INTEGRATION OF INFORMATION COMMUNICATION TECHNOLOGY FOR SUSTAINABLE ROAD TRAFFIC MOVEMENT IN URBAN AREAS IN THE EASTERN CAPE, A CASE OF MTHATHA, SOUTH AFRICA

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BLOEMFONTEIN

Declaration

I, Miranda Londi Mvusi (##########), the undersigned, declare that the dissertation hereby submitted by me for the degree *Master of Engineering (Engineering: Civil)* at the Central University of Technology, Free State, is my own independent work; and complies with the Code of Academic Integrity, as well as other relevant policies, procedures, rules and regulations of the Central University of Technology, Free State; and has not been submitted before to any institution by myself or any other person in fulfilment (or partial fulfilment) of the requirements for the attainment of any engineering qualification.

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Abstract

Road transportation is critical in providing individuals with access to a variety of socio-economic activities, including business, education, employment, recreation and healthcare, particularly in cities. However, population growth, socio-economic activity as well as subsequent urban functions, and increased vehicular travel, have produced long term mobility issues in cities. The scenario of such difficulties in South African cities seem quite significant. Given this, there are claims that widespread utilisation of Information and Communication Technology (ICT) in travel as well as socio-economic pursuits could greatly reduce road transportation and traffic related issues while also promoting sustainable road transportation. As a result, the research investigated ways in which ICT could provide solutions to improve the road transportation system and promote sustainable road traffic movement in South African urban areas. The research used Mthatha, a town in Eastern Cape, South Africa as the subject of the study. The research included data from primary sources, such as road user surveys and a transport characteristic survey conducted using a random sample technique, as well as secondary sources, like published and unpublished statistical information accessed through credible sources. Quantitative statistical analysis and empirical studies have been used to investigate the state of sustainable transport characteristics such as mobility, ICT use, congestion, travel time delay and speed variations. The results revealed that ICT integration and efficient utilisation will minimise the need for travel, minimise traffic volume, as well as allow for optimal route planning, potentially helping to decrease traffic congestion, trip distance and journey time in the town.

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List of Abbreviations and Acronyms

CBD	Central Business District
DoT	Department of Transport
ECMT	European Conference of Ministers of Transport
GDP	Gross Domestic Product
ICT	Information Communication Technology
IDP	Integrated Development Plan
ITS	Intelligent Transportation System
KSD	King Sabata Dalindyebo
LOS	Level of Service
PI	Perception Index
TTI	Travel Time Index

Chapter 1

Introduction

1.1 Background of study

Cities across the world have recently embraced multifarious activities, resulting in population growth in cities and an increase in socio-economic, industrial, and service activities. Demographic changes and the growth of various socio-economic and commercial activities require an increase in the transportation of commodities and human beings (Torres and Pinho, 2011). Besides, with the enhancement of the economy and affordability, people prefer to use privately driven vehicles for their day-to-day activities. This phenomenon is also experienced in South African cities. As a result, many residents in South African cities rely heavily on the use of private vehicles for their local mobility needs. Add to this challenge of a one-person-one-car system and the need to transport industrial goods or for service delivery, there is also a need for operation of a large number of heavy goods vehicles. However, this mixed modal system of heavy goods vehicles and individually driven cars causes a number of road transport-related challenges, which include traffic congestion, traffic accidents, reduction in the speed, and delays in reaching the destination. The reasons for such challenges range from the inability of existing infrastructure and traffic management plans to cope with increasing demand, to the limited use of advanced technology. Although a number of measures are being taken in different cities, such as upgrading the road infrastructure, augmentation of public transport, use of an intelligent transportation system (ITS), the challenges of sustainable road transport remain.

Since road transport plays a vital role in urban development, providing people with access to education, markets, employment, recreation, healthcare and other key services, especially in cities in developing world. There is a need for an enhanced and sustainable mobility system in the cities (Pardo et al., 2011; Shanghai Manual, 2011). However, it is observed that although enhancement of the road transport infrastructure and use of ITS could be able to assist to meet the challenges to a certain extent, they offer only partial solutions. Thus, other perspectives have surfaced suggesting that substantial utilisation of information communication technology ICT in socio-economic as well as travel related pursuits could substantially mitigate the challenges associated with road transport and traffic as well as support sustainable road transport in South Africa (Das and Emuze, 2014; Emuze and Das, 2015; Ezell, 2010). In other words, it is contended that the implementation of ICT into socio-economic and travel related pursuits can support the long-term viability of urban road transport networks (Ezell,2010). As a result, the study was conducted to look at how ICT may affect the road transport system and create a system of sustainable road traffic movement in South African cities. Mthatha, a medium-sized town in the South African province of the Eastern Cape was taken into consideration for the study.

1.2 Problem statement

Numerous global cities have examined a range of strategies aimed at curbing traffic in order to establish a sustainable road transport system over the years. Several significant projects have been started including integrated rapid transit, reducing the number of cars on the road, and expanding the options for walking and bicycling (Thynell et al., 2010; Tiwari et al., 2011). Moreover, attempts have been made worldwide at vehicle sharing, congestion charging, and off-street parking systems (Adler and Blue, 1998; Bajpai, 2016; Hameri and Paatela, 2005; Kanninen, 1996; Thynell et al., 2010). However, it is still unclear if such policy initiatives can lead to long-term solutions for challenges related to road traffic persists. Thus, despite these efforts, traffic related socio-economic, environmental, and road infrastructure issues persists in many cities throughout the world (Thynell et al., 2010). Similarly, African cities, especially in South Africa, are no exception (Das and Emuze, 2014; Deakin, 2001; Emuze and Das, 2015), and achieving sustainable road transport in South African cities continues to be a concern. Insufficient public transport, traffic congestion, accidents, travel delays and fuel use are some of the issues (Elkington, 2004). Mthatha, a town in South Africa's Eastern Cape province, is experiencing similar challenges. In the case of Mthatha, the existing N2 national road going along the town as well as the internal municipal road are in substandard condition. Mthatha is the economic heart of the Transkei region in the Eastern Cape, attracting hundreds of visitors from nearby small towns of Ngqeleni, Libode, Port St Johns and Lusikisiki for shopping, jobs, education and health care. The roads in the town allow for mixed modes of transportation, including heavy vehicles, cars and pedestrians. Resultantly, these routes in and around the towns CBD face serious traffic issues like traffic congestion, travel time delays, low speeds, on-street parking, as well as the occurrence of traffic accidents. heavy vehicles frequently clog traffic, and traffic accidents happen regularly, especially during peak hours. For instance, during peak hours, it might take more than an hour to get across town (Bews,2008), even though the two most congested routes, Madeira Street and Sprigg Street, were converted into one-way streets in 2013. In 2018, traffic law enforcement authorities deployed cutting edge cameras to assess traffic situations and deter possible traffic offenders on Transkei routes. The cameras are on the N2, which connects Mthatha to major towns and cities such as Durban and East London. All road users travelling in and out of Mthatha through the N2 are observed 24 hours a day, seven days a week, while other highways, such as the R61, which caters to Mthatha's traffic difficulties, also require traffic monitoring.

Additionally, Mthatha is significant both socially and economically on a regional and national scale, but the towns inadequate transport infrastructure is seen as a hindrance to development. Furthermore, enhancing road facilities, like expanding existing roads and constructing new roads, presents significant obstacles. It was therefore essential to investigate how traffic flow difficulties can be resolved in the town without investing significant expense. It is also hoped that incorporating ICT into people's daily socio-economic, professional, and travel activities will help them meet the obstacles and contribute to the town's sustainable road transport.

1.3 Purpose of study

1.3.1 Research aim and question

The research aimed to evaluate the impact of ICT use in socio-economic and travel activities on road traffic movement, as well as to provide strategic recommendations for efficient traffic movement in the Eastern Cape province's urban areas, using Mthatha as a case study.

The following major research question was explored:

> How will ICT be used in peoples socio-economic and travel activities to influence or provide solutions to the traffic congestion challenges in Mthatha, ensuring efficient traffic movement in South Africa's urban areas?

1.3.2 Objectives of the study

In response to the study question above, the specific objectives were investigated:

1. To assess the current road network and traffic movement scenario (traffic flow, traffic congestion, and queue length) in Mthatha.
2. To examine how urban functions and land use affect traffic movement in Mthatha.
3. To study the usage of ICT on socio-economic factors, road transport and travel activities in Mthatha.
4. To develop and simulate empirical models to examine how ICT integration affects road traffic movement in Mthatha.
5. To evolve a set of plausible strategic recommendation for effective road traffic movement in the urban area.

1.3.3 Hypothesis

The following hypothesis were tested:

Usage of ICT in everyday urban activities (home, work, travel) will reduce traffic congestion in urban areas specifically Mthatha.

1.4 Scope of study

The study focuses on the integration of ICT for sustainable road traffic movement in urban areas in the Eastern Cape. Data for this study were collected from a selected number of routes in the urban area using pretested questionaries and non-structured interviews. Since this study did not consider developing a new empirical model, traffic congestion scenarios were evaluated, and intervention plans made using available empirical models that are appropriate for the study purpose.

1.5 Research Methodology

Figure 1.1 provides a summary of the research technique applied in this study. The subsections that follow go into detailed on the research methodology.

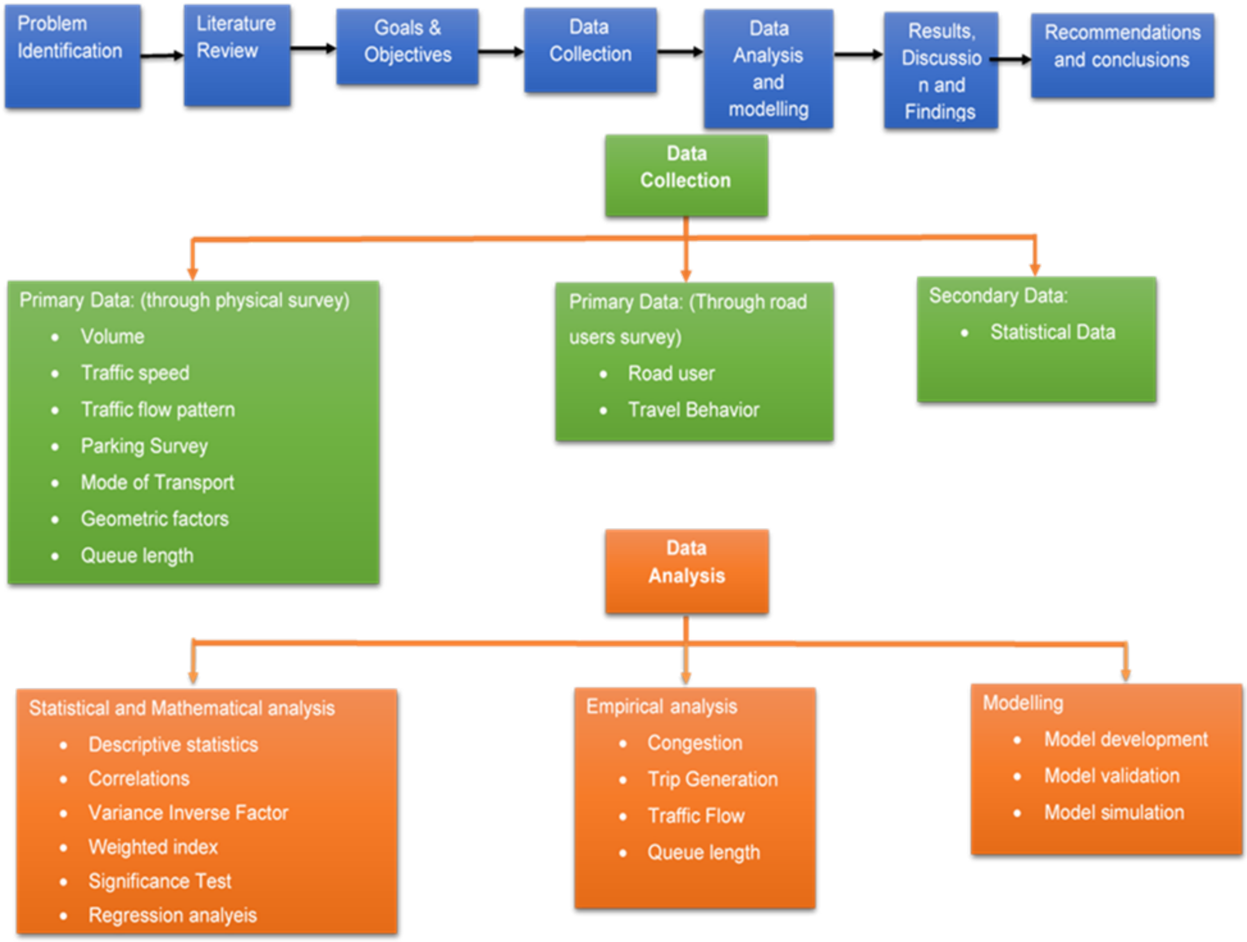


Figure 1.1 Methodology

1.5.1 Methodology of the study

The study utilised a structured approach (Figure1.1) which included the subsequent actions:

- Identifying the problem
- Literature review.
- Declaration of objectives.
- Description of study area and sample selection.
- Data Collection.
- Analysis and data modelling.
- Application of empirical models.
- Policy analysis.
- Develop a set of strategic guidelines and recommendations.

1.5.2 Data collection

Data was gathered from both primary and secondary sources, including road user surveys and traffic characteristics surveys, as well as published and unpublished statistics from actual organisations. Discussions with stakeholders were also conducted.

1.5.3 Primary data

Primary data was gathered through road user surveys, physical and geometric road surveys, and traffic surveys conducted in the town. The surveys were done using generally accepted research methodologies relevant to transportation and traffic planning and design objectives (Ampt, 1995; Kadiyali, 2011; Nardo et al., 2005; Richardson et al., 2012; Saltelli, 2007). Data had to be collected from primary sources as there was no structured, updated statistical data on important variables related to the transport scenario in the study area. In addition, road user perceptions and stakeholder inputs were required to develop strategies and policies to reduce traffic congestion and ensure optimal as well as free flow of traffic.

1.5.4 Selecting survey locations

A large variety of parameters were considered to determine appropriate locations for the various kinds of surveys in Mthatha. Traffic surveys, including traffic volume, speed, queue lengths at traffic intersections, journey times, delays and variations in traffic speed, were carried out at various points on key roads in the CBD (Kadiyali, 2011; Nardo et al., 2005; Richardson et al., 1995; Talpur et al., 2012;). Criteria used to select these particular roads included their significance, proximity and impact on the central business district and related urban activities, volume of traffic, traffic movement patterns and vehicle speeds, traffic congestion levels and safety. On the basis of these variables, traffic surveys were carried out on these particular roads: Nelson Mandela Drive, Sutherland Street (R61), Madeira Street, Sprigg Street, Tutor Ndamase Avenue, Main Road (N2), Nqandu Street, Elliot Street, York Road, and Owen Street.

Studies on the physical and geometrical properties of the roads were also carried out on these roads. Queue length studies were carried out at significant traffic intersections on these roads.

1.5.5 Survey of road geometry parameters

Information related to the physical and geometrical parameters of the road was obtained from critical parts of the road situated along recognised key roads, namely Nelson Mandela Drive, Sutherland Street (R61), Madeira Street, Sprigg Street, Tutor Ndamase Avenue, Main Road (N2), Nqandu Street, Elliot Street, York Road, and Owen Street.

Various parameters related to the current road geometry determined on each road section included traffic systems such as road width, quantity of lanes, lane width, overall width of all lanes in the same direction, existence of service lanes, gradient, radius, width of shoulder, sight distance, presence of kerbs, width of median, road surface type, the kind of parking available along the road and whether roads are one way or two way.

1.5.6 Speed survey

Using conventional templates, speed survey data were gathered from road segments selected for the study (Kadiyali, 2011; Richardson et al., 1995; Talpur et al., 2012). The survey was conducted over the course of a week during peak hours, from 6:30–19:30, 12:00–13:30, and 16:00–17:30. Because the traffic volumes observed during the pilot study period were very low, other periods of the day were not considered. The study was conducted simultaneously on all selected road segments.

Using cars navigating nearby intersections during peak hours, a study of speed variations was carried out, recording variations in speed, distance travelled, intervals between speed variations, and frequency of speed variations (Kadiyali, 2011; Richardson et al., 1995; Talpur et al., 2012).

1.5.7 Survey of traffic volume

Surveys were carried out at the most significant junctions, sections to examine the effects on traffic volumes and congestions on each road namely: Nelson Mandela Drive, Sutherland Street (R61), Madeira Street, Sprigg Street, Tutor Ndamase Avenue, Main Road (N2), Nqandu Street, Elliot Street, York Road, and Owen Street. Intersections were chosen for the traffic volume survey on the basis of their significance to traffic flow, which included the type of intersection, how many intersection legs, proximity to the central business district, various kinds of traffic traveling within the intersection and levels of congestion observed.

The traffic count was also carried out using a standard template that included the quantity of vehicles and the pattern of traffic movement, as well as different modes of transportation like cars, heavy trucks, motorcycles, freight vehicles, buses, taxis and other types of vehicles that enter a junction or road segment every 60 minutes (Kadiyali, 2011; Richardson et al., 1995; Talpur et al., 2012).

1.5.8 Survey of road users

Road users were surveyed at strategic locations of the town to understand road user perceptions of the transport system, road and traffic infrastructure, origins and destinations, problems faced in relation to the transport system in the study area moreover perceptions of the degree of challenges, and potential policy interventions to alleviate traffic congestion problems (Kadiyali, 2011; Lambsdorff, 2006; Nardo et al., 2005; Richardson et al., 1995; Saltelli, 2007; Talpur et al., 2012). To conduct a survey targeting road users, a directory of nodes in the town was compiled. The study focused on the significant nodes in which important urban and traffic activities are noted and were chosen as subjects of the study: bus stops, taxi ranks, and office areas of the King Sabata Dalindyebo (KSD) Local Municipality, the Walter Sisulu campus area, as well as the town's CBD. A total of 200 road users were interviewed, with 30-40 selected for each important location. However,157 proved useful for further investigation. The sample group was based on 1 in 50 travelling through the town every hour at various locations. Validity was proven through comparison to accepted standards (Kadiyali,2011) and research on comparable investigations (Emuze and Das, 2015; Nardo et al., 2005; Saltelli, 2007). Table 1.1 shows the demographic features of the survey group. A total of 51.00% of the road users who participated in the survey were male, and 49.00% were female. Approximately 45.90% of the road users who participated in the survey were in the 15–34 age group, and 42.70% of them were in the 35–64 age group. Approximately 60.51% of the road users who participated in the survey were drivers. Most of the road users (75.20%) mainly travelled inside the town, while around 24.80% travelled outside the own. The study was carried out utilising random selection and a pre-tested questionnaire schedule that included several characteristics related to road users' perceptions of traffic congestion problems. The factors include the goal of the trip, quantity of trips, start and end of trip, vehicle types used, travel time, distance travelled during the trip, awareness of available road infrastructure, traffic congestion, traffic accidents, accessibility of parking, road conditions, incident issues, ICT use in daily activities and travel, and perceptions of traffic congestion scenario improvements. Additionally, informal interviews were conducted with local government officials as well as transportation industry professionals.

Table 1.1 Road User Survey Sample Composition

Gender	Sample size according to age groups			Sample size total	Drivers	Non-drivers	Pre-dominantly inside town movement	Pre-dominantly outside town movement
	15–34	35–64	>65					
Number of males	30 (19.00%)	40 (26%)	10 (6.00%)	80 (51.00%)	52 (33.10%)	28 (17.90%)	64 (40.80%)	16 (10.2%)
Number of females	42 (27.00%)	27 (17.00%)	8 (5.00%)	77 (49.00%)	43 (27.30%)	34 (21.60%)	54 (34.40%)	23 (14.60%)
Sample size total	72 (45.90%)	67 (42.70%)	18 (11.50%)	157 (100%)	95 (60.51%)	62 (39.50%)	118 (75.20%)	39 (24.8%)

1.5.9 Perception Index

A road users perception index (PI) was developed through a weighted average approach, utilising values assigned by participants in road user survey (Lambsdorff, 2006; Nardo, et. al., 2005; Saltelli, 2007). The survey factors were classified into key categories, including land use and urban functions, road geometry, urban patterns connected to urban development and other relevant characteristics. Each variables influence was rated on a scale from 1 to 5 to assess its overall impact.

Participants rated each parameter impacting traffic congestion likelihood on a 1 to 5 scale, based on their own perceptions and experiences with transportation and traffic systems, urban mobility issues and traffic congestion scenarios. The responses were analysed using statistical software, and a weighted average score was calculated using the formula shown below. This method allowed for distinguishing between high and low perceptions scores. The mean values generated were summed and divided by the number of parameters, with the resulting weighted average indicating whether perceptions were generally high or low.

$$\text{Perception Weighted Average} = \frac{\Sigma\, Mean}{Number\ of\ Parameters} \quad \text{(Equation. 1)}$$

1.5.10 Significance of the data collected

Data was needed to be aware of the current scenarios in the study area. The data gathered was very meaningful as it was related to the set objectives of the study. To understand the current scenarios and their impact on traffic flow and congestion in the study area, investigations into traffic volumes, speeds, queue lengths and travel times, and geometrical measurements were needed. Road user perception data acquired from road user surveys gave an understanding into road user conduct, road problems they face, perceptions of available infrastructure, and ways to improve the scenarios.

1.5.11 Secondary data sources

Statistical data for the study were gathered from a variety of secondary sources, including published and unpublished literature, as well as documents from relevant organisations at the town, provincial and national levels (like the KSD Local Municipality and the South African Department of Transport). The information collected included demographic and socio-economic characteristics of the research region, vehicle and traffic volume records including plans or strategies for the town's subsequent growth.

1.5.12 Moral considerations in data collection

All protocols and ethical considerations were adhered to during data collection. Prior to data collection, road users and fitting departments provided appropriate consent. In the survey, the type, purpose, and content of the survey were first explained to road users. Appropriate privacy and anonymity of respondent identities were maintained. During the survey of the physical features of the road, the survey contents were notified to relevant stakeholders such as KSD Local Municipality and traffic department. Precautions were taken to ensure the visibility of inspectors, such as by wearing fluorescent vests and posting appropriate signs. Safety precautions were taken to avoid causing harm to living beings such as people or animals, causing excessive stress and pressure on anyone, and damaging natural or man-made elements.

1.6 Data analysis

The collected data was checked for completeness and accuracy. Cross-validation was used to remove errors or biased results, and the data was carefully transferred to an Excel spreadsheet for computer analysis. A series of questions were used to analyse and tabulate ICT inclusion and test the hypothesis. Details about several tools, methodologies and models utilised in the analysis are provided further down.

1.7 Findings and discussions

Findings were acquired from a variety of analysis, including road user perception survey, road geometry assessments, traffic counts, and traffic congestion analysis, ICT availability or use and modelled cases which were carefully analysed in order to draw credible conclusions.

1.8 Strategies and recommendations

Based on the findings of this study, discussions, recommendations and conclusions were prepared.

1.9 Research Limitations

The study's conclusions are limited to a specific area of study and therefore require additional examination; consequently, the findings cannot be generalised. Additionally, only 157 road users were able to be questioned due to the listed factors:

- Time related restrictions (The research is dependent on time).
- Survey period constraints (Study area being far from place of work and residence and can only be conducted during the day)
- Availability of personnel to conduct the survey.

Another limitation is secondary data relating to the study has been limited.

1.10 Chapter layout

Chapter 1: Introduction, the statement of problems and the objectives, scope, research methodology and limitations of the research.

Chapter 2: Literature review.

Chapter 3: Study area outline, background, demographics, socio-economic factors, basic infrastructure, transport, and traffic management systems.

Chapter 4: Data analysis, findings and discussions and hypothesis testing.

Chapter 5: Findings, Recommendations and Conclusion.

Chapter 2

Literature Review

2.1 Introduction

In current years, the heavy reliance on automobiles holds an important part of urban travel today (Meyer and Miller, 2001). The two most basic needs in any journey are to choose the type of vehicle and to choose the route. Personal preference and the choice of the type of travel in the city depend on many factors. The most essential of these are the city's location, the intention of the trip, the relationship between time and distance, the variety of many types of travel, convenient transportation, cheap and comfortable transportation, comfortable driving and mobility, livelihood and climate. While tourism and associated destinations influence the distribution of urban trips, route and mode selection also affect traffic distribution on various routes or roads. The entire procedure of mode selection, travelling abroad, route selection and travel reasons leads to traffic on urban roads. However, if road capacity is insufficient or the route is unsuitable for the qualities required to handle traffic or the construction works on the road had improper planning, traffic congestion and traffic problems will emerge. As Miller (1972) stated, one of the most obvious manifestations of people's need for more travel and mobility is the production of automobiles and the great dependence on cars has caused traffic congestion in the city. As a result, traffic congestion has become a significant urban transportation issue in many cities throughout the globe (Downs, 1992; Litman, 2004). Added to other mental and physical issues that passengers can encounter, the consequences of overcrowding can lead to financial and time losses.

Therefore, it is critical to comprehend the different elements causing car accidents and the effects thereof. Additionally, it is vital to comprehend not just the methodologies or models employed for prediction of traffic outcomes, but also the varied expectations regarding policies or solutions that can be used to minimise traffic on urban roads and promote rapid and safe travel in cities.

According to this research, a good theoretical background has been established by assessing and correlating various elements of urban transportation that have been studied in depth by many scholars. The various aspects considered in this context embrace the meaning of traffic congestion, its influence, factors affecting traffic congestion, parameters measuring traffic congestion, models or techniques employed to assess traffic congestion, and different policy interventions proposed to lessen traffic congestion. The parts that follow provide a full literature review, literature synthesis and conclusions.

2.2 Definition of traffic congestion

The problem of traffic congestion is multifaceted and lacks a single definition; yet it is typically attributed to an excess of demand for available space (European Conference of Ministers of Transport [ECMT], 2007; Keziä and Durango-Cohen, 2013). According to (Link et al., 1999 US Department of Transportation, 2005), traffic congestion is the result of too many cars on the road at one time, which causes traffic to slow down and become heavier than usual. The quantity of cars on the route surpasses the intended function, thus there will be lengthy queues of cars that will constantly start and stop. Therefore, it slows down transportation and pedestrians cannot move in the best way (ECMT, 1999; Goodwin 2004; Levinson et al., 1997; Lomax, 1990; Lomax et al., 1997); 1998; Weisbrod et al., 2003). Therefore, we can explain traffic congestion in the following ways: a large percentage of low-speed vehicles and the total amount of vehicles on the road nearing or surpassing the roads full capacity which creates a contradiction with travel demand and supply in the transportation system (Hon, 2005; Talukdar, 2013). Traffic congestion is often classified as recurrent congestion, non-recurrent congestion, and pre-congestion condition (Brownfield et al., 2003). Recurrent Congestion happens when there is a high volume of traffic at a single time, which causes traffic delays and longer working hours, which can affect population growth, urban development, and increase vehicle ownership and usage.

Congestion usually happens at busy periods, although it can also happen during non-busy periods. Non-recurring congestion, on the other hand is caused by unforeseen events or exceptional situations, such as traffic accidents that vary from minor car crashes to serious accidents, areas of work with slowly moving traffic, climate conditions and unique conditions. Pre-congestion takes place when mobility is interrupted but complete congestion has not yet developed (Banjo, 1984; Brownfield et al., 2003; Chakwizira, 2007; U.S. Department of Transportation, 2000). Nevertheless, these factors may be divided into these three categories: capacity demand-related, travel time delay-related, and cost-related (Aftabuzzaman, 2007).

2.3 Factors influencing traffic congestion globally

The United States Department of Transport (2005) identified seven major causes of traffic congestion. These causes are often divided into three main classifications: traffic-related factors, traffic demands, and physical road characteristics. Traffic accidents (car accidents, collisions, debris in the lane, shoulder accidents, or roadworks in a work area (such as road construction) and climate conditions (reduced visibility, horizon brightness, fog or smoke) are considered conditions affecting traffic. Transportation demands include daily changes in demand and changes in normal traffic, such as special events. Physical characteristics of highways include the physical and geometric characteristics of the road, inadequate traffic management equipment, and structural limitations of the road (Talukdar, 2013).

2.3.1 Factors influencing traffic congestion in the CBD’s

With so many tourist locations in a small region, especially in the CBD, it is challenging to provide public transportation within a limited physical space while maintaining heritage, politics, culture, economy, and environmental assets and benefits. Observation has been that the proportion of trips in the city (CBD - good and important places in the urban area) is higher and the combination of trips increases as the city gets bigger with size (Levinson et al., 1997; Turok, 2012). Additionally, urban areas are high activity regions, where space is scarce, and people are dependent on cars. However, the number, width, and amount of infrastructure such as parking spaces are often limited according to the needs of the CBD area. These factors, combined with the large number of vehicles and heavy traffic, have caused traffic congestion in the CBD area. For this reason, some researchers have stated that transportation demand is high in an environment with limited space (Keziä et al., 2012; Levinson et al., 1997; Turok, 2012).

2.4 Effects of traffic congestion

Hedges (2001) discusses the numerous effects of traffic congestion as part of a qualitative research undertaken by the Great Britain Department for Transport (DfT), local and regional government. According to Hedges (2001) and supported by several studies (Rao and Rao, 2012; Sorensen et al., 2008; Tiwari et al., 2011; Wang et al., 2014), these effects appear to be

- Reckless driving.
- Fatigued driving
- Capacity to move freely or means to travel when and where driver pleases.
- There is a risk of accidents or mistakes
- High fuel usage; and
- a significant cause of driver tension, resulting in rage, anxiety, bewilderment as well as fatigue.

The findings align with previous studies conducted by the European Union (2003) and Grant-Muller and Laird (2007). Traffic congestion can have a negative impact on gross domestic product (GDP), pollution of the environment, fuel use and subsequent release of carbon as well as other pollutants (Rao and Rao, 2012; Sorensen et al., 2011; Wang et al., 2014).

2.5 Traffic congestion measurement indicators

Various variables were established to assess traffic congestion (Dijker et al., 1998; Grant-Muller, 2005). However, data shows that only a few parameters are used to monitor the road network, and additional variables are required to assess traffic congestion (Grant-Muller and Laird, 2006). Among the most important and popular measures is the total amount of delay experienced, which is determined for each flow using the difference between the actual speed and the expected speed (Dodgson et al., 2002; DfT, 2000a, 2000b). This results in a measure of the average delay experienced by a vehicle per km travelled. While delays are evaluated in terms of travel time, they do not account for differences in occupancy, time values or other elements like operational or environmental problems caused by traffic congestion. As mentioned in Table 2.1, basic speed metrics can also be used to show traffic congestion, especially on roadways (Grant-Muller, 2005). These include average trip time, trip duration, throughput (The aggregate count of cars traversing a certain spot on the roadway during a designated time frame), queue length, speed differences between lanes and hourly or daily delay (Graham and Glaister, 2004; Grant -Mueller, 2005; Grant-Mueller and Laird, 2006; Noland and Polak,2002).

Table 2.1 **Congestion indicators**

Indicator	Description
1. Mean Journey times	Average travel duration on a link-by link basis, periodically for a designated timeframe. These travels must be integrated into coherent experiences.
2. Variability of journey	Standard deviation (variance) of trip durations on both a link-by-link and route basis, as well as within-day and between-day variability
3. Throughput	The aggregate count of cars traversing a certain spot on the roadway during a designated time frame.
4. Total duration: speed under 40 km/hour and 80 km/hour	Overall duration where the mean speed falls under 40/80 km/h within designated time intervals amongst specific segments and intersection.
5. Frequency of speeds of less than 40/80 km/hour	The overall number of cars travelling under the average speed of 40/80 km/hour decreases within a predetermined period between designated sections and intersections.
6. Line length	Lines resulting from flow disruption. Lines have developed at exit slip roads. Lines on off-ramps. Lines that merge with the section.
7. Speed difference between lanes	Variation in average speeds throughout each lane per segment, along with discrepancies in extreme distribution.

8. Delay per hour or per day	Quantification of delay per hour or per day, where delay is defined as the discrepancy between time in free flow and actual travel duration.

Source: Grant-Muller (2005); Grant-Muller and Laird (2007)

2.6 Scenario of traffic congestion in South Africa

Various research on transport in South Africa indicate that traffic congestion remains a challenge in South African urban areas (Kumar and Barrett, 2008; Urmilla et al., 2009). According to a 2008 Human Sciences Research Council study on transport, traffic congestion is the worst and third most common problem in the city (approximately 10% of respondents rated it as a serious problem) (Urmilla et al., 2009). Studies have shown that insufficient traffic control, increased vehicle use, insufficient parking, poor scheduling and poor management, might be the root cause of traffic congestion in South African cities (Roger,2004,2005).It has been predicted that all business trips considerably take longer (between 14 and 23 minutes), using an average of 5% of personal time each day, totalling 72 minutes in 24 hours (Behrens, 2004, 2005). Additionally, a TomTom study revealed that about 70% amongst the 3 million vehicle users on Joburg road networks experience serious traffic problems every day. In 2011 alone, around 10% of passengers (342000) cancelled meetings and over 40% of employees were late because of traffic congestion. Additionally, it was discovered that nearly a third of vehicle users nationwide spent longer than 45 minutes in congestion. Which shows the seriousness of urban traffic congestion in South African cities (Insurance Chat, 2011). Congestion in roads and transportation problems require immediate funding and appropriate policy mediation (Donaldson, 2015; Turok and Watson, 2000).

Therefore, policies and strategies have been developed to solve the problem over the years. The first publication of this study came from the urban movement networks in 1976 produced by the South African Institute of Civil Engineering (1981), following government guidelines established by the CSIR and the Urban Transport Authority for the Department of Transport from the 1980 century (Rogers, 2005; Turok and Watson, 2000).

Therefore, the fundamental characteristics of the regulations designed to oversee urban transportation systems are:

- 1.5 to 2.0 km^2 cells of access and collector road networks, reserved for public convenience and facilities, shut to passing traffic and retrained inside defining grids of restricted access to arterial roads and highways.
- Roads are classified into freeways, major and minor arterial roads, major and minor collector roads, and local streets; the interval between arterial roads is 2 km and between freeways is 5–8 km.
- To reduce traffic in densely populated areas and minimise traffic disturbances, the interval between arterial roads must be 2 km and between freeways is 5–8 km.; to minimise traffic speeds at collector and local roads, crescents, non-continuous linking roads and cul-de-sacs in townships must be used.
- Reducing the quantity of junctions local and collector road networks, as well as the preference for T-intersections.
- Reduce the quantity of crosswalks, divert traffic flow to adjacent freeways or highways and pedestrian movement inwards.
- Provide restricted entry points on surrounding distributors to prevent passing traffic from entering neighbourhood cells.
- Reducing the quantity of junctions in access road networks, focusing on right angle T-junctions that do not require signalisation.
- Concentrate land use that draws traffic on nearby distributors or the regions boundary to reduce inner vehicle flow.
- Pedestrian street crossings at the same level among class 1-3 distributors should be avoided (CSIR, 2000; South African Institution of Civil Engineering, 1981).

Traffic congestion in South African urban areas has not altered despite these recommendations and attempts to control traffic. Therefore, in response to these challenges, various policy interventions have been implemented, particularly in key areas such as the CBD areas of cities, which include staggered business hours and improving road infrastructure, promoting motor-less solutions like walking and pedestrianisation; administration of congestion and carbon emission charges; establishing alternative modes of transportation; special routes strictly for public transportation like buses and taxis; special planning of office spaces, businesses as well as stores; providing park and ride services; more well organised transport systems such as Gautrain and Rea Vaya; bus rapid transit system; single way streets; a contribution to the expense of public transportation; and promotion of carpooling (learn Extra Live,2014;Tiwari et al.,2009). However, the literature review indicated that there is very little research on traffic congestion in South Africa, particularly in urban development, and therefore warrants further research.

2.7 Measurement and analysis of traffic congestion and its impact using empirical approaches and models

A selection of relevant empirical models commonly employed for traffic congestion analysis are described below:

2.7.1 Traffic transmission index

Traffic transmission index(Q-index) eq. (2) evaluates congestion depending on speed. Therefore, traffic congestion is viewed as consequences of low speeds, which are the primary source of time lost which ends up leading to high vehicle managing costs, fuel consumption and increased air pollution and greenhouse gas emissions (Great Britain, DfT, 2001; Hon,2005; Talukdar, 2013). Determining the limit that is precisely linked to driving speeds is necessary. This approach differs from traditional planning in that it uses LOS, comparing volume to capacity and fails to specify speed. Therefore, a threshold based on speed can explain the implications of traffic congestion more than an approach dependant on capacity (Levinson and Lomax, 1996; Rao and Rao, 2012). Yet, understanding the variety of speed and how much speed varies in the research area can be challenging to grasp, let alone its relevance (Levinson and Lomax, 1996; Rao and Rao, 2012).

$Q = \frac{KS}{(\hat{A}s\hat{A}f)}$............................. (Equation.2)

Where:

Q = standard of traffic trans-mission index

K = 1 000 – constant

S = average speed (mph)

Âs = absolute of speed variations per mile

f = number of speed variations per mile

2.7.2 Travel time index

In the opinion of Rao and Rao (2012) and Schrank and Lomax (2005), time dependant measures like TTI eq. (3) provide an alternative perspective on traffic congestion. They offer direction on recognising the main problems, allowing decision makers to more effectively confront them and create more effective solutions. The advantage of TTI is that it can express traffic in both spatial and temporal terms. Therefore, the main points of this index are easy to understand. However, there needs to be a distinction between recurrence and event delays, and it can be difficult to measure non-recurrence data, especially in central business districts areas of cities. Despite this constraint, TTI supports various results (Rao and Rao, 2012; Schrank and Lomax, 2005).

$TTI = (\frac{Peak\ period\ travel\ time}{Free\ flow\ travel\ time}) = (\frac{Free\ flow\ travel;speed}{Peak\ period\ travel\ speed})$ .... (Equation.3)

2.7.3 Segment delay time

Segment delay eq. (4) refers to the extra journey time that road users consume compared to free movement or the reasonable duration of travel on a certain section of the road (Link et al., 1999; US Department of Transportation, 2005). The measure is based on comparative delay. The lag value may be utilised to measure the variation from the true and expected functionality of this system (Lomax et al., 1997). Passengers can connect to past travel experiences by using comparative delays that highlight flow conditions (Hamad and Kikuchi, 2002). In the same way, the overall delay gives us an estimate of how improvements in the transport system will affect a specific route or the system as a whole. Though overall delays are indicative of the impact of congestion in terms of loss in journey time, relative delays are more challenging to assess since congested travel or road distance do not necessarily indicate the differing levels of traffic congestion (Hamad and Kikuchi, 2002 (Hamad and Kikuchi, 2002).

$Ds = (TTac - TTap) \times Vp$................................ (Equation.4)

Where:

TTac = true travel time (minutes)

TTap = allowable travel time (minutes)

Vp = vehicle volume in the peak period (vehicles)

2.7.4 Level of service

Level of service eq. (5) assesses the impacts of many elements such as speed, travel duration, traffic disruptions, freedom of movement, safety, driving comfortability and operational costs. One advantage of utilising LOS to quantify congestion is that it is easy to understand as it is based on two variables that are easy to measure. It is also extensively utilised since it is simple to gather the data needed for calculation. Even though the Highway Capacity Manual (U.S. Department of Transportation, 1986, 2000) provides detailed information on how to assess various congestion levels, scholas claim that LOS fails to give a steady scope of congestion values because it lacks variance between various levels of congestion when a congestion state is achieved.

Additionally, LOS can only be applied to a particular section with congestion, it fails to consider the total volume or areal congestion environment (Mulhall, 1995). Utilising a detailed LOS metric can at times be confusing, particularly if the condition reaches a limit (Hamad and Kikuchi, 2002). However, in CBD areas where traffic flow is almost uniform, LOS is a useful measure of traffic congestion. (U.S. Department of Transportation, 1985, 2000). Furthermore, it is only applicable to a particular section with traffic congestion and neglects to consider the general or areal congestion environment (Mulhall, 1995). Using a detailed LOS metric might be confusing at times, especially when the situation reaches a limit (Hamad and Kikuchi, 2002). Nevertheless, central business district areas where traffic flow is almost uniform, LOS is a useful measure of traffic congestion. (U.S. Department of Transportation, 1985, 2000).

$LOS = \frac{V}{C}$ or $\frac{AADT}{C}$.. (Equation.5)

Where:

V =Overall number of vehicles

C = capacity ratio

AADT = Average annual daily traffic

2.7.5 Lane-mile duration index

Lane mile duration index eq. (6) monitors the amount and time span of highway congestion. It is better suited as opposed to LOS measurements, particularly in highway scenarios. Nevertheless, this model is limited in that it fails to account for the impact of traffic congestion on roads user varying operating conditions (Cottrell, 1999; Rao and Rao, 2012). Potentially it may provide negative findings since traffic information is not obtained from all sections of the highway. Its application in central business district area is restricted except if the road sections exhibit highway-like features (Cottrell, 1999; Rao and Rao, 2012).

LMDIF = _ $\sum^{m}{}_{1}$ .... (Equation.6)

Where i equals a single highway segment and m equals the overall number of highway segments in an urban area

2.7.6 Additional models for measuring traffic congestion

The Great Britain Dft (2000), the Commission for Integrated Transport (2000) proposed that a measure centred around the overall amount of delay experienced be used, computed over every vehicle from the variation between the real speed experienced free-flow speed. This was the foundation for National Model Forecasts (2003) in the United Kingdom. Other metrics of delay were utilised, like the overall delay of traffic volume, divided by the average delay experienced by automobiles per kilometre (Great Britain Dft, 2005). Apart from the Highway Agency (1997), as highlighted in Levinson et al. (1997), suggested the subsequent approach for measuring congestion on a road section or link:

$$CRF = \frac{Capacity \times NL \times Wf \times 100}{PkF \times 100 \times PkD} \times \frac{AADT}{AAWT} \text{.................................. (Equation.7)}$$

Where:

Capacity is the maximum hourly lane throughput

NL is the Number of lanes per direction

Wf is a Width factor

PkF is the proportion(percentage)of overall daily flow (2 way) that happens during peak hours

PkD is the directional split (percentage) of the peak hour flow

AADT is the Average annual daily traffic flow on the link

AAWT is the Average annual weekly daily traffic flow on the link

Leonardo (1993), as highlighted in Levinson et al. (1997), recommended an additional model for measuring congestion over a larger region than just a link, for relative reasons in cities:

$$CI = \frac{\Sigma(ti+di)}{ti} \text{.. (Equation.8)}$$

Where:

CI is the Congestion index

Ti is the Free-flow travel time

Di is the Excess travel time

The following model can be used for all vehicle trips or for flow inside a specific link or passage. If links are combined individually, a flow weighting may be used, model can be modified as follows:

$$CI = \frac{\Sigma fa \times (ta+da)}{\Sigma fa} \text{... (Equation.9)}$$

Where:

CI is the congestion index

Ta is the free-flow travel time on link a

Da is the excess travel time on link a

fa is the flow along a link

Flow forecasts (Yin et al.,20002) have been evaluated in restricted scenarios, alongside sophisticated computation approaches like FNN (Fuzzy Neural Networks) for urban traffic.

2.8 Techniques to addressing traffic congestion challenges

There are many ways to solve the problem of traffic congestion in urban areas, especially in CBD areas, and they can be divided into three categories: Land use, Supply and transport demand management**.** Actions made to enhance the quantity of passengers and journeys provided by a transport system to best meet the traffic needs is supply management. These include increasing the capacity of vehicles, public transport, cyclists, pedestrians and multimodal infrastructure (Farahani et al., 2013; Gao and Yifan, 2002; Meyer, 2003; Yang and Bell, 1998), and even optimising timing for traffic signals (Ceylan and Bell, 2004; Stevanovic et al., 2013). Despite this, sceptics of this approach argue that accidents and incidents, rather than a lack of capacity, cause most of the traffic congestion (STPP, 2001). Increasing infrastructure to reduce congestion is also problematic due to the additional vehicles that will materialize due to more capacity and the environmental and health impacts of increased travel and land usage (Gifford, 2005). Furthermore, supply management practices are less likely to reduce congestion induced by uncommon events. The management of land has also been commended. This addresses use of development control methods, proper plans and zoning to encourage urban population that promotes transportation. (Taylor,2002) cites development focused on transportation and high population land usage as instances of this form of management. Nonetheless, the sceptics of management of land strategies point two significant problems these strategies create: the amount of time required to alter patterns of land use and habits. They further express scepticism with regards to the relationship and correlation between traffic congestion and use of land management.

Likewise, transportation demand management is a method that often promotes employing financial advantages and disadvantages to motivate drivers to utilise alternative roads, periods and modes, or even postpone travel altogether to lessen the need for traffic infrastructure. Transport demand management emerged out of an inclination to investigate alternatives to "supply-side" methods due to detrimental effects of increased demand on communities. Other solutions consist of congestion fees, park and ride sections, high occupancy vehicle lanes and tolls of these lanes, company commuting programmes, remote working, alternate working times and traffic reduction methods. Congestion charges and higher tax rates are amongst the best and lawful form of funding (Gifford, 2005); however, they are also among the most difficult to implement due to the cost they impose on drivers (Bass, 2008; Thynell et al., 2010). This method has also been challenges as being ineffective from a policy standpoint, since all policies related to congestion reduction incur costs (e.g., Goodwin, 2004). Additionally, reduced congestion reduces trip disturbances and increases travel demand and average travel times. This not only increases the costs associated with the environment, accidents and maintenance, it can also raise congestion beyond zero threshold. Congestion control costs have been condemned for being arbitrary (Bass, 2008; Goodwin, 2004; Thynell et al., 2010).

Careful traffic planning and the application of cutting edge technologies like the ITS, Global positioning systems, intelligent interaction between vehicles, various information signals and intelligent mobility methods (Alterkawi, 2006; Chen et al., 2009; Das, 2014; Emuze and Das, 2015; Furth and Muller, 2009; Hardjono, 2011; Rao and Rao, 2009; Salicrú et al., 2011; Santos et al., 2008; Toral et al., 2009; Yin et al., 2004) are additional strategies to reduce traffic congestion. It is also stated that a mix of car and public transportation use can provide the needed degree of effective transportation (Owen, 1992). Other solutions for reducing traffic congestion include optimal vehicle navigation, route timeliness and vehicle rerouting, particularly in crowded cities (Das and Keetse, 2015; Emuze and Das, 2015). Nevertheless, the core of vehicle rerouting challenge is dispersion control, situations are different in each setting, but also the goals and constraints faced in reality are very different. Although considerable study is being conducted in this area, its scope is confined to several model challenges. Furthermore, there is little research on the impact of parameter combinations such as journey duration, vehicle routing (traffic distribution), traffic separation, appropriate traffic distribution on various other highways and local-level traffic systems reengineering. Furthermore, the impact of this on congestion in road networks (Cordeau et al., 2007).

Research and practice to reduce traffic congestion typically involve increasing the supply of road infrastructure, reducing travel demand, or both. However, current research suggests that the expansion of infrastructure may partly be the solution (OECD Co-operation,2013) as many measures are inherently interactive and may need to be considered together. As traffic volumes increase, the development of cost-effective strategies that reduce traffic congestion and manage adverse effects in terms of environmental impacts and economic costs is important (Watling et al., 2012).

2.9 Integration of ICT in managing traffic congestion

The goal of sustainability is to identify more efficient methods for both the now and the future. Since large scale transport and road operations increasingly contribute to the economy, mobility, livelihoods and environmental challenges of regions and cities, sustainable road transport is a crucial component of sustainable development (EC, 2005; Haghshenas et al., 2015; Schipper et al., 2009). In addition to lowering immediate and long-term adverse effects on the local and macro-environments, it offers safe and secure access and mobility for both people and commodities. Scholars recommend economically feasible infrastructure and efficient operations (Banister, 2008; Beaudoin et al., 2015; Bongardt et al., 2011; Broaddus, 2014; Dalkmann and Huizenga, 2010; Litman and Burwell, 2006). Sustainable transport improves accessibility and mobility while also influencing the spatial arrangement, economic vibrancy and environmental conditions of regions and cities (Cervero et al., 2009; Deakin, 2001; Li et al., 2009; Litman, 2007). Sustainable road transport is crucial for urban and regional development requiring safe, fast, energy efficient and low carbon systems (Rockwood and Garmire, 2015) (Dobranskyte-Niskota et al., 2007; Emberger et al., 2008; Haghshenas et al., 2015;

Litman, 2009; Rodrigue et al., 2007). In cities or towns, urban activities, land use, and road transport systems complement each other. The effective operation of road transport can be assessed by variables such as the accessibility and standard of public transport, traffic congestion levels, carbon and pollutant emissions, road use, pedestrian facilities, and traffic accidents (Haghshenas et al., 2015; Litman, 2003, 2007; Schipper et al., 2010; Zhao, 2010). Sustainable road transport policies can alleviate congestion, optimise traffic flow, and reduce accidents by promoting public transport, reducing noise and pollution, and utilising environmental beneficial choices of transportation (Dobranskyte-Niskota et al., 2007; Emberger et al., 2008; Haghshenas et al., 2015; Litman, 2007; Zhao, 2010).

Furthermore, in cities and towns across Africa, notably in South Africa, projects have been launched to implement sustainable transport systems in order to transition to sustainable road transport. Strategies include encouraging the use of sustainable fuels, lowering greenhouse gas emissions by using low-emission fuels, decreasing air pollution, enhancing safety in roads, boosting non-motorized transportation, and improving the quality of public transit. Furthermore, one of the major and crucial methods being examined is investment in clean technology, such as the usage of ICT (United Nations Environment Programme, 2014).

In this context, advances in ICT and the capacity to connect via mobile devices are opening new potential to improve road transport and infrastructure (Loukopoulos, 2005; Vijayakumar and Mehendiratta, 2011). The complexity of ICT applications in transportation systems ranges from simple electronic communications (signalling) to interactive, highly intelligent solutions in traffic management and control, as well as vehicle fuel management (Van Geenhuizen 2009). Video surveillance and response, information signs (variable messages), advanced traveller information systems, adaptive cruise control, intelligent speed adaptation, and dedicated short-range communications are examples of ICT that could help with sustainable road transport systems (Van Geenhuizen, 2009). Thus, it has been stated that the efficient ICT use for socioeconomic activities and travel demands of people, as well as the effective use of ITS in transportation and traffic management, might result in changes in travel patterns and behaviour. Consequently, there is less demand for travel, which reduces congestion, travel times, delays, and fees. Improving traffic management and agility can lead to innovative and sustainable mobility in regions and cities (Belella et al., 2009; Emuze and Das, 2015; Fugate et al., 2009; Monni and Raes, 2008; Schipper et al., 2009; Sietchiping et al., 2012). However, research on sustainable road transport at the city or town scale that takes into account urban activities, travel patterns, people's everyday urban activities and the use of ICT in road transport to address sustainable transport issues is limited, particularly in South Africa.

Furthermore, there has been an increase in internet and social media use throughout the years, with the WeAreSocial digital report (2020) estimating that social media users have surpassed 3.8 billion. According to Rouse, M. (n.d.) social media refers to online communications platforms dedicated to community-based inputs, engagement, content sharing and collaborations. The social media community comprises a rich sample of members, making these platforms effective instruments for collecting travel and transport data through surveys or other means (Gal-Tzura et al., 2014). Social media may be viewed as a tool for transport related applications, and transport companies utilise this platform to engage with their customers (Amey et al., 2011; Bregman, 2011; Gal-Tzura et al., 2014). The primary goal of social media use in organisations include information sharing and updates, advising the public on travel disruption and road conditions, addressing travel questions, and responding to queries and messages (GalTzura et al., 2014).

Similarly, mobile transport applications have been developed to track users, share travel information and provide real time public transport information by enabling access to data resources that were previously difficult to access (Litescu et al., 2015), and smartphones are the ideal travel instruments that can be used on the move, to share and access information of travelling. (Dickinson et al., 2014).

2.10 Conclusion

Each passenger has the option to choose their preferred method of transportation and route. In urban regions, an individual's route or how they travel is determined by a variety of factors, including the accessibility of urban functions, intention of journey, the physical distance and time ratio, road and traffic environment, and the comfort of driving and transportation. The route or method of transport selected by a person influences the general traffic distribution in the region. The entire movement and route selection procedure has the potential to modify or solve the daily commute route, hence affecting traffic congestion.

Traffic congestion is a severe challenge, particularly in urban areas. Traffic congestion is essentially a phenomenon where vehicles travel at low speeds. A disparity occurs between travel demand supply in the transportation system when the quantity of vehicles on a road approaches or surpasses the road's maximum capacity. Traffic congestion is classified into recurring traffic congestion, non-recurring traffic congestion, and pre-congestion conditions. Recurring traffic congestion occurs when too many cars are present at one time, which results in reduced traffic speeds and increased travel times. Recurring congestion can be caused by rapid population growth, urbanization, and increased vehicle use and ownership. Traffic congestion usually takes place around peak times, but it can also happen during non-peak hours. Non-recurring congestion is caused by unforeseen circumstances such as car accidents. Pre-congestion is essentially a period or road condition where traffic flow scenarios increase and lead to congestion.

Traffic congestion on a road section, intersection, or entire road network is determined by the necessity for movement, the goal of the trip, the actual trip generation, the method of travel chosen, and the route choice that generates the traffic flow on urban roadways. Traffic congestion happens when there is an excessive presence of cars on the same route at a certain time, causing traffic delays and slowing down the traffic flow from its usual or unrestricted speed. Insufficient road capacity, inadequately planned roads that do not meet the road design specifications required to accommodate the generated traffic, and inadequate urban facilities around these roads can lead to traffic congestion and vehicle collisions. In addition, excessive dependence on automobiles has been pointed out as another cause of traffic congestion in urban areas. In addition, limited space, high activity concentration, and dependence on automobiles are pointed out as causes of increased congestion in central business districts of cities.

Traffic congestion has negative consequences for the environment as well as the economy. It can lead to travel delays, increased fuel consumption, increased travel costs, and reduced effective working hours, which can have a negative impact on GDP and productivity. Likewise, carbon and other pollutants are released into the atmosphere, causing air pollution. Air pollution has serious consequences for both human health and the environment. It also increases the risk of traffic accidents due to irresponsible driving, difficult or fatigued driving, and reduced flexibility in movement.

Various indicators have been proposed to measure congestion, including the difference between free-flow speed and actual speed, average travel time, travel time variability, throughput (total number of vehicles passing a point on the roadway per time interval), queue length, speed difference between lanes, and delay times per hour or day. These indicators can be broadly classified into three groups: events that affect traffic, such as road accidents, work zones, and weather; movement demands, such as variations in normal traffic; and physical characteristics of the roadway, such as physical and geometrical features of the roadway, inadequate traffic control equipment, and tangible obstructions on the roadway.

Highways Agency (1997), Great Britain DfT (2003), and U.S. Department for Transport (2005) propose various empirical models which include the segment delay index, queue length, travel time index, lane mile index, and LOS. These models however offer both benefits and disadvantages in that they can be applied to various situations. Therefore, it is necessary to define an appropriate model to analyse congestion scenarios in specific areas on a road, road networks, cities, or in a city's central business districts.

Various methods have been proposed to address congestion. Congestion reduction methods are divided into three distinct groups: supply management, use of land management, and transport demand management. The methods within these groups include careful traffic planning, Intelligent Transport System implementation, effective vehicle navigation, route timeliness, and vehicle redirection, congestion fees, park and ride facilities, high occupancy vehicle lanes, toll lanes for high occupancy vehicles, commuter option programs for employees, working remotely, and different working hour to traffic reduction methods. Additionally, it has been suggested that expanding infrastructure will only address a portion of the issue. Therefore, as traffic flows increase, it is most important to develop cost-effective policies that reduce traffic congestion while eliminating adverse effects on the environment and economic costs.

The aforementioned literature evaluation serves as the foundation for both an in-depth analysis of the traffic congestion in the study area and the development of mitigation strategies.

Chapter 3

Profile of Study Area

3.1 Introduction

To successfully develop planning guidelines for an effective transport system, a survey of the research area must be conducted to comprehend its socio-economic, geographical and environmental features, future expectations and challenges and to take initiative to mitigate problems related to transport, such as congestion. This chapter seeks to explore and comprehend the many characteristics of the research area that impact the overall road transport network and traffic congestion in the study area. The aspects examined consist of the research regions demographic and socio-economic factors, spatial characteristic, use of land, social and physical facilities, road network and different difficulties in relation to road transport that the study area faces in the current context.

3.2 Background of study area

Mthatha, originally Umtata, is a town in South Africa's Eastern Cape province. It was the capital of Transkei, a South African province that existed independently until 1994, when it was reunited with South Africa. The settlement, located on the Mthatha ("The Taker") River (called for its regular floods), lies 698 meters above sea level in the Kaffraria area on South Africa's southeastern coast.

The town was founded as a European outpost in 1869 and acted as an intermediary between the Pondo and Tembu tribes. A military post was later created, and the city was formally constituted in 1882. In 1903, it was designated as the seat of the Transkei Territories General Council (also known as Bunga). In 1973, the city held a meeting of black national leaders, who agreed to form a federation following independence. When Transkei gained independence in 1976, Mthatha (as Umtata) became the capital.

The primary economic activity in the region are subsistence agriculture and livestock farming. Mthatha has various secondary industries that manufacture textiles, wood products, food, and processed tobacco. The town's colonial structures include the town hall and the hospital. Mthatha is home to the Nelson Mandela Museum and Walter Sisulu University (2005), which was formed by the amalgamation of Transkei University, Border Technikon, and Eastern Cape Technikon.

Mthatha is a key transit and regional service hub, with the N2 road passing through the town from south to north. Mthatha serves as a gateway to several tourist destinations and is a popular stopover on the route to Coffee Bay and Hole in the Wall in the KSD municipality, as well as Port St Johns and Mbotyi in surrounding municipalities. It connects to East London by Kei Rail and the N2.

Mthatha is under the authority of the KSD Local Municipality. The KSD Local Municipality is situated in the OR Tambo District Municipality, in the interior of Eastern Cape Province. Prior the year 2000 local government elections, the transitional and rural regions of Mthatha and Mqanduli were merged to form the KSD Local Municipality.

The KSD Local Municipality is based in Mthatha and has a satellite office in Mqanduli. The Munitata Building in Mthatha holds all the local government's political and administrative offices. The KSD Local Municipality serves as the district's economic core, housing the offices of both the local and district municipalities.

3.3 Demographic profile

3.3.1 Population

In 2011, Mthatha had a population of just over 140,000 (Statistics South Africa, 2011 Census), which represented about 4% of the Eastern Capes's total population that year. Figure 3.1 shows the population increase of Mthatha over time. Mthatha's population in 2023 was approximated at 206,181. In 2001, Mthatha's population was 98,219. Mthatha's population has increased by 3.43% per year.

The population density of Mthatha is 1.63 people per square kilometre. The entire population has an average yearly growth increase of 1.28%, which results in a decrease in the average household size in Mthatha. This is supported by data showing that the average household size declined from about 4.3 to 4.1 individuals per household in 2019. According to the 2011 census, the town has 294.040 households. The average family size decreased from 4.6 people per household in 2006 to 4.2 people per household from 2006 to 2016 (KSD Annual Report 2019/2020).

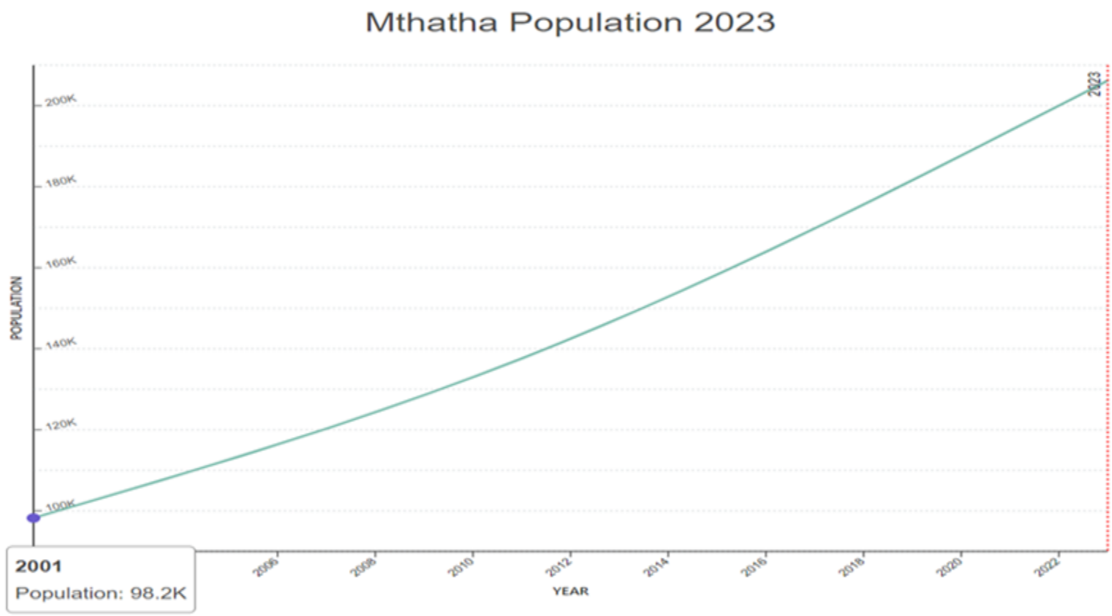


Figure 3.1 ***Population growth of Mthatha for the years 2001 to 2023***

Source: World Population Review (2022)

Table 3.1 shows the projected yearly growth increase of 1.2% from 2016 to 2021. OR Tambo District Municipality, Eastern Cape Province and South Africa will see average annual population growth rates 1.1%, 1.0% and 1.4%, in that order. The province of Eastern Cape's average growth rate is expected to be 1.0% which is close to the KSD Local Municipality. South Africa's average yearly growth rate is estimated at 1.4% which is comparable to the KSD Local Municipality projection.

Table 3.1 Population predictions - King Sabata Dalindyebo, OR Tambo, Eastern Cape and National total, 2016–2021 [numbers and percentages]

Year	King Sabata Dalindyebo	O.R. Tambo	Eastern Cape	National Total	King Sabata Dalindyebo as % of district municipality	King Sabata Dalindyebo as % of province	King Sabata Dalindyebo as % of national
2016	494,000	1,470,000	7,010,000	55,700,000	33.5%	7.0%	0.89%
2017	500,000	1,490,000	7,080,000	56,500,000	33.6%	7.1%	0.89%
2018	507,000	1,510,000	7,160,000	57,400,000	33.7%	7.1%	0.88%
2019	513,000	1,520,000	7,240,000	58,100,000	33.7%	7.1%	0.88%
2020	519,000	1,540,000	7,310,000	58,900,000	33.8%	7.1%	0.88%
2021	525,000	1,550,000	7,380,000	59,600,000	33.8%	7.1%	0.88%
Average Annual growth							
2016-2021	**1.24%**	**1.08%**	**1.05%**	**1.37%**			

Source: HIS Markit Regional eXplorer version 1156

3.3.2 Gender statistics (Age–gender composition)

Figure 3.2 shows the age and gender composition in Mthatha. The population pyramid shows the estimated changes in the population structure from 2020 to 2025. In 2020, the proportion of working-age youth aged 20–34 is predicted to be much higher (30.4%) than in 2025 (27.7%). The number of young working-age people in this age group is predicted to decline in the future. The rate of birth expected to increase marginally in 2025 in comparison to 2020, while the proportion of children aged 0–14 is expected to decrease significantly from 31.8% in 2020 to 29.7% in 2025.

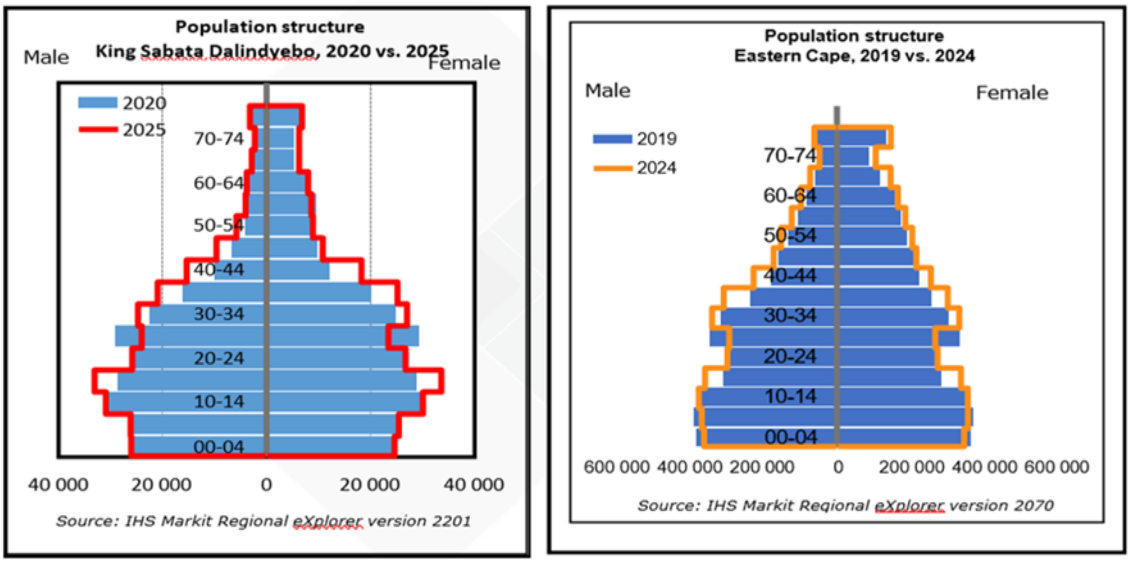


Figure 3.2 *Gender statistics of the population in Mthatha* Source: KSD Local Municipality, Integrated Development Plan (IDP) 2022-2027

3.4 Socio-economic perspective of the town

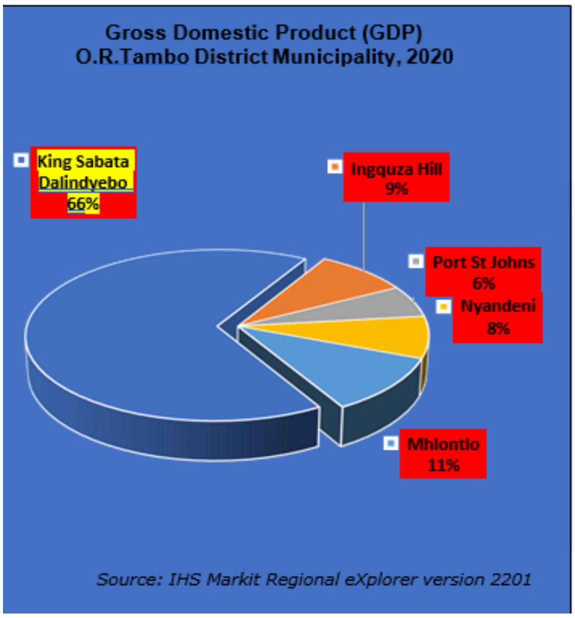
3.4.1 Economical perspective of the town

Mthatha is the OR Tambo District's economic hub, and it houses both the Local and District Municipalities' offices. The primary economic activity are community services (48%), banking (21%), and trade (18%). There are also agricultural and forestry operations.

The local economy boasts a competitive edge in public services. Public administration (18.88% employment and 13.88% gross value added) and education (18.29% employment and 12.21% GDP) account for 47.59% of employment and 40.86% of GDP, respectively. Agriculture, primarily forestry and logging (5.37%), and trade, based on retail and goods repairs (10.33%), both have a comparative advantage in terms of GDP contribution by the local economy. In terms of employment contribution, the local economy has a (15.90%) edge in households.

3.4.2 Gross domestic product of the town

The Eastern Cape province contributes around 7.7% of the national GDP. Mthatha, and surrounding areas of the KSD Local Municipality, contributed R33 billion to the entire GDP of the OR Tambo District Municipality, ranking first among the regional economies. The rank in terms of size in relation to other areas of the KSD Local Municipality, remained the same since 2010. The market share in 2020 (66.6%) is a significant increase from 2010 (62.5%). The average yearly growth rate from 2010 to 2020 was 1.6%, recording the highest growth rate in Mthatha compared to other regions in 2010.



The KSD had a total GDP of R 33 billion and in terms of total contribution towards O.R. Tambo District Municipality the King Sabata Dalindyebo Local Municipality ranked highest relative to all the regional economies to total O.R. Tambo District Municipality GDP.

	2020 (Current prices)	Share of district municipality
King Sabata Dalindyebo	**33.01**	***66.61%***
Ingquza Hill	4.36	*8.79%*
Port St Johns	3.00	*6.05%*
Nyandeni	3.91	*7.90%*
Mhlontlo	5.28	*10.64%*

Figure 3.3 ***GDP contribution of King Sabata Dalindyebo to OR Tambo District Municipality***
Source: KSD Local Municipality IDP, 2022–2027

The GDP of KSD Local Municipality is predicted to increase at a compound annual growth rate of 4.3% from 2020 to 2025. OR Tambo District Municipality and Eastern Cape Province are predicted to see compound annual growth rates of 3.51% and 2.22% respectively.

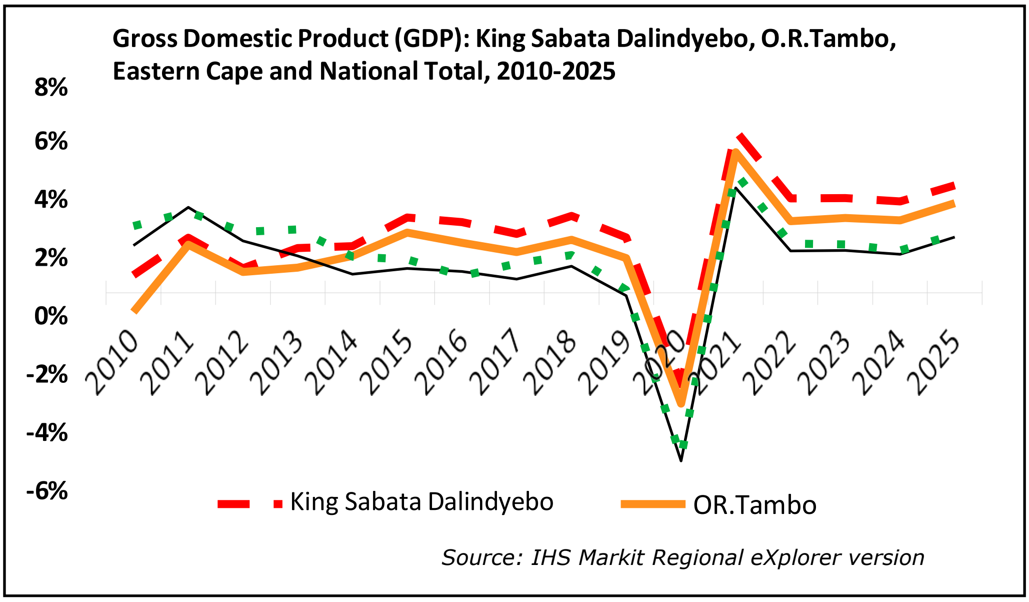


Figure 3.4 GDP growth projections of King Sabata Dalindyebo
Source: KSD Local Municipality, IDP 2022–2027

3.4.3 Employment active population and employment

The local government labour participation rate in 2020 was 45.3%, a significant increase from 35.5% in 2010. In 2010, the rate of unemployment KSD Local Municipality was 28.5%, and over time, it increased to 41.6% in 2020. The employment forecast for KSD Local Municipality is negative as the distinction between the economic activity involvement rate and the unemployment rate narrows.

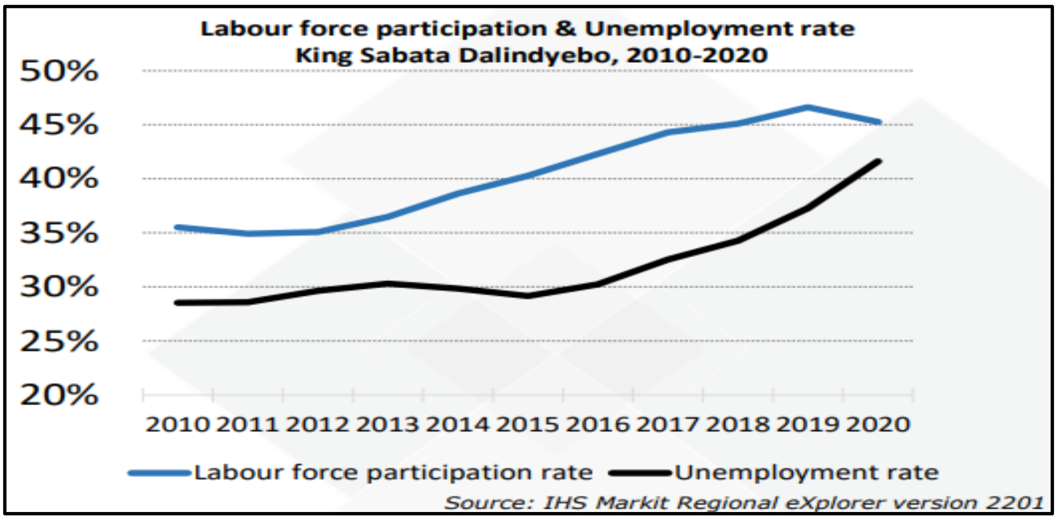


Figure 3.5 Yearly variations between labour force involvement and unemployment in King Sabata Dalindyebo
Source: KSD Local Municipality, IDP 2022–2027

3.4.4 Occupations, Sector wise

The economic sector that recorded the most jobs in KSD Local Municipality in 2020 was the public service sector, employing 34,000 people, accounting for 35.8% of all employment in KSD Local Municipality. The trade industry ranked second in terms of the number of employees compared to other sectors, with a total of 23,800 employees (25.1%). The mining sector was the industry with the fewest employees in the KSD Local Municipality, with 78.1 employees (0.1%), followed by the electrical sector with 267 employees (0.3%).

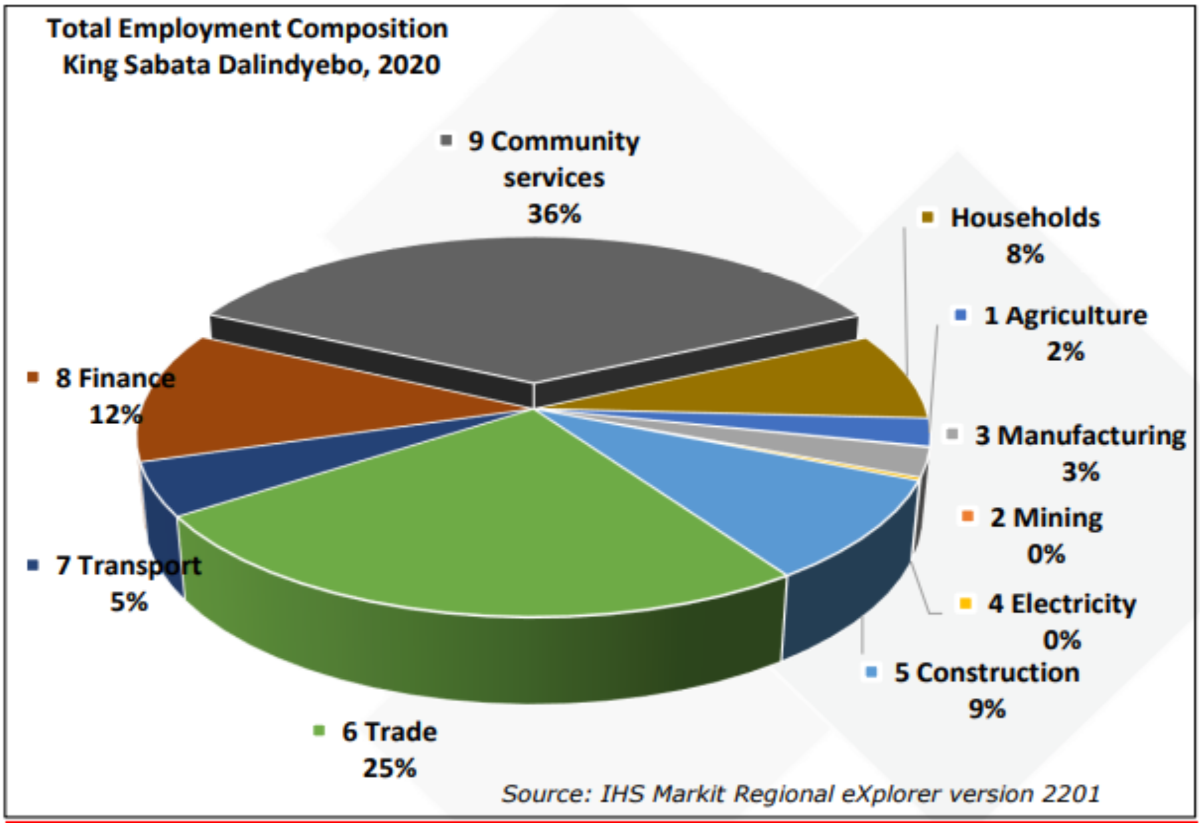


Figure 3.6 Presentation of jobs by sector and employment rates in percentages

Source: KSD Local Municipality, IDP 2022–2027

3.4.5 Income

Figure 3.7 shows the number of households with an income of R30,000 or more from 2009 to 2019. It grew from 55.93% to 80.08% per year. You can see the number of households earning R6 000 or less has decreased significantly per year. In terms of the Gini coefficient for each of the region in the district, KSD Local Municipality has the highest Gini coefficient, with an index value of 0.604, showing uneven income distribution in Mthatha.

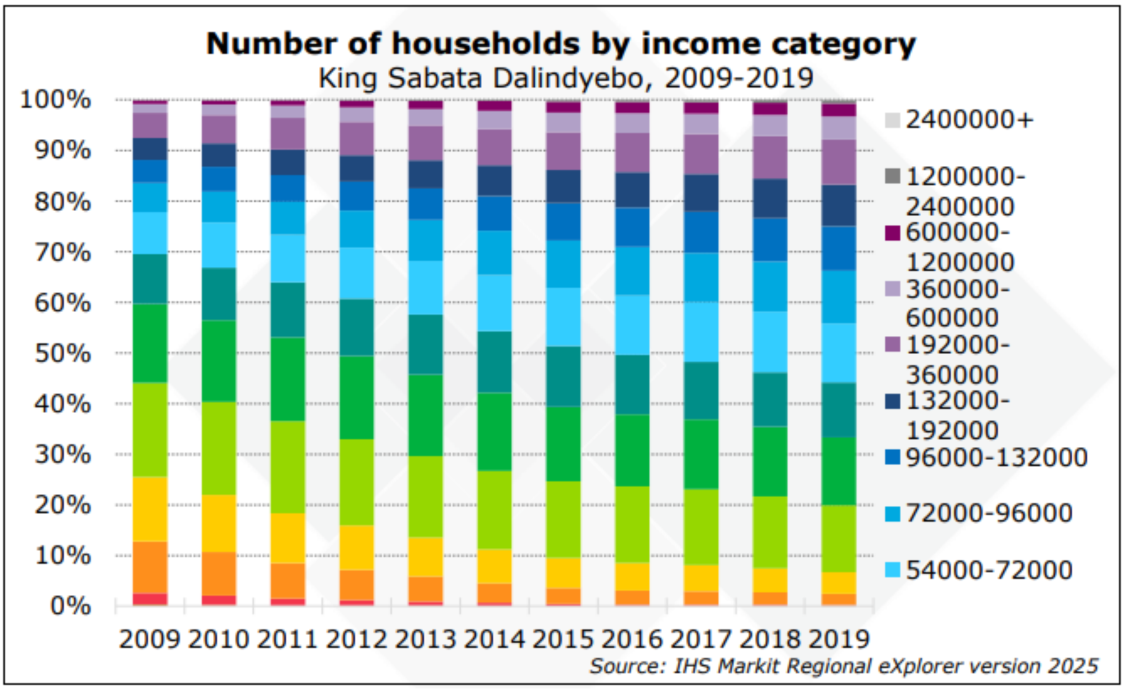


Figure 3.7 Household by income category in Mthatha, King Dalindyebo Sabata Local Municipality

Source: KSD Local Municipality, IDP 2022–2027

3.4.6 Education and health

Figure 3.8 shows the levels of education in the OR Tambo District Municipality. Compared to other local municipalities, KSD Local Municipality has the largest number of educated individuals in all educational levels.

In addition to the public sector, Mthatha also has a few private hospitals and clinics. These hospitals are positioned along the town's major roads, such as the N2 road that passes through the town, which is near the CBD and affects road traffic in and out of the town's central business district area.

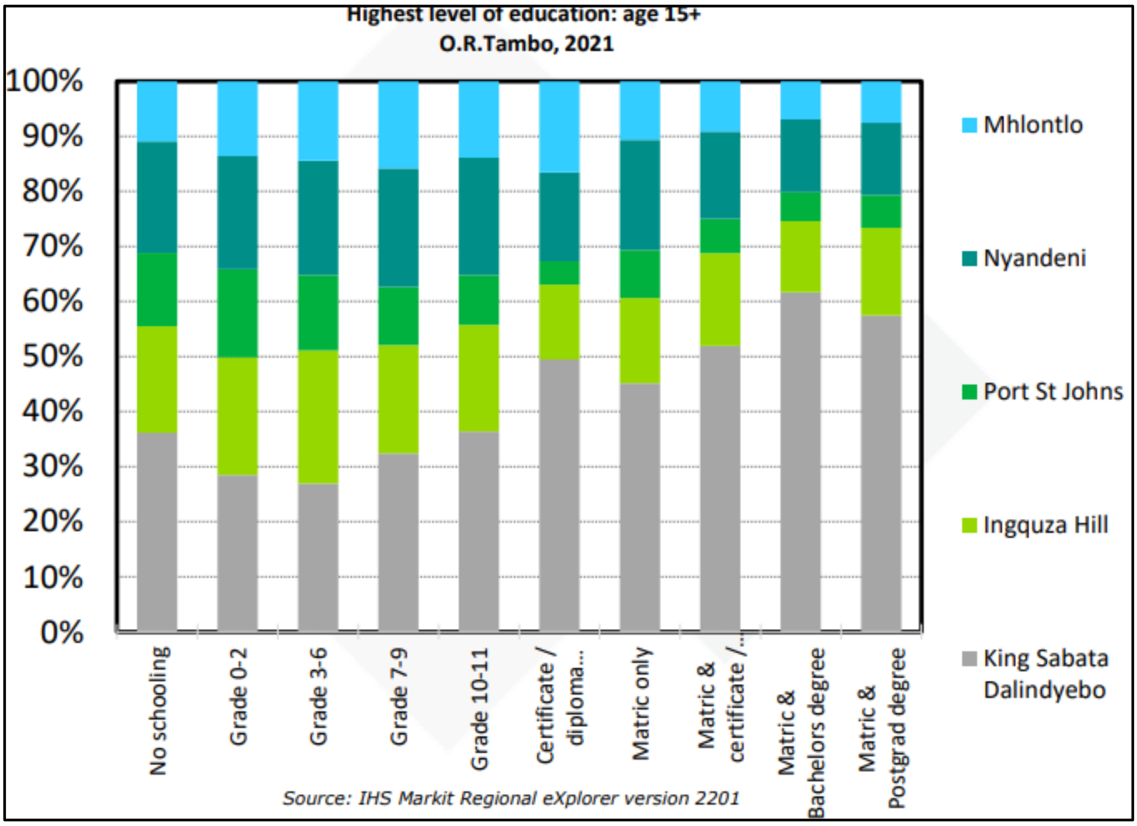


Figure 3.8 Education levels in OR Tambo District Municipality, King Sabata Dalindyebo Local Municipality with the highest levels of education

Source: KSD Local Municipality, IDP 2022–2027

3.4.7 Civic amenities and utilities

From 2010 to 2020, the overall number of households in KSD Local Municipality expanded by an average of 1.19% per year, which is higher than the average annual household growth rate of 1.6% in South Africa. (Data from KSD Local Municipality, IDP 2022–2027).

In 2010, there were 48 800 families without a formal residence in KSD Local Municipality. KSD Local Municipality's IDP 2022 -2027 data show a 1.6% yearly increase from 2010 to 2020, reaching 57 200.

As of 2010, the number of households in KSD Local Municipality with water supply in their houses reached 29 900 (26.07%) households. An overall number of 24 300 (21.17%) households were supplied with piped water in their yards and an overall number of 47 200 (41.08%) households were without water supply (Data from KSD Local Municipality, IDP 2022–2027).

In 2010, the number of households with no electricity in the KSD Local Municipality was 31 300, and this number declined by -10.25% per year to 10 600 households in 2020.

In 2010, the number of households in the KSD Local Municipality local that had no formal refuse removal was 79 000, and this number increased by an annual average of 1.56%, reaching 92,300 households in 2020.

The KSD Local Municipality erected 45 000 flush toilets (38.75% of all households), 42 900 ventilated pit toilets (36.96% of all households), and 17 800 pit toilets (15.30%) between 2006 and 2016. As of 2006, there were 57 100 houses in the KSD Local Municipality without sanitary toilets, according to a historical analysis of the sanitary backlog. In 2016, this number dropped to 28 200, a -6.81% annual decline.

In conclusion the condition of civic amenities and facilities in Mthatha is gradually and improving yearly, but there are still backlogs to be met by the KSD Local Municipality to ensure services are delivered to all people.

3.5 Tourism

Mthatha is not a significant tourist destination but serves as a gateway to other Eastern Cape attractions, such as Coffee Bay’s Hole in the Wall, and historic sites in the region. The town has a diverse history, and the Nelson Mandela Museum documents this history.

From 2009 to 2019, the number of tourists visiting Mthatha from other regions of South Africa declined by an average of -8.02% every year (from 334 000 in 2009 to 145 000 in 2019). The number of international visitors visiting Mthatha decreased by an average of 3.32% every year (from 13 400 in 2009 to 18 600 in 2019). International visitors make up 11.41% of all journeys, while domestic tourism accounted for 88.59%. The majority of the city's tourism comes from visiting family and friends; however, business and vacation tourists are scarce in the area.

3.6 Central business district

Mthatha has a defined CBD area (Figure 3.9) that serves the town's essential urban functions and offers amenities for administrative and commercial operations. Madeira and Sprigg Streets are the two main streets within the central business district. The R61 as well as the N2 national highways converge along the CBD (Figure 3.10). Sprigg Street, Madeira Street, York Road, Nqandu Road, and Sutherland Road are the main streets that often affect traffic flow in the central business district area.

Figure 3.9 Aerial View of Mthatha's CBD

Source: Google Earth (2015).

Figure 3.10 Mthatha's CBD Location

Source: www.google.comGoogle earth, 2013

3.7 Transport

Mthatha is linked to other regions of South Africa through all three modes of transportation, such as road, railway, and aviation. The Mthatha airport offers commercial flights to and from the OR Tambo International Airport in Johannesburg. Upgrades are on the cards so that this airport can expand and develop, welcoming flights from the other major international airports in Cape Town and Durban too. The railway has had significant presence in the town, although the operations of the Kei Rail have been on and off over the years in the town. Operations resumed in July 2011; thus, a single Kei Rail train can comfortably transport 464 passengers between Mthatha and East London. Since the resuscitation of the Kei Rail there has been a rising interest in rural passengers. The N2 national road and the R61 road that leads to other towns in the Eastern Cape, such as East London and Queenstown, cuts through the town causing traffic increase within the CBD of Mthatha.

3.7.1 Road transport network and vehicle population

A reliable road network exists in Mthatha. As was previously mentioned, the N2, one of the main national routes that connects Durban and East London intersects through the CBD of Mthatha. In addition, the provincial route R61, connects the town to other regions of the country. The N2, which begins at the border of Zimbabwe-Beit Bridge, ends in the Cape Town CBD. Similarly, the R61, which starts at Port Shepstone at an interchange with the N2 highway from Durban, ends in Beaufort West at a junction with the N1 and N12 national route co-signage. Amongst the interesting things of the road network system is that the stretch of the N2 that passes along the town changes into the town's main roads known as Nelson Mandela Drive, then changing into one-way streets known as Madeira and Sprigg Street.

Sutherland street is a section of the R61 that runs through the town. Although the principal routes seem to branch out from the town CBD, the town's road network follows a grid plan. Internal roads are designated as U3 urban minor arterial roads (Committee of Transport Officials, 2012). This has caused a large number of heavy vehicles heading to different places outside of town, as well as vehicles travelling from Durban, East London, Port St Johns and Queenstown, to use the CBD's main roads. As a result, the roadways in and around the CBD region are heavily congested due to the concurrent travel of heavy vehicles in and out of town, as well as usual town traffic, resulting in inefficient traffic flow.

Figures 3.11 shows the main roads that travel through the central business district of the town. These main roads are Nelson Mandela Drive, Sprigg Street, Madeira Street, and Sutherland Street; subsequently, the N2 and R61.

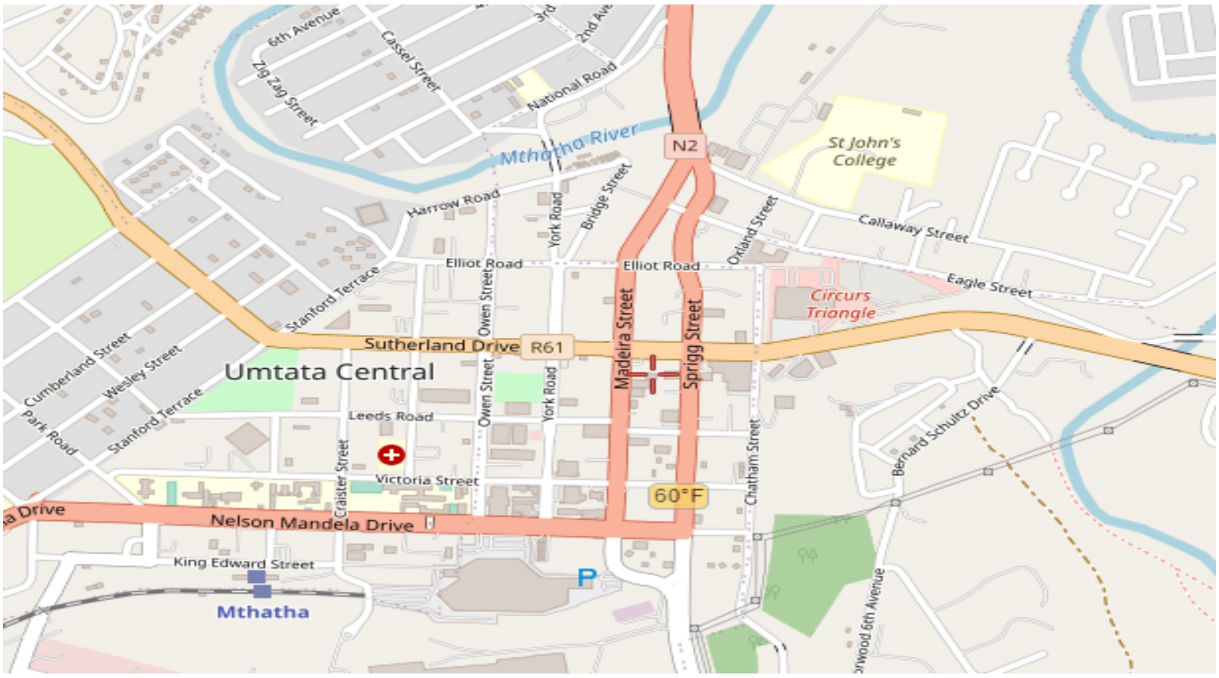


Figure 3.11 Main roads in the Mthatha CBD

Source: Map data AfriGIS (2023)

3.7.2 Transfer nodes on the road network

Figures 3.12 and 3.13 show the locations of the different nodal sites on the road network, which include bus stations, bus stops and taxi ranks. Figure 3.12 depicts the taxi ranks indicated by the taxi icons and Figure 3.13 depicts the bus stations indicated by the bus icons. Except for some secluded routes, all roads are utilised by all types of vehicles daily.

Figure 3.12 Taxi ranks in Mthatha indicated by taxi icon

Source: Map data AfriGIS (2023)

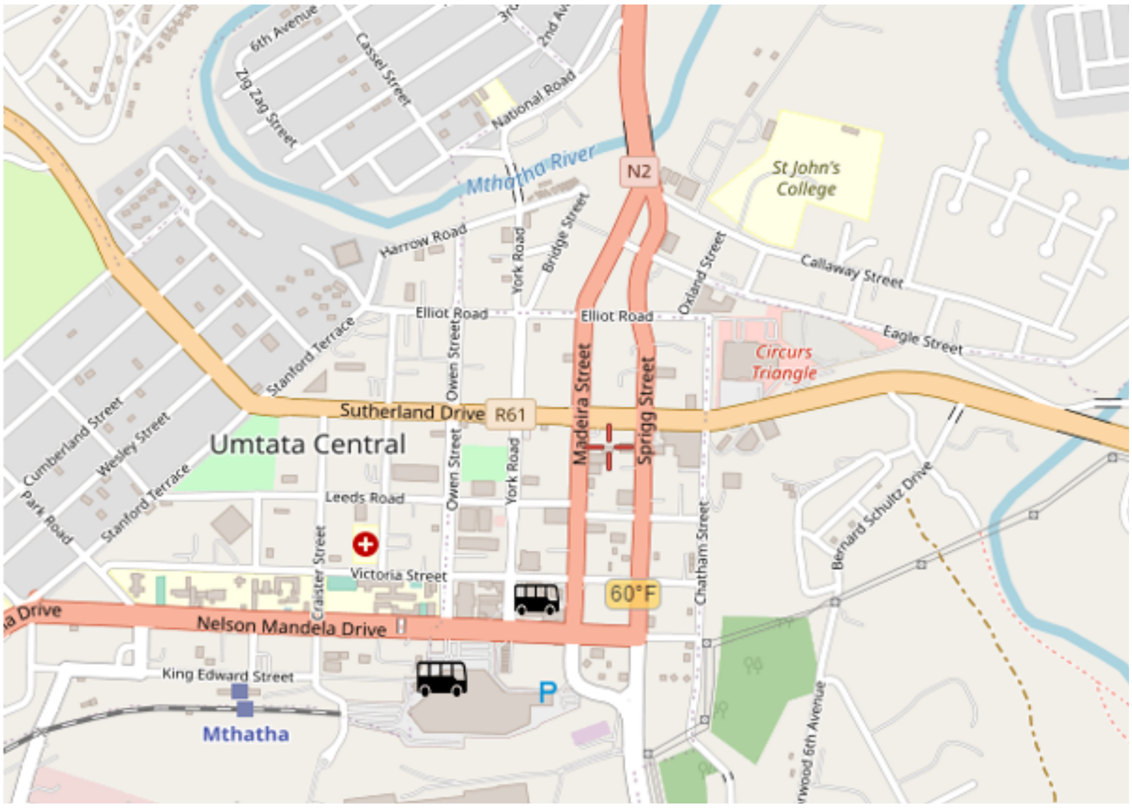


Figure 3.13 Bus stations in Mthatha indicated by bus icons

Source: Map data AfriGIS (2023)

3.7.3 Traffic management systems

During the physical road and traffic system survey in 2019, it was found that the traffic management systems of Mthatha have the following characteristics, which are almost similar to those of other towns in the country:

- **Uncontrolled intersections**: There are several intersections in the town that do not have any type of traffic control, such as traffic lights. However, these systems are limited to small intersections that are rarely used within the town.
- **Stop controlled intersections:** A major road may be accessible from a minor road using this system. Before approaching or crossing the major road, the car must stop completely.
- **Yield controlled intersections**: A major road may be accessible from a minor road using this system. Before approaching or crossing the major road, the car must yield (Allow other vehicles to go first)
- **Traffic signal-controlled intersections**: Traffic lights control traffic by stopping one direction and moving the other. Various stages can be used to manage the directional flow of traffic. Most intersections, especially in the interior areas of the town, are signalled by separate or synchronised signalling systems.
- **All way stops**: This manages traffic by mandating all cars to stop completely at an intersection. The vehicle that stopped first leave first. This system is installed in some junctions of the study area.
- **Pavement markings**: All the town's road pavements have adequate markings in accordance with the *G2 manual* of the South African National Road Agency Limited (SANRAL, 2012). However, these markings have faded over the years and need to be repainted.
- **Signals**: This covers speed control, direction flow, yielding, and stop signs. The town's roadways have adequate signs in accordance with the standards.

- **Speed traps:** They could be either permanent cameras or positioned radars placed at random locations across the town.
- **Parking systems:** The town is equipped with both off-street and on-street parking infrastructure. When the road width is minimal, on-street parking is a challenge.

3.7.4 A few visuals of the study area’s traffic management system

Examples of Mthatha traffic situations and traffic control techniques are shown in Figures 3.14 to 3.16. The traffic situation on Mthatha's roadways at around nine in the morning is depicted in Figure 3.14. Although most vehicles are automobiles, traffic is made up of a variety of vehicle types, including cars, pick-up vans, and heavier vehicles like trucks.

Figure 3.14 The state of traffic on Mthatha’s roads

Source: Author’s own (2019)

In Figure 3.15, the traffic signalling system is displayed. In accordance with the guidelines suggested by the *South African road traffic signs manual*, Volume 3: *Traffic signal design*, section 6.12 (2012), the signal is a three-phase system consisting of green, amber, and red.

Figure 3.15 Facilities for traffic management (signalling and pedestrian crossings) at the intersections in Mthatha

Source: Author's own (2019)

Figure 3.16 depicts the pavement markings noticed on Mthatha's roadways. Relevant markings like lane delineation, no crossing lines, and direction signs have been added to Mthatha's roadways, however they need to be remarked.

Figure 3.16 Facilities for traffic management (pavement markings and lane delineations) at the intersections in Mthatha

Source: Author's own (2019)

Figures 3.17 and 3.18 present pavement markings such as lane delineation, on-street parking spaces for vehicles and pedestrian footpaths on Mthatha's CBD routes.

Figure 3.17 Road markings indicating on-street parking spaces on Mthatha's roads
Source: Author's own (2019)

Figure 3.18 Road markings indicating on-street parking spaces and lane delineation on Mthatha's roads. Source: Author's own (2019)

3.8 Implication of Walter Sisulu University on the transport conditions of Mthatha CBD

One of the campuses at the Walter Sisulu University is located 10 km away from the CBD of Mthatha when driving through Nelson Mandela Drive/N2. The University is fully operational and has an intake of about 30 000 students divided into four campuses in the Eastern Cape, and one of these campuses is situated in Mthatha. Students of the institution travel in and out of the CBD daily for their commercial, shopping, and health needs, thereby contributing to the traffic volumes produced on the Nelson Mandela Drive/N2. Taxis, buses, and cabs (cars whose drivers operate as taxis) are available for use from the University gates to the CBD daily.

3.9 Information and communication technology

ICT access in Mthatha is similar to other small towns of the Eastern Cape and South Africa, where small internet cafes are available. These internet cafes simply provide the basics such as printing, typing, scanning, and internet access that one usually needs to pay for per hour of usage. Free Wi-Fi hotspots are mostly found in banks, where most people will be standing outside to connect, and also found in restaurants like KFC where one needs to sign in to gain access. People in Mthatha mostly rely on data packages to access the internet through their smart phones and tablets. The town also has a few companies that deal with installation of wireless internet to homes that can afford the services as there is little to no availability of fibre connectivity in the area, as found during the physical survey in 2019.

On 11 June 2021, a very first Innovation and Digital Skills Centre was opened in Mthatha where learners and entrepreneurs can equip themselves with the latest and most relevant digital skills. Through this initiative, communities close to the Centre are exposed to learning, business opportunities and high-speed connectivity that will help impact the education and business system in the town (Bizcommunity, 2021).

3.10 Conclusion

Mthatha's location virtually in the heart of the Eastern Cape, as well as its position as the administration of the OR Tambo District, is essentially a commercially orientated town and the hub for health and commercial needs for most villages surrounding the OR Tambo district. One national road and one provincial road, cut past the town and connect in a defined CBD area of the town, which results in the majority of outside traffic adding to the inside traffic travelling through the town on the CBD roads. Several of these routes like Nelson Mandela Drive, Sprigg Street, Madeira Street and Sutherland Road, transport a large volume of traffic going along the CBD. Additionally, it was noted that although the town's roads have sufficient traffic management systems including automatic signalling and pavement markings, they require improvement and maintenance. The location of Walter Sisulu University also adds to the town's traffic problems. The town's demographic, socio-economic characteristics appear to attract a substantial volume of vehicular traffic, resulting in traffic congestion on the roads in the central business district. ICT in the town has an opportunity of growth as it is currently very limited, and people rely on data packages and on their own smart phones or tablets to access the internet. Nevertheless, Chapter 4 provides an in-depth analyses of the numerous elements influencing traffic congestion issues, CT use and congestion levels in the town of Mthatha.

Chapter 4

Analysis and Results

4.1 Introduction

A variety of surveys and secondary sources were used to gather data, which was then combined and statistically evaluated. All-important analytical findings are discussed in this chapter under the subsequent sections:

- Physical and geometric characteristics of roads.
- Traffic scenario analysis.
- Traffic congestion analysis – Road user perceptions of the parameters affecting traffic congestion.
- Scenario of ICT use in transport and traffic congestion in Mthatha.
- Summary of findings on ICT.

4.2 Physical and geometric characteristics of roads

To establish the physical and geometrical characteristics of the roads in Mthatha, a survey was done on several roads with the help of students from the Water Sisulu University. The different features included, the number of lanes, lane width, pedestrian crossings, footpaths, radius, road width, curvature, sight distance, type of road surface, types and availability of parking spaces and types of traffic management systems. The findings were subsequently assessed in relation to the standards proposed in the SANRAL G2 manual (2012) and the CSIR (2005) Guidelines for Human Settlement Planning and Design, Chapter 7, Roads: Geometric Design and Layout Planning, to observe any inconsistencies in the current road system. To determine if there is a link between physical and geometrical elements of the roads and the development of traffic congestion in Mthatha.

Table 4.1 shows the physical and geometric features of the roads within and around Mthatha's central business district, while Table 4.2 shows the proposed physical and geometric guidelines for roads.

Nelson Mandela Drive, Sprigg Street, Sutherland Road, and Madeira Street have all been designated as U3 minor arterials, while Nqandu Street and Tutor Ndamase Avenue are classified as U4 local collector roads. All these roads have a minimum of two driving lanes, which typically expands to three lanes near intersections to allow for right and left turns.

The width of the roads ranged from 6m to 9m. Lane widths varied from 3m to 3.7m. A contrast with the suggested guidelines revealed that the lane widths and road widths of the roads were acceptable apart from sections of Nelson Mandela Drive and Sutherland Road, which were smaller than required requirements and hence did not meet the design criteria.

Except for Nqandu Road, all the roads assessed had pedestrian walkways or shoulders, but there were no bicycle lanes or infrastructure for cycling traffic. The pedestrian walkways of these roads were paved, however in certain sections were not in good condition. The pavement widths ranged from 2.0 m and 9.0 m and were often more than 2.0 m. There were kerbs on the sides of the roads with the exception Sutherland and Nqandu which were without pavement amenities.

Most roads surveyed had medians, except Sprigg Street, which is a one-way road, and Sutherland and Nqandu, which are separated by pavement markings lines. The median widths of these roads ranged from 1.0m to 4.5m

There were no noticeable sharp curves on any of the roads. The roads had gentle turns with a bigger radius than the allowed 210m. The required sight distance of 41m (calculated using the permitted speed of 60km/h on urban roads) was much less than the sight distance observed in various road sections, which was more than 100m and in some locations even more than 150 to 200m.

The gradient of the roads, as assessed at various points along every route in the central business district, was determined to be between 2.0% and 3.0%, which is below the permissible gradient maximum of 6.0%.

The roads assessed were sealed. Sutherland Road and Nqandu Street had satisfactory road surfaces, while other roads assessed were in good condition. There were no potholes damages on these roads but sporadic cracks and lines.

Most intersections on these routes are managed by automatic traffic signals that have cycle intervals ranging from 70 to 140 seconds during non-peak and peak times.

Nelson Mandela Drive, Sprigg Street, Sutherland Road, and Madeira Street have accessible parallel parking in certain sections. There was no parking available on the other roads. It has been noted that on-street parking spaces on these roads were deemed to problematic in terms of traffic congestion, particularly during peak times.

Table 4.1 Physical and geometric qualities of the roads in the Mthatha CBD

Name of the roads	Road type (N/R / Arterial / local streets)	Road width (m)	Number of lanes	Lane width(m)	Availability of pedestrian / bicycle lanes	Pavements / footpaths / shoulders width (m)	Kerbs	Median width (m)	Radius of curvature	Gradient (%)	Type of road surface	Condition of road surface	Availability of traffic control system	On-street parking type right angle / inclined/ parallel
Nelson Mandela Drive (N)	U3	6	2	3	Yes (PD/P)	P-2.1	Yes	Yes (Line) 1.6	Gentle	2.0 - 3.0	Sealed	Good	Automatic traffic signals	Yes (Parallel)
Nelson Mandela Drive (S)		6	2	3		P-2.1	Yes	Yes (Line) 1.6						Yes (Parallel)
Sprigg (N)		7	2	3.5		P-3.5	Yes	No (One-way road)						Yes (Parallel)
Sprigg (N)		9	3	3		P-3.5	Yes	No (One-way road)						Yes (Parallel)
Sutherland (S) Towards Ngcobo		3	1	3		SW-1.7	No	No (Line)				Acceptable	Automated signalling & speed humps	No
Sutherland (N) Towards Ngcobo		3	1	3		SW-1.7	No	No (Line)						No
Sutherland (S) In Town		8	2	4		F-7.5 P-1.3	Yes	1.6				Good	Automatic traffic signals	Yes (Parallel)
Sutherland (N) In Town		8	2	4		F-7.5 P-2.2	Yes	1.6						Yes (Parallel)
Sutherland (S) Towards Port Saint Johns		6	2	3		F-2.2	Yes	4.5						Yes (Parallel)
Sutherland (N) Towards Port Saint Johns		6	2	3		F-2.2	Yes	4.5						Yes (Parallel)
Madeira (S)		9	3	3		P-7.5	Yes	No (One-way road)						Yes (Parallel)
Main/Durban Road (N)		6	2	3		P-2.2	Yes	4.3						Yes (Parallel)
Main/Durban Road (S)		6	2	3		P-2.2	Yes	4.3						Yes (Parallel)
Nqandu (N)	U4	7.4	1	3.7	No	P-1.4	No	No				Acceptable	Speed humps	No
Nqandu (S)		7.4	1	3.7		P-1.4	No	No					Speed humps	No
Tutor Ndamase(N)		7	2	3.5	Yes (PD)	P-1.9	Yes	4.4				Good	Automatic traffic signals	No
Tutor Ndamase(S)		7	2	3.5		P-1.9	Yes	4.4						No

N = North (To the inside the city)
S = South (Towards outside the city)
PD = Pedestrian facilities; B = Bicycle; P = Paved; UN = Unpaved

Source: Author's own (2019).

Table 4.2 Design guidelines and criteria for the physical and geometric qualities of roads

Roads	Road Classification	Minimum lane width (m)	Sight distance (m)	Gradient (%)	Radius of curvature (m)	Speed (km/h)
Nelson Mandela Dr (N)	U3	3.7	41	6	210	60
Nelson Mandela Dr (S)						
Sprigg (N)						
Sprigg (S)						
Sutherland towards Ngcobo (S)						
Sutherland towards Ngcobo (N)						
Sutherland (S) in town						
Sutherland (N) in town						
Sutherland (S) towards Port Saint Johns						
Sutherland (N) towards Port Saint Johns						
Madeira (S)						
Main/Durban Road (N)						
Main/Durban Road (S)						
Nqandu (S)	U4	3.3 -3.5	41	6	210	60
Nqandu (N)						
Tutor Ndamase (N)						
Tutor Ndamase (S)						

4.2.1 An overview of the physical survey results

- According to the guidelines the roads assessed were U3 (minor arterial) or U4 (local collector), national and provincial roads.
- Insufficient lane widths and resulting road widths, were assessed in certain areas of Nelson Mandela Drive and Sutherland Road, causing issues related to traffic congestion.

- Most roads surveyed had physically built median structures, except Sprigg Street where the roadway was separated by pavement marking lines. Due to approaching traffic obstruction this may cause traffic flow issues in the CBD.
- Most roads had kerbs, although Sutherland Road and Nqandu Street lacked pavement infrastructure.
- All roads surveyed apart from Nqandu Street have adequate pedestrian walkways. While most roads have paved pedestrian walks, some roads pedestrian walks are not maintained or are poorly paved. Many informal stalls are placed on some pedestrian walkways, and this appears to disrupt the traffic flow and contributes to traffic congestion.
- Parallel and inclined parking systems were provided in certain sections of Nelson Mandela Drive, Sprigg Street, Sutherland Road, and Madeira Street. These parking spaces do contribute to traffic congestion by interrupting free flow of vehicles especially in peak hours.
- All the roads surveyed had satisfactory or good surfacing conditions. There were no visible issues like potholes or cracking that could be a cause for disruption of traffic flow.
- Sight distances observed were according to the guidelines.
- The gradient and radius of curvature on these roads were gentle and according to the guidelines.

4.3 Traffic scenario analysis

4.3.1 Traffic volume at intersections

Figure 4.1 to 4.5 depicts the volume of traffic at various intersections during peak hours. The five significant intersections under consideration were: Nelson Mandela Drive – Mthatha bypass junction (J1); the Nqandu – N2 Road junction (J2); the Madeira Street – Sutherland Road junction (J3); Nelson Mandela Drive – Madeira Street / Tutor Ndamase Avenue junction (J4); and the R61 – Sisson Street junction (J5). The values shown highlight the amount of traffic per hour during peak periods, while the arrow symbols in the sketches show the direction of traffic. The flow of traffic is separated into: cars turning left, straight ahead and turning right.

Figure 4.1 depicts traffic movement during peak hours of 12:00 to 13:30 at the junction joining Nelson Mandela Drive and Mthatha Bypass. The direction of the traffics is south, away from the town of Mthatha. On each of these roads, there is substantial amount of traffic turning left (24.4%) and traffic going straight ahead (67.7%), whereas the traffic turning right is quite low (7.8%).

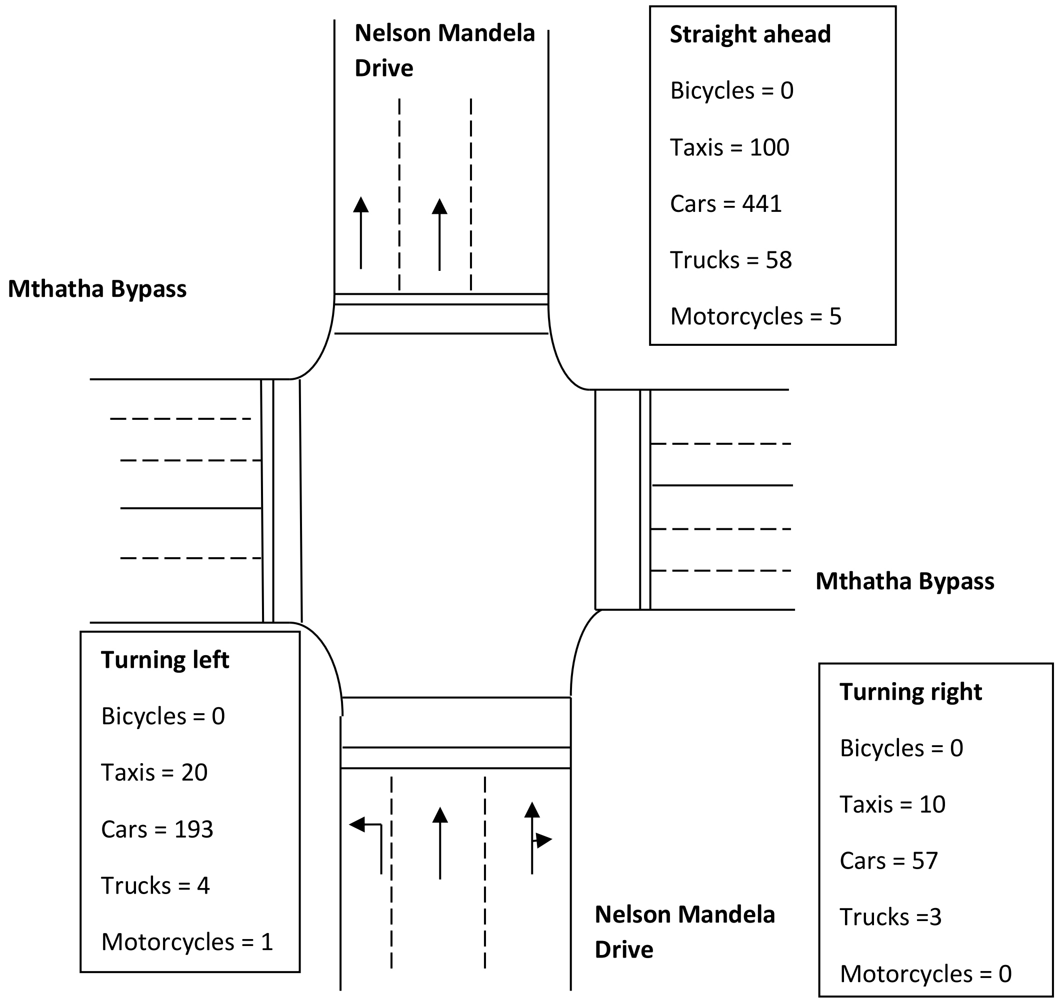


Figure 4.1 Illustrative sketch of traffic movement at the intersection of Nelson Mandela Drive and Mthatha Bypass

Figure 4.2 depicts traffic movement during the peak hours of 16:30 to 17:30 at the junction joining Nqandu and the N2 road. The direction of the traffic is south, away from the town of Mthatha. It was seen that traffic turning left (25.6%) and straight-ahead traffic (70.9%) on the two roads were rather large, clearly showing the movement of citizens out of the town, whereas the number of traffic right was quite low (3.4%).

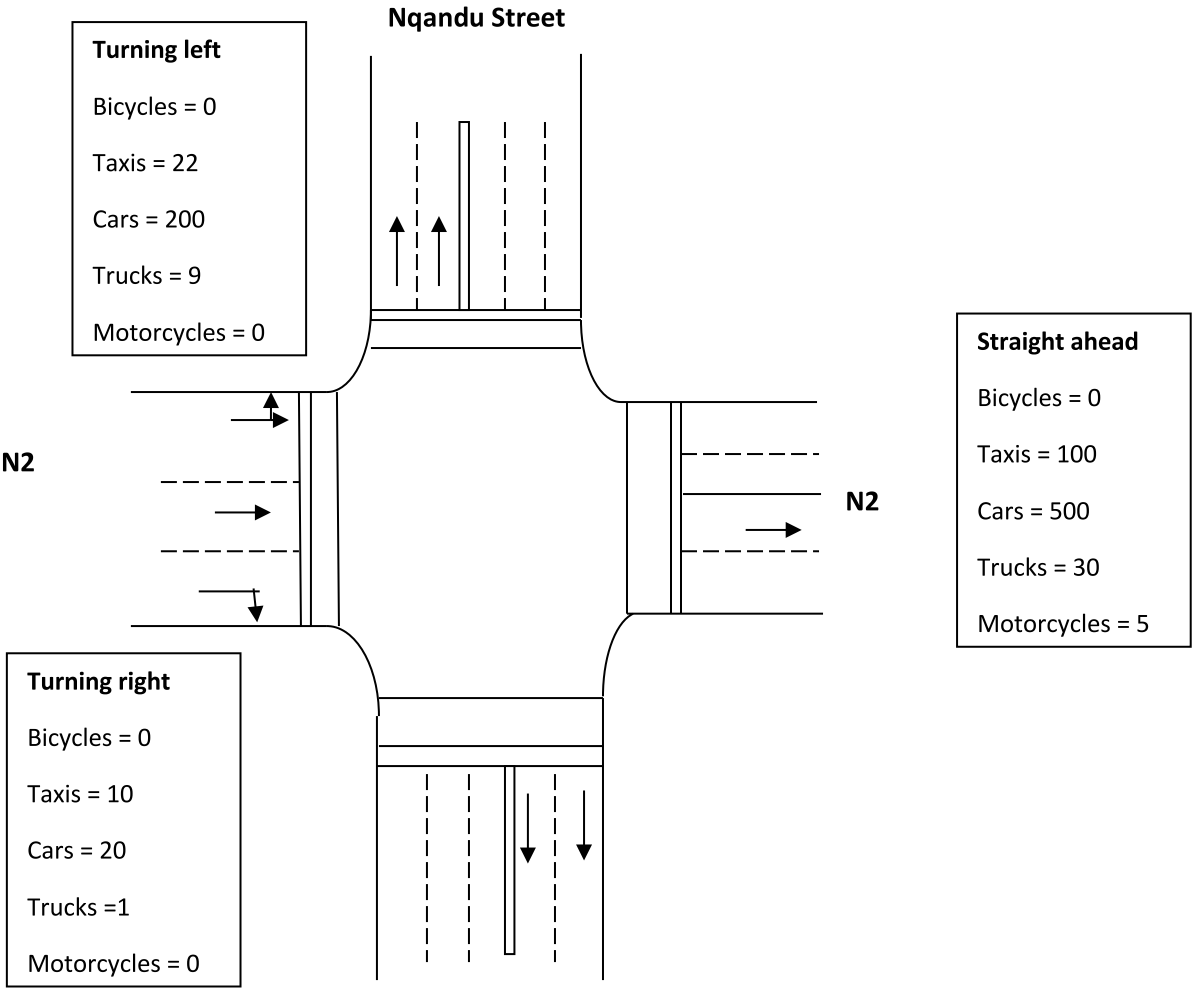


Figure 4.2 Illustrative sketch of traffic movement at the intersection of Nqandu Street and the N2 road

Figure 4.3 depicts traffic movement at the intersection of Madeira Street and Sutherland Road. Madeira Street is a one-way road. It was noted that Madeira Street had substantially more traffic than Sutherland Road. In Madeira, around 19.8% of the vehicles turned right, while 2.2% turned left, and 42.4% remained on the same route. Sutherland Road had 16.4% left turns and 19.2% of straight moving traffic. Sutherland Road also received a notably volume of traffic from Madeira Street, and the traffic traveling down on Madeira Street was appreciable at the junction.

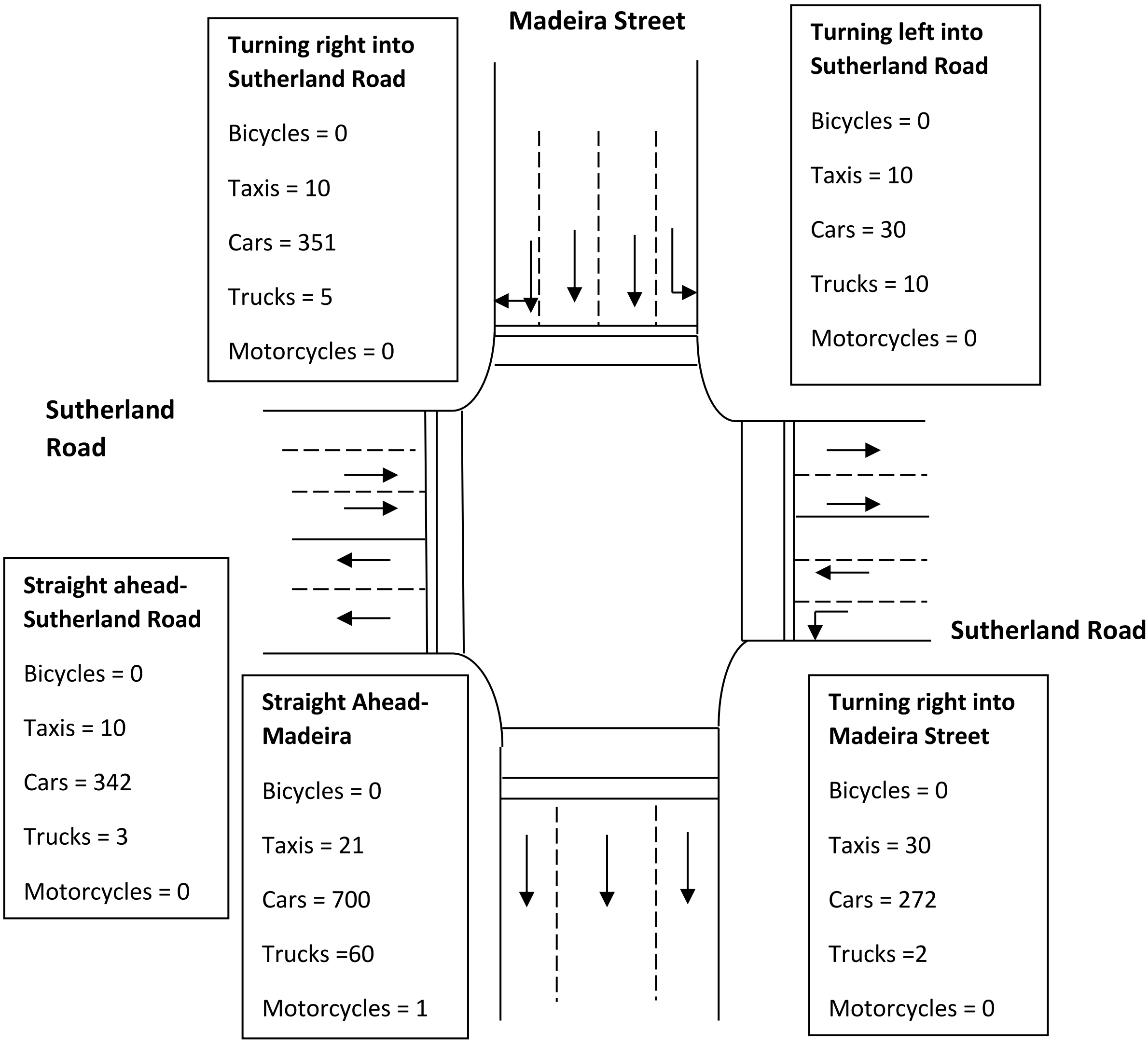


Figure 4.3 Illustrative sketch of traffic movement at the intersection of Madeira Street and Sutherland Road

Figure 4.4 depicts traffic movement during the peak hours of 06:30 to 08:30 at the intersection of Madeira Street and Sutherland Road. The direction of the traffic was south, out of the town of Mthatha. Tutor Ndamase/Madeira Street carried about 10.5% left-turning, and 42.6% straight-moving traffic and Nelson Mandela Drive carried 26.1% and 20.8% left-turning-traffic.

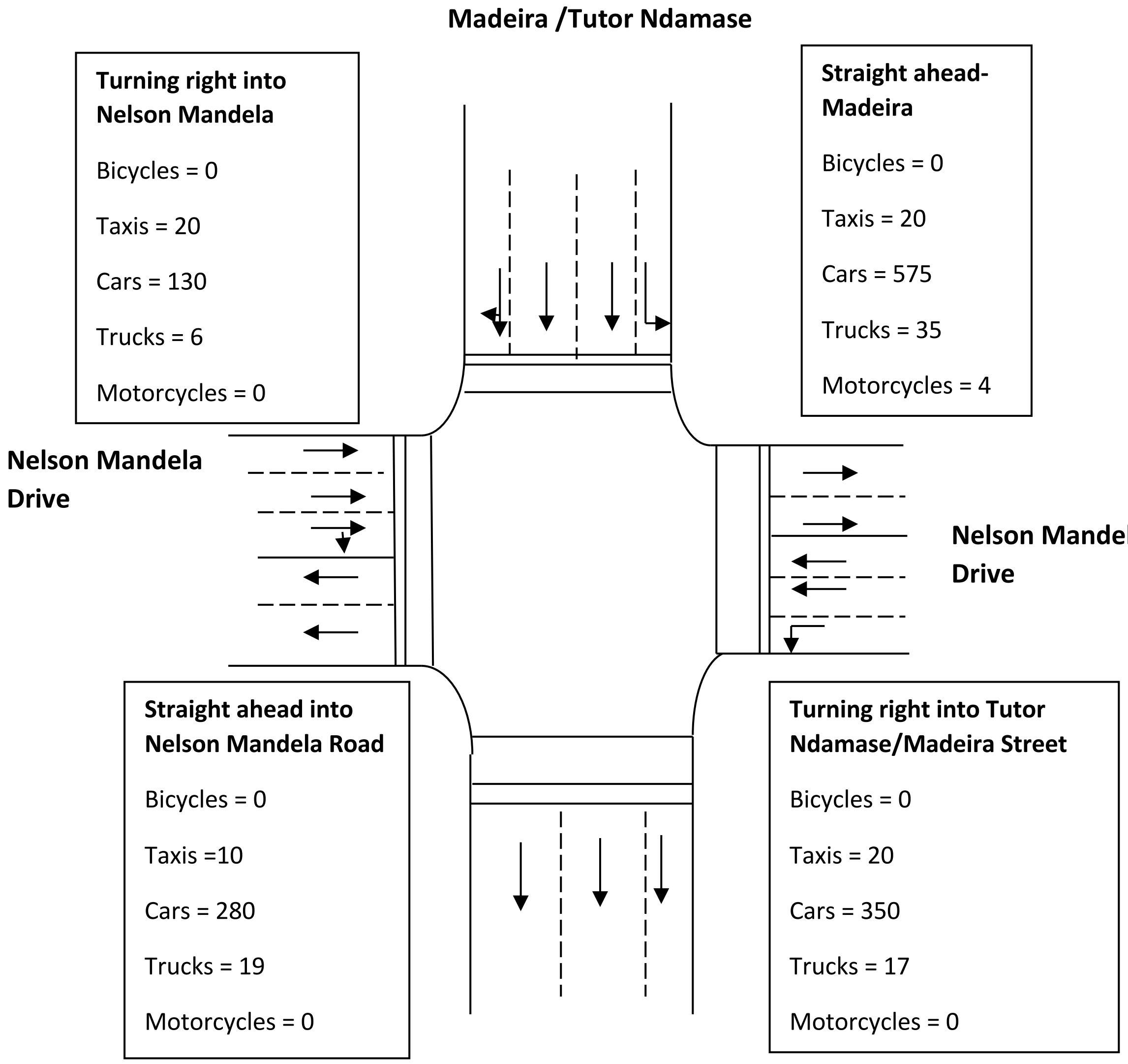


Figure 4.4 Illustrative sketch of traffic movement at the intersection of Nelson Mandela Drive and Tutor Ndamase/Madeira Streets

Figure 4.5 depicts traffic movement at the R61 and Sisson Street intersection. The junction is a T-junction. About 70.7% of the traffic on R61 was straight-moving traffic out of town toward Ngcobo and about 5.9% of the traffic turned left. From Sisson Street, about 23.4% turned left into R61 heading towards Ngcobo away from Mthatha town. This junction experienced a large amount of traffic throughout the day, but this survey was done at 16:00–17:30 peak time.

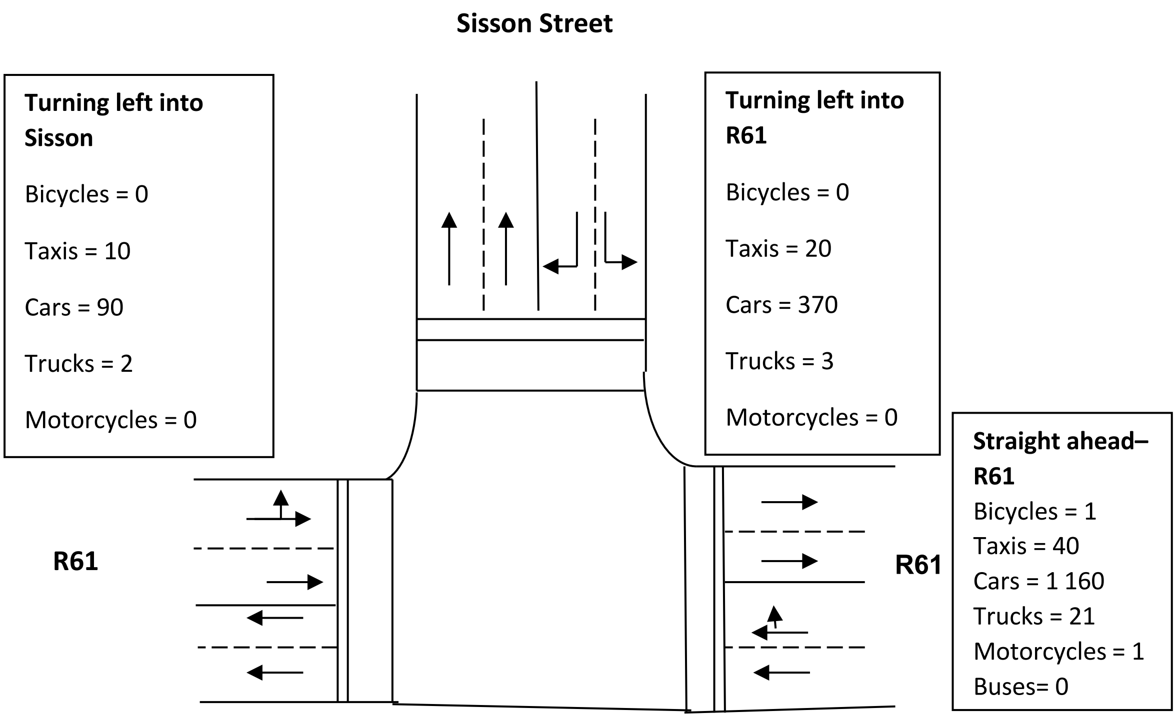


Figure 4.5 Illustrative sketch of traffic movement at the intersection of R61 and Sisson Street

4.3.2 Traffic speed

Table 4.6 shows the average traffic speed during regular and peak hours. During regular hours the speed on these different road's ranges from 40 to 55km/h. Through peak hours, traffic speeds on these roads averaged between 15 and 30km/h. During normal hours, Nelson Mandela Drive (42 km/h), Sutherland (43 km/h) and Sprigg (45 km/h) had low traffic speeds, while Durban Road (52 km/h) and Nqandu (52 km/h) had high traffic speed. The maximum speed limit of 60km/h was not exceeded on any of these roads.

During peak hours, traffic speeds averaged 24km/h on Nelson Mandela Drive, 27km/h on Sutherland Road and 30km/h on Sprigg street. It was discovered that the variation between regular and peak hour speeds was 23.33% to 36.67%. Nqandu, Tutor Ndamase, Nelson Mandela Drive and Durban Road, recorded higher differences in speed between regular and peak hours. Therefore, roads with heavier traffic movement during peak hours have a high difference in speed between peak and regular hours. The low traffic speeds seen on some of the roads also imply that they are under strain from heavy traffic volumes.

Table 4.3 Regular and peak hour speeds on the roads in Mthatha.

Roads	Direction	Average speed in regular hours (km/ h)	Average speed in peak hours (km/ h)	The percentage difference in speed between regular hours and peak hours
Nelson Mandela Drive	North	42	24	30.00
	South	42	24	30.00
Sprigg	North	45	30	25.00
	South	45	30	25.00
Sutherland	North	43	27	26.67
	South	43	27	26.67
Madeira	South	49	35	23.33
	South	49	35	23.33
Nqandu	North	52	30	36.67
	South	52	30	36.67
Tutor Ndamase	North	48	27	35.00
	South	48	27	35.00
Durban Road	North	52	34	30.00
	South	52	34	30.00

4.3.3 Parking amenities

Street parking amenities are accessible is some segments of Nelson Mandela Drive, Madeira Street, Sprigg Street and Sutherland Road as seen from the physical and geometrical parameter study. Parking spaces along these roads are mainly parallel (Figures 4.6, 4.7 and 4.8); but inclined (30°–60° angles) parking spaces are accessible in some segments of these roads. There are no on street parking amenities on the other roads surveyed. These parking spaces do contribute to traffic congestion by interrupting free flow of vehicles especially in peak times.

Figure 4.6 Inclined parking amenities on a section of Madeira Street passing along the CBD of Mthatha

Figure 4.7 Parallel parking amenities on Sutherland Road passing along the CBD of Mthatha

Figure 4.8 Parallel parking amenities on Sprigg Street passing along the CBD of Mthatha

4.3.4 Traffic management system

Majority of intersections in the study area were managed by automatic traffic signals. The smaller intersections were managed by stop signals. Table 4.4 shows the signal cycle times at significant intersections. Most of the intersections assessed were found to be managed by a three-phase signalling system of which one intersection catered for signal timings for left and right turn. The overall cycle time assessed for these intersections was 70 seconds during normal or peak times. It was found that the signal times were not enough for clearing traffic in Mthatha particularly the CBD area.

Table 4.4 Traffic signalling times for significant intersections in the CBD area of Mthatha

Intersection	Green (Seconds)	Right/Left-turn (Seconds)	Amber (Seconds)	Red (Seconds)	Phases	Actual cycle (seconds)
(Nelson Mandela – Mthatha Bypass)	40	10	3	50	2	90
(Nqandu – N2)	30	0	3	34	1	70
(Madeira – Sutherland)	30	0	3	34	1	70
(Tutor Ndamase – Nelson Mandela)	20	0	3	35	1	70
(Sisson – R61)	45	0	3	23	1	70

The South African Road Traffic Manual, Volume 3 (2012) recommends sufficient signage like lane delineation, pedestrian crossings, direction signs, stop signs, parking and no stop signs. Figure 4.9 depicts how most roads conformed to the guidelines, but some of the demarcations required maintenance.

Figure 4.9 Traffic management system on the roads in the CBD of Mthatha

4.4 Traffic congestion analysis

The study's examination of traffic congestion was based on road user perception of the parameters generating traffic congestion PI – Perception Index and their usage of ICT.

4.4.1 Perception index of parameters causing congestion

Road users' perceptions of the different factors that could lead to traffic congestion and alleviation of traffic congestion were the basis for computing perception index, as was covered in the methodology section. Applying the weighted average approach (Equation 1), The Perception index of different factors was determined on the basis of the weighted average (from 1 to 5) that the road users surveyed assigned to each factor. A statistical software was used to compute and analyse the responses of each road user. Several parameters were considered for the analysis, such as but not limited to, commercial, civic or administrative, traffic rules and ICT availability.

Table 4.5. shows the perception index values of different parameters.

Table 4.5 Road user perceptions of the factors affecting traffic congestion

Parameters	EI (%)	FI (%)	NI (%)	LI (%)	NI (%)	N	Mean	σ	Perception
COMMERCIAL FUNCTIONS	73 (46.5)	19 (12.1)	34 (21.7)	15 (9.6)	16 (10.2)	157	3,752	1,385	Low Perception
CIVIC, ADMINISTRATIVE FUNCTIONS	73 (46.5)	27 (17.2)	19 12.1)	18 (11.5)	19 (12.1)	156	3,750	1,444	Low Perception
ON ROAD INFORMAL COMMERCIAL ACTIVITIES	36 (22.9)	20 (12.7)	25 (15.9)	39 (24.8)	36 (22.9)	156	2,878	1,486	Low Perception
TRAFFIC NODES LIKE BUS STOPS, TAXI STOPS	75 (47.8)	29 (18.5)	24 (15.3)	11 (7.0)	16 (10.2)	155	3,877	1,355	High Perception
ON ROAD PARKING FACILITIES	60 (38.2)	26 (16.6)	28 (17.8)	19 (12.1)	19 (12.1)	152	3,586	1,426	Low Perception
ROAD CONDITION	75 (47.8)	25 (15.9)	25 (15.9)	11 (7.0)	16 (10.2)	152	3,868	1,370	High Perception
LACK OF PEDESTRIAN CROSSINGS	64 (40.8)	24 (15.3)	30 (19.1)	18 (11.5)	17 (10.8)	153	3,654	1,402	Low Perception
ACCIDENTS	47 (29.9)	35 (22.3)	27 (17.2)	27 (17.2)	17 (10.8)	153	3,444	1,371	Low Perception
WEATHER CONDITIONS	36 (22.9)	29 (18.5)	33 (21.0)	23 (14.6)	29 (18.5)	150	3,133	1,436	Low Perception

LACK OF RESPECT OF TRAFFIC RULES & REGULATIONS	104 (66.2)	24 (15.3)	10 (6.4)	7 (4.5)	10 (6.4)	155	4,323	1,180	High Perception
TYPES OF TRAFFIC SIGNALLING	55 (35.0)	27 (17.2)	38 (24.2)	17 (10.8)	16)10.2)	153	3,575	1,346	Low Perception
TYPES OF VEHICLES	58 (36.9)	27 (17.2)	18 (11.5)	19 (12.1)	24 (15.3)	146	3,521	1,513	Low Perception
AVAILABILITY OF INFORMATION THROUGH ICT	94 (59.9)	26 (16.6)	22 (14.0)	9 (5.7)	6 (3.8)	157	4,229	1,122	High Perception
SEGREGATION OF HEAVY AND LIGHT VEHICLES	104 (66.2)	17 (10.8)	22 (14.0)	8 (5.1)	6 (3.8)	157	4,306	1,121	High Perception
PERCENT DIVERSION MEASURES	63 (40.1)	35 (22.3)	30 (19.1)	18 (11.5)	7 (4.5)	153	3,843	1,211	High Perception
CHOOSING A DIFFERENT ROUTE	88 (56.1)	29 (18.5)	15 (9.6)	12 (7.6)	6 (3.8)	150	4,207	1,151	High Perception
USING PUBLIC TRANSPORTATION SYSTEM	78 (49.7)	20 (12.7)	23 (14.6)	19 (12.1)	14 (8.9)	154	3,838	1,393	High Perception
PROVISION OF OFF-STREET PARKING	55 (35.0)	28 (17.8)	31 (19.7)	21 (13.4)	11 (7.0)	146	3,651	1,312	Low Perception
PEDESTRIAN FACILITIES IN MAJOR AREAS	68 (43.3)	29 (18.5)	25 (15.9)	14 (8.9)	17 (10.8)	153	3,765	1,385	Low Perception
IMPROVEMENT OF SIGNALLING SYSTEM	97 (61.8)	30 (19.1)	13 (8.3)	11 (7.0)	3 (1.9)	154	4,344	1,028	High Perception
INSTALLING CAMERAS/VIDEOGRAPHY	105 (66.9)	19 (12.1)	12 (7.6)	9 (5.7)	11 (7.0)	156	4,269	1,242	High Perception
CREATING TRAFFIC AWARENESS & IMPROVING DRIVER KNOWLEDGE ON TRAFFIC RULES & REGULATIONS	111 (70.7)	24 (15.3)	8 (5.1)	8 (5.1)	5 (3.2)	156	4,462	1,021	High Perception
CHANGING TRAFFIC PATTERN	45 (28.7)	49 (31.2)	31 (19.7)	16 (10.2)	9 (5.7)	150	3,700	1,176	Low Perception
ONE WAY STREETS	29 (18.5)	23 (18.5)	20 (12.7)	23 (14.6)	55 (35.0)	150	2,653	1,558	Low Perception
SEGREGATION OF VEHICULAR AND PEDESTRIAN TRAFFIC	58 (36.9)	39 (24.8)	19 (12.1)	21 (13.4)	10 (6.4)	147	3,776	1,287	High Perception

Note: N= 157, EI= EXTREMELY IMPORTANT, FI= FAIRLY IMPORTANT, NI= NEUTRALLY IMPORTANT, LI= LEAST IMPORTANT, NI = NOT IMPORTANT.

Perception Weighted Average = $\frac{\Sigma\ Mean}{Number\ of\ Parameters} = \frac{94.404}{25} = \mathbf{3.776.}$

Analysis of the data revealed that respondents viewed road conditions, lack of adherence to traffic rules, and traffic nodes like bus and taxi stops as the most influential contributors to traffic congestion within the category of land use and urban functions. Other factors within this category like commercial functions, civic and administrative and informal roadside commercial activities were seen as having a lesser impact on congestion according to the perceptions.

Road users were surveyed on their views regarding strategies to reduce traffic congestion. According to data analysis in Table 4.5, respondents perceived certain measures as highly effective. These included providing traffic information through ICT, segregation of heavy and light vehicles, implementing diversion measures, choosing alternative routes, using public transport, improving signalling systems, installing traffic monitoring cameras, promoting traffic rule awareness, enhancing driver education, and segregating vehicle and pedestrian traffic. Other measures were rated as less impactful in comparison.

Figure 4.10 shows the opinions of road users on traffic congestion alleviation. With 1 being the least significant and 5 being the most significant measure to alleviate traffic congestion.

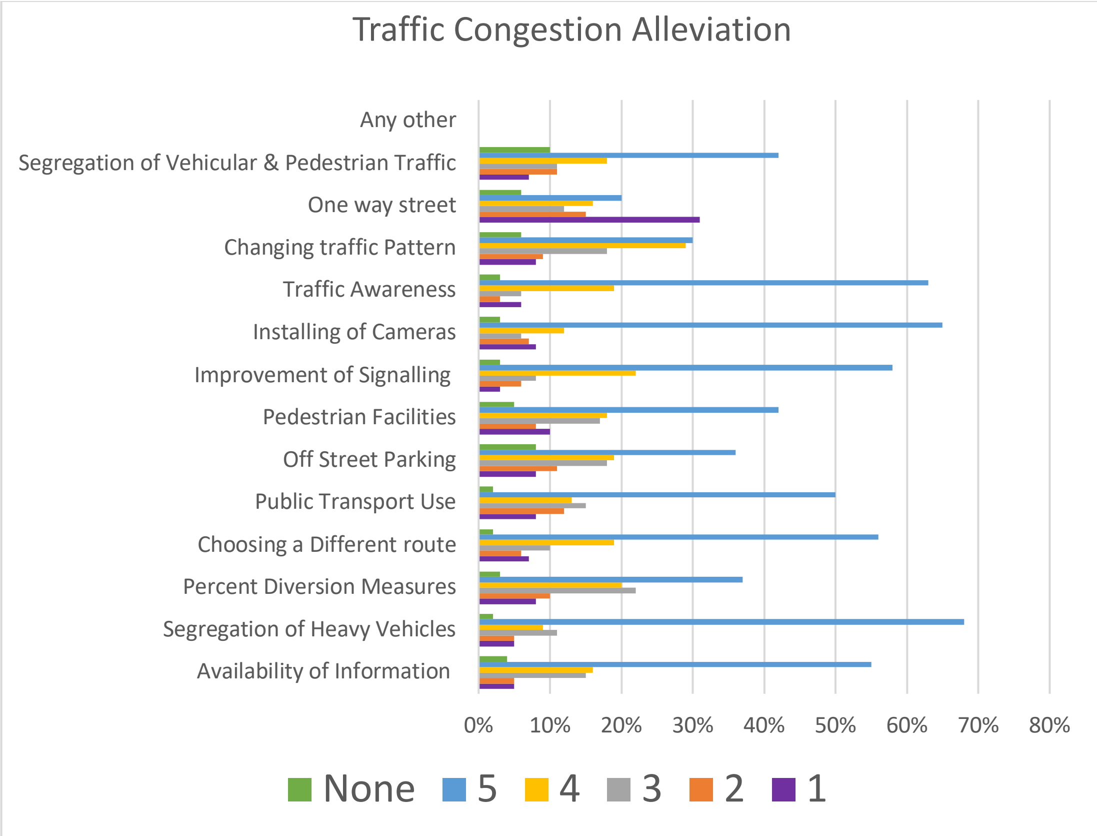


Figure 4.10 Showing perceptions of road users on traffic congestion alleviation
Source: Road user data collected (2019)

4.5 Scenario of ICT use in transport and traffic congestion in Mthatha

A survey was conducted through a set of questions to establish whether residents of Mthatha had any knowledge of ICT. Figure 4.11 shows the results after the responses were analysed.

In terms of ownership, it was found that most of the people owned ICT devices, of which 82% owned smartphones and 53% owned laptops or computers, while only 17% owned tablets. It was also found that about 42% of the people owned more than one laptop or computer; 9% owned more than one smartphone and only 9% of the respondents did not own any smartphone. It was also seen that tablet devices were not popular in Mthatha as 83% of the respondents did not own any tablets.

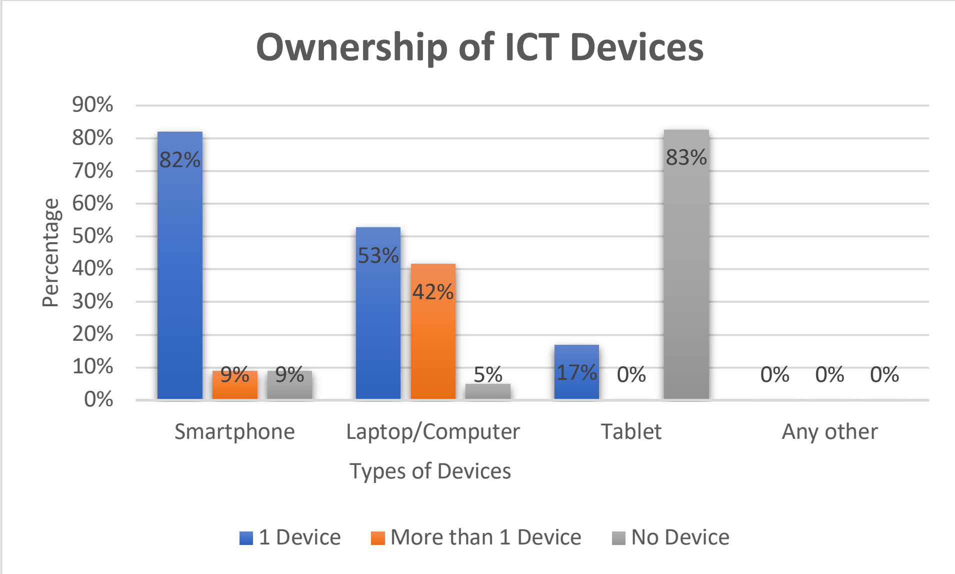


Figure 4.11 Ownership of ICT devices in Mthatha

Source: Author's own (2019).

Figure 4.12 shows the devices the respondents mostly used to access the internet and how long is the use. It was seen that people used their laptops/computers very low at 69%, moderately 18% and highly 13%, while people use their smartphones low 39%, moderately 25% and highly 36%. They further used their tablets at 90% low, moderately 7% and high 3%. Most of the respondents used their devices to access the internet by using a smartphone at 36% high, while using a tablet was only rated at 3% and a; laptop or computer was high in use at 13%.

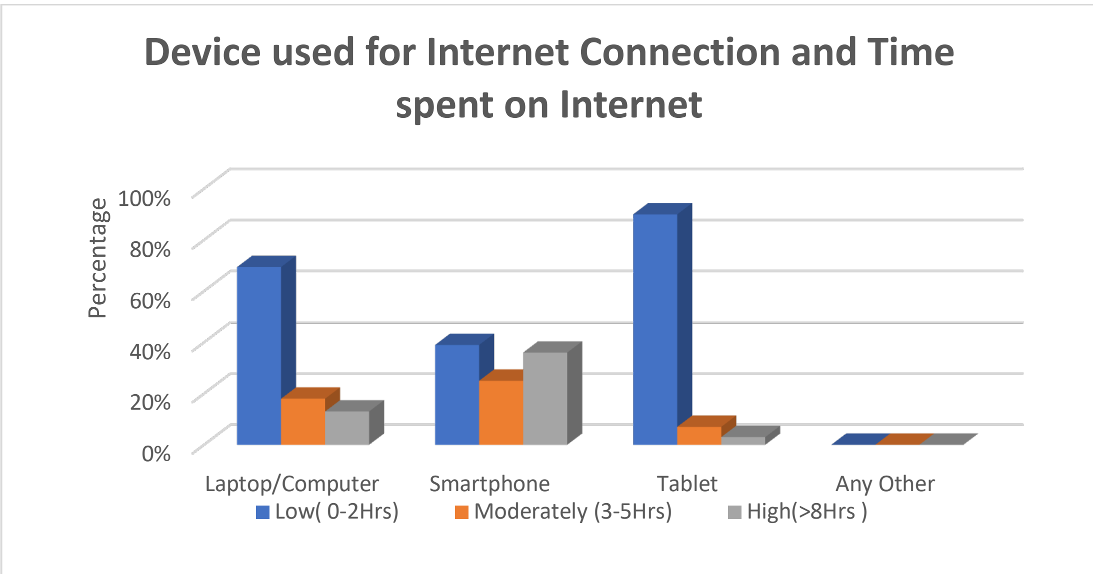


Figure 4.12 Devices used for internet connection, and time spent on internet in Mthatha

Source: Author's own (2019)

Figure 4.13 shows how people accessed the internet in Mthatha. It shows that 73% of the respondents used their own personal data (73%) and 35% of the respondents used public Wi-Fi, while only 17% of the respondents had access to their own personal Wi-Fi and 6% used Wi-Fi hotspots.

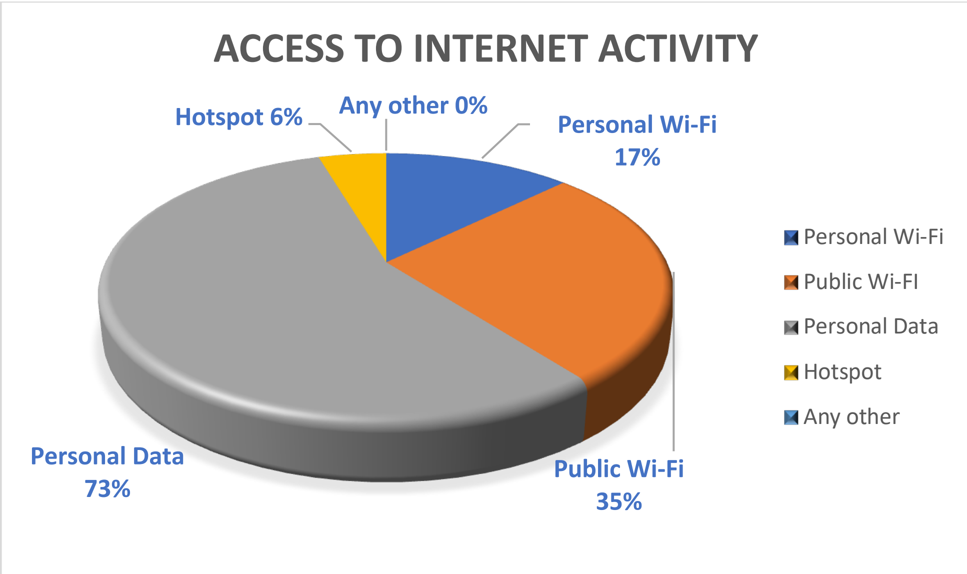


Figure 4.13 Access to internet activity in Mthatha

Source: Author's own (2019)

Figure 4.14 shows places where people get internet accessibility in the Mthatha area. A total of 44% of the respondents accessed internet at home, 28% of the respondents accessed the internet at the office and public spaces and 15% accessed the internet at internet shops or cafes, while only 7% of the respondents, which were mostly students, accessed internet at school and university.

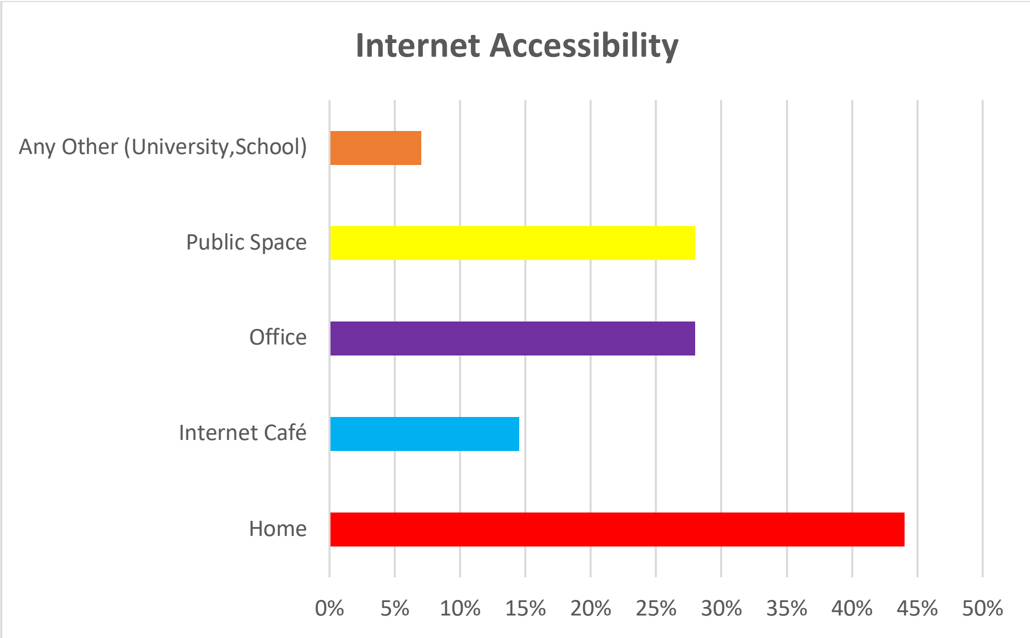


Figure 4.14 ***Access to internet activity in Mthatha***

Source: Author's own (2019)

Figure 4.15 shows the purpose of internet use and how regularly people use the internet in Mthatha. About 74% of the respondents used the internet for study and work-related purposes, 47% used it to access general information, 27% used it for entertainment, and 23% used it for banking, and this was more than once a day. It was also seen that people in Mthatha hardly used internet for travel, as 80% of the respondents answered none, only 13% once a day and 8% more than once a day.

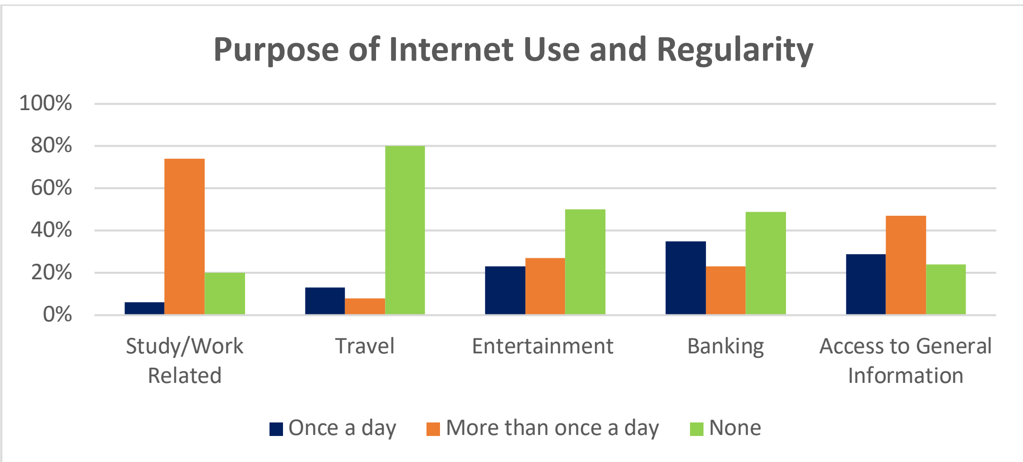


Figure 4.15 ***Purpose of internet use and regularity***

Source: Author's own (2019)

4.6 Testing of Hypothesis

In this section a formula to calculate speed is created using assumptions based on the data collected in the study area. The formula is used to represent the relationship between number of cars and speed of vehicles using the assumptions and data collected. This formula will help calculate the speed if a certain number of cars are reduced during travel in the Mthatha CBD particularly during peak hours. The factors applied in the reduction of cars vary ranging from ICT integration measures, expansion of roads, to separating modes of transportation.

Using an existing formula of speed which is the distance travelled divided by the time it takes. The current approximate time it takes for road users travelling in Mthatha from Ultra city garage and out to Engen Norwood garage through the N2 is 60 minutes during peak hours. The assumption is that to travel at a speed of 30km/h the approximate number of vehicles per 200m distance is 50 cars, therefore, to achieve a speed of 60km/h (which is the maximum allowable speed in the roads in Mthatha), 25 cars would have to be reduced, thereby influencing the overall traffic scenario in the CBD.

The following hypothesis were tested:

Usage of ICT in everyday urban activities (home, work, travel) will reduce traffic congestion in urban areas specifically Mthatha.

$m = \frac{\Delta y}{\Delta x}$.. (Equation.9)

$$m = \frac{30km/h - 60km/h}{50\ cars - 25\ cars}$$

$$y - 60 = m(x - 25)$$

$\boldsymbol{y = -1.2x + 90}$................................. (Equation.10)

Where Y is = Speed and X = number of cars.

Example: Using eq. (9), the speed the vehicles travel in is 30km/h over a distance of 8.3km from Ultra City garage to Engen Norwood, therefore the time it takes is 0.27h (16.2 minutes).

$$y = -1.2x + 90$$

$$y = -1.2(50) + 90$$

$$\underline{y = 30km/h}$$

Where time is calculated using the below formula:

$$Time = \frac{Distance(km)}{Speed\ (km/h} \text{............................ (Equation.11)}$$

So, if traffic were reduced by the integration and implementation of ICT and other measures and the number of vehicles travelling on the road reduced by 25 cars, using the relationship above eq. (10):

$$\boldsymbol{y = -1.2x + 90}$$

$$y = -1.2(25) + 90$$

$$\underline{y = 60km/h}$$

Therefore, the speed of 60km/h is achieved, reducing travel time to 0.13h (7.8minutes) thereby decreasing the overall traffic congestion in Mthatha.

4.7 Summary of findings on ICT

- Ownership of ICT devices in Mthatha is not a problem as a lot of the respondents owned smartphones, tablets, and laptops or computers in the area. This shows that integration of ICT-related transport measures would not be an issue as most people already own these devices.
- People in Mthatha used their smartphones more than they use their computers or laptops, and this was also due to the number of people who owned laptops or computers not being more than those who owned smartphones.
- Internet in Mthatha was not easily accessible in public as most people used their own personal data bundles. Because of affordability, a few people in Mthatha had Wi-Fi connections in their own homes, but most people used public Wi-Fi available in spaces such as banks, malls, and restaurants.
- Other spaces people have access to the internet in Mthatha, besides public spaces and their homes, is at their workplaces, university or school, and internet cafes. Internet cafes in areas like Mthatha have been the most popular if you need reliable Wi-Fi and need to do something important such as job applications.
- People in Mthatha used the internet for different things, but the most common reason was study and work-related use, access to general information, banking, and

entertainment. Travel-related use was significantly low and close to none. If ICT travel-related measures that are best suited for Mthatha can be created and integrated, the use of ICT for travel would increase as people were already using ICT for travel.

- With the implementation of measures to alleviate traffic congestion particularly the integration of ICT in day to day activities and travel such as shopping, banking, online delivery services and travelling applications for the people of Mthatha, the number of cars on the road could potentially reduce thereby reducing the amount of time it takes to travel in and around the town and therefore increasing the speed of vehicles, which will in turn decrease the overall traffic congestion scenario in Mthatha.

Chapter 5

Findings, Recommendations and Conclusion

5.1 Introduction

The main objective of this study was to investigate the integration of information technology for sustainable road traffic movement in urban areas in the Eastern Cape, a case of Mthatha, South Africa. The research sough to answer the following objectives:

- To assess the current road network and traffic movement scenario (traffic flow, traffic congestion, and queue length) in Mthatha.
- To examine how urban functions and land use affect traffic movement in Mthatha.
- To study the usage of ICT on socio-economic factors, road transport and travel activities in Mthatha.
- To develop and simulate empirical models to examine how ICT integration affects road traffic movement in Mthatha.
- To evolve a set of plausible strategic recommendation for effective road traffic movement in the urban area.

5.2 Summary and interpretation of findings

5.2.1 To assess the current road network and traffic movement scenario (traffic flow, traffic congestion, and queue length) in Mthatha

The current road network in Mthatha was assessed by conducting surveys to establish the physical and geometrical characteristics of the roads, as well as traffic surveys which included traffic counts and speed survey measurements at various intersections and roads in Mthatha. Table 4.1 Shows the physical and geometrical characteristics of the roads in Mthatha whereas Table 4.2 shows the design guidelines and criteria for the physical and geometric properties of roads. Table 4.1 classifies these roads mostly as U3(minor arterial) and U4(local collector) national and provincial roads. The roads are all sealed, are in good and acceptable conditions, have automatic traffic signals and speed humps, adequate lane widths, kerbs, adequate gradient and curvature and the majority of these roads provide for on-street parking and pedestrian facilities. Table 4.4 shows the existing traffic management system as well as varying signalling timings at various intersections in Mthatha. These physical and geometrical characteristics findings demonstrate that Mthatha has a functioning road network that is safe for road users to use, with adequate signalling, pedestrian crossings and parking is provided and that the current road network meets the requirements outlined in Table 4.2. However, certain roads require maintenance as some road markings are faded and potholes can be observed in specific areas.

Mthatha's traffic volume was assessed using traffic counts and speed surveys at several intersections and roads. These traffic counts were conducted during peak hours. Figure 4.1 to Figure 4.5 depicts illustrated diagrams of these junctions indicating the amount of traffic carried by the intersection. Table 4.3 shows the speed variations on these roads during normal and peak hours. The findings according to the traffic counts and speed surveys clearly highlight a traffic congestion challenge in Mthatha with speeds dropping by up to 30% from normal speeds during peak hours. The traffic counts also clearly indicate a large number of heavy vehicles at various intersections, which contribute considerably to traffic congestion during peak hours.

5.2.2 To examine how urban functions and land use affect traffic movement in Mthatha

The impact of land use and urban functions on traffic movement was assessed through questionnaires where road users rated various parameters on a scale from 1 to 5, with 1 indicating "not important" and 5 indicating "extremely important" in terms of their effect on traffic flow. The data collected was processed and analysed using statistical software to evaluate the road users' perceptions. Table 4.5 presents the results of the analysis. It reveals that traffic nodes such as bus and taxi stops, were perceived as highly influential on traffic movement, while factors like commercial functions, civic and administrative functions, informal roadside commercial activities and on road parking facilities were viewed as having a lower impact.

The findings indicate that residents of Mthatha view traffic nodes, such as bus and taxi stops, as key contributors to traffic flow in the CBD, with (47.8%) considering them "extremely important". While other factors were rated lower in terms of their impact on traffic, the data in Table 4.5 reveals that parameters like commercial functions (46.5%

deem them “extremely important”), civic and administrative functions (46.5%), informal roadside commercial activities (22.9%), and on-street parking (38.2%) also play a significant role in contributing to traffic congestion in Mthatha.

5.2.3 To study the usage of ICT on socio-economic factors, road transport and travel activities in Mthatha

A survey was conducted to determine whether residents and road users in Mthatha used ICT for their daily activities, and whether they owned ICT devices and had access to reliable internet connections. The results, presented in Figures 4.11 to 4.15, were based on the analysis of the survey responses. The findings reveal that 82% of Mthatha residents and road users owned smart phones, with 36% using them to access the internet. Additionally, 73% of respondents relied on personal data,35% used public Wi-Fi,6% accessed the internet through hotspots, and only 17% had personal Wi-Fi connections.

The findings indicate that people in Mthatha continue to rely heavily on personal data for internet access, highlighting concerns about the affordability of internet services, given the high cost of data. While 35% of people use public Wi-Fi in public spaces, this is not a sustainable long-term solution, as individuals must travel to these locations to access the internet. Additionally, only 17% of Mthatha residents have access to personal Wi-Fi, indicating that the cost of home internet is beyond the reach of many.

Figure 4.15 illustrates the primary uses of the internet, with travel being the least common reason, while activities like studying, entertainment, banking and accessing general information are the most frequent. These findings suggest that internet and ICT usage are not unfamiliar concepts to the people of Mthatha. If strategies and awareness initiatives were introduced to promote the use of ICT for travel-related purposes, it could be successful, as many residents already have some level of familiarity with ICT.

5.2.4 To develop and simulate empirical models to examine how ICT integration affects road traffic movement in Mthatha

Chapter 4, 4.6 shows how the formula was developed using speed and time assumptions based on the data collected.

$$y = -1.2x + 90$$

Where Y = Speed and X = number of cars.

5.2.5 To evolve a set of plausible strategic recommendation for effective road traffic movement in the urban area

To evolve a set of strategic recommendations for effective road traffic movement in the urban area of Mthatha. A survey gathered opinions and perceptions on traffic congestions from road users and residents. Informal interviews were also conducted with stake holders from the KSD Local Municipality and other organisations.

The following are a set of plausible strategic recommendations evolved:

- Segregation of heavy vehicles from regular traffic can be achieved by the Municipality designating a bypass on an outer road in Mthatha for heavy vehicles not delivering within the CBD. For those needing to make deliveries in town, specific delivery times outside peak hours can be established, such as night or early morning when traffic is lighter. To facilitate this, business owners and the municipality can work with logistics companies to coordinate delivery schedules and routes in line with the towns traffic regulations.
- KSD Local Municipality can develop a spatial plan where the relocation of the taxi ranks situated along the N2 in the CBD is a priority, as this ranks also contribute significantly to traffic congestion, as indicated by the perceptions of road users on public transport which are presented in table 4.5.
- Raising awareness about the importance of respecting and following traffic rules and regulations can be achieved through community engagement initiatives and outreach programs like workshops, street campaigns, social media outreach and media partnerships. Collaborating with local schools, businesses and colleges to host interactive sessions at schools or community centres can educate participants on road safety, traffic rules, and the consequences of traffic violations. The municipality can also use its social media platforms to share videos, images, and real-life stories from locals who attribute following traffic rules to positive outcomes. Street campaigns with information booths, flyers, and

local radio segments focused on traffic laws, accident statistics, and safety tips can further reinforce this message.

- The KSD Local Municipality could fund Wi-Fi hotspots throughout the CBD, providing residents with quality internet access whereby promoting ICT usage. These hotspots would allow the municipality to receive real time updates on road and traffic issues reported by locals and drivers in the area. Additionally, a dedicated WhatsApp hotline could be established for reporting traffic-related concerns. Based on the type and severity of the issue such as non-functioning traffic signals causing traffic congestions at intersections, the municipality could respond promptly, for example, by dispatching traffic officers to assist in maintaining smooth traffic flow.
- Safe public transportation system where road users are can rate drivers through their ICT devices. In return, drivers who maintain safe driving practices receive incentives from the Municipality, in partnership with taxi associations, thus promoting for safer public transportation.
- KSD Local Municipality can seek funding from national and international organisations such as the United Nations, that are interested in sustainable development, establish public and private partnerships (i.e. business owners in the town affected by traffic congestion challenges) to fund infrastructure related to sustainable traffic management in the town, the infrastructure can include ICT infrastructure such as smart traffic lights that respond in real time to traffic conditions and monitoring systems that can monitor traffic violations such as illegal parking and unauthorised turns, this will in turn ensure smooth traffic flow, promote road safety and safer driving practices.

5.3 Limitations of the Study and Future research suggestions

The study faced limitations in data analysis, particularly in using statistical software and developing empirical models. Furthermore, some survey questionnaires were unusable due to incomplete responses from participants and that not all roads and intersections in Mthatha were surveyed and that better insight on traffic congestion can be provide in the number of respondents can be increased. The study was only focused in Mthatha, and the findings cannot be general to South Africa. Additional limitations were time-related and significantly impacted by personal struggles.

Future research could focus on developing comprehensive ICT empirical models to enhance traffic movement in Mthatha and examine potential collaborations between the KSD Local Municipality and taxi associations to ensure safer public transport. Further studies could also investigate how the N2 Wild Coast Road Project might impact traffic congestion levels in Mthatha.

5.4 Conclusion

Road transportation is critical in providing individuals with access to a variety of socio-economic activities, including business, education, employment, recreation and healthcare, particularly in cities. However, population growth, socio-economic activity as well as subsequent urban functions, and increased vehicular travel have produced long-term mobility issues in cities. The scenario of such difficulties in South African cities seems quite significant and Mthatha, a town in South Africa's Eastern Cape province, is experiencing similar challenges of traffic congestion in the CBD. Given this, there are claims that widespread utilisation of Information and Communication Technology (ICT) in travel as well as socio-economic pursuits could greatly reduce road transportation and traffic-related issues while also promoting sustainable road transportation. Thus, a study was conducted to examine whether integrating information communication technology for sustainable road traffic movement in urban areas in the Eastern Cape, specifically Mthatha can effectively reduce traffic congestion and contribute to creating a more sustainable town. To accomplish this, a comprehensive literature review was conducted to explore the various factors contributing to traffic congestions, the causes and intervention strategies aimed at alleviating traffic congestion. A structured methodology guided data collection, followed by data analysis which helped develop practical recommendations to reduce congestion and enhance traffic movement within and around Mthatha's CBD.

The findings indicated that, according to road users in Mthatha, the main causes of traffic congestion included poor road conditions, lack of respect of traffic rules and regulations, traffic nodes like bus and taxi stops and the high volume of heavy vehicles. Additionally, the study found that measures such as segregating heavy and light vehicles, implementing percent diversion measures, choosing of alternative routes, using public transportation, improvement of signalling systems, installing cameras and video monitoring, creating traffic awareness and improving driver knowledge on traffic rules, segregating vehicular and pedestrian traffic and providing information through ICT were the most effective ways to reduce traffic congestion. The study also discovered that ICT is relatively familiar to residents of Mthatha, with many people owning smartphones, laptops, and computers, and having internet access through personal data, hotspots, public Wi-Fi or personal Wi-Fi. While people do use ICT for travel, it is primarily used for other activities, including studying, banking, and entertainment.

The hypothesis tested confirmed that travel speeds in Mthatha can improve by reducing the number of cars on the roads through the application of ICT and other sustainable interventions thereby reducing traffic congestion.

Although certain limitations were noted, this study has shown that integrating information communication technology for sustainable road traffic movement in Mthatha is feasible, as people already use the internet for various purposes, including travel, and possess ICT devices. Despite limitations in analysis and scope, the findings offer valuable insights into the traffic congestion challenges facing Mthatha.

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Appendix A
Integration of Information Communication Technology for Sustainable Road Traffic Movement in Urban Areas in the Eastern Cape, A Case of Mthatha, South Africa

Questionnaire for road transportation and traffic survey

The study forms a component of a M. Eng research that evaluates the road and traffic systems in Mthatha, South Africa. Its goal is to determine the impact of urban functions, land use, road transport and traffic systems on traffic congestion in Mthatha, as well as to comprehend road users' and peoples' perspectives on how to address the towns traffic congestion problem.

The survey results will be utilised to investigate the control factors that impact traffic congestion, evaluate congestion levels and determine how ICT integration might influence traffic challenges and provide appropriate policy interventions to alleviate traffic congestion. Data will only be used for academic research reasons.

Questionnaire

1. Demographic Information

1.1 Name:
1.2 Address:
1.3 Location:
1.4 Age
1.5 Gender:
1.6 Number of members in the family:
1.7 Age of family members:

Age	1-6	6-15	16-25	25-45	46-60	>60
Number						

2. Socio-Economic profile

2.1 Occupation: Govt. Service/ self-employed/ Industry/ mining/ Professional/ student/ service activities (traders)/Farming/ unemployed/ any other

2.2 Income: Primary income (self) Secondary income (Household):

2.3 Education: Primary/ Secondary/ Bachelors/ Masters/ Ph.D. / Professional (level of education)/ none

3. Road Travel related.

3.1 Purpose of travel: Job/ education purposes /entertainment/ shopping/ health care/ civic activities/ any other (you can provide more than one choices)
3.2 Use of modes for travel: Private cars/ Public (Bus)/ Shared taxi)/ Private Taxi/ Trams/ Motor Bikes/ by foot/ Bicycle/ any other?
3.3 Average number of trips per day:
3.4 Average travel distance per day:
3.5 Average travel distance per trip:
3.6 Origin of Travel: Destination:
3.7 Frequently travel days: weekday/ weekends/ both
3.8 Frequently travel period of the day: weekdays: (Please provide the time of the day both start and return)
3.9 Frequently travel period of the day: weekends: (Please provide the time of the day both start and return)
3.10 What Route do you use to travel in and out of the Urban Area of Mthatha?
3.11 Major challenges frequently faced during the travel: Congestion/ Delay/ Long queue at junctions/ Long queue on roads/ Long waiting time at junctions/ Slow speed/ Accident/ Pollution/ Parking/ Breakdown/psychological/ Physical stress/ any other
3.12 Do you use any ICT enabled equipment during travel: Y/N?
3.12.1 If Yes, what kind of equipment do you use: GPS/ Mobile Phone GPS/ Real Time Road Signs/ SMS/ or any other.
3.13 On what period of the day does traffic congestion occur?

Level of congestion	6.00-8.00	8.00-10.00	10.00-12.00	12.00-14.00	14.00-16.00	16.00-18.00	18.00-20.00	20.00-22.00	Any other specific period
No congestion									
Appreciable									
Close to maximum									
Maximum									

3.13 Traffic Congestion caused by Land use and Urban Functions and other related parameters (Rate in a scale of 0 to 1, **0 means least important and 1 means most important**)

Parameters	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Commercial functions (Shopping, Malls)											
Civic/administrative functions like schools/ colleges/ hospitals/ offices/ entertainment areas/sports centres											
On road informal commercial stalls											
Traffic nodes like bus stops, taxi stops											
On Road parking facilities											
Road Condition											
Lack of Pedestrian Crossings											
Accidents											
Weather Conditions											
Lack of Respect to traffic rule and regulations											
Types of traffic signalling											
Type of Vehicles											

3.14 Do you use parking in the CBD Area? If yes:

Type of Parking		Duration of Parking (Hrs)	Where do you Park?
Parallel			

Perpendicular			
Angled			
Any other			

4. Information Communication Technology Related Information

4.1 Do you own an ICT Device: Smart Phone/Laptop/Computer/Tablet/ Any other?

4.2 How many devices do you own?

Device	Number
Computer/Laptop	
Tablet	
Smart Phone	
Any Other	

4.3 What device do you use to connect to the internet: Personal Computer/Laptop/Smart Phone/Tablet/ any other?

4.3.1 How often do you use these devices to communicate in terms of Hrs?

Device	Low (0 - 2Hrs)	Moderately (3Hrs - 5Hrs)	High (> 12Hrs)
Computer/Laptop			
Tablet			
Smart Phone			
Any Other			

4.4 How do you access internet connectivity: Personal Wi-Fi/Public Wi-Fi/Personal Data/Hotspots/any other?

4.5 Where do you access the Internet: Home/Internet Café/Office/Public Space/any other?

4.6 How often do you use the internet and for what Purpose?

Purpose	Access to general Information	Study related/Work Related	Travel	Entertainment	Banking
Yes/No					
Duration of Use (Hrs)					
Frequency (How many times a day)					

4.6 How would you suggest traffic congestion can be alleviated? (Rate in a scale of 0 to 1, **0 means least important and 1 means most important**)

Parameters	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Accessibility of information through ICT											
Separation of heavy and light vehicles (Modal split)											
Percent diversion measures (Traffic assignment) Choosing a different route											
Use of public transportation system											
Providing Off street parking											
Pedestrian amenities in major areas											
Improvement of signalling system											
Installing Cameras/ videography											
Creation of traffic awareness and improving driver/user knowledge on traffic rules and regulations											
Changing the traffic pattern											
One-way streets											
Separation of vehicular and pedestrian traffic											

Any other please specify											

4.7 Do you think an Information Communication Technology system informing road users of traffic congestion, accidents ahead, construction ahead, available parking, weather conditions, would help the city's traffic movement? Elaborate.

4.8 Would you pay for use of an ICT system? If Yes How much.

4.9 Do you think that the internet in Mthatha is easily accessible to the public? Elaborate,

4.10 Do you think the internet access in Mthatha is of good quality?

4.11 Do you think the economy of Mthatha can be improved by the better use of Information Communication Technology for the purpose of accessing general and important information, Study/work, Travel, Entertainment or Banking and more?

4.12 What guidelines can be set to ensure that traffic congestion is managed in Mthatha?

4.13 Any other opinions on improved services and enhancement of Information Communication technology use in your city?

Appendix B
Data Collection Form for Traffic Volume Survey at Junctions

Date and day of the week:

Direction of traffic: N (To Town)/ S (Away from Town):
From………………To…………………

Name of the road ……………….. road section ……………………………………

Close to landmark if any:

Traffic entering intersection from

Name of approach road:

Travelling (Compass direction):

Time of the day:

Direction of Flow	**Types of vehicles**						
	Cars	Buses	Trucks	Motorcycles	Bicycles	Others (Specify)	Remarks, including weather conditions
Left Turning							
Straight ahead							
Right Turning							

Appendix C
Integration of Information Communication Technology for Sustainable Road Traffic Movement in Urban Areas in the Eastern Cape: A Case of Mthatha, South Africa

Template for physical and road geometric parameter survey

The study forms a component of a M. Eng research that evaluates the road and traffic systems in Mthatha, South Africa. Its goal is to determine the impact of urban functions, land use, road transport and traffic systems on traffic congestion in Mthatha, as well as to comprehend road users' and peoples' perspectives on how to address the towns traffic congestion problem.

The survey results will be utilised to investigate the control factors that impact traffic congestion, evaluate congestion levels and determine how ICT integration might influence traffic challenges and provide appropriate policy interventions to alleviate traffic congestion. Data will only be used for academic research reasons.

Physical characteristics of the roads in the CBD area of Mthatha

Name of the roads	Road type (N/R/ Arterial/ local streets.)	Road width (m)	Number of lanes	Lane width(m)	Availability of pedestrian/ bicycle lane	Pavements/ footpaths /shoulders	Kerbs	Median width	Sight distance	Radius of Curvature	Gradient (%)	Type of Road surface	Condition of road surface	Availability of Traffic control system	On street parking type Right angle/ inclined/ parallel
Nelson Mandela Dr (N)															
Nelson Mandela Dr (S)															
Sprigg (N)															
Sprigg (N)															
Sutherland (S) Towards Ngcobo															
Sutherland (N) Towards Ngcobo															
Sutherland (S) In Town															
Sutherland (N) In Town															
Sutherland (S) Towards Port Saint Johns															
Sutherland (N) Towards Port Saint Johns															
Madeira (S)															
Nqandu (N)															
Nqandu (S)															
Tutor Ndamase Avenue (N)															
Tutor Ndamase Avenue (S)															
Main/Durban Road (N)															
Main/Durban Road (S)															

N = North (Towards inside of the city)

S = South (Towards outside of the city)

PD = Pedestrian facilities, B = Bicycle, P = Paved, UN = Unpaved, Y = Yes, N = N

PV = Pavement, F = Footpath, SW = Shoulder Width

Appendix D

Speed Survey Schedule

Name of assessor:

Date:

Location:

Name of the Road:

Road section identity:

Type of road:

Road condition:

Duration of the day (Time)	Distance in (m)	Type of vehicles																			
		Car				Bus				Heavy vehicles				Motor bikes				Others			
		Time in	Time out	Diff (s)	Speed	Time in	Time out	Diff (s)	Speed	Time in	Time out	Diff (s)	Speed	Time in	Time out	Diff (s)	Speed	Time in	Time out	Diff (s)	Speed
6:00-6:30																					
6:30-7:00																					
7:00-7:30																					
7:30-8:00																					
8:00-8:30																					
8:30-9:00																					
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19:00-19:30																					
19:30-20:00																					