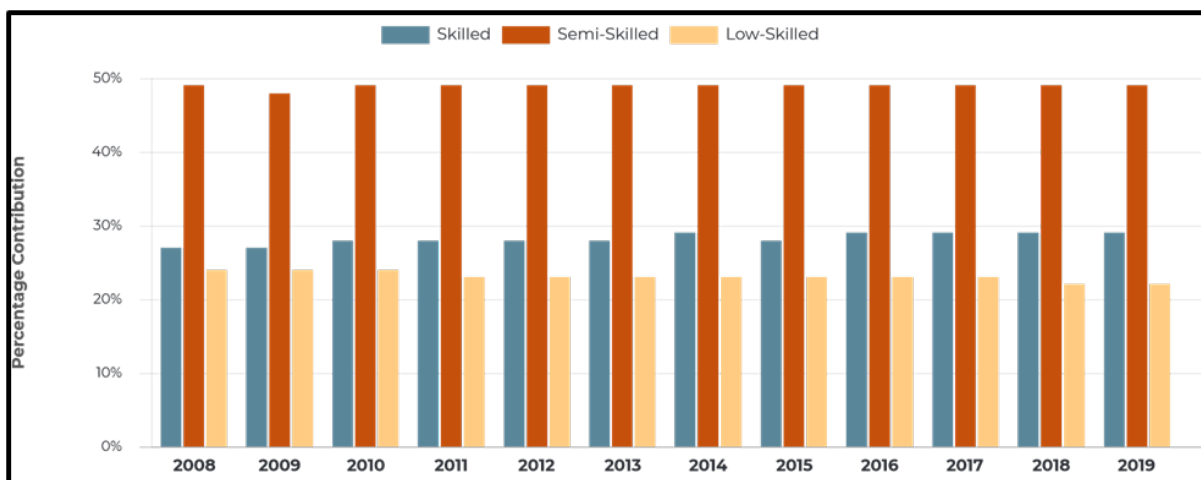
5.2.3. Occupation

The graph in Figure 5.3 below is a representation of the occupation profile of racial groups in Durban. Considering this kind of data provides a sense of racial transformation in the city's workforce. According to the average of all QLFS surveys conducted by Stats SA in 2020, low-skilled jobs are still occupied almost completely by Blacks, while there appears to be more racial diversity amongst top decision-makers such as legislators, senior officials and managers. While this increased racial diversity amongst high-skilled jobs indicates progress, it is still not representative of

the demographic breakdown of the labour force in the city, which was 76% Black in 2020.

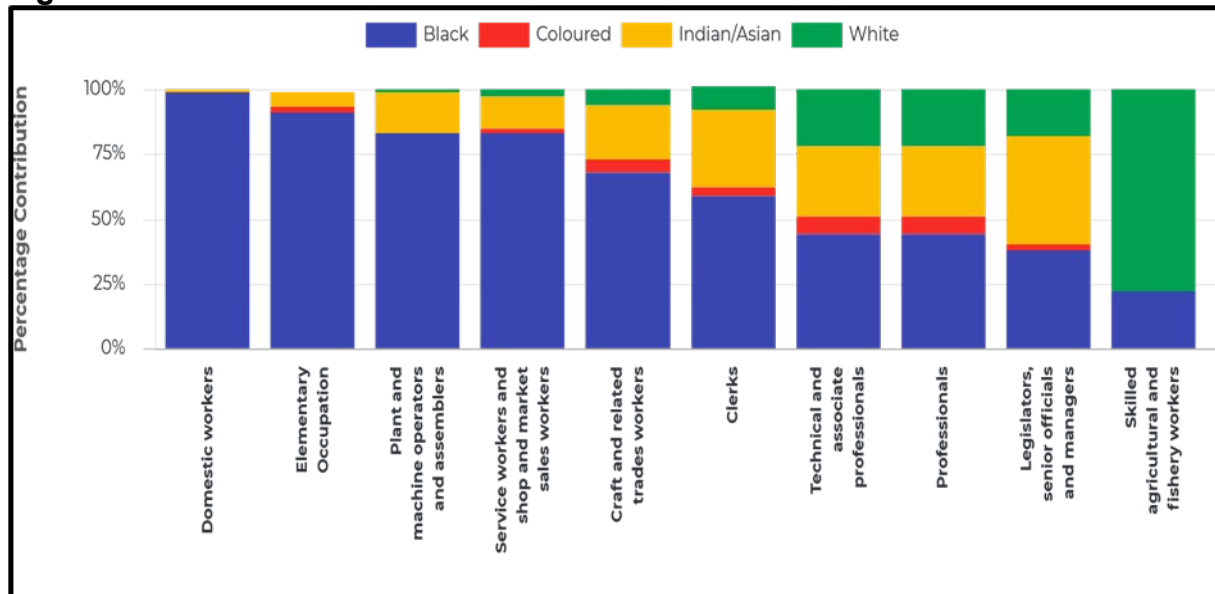
Of all domestic workers, 91% are Black; of all plant elementary occupations, 91% are Black; of all machine operators and assemblers, 83% are Black; 83% of all service workers, shop and market salespeople are Black and 68% of all craft and related trade workers are Black. Other racial groups are more significantly represented in several professional/skilled occupation categories (legislators, senior officials and managers, clerks, professional, technical, and associated professionals) that require tertiary education and offer better remuneration. This racial breakdown is representative of the samples surveyed throughout 2020. This transformation dashboard is updated annually and can be found on the source portal. It helps to identify the stakeholders in the public transport sector. Figures 5.3 and 5.4 shows evidence of findings related to occupation and skills of races in Durban, South Africa.

Figure 5.3: Skills levels in South Africa



Source: <https://repository.uneca.org/>

Figure 5.4: Racial status

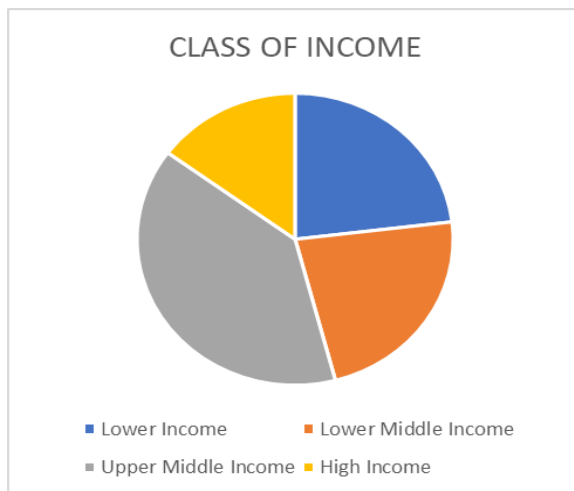


Source: <https://repository.uneca.org/>

5.2.4. Income

The average annual wage in Durban is R207,000. Wage trends fell by -100.0 percent in the first quarter of 2021. Durban has a cost of living that is 100% greater than the national average. Office Administrator, Operations Manager, and Registered Nurse (RN) are the most common jobs in Durban, with annual salaries ranging from R61k to R554k. Mr. Price Group, eThekweni Municipality, and Derivco (Pty) Ltd are the most popular employers in Durban. It is necessary to plan for people of different economic status in Durban to improve public bus transportation. Figures: 5.5 to 5.9 shows the findings and graphs of parameters related to socioeconomic income of Durban. The income is relevant in the analysis because it shows the economic opportunities if the passengers have reasonable income, it will improve the public bus usage. The different results show the economic status of the study area.

Figure 5.5: Chart of class of income socio-economic factor of the study area



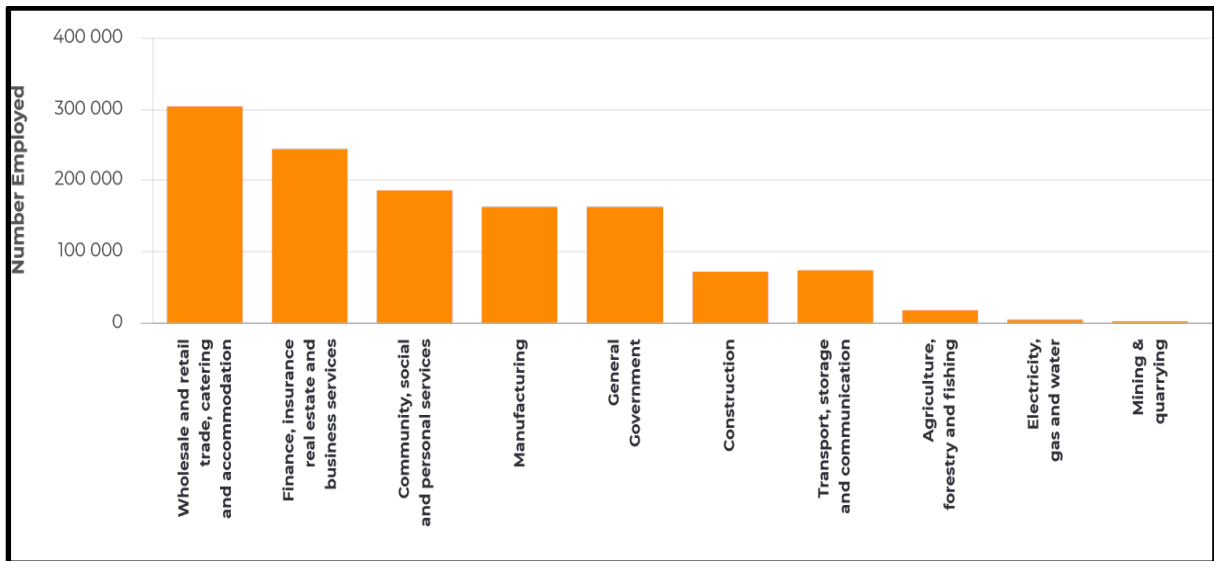
Source: Researcher's own construct

Figure 5.6: Chart of employment status socio-economic factor in the study area



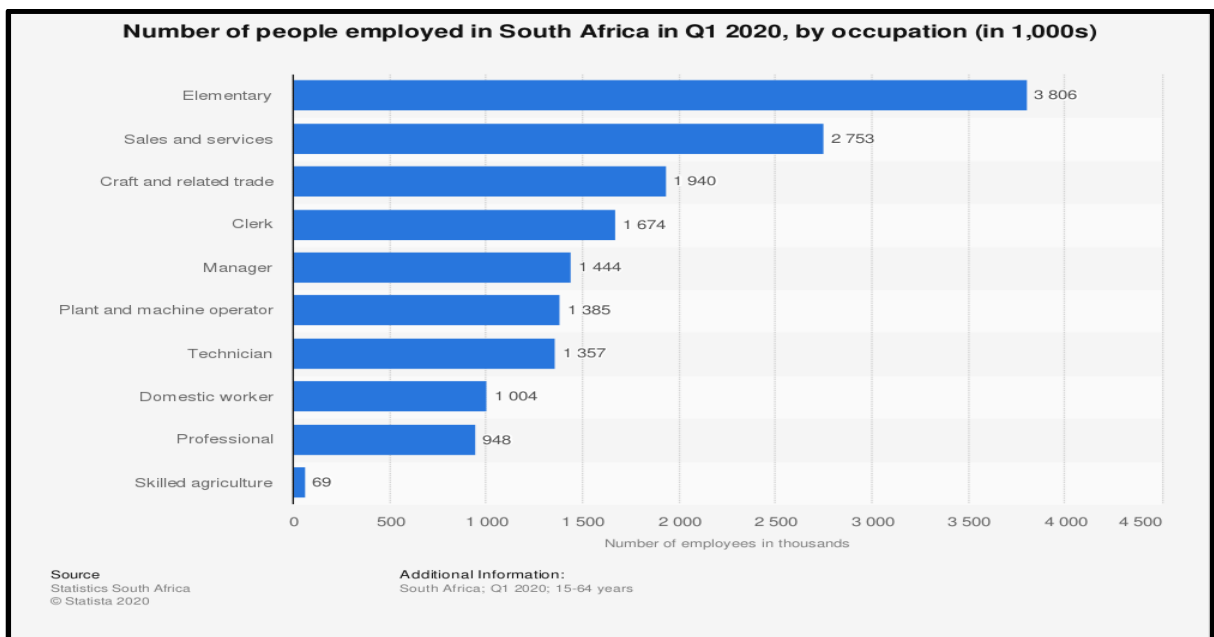
Source: (Stats SA, 2020)

Figure 5.7: Employment status



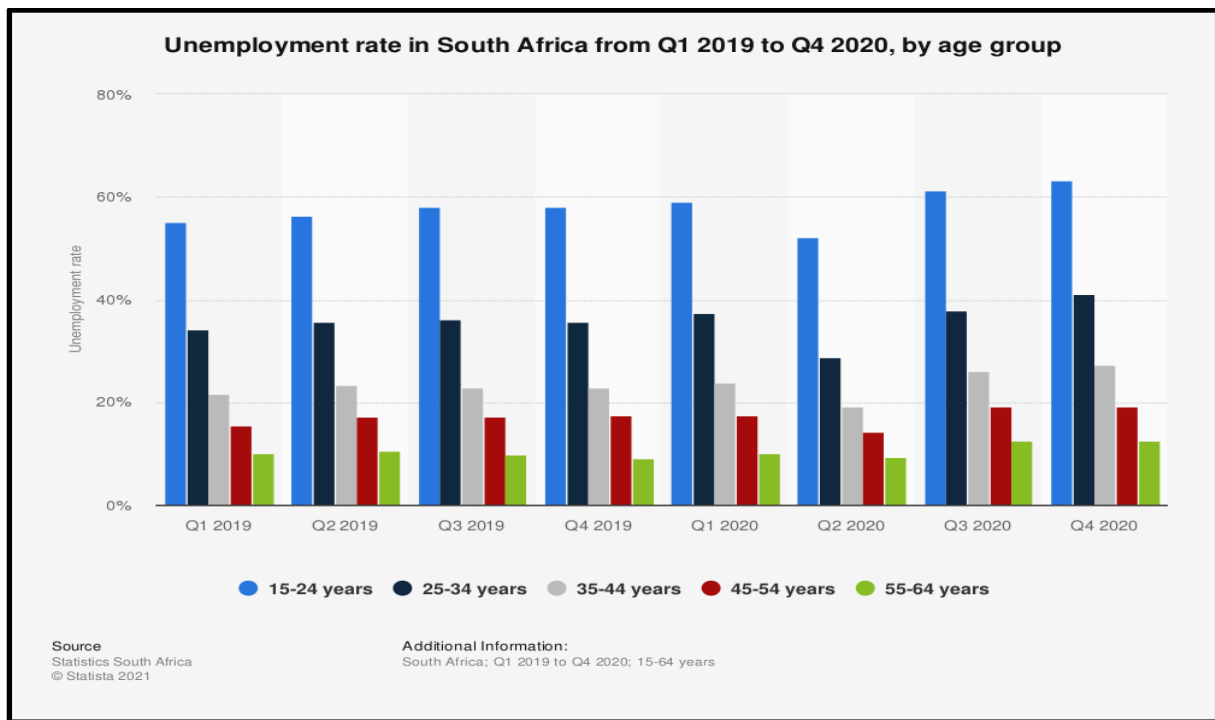
Source: <https://repository.uneca.org/>

Figure 5.8: Employment details in Q1 2021



Source: <https://repository.uneca.org/>

Figure 5.9: Unemployment status according to age in Q1 2018 and Q4 2020



Source: <https://repository.uneca.org/>

5.2.5. Number of People Using Public Transportation

According to the 2013 National Household Travel Survey, 68,8% of South African households use taxi services on a daily basis, followed by commuter buses (21,1%) and commuter rail operations (9.9%), with only 0.2% of the population using either method of public transit.(Stats South Africa, 2014: 6). According to the poll, taxis are the primary mode of transportation for most households (41.6%), followed by private vehicles (13.7%), buses (10.2%), automobile passengers (13.7%), and trains (13.7%). (4,4 percent) .As a result of the preceding, it is critical to invest in and improve public bus transit, which is both safe and beneficial (Stats SA, 2014: 6). The goal of the study was to create a situation that would result in a higher percentage of people using public transit. The socioeconomic statistics from the study area corroborated the difficulties identified in the study. The number of people using public

bus transportation is relevant, that their patronage will improve bus usage in Durban.

Table 5.4 shows the number of people that use public transport daily.

Table 5.4: Public Transport Usage

Public Transport Services	Use (%)
Taxi	68,8%
commuter buses	21,1%
commuter rail	9.9%
either of the modes	0,2%

Source: National Household Travel Survey (2013)

5.2.6. Families Dependent on Pay

The neighborhood in which a family lives is, for the most part, determined by the family's income, and, in general, a family with a higher income level can have better daily settings than those with lower income levels. It is dependent on the employment status of the family, employed or unemployed. When compared to households headed by black Africans, white families spent 4.5 times more on transportation. Furthermore, white-headed families spent about twice as much on transportation than Indian/Asian-headed families, and more than three times as much as the ordinary South African. Families headed by Black Africans spend less on transportation than the national average (R11 676 versus R16 826), whereas families headed by the other three population groups all spend more than the national average. When compared to spending on public or hired transportation, consumption expenditure on operational costs for privately owned automobiles is higher (R6 157). (R3 844).

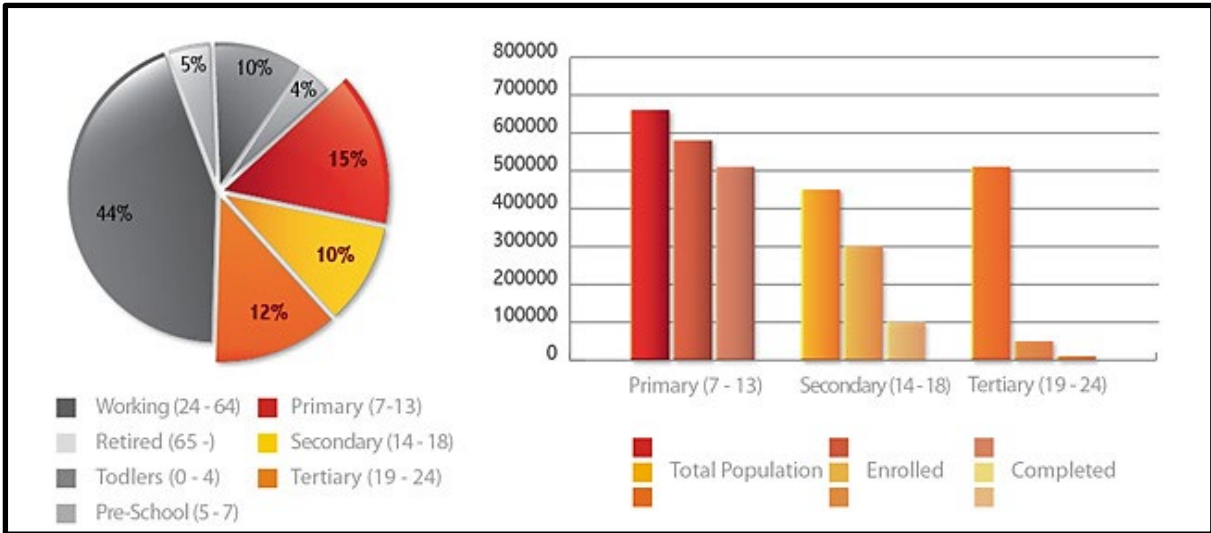
5.2.7. Financial Status of the Study Area

South Africa's GDP is expected to increase at a minus 0.2% pace in 2020, according to the Reserve Bank. Due to the global financial crisis, Durban's GDP shrank by 1.3 percent in 2009. (GFR). Just before the recession, the economy grew at a rate of 4.4%. The pandemic, on the other hand, pushed the economy to a 0.1% growth rate in 2019. The present recession is caused by a mixture of the GFR's impact on global and domestic demand, as well as a coercive limitation on consumer demand. As a result, the Durban EDGE's economic growth prediction for the city in 2020 is similar to that of Economist Dawie Roodt, ranging from -1 to 3%.

5.2.8. Education

A third of South Africa's population, or 37 percent of the total population, is educated between the ages of 7 and 24. With such a big number of potential participants in education, one would expect that South Africa would be more than capable of assuring economic prosperity. Most of this people will need to use public transit. "South Africa's developing economy requires a significant increasing number of higher education graduates with the high-level skills and knowledge that are essential to help the economy expand" (Doe, 2009, Hanushek, 2016). Figure 5.10 shows the evidence of findings related to Durban education completion status and how its increase develops the economy and promote public transportation.

Figure 5.10: Education completion status in Durban, South Africa



Source: <https://repository.uneca.org/>

5.2.9. Activities that Need Transportation in Durban (Statistics on Public Transportation)

There are different activities that need transportation in Durban which ranges from students going to school and people going to work etc. The different people are involved in the activities of public transportation and are evident on the data provided. Taxicabs are the most popular mode of public transportation in South Africa, with 51 percent of families (or 76.7 percent of the population) relying on them. Other modes of transportation (18.1 percent), trains (7.6%), and 23.3 percent using a combination of strolling and other modes of public transportation are also popular. Statistics South Africa published a special report on estimating family use of public transportation (2020). The normal, family, per capita, monthly travel expense was greater for families in the highest pay quintile (R404) than for families in the lowest pay quintile (R136), according to this data (R231). Furthermore, taxis were found to be the most expensive mode of transportation, with a monthly average cost of R254 per capita, followed by trains (R248) and other modes of transport (R248) (R231).

In comparison to families in the highest pay quintile, families in the lowest pay quintile spent a higher percentage of their pay on open vehicles: 66.6% of families in the lowest pay quintile spent more than 20% of their monthly family pay per capita on open vehicles, whereas 2.9% of families in the highest pay quintile spent more than 20% of their monthly family pay per capita on transportation. According to the findings, about 3.7 million students used public transportation as their primary mode of transportation. Taxis were the most popular mode of transportation in every region, followed by public transportation. When compared to students from the lowest pay quintile (R447), students from the highest pay quintile (R447) were more likely to spend more on travel (R351). Trains appeared to be the most expensive mode of transportation, costing an average of R422 a month, followed by public transportation (R393) and taxis (R393) (R375). The majority of students (98.2%) from low-income families spent more than 20% of their monthly family pay per capita on open vehicles, followed by quintile 2 (88.7%) and quintile 3 (88.7%), (62.9 percent). Approximately 6% of workers in families in the highest pay quintile would likely spend more than 20% of their monthly family pay per capita on open vehicles (5.6%). (SSA, 2015). As a result, the socio-economic statistics were critical since they indicated commuter profiles and their regular modes of transportation in the study area, allowing for a clearer understanding of what was being done and the gaps that the study needed to cover.

5.3. Evaluation of the Transportation System

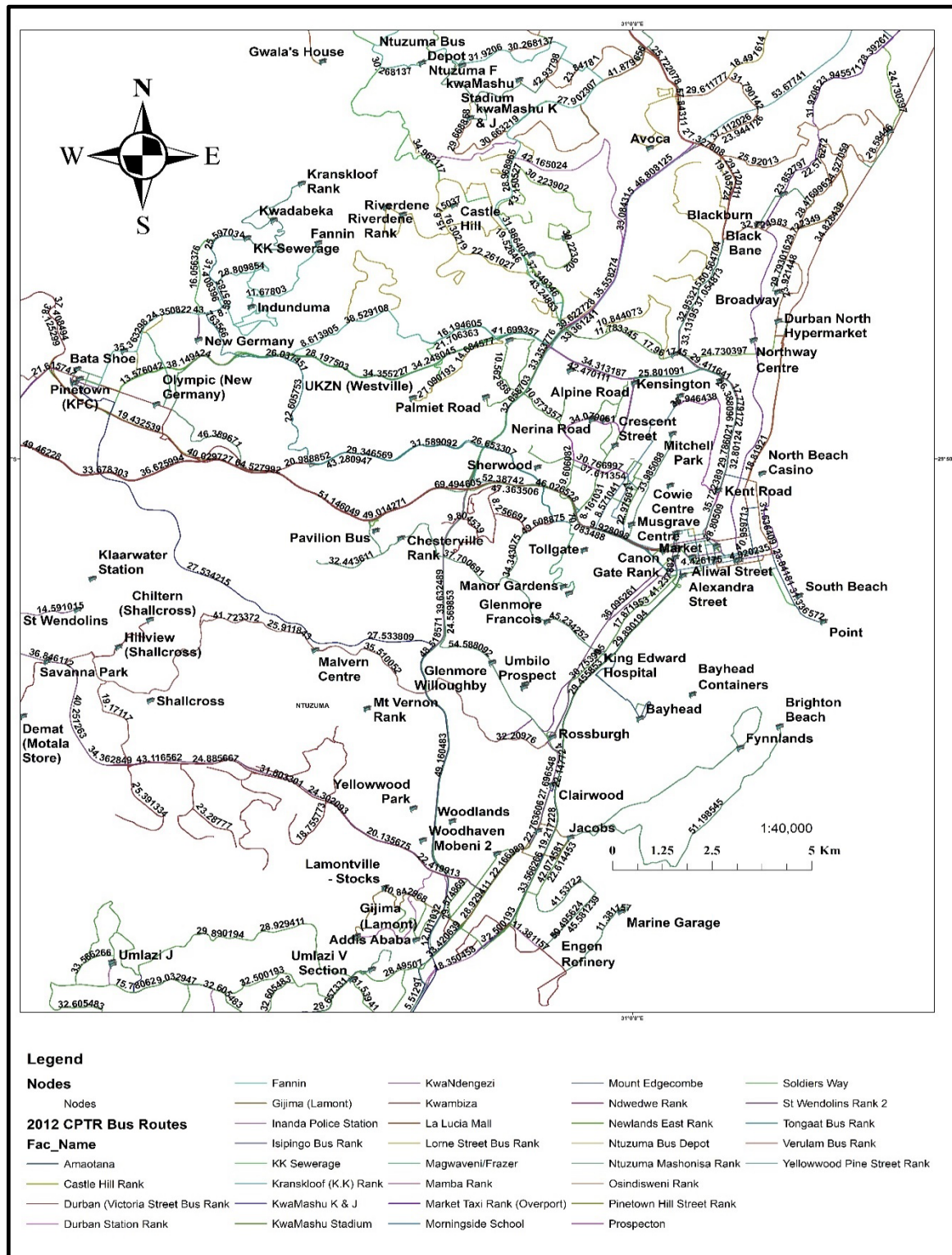
The various categories used in this research to consider transport systems in Durban have been explained in this section. The systems considered under the category of

Road Network are: Types and Category of Transportation System, Car Ownership, Travel Pattern, Modal split, Cost of Transportation, Time Spent on Transportation and Traffic Congestion, Traffic Flow, and Safety. The relevance is to show the current form of the transport system in Durban. The findings are shown in the subheadings listed.

5.3.1. Road Network

It was found that 337 routes were being used by bus operators to serve the public bus transportation system of Durban. The parameter considered is the road network of Durban, public transportation in Durban depends on it for effectiveness. Figure 5.11 shows the findings as the different categories of roads servicing public transport system in Durban. The numbers written on the routes in kilometers and are the lengths with the route's names to evaluate the public transport system. The hierarchical roads also show how they are linked to different suburbs in the transport system.

Figure 5.11: The hierarchical road network of public bus transportation in Durban



Source: Researcher's own construct

Appendix B shows the routes with details of destination, facility name, mode of transportation (bus) and the length (km) of each route.

5.3.1.1. Types and category of transportation system

South Africa's transportation system is contemporary and well-developed. The continent's largest aviation and train networks, as well as well-maintained highways, are available. Shipping to and from Europe, the Americas, Asia, Australasia, and both coastlines of Africa pass through the country's ports. The various modes of transportation include air, water, and land transportation, which include trains or railways, highways, and off-road mobility. Other modes of transportation include pipelines, cable transportation, and space transportation. The whole road network of South Africa is over 747 000 kilometers long, making it Africa's longest. KwaZulu-Natal has a total road length of 25 600 kilometers. This includes 1147km of the road network in the eThekweni Durban Metro area and 1138 km of national routes; 6656 km are surfaced, and 18943 km are gravel. The data shown is relevant to the evaluation carried out and the findings helped to know the categories of the transportation system.

5.3.1.2. Car ownership

More than a third of households indicated they drove to work, and 9% of children stated they were driven to school. In comparison, 24 percent of families said they used a taxi to work, 4,5 percent said they took the bus, and 2,1 percent said they took the train (Barker, 2011, Lareau, 2011). In Durban City, 6.8% of household children reported taking cabs to school, 3.6% took the bus, and 0.4% took the train to get to school (Venter et al., 2007). Walking to work was reported by 20,4 percent of households and walking to school was recorded by 64,6 percent of household

children. The information is important to the study since it informs the model assumptions.

5.3.1.3. Travel pattern

The public transportation sector in Durban, South Africa, consists of three main forms of transportation: traditional commuter rail and road transportation, the Oliver Tambo International Airport, and the subsidised and non-subsidised commuter bus industry (Baffi et al., 2018). Model development is influenced by travel patterns.

5.3.1.4. Modal split

The modal split refers to the percentage of travelers who use a specific mode of transportation versus the total number of trips taken. As a result, mode selection is one of the most crucial issues in transportation planning and policymaking. It reflects the general efficiency with which commuters can access urban areas. In the case of Durban being the third largest city in South Africa and destination of choice for tourists, an improved Public Bus Transportation system is needed. Table 5.5 shows the modal split of the public transportation of Durban. The information of interest to this study of public bus transport is highlighted in red.

Table 5.5: Modal split of public transportation showing travel mode and percentages

Mode of Travel	OHS 1996/ NHTS 2003	OHS 1997/ NHTS 2003	Census 2001/ NHTS 2003	OHS 2003/ NHTS 2003
Train	6	6.1	5.2	5.9
Bus	12.3	11.4	9.1	8.6
Taxi	4.2	4.5	3.2	5.4
Car	30.8	30.3	34.5	31.7
Walk	23	23.5	27.1	23.2
Others	4.2	4.5	3.2	5.4
Public Transport	42	41.7	35.2	39.7
% of all Motorised Trips of Pub. Trans.	57.7	57.9	50.5	55.6
% of Train	14.3	14.6	14.8	14.9
% of Bus	29.1	27.3	25.9	21.7
% of Taxi	56.6	58.1	59.4	63.5

Note: OHS= October Household Survey, NHTS= National Household Travel Survey.

Source: (Durban Public Transport Statistics, www.umweltbundesamt.de)

The modal split reveals that the share of motorized trips using Public Bus Transportation is steadily decreasing. This information should aid in the enhancement of public bus service though it was in 2003..

5.3.1.5. Cost of transportation

Durban People Mover, Mynah Bus Service, and Aqualine's Buses are the most dependable intercity bus lines. The eThekweni Municipality is in charge of these bus services. The cost of transportation varies according to the operating companies in Durban. Table 5.5 shows the details of the services. This information should assist in the model development because cost is related to accessibility of transportation and the distances travelled. The cost of bus transportation discourages patronage. It is relevant since the findings are used in the model assumptions.

Table 5.6: Daily schedules and cost of transportation

S/No	Frequency (Minutes)	Cost (Rands)	Duration	
1	15	5.5	5 a.m-10 p.m.	
S/No	Frequency (Minutes)	Weekly Coupon Discount (%)		
2	5	35		
S/No	Frequency (Minutes)	Cost (Rands) off Peak	Cost (Rands) during Peak	Average of ten tickets daily
3	30	2.40	3.80	28

Source: (Extracts from Durban bus schedules)

Every 30 minutes, Mynah buses run from the suburbs of Berea to the city center. They are one of the most cost-effective methods of getting from the outskirts to the city center. The workshop is where their Pine Street terminus is located. Although buses do not have route numbers, their destinations are always displayed. Aqualine is Durban's oldest bus service, serving the entire metropolitan region. Every 5 minutes, their buses leave. The cost of a ticket is determined by the location and the time of travel, with peak-hour pricing being the most expensive. For daily customers, the program offers a weekly 35 percent discount coupon. However, several of Aqualine's routes have been suspended due to continuing disagreements.

5.3.1.6. Time spent on transportation

Public transportation generally saves time when the timetables and operations are managed effectively. Bus timetables in Durban are available on the internet. Table 5.7 displays the time spent in minutes in vehicle, waiting, and walking when using transport in Durban. The findings show that delays in vehicle and waiting are longest when using public bus transportation. The implication is that there should be

improvement in time management in all the aspects to achieve an improved bus service for the passengers.

Table 5.7: Travelling time between public transport modes, car, train and bus

Components of Travel time	Car	Train	Bus
In vehicle	42.1	55.5	63.8
Waiting	00	31	33.4
Walking	00	35.5	23.8
Total	42.1	122	121

Source: Extract from Hitge and Vanderschuren (2015)

This information should help to understand the lack of patronage on public bus transportation and possible ways to improve it. The 2021 schedules for the public bus transportation in some suburbs in Durban have been enclosed in Appendix D.

5.3.1.7. Traffic congestion, traffic flow and safety

Traffic congestion and traffic flow have been improved by the inputs of TomTom Real-Time end-user traffic information delivered straight to vehicles. This enables subscribers to plan their routes and reach their destinations in the best possible time. This site is updated every 30 seconds to inform operators which routes to take to optimise estimated times of arrival at destinations. Analysing real-time incidents to predict traffic congestion before it happens makes TomTom navigation software more accurate with enhanced route calculations, which is relevant because it is related to the frequency of buses in Durban (Khoza, 2013).

5.3.2. Evaluation of Current Public Bus Transportation System

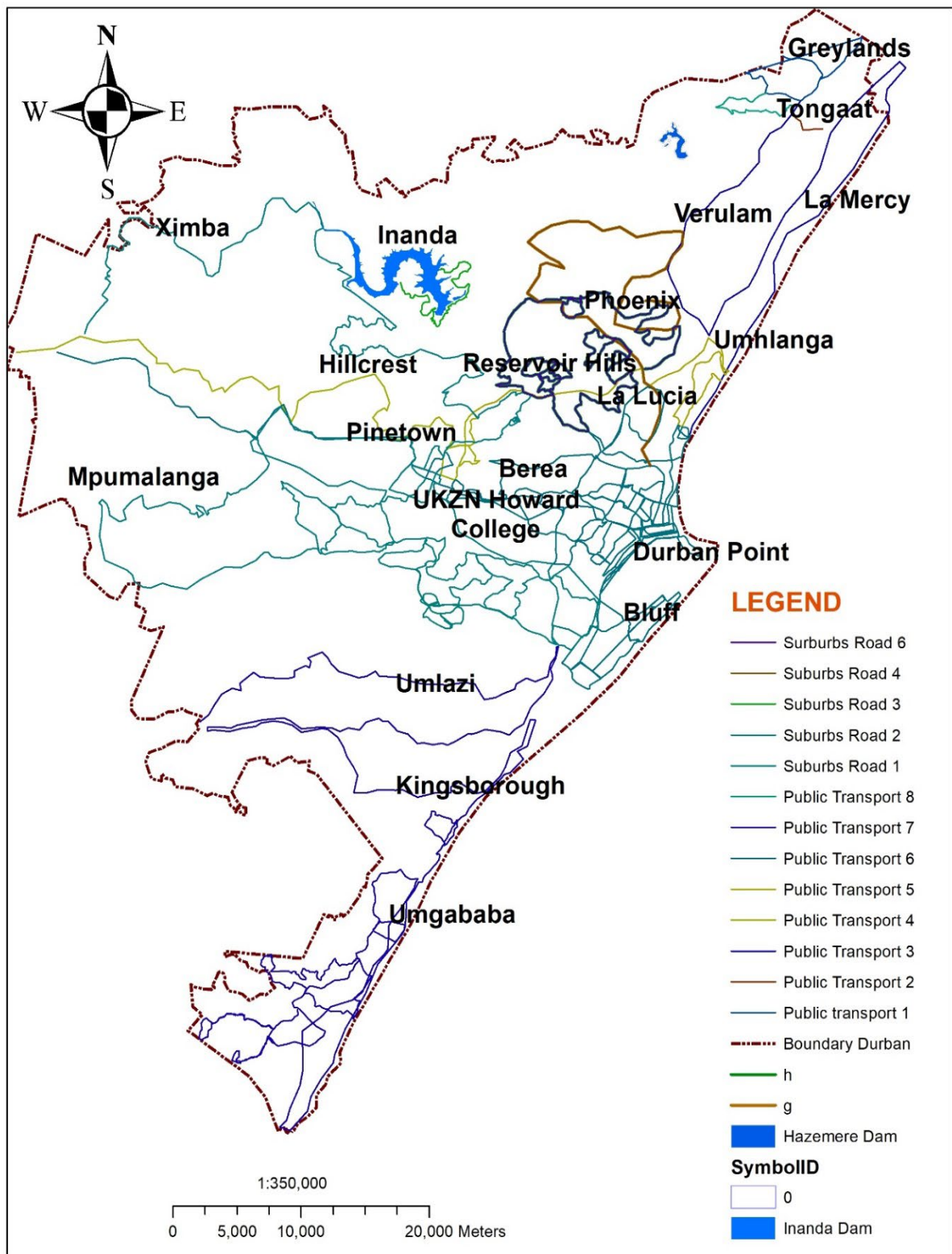
One of the objectives of this study has been analysed in this section under the sub-headings: The results of the assessment of the current public bus transportation system of Durban is presented in this section. The aspects to examine the current public bus transportation system includes public bus transportation route network, number of buses, capacity of buses and occupancy ratio, frequency, fare and cost benefit of public bus transit.

5.3.2.1. Public bus transportation route network

Durban's principal bus lines and interchange across the city to aid commuters in reaching their destinations include the People Mover, Durban Transport, and Mynah buses. Muvo Cards can be used to go everywhere in central and wider Durban, and the eThekwini Transport Authority manages them efficiently. Umbilo, Berea, Mount Vernon, Bluff, Woodlands, Durban North, Chesterville, Shallcross, Lamontville, Umlazi, Ntuzuma, KwaMashu, Phoenix, and Inanda are among the bus lines that serve the central, southern, and northern Durban districts.

Figure 5.12 shows the details of the public transportation routes in Durban, eTheKwini. The supporting evidence is Table 5.8 shows the details of the origin, destinations, routes, distances, time, and mode of travel; the table considered the first 15 routes. The rest of the route is found in Appendix C.

Figure 5.12: Digitised map showing details of transport routes



Source: Researcher's own construct

Table 5.8: Route network of Public Bus Transportation system in Durban

Route No.	Origin	Destination	Route Length in Km	Travel Time (mins)	Travel Mode
1	Ntuzuma Bus Depot	Mitchell Park	33.361241	33:22	Bus
2	Ntuzuma Bus Depot	Morningside School Bus	30.663219	30:40	Bus
3	Ntuzuma Bus Depot	Umlazi V	34.962117	34:58	Bus
4	Ntuzuma Bus Depot	Engen Refinery	42.074581	42:04	Bus
5	Ntuzuma Bus Depot	Durban North Hypermarket	23.921448	23:55	Bus
6	Ntuzuma Bus Depot	Umhlanga Rocks	29.611777	29:37	Bus
7	Ntuzuma Bus Depot	Point (Signal Road)	29.668858	29:40	Bus
8	Ndwedwe Rank	Lorne Street Rank	34.079061	34:05	Bus
9	Ndwedwe Rank	Pine Street Rank	35.558274	35:33	Bus
10	Osindisweni Rank	Tongaat Motor-Man	26.268578	26:16	Bus
11	Castle Hill Rank	Durban(Victoria Street Rank)	15.615037	15:37	Bus
12	Castle Hill Rank	The Workshop	16.30219	16:18	Bus
13	KwaMashu K & J	King Edward Hospital	27.902307	27:54	Bus
14	KwaMashu K & J	Pine Street Rank	25.722078	25:43	Bus
15	KwaMashu K & J	Point (Signal Road)	27.327808	27:20	Bus

Source: Researcher's own construct.

5.3.2.2. Number of buses

In South Africa, there are around 25 000 buses, 19 000 of which are formally utilized as public transportation buses for revenue. The remaining 6,000 buses are found in business and industry, as well as government organizations, where they are largely employed for internal transportation (not for profit). The economic aspects of buses used for public transport can be summarised as follows:

The 19 000 buses are largely owned by Indians and have a replacement value of R4 billion. Public transportation buses are anticipated to travel 40 billion kilometers each year and consume 506 million gallons of diesel fuel.

This sector of the economy employs around 34 200 people directly across the country, with an additional 171 000 individuals relying on the industry in some way (directly related to employment in companies). Approximately 912 million passenger trips are taken by public transportation companies each year. Many suppliers, including as bus and chassis manufacturers, fuel companies, tyre companies, glass and spare-parts firms, insurance companies, and others, rely on the industry for employment in some form (SA Bus Industry in Stats, 2016). Table 5.9 shows the list of buses overseen by eTheKwini transport authority. The detailed table is shown in Table 3.9 in chapter three.

Table 5.9: List of buses used and supervised by ETA

S/No	Buses
1	Durban People Mover
2	Mynah Bus Service
3	Aqualine

Source: (SA Bus Industry in Stats, 2016)

5.3.2.3. Capacity of buses and occupancy ratio

The normal, peak-hour occupancy rate at the point of maximum burden gives an indication of the amplitude. Bus occupancy is related to bus usage (U). If the normal occupancy is less than 100%, there is a hindrance within the transport network. On the off chance that it is 100%, this might imply that the service is simply satisfactory, yet it is likely to mean that there is unsatisfied interest, with travellers waiting unnecessary periods prior to having the option to board transport.

There is a level of subjectivity in determining what actually causes a delay. Most travellers who cannot board transport at busy times would have the option to board transport during off-peak periods, if they stood by for a sufficiently long time. However, for travellers going to work, obviously this is not practicable. While maximum load at busy times includes surplus consumption, it is necessary that there ought to be a modest quantity of extra load, especially in circumstances where demand is expanding. This would enable new interests to be obliged, and potentially new travellers would not be hindered by conditions from using public transport.

An adequate, normal, peak-hour occupancy rate is within 85% to 95%. Some of the buses used in public transportation in Durban have a capacity of 80 passengers and others 60 passengers. However, because of the current pandemic, it has been recommended that all buses should carry 60% of the bus capacity, which implies that, for each three-seater, two people should sit, leaving the middle seat empty. This would help to create social distance and reduce the spread of the virus.

Table 5.10 shows the occupancy ratio of the buses. Where the number of people exceeds the capacity of the bus, reveals that the excess are passengers standing in the bus.

Table 5.10: Showing capacity and occupancy ratio

Route	Number of buses	Average number of seats (Capacity)	Average number of people travel during off peak hours	Average number of people travel during peak hours	Occupancy ratio off peak hours (Total travellers during off peak hours/ total seats) (%)	Occupancy ratio peak hours (Total travellers during peak hours/ total seats) (%)
1	8	60	48	65	0.8	1.08
2	6	60	44	68	0.73	1.13
3	5	80	38	86	0.48	1.08
4	6	80	72	78	0.78	0.98
5	7	80	68	80	0.85	1.0
6	8	80	45	84	0.56	1.05
7	4	80	68	92	0.85	1.15
8	6	80	81	89	0.76	1.11
9	6	80	67	92	0.74	1.15
10	7	80	62	86	0.78	1.08

Source: Researcher's own construct.

5.3.2.4. Frequency

The public transportation buses managed by eThekweni Transport Authority operate at a frequency of 15 minutes interval and leave as scheduled. It is expected that passengers arrive to meet buses that leave every 15 minutes. Buses are certified as road-worthy before being scheduled for the day. The frequencies are dependent on the different routes especially those not controlled by ETA. The buses leave as scheduled, regardless of how many people board the buses. Tables of the schedules have been included in Appendix D.

5.3.2.5. Fare

A fare is the fee paid by a passenger to the operator of a public transportation system, such as train, bus, or cab. Several public bus transportation companies use fare systems. There are four classes of fares: first class, business class, economy plus class, and economy/coach class. The fare is according to the classes differ. ETA controls the fares of the bus companies in table 5.9. Some buses fares are subsidised while others are not subsidised. The implication is that passengers tend to patronise buses that are subsidised by government, making other bus companies with non-subsidy suffer lower patronage.

The tables of the fares of public bus transportation in Durban have been included in Appendix C.

5.3.2.6. Cost benefit of public bus transportation

The cost benefit can be regarded as the benefit of public transportation improvement. The benefits are numerous, as discussed earlier, and can be summarised as: public transit is a safe and equitable transportation mode. Where travel alternatives exist, fewer vehicles are driven, diminishing their harmful consequences for society. Much larger numbers of individuals can be moved using public transportation, in significantly less space, than cars, which assists with keeping gridlock lower, diminishes air contamination from idling vehicles, and assists car owners to avoid the pressure of driving every day in exceptionally dense areas of traffic. The cost benefit can also be viewed from economic, environmental and social points of view, with relevance to improve the public bus transportation.

5.3.3. Analysis of Public Bus Transportation Network for Accessibility Challenges

Number of Bus Users, Number of Bus Stops on Public Transportation Bus Routes, Waiting Time, Walking Time from Home or Suburb to Bus Stop, Network Analysis by GIS, Distance from Bus Stop to Suburb, Home or Workplace, Service Area Maps, and Level of Accessibility are all discussed in this section under the subheadings.

5.3.3.1. Number of bus users

Bus services account for 22 percent of the approximately 3,9 million who subscribe to public transport which amounts to approximately 880,000 commuters scattered across the several suburbs. The goal of this study is to increase the number of bus riders by enhancing public bus network accessibility in various suburbs with poor accessibility. Table 5.11 shows the average number of people that uses buses in Durban daily with the capacity of the buses and the number of buses in the ranks at their frequencies.

Table 5.11: Showing average number of people using buses daily

Route	Number of buses	Average number of seats (Capacity)	Average number of people using Bus daily.
1	8	60	480
2	6	60	440
3	5	80	380
4	6	80	720
5	7	80	680
6	8	80	450
7	4	80	680
8	6	80	810
9	6	80	670
10	7	80	620

Source: Researcher's own construct.

5.3.3.2. Number of bus stops on the public transportation bus routes

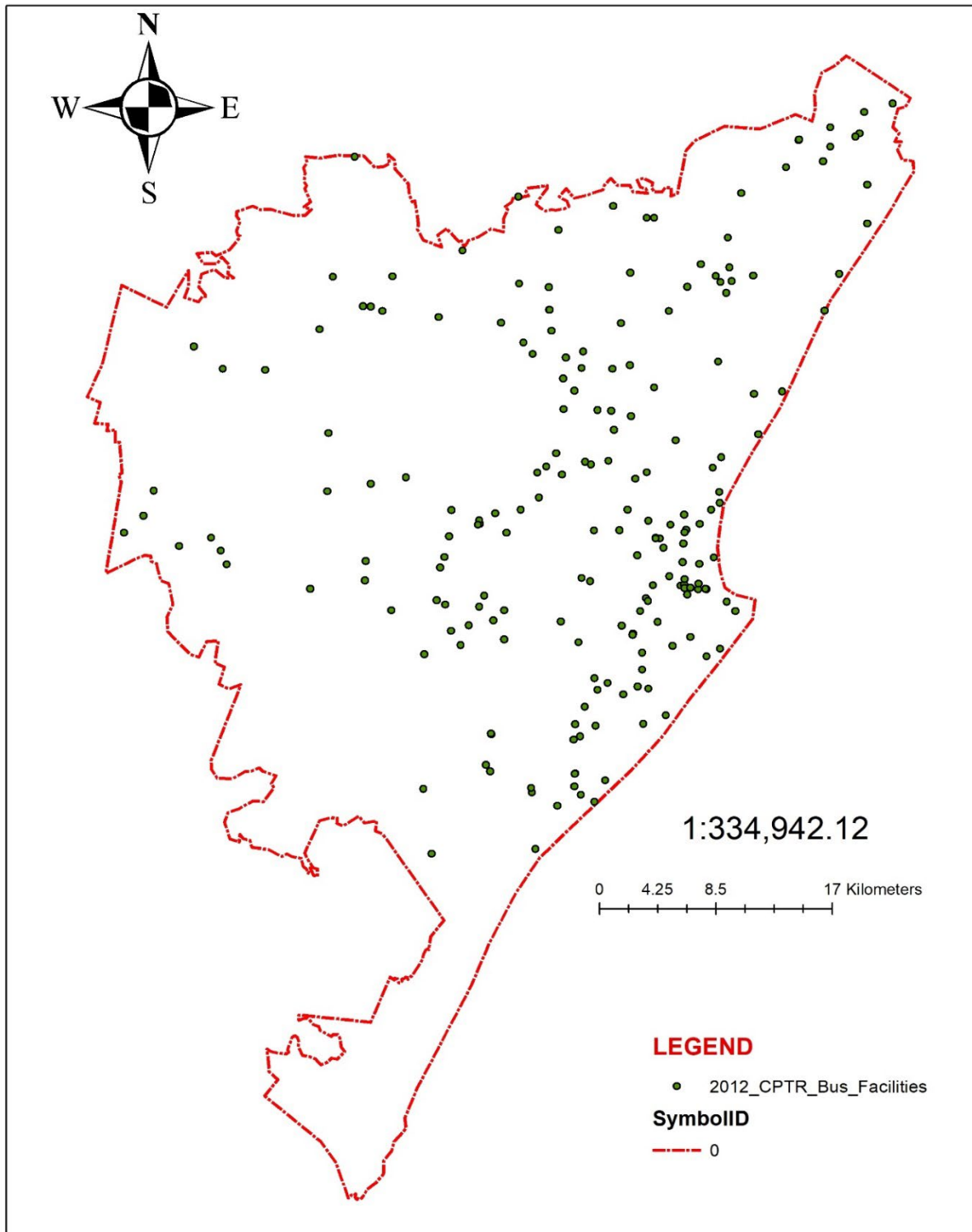
The bus ranks in the Durban study area are concentrated in the central business districts of the city and are reasonably placed. There are approximately 203 bus stops across Durban and its environs, of which approximately 70% are located within the city and CBD. Table 5.12 shows the first 15 bus stops with their locational coordinates, name of the bus stop alphabetically, the type of feature and the transport mode.. Figure 5.13 shows the location of the bus stops on the boundary map of Durban.

Table 5.12: Showing Bus stops and their location in Durban public transportation bus routes

S/No	Feature	Name of B/Stop	Latitude	Longitude	Travel Mode
1	Point	Addis Ababa	-29.94994	30.94395	Bus
2	Point	Alexandra Street	-29.86168	31.01293	Bus
3	Point	Aliwal Street	-29.858026	31.027995	Bus
4	Point	Alpine Road	-29.81497	31.0007	Bus
5	Point	Amaotana	-29.671026	30.999664	Bus
6	Point	Amatata	-29.630268	30.843742	Bus
7	Point	Amatikwe	-29.670133	30.909135	Bus
8	Point	Assagay - Kassier RD	-29.7922	30.7412	Bus
9	Point	Avoca	-29.75807	31.00467	Bus
10	Point	Bata Shoe	-29.80712	30.86821	Bus
11	Point	Bayhead	-29.896278	31.002118	Bus
12	Point	Bayhead Container	-29.89043	31.01575	Bus
13	Point	Black Bane	-29.7765	31.03282	Bus
14	Point	Blackburn	-29.77654	31.03268	Bus
15	Point	Bomvini	-29.608322	30.988441	Bus

Source: Researcher's own construct.

Figure 5.13: Digitised map showing details of bus stops and their locations in Durban



Source: Researcher's own construct

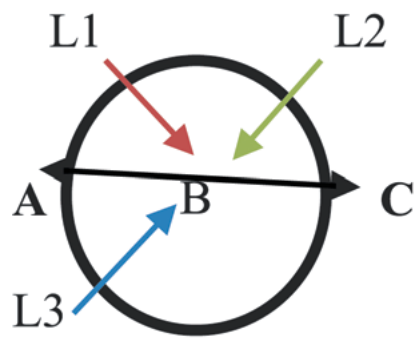
5.3.3.3. Waiting time

It has been established that frequency of public bus transportation in Durban, on average, is quarter hourly (every 15 minutes), and the waiting time is negligible for buses managed by the ETA (within 15 minutes). Other bus companies not overseen by ETA have their waiting times. The accessibility of bus transportation is dependent partially on the waiting time (Chandra et al., 2005). The bus schedules in Appendix D show their waiting times.

5.3.3.4. Walking time from home or suburb to bus stop

The total length of pedestrian links to a bus stop should be within a radius of 400 meters (0.25 miles), according to Okezie et al. (2021). Walking at a speed of 2,3 km/h (1,43 miles/h) would take 10 minutes. It takes 26 seconds to walk from various locations to a bus stop. In order for a public bus transportation system to function, there must be a maximum, acceptable walking time from the suburbs to the bus stop in order to achieve reasonable accessibility. This is relevant to the study's model assumptions. Figure 5.14 shows the details of walking from home to bus stop of the suburbs in public bus transportation in Durban. Its relevance is to aid in the improvement of public bus transportation.

Figure 5.14: Walking time from the bus stops



Source: Okezie et al. (2021).

Where;

L1 W walking distance from settlement 1 to bus stop B

L2 W walking distance from settlement 2 to bus stop B

L3 W walking distance from settlement 3 to bus stop B

A-C Existing Bus route

B Centroid point (bus stop) 400 m (0.25 mi).

5.3.3.5. Distance from bus stop to suburb, home or workplace

The intention in this section was to achieve the first objective which was to evaluate the current public bus transport network of Durban City. The focus was on digitising the public transportation roads in the suburbs in Durban. Further emphasis was placed on the use of GIS, as proposed in the study. GIS analysis was considered in two dimensions: a) The digitised suburbs in Durban, and b) The Network Analysis of Durban.

This was accomplished by obtaining the co-ordinates of the places using a hand-held Global Positioning System (GPS). The maps of some of the suburbs were obtained online. The maps were scanned to achieve the raster image that was geo-referenced using the co-ordinates. The areas of interest such as the suburbs, public transport roads, rivers where they existed, and the boundaries were digitised. This process helped to establish the inputs of GIS in the study and to show the existing road networks. This was possible by applying technical knowledge and ArcGIS Software. Figure 5.15 below is a digitised illustration of the suburbs showing the extent of the public bus transport network in Durban, and the surrounding connection with other suburbs in the neighbourhood. When the layers of each suburb have been overlapped, the current public bus transportation system in Durban is shown clearly.

Table 5.13 shows the list of suburbs and their density and is relevant in the model development in the study.

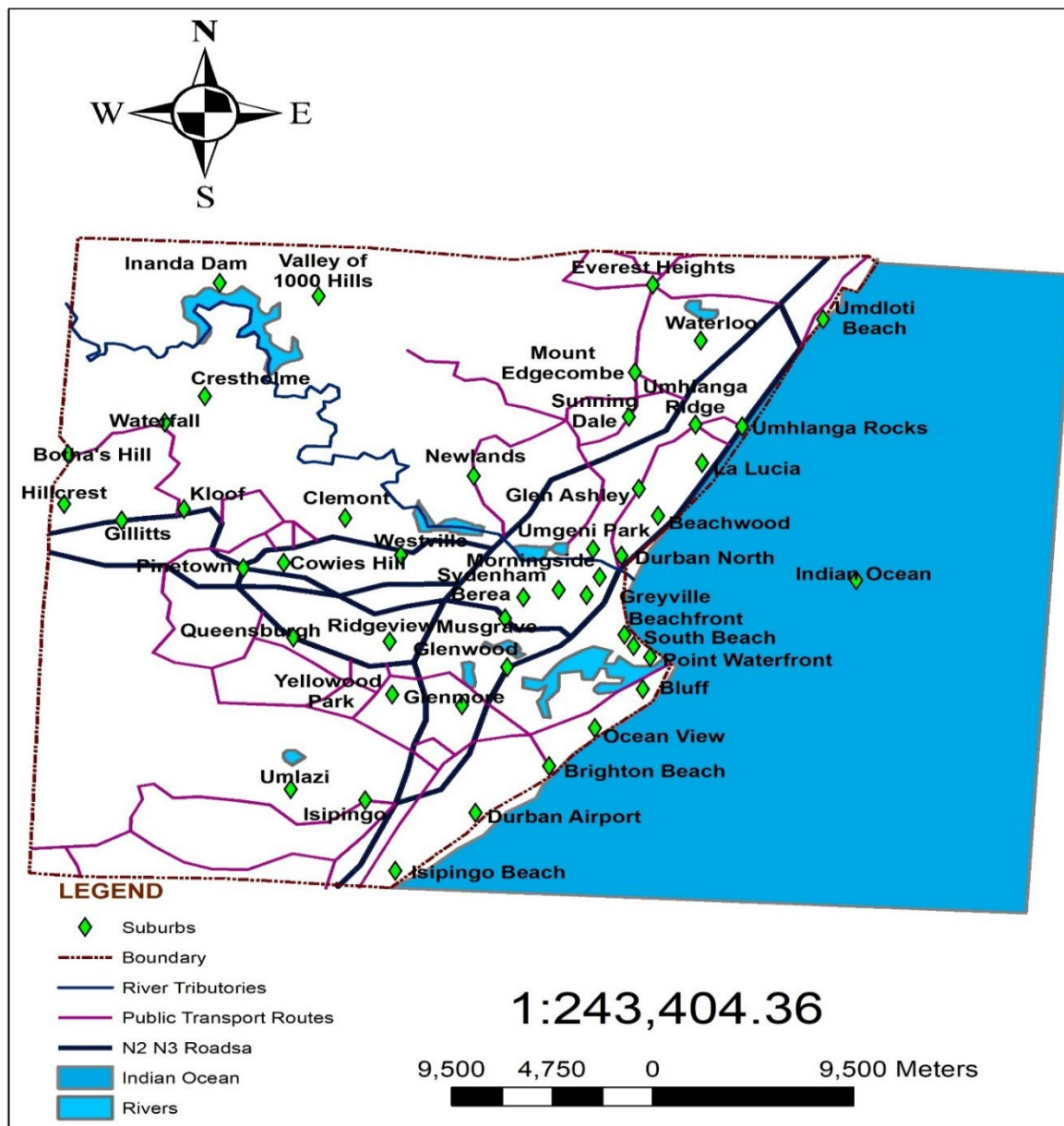
Table 5.13: List of suburbs, population and population density in Durban

Suburbs	Population	Density
Umdloti	1,778	1,100/km ²
Amanzimtoti	13,813	1,503/km ²
Umhlanga	24,238	1,400/km ²
Pinetown	144,026	1,700/km ²
Kloof	29,704	860/km ²
Queensburgh	54,846	2,400/km ²
Glenwood	5,617	3,380/km ²
Bluff	68,124	3,100/km ²
Hillcrest	13,329	620/km ²
Berea	102,920	4,200/km ²
Kingsburgh	16,368	1,405/km ²
La Lucia	6,414	1,600/km ²
La Mercy	2,779	100/km ²
Mt. Edgecombe	7,323	880/km ²
Westville	30,508	991.7/km ²
Glenmore	1,178	3,499.41/km ²
North Beach	7,296	13,000/km ²
South Beach (Point)	20,672	8,300/km ²
Waterfall	7,525	522.4/km ²

Botha's Hill	1,992	270/km ²
Umbilo	11,311	3760/km ²
Winklespruit	1,689	830/km ²
Montclair	16301	4300/Km ²
Reservoir Hills	19,143	2000/km ²
Shongweni	24	24.78/km ²
Morningside	13,074	4,000/km ²

Source: (Census, 2011)

Figure 5.15: Public transport network of Durban showing important features



Source: Researcher's own construct.

5.3.3.6. Service area maps (Network Analysis)

Okezie et al., (2021) discovered that public transportation route networks are between 0.5 km (0.31 mile) and 15 km (9.32 mile) from various parts of the city. Inner-city areas, including significant commercial centers, are relatively accessible, with passengers needing only 8 to 16 minutes to reach a public transportation stop. According to Washington et al., (2021), Chan, (2022) & Jiang et al., (2023) they suggested that the standard buffer circumference be 400m (0.25 mi), for walking home to the bus stop, They are approximately 0.5 km (0.31 miles) and 1 km apart (0,62 miles). Regions with 15 km (9.32 miles) or more from a bus stop, on the other hand, are severely inaccessible, taking more than 4 hours to walk to. Okezie et al. (2021) acknowledged Durban's public transportation system's current accessibility issues, and their findings could help update or re-configure the route network system to make it more accessible. The findings showed further those solutions could be found to improve the challenges currently facing the public bus transportation of Durban. Okezie et al. (2021) recommended that the distance from the bus stop to the suburbs should be minimal and acceptable.

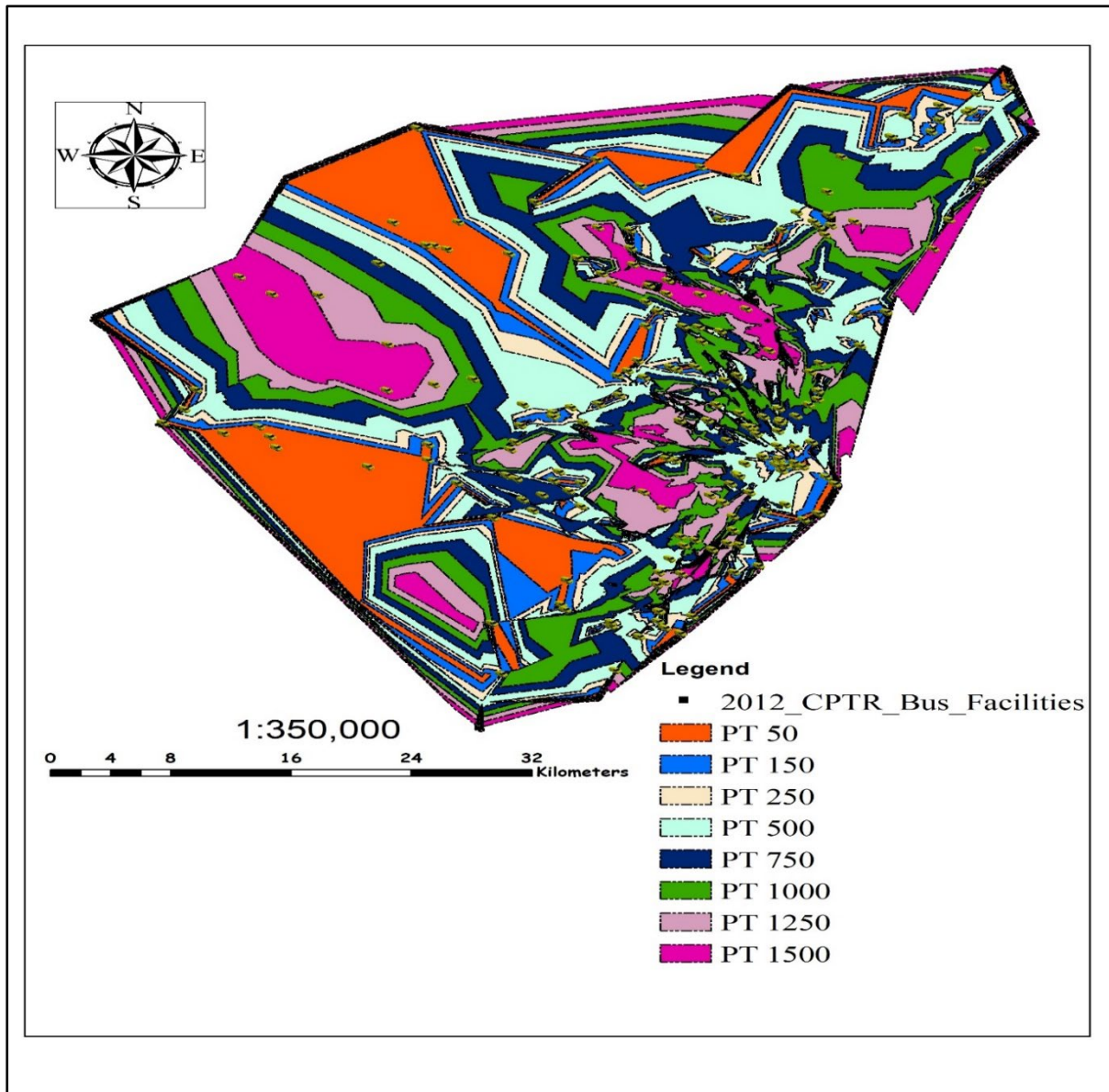
The network analysis resulted in the creation of a service area map, which was one of the inputs of employing GIS in the research.

The statistics came from the CPTR 2012, with the underlying data coming from the eThekweni Transport Authority's Department of Transport. It was noted that GIS inputs in this research were applied in the deductions of distance-related secondary data, all digitised maps and in the network analysis (Service Area Map) Vanclooster

et al., (2016). From the research methods applied, the service area map was one of the key results in the study. ArcGIS 10.7.1 was the software used to conduct the service network analysis of the public transportation of Durban. By applying GIS in the study, the findings obtained from CPTR 2012 showed that there are 337 routes defined by different transport firms, and 203 bus stops.

The process involved opening ArcMap 10.7.1; selecting Geo-processing; searching for the required tools for the process; creating a network analysis layer in the search box; selecting the search tools and the name of the tool that creates the network analysis layer; and inputting the parameters of the tool and perform the service area network analysis Zerfu (2020). The network analysis helped to determine the distances from each suburb to the ranks and bus stop facilities. The analysis could also enable bus commuters to determine the distances to walk to any bus facilities closest to them from their suburbs. It was identified that areas involving distances of 500 metres and above were considered to less accessible in this study (Chen, and Chang, 2015, Truong, and Somenahalli, 2011). Figure 5.16 below shows the result of the service area analysis map (Network Analysis) of the study.

Figure 5.16: Network analysis of Durban showing distances of bus facilities from suburbs



Source: Researcher's own construct

The figure shows the Network Analysis of Durban, which was the second objective of this study. The analysis helped to understand that a commuter could move from one destination to another, knowing where all the Public Bus facilities can be found and how to navigate from one suburb to another in the best possible time. The results show that areas under distances from 50meters to 500meters which indicates walking distance have a good accessibility of public bus transportation, while areas above 500 meters to 1500 meters have poor accessibility to public bus transportation. According to Okezie et al. (2021) the threshold of distance is 0 - 400

meters circumference buffer for more accessibility (Washington et al., 2021, Chan, 2022 & Jiang et al., 2023).

5.3.3.7. Level of accessibility

The level of accessibility refers to the walking time, waiting time, number of buses, the entire trips and number of people using public bus transportation. Accessibility includes the current level of accessibility and the improved version when social inclusivity is applied. If the waiting time is high, it will affect the accessibility negatively. If the frequency of the buses is low, while adding to the low percentage of the population patronising public bus transportation, it will affect accessibility adversely. The improved version would be when the frequency of buses is improved, with a higher percentage of the population patronising public transportation. Furthermore, if fares are decreased, this would encourage the less economically advantaged population to patronise public transportation, thereby improving accessibility to weaker sections. It would also increase generally the number of trips and use bus transportation (Wang and Mu, 2018). Table 5.14 shows the level of accessibility with reference to the study. The result suggests that if frequency and the number of public bus transportation passengers increases, accessibility will improve. The table considered 3 major access point only.

Table 5.14: Levels of accessibility

Access points	Total bus users	Total population around the access point	Share of bus users	Average trips per person per day	Total user: trips bus occupancy + frequency
1	38	1,778	38%	10	4620
2	22	13,813	22%	3	1470
3	18	24,238	18%	2	840

Source: Researcher's own construct.

5.4. Factors Influencing the Public Bus Transportation System

The statistical analysis started with the primary data of the study which were obtained from the field and compared with the secondary data obtained from DoT of ETA in the form of shapefiles compatible with the GIS software ArcGIS. Having decided to use the Negative Binomial Regression Model, which supports the use of count data, to carry out analysis of public transportation, efforts were made to articulate all parameters which influenced accessibility (as the dependent variable) with the help of the data, listed in the tables below, which were provided as evidence. The choice of the most influential parameters (through parametisation) was made with the help of different inferential statistical analyses, such as correlation, a co-linearity test, a significance test (t- or z-test), to verify the parameters used for modelling. The parameters are discussed further under the sub-headings: Identifying the Factors Influencing Public Bus Transportation, Correlation Coefficient between Various Factors and Users, Co-Linearity Test between Various Factors, Significance Tests and Factors Influencing Public Bus Transportation.

5.4.1. Identifying the Factors Influencing Public Bus Transportation

The factors that influence public transportation were examined using the correlation between various parameters, given the general dataset for the study which has been included in Appendix G. The following factors were analysed statistically and were found to influence public transportation as shown in Table 5.15 and 5.16. The acronym for the parameters has been mentioned in section 4.7.2 Figure 4.3.

Table 5.15: The correlation of the study dataset

	A	F	C	TD	WT	WT1	WD1	AS	CM	NN	TT	WD
A Pearson Corr.												
F Pearson Corr.	.957	1										
C Pearson Corr.	- .769**	.812	1									
TD Pearson Corr.	0.086	.034	- .129	1								
WT Pearson Corr.	.557**	.605	- .701	.092	1							
WT1 Pearson Corr.	- 0.227	- .152	.042	- .008	- .111	1						
WD1 Pearson Corr.	- 0.074	- .049	.053	- .069	.197	-.161	1					
AS Pearson Corr.	0.016	.062	- .086	- .002	.073	.041	-.162	1				
CM Pearson Corr.	- 0.203	- .278	.225	.096	.029	-.004	.272	- .297	1			
NN Pearson Corr.	0.048	.066	- .026	- .031	.126	-.021	-.047	.130	.028	1		
TT Pearson Corr.	- 0.238	- .199	.194	- .067	- .231	.358	-.033	- .105	- .234	.027	1	
WD Pearson Corr.	- 0.084	- .025	- .036	.102	.027	.031	-.226	- .012	- .049	- .090	- .099	1

Source: Researcher's own construct

Table 5.16: The One-Sample Test of the study dataset

t	df	Test Value = 0		95% Confidence Interval of the Difference	
		Sig. (2-tailed)	Mean Difference	Lower	Upper
A	53	.000	3619.352	3142.07	4096.64
F 17.142	53	.000	8.259	7.29	9.23
C 18.331	53	.000	7.907	7.04	8.77
TD 337.322	53	.000	13423.444	13343.63	13503.26
WT 19.935	53	.000	7.130	6.41	7.85
WT1 86.278	53	.000	25.685	25.09	26.28
WD1 199.299	53	.000	37.38778	37.0115	37.7640
AS 254.388	53	.000	67.722	67.19	68.26
CM 23.175	53	.000	1.574	1.44	1.71
NN 14.216	53	.000	1.370	1.18	1.56
TT 82.049	53	.000	25.981	25.35	26.62
WD 40.526	53	.000	6.241	5.93	6.55

Source: Researcher's own construct

5.4.2. Correlation Coefficient between Various Factors and Users

The outcome of the correlation coefficient is shown in Table 5.17. The three factors were found to influence the accessibility of public bus transportation in Durban. It is relevant to establish the degree of relationships among the variables.

Table 5.17: Correlation of the parameters

	A	F	C	WT
F Pearson Correlation	.957	1		
C Pearson Correlation	-.769	-.812	1	
WT Pearson Correlation	.557	.605	-.701	1

Source: Researcher's own construct

5.4.3. Co-Linearity Test between Various Factors

The results of the co-linearity test between various factors are shown in Table 5.18. It ensures the linearity affinity between the values of independent variables and that of the dependent variable.

Table 5.18: Variance inflation factor of primary data

Model	B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1 (const.)	-207.455	695.032		-.298	.767		
F	482.952	34.694	.978	13.920	.000	.339	2.951
C	.126	43.257	.000	.003	.998	.272	3.677
WT	-22.864	38.273	-.034	-.597	.553	.505	1.979

Source: Researcher's own construct

5.4.4. Significance tests

The significance test results are reported in Table 5.19. It entails the scale of measurement, random sampling, normality of data distribution and data adequacy.

Table 5.19: One-sample t-test of primary data (test value = 0,95% confidence interval of the difference)

	t	df	Sig. (2-tailed)	Mean Diff.	Lower	Upper
F	17.142	53	.000	8.259	7.29	9.23
C	18.331	53	.000	7.907	7.04	8.77
WT	19.935	53	.000	7.130	6.41	7.85

Source: Researcher's own construct

5.4.5. Factors Influencing Accessibility of Public Bus Transportation

The following criteria were determined to be relevant in influencing the accessibility of public bus transportation: frequency (F), fare (F1), waiting time (WT), and social inclusion (SI) to be introduced. The results of the correlations of the data, VIF and significance test, indicating their influence are shown in Tables 5.15 to 5.19. The process below was the outcome of the analysis in which all the influential parameters to be used in the model were identified. The primary data that were used in the study were analysed further to ascertain the validity of the model parameters. One-sample statistic, one-sample t-test, the correlation and variance inflation factor (VIF) were performed to ascertain the level of influence.

5.5. Evaluation of Social Inclusivity

Premised upon the definition of social inclusivity based on the literature review, social inclusivity in the context of the study area was defined as enabling sections of disadvantaged people to access and use public bus transportation to travel reasonable distances at a reasonable and affordable cost. Therefore, the factors that influence social inclusivity include the number of people provided with access, distance travelled by people, and the use of buses by the people in the suburbs.

Table 5.20 shows the results for the factors above in 3 suburbs of the study area. It was found from the three suburbs considered that the proportion of people using bus is dependent on the suburbs. People who live in the rich areas like Umhlanga tends to use their private cars compared to people who lives in economical poorer suburbs. The implication is that people in the less economical suburbs will give more patronage to public bus transportation, Therefore, needs more accessibility of public bus transportation; the study considers their inclusiveness.

Table 5.20: Status of the factors influencing social inclusivity in the study area

Suburbs	Disadvantaged Population Section (number of people)	Average Distance Travelled (kms)	Use of Bus (proportion of people using the bus compared with total population)
Umdloti	1,778	12.4669	0.38
Amanzimtoti	13,813	19.2671	0.22
Umhlanga	24,238	26.0672	0.18

Source: Researcher's own construct

5.5.1. Provisions for Social Inclusivity

When assessing social inclusion in relation to transportation, the most important factor is that the processes must be people-centered.

Social inclusion is felt on a social level and is based on the barriers that prevent people from gaining access to opportunities for growth and freedom (Marmolejo, 2010). Novel research in social inclusivity of the Public Bus Transportation of Durban is in its early stages. The intention is to decrease limitations and give disadvantaged people access to public bus transportation in Durban. Social inclusivity is defined in this study as the population of weaker economic sections, with transport needs, that travels certain distances using public buses and supported by existing theories (Stanley et al., 2010; Lucas, 2016). The future input of social inclusivity in the Accessibility Model will help to improve the public bus transportation system.

5.5.2. Areas under Social Inclusivity

As a result of this study, it will be recommended that social inclusivity is used in areas considered to have less accessibility, according to the research, to improve patronage of public bus transportation as part of a model to increase accessibility to the region and suburbs including neighboring suburbs around Durban city and increase patronage to public bus transportation.

5.5.3. People under Social Inclusivity

The people being considered are aged people of 60 years and above, pensioners and retirees, students whose parents fall below the lower income class of society and low income or people living on social grants. Preference will be given to old men and women.

5.5.4. Discounts Provided to People Needing Social Inclusivity

Discounts are under consideration because of the prevailing socio-economic situation of people in the suburbs. It is the intention behind the model to give access to economically disadvantaged people to increase patronage of the bus service and for social inclusion.

5.6. Discussion of the Findings

From the perspective of the challenges facing the public bus transportation system in Durban, all the possible socio-economic factors of the study area were identified, and a coherent analysis of the various components was carried out, including population, age structure, education, economy, income, and employment status. The relevant data, figures, tables and graphs were used as part of the analysis.

An investigation of the factors that determine the effective functioning and accessibility of public transportation was conducted in order to meet the study's objectives. The analysis included an evaluation of the current transportation network of Durban, a network analysis of public bus transportation, an examination of social inclusiveness and an evaluation of the model parameters that influenced the

accessibility of public bus transportation. The input of GIS analyses was included which helped considerably in evaluating the modelling of the sustainability of the public bus transportation system. The results obtained concurred with the theories in the literature reviewed.

5.7. Summary

Care was taken in the study to meet the objectives by addressing all the challenges and the research questions. The accessibility and the extent of social inclusivity of the current public bus transportation were illustrated using graphs, figures and maps. The difficulties with accessibility that people face were also demonstrated. This chapter discusses all of the characteristics and metrics that were studied in this study and could influence the accessibility of Durban's public bus transportation network. Additional statistical analyses were conducted, which were accompanied by tables, figures, and graphs. Improvements to the accessibility of public bus transit have been advocated based on statistical studies and the model's robustness. The model and proposed guidelines for improvement of the accessibility of the public bus transport network have been discussed in Chapter Six.

Chapter Six: Modelling and Simulations

6.1. Introduction

The study's model and simulations have been discussed in this chapter. Since the accessibility data were count data and could not have a negative value, there were only two possible modelling options which could be used: the Poisson distribution and Negative Binomial Regression Models, as agreed by several authors (Kiran, Kumaraswamy & Sashidhar, 2017, Milton, Shankar & Mannering, 2008, Noland & Quddus, 2005, Wang, Quddus & Ison, 2013). The Negative Binomial Regression Model was determined to be a good fit for the study after the initial analysis revealed substantial dispersion in the data. Similar assumptions are shared by the Poisson Regression Model and the Negative Binomial Regression Model. The number of trials (X) that must occur until a specific number of successes (r) is reached is the subject of a negative binomial distribution. The number (r) is a whole number that is chosen prior to the start of the trials. The random variable (X) is discrete (Yang & Berdine, 2015; Hoffmann, 2016). Several scholars suggest that there might be spatial correlations among the variables as well as possibly unobserved heterogeneity, which might create bias in the model results if the appropriate effect is not taken into account (Plümper & Neumayer, 2010; Mannering, 2018).

This study was based on a framework to ensure that the last objective, “to propose guidelines to improve the accessibility of the public bus transport network”, was achieved.

Deliberate effort has been made to discuss the parameters in alignment with the objectives of the study.

6.2. Selected Model- Negative Binomial Regression Model

The choice of model was established in Chapter Four to be the Negative Binomial Model (NBRM), which was found to be most suitable for the data. This model has been used in modelling public transportation (Casas, 2007; Cao et al., 2010; Pulugurtha & Agurla, 2012;Saghapour et al., 2018).Table 4.1 explains why the NBRM model was chosen over the Poisson Regression Model. A Poisson Model fits if the dispersion statistic is close to one; if the dispersion statistic is greater than one, a Negative Binomial Model fits better, as it did in this study.

6.3. Model Parameter Estimation and Development

The NBRM conceptual models that were created served as indications for further evaluation of the variables that needed to be done in order to accurately interpret and execute the model's conclusions. Initially, there were eleven factors identified as having an influence on the accessibility of the public bus transportation network (PBTN) of Durban, considered as an Independent Variable (IV), and one Dependent Variable (DV). Choice of the most influential parameters (through parametisation) was achieved by using various inferential statistical analyses, such as correlation, a co-linearity test, a significance test (t- or z-test), variance inflation factor (VIF), model continuous variable information, model goodness of fit, model omnibus test, test of model effects, model parameter estimates, and model covariance of parameter

estimates. These analyses justified why the identified parameters were considered for modelling (Ma et al., 2011; González-Manteiga & Crujeiras, 2013). Variance inflation factor (VIF) tests were used to ensure that the independent variables were exclusive and significant. Based on the tests, the control variables were identified as factors with a significant correlation coefficient that, on average, influenced improving the public bus transportation network in the study area, and could be utilized for future analysis and model development.

The details of the factors that determine public bus transportation accessibility and their values are described in this way.

Frequency, Cost, Waiting Time, and Social Inclusivity are all factors to consider. For Frequency, the correlation coefficient was -0.812 with VIF of 2.951 and its significance was < 0.05 . For Cost, the correlation coefficient was 0,605 with VIF of 3.677 and the significance was < 0.05 , for Waiting Time, the correlation coefficient was -0/701 with VIF of 1.979 and the significance was < 0.05 .

The process of elimination to identify the most influential factors was carried out using inferential statistical analyses and statistical inputs.

The parameters below influenced the accessibility of the public bus transportation system according to the data of the study.

6.3.1. Accessibility (A)

Accessibility of public bus transportation has been defined in terms of users, as bus capacity, multiplied by the frequency (number of trips) of the bus per day (Güner, 2018; Curtis & Scheurer, 2017). This definition was found before the model was

developed and field observations indicated that it needed to be improved. Accessibility according to the model was defined as the function of frequency, fare, waiting time, and social inclusivity (Ford et al., 2015; Saif et al., 2019). Accessibility was the dependent variable of the model under consideration. It was also one of the critical challenges of public transportation in Durban. The equation is found in Chapter four sections 4.74 equation 6 & 7.

6.3.2. Bus Usage (U)

U was defined in the research as the population of the weaker section divided by the number of people in the population who needed public transportation. The level of bus usage was determined by the difference of distance travelled, population of the weaker section, and public bus usage resulting from social inclusivity. Bus usage was one of the characteristics included in the model to determine Social Inclusivity, which was proportional to frequency and inversely proportional to cost in units of ten. The equation is given in Section 4.74, Equation 4 in Chapter 4.

6.3.3. Frequency (F)

Frequency was one of the independent variables used in the model. It was defined as the number of times a bus leaves a node and returns to the same node. Its unit of measurement was time.

6.3.4. **Cost (C)**

Fare was another independent variable used in the model of accessibility of the Public Bus Transport Network of Durban. It was defined as the cost of the bus service charged from a region on the public transport network to another. Its unit of measurement was Rands. Fare and Cost are used interchangeably in the study.

6.3.5. **Social Inclusivity (S)**

Social Inclusion was identified and considered as one of the independent variables that would be useful in the model of accessibility of the public transportation of Durban. Its inclusion would make a major contribution to the knowledge in the study. From current literature it was evident that social inclusivity has not been used as a parameter to model accessibility and, further, has not been defined comprehensively (Lucas & Musso, 2014, Miriam et al., 2016, Gunaruwan & Jayasekera, 2015). Some definitions of social inclusivity are as follows.

According to the World Bank Group (Das and Das, 2016), social inclusion is the process of improving the ability, opportunity, and dignity of those who are disadvantaged due to their identity by changing the terms on which individuals and groups engage in society.

According to Siyka (2020), social inclusion is multi-faceted and influences different aspects of life, including economics, politics, culture, and social life. The integrating processes are not separate from one another. Young people's successful transit

through the educational system gives them with critical resources, such as information, skills, and attitudes, which they can use in other areas of their lives.

Social inclusion is multi-faceted, encompassing social, political, cultural, and economic components and operating at multiple social levels. Markets, services, and spaces are the three interconnected realms where the most important characteristics can be found. Social inclusion is a fluid concept that impacts people in different ways and to different degrees over time, and it is significantly influenced and dependent on people's talent, opportunity, and dignity, all of which are distributed unequally among social groups. Inequality is a notion that focuses on discrepancies between distinct groups of people. Social inclusion is a term that complements inequality. In the context of this study, social inclusivity is a function of the population of weaker sections, the distance they cover and their public bus usage. This was expressed in Equation (5) of section 4.7.4 in chapter 4.

In the current research, social inclusivity is defined as the share of people receiving discount, which equals the total economically weaker people receiving discount divided by the total economically weaker sections (Alves, 2013). Some bus operators give students 30% discount on Travel cards and Bus & Tram. They include consideration of people receiving social security and aged people from 65 years and above for transport fare reduction. This would help to improve accessibility in their localities and promote the use of public transportation to the cities. The unit of measurement is percentages.

6.3.6. Walking Time (WT)

In the modeling of the accessibility of public bus transit in Durban, WT was one of the independent variables. It was the time it took a passenger to walk from his/her region to the node/bus stop. Its unit of measurement was time.

In addition, model estimate of the parameters impacting the public bus transportation system was carried out to determine the model's efficacy. This produced the following model information: case processing summary, model continuous variable information, model goodness of fit, model omnibus test, test of the effects of the model, influential parameter estimates and covariance of parameter estimates.

Based on the factors mentioned above, the Log-Linked Negative Binominal Regression Model estimation was conducted. Before the model estimation was conducted, the validity and robustness of the model were checked. Table 6.1 shows the model goodness of fit predictors. It was found that the dispersion was close to 1.0 (value/df = 1.112), indicating that the data were not significantly dispersed. The Finite Sample Corrected AIC (AICC) and Akaike's Information Criterion (AIC) were also poor. Furthermore, for predictors, the model omnibus test value was found to be 0,05. (Table 6.2). These results revealed that the model was appropriate, resilient, and could be used to estimate model parameters.

Table 6.1: Model goodness of fit for predictors

	Value	df	Value/df
Deviance	54.509	49	1.112
Scaled Deviance	54.509	49	
Pearson Chi-Square	52.371	49	1.069
Scaled Pearson Chi-Square	52.371	49	
Log Likelihood b	-421.216		
Akaike's Information Criterion (AIC)	852.432		
Finite Sample Corrected AIC (AICC)	853.682		
Bayesian Information Criterion (BIC)	862.377		
Consistent AIC (CAIC)	867.377		

Source: Researcher's own construct.

Table 6.2: Model omnibus test for predictors

Likelihood Ratio Chi-Square	df	Sig.
117.645	3	.000

Source: Researcher's own construct.

6.3.7. Model Development for U

Table 6.3 shows the model results (solver results). The model for U is presented in equation (4). The values of U as shown is the unit raw data calculated for the purpose of the model. The details of model calculations and results are presented in appendix (G).

Table 6.3: Determination of the coefficient of the parameters of U (f/c)

	k	0.189434	Sum ssd	1.230471	
S/NO	F	C	U	U1	ssd
1	10	8	0.38	0.236793	0.020508
2	3	15	0.22	0.037887	0.033165
3	2	14	0.18	0.027062	0.02339
4	4	12	0.27	0.063145	0.042789
5	5	8	0.31	0.118397	0.036712
6	6	10	0.3	0.113661	0.034722
7	8	7	0.33	0.216497	0.012883
8	6	7	0.35	0.162372	0.035204
9	7	8	0.34	0.165755	0.030361
10	10	6	0.4	0.315724	0.007102
11	11	5	0.42	0.416756	1.05E-05
12	13	4	0.45	0.615662	0.027444

	k	0.189434	Sum ssd	1.230471	
S/NO	F	C	U	U1	ssd
13	12	4	0.43	0.568303	0.019128
14	11	3	0.43	0.694593	0.070009
15	8	6	0.35	0.252579	0.009491
16	9	6	0.37	0.284152	0.00737
17	6	10	0.28	0.113661	0.027669
18	12	7	0.43	0.324745	0.011079
19	13	6	0.39	0.410441	0.000418
20	12	9	0.34	0.252579	0.007642
21	15	6	0.44	0.473586	0.001128
22	10	8	0.38	0.236793	0.020508
23	3	15	0.22	0.037887	0.033165
24	2	14	0.18	0.027062	0.02339
25	4	12	0.27	0.063145	0.042789
26	5	8	0.31	0.118397	0.036712
27	6	10	0.3	0.113661	0.034722
28	8	7	0.33	0.216497	0.012883
29	6	7	0.35	0.162372	0.035204
30	7	8	0.34	0.165755	0.030361
31	10	6	0.4	0.315724	0.007102
32	11	5	0.42	0.416756	1.05E-05
33	13	4	0.45	0.615662	0.027444
34	12	4	0.43	0.568303	0.019128
35	11	3	0.43	0.694593	0.070009
36	8	6	0.35	0.252579	0.009491
37	9	6	0.37	0.284152	0.00737
38	7	8	0.31	0.165755	0.020807
39	6	10	0.28	0.113661	0.027669
40	13	6	0.39	0.410441	0.000418
41	12	9	0.34	0.252579	0.007642
42	15	6	0.44	0.473586	0.001128
43	10	8	0.38	0.236793	0.020508
44	3	15	0.22	0.037887	0.033165
45	2	14	0.18	0.027062	0.02339
46	4	12	0.27	0.063145	0.042789
47	5	8	0.31	0.118397	0.036712
48	6	10	0.3	0.113661	0.034722
49	8	7	0.33	0.216497	0.012883
50	6	7	0.35	0.162372	0.035204
51	7	8	0.34	0.165755	0.030361
52	10	6	0.4	0.315724	0.007102
53	11	5	0.42	0.416756	1.05E-05

	k	0.189434	Sum ssd	1.230471	
S/N0	F	C	U	U1	ssd
54	13	4	0.45	0.615662	0.027444

Source: Researcher's own construct.

The model equation is expressed as: $U=0.19*f/c$. U is defined in the research as the raw values for population of the economically weaker section divided by the number of people in the population that needed public transportation (Jansuwan et al., 2013; Chang et al., 2019).

6.3.8. Model Development for S

The model for social inclusivity is presented in equation (5). The model estimation results are presented in Table x and validation parameters are presented in Table y. It was found that all three indecent variables such as Dp, Pe, and U are statistically significant and influence social inclusivity.

The regression model results for the parameters of S are shown in Table 6.4.

Table 6.4: Model estimation results for social inclusivity

Summary Output								
<i>Regression Statistics</i>								
Multiple R	0.875659							
R Square	0.766778							
Adjusted R Square	0.752785							
Standard Error	0.048999							
Observations	54							
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>			
Regression	3	0.394683	0.131561	54.79609	7.89E-16			
Residual	50	0.120046	0.002401					
Total	53	0.514729						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-0.11899	0.065421	-1.81881	0.074932	-0.25039	0.012413	-0.25039	0.012413

Dp Variable 1	0.00721	0.003266	2.207904	0.031866	0.000651	0.013769	0.000651	0.013769
Pe Variable 2	0.009618	0.004072	2.362161	0.022103	0.00144	0.017796	0.00144	0.017796
U Variable 3	0.034459	0.003603	9.565279	7.02E-13	0.027223	0.041695	0.027223	0.041695

Source: Researcher's own construct.

The model equation is expressed as: $S=0.007*Pe+0.01*Dp+0.03*U-0.12$.

6.3.9. Model Development for Accessibility (without S)

Validity is shown in Table 6.5.

Table 6.5: Determination of NBR Model coefficients for accessibility without SI

Summary Output								
Regression Statistics								
Multiple R	0.95728283							
R Square	0.91639042							
Adjusted R Square	0.91137385							
Standard Error	520.56875							
Observations	54							
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>			
Regression	3	148508297	49502766	182.67254	6.25E-27			
Residual	50	13549591.2	270991.82					
Total	53	162057888						
	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95.0%</i>	<i>Upper 95.0%</i>
Intercept	-207.455211	695.031617	-0.298483	0.7665714	-1603.47	1188.557	-1603.4673	1188.556876
F Variable 1	482.951701	34.6937634	13.920418	7.896E-19	413.2672	552.6362	413.267226	552.6361752
C Variable 2	0.12620789	43.2571758	0.0029176	0.9976837	-86.7584	87.0108	-86.758387	87.01080253
WT Variable 3	-22.864332	38.2734331	-0.597394	0.5529401	-99.7388	54.01012	-99.738785	54.01012078

Source: Researcher's own construct.

Table 6.6 displays the model estimation results.

Table 6.6: Model parameter estimates for predictors (95% Wald Confidence Interval) hypothesis test

Parameter	B	Std. Error	Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	7.183	.2469	6.699	7.667	846.149	1	.000
F	.117	.0122	.093	.141	92.921	1	.000
C	-.038	.0154	-.068	-.008	6.114	1	.013
WT	.029	.0141	.002	.057	4.386	1	.036
(Scale)	1a						
(Negative binomial)	.035	.0068	.024	.051			

Source: Researcher's own construct.

The model equation is expressed as: $\ln(A) = 482.95*f + 0.13*c - 22.86*wt - 207.45$.

6.3.10. Model Development for Accessibility (with S)

Table 6.7 shows the validity.

Table 6.7: Determination of NBR Model coefficients for accessibility with SI

Summary Output								
Regression Statistics								
Multiple R	0.957301							
R Square	0.916425							
Adjusted R Square	0.909602							
Standard Error	525.7456							
Observations	54							
	df	SS	MS	F	Significance F			
Regression	4	1.49E+08	37128468	134.3246	9.14E-26			
Residual	49	13544016	276408.5					
Total	53	1.62E+08						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-181.812	724.7924	-0.25085	0.802981	-1638.34	1274.713	-1638.34	1274.71307
F Variable 1	481.3978	36.70715	13.11455	1.2E-17	407.6321	555.1636	407.6321	555.163609
C Variable 2	-1.94655	46.06056	-0.04226	0.966463	-94.5087	90.61562	-94.5087	90.6156162
WT Variable 3	-30.2907	65.02493	-0.46583	0.6434	-160.963	100.3818	-160.963	100.381782
S Variable 4	215.5118	1517.406	0.142026	0.887641	-2833.83	3264.853	-2833.83	3264.85306

Source: Researcher's own construct.

The model equation is expressed as: $\ln A = (481.39*f - 1.95*c - 30.29*wt + 215.51*s - 181.81)$.

The data correlation value, one-sample test (test value = 0,95 percent confidence interval of the difference), and VIF were all shown in Section 5.4.1 Table 5.19 of Chapter Five.

$$A = \text{LN}(482.95 * f + 0.13 * C - 22.86 * wt - 207.45).$$

6.3.11. Relative Influence of the Factors

The parameters used in the model estimation influenced it relatively, reflecting the current situation of the accessibility of the public transportation system.

The relative influence on the model was significant. The value of F was directly proportional, and C(cost) was inversely proportional to U, which implied that, when F was increased it increased the values of U. When C(cost) was decreased, it also had a positive influence on the value of U. The values of F and C invariably influenced the value of S sensitively.

The model parameters responded in the analysis according to how they were found to influence the model. It was evident that the introduction of social inclusivity positively influenced the accessibility of public bus transportation in Durban. It was evident also that some suburbs had more accessibility than others.

6.4. Simulated Scenarios

The model was used to simulate different scenarios which were considered to be relevant for the study. Simulations were performed to evaluate how the accessibility

of public transportation in Durban could be improved. Simulations were considered where the parameters of the model were increased from 10% up to 100% and decreased from 10% up to 50%. Frequency, Cost, Waiting Time, and Social Inclusivity were all increased to 100% to ascertain how this would influence the model.

6.4.1. Simulated Scenarios for Assessing Social Inclusivity

The social inclusion model was simulated to see how frequency and cost affected it. Because U is directly proportional to frequency and inversely proportional to cost, it was noted in the regression model that the value of (D_p) , which was in kilometers, altered the model because it changed. The model was also influenced by the economically disadvantaged population (P_e) , which represented a percentage of the overall population. The greater the distance between the two points, the better the result.

6.4.1.1. Conditions of simulation scenarios

When the base value (BS) conditions were normal, it was observed that some distances within the less disadvantaged group produced a negative value for the estimated social inclusivity.

6.4.1.2. Important scenarios to improve social inclusivity (SI)

The distances (D_p) less than 11km in the SI model were observed to generate negative values for the estimated SI model, indicating that any increase in the

distances would negatively affect the SI of accessibility of the public transportation in Durban. Moreover, if the value of U were increased to 100% it would significantly improve social inclusivity. It implies that it is practically possible to increase Usage to almost 100% (García-Olivares et al., 2018).

6.4.2. Simulated Scenarios for Accessibility without Social Inclusivity

The scenarios for accessibility without social inclusivity were performed by increasing the base data by 100% and decreasing them by 50% to observe the influence the parameters had on the model. The details of the simulations are shown in Appendix G.

6.4.2.1. Conditions of simulation scenarios

The conditions changed from the base value (business as usual) where the frequency of buses, cost of transportation, and waiting time is constant. They were increased by 100% because the influence on the model of 10% to 50% was insignificant (Cats,& Jenelius, 2018). In the case of decreasing the percentage, 50% was adopted for all the base values (Han et al., 2018, Ford et al., 2015, & Martínez et al., 2014). Table 6.8 shows the simulation conditions with positive results for accessibility without social inclusivity and the results with social inclusivity. Table 6.9 shows the best results for 10-15 scenarios.

Table 6.8: Conditions for simulations with good results

Without SI		With SI	
Change in variables	Simulation conditions	Change in variables	Simulation conditions
Frequency	Changing (increasing/ decreasing) waiting time by from 50% to 100%.	Frequency	Changing (increasing/ decreasing) waiting time by from 50% to 100%.
Cost	Changing (increasing/ decreasing)	Cost	Changing (Increasing/

	waiting time by from 50% to 100%.		decreasing) waiting time by from 50% to 100%.
Waiting Time	Changing (increasing/ decreasing) waiting time by from 50% to 100%.	Waiting time	Changing (increasing/ decreasing) waiting time by from 50% to 100%.
Frequency	Changing (increasing/ decreasing) Frequency 200%.	Frequency	Changing (increasing/ decreasing) Frequency 200%.

Source: Researcher's own construct.

Table 6.9: Best simulation results for 10 – 15 scenarios

Scenarios	Conditions Model of A without SI	Conditions Model of A with SI	Difference between BS and Simulated Scenarios (%)
S1	F 100% C, WT (BS)	F 100% C, WT,& S (BS)	
S2	F&C100%, WT (BS)	F, C, WT & S100%	
S3	F& WT 100% & C-50%	F 200%, C,WT,&S (BS)	
S4		S100%, F,C %WT(BS)	

Source: Researcher's own construct.

Table 6.10 to 6.12 show 10-15 simulated results of different scenarios performed according to Table 6.9.

Table 6.10: Simulation (S1) for A with S, F(100%), C & WT (BS)

S/N0	F (100%)	C	WT	A(f100)	Diff
1	20	8	10	9.13	0.74
2	6	15	3	7.87	0.80
3	4	14	2	7.43	0.86
4	8	12	5	8.17	0.79
5	10	8	4	8.42	0.76
24	4	14	2	7.43	0.86
25	8	12	5	8.17	0.79
26	10	8	4	8.42	0.76
27	12	10	7	8.60	0.76
28	18	7	7	9.03	0.87
49	16	7	7	8.90	0.74
50	12	7	7	8.60	0.76
51	14	8	9	8.76	0.76
52	10	6	11	8.38	0.00
53	22	5	10	9.23	0.74

Source: Researcher's own construct.

The simulation values are subtracted from the model's base value before simulation.

For instance, $A(100) - A = 9.13 - 8.39 = 0.74$. The rest of the values are found in

Appendix G.

Table 6.11: Simulation (S2) results for A without S, F&C (200%), & WT (BS)

S/N0	F (100%)	C (100)	WT	A(100%fc,wt)	Diff
1	20	16	10	9.13	0.74
2	6	30	3	7.87	0.80
3	4	28	2	7.43	0.86
4	8	24	5	8.17	0.79
5	10	16	4	8.42	0.76
24	4	28	2	7.43	0.86
25	8	24	5	8.17	0.79
26	10	16	4	8.42	0.76
27	12	20	7	8.60	0.76
28	18	14	7	9.03	0.87
49	16	14	7	8.90	0.74
50	12	14	7	8.60	0.76
51	14	16	9	8.76	0.76
52	10	12	11	8.38	0.00
53	22	10	10	9.23	0.74

Source: Researcher's own construct.

Table 6.12: The simulations (S3) if F100 & WT100 were increased by 100% & C-50 decreased by 50% for model without SI

S/N0	F (100%)	C(-50%)	WT(100%)	A(fwt100, c-50)	A1	Diff
1	20	4	20	9.10	8.39	0.72
2	6	7.5	6	7.85	7.07	0.78
3	4	7	4	7.40	6.57	0.83
4	8	6	10	8.14	7.38	0.75
5	10	4	8	8.40	7.66	0.74
23	6	7.5	6	7.85	7.07	0.78
24	4	7	4	7.40	6.57	0.83

25	8	6	10	8.14	7.38	0.75
26	10	4	8	8.40	7.66	0.74
28	18	3.5	14	9.01	8.16	0.85
49	16	3.5	14	8.88	8.16	0.72
50	12	3.5	14	8.57	7.84	0.73
51	14	4	18	8.72	8.00	0.73
52	10	3	22	8.32	8.38	-0.06
53	22	2.5	20	9.21	8.49	0.71

Source: Researcher's own construct.

The remaining scenarios have been included in Appendix G.

6.4.2.2. Important scenarios to improve accessibility

It was observed that, when the frequency of buses, cost of transportation, and waiting time were increased to 100%, there was a reasonable change in the accessibility model. It was also observed that the frequency of buses showed more influence on the accessibility model. By decreasing the parameters of the current situation (BS) by 50%, it was observed that, when the cost is reduced by 50%, the accessibility model was stable. Accessibility of public transportation was most improved when frequency and cost were increased to 100% (Koopmans et al., 2013).

6.4.3. Simulated Scenarios for Accessibility with Social Inclusivity

6.4.3.1. Conditions of simulation scenarios

When social inclusivity was introduced, there was a gradual, positive improvement in accessibility. The model parameters were all increased to observe the influence they had on the model. The simulations performed are shown in Appendix G.

6.4.3.2. Important scenarios to improve accessibility with social inclusivity (SI)

It was observed that, when the frequency of the buses was increased, this significantly improved the accessibility model. If SI were increased, it also improved the accessibility model gradually. The decrease of cost above 50% improved accessibility. Tables 6.13 to 6.16 below shows the best simulation results which positively improved the accessibility model.

Table 6.13: The simulations (S1)if F was increased by 100% for model with SI

S/No	F (100%)	C	WT	S	A2	A(f100)	Diff
1	20	8	10	0.37	8.39	9.13	0.74
2	6	15	3	0.21	7.08	7.88	0.80
3	4	14	2	0.12	6.58	7.43	0.85
4	8	12	5	0.20	7.39	8.17	0.79
5	10	8	4	0.31	7.68	8.43	0.75
23	6	15	3	0.10	7.06	7.87	0.81
24	4	14	2	0.10	6.57	7.43	0.85
25	8	12	5	0.20	7.39	8.17	0.79
26	10	8	4	0.18	7.66	8.42	0.76
28	18	7	7	0.21	8.16	9.02	0.87
50	12	7	7	0.18	7.83	8.60	0.76
51	14	8	9	0.31	8.00	8.75	0.76
52	10	6	11	0.37	8.38	8.38	0.00
53	22	5	10	0.38	8.49	9.23	0.73

Source: Researcher's own construct.

Table 6.14: The simulations (S2) if F, C, WT & S were increased by 100% for model with SI

S/N0	F (100%)	C (100)	WT(100%)	S(100)	A(100)	A2	Diff
1	20	16	20	0.74	9.10	8.39	0.71
2	6	30	6	0.43	7.85	7.08	0.77
3	4	28	4	0.24	7.39	6.58	0.81
4	8	24	10	0.40	8.13	7.39	0.75
5	10	16	8	0.62	8.41	7.68	0.73
23	6	30	6	0.20	7.83	7.06	0.77
24	4	28	4	0.20	7.38	6.57	0.81
25	8	24	10	0.40	8.13	7.39	0.75
26	10	16	8	0.36	8.40	7.66	0.73
28	18	14	14	0.42	9.00	8.16	0.85
45	4	28	4	0.22	7.39	6.57	0.81
46	8	24	10	0.40	8.13	7.39	0.75
47	10	16	8	0.30	8.39	7.66	0.74
50	12	14	14	0.36	8.56	7.83	0.73
52	10	12	22	0.74	8.32	8.38	-0.06

Source: Researcher's own construct.

Table 6.15: The simulations (S3) if F was increased by 200% for model with SI

S/N0	F(200)	C	WT	S	A2	A(f200)	Diff
1	40	8	10	0.37	8.39	9.84	1.46
2	12	15	3	0.21	7.08	8.62	1.54
3	8	14	2	0.12	6.58	8.19	1.61
4	16	12	5	0.20	7.39	8.91	1.52
5	20	8	4	0.31	7.68	9.15	1.47
23	12	15	3	0.10	7.06	8.61	1.55
24	8	14	2	0.10	6.57	8.19	1.62
25	16	12	5	0.20	7.39	8.91	1.52
26	20	8	4	0.18	7.66	9.14	1.48
27	24	10	7	0.30	7.84	9.32	1.48

45	8	14	2	0.11	6.57	8.19	1.62
46	16	12	5	0.20	7.39	8.91	1.52
47	20	8	4	0.15	7.66	9.14	1.48
48	24	10	7	0.21	7.83	9.32	1.49
52	20	6	11	0.37	8.38	9.12	0.74

Source: Researcher's own construct.

Table 6.16: Simulation (S4) results for A with S (100%)

S/No	F	C	WT	S(100)	A(S100)	A2(BS)	Diff
1	10	8	10	0.74	8.41	8.39	0.02
2	3	15	3	0.43	7.12	7.08	0.04
3	2	14	2	0.24	6.61	6.58	0.03
4	4	12	5	0.40	7.41	7.39	0.03
5	5	8	4	0.62	7.71	7.68	0.03
23	3	15	3	0.20	7.08	7.06	0.02
24	2	14	2	0.20	6.60	6.57	0.03
25	4	12	5	0.40	7.41	7.39	0.03
26	5	8	4	0.36	7.68	7.66	0.02
27	6	10	7	0.60	7.86	7.84	0.03
49	8	7	7	0.32	8.16	8.15	0.01
50	6	7	7	0.36	7.85	7.83	0.02
51	7	8	9	0.62	8.02	8.00	0.02
52	10	6	11	0.74	8.40	8.38	0.02
53	11	5	10	0.76	8.51	8.49	0.02

Source: Researcher's own construct.

Table 6.13 and 6.16 showed very important simulation results of dataset 52 marked in red. The introduction of social inclusivity improved the dataset results which had been zero and negative to a positive value improvement. The simulation was best when frequency was increased to 200% and the results improved significantly, even dataset 52 improved to 0.74. The remaining scenarios have been included in Appendix G.

Table 6.17: Simulation indicators

Simulation Indicator (m)	Interpretation
Negative values	Opposes improvement
Positive values	Shows improvement
Zero value	Shows stability

Source: *Researcher’s own construct.*

6.4.4. Comparative Analyses of Accessibility with and Without Social Inclusivity

The outcome of the comparison is shown in Table 6.18, considering S/No 52 of the parameters used in the simulation.

Table 6.18: Comparative analyses between accessibility without SI and with SI by using Table 6.16

Scenario	A(t)	Normal Conditions of Simulated Scenarios	Scenario	A(ts)	Including Social Inclusivity A(ts) under Simulated Scenarios	Compare between A(t) and AS(t) (m)
BS		8.39	BS		8.38	0.02
A(f100) 100%		9.13	S(100%)	100	8.40	

Source: *Researcher’s own construct.*

Table 6.18 shows a positive increase of 0.02 if the value of SI is increased to 100%, thus signifying that, if increased, social inclusivity improves the accessibility of public transportation. From the simulation performed on the parameter for the model with SI or without SI, the results were closely related, even the base values that showed A1 and A2 being the same. When the value of SI was increased to 100% it revealed relative improvement of all datasets, indicating that, when positively increased to a

higher percentage, social inclusivity certainly improves the accessibility of public bus transportation in Durban.

6.5. Summary of Critical Findings

It was observed that, when proper proceedings and methodologies are followed, the results are acceptable scientifically. The findings of this study showed that the independent variables used could solve public transportation challenges of similar degrees. The findings showed further that social inclusivity could be used to help to improve the usage of public bus transportation that was currently depreciating in patronage, measuring 10,2% compared with other modes of public transportation in the study area(Statistics SA, 2014:6).

The findings of this study also revealed that the frequency of buses has a significant impact on public bus accessibility. The independent variables of frequency cost and waiting time had significant correlations. The findings showed further that the independent variables (model parameters) have the capacity to improve the dependent variable (accessibility).

According to Chiou et al. (2015), Woldeamanuel & Kent (2016), Cao et al. (2010), Oviedo et al. (2019), and Chang et al. (2019), a positive difference indicates improved accessibility, while a negative difference indicates lack of accessibility, based on the nature of the model and simulations that demonstrated the accessibility of public bus transportation.

This study's findings support this assumption, thereby justifying the methods used in this study both theoretically and practically.

It was observed that, when the frequency of the bus was increased to 200%, accessibility of public bus transportation was improved most. Moreover, if social inclusivity were added to the modelling parameters, a gradual improvement in the accessibility parameters was evident. Although improvement was small, the accessibility of the public transportation of Durban was influenced positively.

The model also revealed that, if the coefficient of frequency is increased by a percentage or the coefficient of Cost is reduced by a percentage before considering social inclusivity, this would further improve the values of social inclusivity. The model showed further that, if the coefficient of Frequency, Fare (cost), and Waiting Time were increased by 100%, this would improve accessibility of public bus transportation. It was also observed from the model that, when social inclusivity is increased between different scales of percentages, this showed a gradual improvement in the accessibility of public bus transportation, according to the indicator Table6.22. Finally, the incorporation of social inclusivity in the model of public bus transportation accessibility in Durban is a unique feature of this research.

6.6. Guidelines for Improvement of the Public Bus Transport Network of Durban, South Africa

The intention of undertaking this study was to suggest some guidelines, deduced from the results of the analysis conducted, that would optimise the public bus transportation network of Durban as follows.

- 1) The policies on public transportation should be implemented fully to meet the transportation needs of the increasing populace of Durban South Africa.
- 2) It is necessary to construct and extend accessible roads to neighbouring suburbs to avoid persisting challenges to public transportation in Durban.
- 3) The roads constructed should be sizeable to avoid future challenges ,e.g. traffic congestion in Durban.
- 4) Speed limits must be enforced on the roads to caution drivers regarding road usage in Durban.
- 5) The stakeholders of public bus transportation must take a stand to strategise to ensure the security of buses in Durban.
- 6) The vehicles used must meet the minimum global standards for buses to assure comfort and functionality to commuters in Durban.
- 7) The bus capacity should be enough to convey passengers to and from their destinations within Durban South Africa.
- 8) There should not be any limitations on access to suburbs, cities, and regions within Durban and environs.
- 9) More buses should be assigned to regions considered to have less or poor accessibility within Durban.
- 10) A spatial approach should be considered in allocating transport routes to operators of buses in Durban.
- 11) Road services should be timely to avoid possible mishaps within Durban.
- 12) Public transportation routes in Durban should be improved to match global standards.
- 13) Social inclusivity should be maintained to avoid lower patronage in Durban.

- 14) Youths should be empowered or employed to reduce the pressures of social inclusivity so that they can pay for their fares to their destinations in Durban.
- 15) Waiting times should be as minimal as possible to improve frequency of buses in Durban.
- 16) Drainages that are not functioning should be cleared to help lengthen the life-span of the roads within Durban and environs.
- 17) When public bus transportation is effective it will improve bus hire by organisations that provide the services in Durban.

6.7. Conclusion

In this chapter, the results of model proceedings were examined, and they were aligned to the objectives of the study. Critical findings from the model simulation were presented in the chapter. It is noted that the objectives of the study were met, which culminated in the guidelines provided in Section 6.6. This made it possible to provide robust recommendations and conclusions in the final chapter.

Chapter Seven: Recommendations and Conclusion

7.1. Introduction

The goal of this study was to determine the purpose of public bus transportation in Durban's regions and suburbs, as well as alternative ways to improve the public bus network's accessibility in all areas. This necessitated the gathering of thorough planning and design criteria through extensive inquiry and review. It was successful in identifying and categorizing the various public bus transportation locations. Their status was examined, and social challenges to creating an effective public bus transportation system were identified. The factors that influence the accessibility of public bus transportation, such as bus frequency, cost, social inclusion, and waiting time, were analyzed and used to design a count model in the form of a Negative Binomial Regression Model to improve public bus transportation accessibility.

The data from primary and secondary sources were gathered, improved, and investigated to make them relevant to the study. Together with information from available and relevant literature, a series of statistical, GIS and model analyses were performed consistently at different times. The challenges presented by the research questions were resolved. The issues of public transportation accessibility were investigated, and a count model was devised to increase public transportation accessible.

7.2. Discussion of the Critical Findings in Alignment with the Research Objectives

With reference to the first research objective regarding the evaluation of the current public bus transport network of Durban, it was found, among other things, that

Durban

has a well-connected network of 337 roads and 203 bus stop facilities, according to the secondary data from CPTR (2012).

The reality of Durban's transportation network's accessibility was disclosed in relation to the second aim, which focused on a network analysis of public bus transportation. The public bus transportation is concentrated in the Central Business Districts and hearts of the cities. Some walking distances were commuter-friendly while others were not. It was found that 50% of the intervals chosen from 50 - 1500m were accessible, while the other 50% were not. It was found that accessibility was not related to the size of the region or suburbs, according to the network analysis of the study area.

With reference to the third objective, which was to examine the social inclusiveness of the current public bus transport network, it was observed that social inclusivity was a novel study in the public bus transportation of Durban. According to the outputs and deliverables of the model simulations, social inclusion has an impact on the accessibility model of the public bus transit system in Durban.

Given that the other predictor variables in the model were kept constant, a one-unit change in the predictor variable (either F, C, WT, or S) was predicted to change the

difference in the logs of expected counts by the respective regression coefficient for the fourth objective, which was to develop a public bus transportation model that would improve accessibility in Durban as a pilot study. This finding explains further that all the independent variables evaluated had the capacity to influence the dependent variable.

The findings of the study showed further that social inclusivity helped to improve the usage of public transportation that was currently depreciating in patronage in the study area. With different approaches available, the model indicated that frequency and social inclusivity were major contributors, among others, that could bring about the improvement of the accessibility of public bus transportation in Durban.

The proposed guidelines to improve the development of public bus transport network of Durban are highly relevant, as they are based on inferences from the reality of the study. They will help to enhanced public bus transit in Durban if they are executed correctly .As a result, all of the study's objectives were met.

7.3. Conclusion

It was evident that people could not connect easily to their desired location because of limited accessibility. The bus network system was still struggling to satisfy the challenges faced by the people accessing the cities and suburbs because of the current design of the transport network. Some identified challenges included lack of accessibility to the suburbs, affordability of public bus transportation, and the preference for mini-buses and taxis over public bus transportation. The spatial evaluation of the data acquired together with the methodology adopted and the

several analyses performed, it became clear that there was a need to address all the challenges related to public transportation. The model developed has the capacity to improve the accessibility the study's effectiveness was highlighted by the use of public bus transit (transportation) in Durban. Moreover, the existing theories supported the application of the Negative Binomial Regression Model (NBRM) to public transportation. The gaps identified in the literature review were also addressed effectively during the course of the study. The objectives of the research were all met satisfactorily as demonstrated in Chapters Four, Five and Six.

The critical findings of the study concur with the existing theories of using a modelling approach to solve challenges to public bus transportation.

7.4. Recommendations

From the insights gained from the study, it would be right to recommend that passengers should access and work with the schedules of the bus operators to get better service.

The guidelines outlined in the study should be implemented effectively to achieve and sustain the improvement of public bus transportation.

The model can be used as a pilot study in Durban. When it has been proven to be effective, it can be used to improve public bus transportation in other cities in South Africa to encourage patronage of public bus transportation. The model should be applied correctly to achieve the desired results.

7.5. Contributions of the Study

This research contributed to the accessibility of public bus transportation through the model developed in which parameters, such as frequency, cost, waiting time and social inclusivity are used as the factors that influence and can sustain public bus transportation. Social Inclusivity being the notable novelty contribution of the study.

The use of GIS to digitise spatial maps and tackle social concerns using an engineering and technology approach was another contribution to the body of knowledge.

7.6. Limitations of the Study

Some challenges were encountered during the research process that affected the results obtained.

The data acquired cannot be generalised globally because it applied specifically to the Durban the study area. The non-availability of transport route maps, which should have assisted in obtaining the details of transportation parameters, such as time, speed, distance, and routes, was a data constraint on the study. The Covid-19 pandemic which broke out at the time of data collection caused a major limitation to this study. It delayed the research because of the category of severe lockdowns observed at the time to reduce the spread of the virus.

7.7. Future Research Scope

The knowledge about the accessibility of public bus transportation should be extended. Future scope could be directed to using other types of modelling techniques applied in public transportation. A Bayesian inference approach could also be investigated to compare results.

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Appendix A: Definition of Some Terms Relevant for the Study

ACCESSIBILITY

Accessibility is defined by U.S. Department of Environment (1996) as “the ease and convenience of access to spatially distributed opportunities with a choice of travel.”

Accessibility depends on the transportation, temporal (time), and spatial location constraints which limit the ability of individuals to participate in productive activities (Odoki et al., 2001).

PRACTICAL IMPLICATION OF SOCIAL INCLUSIVITY

The process of enhancing the conditions under which people and groups participate in society improving the capacity, opportunity, and dignity of those who are disadvantaged due to their identity is called social inclusion. Social inclusivity is the process of making it easier for people and groups to participate in society. Via

markets (such as labour or finance), services (access to transportation, health and education), and venues, people participate in society Boardman et al., (2022) & Fisk et al., (2018).

Certain groups face obstacles that prohibit them from fully participating in transportation, political, economic, and social life in every nation. The groups may be excluded not just by the law, the market for real estate, transportation and the labour force, but also by stigmatising or discriminatory attitudes, beliefs, or perceptions. Disadvantage is frequently determined by a person's gender, age, place of residence, job, race, ethnicity, religion, citizenship status, ability, and, among other things. This type of social isolation deprives people of their dignity, sense of security, and chance to live a better life. It will be difficult to promote inclusive growth that is sustainable and quick poverty reduction if the underlying causes of structural exclusion and discrimination are not addressed Lucas (2012).

Social inclusion implies persons to maintain their dignity, sense of security, and chance at a better life. It has been repeatedly demonstrated how crucial it is to support people in feeling connected to and valued by society and to address any kind of social isolation that people may be dealing with on a daily basis. Focusing on the need to "put people first" in development processes, social sustainability and inclusion. By empowering people, creating cohesive and resilient societies, and making institutions accessible and answerable to citizens, it encourages social inclusion of the underprivileged and the vulnerable. Employee engagement and a sense of belonging are produced via inclusion. Organizations must embrace and promote involvement in order to have successful talent. Organizations must also ensure that their environments are inclusive and diverse Pittaway (2012).

The purpose of social inclusivity?

The benefits of inclusion include improved employee satisfaction, increased innovation, improved leadership skills and abilities, increased employee engagement, and a sense of belonging. An inclusive culture is crucial for attracting and keeping the kind of talent a company needs to thrive. Social inclusion can also help young people develop leadership skills, acceptance of those with and without impairments, and age-appropriate, socially desirable behaviours (Tillott et al., 2013 & Randel et al., 2018).

The aims of social inclusivity?

The aim of an inclusive society is respect for all fundamental freedoms and human rights, cultural and religious diversity, social justice and the unique needs of marginalized and vulnerable groups, democratic involvement, and the rule of law Moreno de la Santa (2020).

Some characteristics of social inclusivity?

Diversity is evident throughout the institution in social inclusivity. Both the labour and the consumer populations have a wide variety of cultures, customs, beliefs, languages, and lifestyles, all of which are recognised without prejudice DeLuca et al., (2022).

The barriers to social inclusivity?

Inequitable access to opportunities and resources, along with identity exclusion, stereotyping, and implicit bias, are some of the hurdles that contribute to the reproduction of racial and gendered inequality. It's morally right to promote social inclusiveness, and it also makes sound financial sense. Disadvantaged group exclusion can be expensive if ignored. The impacts that are most frequently

measured at the individual level include lost wages, lifetime earnings, inadequate schooling, and poor employment outcomes. Also harmful to one's physical and emotional health, racism and discrimination. Foregone GDP and human capital wealth can be used as measures of the economic cost of social exclusion at the national level Farrington & Farrington (2005).

MODELLING

A model is an abstraction of reality or a representation of a real object or situation.

To put abstract perception into reality.

List of different types of optimisation models used in public transportation design:

- i) Evaluation model in which an origin-destination (OD) matrix is assigned to a network and with which all kinds of evaluation characteristics are calculated. Such an evaluation model enables a systematic comparison between alternative network designs. Although the use of evaluation models must be considered as a major improvement to the quality of the planning process, the disadvantage remains that only a few alternatives can be compared because of the effort involved.
- ii) Analytical models use simplified networks to derive optimum relations for parameters of the public transport system, for instance, headway and route spacing. Models determining which links should be used to construct routes for a public transport network.
- iii) Models determining routes without considering the frequencies of the routes.
- iv) Models assigning frequencies to a given set of routes.
- v) Models determining routes in a first stage and assigning frequencies in a second stage.

vi) Models determining routes and frequencies simultaneously (Nes,1988).

POISSON REGRESSION MODEL

Poisson regression is a popular tool for modeling count data and is applied in a vast array of applications from the social to the physical sciences and beyond. Real data, however, are often over- or under-dispersed and, thus, not conducive to Poisson regression. Regression models as the most popular tool for modeling the relationship between a response variable and a set of predictors. In many applications, the response variable of interest is a count, that is, takes on non-negative integer values. (Kimberly &Gali,t2010).

A certain variable Y is considered to follow a Poisson distribution with a parameter μ if it takes on non-negative integer values $y= 0,1,2, 3, \dots$ with probability seen on the first equation for $\mu >0$.

OPTIMISATION

An act, process, or methodology of making something (such as a design, system, or decision) as fully perfect, functional, or effective as possible, specifically: the mathematical procedures (such as finding the maximum of a function) involved in this. Optimisation should be suited for several design problems ranging from short-term analyses to long-term decisions and predictions, meanwhile assigning frequencies, designing part of a network, and designing a complete network. It should be easily accessible and un P-TRANE.

P-TRANE is a simulation framework aimed to model the bus transit network evolution. P-TRANE is a GIS-based model that develops future predictions of service changes in the bus transit spatial network and service functionality at future time

steps. These changes happen because of the periodic service review process and are influenced by a group of variables, including the changes in the future transit ridership pattern and future land-use distribution changes. The main objective for P-TRANE is to function as a transit supply prediction component for the ILUTE simulation framework, by generating the future bus network (supply) information for ILUTE (Amrmohammed, 2014).

COMPLEX NETWORK

Complex networks are networks that feature patterns of connection between their elements that are neither purely regular nor purely random. Most real-world networks, such as transportation, social or gene-regulatory networks, are complex. It is a graph with non-trivial topological features that do not occur in simple networks such as lattices or random graphs but often occur in graphs modelling real systems components. Symmetry and heterogeneity statistics of many real networks were summarised, finding that real networks are more heterogeneous in the view of automorphism partition than what have been depicted under the measurement of degree-based entropies; and that structural heterogeneity is strongly negatively correlated to symmetry of real networks (Yang-Hua et al., 2008).

L-SPACE

L-space depicts the original configuration of real-life transport networks, in which stops or stations are vertices. Two vertices are connected if they are consecutive on an arbitrary route (Jingyi&Yifang, 2013).

P-SPACE

P-space is a new representation pattern. All the stops of a route can be connected because a directed line can be detected between one another; that is to say, if there

is at least one line connecting two nodes, then a link will be constructed between them (Sen et al., 2003). In computational complexity theory (mathematical field of topology), P-space is the set of all decision problems that can be solved by a Turing machine using a polynomial amount of space. It is a space in which there is the intersection of any countably, many open sets (Jingyi&Yifang, 2013) understandable for the end user (Nes, 1988).

Appendix B: Bus Transportation Details in Durban

Table Showing number of Bus Transportation Routes in Durban and distance in Km.

S/N	From Fac_Name Length(Km)	Destination Fac_Name	Mode	
0	Ntuzuma Bus Depot	Mitchell Park	Bus	33.361241
1	Ntuzuma Bus Depot	Morningside School	Bus	30.663219
2	Ntuzuma Bus Depot	Umlazi V	Bus	34.962117
3	Ntuzuma Bus Depot	Engen Refinery	Bus	42.074581
4	Ntuzuma Bus Depot	Durban North Hypermarket	Bus	23.921448
5	Ntuzuma Bus Depot	Umhlanga Rocks	Bus	29.611777
6	Ntuzuma Bus Depot	Point (Signal Road)	Bus	29.668858
7	Ndwedwe Rank	Lorne Street Rank	Bus	34.079061
8	Ndwedwe Rank	Pine Street Rank	Bus	35.558274
9	Osindisweni Rank	Tongaat Motor-Man	Bus	26.268578
10	Castle Hill Rank	Durban (Victoria Street Bus Rank)	Bus	15.615037
11	Castle Hill Rank	The Workshop	Bus	16.30219
12	KwaMashu K & J	King Edward Hospital	Bus	27.902307
13	KwaMashu K & J	Pine Street Rank	Bus	25.722078
14	KwaMashu K & J	Point (Signal Road)	Bus	27.327808
15	KwaMashu K & J	Umhlanga Rocks	Bus	23.945511
16	KwaMashu Stadium	Durban North Hypermarket	Bus	19.105724
17	KwaMashu Stadium	Point (Signal Road)	Bus	23.84181
18	KwaMashu Stadium	Umhlanga Rocks	Bus	23.852797
19	Newlands East Rank	Pinetown (KFC)	Bus	23.172141
20	Newlands East Rank	Point (Signal Road)	Bus	22.975027
21	Newlands East Rank	Bayhead	Bus	30.223902
22	Newlands East Rank	Gwala's House	Bus	31.282353
23	Newlands East Rank	Mobeni	Bus	24.569853
24	Newlands East Rank	Pavilion	Bus	13.041506
25	Newlands East Rank	Pine Street Rank	Bus	19.873822
26	Newlands East Rank	Umhlanga Rocks	Bus	24.730397
27	Isipingo Bus Rank	Kingsway	Bus	6.95728
28	Isipingo Bus Rank	Isipingo Tiger Rocks	Bus	11.839512
29	Isipingo Bus Rank	Pine Street Rank	Bus	18.350458
30	Isipingo Bus Rank	Madundube	Bus	24.10327
31	Isipingo Bus Rank	Fakazi	Bus	21.690457
32	Isipingo Bus Rank	Nkomokazi	Bus	41.309261
33	Isipingo Bus Rank	Mobeni	Bus	5.51297
34	Isipingo Bus Rank	Jacobs	Bus	9.079114
35	Umlazi	Z (Unit AA)	Bus	12.975667
36	Gijima	(Lamont)	Bus	12.011032
37	Prospecton	Marine Garage	Bus	11.381157
38	Prospecton	Umlazi Station	Bus	15.78062
39	Prospecton	Ntuzuma F	Bus	42.165024
40	Prospecton	Umlazi BB	Bus	14.014322
41	Castle Hill Rank	Durban (Victoria Street Bus Rank)	Bus	15.615037
42	Castle Hill Rank	The Workshop	Bus	16.30219
43	KwaNdengezi	Mpumalanga Magistrate Court	Bus	25.433103
44	KwaNdengezi	Pine Street Rank	Bus	36.095261
45	KwaNdengezi	Pinetown (Hill Street)	Bus	16.207843
46	KwaNdengezi	Pinetown (Hill Street) and New Germany	Bus	24.350822
47	Pinetown Hill Street Rank	Bredasfontein	Bus	38.125299
48	Pinetown Hill Street Rank	Durban (Victoria Street Bus Rank)	Bus	19.432539

49	Pinetown Hill Street Rank	Ekukhanyeni	Bus	46.808125
50	Pinetown Hill Street Rank to Amatikwe		Bus	33.778605
51	Pinetown Hill Street Rank to Kranskloof (K.K) Sewerage		Bus	8.585785
52	Pinetown Hill Street Rank to Mpumalanga Unit 1		Bus	37.408494
53	Pinetown Hill Street Rank to Nyuswa		Bus	28.66814
54	Pinetown Hill Street Rank to Amatikwe Ext		Bus	38.149424
55	KK Sewerage to Ntuzuma E		Bus	28.197503
56	KK Sewerage to Pine Street Rank		Bus	22.605753
57	KK Sewerage to Point (Signal Road)		Bus	26.037451
58	KK Sewerage to Reservoir Hills		Bus	8.613905
59	KK Sewerage to Pinetown U.D.W		Bus	16.056376
60	KK Sewerage to Westmead		Bus	13.576042
61	KwaNdengezi to Mpumalanga Magistrate Court		Bus	25.433103
62	KwaNdengezi to Pine Street Rank		Bus	36.095261
63	KwaNdengezi to Pinetown (Hill Street)		Bus	16.207843
64	KwaNdengezi to Pinetown (Hill Street) and New Germany		Bus	24.350822
65	Isipingo Bus Rank to Pinetown		Bus	27.534215
66	Isipingo Bus Rank to Orient		Bus	4.307017
67	Isipingo Bus Rank to Lotus		Bus	2.999059
68	Isipingo Bus Rank to Clairwood		Bus	9.801398
69	Verulam Bus Rank to Buffelsdraai		Bus	8.630629
70	Verulam Bus Rank to Kwajoji	Bus	15.375065	
71	Verulam Bus Rank to Lorne Street Bus Rank (Durban)		Bus	34.828438
72	Verulam Bus Rank to Enkangala		Bus	17.420607
73	Verulam Bus Rank to Ekukhanyeni		Bus	17.159301
74	Verulam Bus Rank to Sonkombo		Bus	16.518176
75	Verulam Bus Rank to Mzinyathi		Bus	24.852642
76	Verulam Bus Rank to Ntaphuka		Bus	17.420607
77	Verulam Bus Rank to Etafuleni		Bus	16.601984
78	Verulam Bus Rank to Zwelitsha		Bus	6.81277
79	Verulam Bus Rank to Oaklands		Bus	4.227564
80	Verulam Bus Rank to Umhlanga		Bus	17.367927
81	Verulam Bus Rank to Ndwedwe		Bus	25.253295
82	Verulam Bus Rank to Mt Edgecome		Bus	8.74584
83	Verulam Bus Rank to Ezimbomvini		Bus	14.300727
84	Verulam Bus Rank to Tongaat		Bus	12.992626
85	Isipingo Bus Rank to Pinetown		Bus	27.533809
86	Isipingo Bus Rank to Mshiyeni Hospital Rank	Bus	5.804168	
87	Isipingo Bus Rank to Orient		Bus	4.307017
88	Isipingo Bus Rank to Lotus		Bus	2.999059
89	Isipingo Bus Rank to Clairwood		Bus	9.80099
90	Isipingo Bus Rank to Umlazi F&G		Bus	9.032947
91	NtuzumaMashonisa Rank to Pinetown (Kentucky) (A005)		Bus	37.349346
92	NtuzumaMashonisa Rank to Pinetown (Kentucky) (A005)		Bus	40.029727
93	NtuzumaMashonisa Rank to Pinetown (Kentucky) (A005)		Bus	40.029727
94	NtuzumaMashonisa Rank to Pinetown (Kentucky) (A005)		Bus	35.363298
95	NtuzumaMashonisa Rank to Pinetown (Kentucky) (A005)		Bus	34.355227
96	NtuzumaMashonisa Rank to Pinetown (Kentucky) (A005)		Bus	34.248045
97	NtuzumaMashonisa Rank to Pinetown (Kentucky) (A005)		Bus	46.389671
98	NtuzumaMashonisa Rank to Pinetown (Kentucky) (A005)		Bus	38.529108
99	NtuzumaMashonisa Rank to Pinetown (Kentucky) (A005)		Bus	43.763566
100	NtuzumaMashonisa Rank to Kranskloof (A012)		Bus	43.24853
101	NtuzumaMashonisa Rank to Checkers Umlazi C (B002)		Bus	54.588092
102	NtuzumaMashonisa Rank to Umlazi V (B006)		Bus	49.608875
103	NtuzumaMashonisa Rank to Umlazi V (B006)		Bus	52.38742
104	NtuzumaMashonisa Rank to Prospecton (C007)		Bus	48.518571
105	NtuzumaMashonisa Rank to Prospecton (C007)		Bus	49.160483
106	Ntuzuma Mashonisa Rank to UKZN (Westville) (D029)		Bus	27.090193
107	Ntuzuma Mashonisa Rank to Prison Westville (D062)		Bus	32.443611
108	Ntuzuma Mashonisa Rank to Soldiers Bus Rank (E004)		Bus	34.313187

109 Ntuzuma Mashonisa Rank to Soldiers Bus Rank (E004)	Bus	32.658703
110 Ntuzuma Mashonisa Rank to Soldiers Bus Rank (E004)	Bus	31.986403
111 Ntuzuma Mashonisa Rank to Pine Street Rank 2 (E006)	Bus	28.80509
112 Ntuzuma Mashonisa Rank to Pine Street Rank 2 (E006)	Bus	29.786021
113 Ntuzuma Mashonisa Rank to Point (Signal Road) (E008)	Bus	29.720111
114 Ntuzuma Mashonisa Rank to Point (Signal Road) (E008)	Bus	30.730799
115 Ntuzuma Mashonisa Rank to Point (Signal Road) (E008)	Bus	31.536409
116 Ntuzuma Mashonisa Rank to Point (Signal Road) (E008)	Bus	32.486398
117 Ntuzuma Mashonisa Rank to Mobeni 1 (F027)	Bus	39.632489
118 Ntuzuma Mashonisa to Chesterville (F002)	Bus	37.700691
119 Ntuzuma Mashonisa Rank to Marine Garage (F021)	Bus	50.495624
120 Ntuzuma Mashonisa Rank to Marine Garage (F021)	Bus	45.581239
121 Ntuzuma Mashonisa Rank to Engen Refinery (F022)	Bus	45.234252
122 Ntuzuma Mashonisa Rank to Engen Refinery (F022)	Bus	41.53722
123 Ntuzuma Mashonisa Rank to Brighton Beach (F023)	Bus	51.198545
124 Ntuzuma Mashonisa Rank to Fynnland (F024)	Bus	47.363506
125 Ntuzuma Mashonisa Rank to Bayhead (F025)	Bus	40.229242
126 Ntuzuma Mashonisa Rank to Glenmore Francois (F028)	Bus	34.343075
127 Ntuzuma Mashonisa Rank to Mitchell Park (F029)	Bus	33.985088
128 Ntuzuma Mashonisa Rank to Morningside School (F031)	Bus	30.766997
129 Ntuzuma Mashonisa Rank to Hypermarket (G048)	Bus	29.793016
130 Ntuzuma Mashonisa Rank to Hypermarket (G048)	Bus	29.722349
131 Ntuzuma Mashonisa Rank to Umhlanga Rocks (H010)	Bus	28.779418
132 Ntuzuma Mashonisa Rank to Umhlanga Rocks (H010)	Bus	28.39261
133 Ntuzuma Mashonisa Rank to Umhlanga Rocks (H010)	Bus	31.9206
134 Ntuzuma Mashonisa Rank to Umhlanga Rocks (H010)	Bus	42.93798
135 Ntuzuma Mashonisa Rank to Umhlanga Rocks (H010)	Bus	41.879656
136 Ntuzuma Mashonisa Rank to La Lucia Mall (H011)	Bus	28.476996
137 Ntuzuma Mashonisa Rank to La Lucia Mall (H011)	Bus	32.724983
138 Inanda Police Station to Point (Signal Road) (E008)	Bus	31.336572
139 Amaotana to Umhlanga Rocks (H010)	Bus	20.369049
140 Amaotana to Soldiers Bus Rank (E004)	Bus	29.755881
141 Amaotana to Pine Street Rank 3 (E007)	Bus	32.953215
142 Amaotana to Point (Signal Road) (E008)	Bus	40.959713
143 Amaotana to Point (Signal Road) (E008)	Bus	40.959713
144 Amaotana to Point (Signal Road) (E008)	Bus	32.80124
145 Amaotana to Bayhead (F025)	Bus	41.237882
146 Amaotana to Umhlanga Rocks (H010)	Bus	20.369049
147 Mamba Rank to Mansfield Bus Rank (E002)	Bus	29.411641
148 Mamba Rank to Mansfield Bus Rank (E002)	Bus	32.645471
149 Mamba Rank to Mansfield Bus Rank (E002)	Bus	33.084315
150 Magwaveni/Frazer to Tongaat Bus Rank (H006)	Bus	8.813234
151 Magwaveni/Frazer to UKZN (Durban Campus) (F035)	Bus	53.67741
152 Magwaveni/Frazer to Pinetown (Kentucky) (A005)	Bus	64.527992
153 Mount Edgecombe to Verulam Bus Rank (H007)	Bus	18.049971
154 Tongaat Bus Rank to M4 Municipal Boundary (H020)	Bus	10.08676
155 Tongaat Bus Rank to R102 Municipal Boundary (H004)	Bus	8.146113
156 Tongaat Bus Rank to R102 Municipal Boundary (H004)	Bus	8.146113
157 Tongaat Bus Rank to R614 Municipal Boundary (H021)	Bus	7.443898
158 Tongaat Bus Rank to R614 Municipal Boundary (H021)	Bus	7.443898
159 Tongaat Bus Rank to R614 Municipal Boundary (H021)	Bus	7.443898
160 Tongaat Bus Rank to R614 Municipal Boundary (H021)	Bus	7.443898
161 Tongaat Bus Rank to R614 Municipal Boundary (H021)	Bus	7.443898
162 Tongaat Bus Rank to R614 Municipal Boundary (H021)	Bus	7.443898
163 Tongaat Bus Rank to R614 Municipal Boundary (H021)	Bus	7.443898
164 Tongaat Bus Rank to R614 Municipal Boundary (H021)	Bus	7.443898
165 Tongaat Bus Rank to R614 Municipal Boundary (H021)	Bus	7.443898
166 Tongaat Bus Rank to R102 Municipal Boundary (H004)	Bus	8.146113
167 Tongaat Bus Rank to Soldiers Bus Rank (E004)	Bus	46.026528
168 Tongaat Bus Rank to Newtown (H026)	Bus	5.80577

169 Tongaat Bus Rank to Burbreeze (H025)	Bus	5.406283
170 Tongaat Bus Rank to R102 Municipal Boundary (H004)	Bus	8.146113
171 Tongaat Bus Rank to Mgwani (H036)	Bus	5.160883
172 Tongaat Bus Rank to Frasers (H027)	Bus	8.585656
173 Tongaat Bus Rank to D800 Municipal Boundary (H022)	Bus	7.353742
174 Tongaat Bus Rank to D800 Municipal Boundary (H022)	Bus	7.353742
175 Tongaat Bus Rank to D800 Municipal Boundary (H022)	Bus	7.353742
176 Tongaat Bus Rank to La Mercy (H051)	Bus	18.498469
177 Tongaat Bus Rank to Hambanati (H030)	Bus	5.225325
178 Tongaat Bus Rank to Fire Tower (H028)	Bus	5.192772
179 Tongaat Bus Rank to Moola's Farm (H076)	Bus	4.299533
180 Tongaat Bus Rank to Harry's Farm (H077)	Bus	4.590268
181 Tongaat Bus Rank to R614 Municipal Boundary (H021)	Bus	7.443898
182 Tongaat Bus Rank to R614 Municipal Boundary (H021)	Bus	7.443898
183 Tongaat Bus Rank to R614 Municipal Boundary (H021)	Bus	7.443898
184 Tongaat Bus Rank to R614 Municipal Boundary (H021)	Bus	7.443898
185 Tongaat Bus Rank to Redfern (Phoenix) (H014)	Bus	34.462893
186 Tongaat Bus Rank to Buffelsdale (H035)	Bus	4.960798
187 Tongaat Bus Rank to Buffelsdale (H035)	Bus	6.275033
188 Tongaat Bus Rank to Flamingo Heights (H034)	Bus	5.821535
189 Tongaat Bus Rank to Flamingo Heights (H034)	Bus	7.13577
190 Tongaat Bus Rank to Belvedere (H033)	Bus	7.332919
191 Tongaat Bus Rank to Belvedere (H033)	Bus	8.647154
192 Tongaat Bus Rank to Gwala's Farm (H032)	Bus	8.485049
193 Tongaat Bus Rank to Umhlanga Hospital (H054)	Bus	26.578985
194 Durban (Victoria Street Bus Rank to Chatsworth Unit 2 (F005)	Bus	18.755773
195 Durban (Victoria Street Bus Rank to Chatsworth Unit 3A (F009)	Bus	20.135675
196 Durban (Victoria Street Bus Rank to Chatsworth 3 B (F064)	Bus	19.735801
197 Durban (Victoria Street Bus Rank to Silverglen (F065)	Bus	24.302093
198 Durban (Victoria Street Bus Rank to Chatsworth 5 B (F062)	Bus	23.370241
199 Durban (Victoria Street Bus Rank to Chatsworth 5 A (F063)	Bus	23.28777
200 Durban (Victoria Street Bus Rank to Warangal Road (F069)	Bus	22.614453
201 Durban (Victoria Street Bus Rank to S J Smith Hostels (F078)	Bus	14.025055
202 Durban (Victoria Street Bus Rank to Mpumalanga Unit 1 (D019)	Bus	52.317109
203 Durban (Victoria Street Bus Rank to Mpumalanga Unit 6 (D017)	Bus	49.46228
204 Durban (Victoria Street Bus Rank to Mpumalanga Unit 4 (D018)	Bus	51.146049
205 Durban (Victoria Street Bus Rank to eMophela Bus (D021)	Bus	56.205939
206 Durban (Victoria Street Bus Rank to Geogedale Bus (D020)	Bus	49.014271
207 Durban (Victoria Street Bus Rank to Chatsworth 7 (F060)	Bus	25.391334
208 Durban (Victoria Street Bus Rank to Chatsworth 11 (F056)	Bus	24.885667
209 Durban (Victoria Street Bus Rank to Chatsworth 3 B (F064)	Bus	20.151616
210 Durban (Victoria Street Bus Rank to Chatsworth 10 (F066)	Bus	22.419913
211 Durban (Victoria Street Bus Rank to D1102 Municipal Boundary (D022)	Bus	69.494605
212 Durban (Victoria Street Bus Rank to Hill Street Bus Rank (A004)	Bus	20.988852
213 Durban (Victoria Street Bus Rank to kwaNdengezi (D001)	Bus	35.510052
214 Durban (Victoria Street Bus Rank to kwaNdengezi (D001)	Bus	36.846112
215 Durban (Victoria Street Bus Rank to kwaNdengezi (D001)	Bus	33.678303
216 Durban (Victoria Street Bus Rank to Intake (D005)	Bus	32.20976
217 Durban (Victoria Street Bus Rank to TafelkopMguni (C011)	Bus	40.251263
218 Durban (Victoria Street Bus Rank to Motala Store (D004)	Bus	31.803301
219 Durban (Victoria Street Bus Rank to Chiltern (Shallcross) (F019)	Bus	25.911843
220 Durban (Victoria Street Bus Rank to Wiggins (F090)	Bus	9.804539
221 Durban (Victoria Street Bus Rank to Wiggins (F090)	Bus	9.928098
222 Durban (Victoria Street Bus Rank to Bonela (F091)	Bus	8.133131
223 Durban (Victoria Street Bus Rank to Bonela (F091)	Bus	8.256691
224 Durban (Victoria Street Bus Rank to Phoenix Plaza (H002)	Bus	27.721908
225 Durban (Victoria Street Bus Rank to Isipingo Bus Rank (C009)	Bus	17.871953
226 Durban (Victoria Street Bus Rank to Joyner Road (C022)	Bus	22.493993
227 Durban (Victoria Street Bus Rank to Folweni A (C001)	Bus	31.877749
228 Durban (Victoria Street Bus Rank to Isipingo Beach (C010)	Bus	22.147724

229 Durban (Victoria Street Bus Rank to Lotus Park Bus (C015)	Bus	26.034335
230 Durban (Victoria Street Bus Rank to Malakazi Bus (C014)	Bus	23.362054
231 Durban (Victoria Street Bus Rank to Shell Refinery (C008)	Bus	21.541561
232 Lorne Street Bus Rank to Ngoza (G018)	Bus	57.84311
233 Lorne Street Bus Rank to Gawula Store (G019)	Bus	44.500791
234 Lorne Street Bus Rank to P100 (W) Municipal Boundary (G022)	Bus	43.610203
235 Lorne Street Bus Rank to P100 (W) Municipal Boundary (G022)	Bus	43.610203
236 Lorne Street Bus Rank to P100 (W) Municipal Boundary (G022)	Bus	43.610203
237 Lorne Street Bus Rank to P100 (W) Municipal Boundary (G022)	Bus	43.610203
238 Lorne Street Bus Rank to P100 (W) Municipal Boundary (G022)	Bus	43.610203
239 Lorne Street Bus Rank to Amatata (G024)	Bus	41.850327
240 Lorne Street Bus Rank to Inanda SAP (G006)	Bus	26.388096
241 Lorne Street Bus Rank to eMatikwe Ext. (G008)	Bus	31.760792
242 Lorne Street Bus Rank to eKukhanyeni (G009)	Bus	40.765728
243 Lorne Street Bus Rank to Gqokazi Bus (G026)	Bus	33.199191
244 Lorne Street Bus Rank to Effingham Road (G041)	Bus	13.307581
245 Lorne Street Bus Rank to Greenwood Park (G042)	Bus	10.37372
246 Lorne Street Bus Rank to Rosary Road (G043)	Bus	10.321662
247 Lorne Street Bus Rank to Kenville Bus (G044)	Bus	10.844073
248 Lorne Street Bus Rank to Bailey Road (G045)	Bus	11.875016
249 Lorne Street Bus Rank to Siyanda West Bus (G031)	Bus	17.779172
250 Lorne Street Bus Rank to Siyanda East Bus (G032)	Bus	17.961745
251 Lorne Street Bus Rank to Riverdene Bus (G033)	Bus	22.261027
252 Lorne Street Bus Rank to Valleydale (G035)	Bus	19.52846
253 Lorne Street Bus Rank to Hippo Road (G037)	Bus	11.783345
254 Lorne Street Bus Rank to Parlock (G038)	Bus	12.714966
255 Lorne Street Bus Rank to Duffs Road (G039)	Bus	23.944126
256 Lorne Street Bus Rank to Whitehouse (H059)	Bus	18.491614
257 Lorne Street Bus Rank to Pinetown (Kentucky) (A005)	Bus	25.801091
258 Lorne Street Bus Rank to UKZN (Westville) (D029)	Bus	14.684577
259 Lorne Street Bus Rank to Reservoir Hills Annet (F079)	Bus	16.194605
260 Lorne Street Bus Rank to Reservoir Hills Shannon (F080)	Bus	21.706363
261 Soldiers Way to Ngcolosi Pass (D048)	Bus	46.349906
262 Soldiers Way to Mbeje Store (G015)	Bus	50.564704
263 Soldiers Way to Shezi Store (G016)	Bus	46.729159
264 Soldiers Way to Umgeni Drift (G017)	Bus	38.061317
265 Soldiers Way to Umgeni Drift (G017)	Bus	33.13195
266 Soldiers Way to Ntabende (G020)	Bus	31.921898
267 Soldiers Way to Nyoni (G021)	Bus	33.853596
268 Soldiers Way to Ntuzuma E (G002)	Bus	37.611354
269 Soldiers Way to Ntuzuma E (G002)	Bus	43.150527
270 Soldiers Way to Ntuzuma E (G002)	Bus	33.353776
271 Soldiers Way to Ntuzuma E (G002)	Bus	28.968965
272 Soldiers Way to Ntuzuma F (G003)	Bus	42.470111
273 Soldiers Way to Ntuzuma F (G003)	Bus	30.268137
274 Soldiers Way to Umlazi Station (B001)	Bus	28.929411
275 Soldiers Way to Umlazi Station (B001)	Bus	29.890194
276 Soldiers Way to Umlazi Station (B001)	Bus	32.605483
277 Soldiers Way to Umlazi Station (B001)	Bus	33.566266
278 Soldiers Way to Umlazi Station (B001)	Bus	31.53941
279 Soldiers Way to Umlazi Station (B001)	Bus	32.500193
280 Soldiers Way to Umlazi BB (B003)	Bus	30.753995
281 Soldiers Way to Umlazi BB (B003)	Bus	28.49507
282 Soldiers Way to Umlazi BB (B003)	Bus	29.574869
283 Soldiers Way to Umlazi BB (B003)	Bus	29.455853
284 Soldiers Way to Umlazi BB (B003)	Bus	29.165301
285 Soldiers Way to Umlazi U (B005)	Bus	27.696548
286 Soldiers Way to Umlazi U (B005)	Bus	28.657331
287 Soldiers Way to Umlazi Z (Unit AA) (B004)	Bus	33.420639
288 Soldiers Way to Umlazi Z (Unit AA) (B004)	Bus	34.09087

289 Soldiers Way to Gijima (Lamont) (F001)	Bus	22.763606
290 Soldiers Way to Gijima (Lamont) (F001)	Bus	22.166989
291 Soldiers Way to Sparks (F084)	Bus	7.461666
292 Soldiers Way to Burnwood Road (F085)	Bus	7.895412
293 Soldiers Way to Isipingo Bus Rank (C009)	Bus	19.217228
294 Soldiers Way to Quarry Road West (F082)	Bus	10.562858
295 Soldiers Way to Quarry Road West (F082)	Bus	10.573357
296 Soldiers Way to Palmiet Road (F083)	Bus	9.606082
297 Soldiers Way to Nerina Road (F086)	Bus	10.083488
298 Soldiers Way to Crescent Street (F088)	Bus	6.492109
299 Soldiers Way to Alpine Road (F089)	Bus	8.161031
300 Soldiers Way to Amaotana (G025)	Bus	29.776221
301 Soldiers Way to Amaotana (G025)	Bus	35.722389
302 Yellowwood Pine Street Rank to Goqokazi Bus (G026)	Bus	37.054873
303 Yellowwood Pine Street Rank to Fannin (A013)	Bus	29.346569
304 Yellowwood Pine Street Rank to Kranskloof (A012)	Bus	31.589092
305 Yellowwood Pine Street Rank to Indunduma Bus (A010)	Bus	26.653307
306 Yellowwood Pine Street Rank to Kranskloof (A012)	Bus	31.408396
307 Yellowwood Pine Street Rank to Kranskloof (A012)	Bus	43.280947
308 Market Taxi Rank (Overport) to Umhlanga Rocks (H010)	Bus	22.576272
309 Market Taxi Rank (Overport) to North beach (E048)	Bus	4.920235
310 Market Taxi Rank (Overport) to South Beach (E036)	Bus	4.426175
311 Durban Station Rank to eMatikwe Ext. (G008)	Bus	39.622728
312 Durban Station Rank to Inanda Old Post Office (G051)	Bus	35.946438
313 Morningside School to Pine Street Rank 1 (E005)	Bus	8.258071
314 Morningside School to Pine Street Rank 1 (E005)	Bus	8.571041
315 La Lucia Mall to eMatikwe Ext. (G008)	Bus	29.444389
316 La Lucia Mall to Mawothi (G010)	Bus	25.92013
317 La Lucia Mall to Gwala's House (G001)	Bus	34.527059
318 La Lucia Mall to Gwala's House (G001)	Bus	37.112026
319 La Lucia Mall to Ntuzuma E (G002)	Bus	28.58446
320 La Lucia Mall to Gwala's House (G001)	Bus	31.790142
321 La Lucia Mall to kwaMashu K & J (G028)	Bus	22.281603
322 La Lucia Mall to West Street 1 (E020)	Bus	18.81921
323 Fannin to Pine Street Rank 3 (E007)	Bus	28.809854
324 Fannin to Pinetown (Kentucky) (A005)	Bus	11.67803
325 Fannin to Ntuzuma E (G002)	Bus	41.699357
326 Kranskloof (K.K) Rank to Pine Street Rank 3 (E007)	Bus	25.597034
327 Kwambiza to Victoria Bus Rank (E001)	Bus	41.723372
328 Kwambiza to Victoria Bus Rank (E001)	Bus	43.116562
329 Kwambiza to Victoria Bus Rank (E001)	Bus	36.625994
330 Kwambiza to Chatsworth Unit 9 (F008)	Bus	19.17117
331 Kwambiza to Klaarwater Bus (D010)	Bus	14.205357
332 Kwambiza to St Wendolins (D007)	Bus	14.591015
333 Kwambiza to Mariannridge (D011)	Bus	15.291462
334 Kwambiza to Desai's Store (D003)	Bus	7.272801
335 Kwambiza to Pinetown (Kentucky) (A005)	Bus	21.764277
336 Kwambiza to Hill Street Bus Rank (A004)	Bus	21.615747
337 St Wendolins Rank 2 to Victoria Bus Rank (E001)	Bus	34.362849

SOUTH TIMETABLE: UMLAZI BB - ROUTE 4



MONDAY-FRIDAY FROM UMLAZI BB						MONDAY-FRIDAY TO UMLAZI BB					
ROUTE NO.	TIME	TO	ROUTE NO.	TIME	TO	ROUTE NO.	TIME	FROM	ROUTE NO.	TIME	FROM
208	04.30	Point	200	07.05	City	201	05.35	City	225	15.55	Jacobs Crossing
203	04.45	Mahogany Ridge	200	07.30	City	202	06.40	City	216	16.05	Sydenham
218	04.45	Fynnlans	200	08.00	City	208	06.55	Point	290	16.15	Chief Albert LH
208	05.00	Point	200	08.30	City	228	07.00	Westmead	222	16.15	Marine Garage
206	05.15	Umhlanga Rocks	200	09.00	City	216	07.05	Sydenham	208	16.20	Point
216	05.20	Sydenham	200	09.20	City	290	07.15	Chief Albert LH	228	16.20	Westmead
215	05.20	S.A Containers	200	09.40	City	218	07.35	Fynnlans	203	16.30	Mahogany Ridge
290	05.20	Chief Albert LH	200	10.00	City	200	08.00	City	237	16.40	Manor Gardens
203	05.25	Mahogany Ridge	200	10.40	City	200	09.20	City	233	16.40	Sapreff
220	05.30	Brighton Beach	200	11.15	City	200	10.00	City	215	16.40	S.A Containers
218	05.30	Fynnlans	200	12.00	City	200	11.15	City	208	16.45	Point
222	05.40	Marine Garage	222	12.30	Oil Refinery	200	12.30	City	218	16.45	Brighton Beach
207	05.45	Point	200	12.45	City	200	13.00	City	205	16.45	City
229	05.45	Westmead	200	14.05	City	290	13.30	Chief Albert LH	203	17.00	Mahogany Ridge
226	05.50	Afritex	290	14.40	Chief Albert LH	200	13.30	City	235	17.10	W.ville University
233	05.50	Sapreff	200	14.45	City	222	13.55	St Mary's School	206	17.10	Umhlanga Rocks
237	05.50	Manor Gardens	263	15.00	Gijima	218	14.10	Jacobs Crossing	205	17.15	City
208	05.55	Point	204	15.00	Mahogany Ridge	200	14.15	City	208	17.30	Point
203	06.00	Mahogany Ridge	208	15.30	Point	229	14.25	Westmead	216	18.05	Sydenham
218	06.05	Fynnlans	220	15.40	Brighton Beach	208	14.30	Point	229	18.10	Westmead
220	06.10	Brighton Beach	237	15.40	Manor Gardens	218	14.45	Brighton Beach	290	18.30	Westville Pavilion
225	06.10	Jacobs Crossing	200	16.15	City	225	14.50	Jacobs Crossing	209	19.10	Point
208	06.15	Point	290	16.30	Chief Albert LH	213	14.50	Umbilo	200	20.00	City
235	06.20	W.ville University	216	16.30	Sydenham	200	15.00	City	200	20.30	City
207	06.30	Point	222	16.55	Oil Refinery	200	15.20	City	200	21.00	City
218	06.30	Fynnlans	208	17.45	Point	200	15.40	City	232	22.10	Oil Refinery
200	06.40	City	200	18.45	City	230	15.45	Prospecton	208	22.15	Point
225	07.00	Jacobs Crossing	200	19.45	City	200	15.55	City			
226	07.00	Afritex	208	20.30	Point						
217	07.00	Westville Pavilion									

SATURDAY FROM UMLAZI BB						SATURDAY TO UMLAZI BB					
ROUTE NO.	TIME	TO	ROUTE NO.	TIME	TO	ROUTE NO.	TIME	FROM	ROUTE NO.	TIME	FROM
200	04.15	City	200	10.55	City	200	05.45	City	200	14.50	City
206	05.30	Umhlanga Rocks	205	11.25	City	218	06.10	Fynnlans	200	15.20	City
216	05.30	Sydenham	200	11.35	City	202	06.40	City	200	16.00	City
290	05.30	Chief Albert LHosp	200	12.15	City	230	07.00	Prospecton	222	16.10	Oil Refinery
229	06.00	Westmead	200	12.40	City	216	07.05	Sydenham	200	16.40	City
200	06.25	City	200	13.00	City	222	07.05	Marine Garage	229	16.45	Westmead
220	06.30	Brighton Beach	200	13.45	City	290	07.15	Chief Albert LHosp	200	17.05	City
205	06.50	City	200	14.30	City	200	09.00	City	206	17.10	Umhlanga Rocks
217	07.00	Westville Pavilion	200	15.15	City	200	10.00	City	217	17.30	Westville Pavilion
200	07.15	City	208	15.50	Point	200	10.30	City	200	17.35	City
200	07.40	City	200	16.00	City	200	11.00	City	200	18.00	City
200	08.00	City	216	16.30	Sydenham	200	11.30	City	232	18.05	Oil Refinery
200	08.25	City	208	17.00	Point	200	12.00	City	216	18.05	Sydenham
200	08.55	City	200	18.15	City	200	12.30	City	200	18.55	City

Source: <https://www.godurban.co.za/services-and-timetables/>

SOUTH TIMETABLE: UMLAZI M&R - ROUTE 2



MONDAY-FRIDAY FROM UMLAZI STATION VIA M&R SECTION						MONDAY-FRIDAY TO UMLAZI STATION VIA M&R SECTION					
ROUTE NO.	TIME	TO	ROUTE NO.	TIME	TO	ROUTE NO.	TIME	FROM	ROUTE NO.	TIME	FROM
200	04.10	City	200	08.00	City	208	05.30	Point	220	15.55	Fynnlands
208	04.30	Point	200	08.10	City	219	05.55	Fynnlands	216	16.05	Sydenham
218	04.40	Fynnlands	200	08.20	City	233	05.55	Sapreff	200	16.10	City
233	04.50	Sapreff	200	08.30	City	208	06.00	Point	226	16.10	Clairwood Hosp
200	04.50	City	200	08.40	City	215	06.45	S.A Containers	222	16.25	Marine Garage
226	04.50	Afritex	200	09.00	City	204	06.45	Mahogany Ridge	206	16.30	Umlhanga Rocks
203	05.00	Mahogany Ridge	200	09.20	City	203	07.15	Mahogany Ridge	205	16.30	City
208	05.10	Point	200	09.40	City	290	07.15	Chief Albert LH	237	16.35	Francois Road
222	05.10	Oil Refinery	200	10.00	City	200	07.45	City	200	16.40	City
229	05.15	Westmead	200	10.20	City	200	09.15	City	207	16.40	Point
206	05.15	Umlhanga Rocks	200	10.40	City	200	09.45	City	210	16.40	Phoenix Ind.Park
210	05.20	Phoenix	200	11.00	City	200	10.15	City	218	16.40	Brighton Beach
203	05.20	Mahogany Ridge	200	11.20	City	200	10.45	City	239	16.40	City Electrical
216	05.20	Sydenham	200	11.30	City	200	11.15	City	203	16.40	Mahogany Ridge
290	05.20	Chief Albert LH	200	11.40	City	200	11.45	City	233	16.40	Sapreff
215	05.20	S.A Containers	223	12.05	St Mary's School	200	12.00	City	215	16.45	S.A Containers
200	05.30	City	200	12.20	City	200	12.15	City	205	16.45	City
203	05.30	Mahogany Ridge	200	12.40	City	200	12.30	City	228	16.45	Pinetown
218	05.30	Fynnlands	200	13.00	City	200	12.45	City	220	16.50	Fynnlands
222	05.30	Marine Garage	200	13.30	City	200	13.15	City	203	17.00	Mahogany Ridge
207	05.35	Point	200	14.30	City	208	13.15	Point	200	17.15	City
233	05.40	Sapreff	207	15.20	Point	200	13.50	City	207	17.15	Point
208	05.50	Point	208	15.40	Point	222	13.55	St Mary's School	218	17.20	Fynnlands
233	05.55	Sapreff	233	15.45	Sapreff	218	14.10	Brighton Beach	233	17.40	Sapreff
203	06.00	Mahogany Ridge	203	16.00	Mahogany Ridge	226	14.10	Clairwood Hosp	200	18.00	City
218	06.00	Fynnlands	208	16.00	Point	200	14.10	City	223	18.05	Oil Refinery
237	06.05	Manor Gardens	290	16.30	Chief Albert LH	208	14.30	Point	203	18.05	Mahogany Ridge
229	06.15	Westmead	216	16.30	Sydenham	200	14.30	City	216	18.05	Sydenham
200	06.20	City	223	17.00	Oil Refinery	216	14.40	Sydenham	290	18.15	Chief Albert LH
218	06.25	Fynnlands	209	17.30	Point	218	14.40	Brighton Beach	222	18.30	Marine Garage
220	06.30	Brighton Beach	200	19.00	City	213	14.45	Umbilo	208	18.45	Point
207	06.35	Point	200	19.45	City	225	14.45	Jacobs Crossing	208	19.15	Point
200	07.00	City	234	20.15	City	229	15.00	Westmead	208	19.45	Point
220	07.00	Brighton Beach	232	20.45	Jacobs (Dbn Bags)	200	15.00	City	200	20.30	City
200	07.15	City	208	21.00	Point	218	15.15	Brighton Beach	200	21.30	City
200	07.30	City	208	22.00	Point	200	15.20	City	232	22.10	Jacobs (Dbn Bags)
						230	15.45	Prospecton	208	22.20	Point

SATURDAY FROM UMLAZI STATION VIA M&R SECTION						SATURDAY TO UMLAZI STATION VIA M&R SECTION					
ROUTE NO.	TIME	TO	ROUTE NO.	TIME	TO	ROUTE NO.	TIME	FROM	ROUTE NO.	TIME	FROM
200	04.15	City	200	09.30	City	200	06.00	City	229	13.30	Westmead
218	05.00	Fynnlands	200	09.45	City	218	06.05	Fynnlands	202	13.45	City
234	05.00	City	200	10.00	City	208	06.10	Point	200	14.00	City
208	05.30	Point	200	10.10	City	202	06.45	City	200	14.15	City
229	05.30	Westmead	200	10.15	City	222	07.00	Marine Garage	200	14.45	City
216	05.30	Sydenham	200	10.50	City	233	07.00	Sapreff	200	15.15	City
230	05.45	Prospecton	200	11.10	City	216	07.05	Sydenham	230	15.40	Prospecton

Source: <https://www.godurban.co.za/services-and-timetables/>

NORTH TIMETABLE: NEWLANDS EAST - NEW DAWN PARK



MONDAY-FRIDAY FROM NEWLANDS EAST						MONDAY-FRIDAY TO NEWLANDS EAST					
ROUTE NO.	TIME	TO	ROUTE NO.	TIME	TO	ROUTE NO.	TIME	FROM	ROUTE NO.	TIME	FROM
818	05.30	Point	817	08.00	City	817	07.00	City	827	16.30	Mahogany Ridge
813	05.30	Prince Mshyeni H.	815	08.00	City	815	08.30	City	825	16.30	Bayhead
827	05.30	Mahogany Ridge	823	08.00	Westville Shop.C	815	10.30	City	818	16.35	Point
822	05.45	Bayhead	828	08.00	Umlhlanga Rocks	815	11.30	City	815	16.40	City
817	05.50	City	815	08.30	City	815	12.30	City	815	17.10	City
824	06.15	Westmead	815	09.30	City	815	13.00	City	828	17.10	Umlhlanga Rocks
828	06.20	Umlhlanga Rocks	815	10.30	City	815	14.00	City	823	17.10	Westville Shop.C
817	06.35	City	815	11.30	City	817	14.30	City	818	17.30	Point
821	06.45	Point	815	12.35	City	815	15.00	City	823	19.15	Westville Pavilion
823	07.00	Westville Shop.C	815	16.10	City	821	16.00	Point	815	22.00	City
821	07.30	Point	815	18.15	City	817	16.10	City			

SATURDAY FROM NEWLANDS EAST						SATURDAY TO NEWLANDS EAST					
ROUTE NO.	TIME	TO	ROUTE NO.	TIME	TO	ROUTE NO.	TIME	FROM	ROUTE NO.	TIME	FROM
823	07.00	Westville Shop.C	815	09.30	City	818	07.15	Point	815	13.45	City
817	07.00	City	815	10.00	City	815	08.00	City	815	14.05	City
828	07.00	Umlhlanga Rocks	815	11.00	City	815	10.00	City	815	14.45	City
815	07.30	City	817	12.00	City	815	10.30	City	815	15.15	City
815	08.00	City	815	12.30	City	815	11.00	City	817	16.00	City
815	08.30	City	815	13.00	City	815	11.30	City	828	17.10	Umlhlanga Rocks
815	09.00	City				815	12.00	City	817	17.15	City
						815	12.35	City	823	17.15	Westville Pavilion
						815	13.05	City	815	18.15	City
						818	13.05	Point	823	19.15	Westville Pavilion

SUNDAY FROM NEWLANDS EAST						SUNDAY TO NEWLANDS EAST					
ROUTE NO.	TIME	TO	ROUTE NO.	TIME	TO	ROUTE NO.	TIME	FROM	ROUTE NO.	TIME	FROM
823	08.00	Westville Shop.C	817	12.00	City	817	13.00	City	828	17.10	Umlhlanga Rocks
828	09.00	Umlhlanga Rocks	817	14.00	Point	817	14.30	City	817	17.40	City
817	09.00	City	821	19.00	Point	815	15.30	City	823	19.15	Westville Pavilion
815	10.00	City				823	16.15	Westville Pavilion			

Source: <https://www.godurban.co.za/services-and-timetables/>



CENTRAL TIMETABLE: MT VERNON - MALVERN

FROM MT VERNON-MALVERN						TO MT VERNON-MALVERN					
ROUTE NO.	TIME	TO	ROUTE NO.	TIME	TO	ROUTE NO.	TIME	FROM	ROUTE NO.	TIME	FROM
112	05.45	City	112	11.00	City	104	08.15	City	101	15.30	City
104	06.10	City	103	11.45	City	112	10.00	City	112	16.00	City
112	06.10	City	112	13.15	City	113	12.15	City	108	16.10	City
108	06.40	City	100	14.15	City	105	13.15	City	103	16.20	City
118	06.45	City	112	14.45	City	112	13.45	City	118	16.30	City
100	07.00	City	110	15.15	City	103	14.15	City	108	16.40	City
108	07.05	City	103	15.40	City	105	14.40	George Campbell S	112	16.45	City
112	07.40	City	110	15.45	City	103	15.00	City	103	17.00	City
103	08.15	City	112	16.15	City	112	15.15	City	103	17.45	City
104	09.15	City									

SATURDAY FROM MT VERNON-MALVERN						SATURDAY TO MT VERNON-MALVERN					
ROUTE NO.	TIME	TO	ROUTE NO.	TIME	TO	ROUTE NO.	TIME	FROM	ROUTE NO.	TIME	FROM
103	06.25	City	100	10.45	City	103	07.40	City	113	13.15	City
113	07.10	City	112	11.45	City	102	08.25	City	103	14.00	City
100	07.30	City	100	13.25	City	112	08.55	City	103	15.00	City
103	08.20	City	112	14.10	City	100	10.05	City	103	16.15	City
104	09.00	City	103	14.40	City	113	10.45	City	103	17.15	City
112	09.50	City	110	17.55	City	102	12.40	City			

SUNDAY FROM MT VERNON-MALVERN						SUNDAY TO MT VERNON-MALVERN					
ROUTE NO.	TIME	TO	ROUTE NO.	TIME	TO	ROUTE NO.	TIME	FROM	ROUTE NO.	TIME	FROM
103	07.30	City	103	15.30	City	103	08.45	City	103	14.45	City
103	09.30	City	103	17.25	City	103	12.45	City	103	16.45	City
110	13.30	City									

Source: <https://www.godurban.co.za/services-and-timetables/>

Morningside to/from City



MONDAY-FRIDAY FROM MORNINGSIDE						MONDAY-FRIDAY TO MORNINGSIDE					
ROUTE NO.	TIME	TO	ROUTE NO.	TIME	TO	ROUTE NO.	TIME	FROM	ROUTE NO.	TIME	FROM
33	06,20	City	33	12,30	City	33	06,15	City	21	15,00	City
21	06,30	City	21	12,45	City	21	06,20	City	21	15,50	City
33	06,45	City	21	13,15	City	33	06,45	City	21	16,00	City
21	07,05	City	21	15,30	City	33	06,50	City	33	16,00	City
33	07,15	City	21	16,25	City	21	07,00	City	33	16,15	City
33	07,25	City	33	16,30	City	33	07,20	City	21	16,20	City
21	07,35	City	21	16,35	City	21	07,40	City	33	16,35	City
33	07,55	City	33	16,45	City	21	08,05	City	33	16,45	City
21	08,15	City	21	16,55	City	33	08,15	City	21	16,55	City
21	08,45	City	21	17,05	City	21	09,00	City	21	17,00	City
33	09,00	City	21	17,15	City	33	09,20	City	33	17,05	City
21	09,30	City	21	17,25	City	21	10,00	City	33	17,20	City
33	10,00	City	21	17,30	City	21	10,30	City	21	17,30	City
33	10,30	City	33	17,35	City	21	11,00	City	21	17,40	City
21	11,15	City	33	18,00	City	33	11,15	City	21	17,45	City
33	11,30	City	21	18,10	City	21	12,00	City	33	18,05	City
21	11,45	City	33	18,15	City	33	12,15	City	21	18,15	City
						33	12,45	City			

SATURDAY FROM MORNINGSIDE						SATURDAY TO MORNINGSIDE					
ROUTE NO.	TIME	TO	ROUTE NO.	TIME	TO	ROUTE NO.	TIME	FROM	ROUTE NO.	TIME	FROM
33	06,20	City	21	09,30	City	33	06,15	City	21	13,50	City
21	06,30	City	33	09,50	City	21	06,20	City	33	14,00	City
33	06,45	City	21	14,25	City	33	06,50	City	21	14,00	City
21	07,05	City	33	14,30	City	21	07,00	City	33	14,15	City
33	07,25	City	21	14,30	City	33	07,20	City	21	14,55	City
21	07,35	City	33	14,45	City	21	07,40	City	21	15,00	City
33	07,55	City	21	15,25	City	21	08,05	City	33	15,05	City
21	08,15	City	21	15,30	City	33	08,15	City	33	15,20	City
21	08,45	City	33	15,35	City	21	09,00	City	33	16,05	City
33	09,00	City	33	16,00	City	33	09,20	City	21	16,15	City

SUNDAY FROM MORNINGSIDE						SUNDAY TO MORNINGSIDE					
ROUTE NO.	TIME	TO	ROUTE NO.	TIME	TO	ROUTE NO.	TIME	FROM	ROUTE NO.	TIME	FROM
21	08,30	City	33	13,00	City	21	08,00	City	33	12,30	City
33	09,00	City	21	13,30	City	33	08,30	City	21	13,00	City
21	09,30	City	33	14,00	City	21	09,00	City	33	13,30	City
33	10,00	City	33	15,00	City	33	09,30	City	33	14,30	City
21	10,30	City	33	16,00	City	21	10,00	City	33	15,30	City
33	11,00	City	21	16,30	City	33	10,30	City	21	16,00	City
21	11,30	City	33	17,00	City	21	11,00	City	33	16,30	City
33	12,00	City	21	17,30	City	33	11,30	City	21	17,00	City
21	12,30	City				21	12,00	City			

Source: <https://www.godurban.co.za/services-and-timetables/>

Musgrave road via Berea Road



MONDAY-FRIDAY						MONDAY-FRIDAY					
FROM MUSGRAVE ROAD CIRCLE VIA BEREA ROAD						TO MUSGRAVE ROAD CIRCLE VIA BEREA ROAD					
ROUTE NO.	TIME	TO	ROUTE NO.	TIME	TO	ROUTE NO.	TIME	FROM	ROUTE NO.	TIME	FROM
43	06,25	City	43	10,05	City	41	06,00	City	41	10,30	City
41	06,35	City	43	10,50	City	43	06,15	City	41	13,35	City
41	06,50	City	43	14,05	City	43	06,30	City	43	15,00	City
43	07,15	City	41	15,20	City	41	06,50	City	41	15,45	City
41	07,25	City	43	16,05	City	43	07,05	City	41	16,00	City
41	07,35	City	43	16,20	City	43	07,15	City	43	16,00	City
43	07,55	City	41	16,20	City	41	07,30	City	43	16,10	City
43	08,05	City	41	16,30	City	41	07,40	City	43	16,15	City
41	08,15	City	41	16,40	City	41	07,50	City	41	16,45	City
43	08,15	City	43	17,10	City	43	07,55	City	43	16,50	City
41	08,25	City	41	17,10	City	43	08,05	City	43	17,00	City
43	08,55	City	43	17,35	City	43	08,25	City	41	17,15	City
41	09,00	City	43	17,55	City	41	08,30	City	41	17,35	City
43	09,10	City	41	18,00	City	41	08,45	City	43	17,40	City
41	09,30	City	43	18,20	City	43	09,00	City	41	18,00	City
43	09,35	City	43	19,20	City	41	09,00	City	43	18,20	City
41	10,00	City	41	19,20	City	43	09,25	City	41	18,30	City
						43	09,30	City	41	19,00	City
						41	09,30	City	43	19,00	City

SATURDAY						SATURDAY					
FROM MUSGRAVE ROAD CIRCLE VIA BEREA ROAD						TO MUSGRAVE ROAD CIRCLE VIA BEREA ROAD					
ROUTE NO.	TIME	TO	ROUTE NO.	TIME	TO	ROUTE NO.	TIME	FROM	ROUTE NO.	TIME	FROM
43	06,25	City	43	10,05	City	41	06,00	City	41	09,30	City
41	06,50	City	43	10,50	City	43	06,30	City	41	10,30	City
43	07,15	City	41	14,20	City	41	06,50	City	43	14,00	City
41	07,35	City	43	14,20	City	43	07,15	City	41	14,00	City
43	08,05	City	41	15,10	City	41	07,40	City	41	14,45	City
41	08,25	City	43	15,10	City	43	08,05	City	43	14,50	City
43	08,55	City	43	15,55	City	43	08,25	City	41	15,35	City
41	09,00	City	41	16,00	City	41	08,30	City	43	15,40	City
41	09,30	City				43	08,55	City	41	16,30	City

SUNDAY						SUNDAY					
FROM MUSGRAVE ROAD CIRCLE VIA BEREA ROAD						TO MUSGRAVE ROAD CIRCLE VIA BEREA ROAD					
ROUTE NO.	TIME	TO	ROUTE NO.	TIME	TO	ROUTE NO.	TIME	FROM	ROUTE NO.	TIME	FROM
41	07,20	City	43	14,20	City	43	07,00	City	41	14,00	City
43	07,50	City	43	16,20	City	41	07,30	City	41	16,00	City
41	08,20	City	41	16,45	City	43	08,00	City	43	16,25	City
41	09,20	City	43	16,50	City	43	09,00	City	41	16,30	City
43	10,20	City	43	17,15	City	41	10,00	City	41	16,55	City
43	10,50	City	41	17,35	City	41	10,30	City	43	17,15	City
43	11,50	City	43	17,40	City	41	11,30	City	41	17,20	City
41	12,50	City				43	12,30	City			

Source: <https://www.godurban.co.za/services-and-timetables/>

CENTRAL TIMETABLE: DURBAN NORTH - UMHLANGA ROCKS



MONDAY-FRIDAY						MONDAY-FRIDAY					
FROM DURBAN NORTH-UMHLANGA ROCKS						TO DURBAN NORTH-UMHLANGA ROCKS					
ROUTE NO.	TIME	TO	ROUTE NO.	TIME	TO	ROUTE NO.	TIME	FROM	ROUTE NO.	TIME	FROM
716	07.15	City	716	16.10	Market	716	06.15	Market	716	08.00	Market
716	08.00	Market	716	16.30	City-Gijima	716	06.30	Market	716	09.00	Market
706	08.20	City	701	16.30	Market	716	07.00	Market	716	12.00	Market
716	08.30	Market	701	16.35	Market	701	07.05	Market	706	16.10	City
716	09.00	Market	716	16.35	Market	706	07.10	City	716	17.05	Market
716	10.00	Market	716	17.10	Market	701	07.20	City	716	18.10	Market
716	13.00	Market	716	18.10	Market	716	07.30	Market			
716	15.00	Market	716	19.10	Market						
716	15.30	City									

SATURDAY						SATURDAY					
FROM DURBAN NORTH-UMHLANGA ROCKS						TO DURBAN NORTH-UMHLANGA ROCKS					
ROUTE NO.	TIME	TO	ROUTE NO.	TIME	TO	ROUTE NO.	TIME	FROM	ROUTE NO.	TIME	FROM
716	07.05	City-Market	716	16.35	City-Market	716	06.15	Market-City	716	12.30	Market-City
716	07.15	City-Market	716	17.15	City-Market	716	06.10	Market-City	716	16.15	Market-City
716	09.00	City-Market	716	19.10	City-Market	716	08.00	Market-City	716	18.10	Market-City
716	13.30	City-Market									

SUNDAY						SUNDAY					
FROM DURBAN NORTH-UMHLANGA ROCKS						TO DURBAN NORTH-UMHLANGA ROCKS					
ROUTE NO.	TIME	TO	ROUTE NO.	TIME	TO	ROUTE NO.	TIME	FROM	ROUTE NO.	TIME	FROM
716	07.15	City-Market	716	17.15	City-Market	716	06.10	Market-City	716	16.15	Market-City
716	09.00	City-Market	716	19.10	City-Market	716	08.00	Market-City	716	18.10	Market-City
716	16.15	City-Market				716	08.30	Market-City			

Source: <https://www.godurban.co.za/services-and-timetables/>

CENTRAL TIMETABLE: UMBILO

MONDAY-FRIDAY FROM UMBILO						MONDAY-FRIDAY TO UMBILO					
ROUTE NO.	TIME	TO	ROUTE NO.	TIME	TO	ROUTE NO.	TIME	FROM	ROUTE NO.	TIME	FROM
22	06.30	South Beach	7	11.30	City	23	07.00	South Beach	7	14.00	City
7	06.30	City	7	13.30	City	7	07.00	City	22	14.30	South Beach
22	07.10	South Beach	22	14.30	South Beach	23	07.45	South Beach	7	15.00	City
7	07.30	City	7	14.30	City	7	08.00	City	7	16.00	City
7	08.30	City	23	15.00	South Beach	7	09.00	City	23	16.35	South Beach
7	09.30	City	7	15.30	City	7	11.00	City	7	17.00	City
7	10.30	City	7	16.30	City	7	12.00	City	7	17.30	City
						7	13.00	City			

SATURDAY FROM UMBILO						SATURDAY TO UMBILO					
ROUTE NO.	TIME	TO	ROUTE NO.	TIME	TO	ROUTE NO.	TIME	FROM	ROUTE NO.	TIME	FROM
7	07.00	City	7	11.30	City	7	07.30	City	7	12.00	City
7	08.00	City	7	12.00	City	7	08.30	City	7	13.00	City
7	09.00	City	7	13.00	City	7	09.30	City	7	14.00	City
7	10.00	City	7	14.30	City	7	10.00	City	7	15.00	City
7	10.30	City	7	16.30	City	7	10.30	City	7	16.00	City
7	11.00	City	7	17.30	City	7	11.00	City	7	17.00	City
						7	11.30	City			

SUNDAY FROM UMBILO						SUNDAY TO UMBILO					
ROUTE NO.	TIME	TO	ROUTE NO.	TIME	TO	ROUTE NO.	TIME	FROM	ROUTE NO.	TIME	FROM
7	08.30	City	7	12.00	City	7	08.00	City	7	13.30	City
7	09.00	City	7	13.00	City	7	09.30	City	7	14.30	City
7	10.00	City	7	15.00	City	7	10.30	City	7	15.30	City
7	11.00	City				7	11.30	City	7	16.30	City
						7	12.30	City			

Source: <https://www.godurban.co.za/services-and-timetables/>

Durban CBD Bus Service

A high quality wheelchair friendly bus service operates on the routes shown on this map



- KEY**
- T Transfer points
 - Beach Line
 - City Line
 - Circle Line



BUSES DEPART EVERY 15 MINUTES FROM 05H00 TO 22H00 - DAILY

Fares: R5.50 Single trip; R16 Day pass

Free Transfer only at Transfer Points (T) - valid within 60 minutes of ticket issue

<p>Beach Line</p> <ul style="list-style-type: none"> T 1. Beach Terminal 2. Victoria Park T 3. KE Masinga 4. Playfair 5. Sol Harris 6. Sandown 6A. Blue Waters 7. Suncoast 8. Kings Park 9. The Wheel 10. Prince 11. Hospital 	<p>City Line</p> <ul style="list-style-type: none"> 12. Bell 13. Ushaka 14. Timeball 15. Signal 16. Mahatma Gandhi 17A. Point 17. Florence Nzama 18. Mills T 19. Playhouse 20. Devonshire 20A. Parry 	<ul style="list-style-type: none"> 21. Dullah Omar T 22. Anton Lembede 22A. Bishopsgate 23. Brook 24. Julius Nyerere 25. Warwick Terminal 26. ML Sultan 27. Carlisle 28. Johannes Nkosi 29. Dr Yusuf Dadoo T 29A. Madressa 30. Dr Pixley KaSeme 30A. West Walk 31. Joe Slovo 	<ul style="list-style-type: none"> T 32. City Hall 32A. SARS 33. Union 34. Farewell <p>Circle Line</p> <ul style="list-style-type: none"> T 3. KE Masinga 42. City Lodge 43. ICC 44. Exhibition Centre 45. Reserve Bank T 46. History Museum 47. Maritime Museum 	<ul style="list-style-type: none"> 48. Dick King 49. Yacht Mole 50. Albert Park T 50A. McArthur 51. Post Office T 52. Victoria Market 53. Berta Mkhize Parkade 54. Soldiers Way 56. City Engineers 57. Durban Station 58. The Courthouse 59. UNISA
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* Discounted concession and Muvo card fares are available. Contact our Muvo Call Centre on 0800 00 6886.



Source: <https://www.godurban.co.za/services-and-timetables/>

Appendix D: Public Bus Transportation Fares in Durban of the Bus Operators Managed by EtheKwini Transport Authority

PEAK TIMES

STAGES	CASH	10 JOURNEY (Muvo Card)	12 JOURNEY (Muvo Card)
Stage 1	R 11.50	R 110.50	R 132.00
Stage 2	R 13.50	R 113.00	R 137.00
Stage 3	R 15.00	R 122.50	R 146.50
Stage 4	R 19.00	R 135.50	R 161.50
Stage 5	R 22.00	R 155.50	R 188.50
Stage 6	R 23.50	R 167.00	R 200.50
Stage 7	R 26.50	R 174.00	R 207.00
Stage 8	R 29.50	R 180.50	R 214.00
Stage 9	R 32.00	R 182.50	R 221.00
Stage 10	R 34.50	R 188.50	R 226.00
Stage 11	R 35.50	R 192.00	R 230.00
Stage 12	R 37.50	R 209.00	R 251.00
Stage 13	R 41.00	R 213.50	R 257.50
Stage 14	R 42.00	R 225.00	R 269.00
Stage 15	R 45.00	R 232.50	R 279.00

OFF PEAK TIMES

STAGE	1 TO 3	R 8.00
STAGE	4 TO 5	R 10.00
STAGE	6 AND UPWARDS	R 14.00
SCHOLAR MUVO CARD	10 JOURNEYS	R 98.50
PENSIONER MUVO CARD	10 JOURNEYS	R 37.50
SCHOLAR FARE	CASH	R 12.00
TOWNSHIP FARE	CASH	R 8.00

Mynah services

The Mynah buses service areas just outside of the CBD such as Musgrave Road, Florida Road and Ridge Road.

STAGE 1	R 7.00
STAGE 2	R 8.00
PEAK FARE	R 8.00
CITY FARE	R 7.00

Mynah: Muvo Card – 10 Journey

ADULT	R 76.50
PENSIONER	R 32.50
SCHOLAR	R 45.50

People Mover

The People Mover buses have two main bus routes. The City Loop transfers passengers to and from the Dr Pixley Ka Seme transfer interchange, stopping close to City Hall, The Playhouse Theatre, Tourism Information Centre, Inkosi Albert Luthuli ICC Complex, the Victoria street market and Durban’s mosque and cathedral. The Beach Line starts at Suncoast Casino and ends at uShaka Marine World. This route also runs through the interchange at Dr Pixley Ka Seme Street and transfers passengers to the City Loop route.

	Adult	Scholar	Pensioner	Disabilities
Cash Fare	R 5.50	R 4.50	R 4.50	R 4.50
Cash Fare – day pass	R 16.00	R 13.00	R 13.00	R 13.00
10 Trips – Muvo Card	R 50.00	R 40.00	R 40.00	R 40.00

Appendix E: Any Figures Relevant in the Research but not Presented in the Chapters

Open street map of different suburbs of Durban covering the entire study area, that shows the current Public Bus Transportation Network in Durban. When carefully overlapped the study area will be available in one view.



Plate 1: Musgrave and Environs.

Source: OSM 2021 (Not to scale)

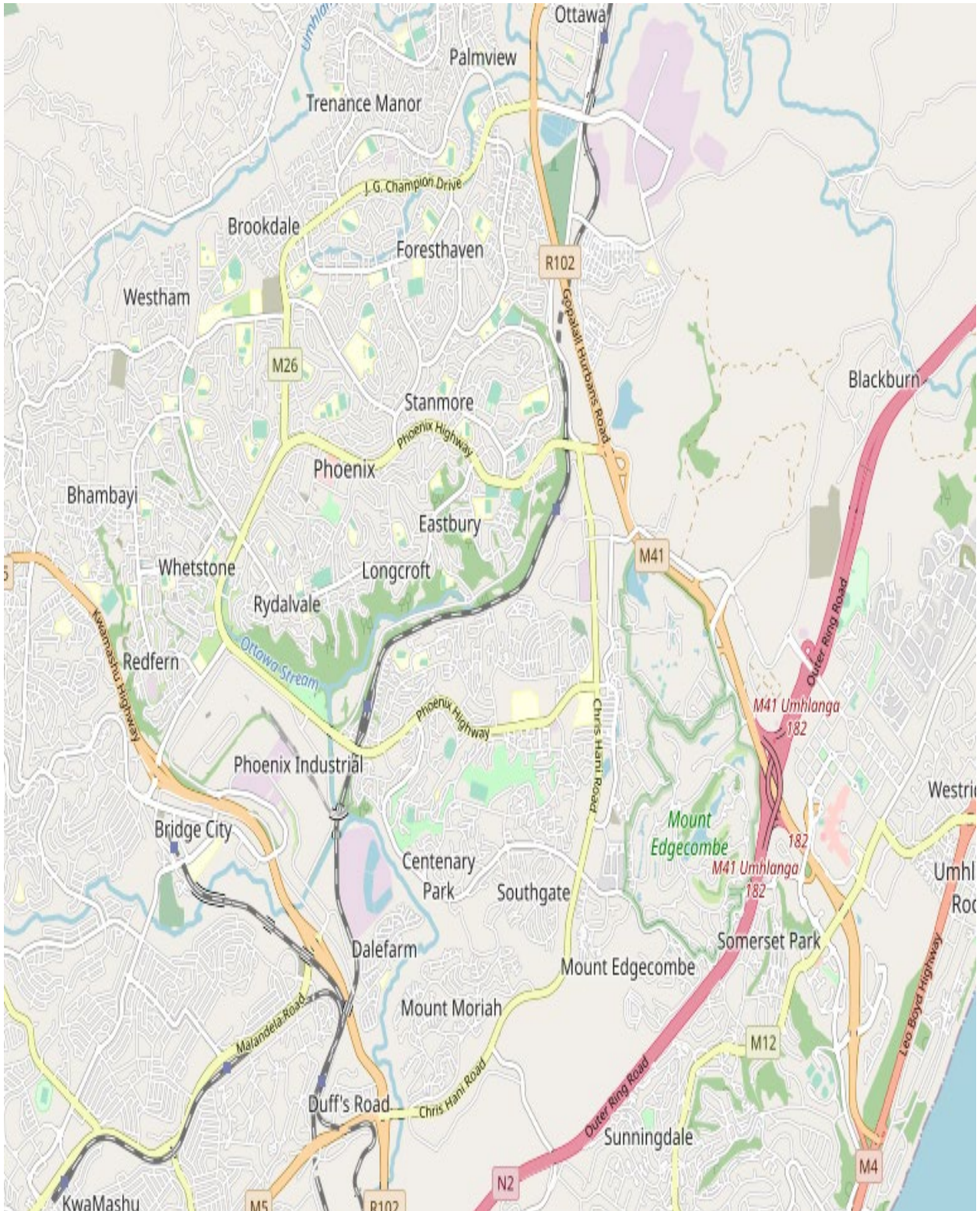


Plate 2: Kwamashu and Environs.

Source: OSM 2021 (Not to scale)



Plate 3: Phoenix and Environs.

Source: OSM 2021 (Not to scale)

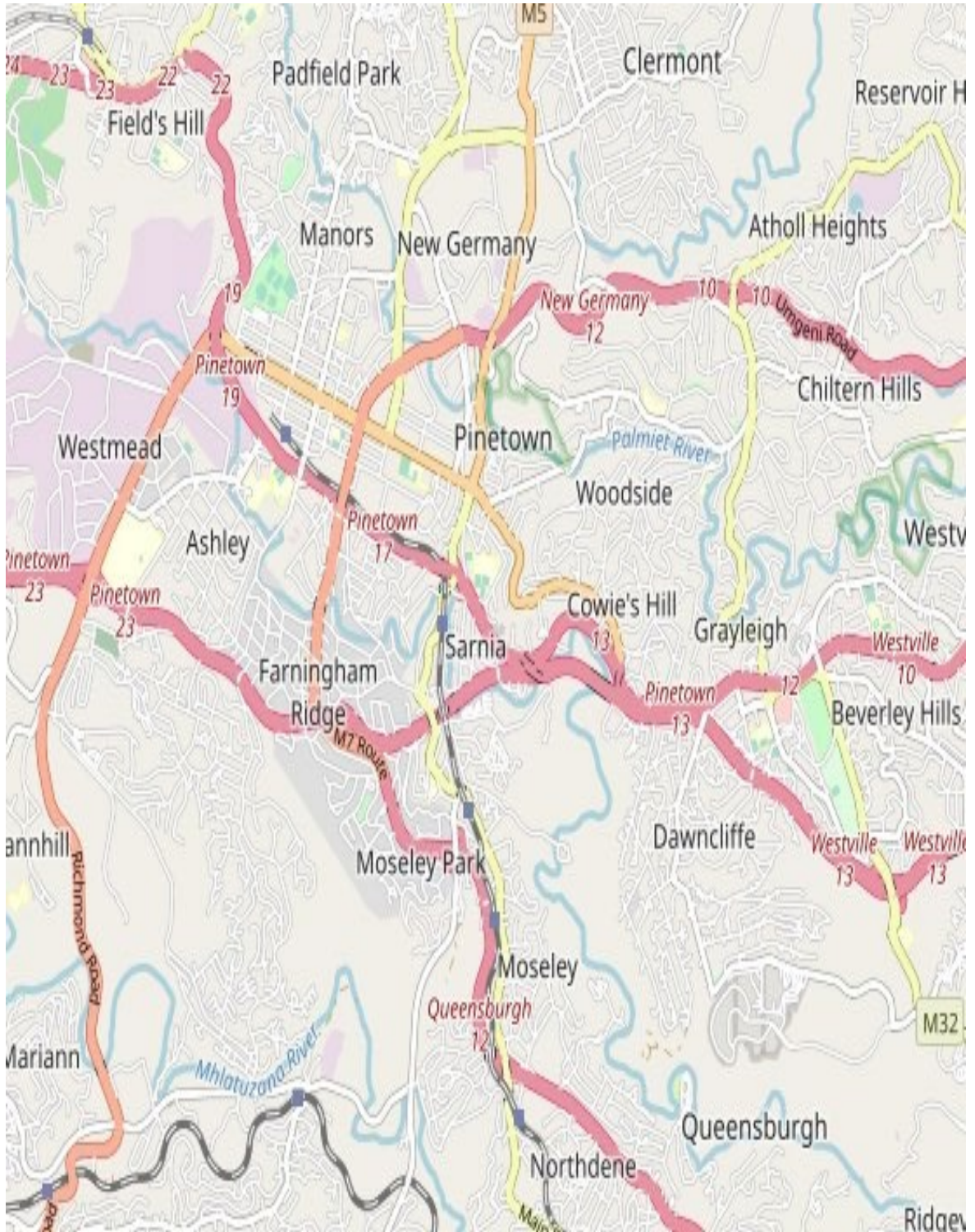


Plate 4: Queensburgh and Environs.

Source: OSM 2021 (Not to scale)



Plate 5: Glenwood & Environs (UKZN Howard college). Source: OSM 2021 (Not to scale)

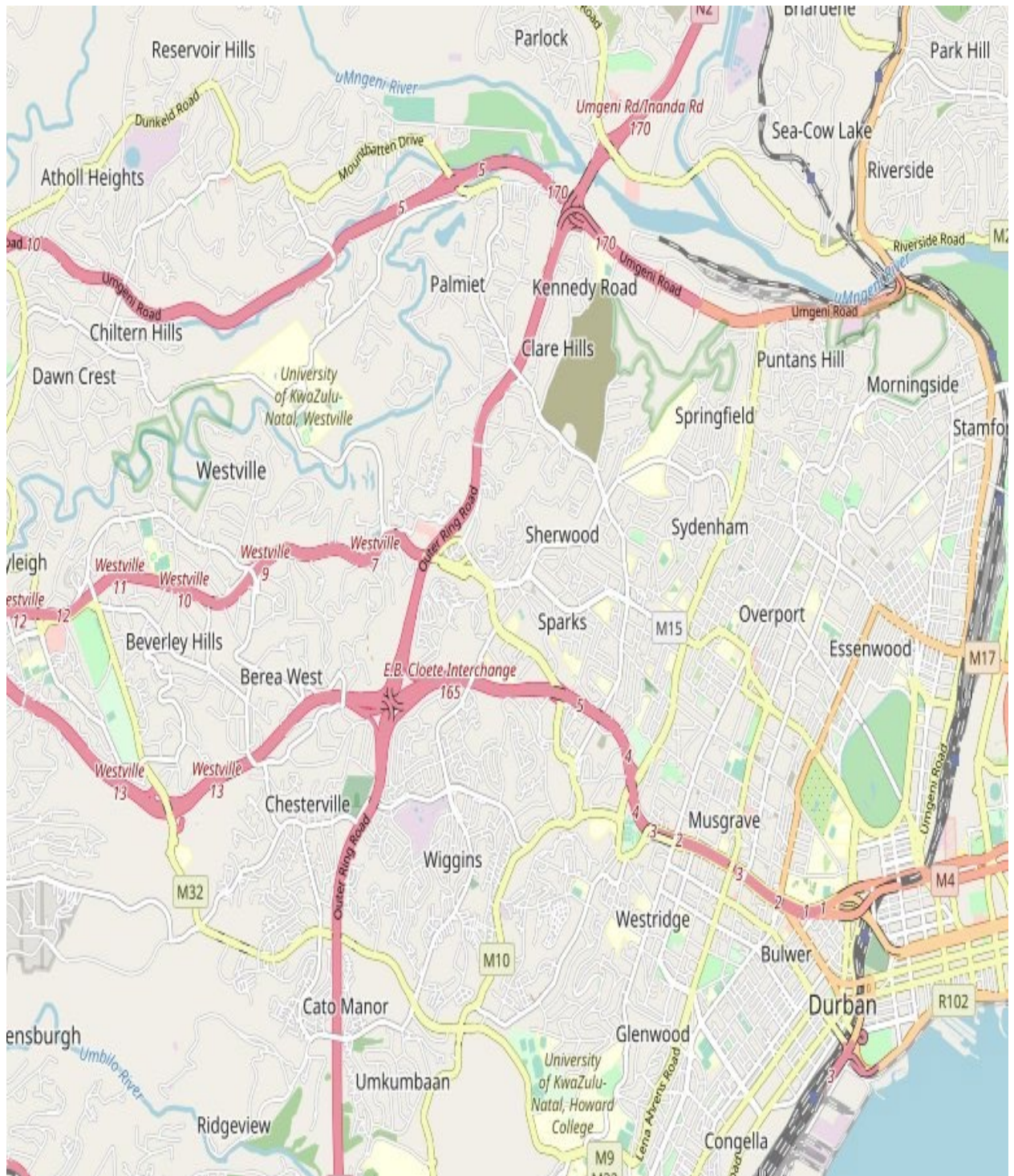


Plate 6: Westville and Environs (UKZN Westville). Source: OSM 2021 (Not to scale)



Plate 7: Umbilo and Environs.

Source: OSM 2021 (Not to scale)

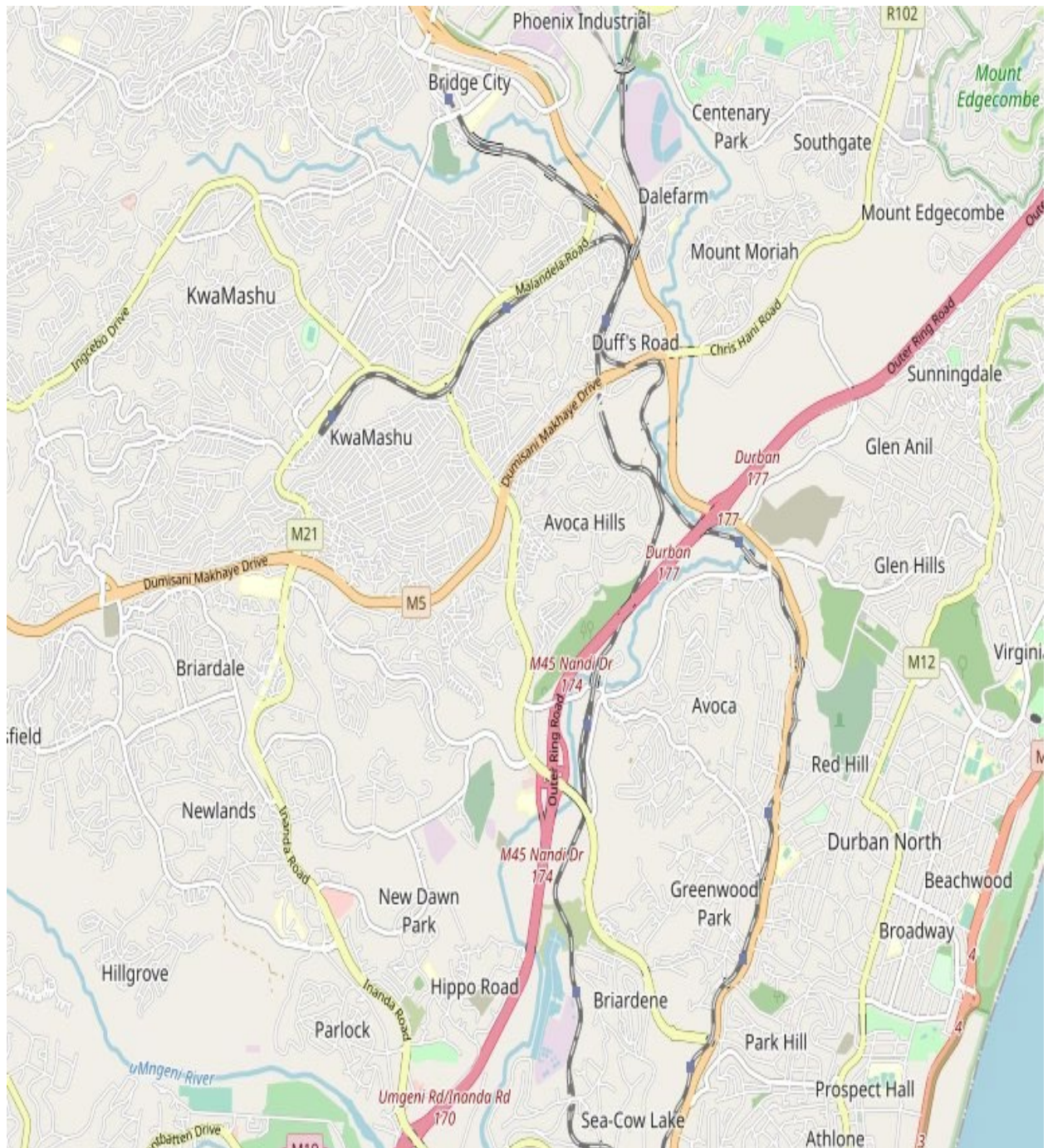


Plate 8: Umgeni Road and Environs.

Source: OSM 2021 (Not to scale)

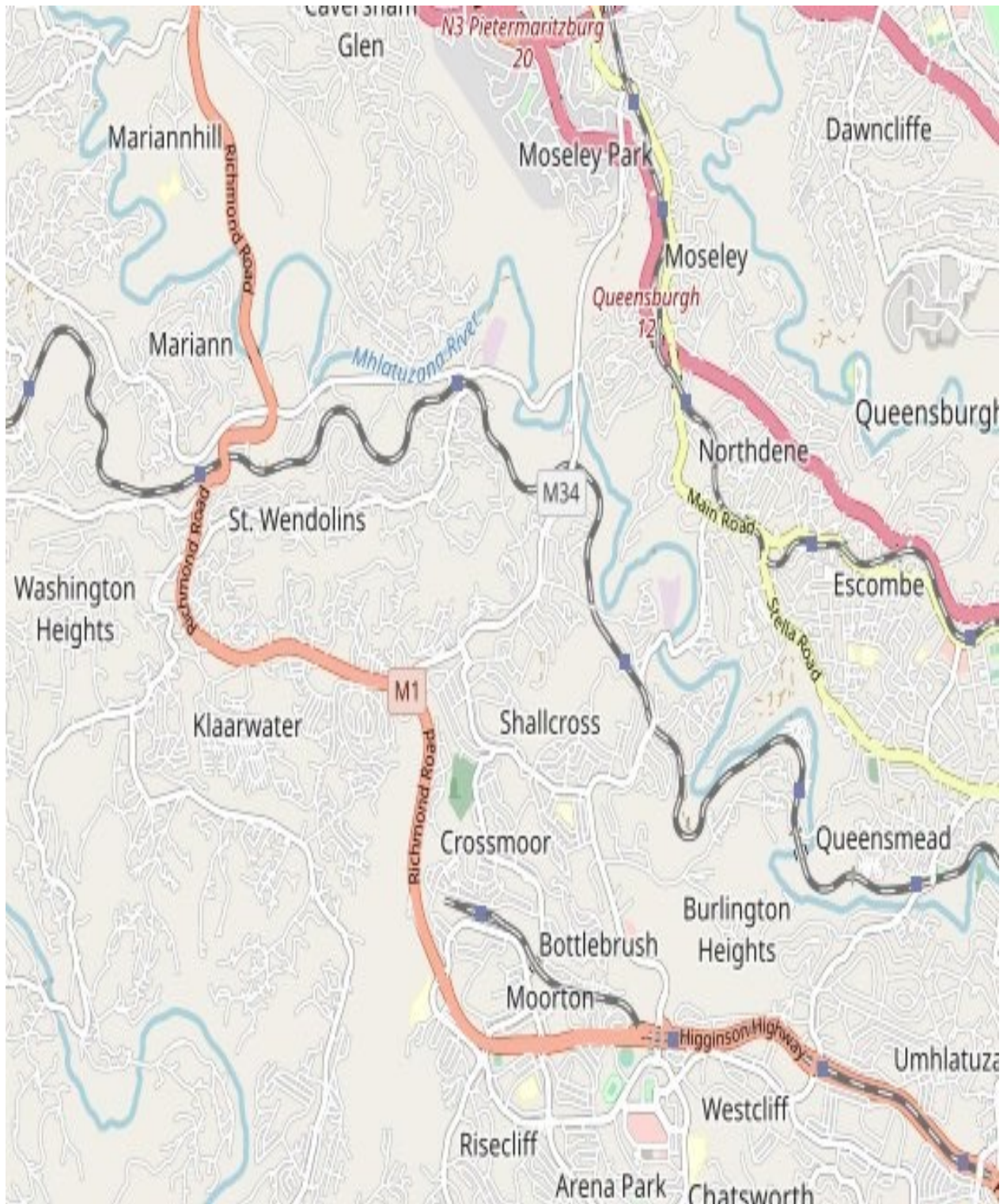


Plate 9: Washington Height and Environs. Source: OSM 2021 (Not to scale)

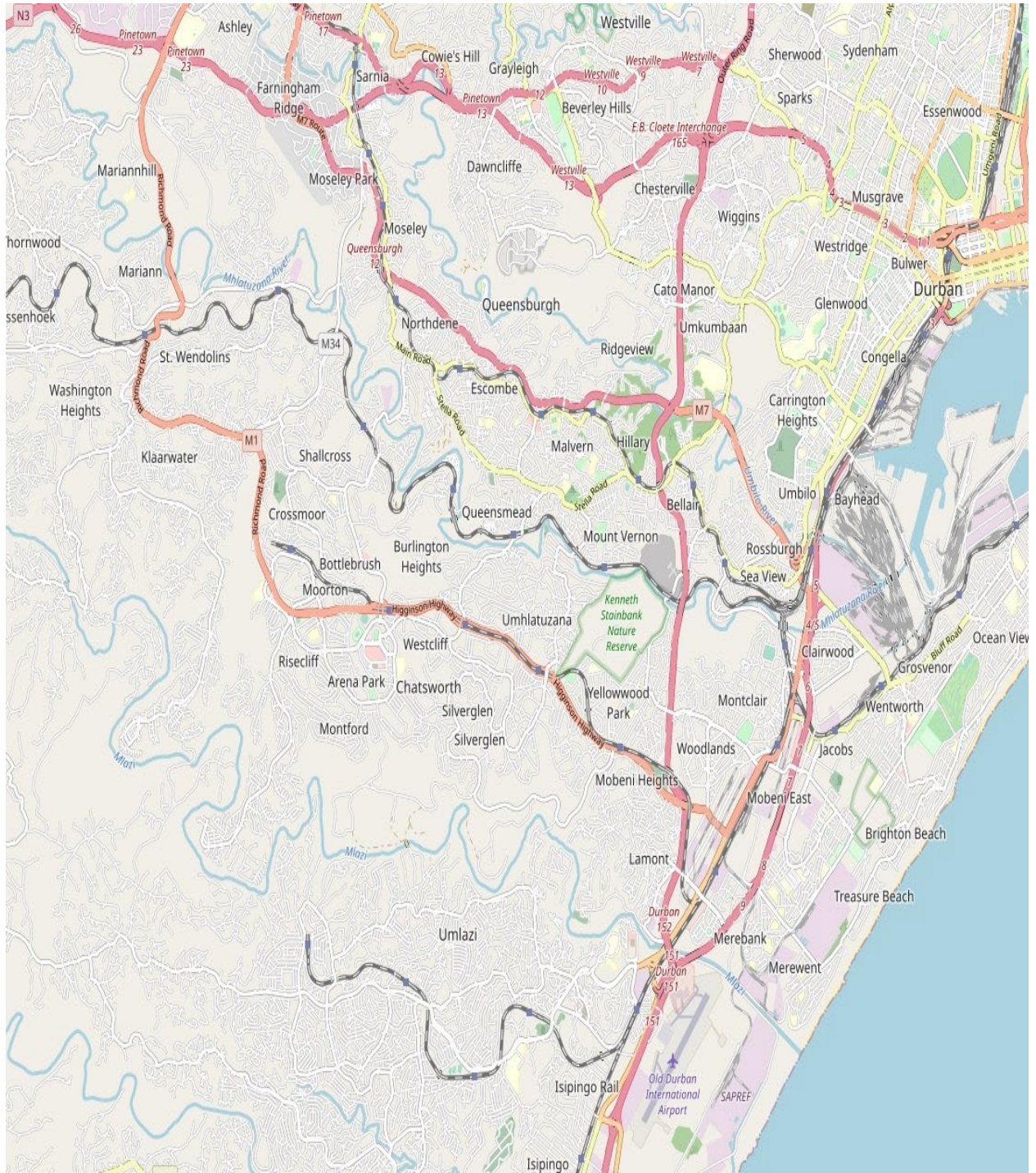


Plate 10: Wider view showing suburbs in Durban. Source: OSM 2021 (Not to scale)

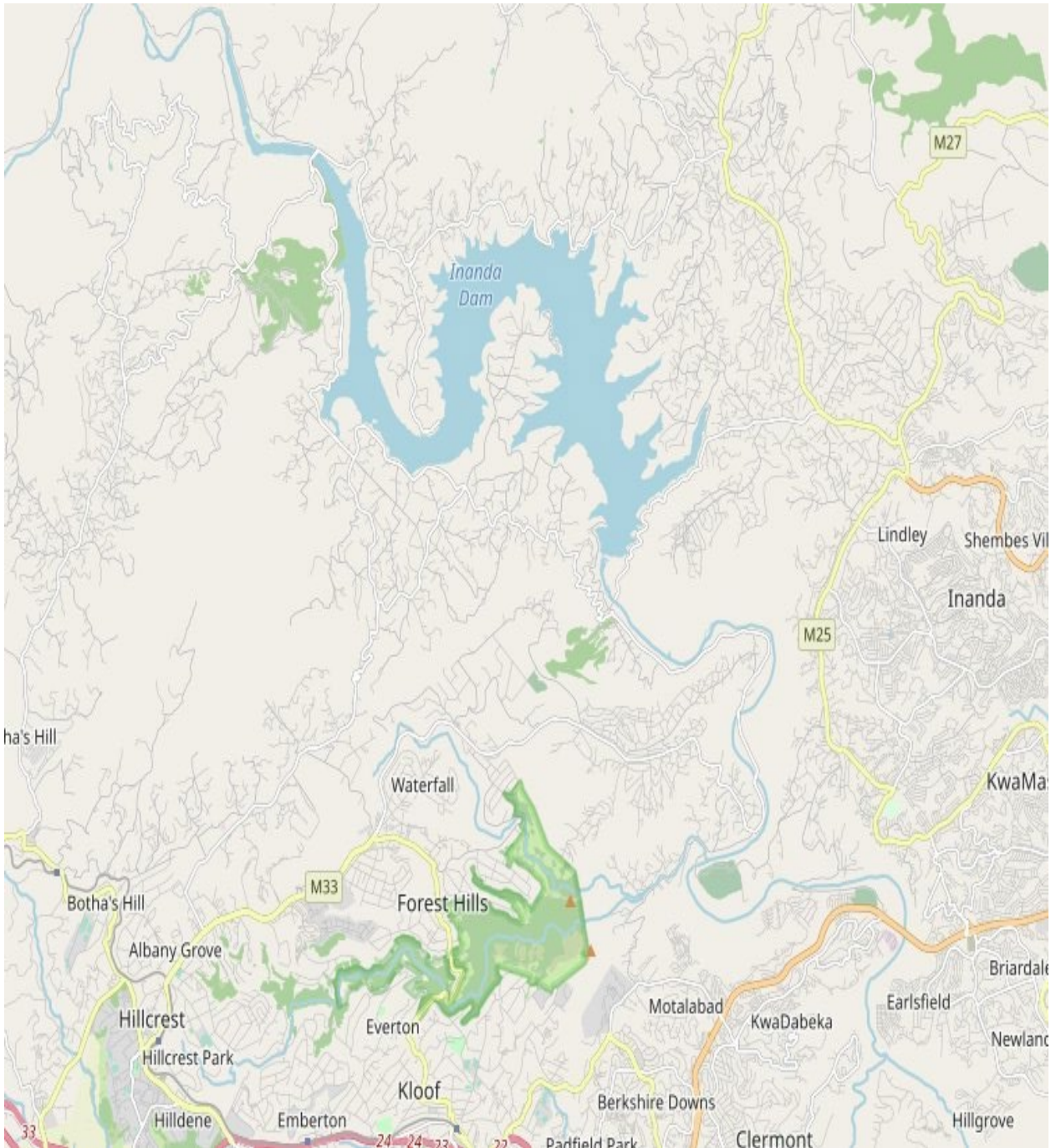


Plate 11: Inanda and Environs.

Source: OSM 2021 (Not to scale)



Plate 12: Carrington Height and Environs.

Source: OSM 2021 (Not to scale)

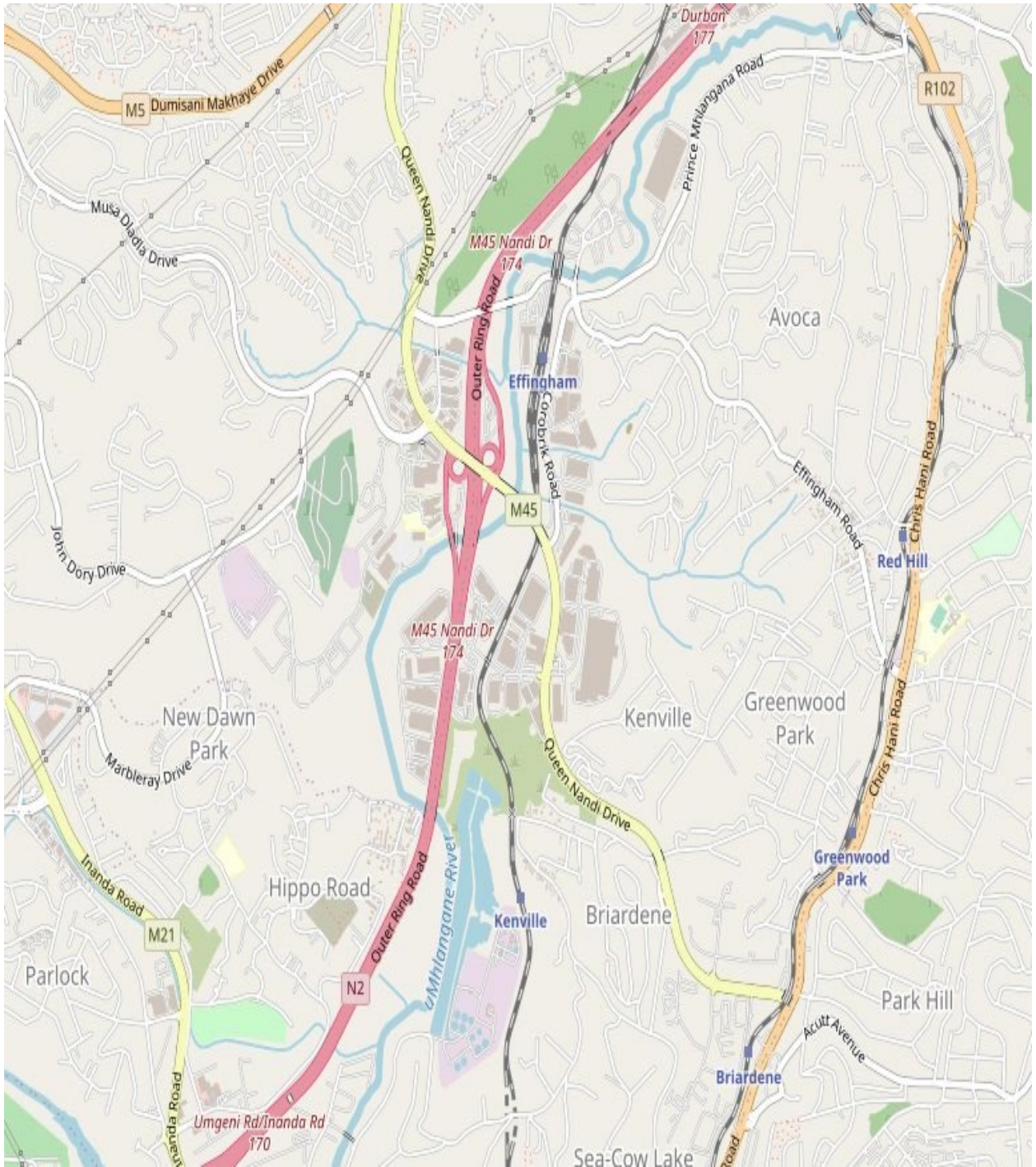


Plate 13: Greenwood Park and Environs.

Source: OSM 2021 (Not to scale)



Plate 14: Durban study area in one view. Source: OSM 2021 (Not to scale).

Appendix F: List of Research Publications from the PhD

Ifeanyi Okezie and Mulemwa Akombelwa. (2018).A spatial analysis of transport network in Durban, postgraduate research & innovation symposium poster presentation.

Ifeanyi Okezie and Mulemwa Akombelwa.(2019). The challenges created by Apartheid on transportation. 40th Canadian Symposium on Remote Sensing and Geomatics Atlantic Fredericton, NB; 4-6 June pages 224-225.

Ifeanyi Washington Okezie, Dillip Kumar Das, Mulemwa Akombelwa. (2021). Assessment of accessibility of public bus transportation in Durban by GIS-Based Network Analysis. International Journal of Transport Development and Integration, Witpress UK.

Appendix G: Modelling and Simulation Tables / Other Tables

Table: Showing the dataset for the study

F	C	TD	WT	WT1	WD1	AS	CM	NN	TT	WD
10	8	12970	10	25	38	68	2	2	25	7
3	15	13270	3	25	38.33	68	2	1	27	5
2	14	13010	2	26	39	68	2	1	23	5
4	12	13010	5	24	39	68	2	1	25	5
5	8	13867	4	25	38.33	66	2	1	27	6
6	10	13401	7	26	37	68	2	1	33	5
8	7	13480	7	26	38.33	67	2	1	23	7
6	7	13270	7	26	38.33	68	2	2	27	6
7	8	14004	9	26	38.33	68	2	1	24	5
10	6	13070	11	23	38	67	1	1	23	7
11	5	13467	10	23	38.33	68	1	1	26	5
13	4	13867	6	24	38.33	68	1	1	27	5
12	4	13800	11	23	39	66	2	3	24	6
11	3	13700	9	26	36	68	2	1	25	5
8	6	13800	7	25	38	68	2	1	26	8
9	6	13500	10	25	37	60	2	1	25	5
6	10	13600	6	23	36	66	2	1	24	6
12	7	13800	10	25	38.3	66	2	1	25	5
13	6	12950	9	24	38.33	67	1	1	28	5
12	9	13850	6	23	35	69	1	2	27	8
15	6	13020	5	29	36	67	1	1	25	5
10	8	13600	10	27	39	69	2	1	25	6
3	15	13240	3	26	39	60	2	1	31	7
2	14	13440	2	26	34	69	1	2	26	6
4	12	13320	5	26	37	69	1	1	28	7
5	8	13120	4	28	35	69	1	1	29	7
6	10	13600	7	34	36	69	1	3	31	5
8	7	13090	7	33	37	66	2	1	30	8
6	7	13610	7	30	38	69	2	2	27	5
7	8	13870	9	27	38	69	2	3	28	6
10	6	13310	11	22	36	69	2	2	24	7
11	5	13060	10	27	37	68	2	1	24	8
13	4	13370	6	24	39	69	1	1	26	5
12	4	13080	11	24	38	69	1	3	27	6
11	3	13300	9	26	35	69	1	1	24	7
8	6	13650	7	26	34	69	1	1	25	8

9	6	13430	10	26	38	67	1	1	28	5
7	8	13630	6	27	36	69	2	1	23	8
6	10	13210	6	25	39	69	2	1	25	6
13	6	13510	9	25	36	69	2	1	24	7
12	9	13730	6	27	36	67	2	1	23	6
15	6	13050	5	24	36	69	1	3	27	5
10	8	13630	10	26	39	69	1	1	29	8
3	15	13290	3	23	37	69	2	1	27	6
2	14	13340	2	24	37	65	2	3	24	7
4	12	13790	5	26	39	69	1	1	24	8
5	8	13300	4	26	36	69	1	1	28	5
6	10	13000	7	26	38	69	1	1	28	6
8	7	13790	7	25	37	69	1	1	26	7
6	7	13600	7	26	37	65	2	1	27	8
7	8	13200	9	27	39	69	2	1	24	5
10	6	13100	11	24	39	69	2	3	22	6
11	5	13600	10	26	37	69	1	1	23	7
13	4	13300	6	26	38	65	1	1	27	8

Table :The Verified and Accurate Data

S/No	F	C	WT	A
1	10	8	10	4620
2	3	15	3	1470
3	2	14	2	840
4	4	12	5	1736
5	5	8	4	2520
6	6	10	7	3024
7	8	7	7	3920
8	6	7	7	3150
9	7	8	9	2940
10	10	6	11	4410
11	11	5	10	5313
12	13	4	6	6552
13	12	4	11	5712
14	11	3	9	5236
15	8	6	7	4088
16	9	6	10	4284
17	6	10	6	3024
18	12	7	10	5880
19	13	6	9	6279
20	12	9	6	5796
21	15	6	5	7245

22	10	8	10	3600
23	3	15	3	900
24	2	14	2	708
25	4	12	5	1200
26	5	8	4	1770
27	6	10	7	2160
28	8	7	7	3120
29	6	7	7	2160
30	7	8	9	3087
31	10	6	11	5040
32	11	5	10	3630
33	13	4	6	4680
34	12	4	11	4032
35	11	3	9	5236
36	8	6	7	3024
37	9	6	10	3348
38	7	8	6	2520
39	6	10	6	2196
40	13	6	9	6279
41	12	9	6	5712
42	15	6	5	6615
43	10	8	10	3300
44	3	15	3	1062
45	2	14	2	600
46	4	12	5	1416
47	5	8	4	2100
48	6	10	7	2730
49	8	7	7	4200
50	6	7	7	2520
51	7	8	9	3087
52	10	6	11	4830
53	11	5	10	4928
54	13	4	6	5616

Table :Correlation Relation of the data

	A	F	C	TD	WT	WT1	WD1	AS	CM	NN	TT	W D
A	1											
F	.957*	1										

	*											
C	- .769* *	- .812* *	1									
TD	0.086	0.034	- 0.129	1								
WT	.557* *	.605* *	- .701* *	0.09 2	1							
WT1	- 0.227	- 0.152	0.042	- 0.00 8	- 0.11 1	1						
WD 1	- 0.074	- 0.049	0.053	- 0.06 9	0.19 7	- 0.161	1					
AS	0.016	0.062	- 0.086	- 0.00 2	0.07 3	0.041 0.16 2	- 1					
CM	- 0.203	-.278*	0.225	0.09 6	0.02 9	- 0.004	.272* .297*	- 1				
NN	0.048	0.066	- 0.026	- 0.03 1	0.12 6	- 0.021	- 0.04 7	0.13 0.02 8	1			
TT	- 0.238	- 0.199	0.194	- 0.06 7	- 0.23 1	.358* *	- 0.03 3	- 0.10 5	- 0.23 4	0.02 7	1	
WD	- 0.084	- 0.025	- 0.036	0.10 2	0.02 7	0.031	- 0.22 6	- 0.01 2	- 0.04 9	-0.09	- 0.09 9	1

Table :The determination of regression model coefficients of U (Solver)

	k	0.189434	Sum ssd	1.230471	U=0.19*f/c
S/N0	F	C	U	U1	ssd

1	10	8	0.38	0.236793	0.020508
2	3	15	0.22	0.037887	0.033165
3	2	14	0.18	0.027062	0.02339
4	4	12	0.27	0.063145	0.042789
5	5	8	0.31	0.118397	0.036712
6	6	10	0.3	0.113661	0.034722
7	8	7	0.33	0.216497	0.012883
8	6	7	0.35	0.162372	0.035204
9	7	8	0.34	0.165755	0.030361
10	10	6	0.4	0.315724	0.007102
11	11	5	0.42	0.416756	1.05E-05
12	13	4	0.45	0.615662	0.027444
13	12	4	0.43	0.568303	0.019128
14	11	3	0.43	0.694593	0.070009
15	8	6	0.35	0.252579	0.009491
16	9	6	0.37	0.284152	0.00737
17	6	10	0.28	0.113661	0.027669
18	12	7	0.43	0.324745	0.011079
19	13	6	0.39	0.410441	0.000418
20	12	9	0.34	0.252579	0.007642
21	15	6	0.44	0.473586	0.001128
22	10	8	0.38	0.236793	0.020508
23	3	15	0.22	0.037887	0.033165
24	2	14	0.18	0.027062	0.02339
25	4	12	0.27	0.063145	0.042789
26	5	8	0.31	0.118397	0.036712
27	6	10	0.3	0.113661	0.034722
28	8	7	0.33	0.216497	0.012883
29	6	7	0.35	0.162372	0.035204
30	7	8	0.34	0.165755	0.030361
31	10	6	0.4	0.315724	0.007102
32	11	5	0.42	0.416756	1.05E-05
33	13	4	0.45	0.615662	0.027444
34	12	4	0.43	0.568303	0.019128
35	11	3	0.43	0.694593	0.070009
36	8	6	0.35	0.252579	0.009491
37	9	6	0.37	0.284152	0.00737
38	7	8	0.31	0.165755	0.020807
39	6	10	0.28	0.113661	0.027669
40	13	6	0.39	0.410441	0.000418
41	12	9	0.34	0.252579	0.007642
42	15	6	0.44	0.473586	0.001128
43	10	8	0.38	0.236793	0.020508

44	3	15	0.22	0.037887	0.033165
45	2	14	0.18	0.027062	0.02339
46	4	12	0.27	0.063145	0.042789
47	5	8	0.31	0.118397	0.036712
48	6	10	0.3	0.113661	0.034722
49	8	7	0.33	0.216497	0.012883
50	6	7	0.35	0.162372	0.035204
51	7	8	0.34	0.165755	0.030361
52	10	6	0.4	0.315724	0.007102
53	11	5	0.42	0.416756	1.05E-05
54	13	4	0.45	0.615662	0.027444

Table :The data for determination of regression model coefficients of S

S/N0	F	C	WT	S
1	10	8	10	0.37
2	3	15	3	0.21
3	2	14	2	0.12
4	4	12	5	0.20
5	5	8	4	0.31
6	6	10	7	0.19
7	8	7	7	0.21
8	6	7	7	0.16
9	7	8	9	0.33
10	10	6	11	0.41
11	11	5	10	0.41
12	13	4	6	0.24
13	12	4	11	0.42
14	11	3	9	0.32
15	8	6	7	0.19
16	9	6	10	0.37
17	6	10	6	0.27
18	12	7	10	0.44
19	13	6	9	0.39
20	12	9	6	0.30

21	15	6	5	0.20
22	10	8	10	0.41
23	3	15	3	0.10
24	2	14	2	0.10
25	4	12	5	0.20
26	5	8	4	0.18
27	6	10	7	0.30
28	8	7	7	0.21
29	6	7	7	0.16
30	7	8	9	0.29
31	10	6	11	0.37
32	11	5	10	0.31
33	13	4	6	0.27
34	12	4	11	0.37
35	11	3	9	0.32
36	8	6	7	0.23
37	9	6	10	0.41
38	7	8	6	0.18
39	6	10	6	0.25
40	13	6	9	0.33
41	12	9	6	0.19
42	15	6	5	0.20
43	10	8	10	0.37
44	3	15	3	0.13
45	2	14	2	0.11
46	4	12	5	0.20
47	5	8	4	0.15
48	6	10	7	0.21
49	8	7	7	0.16
50	6	7	7	0.18
51	7	8	9	0.31

52	10	6	11	0.37
53	11	5	10	0.38
54	13	4	6	0.14

Table The determination of regression model coefficients of S

SUMMARY OUTPUT								
<i>Regression Statistics</i>								
Multiple R	0.875659							
R Square	0.766778							
Adjusted R Square	0.752785							
Standard Error	0.048999							
Observations	54							
<i>ANOVA</i>								
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>			
Regression	3	0.394683	0.131561	54.79609	7.89E-16			
Residual	50	0.120046	0.002401		S=0.007*Pe+0.01*Dp+0.03*U-0.12			
Total	53	0.514729						
	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95.0%</i>	<i>Upper 95.0%</i>
Intercept	-0.11899	0.065421	-1.81881	0.074932	-0.25039	0.012413	-0.25039	0.012413
X Variable 1	0.00721	0.003266	2.207904	0.031866	0.000651	0.013769	0.000651	0.013769
X Variable 2	0.009618	0.004072	2.362161	0.022103	0.00144	0.017796	0.00144	0.017796

X Variable 3	0.034459	0.0036 03	9.5652 79	7.02E- 13	0.027223	0.0416 95	0.0272 23	0.0416 95
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The Value of S in the regression model

S/N0	Pe	D	U	S
1	0.003	12.467	0.38	0.016
2	0.022	19.267	0.22	0.079
3	0.039	26.067	0.18	0.146
4	0.048	17	0.27	0.058
5	0.088	15.867	0.31	0.049
6	0.232	37.401	0.3	0.265
7	0.110	12.467	0.33	0.015
8	0.021	19.267	0.35	0.083
9	0.165	24.934	0.34	0.141
10	0.026	26.067	0.4	0.153
11	0.009	29.467	0.42	0.187
12	0.232	32.867	0.45	0.224
13	0.010	23.801	0.43	0.131
14	0.004	9.7	0.43	-0.010
15	0.232	40.801	0.35	0.300
16	0.018	5.5	0.37	-0.054
17	0.018	8	0.28	-0.031
18	0.018	2.9	0.43	-0.078
19	0.012	15.59	0.39	0.048
20	0.049	25.24	0.34	0.143
21	0.002	31.44	0.44	0.208
22	0.232	32.32	0.38	0.216
23	0.232	34.12	0.22	0.229
24	0.232	35.6	0.18	0.243
25	0.018	2.09	0.27	-0.091

26	0.018	7.61	0.31	-0.034
27	0.018	8.87	0.3	-0.022
28	0.012	12.31	0.33	0.013
29	0.033	16.06	0.35	0.051
30	0.012	18.37	0.34	0.074
31	0.018	3.08	0.4	-0.077
32	0.018	4.3	0.42	-0.064
33	0.018	5.65	0.45	-0.050
34	0.018	9.43	0.43	-0.013
35	0.018	10.63	0.43	-0.001
36	0.003	13.21	0.35	0.023
37	0.018	22.51	0.37	0.116
38	0.003	26.73	0.31	0.157
39	0.026	31.05	0.28	0.199
40	0.021	16.79	0.39	0.060
41	0.165	21.3	0.34	0.104
42	0.026	3	0.44	-0.077
43	0.018	6.79	0.38	-0.041
44	0.012	19.6	0.22	0.083
45	0.049	23.2	0.18	0.118
46	0.002	25.1	0.27	0.139
47	0.012	27.6	0.31	0.165
48	0.018	4.3	0.3	-0.068
49	0.031	21.9	0.33	0.109
50	0.000	27.53	0.35	0.166
51	0.021	34.1	0.34	0.231
52	0.232	35.47	0.4	0.248
53	0.232	38.6	0.42	0.280
54	0.232	40.6	0.45	0.301

Table The determination of the value of U.

S/N0	F	C	U
1	10	8	0.24
2	3	15	0.04
3	2	14	0.03
4	4	12	0.06
5	5	8	0.12
6	6	10	0.11
7	8	7	0.22
8	6	7	0.16
9	7	8	0.17
10	10	6	0.32
11	11	5	0.42
12	13	4	0.62
13	12	4	0.57
14	11	3	0.70
15	8	6	0.25
16	9	6	0.29
17	6	10	0.11
18	12	7	0.33
19	13	6	0.41
20	12	9	0.25
21	15	6	0.48
22	10	8	0.24
23	3	15	0.04
24	2	14	0.03
25	4	12	0.06
26	5	8	0.12
27	6	10	0.11
28	8	7	0.22
29	6	7	0.16
30	7	8	0.17
31	10	6	0.32
32	11	5	0.42
33	13	4	0.62
34	12	4	0.57
35	11	3	0.70
36	8	6	0.25
37	9	6	0.29
38	7	8	0.17
39	6	10	0.11
40	13	6	0.41
41	12	9	0.25
42	15	6	0.48

43	10	8	0.24
44	3	15	0.04
45	2	14	0.03
46	4	12	0.06
47	5	8	0.12
48	6	10	0.11
49	8	7	0.22
50	6	7	0.16
51	7	8	0.17
52	10	6	0.32
53	11	5	0.42
54	13	4	0.62

Table : The determination of the value of U with F(100%).

S/N0	F (100%)	C	U
1	20	8	0.48
2	6	15	0.08
3	4	14	0.05
4	8	12	0.13
5	10	8	0.24
6	12	10	0.23
7	16	7	0.43
8	12	7	0.33
9	14	8	0.33
10	20	6	0.63
11	22	5	0.84
12	26	4	1.24
13	24	4	1.14
14	22	3	1.39
15	16	6	0.51
16	18	6	0.57
17	12	10	0.23
18	24	7	0.65
19	26	6	0.82

20	24	9	0.51
21	30	6	0.95
22	20	8	0.48
23	6	15	0.08
24	4	14	0.05
25	8	12	0.13
26	10	8	0.24
27	12	10	0.23
28	18	7	0.49
29	12	7	0.33
30	14	8	0.33
31	20	6	0.63
32	22	5	0.84
33	26	4	1.24
34	24	4	1.14
35	22	3	1.39
36	16	6	0.51
37	18	6	0.57
38	14	8	0.33
39	12	10	0.23
40	26	6	0.82
41	24	9	0.51
42	30	6	0.95
43	20	8	0.48
44	6	15	0.08
45	4	14	0.05
46	8	12	0.13
47	10	8	0.24
48	12	10	0.23
49	16	7	0.43
50	12	7	0.33

51	14	8	0.33
52	10	6	0.32
53	22	5	0.84
54	26	4	1.24

Table The determination of the value of U with C(100%).

S/N0	F	C (100)	U
1	10	16	0.12
2	3	30	0.02
3	2	28	0.01
4	4	24	0.03
5	5	16	0.06
6	6	20	0.06
7	8	14	0.11
8	6	14	0.08
9	7	16	0.08
10	10	12	0.16
11	11	10	0.21
12	13	8	0.31
13	12	8	0.29
14	11	6	0.35
15	8	12	0.13
16	9	12	0.14
17	6	20	0.06
18	12	14	0.16
19	13	12	0.21
20	12	18	0.13
21	15	12	0.24
22	10	16	0.12
23	3	30	0.02
24	2	28	0.01

25	4	24	0.03
26	5	16	0.06
27	6	20	0.06
28	8	14	0.11
29	6	14	0.08
30	7	16	0.08
31	10	12	0.16
32	11	10	0.21
33	13	8	0.31
34	12	8	0.29
35	11	6	0.35
36	8	12	0.13
37	9	12	0.14
38	7	16	0.08
39	6	20	0.06
40	13	12	0.21
41	12	18	0.13
42	15	12	0.24
43	10	16	0.12
44	3	30	0.02
45	2	28	0.01
46	4	24	0.03
47	5	16	0.06
48	6	20	0.06
49	8	14	0.11
50	6	14	0.08
51	7	16	0.08
52	10	12	0.16
53	11	10	0.21
54	13	8	0.31

Table The determination of NBR model coefficients for Accessibility without SI

SUMMARY OUTPUT								
Regression Statistics						A=482.95*f+0.13*C-22.86*wt-207.45		
Multiple R	0.95728283							
R Square	0.91639042							
Adjusted R Square	0.91137385							
Standard Error	520.56875							
Observations	54							
ANOVA								
	df	SS	MS	F	Significance F			
Regression	3	148508297	49502766	182.67254	6.25E-27			
Residual	50	13549591.2	270991.82					
Total	53	162057888						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-207.455211	695.031617	-0.298483	0.7665714	-1603.47	1188.557	-1603.4673	1188.56876
X Variable 1	482.951701	34.6937634	13.920418	7.896E-19	413.2672	552.6362	413.267226	552.6361752
X Variable 2	0.12620789	43.2571758	0.0029176	0.9976837	-86.7584	87.0108	-86.758387	87.01080253
X Variable 3	-22.864332	38.2734331	-0.597394	0.5529401	-99.7388	54.01012	-99.738785	54.01012078

Table The NBR model for Accessibility without SI (with Initial value of A)

S/No	F	C	WT	A	A1
1	10	8	10	4620	8.39
2	3	15	3	1470	7.07
3	2	14	2	840	6.57
4	4	12	5	1736	7.38

5	5	8	4	2520	7.66
6	6	10	7	3024	7.84
7	8	7	7	3920	8.16
8	6	7	7	3150	7.84
9	7	8	9	2940	8.00
10	10	6	11	4410	8.38
11	11	5	10	5313	8.49
12	13	4	6	6552	8.69
13	12	4	11	5712	8.58
14	11	3	9	5236	8.50
15	8	6	7	4088	8.16
16	9	6	10	4284	8.27
17	6	10	6	3024	7.85
18	12	7	10	5880	8.59
19	13	6	9	6279	8.68
20	12	9	6	5796	8.60
21	15	6	5	7245	8.84
22	10	8	10	3600	8.39
23	3	15	3	900	7.07
24	2	14	2	708	6.57
25	4	12	5	1200	7.38
26	5	8	4	1770	7.66
27	6	10	7	2160	7.84
28	8	7	7	3120	8.16
29	6	7	7	2160	7.84
30	7	8	9	3087	8.00
31	10	6	11	5040	8.38
32	11	5	10	3630	8.49
33	13	4	6	4680	8.69
34	12	4	11	4032	8.58
35	11	3	9	5236	8.50
36	8	6	7	3024	8.16
37	9	6	10	3348	8.27
38	7	8	6	2520	8.02
39	6	10	6	2196	7.85
40	13	6	9	6279	8.68
41	12	9	6	5712	8.60
42	15	6	5	6615	8.84
43	10	8	10	3300	8.39
44	3	15	3	1062	7.07
45	2	14	2	600	6.57
46	4	12	5	1416	7.38
47	5	8	4	2100	7.66

48	6	10	7	2730	7.84
49	8	7	7	4200	8.16
50	6	7	7	2520	7.84
51	7	8	9	3087	8.00
52	10	6	11	4830	8.38
53	11	5	10	4928	8.49
54	13	4	6	5616	8.69

Table The NBR model for Accessibility without SI

S/No	F	C	WT	A1
1	10	8	10	8.39
2	3	15	3	7.07
3	2	14	2	6.57
4	4	12	5	7.38
5	5	8	4	7.66
6	6	10	7	7.84
7	8	7	7	8.16
8	6	7	7	7.84
9	7	8	9	8
10	10	6	11	8.38
11	11	5	10	8.49
12	13	4	6	8.69
13	12	4	11	8.58
14	11	3	9	8.5
15	8	6	7	8.16
16	9	6	10	8.27
17	6	10	6	7.85
18	12	7	10	8.59
19	13	6	9	8.68
20	12	9	6	8.6
21	15	6	5	8.84
22	10	8	10	8.39
23	3	15	3	7.07
24	2	14	2	6.57
25	4	12	5	7.38
26	5	8	4	7.66
27	6	10	7	7.84
28	8	7	7	8.16
29	6	7	7	7.84
30	7	8	9	8
31	10	6	11	8.38
32	11	5	10	8.49

33	13	4	6	8.69
34	12	4	11	8.58
35	11	3	9	8.5
36	8	6	7	8.16
37	9	6	10	8.27
38	7	8	6	8.02
39	6	10	6	7.85
40	13	6	9	8.68
41	12	9	6	8.6
42	15	6	5	8.84
43	10	8	10	8.39
44	3	15	3	7.07
45	2	14	2	6.57
46	4	12	5	7.38
47	5	8	4	7.66
48	6	10	7	7.84
49	8	7	7	8.16
50	6	7	7	7.84
51	7	8	9	8
52	10	6	11	8.38
53	11	5	10	8.49
54	13	4	6	8.69

Table: The Estimated value of SI

S/N0	Pe	D	U	S
1	0.003	12.467	0.38	0.016
2	0.022	19.267	0.22	0.079
3	0.039	26.067	0.18	0.146
4	0.048	17	0.27	0.058
5	0.088	15.867	0.31	0.049
6	0.232	37.401	0.3	0.265
7	0.110	12.467	0.33	0.015
8	0.021	19.267	0.35	0.083
9	0.165	24.934	0.34	0.141
10	0.026	26.067	0.4	0.153
11	0.009	29.467	0.42	0.187
12	0.232	32.867	0.45	0.224
13	0.010	23.801	0.43	0.131
14	0.004	9.7	0.43	-0.010
15	0.232	40.801	0.35	0.300
16	0.018	5.5	0.37	-0.054
17	0.018	8	0.28	-0.031

18	0.018	2.9	0.43	-0.078
19	0.012	15.59	0.39	0.048
20	0.049	25.24	0.34	0.143
21	0.002	31.44	0.44	0.208
22	0.232	32.32	0.38	0.216
23	0.232	34.12	0.22	0.229
24	0.232	35.6	0.18	0.243
25	0.018	2.09	0.27	-0.091
26	0.018	7.61	0.31	-0.034
27	0.018	8.87	0.3	-0.022
28	0.012	12.31	0.33	0.013
29	0.033	16.06	0.35	0.051
30	0.012	18.37	0.34	0.074
31	0.018	3.08	0.4	-0.077
32	0.018	4.3	0.42	-0.064
33	0.018	5.65	0.45	-0.050
34	0.018	9.43	0.43	-0.013
35	0.018	10.63	0.43	-0.001
36	0.003	13.21	0.35	0.023
37	0.018	22.51	0.37	0.116
38	0.003	26.73	0.31	0.157
39	0.026	31.05	0.28	0.199
40	0.021	16.79	0.39	0.060
41	0.165	21.3	0.34	0.104
42	0.026	3	0.44	-0.077
43	0.018	6.79	0.38	-0.041
44	0.012	19.6	0.22	0.083
45	0.049	23.2	0.18	0.118
46	0.002	25.1	0.27	0.139
47	0.012	27.6	0.31	0.165
48	0.018	4.3	0.3	-0.068
49	0.031	21.9	0.33	0.109
50	0.000	27.53	0.35	0.166
51	0.021	34.1	0.34	0.231
52	0.232	35.47	0.4	0.248
53	0.232	38.6	0.42	0.280
54	0.232	40.6	0.45	0.301

Table: The Improved value of SI if U is increased to hundred percent

S/N0	Pe	D	U	S	U(100)	S1
1	0.003	12.467	0.38	0.016	0.76	0.27
2	0.022	19.267	0.22	0.079	0.44	0.33

3	0.039	26.067	0.18	0.146	0.36	0.39
4	0.048	17	0.27	0.058	0.54	0.31
5	0.088	15.867	0.31	0.049	0.62	0.30
6	0.232	37.401	0.3	0.265	0.6	0.51
7	0.110	12.467	0.33	0.015	0.66	0.27
8	0.021	19.267	0.35	0.083	0.7	0.33
9	0.165	24.934	0.34	0.141	0.68	0.39
10	0.026	26.067	0.4	0.153	0.8	0.40
11	0.009	29.467	0.42	0.187	0.84	0.44
12	0.232	32.867	0.45	0.224	0.9	0.48
13	0.010	23.801	0.43	0.131	0.86	0.38
14	0.004	9.7	0.43	-0.010	0.86	0.24
15	0.232	40.801	0.35	0.300	0.7	0.55
16	0.018	5.5	0.37	-0.054	0.74	0.20
17	0.018	8	0.28	-0.031	0.56	0.22
18	0.018	2.9	0.43	-0.078	0.86	0.17
19	0.012	15.59	0.39	0.048	0.78	0.30
20	0.049	25.24	0.34	0.143	0.68	0.39
21	0.002	31.44	0.44	0.208	0.88	0.46
22	0.232	32.32	0.38	0.216	0.76	0.47
23	0.232	34.12	0.22	0.229	0.44	0.48
24	0.232	35.6	0.18	0.243	0.36	0.49
25	0.018	2.09	0.27	-0.091	0.54	0.16
26	0.018	7.61	0.31	-0.034	0.62	0.21
27	0.018	8.87	0.3	-0.022	0.6	0.23
28	0.012	12.31	0.33	0.013	0.66	0.26
29	0.033	16.06	0.35	0.051	0.7	0.30
30	0.012	18.37	0.34	0.074	0.68	0.32
31	0.018	3.08	0.4	-0.077	0.8	0.17
32	0.018	4.3	0.42	-0.064	0.84	0.19
33	0.018	5.65	0.45	-0.050	0.9	0.20
34	0.018	9.43	0.43	-0.013	0.86	0.24
35	0.018	10.63	0.43	-0.001	0.86	0.25
36	0.003	13.21	0.35	0.023	0.7	0.27
37	0.018	22.51	0.37	0.116	0.74	0.37
38	0.003	26.73	0.31	0.157	0.62	0.41
39	0.026	31.05	0.28	0.199	0.56	0.45
40	0.021	16.79	0.39	0.060	0.78	0.31
41	0.165	21.3	0.34	0.104	0.68	0.35
42	0.026	3	0.44	-0.077	0.88	0.18
43	0.018	6.79	0.38	-0.041	0.76	0.21
44	0.012	19.6	0.22	0.083	0.44	0.33
45	0.049	23.2	0.18	0.118	0.36	0.36

46	0.002	25.1	0.27	0.139	0.54	0.39
47	0.012	27.6	0.31	0.165	0.62	0.41
48	0.018	4.3	0.3	-0.068	0.6	0.18
49	0.031	21.9	0.33	0.109	0.66	0.36
50	0.000	27.53	0.35	0.166	0.7	0.42
51	0.021	34.1	0.34	0.231	0.68	0.48
52	0.232	35.47	0.4	0.248	0.8	0.50
53	0.232	38.6	0.42	0.280	0.84	0.53
54	0.232	40.6	0.45	0.301	0.9	0.55

Table :The determination of NBR model coefficients for Accessibility with SI

SUMMARY OUTPUT								
<i>Regression Statistics</i>								
				A=ln(481.39*f-1.95*c-30.29*wt+215.51*s-181.81)				
Multiple R	0.957301							
R Square	0.916425							
Adjusted R Square	0.909602							
Standard Error	525.7456							
Observations	54							
<i>ANOVA</i>								
	<i>df</i>	<i>SS</i>	<i>MS</i>	<i>F</i>	<i>Significance F</i>			
Regression	4	1.49E+08	37128468	134.3246	9.14E-26			
Residual	49	13544016	276408.5					
Total	53	1.62E+08						
	<i>Coefficients</i>	<i>Standard Error</i>	<i>t Stat</i>	<i>P-value</i>	<i>Lower 95%</i>	<i>Upper 95%</i>	<i>Lower 95.0%</i>	<i>Upper 95.0%</i>
Intercept	-181.812	724.7924	-0.2508	0.802981	-1638.34	1274.713	-1638.3	1274.71307

			5				4	
X Variable 1	481.397 8	36.707 15	13.114 55	1.2E- 17	407.632 1	555.16 36	407.63 21	555.163 609
X Variable 2	-1.94655	46.060 56	- 0.0422 6	0.9664 63	-94.5087	90.615 62	- 94.508 7	90.6156 162
X Variable 3	-30.2907	65.024 93	- 0.4658 3	0.6434	-160.963	100.38 18	- 160.96 3	100.381 782
X Variable 4	215.511 8	1517.4 06	0.1420 26	0.8876 41	-2833.83	3264.8 53	- 2833.8 3	3264.85 306

Table : The NBR model for Accessibility with SI

S/N0	F	C	WT	S	A	A2	A1
1	10	8	10	0.37	4620	8.39	8.39
2	3	15	3	0.21	1470	7.08	7.07
3	2	14	2	0.12	840	6.58	6.57
4	4	12	5	0.20	1736	7.39	7.38
5	5	8	4	0.31	2520	7.68	7.66
6	6	10	7	0.19	3024	7.83	7.84
7	8	7	7	0.21	3920	8.16	8.16
8	6	7	7	0.16	3150	7.83	7.84
9	7	8	9	0.33	2940	8.00	8
10	10	6	11	0.41	4410	8.38	8.38
11	11	5	10	0.41	5313	8.49	8.49
12	13	4	6	0.24	6552	8.69	8.69
13	12	4	11	0.42	5712	8.58	8.58
14	11	3	9	0.32	5236	8.50	8.5
15	8	6	7	0.19	4088	8.16	8.16
16	9	6	10	0.37	4284	8.27	8.27
17	6	10	6	0.27	3024	7.85	7.85
18	12	7	10	0.44	5880	8.59	8.59
19	13	6	9	0.39	6279	8.68	8.68
20	12	9	6	0.30	5796	8.61	8.6
21	15	6	5	0.20	7245	8.84	8.84
22	10	8	10	0.41	3600	8.39	8.39
23	3	15	3	0.10	900	7.06	7.07
24	2	14	2	0.10	708	6.57	6.57
25	4	12	5	0.20	1200	7.39	7.38
26	5	8	4	0.18	1770	7.66	7.66

27	6	10	7	0.30	2160	7.84	7.84
28	8	7	7	0.21	3120	8.16	8.16
29	6	7	7	0.16	2160	7.83	7.84
30	7	8	9	0.29	3087	7.99	8
31	10	6	11	0.37	5040	8.38	8.38
32	11	5	10	0.31	3630	8.49	8.49
33	13	4	6	0.27	4680	8.69	8.69
34	12	4	11	0.37	4032	8.58	8.58
35	11	3	9	0.32	5236	8.50	8.5
36	8	6	7	0.23	3024	8.16	8.16
37	9	6	10	0.41	3348	8.28	8.27
38	7	8	6	0.18	2520	8.02	8.02
39	6	10	6	0.25	2196	7.85	7.85
40	13	6	9	0.33	6279	8.68	8.68
41	12	9	6	0.19	5712	8.60	8.6
42	15	6	5	0.20	6615	8.84	8.84
43	10	8	10	0.37	3300	8.39	8.39
44	3	15	3	0.13	1062	7.06	7.07
45	2	14	2	0.11	600	6.57	6.57
46	4	12	5	0.20	1416	7.39	7.38
47	5	8	4	0.15	2100	7.66	7.66
48	6	10	7	0.21	2730	7.83	7.84
49	8	7	7	0.16	4200	8.15	8.16
50	6	7	7	0.18	2520	7.83	7.84
51	7	8	9	0.31	3087	8.00	8
52	10	6	11	0.37	4830	8.38	8.38
53	11	5	10	0.38	4928	8.49	8.49
54	13	4	6	0.14	5616	8.69	8.69

Table: The Simulations if F is increased with 100% for model without SI

S/No	F 100%	C	WT	A(f100)	A1	Diff
1	20	8	10	9.13	8.39	0.74
2	6	15	3	7.87	7.07	0.80
3	4	14	2	7.43	6.57	0.86
4	8	12	5	8.17	7.38	0.79
5	10	8	4	8.42	7.66	0.76
6	12	10	7	8.60	7.84	0.76
7	16	7	7	8.90	8.16	0.74
8	12	7	7	8.60	7.84	0.76
9	14	8	9	8.76	8.00	0.76
10	20	6	11	9.13	8.38	0.74
11	22	5	10	9.23	8.49	0.74

12	26	4	6	9.41	8.69	0.72
13	24	4	11	9.32	8.58	0.74
14	22	3	9	9.23	8.50	0.73
15	16	6	7	8.90	8.16	0.74
16	18	6	10	9.02	8.27	0.75
17	12	10	6	8.60	7.85	0.76
18	24	7	10	9.32	8.59	0.73
19	26	6	9	9.40	8.68	0.73
20	24	9	6	9.33	8.60	0.72
21	30	6	5	9.56	8.84	0.72
22	20	8	10	9.13	8.39	0.74
23	6	15	3	7.87	7.07	0.80
24	4	14	2	7.43	6.57	0.86
25	8	12	5	8.17	7.38	0.79
26	10	8	4	8.42	7.66	0.76
27	12	10	7	8.60	7.84	0.76
28	18	7	7	9.03	8.16	0.87
29	12	7	7	8.60	7.84	0.76
30	14	8	9	8.76	8.00	0.76
31	20	6	11	9.13	8.38	0.74
32	22	5	10	9.23	8.49	0.74
33	26	4	6	9.41	8.69	0.72
34	24	4	11	9.32	8.58	0.74
35	22	3	9	9.23	8.50	0.73
36	16	6	7	8.90	8.16	0.74
37	18	6	10	9.02	8.27	0.75
38	14	8	6	8.77	8.02	0.75
39	12	10	6	8.60	7.85	0.76
40	26	6	9	9.40	8.68	0.73
41	24	9	6	9.33	8.60	0.72
42	30	6	5	9.56	8.84	0.72
43	20	8	10	9.13	8.39	0.74
44	6	15	3	7.87	7.07	0.80
45	4	14	2	7.43	6.57	0.86
46	8	12	5	8.17	7.38	0.79
47	10	8	4	8.42	7.66	0.76
48	12	10	7	8.60	7.84	0.76
49	16	7	7	8.90	8.16	0.74
50	12	7	7	8.60	7.84	0.76
51	14	8	9	8.76	8.00	0.76
52	10	6	11	8.38	8.38	0.00
53	22	5	10	9.23	8.49	0.74
54	26	4	6	9.41	8.69	0.72

Table: The Simulations if C is increased with 100% for model without SI

S/No	F	c (100)	WT	A(c100)	A1	Diff
1	10	16	10	8.39	8.39	0.00
2	3	30	3	7.07	7.07	0.00
3	2	28	2	6.57	6.57	0.00
4	4	24	5	7.39	7.39	0.00
5	5	16	4	7.66	7.66	0.00
6	6	20	7	7.84	7.84	0.00
7	8	14	7	8.16	8.16	0.00
8	6	14	7	7.84	7.84	0.00
9	7	16	9	8.00	8.00	0.00
10	10	12	11	8.38	8.38	0.00
11	11	10	10	8.49	8.49	0.00
12	13	8	6	8.69	8.69	0.00
13	12	8	11	8.58	8.58	0.00
14	11	6	9	8.50	8.50	0.00
15	8	12	7	8.16	8.16	0.00
16	9	12	10	8.27	8.27	0.00
17	6	20	6	7.85	7.85	0.00
18	12	14	10	8.59	8.59	0.00
19	13	12	9	8.68	8.68	0.00
20	12	18	6	8.60	8.60	0.00
21	15	12	5	8.84	8.84	0.00
22	10	16	10	8.39	8.39	0.00
23	3	30	3	7.07	7.07	0.00
24	2	28	2	6.57	6.57	0.00
25	4	24	5	7.39	7.39	0.00
26	5	16	4	7.66	7.66	0.00
27	6	20	7	7.84	7.84	0.00
28	8	14	7	8.16	8.16	0.00
29	6	14	7	7.84	7.84	0.00
30	7	16	9	8.00	8.00	0.00
31	10	12	11	8.38	8.38	0.00
32	11	10	10	8.49	8.49	0.00
33	13	8	6	8.69	8.69	0.00
34	12	8	11	8.58	8.58	0.00
35	11	6	9	8.50	8.50	0.00
36	8	12	7	8.16	8.16	0.00
37	9	12	10	8.27	8.27	0.00
38	7	16	6	8.02	8.02	0.00
39	6	20	6	7.85	7.85	0.00

40	13	12	9	8.68	8.68	0.00
41	12	18	6	8.60	8.60	0.00
42	15	12	5	8.84	8.84	0.00
43	10	16	10	8.39	8.39	0.00
44	3	30	3	7.07	7.07	0.00
45	2	28	2	6.57	6.57	0.00
46	4	24	5	7.39	7.39	0.00
47	5	16	4	7.66	7.66	0.00
48	6	20	7	7.84	7.84	0.00
49	8	14	7	8.16	8.16	0.00
50	6	14	7	7.84	7.84	0.00
51	7	16	9	8.00	8.00	0.00
52	10	12	11	8.38	8.38	0.00
53	11	10	10	8.49	8.49	0.00
54	13	8	6	8.69	8.69	0.00

Table: The Simulations if WT is increased with 100% for model without SI

S/No	F	C	WT(100%)	A(wt100)	A1	Diff
1	10	8	20	8.33	8.39	-0.05
2	3	15	6	7.01	7.07	-0.06
3	2	14	4	6.51	6.57	-0.07
4	4	12	10	7.31	7.38	-0.07
5	5	8	8	7.61	7.66	-0.04
6	6	10	14	7.77	7.84	-0.07
7	8	7	14	8.11	8.16	-0.05
8	6	7	14	7.77	7.84	-0.07
9	7	8	18	7.92	8.00	-0.07
10	10	6	22	8.32	8.38	-0.06
11	11	5	20	8.44	8.49	-0.05
12	13	4	12	8.67	8.69	-0.02
13	12	4	22	8.53	8.58	-0.05
14	11	3	18	8.45	8.50	-0.04
15	8	6	14	8.11	8.16	-0.05
16	9	6	20	8.21	8.27	-0.06
17	6	10	12	7.79	7.85	-0.06
18	12	7	20	8.54	8.59	-0.04
19	13	6	18	8.64	8.68	-0.04
20	12	9	12	8.58	8.60	-0.03
21	15	6	10	8.83	8.84	-0.02
22	10	8	20	8.33	8.39	-0.05
23	3	15	6	7.01	7.07	-0.06
24	2	14	4	6.51	6.57	-0.07

25	4	12	10	7.31	7.38	-0.07
26	5	8	8	7.61	7.66	-0.04
27	6	10	14	7.77	7.84	-0.07
28	8	7	14	8.11	8.16	-0.05
29	6	7	14	7.77	7.84	-0.07
30	7	8	18	7.92	8.00	-0.07
31	10	6	22	8.32	8.38	-0.06
32	11	5	20	8.44	8.49	-0.05
33	13	4	12	8.67	8.69	-0.02
34	12	4	22	8.53	8.58	-0.05
35	11	3	18	8.45	8.50	-0.04
36	8	6	14	8.11	8.16	-0.05
37	9	6	20	8.21	8.27	-0.06
38	7	8	12	7.97	8.02	-0.05
39	6	10	12	7.79	7.85	-0.06
40	13	6	18	8.64	8.68	-0.04
41	12	9	12	8.58	8.60	-0.03
42	15	6	10	8.83	8.84	-0.02
43	10	8	20	8.33	8.39	-0.05
44	3	15	6	7.01	7.07	-0.06
45	2	14	4	6.51	6.57	-0.07
46	4	12	10	7.31	7.38	-0.07
47	5	8	8	7.61	7.66	-0.04
48	6	10	14	7.77	7.84	-0.07
49	8	7	14	8.11	8.16	-0.05
50	6	7	14	7.77	7.84	-0.07
51	7	8	18	7.92	8.00	-0.07
52	10	6	22	8.32	8.38	-0.06
53	11	5	20	8.44	8.49	-0.05
54	13	4	12	8.67	8.69	-0.02

Table: The Simulations if f is decreased with 50% for model without SI

S/No	F(-50%)	C	WT	A(f-50%)	A1	Diff
1	5	8	10	7.59	8.39	-0.80
2	1.5	15	3	6.11	7.07	-0.96
3	1	14	2	5.45	6.57	-1.13
4	2	12	5	6.47	7.38	-0.91
5	2.5	8	4	6.81	7.66	-0.84
6	3	10	7	6.99	7.84	-0.85
7	4	7	7	7.36	8.16	-0.80
8	3	7	7	6.99	7.84	-0.85
9	3.5	8	9	7.15	8.00	-0.84

10	5	6	11	7.58	8.38	-0.80
11	5.5	5	10	7.71	8.49	-0.79
12	6.5	4	6	7.94	8.69	-0.75
13	6	4	11	7.80	8.58	-0.78
14	5.5	3	9	7.72	8.50	-0.78
15	4	6	7	7.36	8.16	-0.80
16	4.5	6	10	7.46	8.27	-0.81
17	3	10	6	7.01	7.85	-0.84
18	6	7	10	7.81	8.59	-0.78
19	6.5	6	9	7.91	8.68	-0.77
20	6	9	6	7.85	8.60	-0.76
21	7.5	6	5	8.10	8.84	-0.74
22	5	8	10	7.59	8.39	-0.80
23	1.5	15	3	6.11	7.07	-0.96
24	1	14	2	5.45	6.57	-1.13
25	2	12	5	6.47	7.38	-0.91
26	2.5	8	4	6.81	7.66	-0.84
27	3	10	7	6.99	7.84	-0.85
28	4	7	7	7.36	8.16	-0.80
29	3	7	7	6.99	7.84	-0.85
30	3.5	8	9	7.15	8.00	-0.84
31	5	6	11	7.58	8.38	-0.80
32	5.5	5	10	7.71	8.49	-0.79
33	6.5	4	6	7.94	8.69	-0.75
34	6	4	11	7.80	8.58	-0.78
35	5.5	3	9	7.72	8.50	-0.78
36	4	6	7	7.36	8.16	-0.80
37	4.5	6	10	7.46	8.27	-0.81
38	3.5	8	6	7.21	8.02	-0.81
39	3	10	6	7.01	7.85	-0.84
40	6.5	6	9	7.91	8.68	-0.77
41	6	9	6	7.85	8.60	-0.76
42	7.5	6	5	8.10	8.84	-0.74
43	5.5	8	10	7.71	8.39	-0.68
44	1.5	15	3	6.11	7.07	-0.96
45	1	14	2	5.45	6.57	-1.13
46	2	12	5	6.47	7.38	-0.91
47	2.5	8	4	6.81	7.66	-0.84
48	3	10	7	6.99	7.84	-0.85
49	4	7	7	7.36	8.16	-0.80
50	3	7	7	6.99	7.84	-0.85
51	3.5	8	9	7.15	8.00	-0.84
52	5	6	11	7.58	8.38	-0.80

53	5.5	5	10	7.71	8.49	-0.79
54	6.5	4	6	7.94	8.69	-0.75

Table: The Simulations if C is decreased with 50% for model without SI

S/No	F	C(-50%)	WT	A(c-50%)	A1	Diff
1	10	4	10	8.39	8.39	0.00
2	3	7.5	3	7.07	7.07	0.00
3	2	7	2	6.57	6.57	0.00
4	4	6	5	7.38	7.38	0.00
5	5	4	4	7.66	7.66	0.00
6	6	5	7	7.84	7.84	0.00
7	8	3.5	7	8.16	8.16	0.00
8	6	3.5	7	7.84	7.84	0.00
9	7	4	9	8.00	8.00	0.00
10	10	3	11	8.38	8.38	0.00
11	11	2.5	10	8.49	8.49	0.00
12	13	2	6	8.69	8.69	0.00
13	12	2	11	8.58	8.58	0.00
14	11	1.5	9	8.50	8.50	0.00
15	8	3	7	8.16	8.16	0.00
16	9	3	10	8.27	8.27	0.00
17	6	5	6	7.85	7.85	0.00
18	12	3.5	10	8.59	8.59	0.00
19	13	3	9	8.68	8.68	0.00
20	12	4.5	6	8.60	8.60	0.00
21	15	3	5	8.84	8.84	0.00
22	10	4	10	8.39	8.39	0.00
23	3	7.5	3	7.07	7.07	0.00
24	2	7	2	6.57	6.57	0.00
25	4	6	5	7.38	7.38	0.00
26	5	4	4	7.66	7.66	0.00
27	6	5	7	7.84	7.84	0.00
28	8	3.5	7	8.16	8.16	0.00
29	6	3.5	7	7.84	7.84	0.00
30	7	4	9	8.00	8.00	0.00
31	10	3	11	8.38	8.38	0.00
32	11	2.5	10	8.49	8.49	0.00
33	13	2	6	8.69	8.69	0.00
34	12	2	11	8.58	8.58	0.00
35	11	1.5	9	8.50	8.50	0.00
36	8	3	7	8.16	8.16	0.00
37	9	3	10	8.27	8.27	0.00

38	7	4	6	8.02	8.02	0.00
39	6	5	6	7.85	7.85	0.00
40	13	3	9	8.68	8.68	0.00
41	12	4.5	6	8.60	8.60	0.00
42	15	3	5	8.84	8.84	0.00
43	10	4	10	8.39	8.39	0.00
44	3	7.5	3	7.07	7.07	0.00
45	2	7	2	6.57	6.57	0.00
46	4	6	5	7.38	7.38	0.00
47	5	4	4	7.66	7.66	0.00
48	6	5	7	7.84	7.84	0.00
49	8	3.5	7	8.16	8.16	0.00
50	6	3.5	7	7.84	7.84	0.00
51	7	4	9	8.00	8.00	0.00
52	10	3	11	8.38	8.38	0.00
53	11	2.5	10	8.49	8.49	0.00
54	13	2	6	8.69	8.69	0.00

Table: The Simulations if WT is decreased with 50% for model without SI

S/No	F	C	WT(-50)	A(wt-50%)	A1	Diff
1	10	8	5	8.41	8.39	0.03
2	3	15	1.5	7.10	7.07	0.03
3	2	14	1	6.60	6.57	0.03
4	4	12	2.5	7.42	7.38	0.03
5	5	8	2	7.68	7.66	0.02
6	6	10	3.5	7.87	7.84	0.03
7	8	7	3.5	8.18	8.16	0.02
8	6	7	3.5	7.87	7.84	0.03
9	7	8	4.5	8.03	8.00	0.03
10	10	6	6.5	8.41	8.38	0.02
11	11	5	5	8.52	8.49	0.02
12	13	4	3	8.70	8.69	0.01
13	12	4	5.5	8.61	8.58	0.02
14	11	3	4.5	8.52	8.50	0.02
15	8	6	3.5	8.18	8.16	0.02
16	9	6	5	8.30	8.27	0.03
17	6	10	3	7.87	7.85	0.03
18	12	7	5	8.61	8.59	0.02
19	13	6	4.5	8.69	8.68	0.02
20	12	9	3	8.62	8.60	0.01
21	15	6	2.5	8.85	8.84	0.01
22	10	8	10	8.39	8.39	0.00

23	3	15	1.5	7.10	7.07	0.03
24	2	14	1	6.60	6.57	0.03
25	4	12	2.5	7.42	7.38	0.03
26	5	8	2	7.68	7.66	0.02
27	6	10	3.5	7.87	7.84	0.03
28	8	7	3.5	8.18	8.16	0.02
29	6	7	3.5	7.87	7.84	0.03
30	7	8	4.5	8.03	8.00	0.03
31	10	6	5.5	8.41	8.38	0.03
32	11	5	5	8.52	8.49	0.02
33	13	4	3	8.70	8.69	0.01
34	12	4	5.5	8.61	8.58	0.02
35	11	3	4.5	8.52	8.50	0.02
36	8	6	3.5	8.18	8.16	0.02
37	9	6	5	8.30	8.27	0.03
38	7	8	3	8.04	8.02	0.02
39	6	10	3	7.87	7.85	0.03
40	13	6	4.5	8.69	8.68	0.02
41	12	9	3	8.62	8.60	0.01
42	15	6	2.5	8.85	8.84	0.01
43	10	8	5	8.41	8.39	0.03
44	3	15	1.5	7.10	7.07	0.03
45	2	14	1	6.60	6.57	0.03
46	4	12	2.5	7.42	7.38	0.03
47	5	8	2	7.68	7.66	0.02
48	6	10	3.5	7.87	7.84	0.03
49	8	7	3.5	8.18	8.16	0.02
50	6	7	3.5	7.87	7.84	0.03
51	7	8	4.5	8.03	8.00	0.03
52	10	6	5.5	8.41	8.38	0.03
53	11	5	5	8.52	8.49	0.02
54	13	4	3	8.70	8.69	0.01

Table: The Simulations if F,C&WT is increased with 100% for model without SI

S/No	F(100%)	C(100%)	WT(100%)	A1	A(fcwt100%)	Diff
1	20	16	20	8.39	9.10	0.72
2	6	30	6	7.07	7.85	0.78
3	4	28	4	6.57	7.40	0.83
4	8	24	10	7.38	8.14	0.76

5	10	16	8	7.66	8.40	0.74
6	12	20	14	7.84	8.57	0.73
7	16	14	14	8.16	8.88	0.72
8	12	14	14	7.84	8.57	0.73
9	14	16	18	8.00	8.72	0.73
10	20	12	22	8.38	9.10	0.72
11	22	10	20	8.49	9.21	0.71
12	26	8	12	8.69	9.40	0.71
13	24	8	22	8.58	9.29	0.71
14	22	6	18	8.50	9.21	0.71
15	16	12	14	8.16	8.88	0.72
16	18	12	20	8.27	8.99	0.72
17	12	20	12	7.85	8.58	0.73
18	24	14	20	8.59	9.30	0.71
19	26	12	18	8.68	9.39	0.71
20	24	18	12	8.60	9.32	0.71
21	30	12	10	8.84	9.55	0.71
22	20	16	20	8.39	9.10	0.72
23	6	30	6	7.07	7.85	0.78
24	4	28	4	6.57	7.40	0.83
25	8	24	10	7.38	8.14	0.76
26	10	16	8	7.66	8.40	0.74
27	12	20	14	7.84	8.57	0.73
28	18	14	14	8.16	9.01	0.85
29	12	14	14	7.84	8.57	0.73
30	14	16	18	8.00	8.72	0.73
31	20	12	22	8.38	9.10	0.72
32	22	10	20	8.49	9.21	0.71
33	26	8	12	8.69	9.40	0.71
34	24	8	22	8.58	9.29	0.71
35	22	6	18	8.50	9.21	0.71
36	16	12	14	8.16	8.88	0.72
37	18	12	20	8.27	8.99	0.72
38	14	16	12	8.02	8.75	0.73
39	12	20	12	7.85	8.58	0.73
40	26	12	18	8.68	9.39	0.71
41	24	18	12	8.60	9.32	0.71
42	30	12	10	8.84	9.55	0.71
43	20	16	20	8.39	9.10	0.72
44	6	30	6	7.07	7.85	0.78
45	4	28	4	6.57	7.40	0.83
46	8	24	10	7.38	8.14	0.76
47	10	16	8	7.66	8.40	0.74

48	12	20	14	7.84	8.57	0.73
49	16	14	14	8.16	8.88	0.72
50	12	14	14	7.84	8.57	0.73
51	14	16	18	8.00	8.72	0.73
52	10	12	22	8.38	8.32	-0.06
53	22	10	20	8.49	9.21	0.71
54	26	8	12	8.69	9.40	0.71

Table: The Simulations if F & C is increased with 100% for model without SI

S/No	F(100%)	C(100%)	WT	A1	A(fc100%,wt)	Diff
1	20	16	10	8.39	9.13	0.74
2	6	30	3	7.07	7.87	0.80
3	4	28	2	6.57	7.43	0.86
4	8	24	5	7.38	8.17	0.79
5	10	16	4	7.66	8.42	0.76
6	12	20	7	7.84	8.60	0.76
7	16	14	7	8.16	8.90	0.74
8	12	14	7	7.84	8.60	0.76
9	14	16	9	8.00	8.76	0.76
10	20	12	11	8.38	9.13	0.74
11	22	10	10	8.49	9.23	0.74
12	26	8	6	8.69	9.41	0.72
13	24	8	11	8.58	9.32	0.74
14	22	6	9	8.50	9.23	0.73
15	16	12	7	8.16	8.90	0.74
16	18	12	10	8.27	9.02	0.75
17	12	20	6	7.85	8.60	0.76
18	24	14	10	8.59	9.32	0.73
19	26	12	9	8.68	9.40	0.73
20	24	18	6	8.60	9.33	0.72
21	30	12	5	8.84	9.56	0.72
22	20	16	10	8.39	9.13	0.74
23	6	30	3	7.07	7.87	0.80
24	4	28	2	6.57	7.43	0.86
25	8	24	5	7.38	8.17	0.79
26	10	16	4	7.66	8.42	0.76
27	12	20	7	7.84	8.60	0.76
28	18	14	7	8.16	9.03	0.87
29	12	14	7	7.84	8.60	0.76
30	14	16	9	8.00	8.76	0.76
31	20	12	11	8.38	9.13	0.74
32	22	10	10	8.49	9.23	0.74

33	26	8	6	8.69	9.41	0.72
34	24	8	11	8.58	9.32	0.74
35	22	6	9	8.50	9.23	0.73
36	16	12	7	8.16	8.90	0.74
37	18	12	10	8.27	9.02	0.75
38	14	16	6	8.02	8.77	0.75
39	12	20	6	7.85	8.60	0.76
40	26	12	9	8.68	9.40	0.73
41	24	18	6	8.60	9.33	0.72
42	30	12	5	8.84	9.56	0.72
43	20	16	10	8.39	9.13	0.74
44	6	30	3	7.07	7.87	0.80
45	4	28	2	6.57	7.43	0.86
46	8	24	5	7.38	8.17	0.79
47	10	16	4	7.66	8.42	0.76
48	12	20	7	7.84	8.60	0.76
49	16	14	7	8.16	8.90	0.74
50	12	14	7	7.84	8.60	0.76
51	14	16	9	8.00	8.76	0.76
52	10	12	11	8.38	8.38	0.00
53	22	10	10	8.49	9.23	0.74
54	26	8	6	8.69	9.41	0.72

Table: The Simulations if F & WT is increased with 100% for model without SI

S/No	F(100%)	C	WT(100%)	A(F,WT100,C)	A1	Diff
1	20	8	20	9.10	8.39	0.72
2	6	15	6	7.85	7.07	0.78
3	4	14	4	7.40	6.57	0.83
4	8	12	10	8.14	7.38	0.76
5	10	8	8	8.40	7.66	0.74
6	12	10	14	8.57	7.84	0.73
7	16	7	14	8.88	8.16	0.72
8	12	7	14	8.57	7.84	0.73
9	14	8	18	8.72	8.00	0.73
10	20	6	22	9.10	8.38	0.72
11	22	5	20	9.21	8.49	0.71
12	26	4	12	9.40	8.69	0.71
13	24	4	22	9.29	8.58	0.71
14	22	3	18	9.21	8.50	0.71
15	16	6	14	8.88	8.16	0.72
16	18	6	20	8.99	8.27	0.72
17	12	10	12	8.58	7.85	0.73

18	24	7	20	9.30	8.59	0.71
19	26	6	18	9.39	8.68	0.71
20	24	9	12	9.32	8.60	0.71
21	30	6	10	9.55	8.84	0.71
22	20	8	20	9.10	8.39	0.72
23	6	15	6	7.85	7.07	0.78
24	4	14	4	7.40	6.57	0.83
25	8	12	10	8.14	7.38	0.76
26	10	8	8	8.40	7.66	0.74
27	12	10	14	8.57	7.84	0.73
28	18	7	14	9.01	8.16	0.85
29	12	7	14	8.57	7.84	0.73
30	14	8	18	8.72	8.00	0.73
31	20	6	22	9.10	8.38	0.72
32	22	5	20	9.21	8.49	0.71
33	26	4	12	9.40	8.69	0.71
34	24	4	22	9.29	8.58	0.71
35	22	3	18	9.21	8.50	0.71
36	16	6	14	8.88	8.16	0.72
37	18	6	20	8.99	8.27	0.72
38	14	8	12	8.75	8.02	0.73
39	12	10	12	8.58	7.85	0.73
40	26	6	18	9.39	8.68	0.71
41	24	9	12	9.32	8.60	0.71
42	30	6	10	9.55	8.84	0.71
43	20	8	20	9.10	8.39	0.72
44	6	15	6	7.85	7.07	0.78
45	4	14	4	7.40	6.57	0.83
46	8	12	10	8.14	7.38	0.76
47	10	8	8	8.40	7.66	0.74
48	12	10	14	8.57	7.84	0.73
49	16	7	14	8.88	8.16	0.72
50	12	7	14	8.57	7.84	0.73
51	14	8	18	8.72	8.00	0.73
52	10	6	22	8.32	8.38	-0.06
53	22	5	20	9.21	8.49	0.71
54	26	4	12	9.40	8.69	0.71

Table: The Simulations if WT is decreased with 50% for model without SI

S/N0	F	C	WT(-50)	A1	A(wt-50, fc)	Diff
1	10	8	5	8.39	8.41	0.03

2	3	15	1.5	7.07	7.10	0.03
3	2	14	1	6.57	6.60	0.03
4	4	12	2.5	7.38	7.42	0.03
5	5	8	2	7.66	7.68	0.02
6	6	10	3.5	7.84	7.87	0.03
7	8	7	3.5	8.16	8.18	0.02
8	6	7	3.5	7.84	7.87	0.03
9	7	8	4.5	8.00	8.03	0.03
10	10	6	6.5	8.38	8.41	0.02
11	11	5	5	8.49	8.52	0.02
12	13	4	3	8.69	8.70	0.01
13	12	4	5.5	8.58	8.61	0.02
14	11	3	4.5	8.50	8.52	0.02
15	8	6	3.5	8.16	8.18	0.02
16	9	6	5	8.27	8.30	0.03
17	6	10	3	7.85	7.87	0.03
18	12	7	5	8.59	8.61	0.02
19	13	6	4.5	8.68	8.69	0.02
20	12	9	3	8.60	8.62	0.01
21	15	6	2.5	8.84	8.85	0.01
22	10	8	10	8.39	8.39	0.00
23	3	15	1.5	7.07	7.10	0.03
24	2	14	1	6.57	6.60	0.03
25	4	12	2.5	7.38	7.42	0.03
26	5	8	2	7.66	7.68	0.02
27	6	10	3.5	7.84	7.87	0.03
28	8	7	3.5	8.16	8.18	0.02
29	6	7	3.5	7.84	7.87	0.03
30	7	8	4.5	8.00	8.03	0.03
31	10	6	5.5	8.38	8.41	0.03
32	11	5	5	8.49	8.52	0.02

33	13	4	3	8.69	8.70	0.01
34	12	4	5.5	8.58	8.61	0.02
35	11	3	4.5	8.50	8.52	0.02
36	8	6	3.5	8.16	8.18	0.02
37	9	6	5	8.27	8.30	0.03
38	7	8	3	8.02	8.04	0.02
39	6	10	3	7.85	7.87	0.03
40	13	6	4.5	8.68	8.69	0.02
41	12	9	3	8.60	8.62	0.01
42	15	6	2.5	8.84	8.85	0.01
43	10	8	5	8.39	8.41	0.03
44	3	15	1.5	7.07	7.10	0.03
45	2	14	1	6.57	6.60	0.03
46	4	12	2.5	7.38	7.42	0.03
47	5	8	2	7.66	7.68	0.02
48	6	10	3.5	7.84	7.87	0.03
49	8	7	3.5	8.16	8.18	0.02
50	6	7	3.5	7.84	7.87	0.03
51	7	8	4.5	8.00	8.03	0.03
52	10	6	5.5	8.38	8.41	0.03
53	11	5	5	8.49	8.52	0.02
54	13	4	3	8.69	8.70	0.01

Table: The Simulations if F,C, &WT is decreased with 50% for model without SI

S/N0	F(-50%)	C(-50%)	WT(-50)	A(fcwt-50)	A1	Diff
1	5	4	5	7.65	8.39	-0.74
2	1.5	7.5	1.5	6.18	7.07	-0.89
3	1	7	1	5.54	6.57	-1.04
4	2	6	2.5	6.55	7.38	-0.83
5	2.5	4	2	6.86	7.66	-0.80

6	3	5	3.5	7.06	7.84	-0.78
7	4	3.5	3.5	7.41	8.16	-0.75
8	3	3.5	3.5	7.06	7.84	-0.78
9	3.5	4	4.5	7.23	8.00	-0.77
10	5	3	6.5	7.63	8.38	-0.75
11	5.5	2.5	5	7.76	8.49	-0.74
12	6.5	2	3	7.96	8.69	-0.73
13	6	2	5.5	7.85	8.58	-0.73
14	5.5	1.5	4.5	7.76	8.50	-0.74
15	4	3	3.5	7.41	8.16	-0.75
16	4.5	3	5	7.52	8.27	-0.75
17	3	5	3	7.07	7.85	-0.78
18	6	3.5	5	7.85	8.59	-0.73
19	6.5	3	4.5	7.95	8.68	-0.73
20	6	4.5	3	7.87	8.60	-0.73
21	7.5	3	2.5	8.12	8.84	-0.72
22	5	4	10	7.59	8.39	-0.80
23	1.5	7.5	1.5	6.18	7.07	-0.89
24	1	7	1	5.54	6.57	-1.04
25	2	6	2.5	6.55	7.38	-0.83
26	2.5	4	2	6.86	7.66	-0.80
27	3	5	3.5	7.06	7.84	-0.78
28	4	3.5	3.5	7.41	8.16	-0.75
29	3	3.5	3.5	7.06	7.84	-0.78
30	3.5	4	4.5	7.23	8.00	-0.77
31	5	3	5.5	7.64	8.38	-0.74
32	5.5	2.5	5	7.76	8.49	-0.74
33	6.5	2	3	7.96	8.69	-0.73
34	6	2	5.5	7.85	8.58	-0.73
35	5.5	1.5	4.5	7.76	8.50	-0.74
36	4	3	3.5	7.41	8.16	-0.75

37	4.5	3	5	7.52	8.27	-0.75
38	3.5	4	3	7.25	8.02	-0.76
39	3	5	3	7.07	7.85	-0.78
40	6.5	3	4.5	7.95	8.68	-0.73
41	6	4.5	3	7.87	8.60	-0.73
42	7.5	3	2.5	8.12	8.84	-0.72
43	5.5	4	5	7.76	8.39	-0.63
44	1.5	7.5	1.5	6.18	7.07	-0.89
45	1	7	1	5.54	6.57	-1.04
46	2	6	2.5	6.55	7.38	-0.83
47	2.5	4	2	6.86	7.66	-0.80
48	3	5	3.5	7.06	7.84	-0.78
49	4	3.5	3.5	7.41	8.16	-0.75
50	3	3.5	3.5	7.06	7.84	-0.78
51	3.5	4	4.5	7.23	8.00	-0.77
52	5	3	5.5	7.64	8.38	-0.74
53	5.5	2.5	5	7.76	8.49	-0.74
54	6.5	2	3	7.96	8.69	-0.73

Table: The Simulations if F100 & WT100 is increased with 100% & C-50 decreased with 50% for model without SI

S/N0	F (100%)	C(-50%)	WT(100%)	A(fwt100, c-50)	A1	Diff
1	20	4	20	9.10	8.39	0.72
2	6	7.5	6	7.85	7.07	0.78
3	4	7	4	7.40	6.57	0.83
4	8	6	10	8.14	7.38	0.75
5	10	4	8	8.40	7.66	0.74
6	12	5	14	8.57	7.84	0.73
7	16	3.5	14	8.88	8.16	0.72
8	12	3.5	14	8.57	7.84	0.73
9	14	4	18	8.72	8.00	0.73

10	20	3	22	9.10	8.38	0.72
11	22	2.5	20	9.21	8.49	0.71
12	26	2	12	9.40	8.69	0.71
13	24	2	22	9.29	8.58	0.71
14	22	1.5	18	9.21	8.50	0.71
15	16	3	14	8.88	8.16	0.72
16	18	3	20	8.99	8.27	0.72
17	12	5	12	8.58	7.85	0.73
18	24	3.5	20	9.30	8.59	0.71
19	26	3	18	9.39	8.68	0.71
20	24	4.5	12	9.32	8.60	0.71
21	30	3	10	9.55	8.84	0.71
22	20	4	20	9.10	8.39	0.72
23	6	7.5	6	7.85	7.07	0.78
24	4	7	4	7.40	6.57	0.83
25	8	6	10	8.14	7.38	0.75
26	10	4	8	8.40	7.66	0.74
27	12	5	14	8.57	7.84	0.73
28	18	3.5	14	9.01	8.16	0.85
29	12	3.5	14	8.57	7.84	0.73
30	14	4	18	8.72	8.00	0.73
31	20	3	22	9.10	8.38	0.72
32	22	2.5	20	9.21	8.49	0.71
33	26	2	12	9.40	8.69	0.71
34	24	2	22	9.29	8.58	0.71
35	22	1.5	18	9.21	8.50	0.71
36	16	3	14	8.88	8.16	0.72
37	18	3	20	8.99	8.27	0.72
38	14	4	12	8.75	8.02	0.73
39	12	5	12	8.58	7.85	0.73
40	26	3	18	9.39	8.68	0.71

41	24	4.5	12	9.32	8.60	0.71
42	30	3	10	9.55	8.84	0.71
43	20	4	20	9.10	8.39	0.72
44	6	7.5	6	7.85	7.07	0.78
45	4	7	4	7.40	6.57	0.83
46	8	6	10	8.14	7.38	0.75
47	10	4	8	8.40	7.66	0.74
48	12	5	14	8.57	7.84	0.73
49	16	3.5	14	8.88	8.16	0.72
50	12	3.5	14	8.57	7.84	0.73
51	14	4	18	8.72	8.00	0.73
52	10	3	22	8.32	8.38	-0.06
53	22	2.5	20	9.21	8.49	0.71
54	26	2	12	9.40	8.69	0.71

Table: The Simulations if WT is increased with 100% for model without SI

S/N0	F	C	WT(100%)	A(wt100)	A1	Diff
1	10	8	20	8.33	8.39	-0.05
2	3	15	6	7.01	7.07	-0.06
3	2	14	4	6.51	6.57	-0.07
4	4	12	10	7.31	7.38	-0.07
5	5	8	8	7.61	7.66	-0.04
6	6	10	14	7.77	7.84	-0.07
7	8	7	14	8.11	8.16	-0.05
8	6	7	14	7.77	7.84	-0.07
9	7	8	18	7.92	8.00	-0.07
10	10	6	22	8.32	8.38	-0.06
11	11	5	20	8.44	8.49	-0.05
12	13	4	12	8.67	8.69	-0.02
13	12	4	22	8.53	8.58	-0.05
14	11	3	18	8.45	8.50	-0.04

15	8	6	14	8.11	8.16	-0.05
16	9	6	20	8.21	8.27	-0.06
17	6	10	12	7.79	7.85	-0.06
18	12	7	20	8.54	8.59	-0.04
19	13	6	18	8.64	8.68	-0.04
20	12	9	12	8.58	8.60	-0.03
21	15	6	10	8.83	8.84	-0.02
22	10	8	20	8.33	8.39	-0.05
23	3	15	6	7.01	7.07	-0.06
24	2	14	4	6.51	6.57	-0.07
25	4	12	10	7.31	7.38	-0.07
26	5	8	8	7.61	7.66	-0.04
27	6	10	14	7.77	7.84	-0.07
28	8	7	14	8.11	8.16	-0.05
29	6	7	14	7.77	7.84	-0.07
30	7	8	18	7.92	8.00	-0.07
31	10	6	22	8.32	8.38	-0.06
32	11	5	20	8.44	8.49	-0.05
33	13	4	12	8.67	8.69	-0.02
34	12	4	22	8.53	8.58	-0.05
35	11	3	18	8.45	8.50	-0.04
36	8	6	14	8.11	8.16	-0.05
37	9	6	20	8.21	8.27	-0.06
38	7	8	12	7.97	8.02	-0.05
39	6	10	12	7.79	7.85	-0.06
40	13	6	18	8.64	8.68	-0.04
41	12	9	12	8.58	8.60	-0.03
42	15	6	10	8.83	8.84	-0.02
43	10	8	20	8.33	8.39	-0.05
44	3	15	6	7.01	7.07	-0.06
45	2	14	4	6.51	6.57	-0.07

46	4	12	10	7.31	7.38	-0.07
47	5	8	8	7.61	7.66	-0.04
48	6	10	14	7.77	7.84	-0.07
49	8	7	14	8.11	8.16	-0.05
50	6	7	14	7.77	7.84	-0.07
51	7	8	18	7.92	8.00	-0.07
52	10	6	22	8.32	8.38	-0.06
53	11	5	20	8.44	8.49	-0.05
54	13	4	12	8.67	8.69	-0.02

Table: The Simulations if F(-50%) is decreased with 50% for model without SI

S/N0	F(-50%)	C	WT	A(f-50%)	A1	Diff
1	5	8	10	7.59	8.39	-0.80
2	1.5	15	3	6.11	7.07	-0.96
3	1	14	2	5.45	6.57	-1.13
4	2	12	5	6.47	7.38	-0.91
5	2.5	8	4	6.81	7.66	-0.84
6	3	10	7	6.99	7.84	-0.85
7	4	7	7	7.36	8.16	-0.80
8	3	7	7	6.99	7.84	-0.85
9	3.5	8	9	7.15	8.00	-0.84
10	5	6	11	7.58	8.38	-0.80
11	5.5	5	10	7.71	8.49	-0.79
12	6.5	4	6	7.94	8.69	-0.75
13	6	4	11	7.80	8.58	-0.78
14	5.5	3	9	7.72	8.50	-0.78
15	4	6	7	7.36	8.16	-0.80
16	4.5	6	10	7.46	8.27	-0.81
17	3	10	6	7.01	7.85	-0.84

18	6	7	10	7.81	8.59	-0.78
19	6.5	6	9	7.91	8.68	-0.77
20	6	9	6	7.85	8.60	-0.76
21	7.5	6	5	8.10	8.84	-0.74
22	5	8	10	7.59	8.39	-0.80
23	1.5	15	3	6.11	7.07	-0.96
24	1	14	2	5.45	6.57	-1.13
25	2	12	5	6.47	7.38	-0.91
26	2.5	8	4	6.81	7.66	-0.84
27	3	10	7	6.99	7.84	-0.85
28	4	7	7	7.36	8.16	-0.80
29	3	7	7	6.99	7.84	-0.85
30	3.5	8	9	7.15	8.00	-0.84
31	5	6	11	7.58	8.38	-0.80
32	5.5	5	10	7.71	8.49	-0.79
33	6.5	4	6	7.94	8.69	-0.75
34	6	4	11	7.80	8.58	-0.78
35	5.5	3	9	7.72	8.50	-0.78
36	4	6	7	7.36	8.16	-0.80
37	4.5	6	10	7.46	8.27	-0.81
38	3.5	8	6	7.21	8.02	-0.81
39	3	10	6	7.01	7.85	-0.84
40	6.5	6	9	7.91	8.68	-0.77
41	6	9	6	7.85	8.60	-0.76
42	7.5	6	5	8.10	8.84	-0.74
43	5.5	8	10	7.71	8.39	-0.68
44	1.5	15	3	6.11	7.07	-0.96
45	1	14	2	5.45	6.57	-1.13
46	2	12	5	6.47	7.38	-0.91
47	2.5	8	4	6.81	7.66	-0.84
48	3	10	7	6.99	7.84	-0.85

49	4	7	7	7.36	8.16	-0.80
50	3	7	7	6.99	7.84	-0.85
51	3.5	8	9	7.15	8.00	-0.84
52	5	6	11	7.58	8.38	-0.80
53	5.5	5	10	7.71	8.49	-0.79
54	6.5	4	6	7.94	8.69	-0.75

Table: The Simulations if C(-50%) is decreased with 50% for model without SI

S/N0	F	C(-50%)	WT	A(c-50%)	A1	Diff
1	10	4	10	8.39	8.39	0.00
2	3	7.5	3	7.07	7.07	0.00
3	2	7	2	6.57	6.57	0.00
4	4	6	5	7.38	7.38	0.00
5	5	4	4	7.66	7.66	0.00
6	6	5	7	7.84	7.84	0.00
7	8	3.5	7	8.16	8.16	0.00
8	6	3.5	7	7.84	7.84	0.00
9	7	4	9	8.00	8.00	0.00
10	10	3	11	8.38	8.38	0.00
11	11	2.5	10	8.49	8.49	0.00
12	13	2	6	8.69	8.69	0.00
13	12	2	11	8.58	8.58	0.00
14	11	1.5	9	8.50	8.50	0.00
15	8	3	7	8.16	8.16	0.00
16	9	3	10	8.27	8.27	0.00
17	6	5	6	7.85	7.85	0.00
18	12	3.5	10	8.59	8.59	0.00
19	13	3	9	8.68	8.68	0.00
20	12	4.5	6	8.60	8.60	0.00
21	15	3	5	8.84	8.84	0.00

22	10	4	10	8.39	8.39	0.00
23	3	7.5	3	7.07	7.07	0.00
24	2	7	2	6.57	6.57	0.00
25	4	6	5	7.38	7.38	0.00
26	5	4	4	7.66	7.66	0.00
27	6	5	7	7.84	7.84	0.00
28	8	3.5	7	8.16	8.16	0.00
29	6	3.5	7	7.84	7.84	0.00
30	7	4	9	8.00	8.00	0.00
31	10	3	11	8.38	8.38	0.00
32	11	2.5	10	8.49	8.49	0.00
33	13	2	6	8.69	8.69	0.00
34	12	2	11	8.58	8.58	0.00
35	11	1.5	9	8.50	8.50	0.00
36	8	3	7	8.16	8.16	0.00
37	9	3	10	8.27	8.27	0.00
38	7	4	6	8.02	8.02	0.00
39	6	5	6	7.85	7.85	0.00
40	13	3	9	8.68	8.68	0.00
41	12	4.5	6	8.60	8.60	0.00
42	15	3	5	8.84	8.84	0.00
43	10	4	10	8.39	8.39	0.00
44	3	7.5	3	7.07	7.07	0.00
45	2	7	2	6.57	6.57	0.00
46	4	6	5	7.38	7.38	0.00
47	5	4	4	7.66	7.66	0.00
48	6	5	7	7.84	7.84	0.00
49	8	3.5	7	8.16	8.16	0.00
50	6	3.5	7	7.84	7.84	0.00
51	7	4	9	8.00	8.00	0.00
52	10	3	11	8.38	8.38	0.00

53	11	2.5	10	8.49	8.49	0.00
54	13	2	6	8.69	8.69	0.00

Table: The Simulations if WT(-50) is decreased with 50% for model without SI

S/N0	F	C	WT(-50%)	A(wt-50%)	A1	Diff
1	10	8	5	8.41	8.39	0.03
2	3	15	1.5	7.10	7.07	0.03
3	2	14	1	6.60	6.57	0.03
4	4	12	2.5	7.42	7.38	0.03
5	5	8	2	7.68	7.66	0.02
6	6	10	3.5	7.87	7.84	0.03
7	8	7	3.5	8.18	8.16	0.02
8	6	7	3.5	7.87	7.84	0.03
9	7	8	4.5	8.03	8.00	0.03
10	10	6	6.5	8.41	8.38	0.02
11	11	5	5	8.52	8.49	0.02
12	13	4	3	8.70	8.69	0.01
13	12	4	5.5	8.61	8.58	0.02
14	11	3	4.5	8.52	8.50	0.02
15	8	6	3.5	8.18	8.16	0.02
16	9	6	5	8.30	8.27	0.03
17	6	10	3	7.87	7.85	0.03
18	12	7	5	8.61	8.59	0.02
19	13	6	4.5	8.69	8.68	0.02
20	12	9	3	8.62	8.60	0.01
21	15	6	2.5	8.85	8.84	0.01
22	10	8	10	8.39	8.39	0.00
23	3	15	1.5	7.10	7.07	0.03
24	2	14	1	6.60	6.57	0.03
25	4	12	2.5	7.42	7.38	0.03

26	5	8	2	7.68	7.66	0.02
27	6	10	3.5	7.87	7.84	0.03
28	8	7	3.5	8.18	8.16	0.02
29	6	7	3.5	7.87	7.84	0.03
30	7	8	4.5	8.03	8.00	0.03
31	10	6	5.5	8.41	8.38	0.03
32	11	5	5	8.52	8.49	0.02
33	13	4	3	8.70	8.69	0.01
34	12	4	5.5	8.61	8.58	0.02
35	11	3	4.5	8.52	8.50	0.02
36	8	6	3.5	8.18	8.16	0.02
37	9	6	5	8.30	8.27	0.03
38	7	8	3	8.04	8.02	0.02
39	6	10	3	7.87	7.85	0.03
40	13	6	4.5	8.69	8.68	0.02
41	12	9	3	8.62	8.60	0.01
42	15	6	2.5	8.85	8.84	0.01
43	10	8	5	8.41	8.39	0.03
44	3	15	1.5	7.10	7.07	0.03
45	2	14	1	6.60	6.57	0.03
46	4	12	2.5	7.42	7.38	0.03
47	5	8	2	7.68	7.66	0.02
48	6	10	3.5	7.87	7.84	0.03
49	8	7	3.5	8.18	8.16	0.02
50	6	7	3.5	7.87	7.84	0.03
51	7	8	4.5	8.03	8.00	0.03
52	10	6	5.5	8.41	8.38	0.03
53	11	5	5	8.52	8.49	0.02
54	13	4	3	8.70	8.69	0.01

Table: The Simulations if F is increased with 100% for model with SI

S/No	F (100%)	C	WT	S	A2	A(f100)	Diif
1	20	8	10	0.37	8.39	9.13	0.74
2	6	15	3	0.21	7.08	7.88	0.80
3	4	14	2	0.12	6.58	7.43	0.85
4	8	12	5	0.20	7.39	8.17	0.79
5	10	8	4	0.31	7.68	8.43	0.75
6	12	10	7	0.19	7.83	8.59	0.76
7	16	7	7	0.21	8.16	8.90	0.74
8	12	7	7	0.16	7.83	8.59	0.76
9	14	8	9	0.33	8.00	8.75	0.76
10	20	6	11	0.41	8.38	9.13	0.74
11	22	5	10	0.41	8.49	9.23	0.73
12	26	4	6	0.24	8.69	9.41	0.72
13	24	4	11	0.42	8.58	9.32	0.73
14	22	3	9	0.32	8.50	9.23	0.73
15	16	6	7	0.19	8.16	8.90	0.74
16	18	6	10	0.37	8.27	9.02	0.74
17	12	10	6	0.27	7.85	8.60	0.75
18	24	7	10	0.44	8.59	9.32	0.73
19	26	6	9	0.39	8.68	9.40	0.73
20	24	9	6	0.30	8.61	9.33	0.72
21	30	6	5	0.20	8.84	9.56	0.71
22	20	8	10	0.41	8.39	9.13	0.74
23	6	15	3	0.10	7.06	7.87	0.81
24	4	14	2	0.10	6.57	7.43	0.85
25	8	12	5	0.20	7.39	8.17	0.79
26	10	8	4	0.18	7.66	8.42	0.76
27	12	10	7	0.30	7.84	8.60	0.76
28	18	7	7	0.21	8.16	9.02	0.87
29	12	7	7	0.16	7.83	8.59	0.76
30	14	8	9	0.29	7.99	8.75	0.76
31	20	6	11	0.37	8.38	9.12	0.74
32	22	5	10	0.31	8.49	9.23	0.74
33	26	4	6	0.27	8.69	9.41	0.72
34	24	4	11	0.37	8.58	9.32	0.73
35	22	3	9	0.32	8.50	9.23	0.73
36	16	6	7	0.23	8.16	8.90	0.74
37	18	6	10	0.41	8.28	9.02	0.74
38	14	8	6	0.18	8.02	8.76	0.75
39	12	10	6	0.25	7.85	8.60	0.76
40	26	6	9	0.33	8.68	9.40	0.73
41	24	9	6	0.19	8.60	9.32	0.72

42	30	6	5	0.20	8.84	9.56	0.71
43	20	8	10	0.37	8.39	9.13	0.74
44	6	15	3	0.13	7.06	7.87	0.80
45	4	14	2	0.11	6.57	7.43	0.85
46	8	12	5	0.20	7.39	8.17	0.79
47	10	8	4	0.15	7.66	8.42	0.76
48	12	10	7	0.21	7.83	8.60	0.76
49	16	7	7	0.16	8.15	8.90	0.75
50	12	7	7	0.18	7.83	8.60	0.76
51	14	8	9	0.31	8.00	8.75	0.76
52	10	6	11	0.37	8.38	8.38	0.00
53	22	5	10	0.38	8.49	9.23	0.73
54	26	4	6	0.14	8.69	9.41	0.72

Table: The Simulations if F,C,WT&S is increased with 100% for model with SI

S/NO	F (100%)	C (100)	WT(100%)	S(100)	A(100)	A2	Diff
1	20	16	20	0.74	9.10	8.39	0.71
2	6	30	6	0.43	7.85	7.08	0.77
3	4	28	4	0.24	7.39	6.58	0.81
4	8	24	10	0.40	8.13	7.39	0.75
5	10	16	8	0.62	8.41	7.68	0.73
6	12	20	14	0.38	8.56	7.83	0.73
7	16	14	14	0.42	8.88	8.16	0.72
8	12	14	14	0.32	8.56	7.83	0.73
9	14	16	18	0.67	8.72	8.00	0.72
10	20	12	22	0.82	9.10	8.38	0.71
11	22	10	20	0.82	9.21	8.49	0.71
12	26	8	12	0.48	9.40	8.69	0.71
13	24	8	22	0.85	9.29	8.58	0.71
14	22	6	18	0.64	9.21	8.50	0.71
15	16	12	14	0.37	8.88	8.16	0.72
16	18	12	20	0.75	8.99	8.27	0.72
17	12	20	12	0.53	8.58	7.85	0.73
18	24	14	20	0.87	9.30	8.59	0.71
19	26	12	18	0.79	9.39	8.68	0.71
20	24	18	12	0.60	9.31	8.61	0.71
21	30	12	10	0.40	9.55	8.84	0.71
22	20	16	20	0.82	9.10	8.39	0.71
23	6	30	6	0.20	7.83	7.06	0.77
24	4	28	4	0.20	7.38	6.57	0.81
25	8	24	10	0.40	8.13	7.39	0.75
26	10	16	8	0.36	8.40	7.66	0.73

27	12	20	14	0.60	8.57	7.84	0.73
28	18	14	14	0.42	9.00	8.16	0.85
29	12	14	14	0.32	8.56	7.83	0.73
30	14	16	18	0.58	8.72	7.99	0.72
31	20	12	22	0.74	9.10	8.38	0.71
32	22	10	20	0.62	9.20	8.49	0.71
33	26	8	12	0.53	9.40	8.69	0.71
34	24	8	22	0.73	9.29	8.58	0.71
35	22	6	18	0.64	9.21	8.50	0.71
36	16	12	14	0.46	8.88	8.16	0.72
37	18	12	20	0.82	8.99	8.28	0.72
38	14	16	12	0.36	8.74	8.02	0.72
39	12	20	12	0.50	8.58	7.85	0.73
40	26	12	18	0.66	9.38	8.68	0.71
41	24	18	12	0.38	9.31	8.60	0.71
42	30	12	10	0.40	9.55	8.84	0.71
43	20	16	20	0.74	9.10	8.39	0.71
44	6	30	6	0.26	7.83	7.06	0.77
45	4	28	4	0.22	7.39	6.57	0.81
46	8	24	10	0.40	8.13	7.39	0.75
47	10	16	8	0.30	8.39	7.66	0.74
48	12	20	14	0.42	8.56	7.83	0.73
49	16	14	14	0.32	8.87	8.15	0.72
50	12	14	14	0.36	8.56	7.83	0.73
51	14	16	18	0.62	8.72	8.00	0.72
52	10	12	22	0.74	8.32	8.38	-0.06
53	22	10	20	0.76	9.21	8.49	0.71
54	26	8	12	0.28	9.39	8.69	0.71

Table: The Simulations if WT is increased with 100% for model with SI

S/N0	F	C	WT(100%)	S	A2	A(WT100)	Diff
1	10	8	20	0.37	8.39	8.32	-0.07
2	3	15	6	0.21	7.08	7.00	-0.08
3	2	14	4	0.12	6.58	6.49	-0.09
4	4	12	10	0.20	7.39	7.29	-0.10
5	5	8	8	0.31	7.68	7.62	-0.06
6	6	10	14	0.19	7.83	7.74	-0.09
7	8	7	14	0.21	8.16	8.09	-0.06
8	6	7	14	0.16	7.83	7.74	-0.09
9	7	8	18	0.33	8.00	7.90	-0.10
10	10	6	22	0.41	8.38	8.30	-0.08

11	11	5	20	0.41	8.49	8.43	-0.06
12	13	4	12	0.24	8.69	8.66	-0.03
13	12	4	22	0.42	8.58	8.52	-0.06
14	11	3	18	0.32	8.50	8.44	-0.06
15	8	6	14	0.19	8.16	8.09	-0.06
16	9	6	20	0.37	8.27	8.19	-0.08
17	6	10	12	0.27	7.85	7.78	-0.07
18	12	7	20	0.44	8.59	8.53	-0.06
19	13	6	18	0.39	8.68	8.63	-0.05
20	12	9	12	0.30	8.61	8.57	-0.03
21	15	6	10	0.20	8.84	8.82	-0.02
22	10	8	20	0.41	8.39	8.32	-0.07
23	3	15	6	0.10	7.06	6.98	-0.08
24	2	14	4	0.10	6.57	6.48	-0.09
25	4	12	10	0.20	7.39	7.29	-0.10
26	5	8	8	0.18	7.66	7.60	-0.06
27	6	10	14	0.30	7.84	7.75	-0.09
28	8	7	14	0.21	8.16	8.09	-0.06
29	6	7	14	0.16	7.83	7.74	-0.09
30	7	8	18	0.29	7.99	7.90	-0.10
31	10	6	22	0.37	8.38	8.30	-0.08
32	11	5	20	0.31	8.49	8.43	-0.06
33	13	4	12	0.27	8.69	8.66	-0.03
34	12	4	22	0.37	8.58	8.52	-0.06
35	11	3	18	0.32	8.50	8.44	-0.06
36	8	6	14	0.23	8.16	8.10	-0.06
37	9	6	20	0.41	8.28	8.19	-0.08
38	7	8	12	0.18	8.02	7.95	-0.06
39	6	10	12	0.25	7.85	7.77	-0.07
40	13	6	18	0.33	8.68	8.63	-0.05
41	12	9	12	0.19	8.60	8.57	-0.03
42	15	6	10	0.20	8.84	8.82	-0.02
43	10	8	20	0.37	8.39	8.32	-0.07
44	3	15	6	0.13	7.06	6.98	-0.08
45	2	14	4	0.11	6.57	6.49	-0.09
46	4	12	10	0.20	7.39	7.29	-0.10
47	5	8	8	0.15	7.66	7.60	-0.06
48	6	10	14	0.21	7.83	7.74	-0.09
49	8	7	14	0.16	8.15	8.09	-0.06
50	6	7	14	0.18	7.83	7.74	-0.09
51	7	8	18	0.31	8.00	7.90	-0.10
52	10	6	22	0.37	8.38	8.30	-0.08
53	11	5	20	0.38	8.49	8.43	-0.06

54	13	4	12	0.14	8.69	8.65	-0.03
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Table: The Simulations if S is increased with 100% for model with SI

S/N0	F	C	WT	S(100)	A(S100)	A2	Diff
1	10	8	10	0.74	8.41	8.39	0.02
2	3	15	3	0.43	7.12	7.08	0.04
3	2	14	2	0.24	6.61	6.58	0.03
4	4	12	5	0.40	7.41	7.39	0.03
5	5	8	4	0.62	7.71	7.68	0.03
6	6	10	7	0.38	7.85	7.83	0.02
7	8	7	7	0.42	8.17	8.16	0.01
8	6	7	7	0.32	7.84	7.83	0.01
9	7	8	9	0.67	8.02	8.00	0.02
10	10	6	11	0.82	8.40	8.38	0.02
11	11	5	10	0.82	8.51	8.49	0.02
12	13	4	6	0.48	8.70	8.69	0.01
13	12	4	11	0.85	8.60	8.58	0.02
14	11	3	9	0.64	8.51	8.50	0.01
15	8	6	7	0.37	8.17	8.16	0.01
16	9	6	10	0.75	8.29	8.27	0.02
17	6	10	6	0.53	7.87	7.85	0.02
18	12	7	10	0.87	8.61	8.59	0.02
19	13	6	9	0.79	8.69	8.68	0.01
20	12	9	6	0.60	8.62	8.61	0.01
21	15	6	5	0.40	8.85	8.84	0.01
22	10	8	10	0.82	8.41	8.39	0.02
23	3	15	3	0.20	7.08	7.06	0.02
24	2	14	2	0.20	6.60	6.57	0.03
25	4	12	5	0.40	7.41	7.39	0.03
26	5	8	4	0.36	7.68	7.66	0.02
27	6	10	7	0.60	7.86	7.84	0.03
28	8	7	7	0.42	8.17	8.16	0.01
29	6	7	7	0.32	7.84	7.83	0.01
30	7	8	9	0.58	8.01	7.99	0.02
31	10	6	11	0.74	8.40	8.38	0.02
32	11	5	10	0.62	8.50	8.49	0.01
33	13	4	6	0.53	8.70	8.69	0.01
34	12	4	11	0.73	8.60	8.58	0.01
35	11	3	9	0.64	8.51	8.50	0.01
36	8	6	7	0.46	8.17	8.16	0.01
37	9	6	10	0.82	8.30	8.28	0.02
38	7	8	6	0.36	8.03	8.02	0.01

39	6	10	6	0.50	7.87	7.85	0.02
40	13	6	9	0.66	8.69	8.68	0.01
41	12	9	6	0.38	8.61	8.60	0.01
42	15	6	5	0.40	8.85	8.84	0.01
43	10	8	10	0.74	8.41	8.39	0.02
44	3	15	3	0.26	7.09	7.06	0.02
45	2	14	2	0.22	6.61	6.57	0.03
46	4	12	5	0.40	7.41	7.39	0.03
47	5	8	4	0.30	7.67	7.66	0.02
48	6	10	7	0.42	7.85	7.83	0.02
49	8	7	7	0.32	8.16	8.15	0.01
50	6	7	7	0.36	7.85	7.83	0.02
51	7	8	9	0.62	8.02	8.00	0.02
52	10	6	11	0.74	8.40	8.38	0.02
53	11	5	10	0.76	8.51	8.49	0.02
54	13	4	6	0.28	8.69	8.69	0.01

Table: The Simulations if F is increased with 200% for model with SI

S/N0	F(200)	C	WT	S	A2	A(f200)	Diff
1	40	8	10	0.37	8.39	9.84	1.46
2	12	15	3	0.21	7.08	8.62	1.54
3	8	14	2	0.12	6.58	8.19	1.61
4	16	12	5	0.20	7.39	8.91	1.52
5	20	8	4	0.31	7.68	9.15	1.47
6	24	10	7	0.19	7.83	9.32	1.49
7	32	7	7	0.21	8.16	9.62	1.46
8	24	7	7	0.16	7.83	9.32	1.49
9	28	8	9	0.33	8.00	9.48	1.48
10	40	6	11	0.41	8.38	9.84	1.46
11	44	5	10	0.41	8.49	9.94	1.45
12	52	4	6	0.24	8.69	10.12	1.43
13	48	4	11	0.42	8.58	10.03	1.45
14	44	3	9	0.32	8.50	9.94	1.44
15	32	6	7	0.19	8.16	9.62	1.46
16	36	6	10	0.37	8.27	9.74	1.46
17	24	10	6	0.27	7.85	9.33	1.48
18	48	7	10	0.44	8.59	10.03	1.44
19	52	6	9	0.39	8.68	10.11	1.43
20	48	9	6	0.30	8.61	10.03	1.43
21	60	6	5	0.20	8.84	10.26	1.42
22	40	8	10	0.41	8.39	9.84	1.45
23	12	15	3	0.10	7.06	8.61	1.55

24	8	14	2	0.10	6.57	8.19	1.62
25	16	12	5	0.20	7.39	8.91	1.52
26	20	8	4	0.18	7.66	9.14	1.48
27	24	10	7	0.30	7.84	9.32	1.48
28	36	7	7	0.21	8.16	9.74	1.58
29	24	7	7	0.16	7.83	9.32	1.49
30	28	8	9	0.29	7.99	9.48	1.48
31	40	6	11	0.37	8.38	9.84	1.46
32	44	5	10	0.31	8.49	9.94	1.45
33	52	4	6	0.27	8.69	10.12	1.43
34	48	4	11	0.37	8.58	10.03	1.45
35	44	3	9	0.32	8.50	9.94	1.44
36	32	6	7	0.23	8.16	9.62	1.46
37	36	6	10	0.41	8.28	9.74	1.46
38	28	8	6	0.18	8.02	9.48	1.47
39	24	10	6	0.25	7.85	9.33	1.48
40	52	6	9	0.33	8.68	10.11	1.44
41	48	9	6	0.19	8.60	10.03	1.43
42	60	6	5	0.20	8.84	10.26	1.42
43	40	8	10	0.37	8.39	9.84	1.46
44	12	15	3	0.13	7.06	8.61	1.55
45	8	14	2	0.11	6.57	8.19	1.62
46	16	12	5	0.20	7.39	8.91	1.52
47	20	8	4	0.15	7.66	9.14	1.48
48	24	10	7	0.21	7.83	9.32	1.49
49	32	7	7	0.16	8.15	9.62	1.46
50	24	7	7	0.18	7.83	9.32	1.49
51	28	8	9	0.31	8.00	9.48	1.48
52	20	6	11	0.37	8.38	9.12	0.74
53	44	5	10	0.38	8.49	9.94	1.45
54	52	4	6	0.14	8.69	10.11	1.43

Table 6-2: Model Information

Dependent Variable	A
Probability Distribution	Negative binomial (MLE)
Link Function	Log

Table 6-2: Model Case Processing Summary

	N	Percent
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Included	54	100.0%
Excluded	0	0.0%
Total	54	100.0%

Table 6-3: Model Continuous Variable Information for Predictors

	N	Minimum	Maximum	Mean	Std. Deviation
Dependent Variable A	54	600	7245	3619.35	1748.627
Covariate F	54	2	15	8.26	3.541
C	54	3	15	7.91	3.170
WT	54	2	11	7.13	2.628

Table 6-5: Model Omnibus Test for Predictors

Likelihood Ratio Chi-Square	df	Sig.
117.645	3	.000

Table 6-6: Test of Model Effects for Predictors

Source	Wald Chi-Square	df	Sig.
(Intercept)	846.149	1	.000
F	92.921	1	.000
C	6.114	1	.013
WT	4.386	1	.036

Table 6-7: Model Parameter Estimates Predictors (95% Wald Confidence Interval) Hypothesis Test

Parameter	B	Std. Error	Lower	Upper	Wald Chi-Square	df	Sig.
(Intercept)	7.183	.2469	6.699	7.667	846.149	1	.000
F	.117	.0122	.093	.141	92.921	1	.000
C	-.038	.0154	-.068	-.008	6.114	1	.013
WT	.029	.0141	.002	.057	4.386	1	.036
(Scale)	1a						
(Negative binomial)	.035	.0068	.024	.051			

Table 6-8 Descriptive Statistics of the model

	Mean	Std. Deviation	N
F	8.26	3.541	54
C	7.91	3.170	54
WT	7.13	2.628	54
A	3619.35	1748.627	54

Table 6-9 The Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.957a	.916	.911	520.569

Table : One-Sample Statistics of Primary Data

	N	Mean	Std. Deviation	Std. Error Mean
F	54	8.26	3.541	.482
C	54	7.91	3.170	.431
WT	54	7.13	2.628	.358

Table: Variance Inflation Factor of data

	B	Std. Error	Beta	t	Sig.	Coll Stat	
						Tolerance	VIF
(Constant)	3794.997	5089.433		0.746	0.46		
F	476.059	34.271	0.964	13.891	0	0.301	3.323
C	-9.768	42.422	-0.018	-0.23	0.819	0.245	4.081
TD	0.288	0.235	0.048	1.227	0.227	0.939	1.065
WT	-24.374	39.812	-0.037	-0.612	0.544	0.405	2.471
WT1	-69.065	34.157	-0.086	-2.022	0.05	0.793	1.26
WD1	-91.334	55.447	-0.072	-1.647	0.107	0.758	1.319
AS	-26.905	37.628	-0.03	-0.715	0.479	0.818	1.223
CM	240.49	167.859	0.069	1.433	0.159	0.631	1.584
NN	-49.296	97.614	-0.02	-0.505	0.616	0.927	1.079
TT	-10.394	34.308	-0.014	-0.303	0.763	0.695	1.439
WD	-120.746	62.111	-0.078	-1.944	0.059	0.897	1.115

Table: One Sample test of data

		One-Sample Test					
		Test Value = 0					
	t	df	Sig. (2-tailed)	95% Confidence Interval of the Difference			
				Mean Diff.	Lower	Upper	
A	15.21	53	0	3619.352	3142.07	4096.64	
F	17.142	53	0	8.259	7.29	9.23	
C	18.331	53	0	7.907	7.04	8.77	
TD	337.322	53	0	13423.44	13343.63	13503.26	
WT	19.935	53	0	7.13	6.41	7.85	
WT1	86.278	53	0	25.685	25.09	26.28	
WD1	199.299	53	0	37.38778	37.0115	37.764	
AS	254.388	53	0	67.722	67.19	68.26	
CM	23.175	53	0	1.574	1.44	1.71	

NN	14.216	53	0	1.37	1.18	1.56		
TT	82.049	53	0	25.981	25.35	26.62		
WD	40.526	53	0	6.241	5.93	6.55		

Table showing Train, Test and Validation Data for F/C

A	Count	Percent	A	Count	Percent
600	1	1.6%	4032	2	3.1%
708	1	1.6%	4088	1	1.6%
840	1	1.6%	4200	1	1.6%
900	1	1.6%	4284	1	1.6%
1062	1	1.6%	4410	1	1.6%
1200	1	1.6%	4608	1	1.6%
1416	1	1.6%	4620	1	1.6%
1470	1	1.6%	4680	1	1.6%
1736	1	1.6%	4830	1	1.6%
1770	1	1.6%	4851	1	1.6%
2100	1	1.6%	4928	1	1.6%
2160	2	3.1%	5040	2	3.1%
2196	1	1.6%	5236	2	3.1%
2520	3	4.7%	5313	1	1.6%
2730	1	1.6%	5616	1	1.6%
2940	1	1.6%	5712	2	3.1%
3024	3	4.7%	5796	1	1.6%
3087	3	4.7%	5880	1	1.6%
3120	1	1.6%	6279	2	3.1%
3150	1	1.6%	6300	2	3.1%
3300	1	1.6%	6552	1	1.6%
3348	1	1.6%	6615	1	1.6%
3600	1	1.6%	6664	1	1.6%
3630	1	1.6%	7140	1	1.6%
3864	1	1.6%	7245	1	1.6%
3920	1	1.6%			
Overall	64	100.0%			
Excluded	38				
Total	102				

Table showing Train, Test and Validation Data for WT & Daily Bus occupancy

A	Count	Percent	A	Count	Percent
600	1	1.6%	3630	1	1.6%
708	1	1.6%	3864	1	1.6%
840	1	1.6%	3920	1	1.6%
900	1	1.6%	4032	2	3.1%
1062	1	1.6%	4088	1	1.6%
1200	1	1.6%	4200	1	1.6%
1416	1	1.6%	4284	1	1.6%
1470	1	1.6%	4410	1	1.6%
1736	1	1.6%	4608	1	1.6%
1770	1	1.6%	4620	1	3.1%
2100	1	1.6%	4680	1	3.1%
2160	2	3.1%	4830	1	1.6%

2196	1	1.6%	4851	1	1.6%
2520	3	4.7%	4928	1	1.6%
2730	1	1.6%	5040	2	3.1%
2940	1	1.6%	5236	2	3.1%
3024	3	4.7%	5313	1	1.6%
3087	3	4.7%	5616	1	1.6%
3120	1	1.6%	5712	2	3.1%
3150	1	1.6%	5796	1	1.6%
3300	1	1.6%	5880	1	3.1%
3348	1	1.6%	6279	2	3.1%
3600	1	1.6%	6300	2	3.1%
			6552	1	1.6%
			6615	1	1.6%
			6664	1	1.6%
			7140	1	1.6%
			7245	1	1.6%
Overall	64	100.0%			
Excluded	38				
Total	102				

Table showing Incident Rate Ratio (IRR) Statistics for F / C

Group	Mean	Median	Std. Deviation	Coefficient of Dispersion	Median Centered	Within 20% of Median inclusive
600	.143	.143	.000			100.0%
708	.143	.143	.000			100.0%
840	.143	.143	.000			100.0%
900	.200	.200	.000			100.0%
1062	.200	.200	.000			100.0%
1200	.333	.333	.000			100.0%
1416	.333	.333	.000			100.0%
1470	.200	.200	.000			100.0%
1736	.333	.333	.000			100.0%
1770	.625	.625	.000			100.0%
2100	.625	.625	.000			100.0%
2160	.729	.729	.182	176	25.0%	100.0%
2196	.600	.600	.000			100.0%
2520	.786	.857	.139	.097	19.2%	66.7%
2730	.600	.600	.000			100.0%
2940	.875	.875	.000			100.0%
3024	.844	.600	.423	.407	86.4%	66.7%
3087	.875	.875	.000	.000	0.0%	100.0%
3120	1.143	1.143	.000			100.0%
3150	.857	.857	.000			100.0%
3300	1.250	1.250	.000			100.0%
3348	1.500	1.500	.000			100.0%
3600	1.250	1.250	.000			100.0%
3630	2.200	2.200	.000			100.0%
3864	1.333	1.333	.000			100.0%
3920	1.143	1.143	.000			100.0%
4032	2.250	2.250	1.061	.333	47.1%	0.0%
4088	1.333	1.333	.000			100.0%
4200	1.143	1.143	.000			100.0%
4284	1.500	1.500	.000			100.0%

4410	1.667	1.667	.000			100.0%
4608	1.714	1.714	.000			100.0%
4620	1.250	1.250	.000			100.0%
4680	3.250	3.250	.000			100.0%
4830	1.667	1.667	.000			100.0%
4851	3.667	3.667	.000			100.0%
4928	2.200	2.200	.000			100.0%
5040	2.333	2.333	.943	.286	40.4%	0.0%
5236	3.667	3.667	.000	.000	0.0%	100.0%
5313	2.200	2.200	.000			100.0%
5616	3.250	3.250	.000			100.0%
5712	.1672	2.167	1.179	.385	.54.4%	0.00
5796	1.333	1.333	.000			100.0%
5880	1.714	1.714	.000			100.0%
6279	2.167	2.167	.000			100.0%
6300	3.250	3.250	.354	.077	10.9%	100.0%
6552	3.250	3.250	.000			100.0%
6615	2.500	2.500	.000			100.0%
6664	3.500	3.500	.000			100.0%
7140	3.000	3.000	.000			100.0%
7245	2.500	2.500	.000			100.0%
Overall	1.552	1.333	1.068	.640	81.8%	21.9%

Table showing Ratio Statistics for WT / Daily Bus occupancy

Group	Mean	Median	Std. Deviation	Median Centered	Within 20% of Median inclusive
600	.007	.007			100.0%
708	.006	.006			100.0%
840	.005	.005			100.0%
900	.010	.010			100.0%
1062	.008	.008			100.0%
1200	.017	.017			100.0%
1416	.014	.014			100.0%
1470	.006	.006			100.0%
1736	.012	.012			100.0%
1770	.011	.011			100.0%
2100	.010	.010			100.0%
2160	.019	.019	.000	0.0%	100.0%
2196	.016	.016			100.0%
2520	.014	.017	.005	37.0%	66.7%
2730	.015	.015			100.0%
2940	.021	.021			100.0%
3024	.015	.014	.003	25.6%	66.7%
3087	.018	.020	.004	23.6%	66.7%
3120	.018	.018			100.0%
3150	.013	.013			100.0%
3300	.021	.021			100.0%
3348	.030	.030			100.0%
3600	.028	.028			100.0%
3630	.030	.030			100.0%
3864	.014	.014			100.0%
3920	.014	.014			100.0%
4032	.028	.028		26.8%	100.0%
4088	.014	.014			100.0%
4200	.013	.013			100.0%

4284	.021	.021			100.0%
4410	.025	.025			100.0%
4608	.026	.026			100.0%
4620	.022	.022			100.0%
4680	.017	.017			100.0%
4830	.023	.023			100.0%
4851	.020	.020			100.0%
4928	.022	.020			100.0%
5040	.024	.024	.003	12.9%	100.0%
5236	.019	.019	.000	0.0%	100.0%
5313	.021	.021			100.0%
5616	.014	.014			100.0%
5712	.018	.018	.007	41.6%	0.00
5796	.012	.012			100.0%
5880	.020	.020			100.0%
6279	.019	.019	.000	0.0%	100.0%
6300	.032	.032	.002	5.2%	100.0%
6552	.012	.012			100.0%
6615	.011	.011			100.0%
6664	.032	.032			100.0%
7140	.027	.027			100.0%
7245	.010	.010			100.0%
Overall	.018	.018		38.7%	35.9%