INVESTIGATION OF THE INFLUENCE OF INFORMATION AND COMMUNICATION TECHNOLOGIES ON SUSTAINABLE ROAD TRANSPORTATION IN BLOEMFONTEIN CITY, SOUTH AFRICA

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DECLARATION OF INDEPENDENT WORK

DECLARATION WITH REGARD TO INDEPENDENT WORK

I, XOLISWA EVELYN FEIKIE, identity number and student number , do hereby declare that this research project submitted to the Central University of Technology, Free State for the Degree MASTER OF ENGINEERING: IN CIVIL ENGINEERING:, 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 qualification.

SIGNATURE OF STUDENT

02/NOV/2020

DATE

Dedication

This dissertation is dedicated to the ALMIGHTY GOD, my family and loved ones.

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With a grateful heart, I give thanks to ALMIGHTY GOD for HIS love, strength, grace, knowledge, wisdom and understanding. I thank HIM for always being by my side. Without HIM, the completion of this research study would not have been possible.

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Abstract

The concept of sustainable road transportation as an important measure of sustainable development has been adopted globally, by different countries and cities after the Brundtland report, along with other environmental initiatives that have aimed to sustain and make the planet liveable for future generation. African cities have also taken the initiative to move towards sustainability of transportation in their cities. Different scholars have identified various sustainable road transportation indicators as a guide to what governments and policy makers need to focus on to solve different challenges the cities are facing. Although different policies have been effective in some cities, there are other challenges that have not been alleviated, such as congestion, traffic delays, carbon emissions, and the dominant use of private vehicles. The incorporation of Information and Communication Technology (ICT) in sustainable road transportation is argued to be one of the ways to make road transportation efficient and effective. This could alleviate challenges such as congestion, carbon emissions, and the use of public transportation, and help make road transportation and cities sustainable. However, literature is scarce on how integration of ICT will influence sustainability of road transportation, in particular in cities of South Africa. Therefore, using the study context of Bloemfontein city of South Africa, this study examined the current scenario of the road transportation system in city and explored how sustainable road transportation in the city can be achieved by use of relevant innovative systems like Information and Communication Technologies (ICT) in the daily personal and professional activities of people and their travel needs in and around the city.

The study followed a quantitative research method. Data was collected by the use of survey method and was followed by statistical analyses and empirical modelling. The findings indicate that the integration of ICT into road transportation reduces the need for travel and consequently reduces the levels of congestion on the road, which will lead to reduced CO_2 emissions. Through the results, it can be recommended that for Bloemfontein to be a sustainable city, the integration of ICT into road transportation should be a priority, which can assist to alleviate the existing transportation challenges and provide transportation that is sustainable, reliable, safe, efficient and cost effective.

Abbreviations

BEPP	Business Economics and Public Policy
BREEAM	Building Research Establishment Environmental Assessment
BRT	Bus Rapid Transit
CO_2	Carbon Dioxide
CBD	Central Business District
CST	Computer Systems Technology
EU	European Union
EC	European Community
ICT	Information and Communications Technologies
IDP	Integrated Development Plan
IPTN	Integrated Public Transport Network
IRT	Information Resources and Technology
ITS	Intelligent Transportation System
LA	Local Agenda
LEED	Leadership in Energy and Environmental Design Method
LOS	Level of Service
PSUTA	Partnership for Sustainable Urban Transport in Asia
SANDF	South African National Defence Force
SDF	Sustainable Development Framework
SMART	Specific, Measurable, Achievable, Relevant, Time-Bound
UN	United Nations
WCED	World Commission on Environment and Development
WEO	World Environmental Organization
WHO	World Health Organization

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CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION

Sustainable transportation is an important part of sustainable development. Cities are experiencing challenges relating to environmental, economic and mobility challenges which are caused by transportation and vehicular activities (Schipper, Deakin, & McAndrews, 2009; Haghshenas, Vaziri, & Gholamialam 2015). The sustainability of cities and regions is highly dependent safe, reliable, cost effective and low emission transportation systems (Rockwood & Garmire 2015). Therefore, sustainable transportation at different scales of habitation should be a priority (Rodrigue, 2007; Dobranskyte-Niskota, Perujo, & Pregl, 2007).

However, before road sustainable transportation can be implemented, it is imperative to understand the concept of sustainable development and how it is linked to sustainable transportation. Sustainable development can be interpreted as a development that protects and focuses on the necessities of the present generation without destroying the needs the future generation (Castro, 2004; WCED, 1987; Feikie & Das, 2017). Sustainable transportation allows the needs of individuals to be met, in a way that is consistent. Among other things, sustainable transportation must ensure the following: human and environmental health; cost effectiveness and efficiency; choice of transport modes, support of a lively economy that includes all income levels; limiting of emissions, minimising of consumption of non-renewable resources, focusing on reusing and recycling, and minimising noise pollution. In other words, sustainable transportation must reduce negative impacts in cities and environment while providing accessibility and efficiency for both people and goods (Beaudoin, Farzin, & Lawell, 2015). Sustainable transportation is a concept that has been accepted and implemented worldwide. Indicators are used and actions have been taken to formulate policies and plans (Feikie & Das, 2017).

The concept of sustainable transportation has been adopted and implemented worldwide and sustainable indicators have been put in place to classify cities with regards to sustainable transportation. However, scholars have highlighted that the concept of sustainable transportation cannot be defined by a single indicator (Feikie &

Das, 2017). Many international organizations, such as: Energy and Environmental Analysis; European Union; European Economic Association; United Nations and World Health Organization highlight that the set of indicators should be based on the selected areas (Dobranskyte-Niskota, Perujo & Pregl, 2007). The set of indicators is based on factors relating to as economic, social and environmental aspects (Zhao, 2009; Vaziri & Gholamialam, 2015). Therefore, important indicators that are used to measure sustainable road transportation, according to scholars, should include carbon dioxide emissions from vehicles, traffic fatalities, transport land consumption and roadway conditions (Thynell, Mohan & Tiwari, 2010; Sietchiping, Permezel & Ngomsi, 2012). In addition to the indicators listed above, some scholars highlight that urban activities in cities are dependent on land use and transportation systems, therefore these indicators should take in to consideration accessibility to public transportation, quality and reliability of public transportation, congestion levels, pollution, utilization of roads, pedestrian movement facilities and traffic accidents/crashes (Zhao, 2009; Haghshenas, Vaziri & Gholamialam, 2015). Therefore, based on these indicators, transportation policies in cities should solve challenges such as high congestion levels, sound, land and air pollution, use of different modes of transport and effective public transportation, lead to the reduced traffic crashes and greater use of Information and Communication Technologies (ICT) to reduce need to travel (Emuze & Das, 2015; Haghshenas, Vaziri, Gholamialam, 2015).

Some of the initiatives towards attaining a more sustainable road transportation system that are taken comprise, but are not limited, to limiting car use; improving the usage of public transportation; introducing Integrated Rapid Transit (IRT) and encourage and increase the opportunities of walking and cycling (Bertolini & LeClercq, 2003; Hensher & Stanley, 2003; Henning, Muruvan,; Wolfram, 2004; Feng & Dunn, 2011 Faye, 2012). Besides, car sharing, electro-mobility, congestion pricing and energy efficient low carbon mobility systems have been attempted (Fournier, Seign, Gohlich, & Würzer, 2012; Seign; Schüßler & Bogenberger, 2015). Some scholars have developed a road network design considering the interaction of the transportation system with land use (Szeto, 2013; Maheshwari, Kachroo, Paz & Khaddar, 2015).

The African continent has been active on the concept and measures have been adopted towards the implementation of transportation frameworks that will enable cities to transition to sustainability. The main objective was to encourage the use of sustainable fuels, reduce the emission of greenhouse gases and introduce the use of low-emission gases that will reduce air pollution, provide safe public transport with improved facilities that will promote non-motorised transportation and invest in clean technologies including the use of Information and Communication Technology (ICT). Sub-Saharan cities and some of the South African cities such as Johannesburg, Cape Town and Durban have also adopted this strategy (UNEP, 2014).

Besides, many strategies and policy interventions have been recommended to create more sustainable road transportation that include, engineering and management solutions. For instance, urban land use, which correlates to sustainable development, can influence the transportation system of a region or a city. Monni and Raes (2008) and Cervero (2009), argue that effective sustainable urban development can alleviate challenges such as the use of private vehicles, carbon emissions and pollution. However, contrary to this, over the last decades, the low density and car dependent urban development models have become dominant (Banister, 2008). Similarly, all forms of transport are bound to consume energy and produce carbon and particulate matter emissions (Zegras, 2007) as carbon emissions depend on the distance travelled by each vehicle, the fuel used to produce energy and CO_2 emissions factor (Monni & Raes, 2008). Furthermore, findings from literature established that economic growth induces higher trips and a lowering of vehicles occupancy rates, consequently increasing traffic volume on the roads (Banister, 2008; Monni & Raes, 2008). This results in high traffic volume, increase in congestion, traffic crashes, economic impacts through increase in fuel consumption, reduction in effective productivity hours, and increase in pollution levels, thus contributing to un-sustainable road transportation.

However, since sustainable road transportation involves a complex set of socio-economic and environmental variables, and influences sustainable development at different scales of habitation, scholars argue for a paradigm shift – a new approach in the way people perceive and solve challenges concerning road transportation (Litman, 2003; Broaddus, 2014; Sietchiping Permezel, Ngomsi, 2012).

The reason is that the conservative transportation planning uses the reductionist way of solving problems. For example, one agency is assigned the responsibility of solving carbon emission problems, another looks after traffic crashes, some organisations focus on protecting the environment, while others focus on the location public facilities, such as parks, hospitals, etc. Often, it is found that they lack comprehensive and integrated analysis and one solution exacerbates another problem. For instance, while traffic engineers describe increased capacity in roads and parking as an improvement, from many perceptions of road users, occupants and environmental quality, it may be characterized as a degradation (Berger, 1998; Litman & Burwell, 2006; Sietchiping, Permezel & Ngomsi, 2012). Similarly, at a local scale it is observed that, while providing transportation solutions for vehicles such as improving road infrastructure and increasing mobility, urban roads are transformed into disputed territories where pedestrians, cyclists and other non-vehicular travellers often pay the highest price with regard to their safety and occurrence of traffic crashes (Odero, 2009; Ouongo, 2009; Sietchiping, Permezel & Ngomsi, 2012). Therefore, a comprehensive analysis of impacts, consideration of solutions, and public participation in transport planning is a need (Berger, 1998; Litman & Burwell, 2006; Sietchiping, Permezel & Ngomsi, 2012).

Therefore, the main challenge is to explore ways to reduce road transportation and traffic challenges such as congestion, travel time, travel distance, crashes, fuel consumption and vehicular emissions, to improve the sustainability of the built environment (Stern, 2007; Banister, 2008). Some scholars believe that ICT and intelligent transportation systems can considerably contribute towards travel patterns and travel behaviour. This can consequently reduce the levels of congestion, reduce travel time, reduce delays and travel costs while enhancing traffic systems which will enable cities to attain sustainable transportation in regions/cities (Monni & Raes, 2008; Belella, 2009; Schipper, Deakin, & McAndrews, 2009; Sietchiping, Permezel & Ngomsi, 2012; Emuze and Das, 2015). However, there are few South African studies relating to sustainable road transportation at a city scale that consider the urban activity, travel pattern and use of ICT in day to day urban activities of people and in road transportation to meet sustainable transportation challenges. Thus, by using a case study of Bloemfontein city, this study explored how sustainable road transportation by using ICT can be attained in South African cities.

1.2 PROBLEM STATEMENT

Sustainable road transportation is proving to be a challenge in South African cities; in recent years because of the market economy and globalisation, many South African cities are more and more embracing multifarious economic activities that include incorporation of industrial and service activities. This advancement of economic activities in the cities has attracted a higher influx of people, which requires increased movement of goods and people (Torres & Pinho, 2011). Consequently, it is seen that a large proportion of the people in South African cities primarily depend on private or individually driven cars for their local movement needs. Without adequate and quality public transportation systems, it is expected that this current occurrence of high use of private vehicles in the cities will be strengthened, which would lead to environmental as well as spatial development concerns (Bhatta, 2010) that include occurrence of traffic crashes (Handy, 1996), traffic congestion, environmental ailments like noise, carbon emissions and air pollution and requirement of more road infrastructure (Mansourianfar & Haghshenas, 2018).

Bloemfontein is the leading city in Free State, and it offers better and developed socio-economic and infrastructural facilities. People commute daily from the neighbouring towns for activities such as work, entertainment, and school. These activities contribute to increased need to travel for people living in the city as well as those from neighbouring towns, which lead to the dependence on vehicular transportation. As observed in the Integrated Development Plan (IDP), the city faces challenges of transportation. The current road transportation system is inadequate, overcrowded and almost non-existent during peak periods, unsafe, inconvenient and often unreliable (Mangaung Metro Municipality IDP, 2011). Similarly, the other major road transportation concerns in the city are lack of effective public transportation, predominant use of individually driven vehicles, road traffic accidents, congestion on certain arterial road sections, underutilisation of some of the roads, lack of parking facilities at important nodal points, and poor quality of roads in certain parts of the city (Das, Burger & Eromobor, 2012; Luke & Heyns, 2013; Emuze & Das; 2015; Das & Burger, 2016). These challenges, along with the environmental concerns like carbon emissions and consequent air pollution, make the road transportation system unsustainable. However, studies on the aspect of sustainable road transportation in the cities of South Africa, including the city of Bloemfontein, are observed to be scarce.

1.3 PURPOSE AND OBJECTIVES OF THE STUDY

1.3.1 PURPOSE OF THE STUDY

The purpose of this study was to examine the current scenario of the road transportation system in Bloemfontein city and explore how sustainable road transportation in the city can be achieved by use of relevant innovative systems like Information and Communication Technologies (ICT) in the daily personal and professional activities of people and travel needs in and around the city.

1.3.2 OBJECTIVES OF THE STUDY

A specific set of objectives were framed to realise the purpose stated in section 1.3.1 and they are as follows:

- To assess the current scenario of road transportation system in terms of trip generation, traffic volume, speed, modes of transportation, travel pattern and travel behaviour, vehicular distance travel (Vehicle – kms) and the current use of ICT in Bloemfontein city.

- To examine the land use, urban function, and road transportation inter-linkage in the city.

- To evaluate the sustainable road transportation indicators, such as congestion (LOS), travel time delay, use of public transportation, and carbon emissions level in the city.

- To establish the relationships between road transportation indicators such as use of public transportation, congestion and carbon emissions and evaluate their performance under different ICT usage levels.

- To evolve a set of plausible strategic urban and transportation planning guidelines to attain sustainable road transportation in the city.

1.4 HYPOTHESIS

In the attainment of the aim and objectives of the investigation stated in section 1.3.1 and 1.3.2 respectively, the following hypothesis was formulated and tested.

The hypothesis states that:

"*The use of ICT in day to day urban functions (household and professional activities) will reduce trip generations and consequent carbon emissions on the urban roads*".

1.5 SCOPE OF THE STUDY

The scope of the study is limited to assessing sustainability indicators such as the use of public transportation, congestion, and carbon emissions. The indicators belonging to economic, social and other road transportation indicators, such as road safety and parking challenges, have been kept out of the scope of the study.

1.6 IMPORTANCE AND JUSTIFICATION OF THE STUDY

The study is important because all the cities globally are moving towards sustainability. Even though Bloemfontein city is still developing, there are real transportation challenges such as congestion that cause delays and consequently lead to pollution, lack of reliable public transportation and limited modes of transportation (Emuze & Das; 2015; Das & Burger, 2016; BEPP, 2017/18; Feikie, Das & Mostafa 2018). Therefore, the study attempts to contribute to solving challenges faced by the city of Bloemfontein in the journey towards being a sustainable city.

The contribution of the study is based on four scholarships in the advancement of education namely: discovery, integration, application and teaching.

Discovery: the study will lead to the discovery of new knowledge in the city of Bloemfontein in the attempt to make Bloemfontein a sustainable city, focusing on road transportation.

Integration: the study follows a multidisciplinary approach of integrating the knowledge in civil engineering (transportation) with ICT to solve road transportation challenges in the city.

Application: The results, findings and guidelines of the study can be adopted by the city of Bloemfontein, which can assist in alleviating the challenges faced by the city relating to road transportation.

Teaching: In the academic world, the study contributes to the knowledge on how Multi/Inter/Transdisciplinary education can be a solution to producing versatile students who have broad knowledge of the daily challenges faced by the society.

1.7 LIMITATIONS

The limitation of this investigation is based on the scope and the study area. Time was also a major limitation, as the research had to be conducted within a period specified by the University. Further, the study was conducted for one city only, and addressed limited but adequate data, because of the constraints of time and financial resources.

1.8 CHAPTER SCHEME

The layout of the study is outlined in terms of chapters that are explained in the following:

Chapter 1 - Introduction of the study: The chapter introduces the concept of sustainability and how it has been adopted globally. It further explains the problem statement of Bloemfontein city in the Free State, highlighting the aim, scope, and the objectives of the study. The importance, contributions and limitations of the study are also explained thoroughly.

Chapter 2 - Literature review: In order to understand the current understanding of sustainability around the world, literature relating to sustainability was considered. The chapter explains the concepts of sustainable cities, of sustainable transportation and of information and communication technology. Sustainable road transportation indicators, challenges, methods, policies, frameworks and implications are explained. The interlinkage of ICT and transportation is discussed with different challenges that other cities across the world have encountered in attempting to integrate ICT with road transportation, and, finally, the influence and implications of ICT on road transportation in other South African cities is explained.

Chapter 3 - The profile of the study area: The current transportation system, covering all the chosen suburbs, intersections and important roads of the city, is explained in this chapter. The land use and routes that the transportation system covers are highlighted, with the idea of understanding how the current scenario in road transportation system can be improved in order to contribute positively towards sustainability.

Chapter 4 - Methodology and research design of the study: The chapter discusses the detail on which data was collected and the method followed to collect it. The intersections and roads surveyed are listed and the characteristics of the roads are explained. It also discusses the various methods used for analysis and modelling.

Chapter 5 - Results: The chapter includes the results obtained from the quantitative analyses and modelling.

Chapter 6 - Findings and conclusion: This chapter constitutes inference and findings, policy analysis and strategic sustainable urban and transportation planning guidelines, recommendations and conclusions of the study.

1.9 CONCLUSION

This chapter has provided an introduction to, as well as an outline of, the study. The purpose, objectives, aim, and hypothesis of the study were outlined. The processes followed and study profile was highlighted and will be discussed in the following chapters. The following chapter will be focusing on explaining the literature reviewed in order to find the research gap in sustainable road transportation.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION

This chapter critically discusses the literature related to sustainable road transportation and its implications that are available in the mainstream literature. The literature has been drawn from the research articles, book chapters, conference proceedings, reports, and news articles literature, that are available in various research publication data bases such as Science Direct, Scopus, ISI Web of Science, and International Bibliographic of Social Sciences (IBSS). The various aspects on which the literature review were conducted include a thorough review on sustainable cities, focusing on the concept and the indicators of sustainable cities as well as the challenges associated with the sustainable development of cities. The focus on sustainable transportation included a review of the indicators and implications of sustainable road transportation, as well as the initiatives, framework and techniques used in understanding sustainability of cities and transportation systems, and policy interventions adopted in different cities. The prioritisation of public transport in cities is discussed and the integration of ICT with road transportation. The link between ICT, urban development and transportation is thoroughly reviewed, as well as the challenges that are associated with the application of ICT on sustainable road transportation. Lastly sustainable road transportation in South Africa and Africa is discussed, looking at the integration of ICT and how it has influenced the shift in road transportation.

2.2 SUSTAINABLE CITIES

According to the United Nations (UN), about 66.0% of the world's population will live in urban areas by 2030, giving rise to extensive challenges with regards to, but not limited to air pollution, traffic congestion, waste management and human health (Kitamori, Manders, Dellink, & Tabeau, 2012; United Nations, 2016). Consequently, the sustainability of human habitation, specifically in cities, will be a serious challenge. Although there are no unequivocal definitions of sustainability or sustainable development, a city can be classified as sustainable if it has clean methods of production (World Commission on Environment and Development (WCED), 1987; Castells, 2000). Recently urban sustainability has been characterised as sticking a balance between urban development and the protection of the environment (Hiremath, Balachandra, Kumar, Bansode, & Murali, 2013).

The release of the Brundtland report increased the attention around the importance of sustainable cities and urban sustainability (Brundtland, Khalid, Agnelli & Al-Athel, 1987). Besides the concept of sustainable cities and urban sustainability, there are other concepts, such as the smart cities and sustainable communities, some of which were initiated and supported through the sustainable development action plan of the UN referred to as the “Agenda 21” (Sitarz, 1993; Trindade, Hinnig, Moreira, Marques, Bastos, and Yigitcanlar, 2017).

Despite the recognition that cities and sustainable communities are a desirable goal, there is less understanding about its meaning in practice (Stead, 2016), leading to practical challenges when putting the sustainable cities concept in place (Portney, 2013). Most analyses of this concept, document the sustainability of cities by using indicators, flows and footprints. Because of this reason, some scholars criticise the so-called “green” or “sustainable” design approaches, because they do not really focus on the harm being done on the environment. Rather they reduce the rate at which the harm is being done (Reed, 2007; Cole, 2012). Therefore, a more holistic term of “regenerative sustainability” has been suggested (Robinson & Cole, 2015). Most of the assessment tools follow the top-down approach, and many scholars have also criticized this approach and suggesting a tool that focuses on the needs of citizens (Reed, Fraser, & Dougill, 2006; Berardi, 2013; Turcu, 2013; Robinson & Cole, 2015).

In other words, arguments have also emerged that systems approach is needed to integrate the above-mentioned aspects as well as to take a holistic view of different aspects of the city while making efforts for their sustainable development (Hallstedt, Robèrt & Broman, 2010). Cities need to be understood as urban systems that facilitate the interaction between social, biological and environmental components (Nilon, Berkowitz, & Hollweg, 2003). The key achievement in sustainability is understanding the relationship between people, their movement, activities and their environment.

Diverse technologies need to be incorporated in achieving sustainability. Marvin and Guy (1997) clearly indicate that in understanding sustainable cities, issues of effectiveness and likelihood cannot be based only on the physical footprint, as this approach is limiting when looking at the nature of urban change and social interests. They propose and highlight behavioural management as an important key to sustainable cities. They highly stress that the city is shaped by the social, organisational, temporal and spatial contexts of action. All the active stakeholders are voices that need to form part of the debate of a sustainable city (Marvin & Guy, 1997 Wadhwa, 2000).

Concerning the various concepts surrounding sustainability, Bulkeley and Bestill (2005) highlight that previously the focus of urbanisation in the 1970s focused more on the need for human settlement, sanitation and environmental impacts, rather than the wider potential impacts of urbanisation. However, through its genesis, the Brundtland report, with its concept of sustainable development, focused on urban challenges. It argued that the focus should shift to urban areas, and cities should be the central attention in order to attain sustainable development (WCED, 1987). The new shift has prioritised the integration of economic, social and environmental concerns, together with global and local concerns (Hezri & Dovers, 2006). There have always been different views regarding concepts that are linked to sustainable development, and "smart city" is one of them. Different scholars have been discussing the origin of this concept and they have different views. According to Gabrys (2014), the roots of the concept can be dated back to the 1960s, and was included in proposals in the 1980s. However, Cocchia (2014) date the concept to 1994, while, according to Neirotti (2014), the concept was linked to smart growth in the late 1990s. Though scholars and experts share a different view about the origin of sustainable cities, Batty (2012) highlights that the concept has been adopted in the planning stage of many cities though the movement of smart (Batty, 2012; Cocchia, 2014; Gabrys, 2014).

The popularity of the concept of "smart city" is understood as the potential of ICT to help cities get to a competitive advantage (Kramers, Höjer, Lövehagen & Wangel, 2014). While this indicates clearly, why cities would like to adopt this concept, it says a little about any substance behind the claim of being "smart" or how that links to sustainability (Caragliu 2009). From this, it can be concluded that there is a need for an understanding of the extent a city can be classified as sustainable (Mori & Christodoulou, 2012).

Even though authors, scholars and environmentalists may have different views concerning the origin, definition, and indicators of sustainable cities, they do have a consensus that a sustainable city should have a role in fighting climate change, by moving to intelligent technologies, which will decrease greenhouse gas emissions and improve energy efficiency in the cities (Omer, 2008; Banister, 2011; Mori & Christodoulou, 2012; Bulkeley, 2013). They also agree that the technologies used have to be cost effective and have positive impact on the environment (Ahvenniemi, Huovila, Pinto-Seppä & Airaksinen, 2017).

2.2.1 CONCEPT AND INDICATORS OF SUSTAINABLE CITIES

The concept of 'liveable city' is considered as a close concept to the one of sustainable cities, which is presented by two well-known rankings companies: Monocle's Most Liveable City ranking and International Living's Quality of Life Index (Jones & Newsome, 2015). McManus (2012) argue that urban sustainability indicators are shaped by three types of organisations: environmental organisations, organisations promoting green citizenship and sustainable organisations. Developed tools are based on either city rankings or tools that allow cities to be compared for best solution and find reasonable practices.

According to Tanguay, Rajaonson, Lefebvre, and Lanoie (2010), monitoring of activities and assessments is done using sustainable development indicators. However, as Huang, Yeh, Budd, and Chen (2009) highlight sustainability indicators have limitations, as they do not reflect systematic interactions or provide direction (Dobranskyte-Niskota, Perujo and Pregl, 2007; Litman & Burwell, 2006). Many scholars and experts indicate that indicators should be based on economic, social and environmental factors (May, 2005; Litman, 2007; Emberger, Pfaffenbichler, Jaensirisak, & Timms, 2008; Zhao, 2009; Li, Liu, Hu, Wang, & Yang, 2009; Haghshenas, Vaziri, Gholamialam 2015). The way cities are developed and managed is of fundamental importance for sustainable development (Egger, 2006; Kramers, 2014). Where sustainable cities, smart cities and liveable cities are concerned, the efficient monitoring is not only dependent on a set of indicators but there is also a need for a synthetic/ aggregative index to visualise the initiative's achievements. The local agendas (LA21) initiative sought to classify cities as "sustainable" or "smart" depending on a set of indicators (Sitarz, 1993; Lafferty & Katarina, 2013). These indicators classified all cities, no matter how big or small and different they might be, but it is well observed that cities develop differently according to their needs. Therefore, indicators set on real-time information seem more plausible and practical as they give a more accurate scenario of different cities, and the existing indicators do not include the measurement of how "intelligent" cities are. Despite these lacks and the controversy regarding the lack of connection between smart and sustainable cities, ICT has the potential for supporting the transition to more sustainable cities (Kramers, 2014; Marsal-Llacuna, Colomer-Llinàs, & Meléndez-Frigola, 2015).

2.2.2 CHALLENGES OF SUSTAINABLE DEVELOPMENT OF CITIES

Since the implementation of sustainability on a global scale, planners and governments in different cities have recognised and started adopting some policies to alleviate transportation challenges. The World Commission on Environment and Development (1987) concurs that a city can be declared as sustainable if it meets certain criteria associated with the set-out indicators and, most importantly, if its conditions of production do not destroy over time the conditions of its reproduction (Castells, 2000). With that being said, many authors still criticise the so called "green" or "sustainable" approaches because, as mentioned previously, they do not really focus on reducing the harm to the environment but rather reduce only the pace at which the harm is done (Reed, 2007; Cole, 2012). It is clear that authors and scholars from different disciplines concerned with sustainable issue have still not reached a consensus about the roots and definition of the concept.

While there are still deliberations about the origin and definitions of different concepts that might lead to sustainable development and consequently sustainable transportation, cities face diverse challenges that are proving to be hard to solve as populations increase in cities and urban areas. Hollands (2008), Greenfield (2013) and Bibri and Krogstie (2017), highlight that the challenge is that dwellers have to see cities as laboratories for innovation. These may be used to inform future designs that should be used to develop technologies that will ensure efficiency, sustainability, and also create shared knowledge. Essentially, this will ensure greater and more effective mobility and access to opportunities for urban populations. Cities also have a negative impact on the environmental sustainability, due to the use of enormous use of ICT across urban domains and systems, and the most eminent challenge about using ICT includes, limiting energy use to alleviate environmental impacts (Hollands, 2008; Greenfield, 2013; Bibri & Krogstie, 2017). The biggest assumption with ICT is that, when integrated into the socio-technical landscape, it will provide positive results. It is also believed that, when embedded in policy and planning instruments, it will lead to efficiency and lead to reduced energy needs (Elzen, Geels, Hofman & Green, 2004; Kemp & Rotmans, 2004; Wieczorek, 2018). Further, as evident from the cities of developing countries such as China and India, energy, public transportation, use of fossil fuels for transportation and environmental pollution are other major obstacles to the development of sustainable cities (EIA 2007; WEO, 2007; Hu, Chang, Li & Qin, 2010)

Furthermore, according to Simon and John (2017), who try to elucidate the concept of smart sustainable cities of the future, such cities are likely to involve challenges that already exist in so-called sustainable cities. In order to adhere to a more holistic approach to realise sustainable development in urban cities, they list discrepancies between smart and sustainable cities. They argue that cities should have rooted the emphasis on design concepts and principles, while not overlooking smart solutions and the use of modern ICT and efficient solutions. The planning and management of cities should be based both on sustainable goals and on smart targets, where there is a clear interlinkage and connection between sustainable goals and smartness targets. Cities should have a strong connection and adhere to environmental sustainability, and should not only be assessed on technological aspect and targets, but they should be re-developed to incorporate environmental indicators, where all technologies integrated in cities are sustainable and linked with the goals of sustainable urban strategies.

Authors, scholars and environmentalists have not reached a consensus on some matters relating to sustainable cities, but there is an agreement on some of the consequences of having sustainable cities that prioritise social, economic, energy and environmental aspects. Sustainable cities provide theoretical and practical strategies for achieving sustainable development goals, with different approaches of applying knowledge of environmental technologies to the planning and design of sustainable cities (Keirstead & Leach, 2008; Vallance, Perkins & Dixon, 2011). They provide solutions for energy efficiency, while alleviating pollution and improving the quality of life, they bring about knowledge and expertise through models of urban sustainability in different spatial regions at different levels of government. They provide different methods that allows for the integration, diversification, and interlinkage of different land use, ecological design, and solar design as a means of contributing to sustainability, through the use of green technology, integrated solutions ecological diversity and environmental management (Smith, Voß, & Grin, 2010; Zuki, Cervero & Luchi, 2013). They provide advanced and technological frameworks that provide efficiency, promote the practices of renewable energy and zero waste, to make sure that the future generation have resources. These developments give the perspective that cities are efficient and successful if factors such as environment, social, institutional and land use policies are given priority in the planning and management of urban spaces (Lee, Hancock, & Hu, 2014).

2.3 SUSTAINABLE TRANSPORTATION

2.3.1 DEFINITION

Sustainable road transportation is an important part sustainable development (Feikie, Das & Mostafa, 2017). Unsustainable transportation can jeopardise the sustainability of cities (Emuze & Das, 2014; Emuze & Das, 2015). Therefore, attainment of sustainable transportation remains a paramount concern. Sustainable transportation can be interpreted as a system that ensures that the basic needs of people are met, by providing affordable systems, provides different modes of transport, protects the use of non-renewable resources, and limit emissions (Transportation Research Board, 1997; Litman, 2003; Litman, 2007; Behrends, Lindholm & Woxenius, 2008; Jeon, Amekudzi & Guensler, 2010; Haghshenas & Vaziri, 2012). Sustainable transportation reduces negative impacts on the environment, and provides security for people and goods (Dalkmann and Huizenga 2010; Bongardt, Schmid, Huizenga & Litman, 2011; Beaudoin, Farzin & Lawell, 2015).Therefore, it is important to attain sustainable transportation first in order to realise the goal of sustainable cities (Deakin, 2001; Cervero, 2009).

2.3.2 CONCEPT AND INDICATORS OF SUSTAINABLE TRANSPORTATION

There are various indicators used in sustainable road transportation. Their viability is dependent on economic, social and environmental factors (May et al. 2005; Litman, 2007; Emberger, Pfaffenbichler, Jaensirisak, & Timms, 2008; Li, Liu, Hu, Wang & Yang, 2009; Zhao, 2009; Haghshenas, Vaziri & Gholamialam 2015; Feikie, Das & Mostafa, 2017).

Important indicators proposed by researchers and experts includes, carbon dioxide emissions, traffic fatalities and crashes, consumption of land, conditions of roads, access to public transportation, congestion levels, pedestrian movement facilities, and pollution. (May et al. 2005; Litman, 2007; Emberger, Pfaffenbichler, Jaensirisak, & Timms, 2008; Li, Liu, Hu, Wang & Yang, 2009; Zhao, 2009; Haghshenas, Vaziri & Gholamialam 2015; Feikie, Das & Mostafa, 2017).

Therefore, based on these indicators, researchers highlight that policies for sustainable road transportation should solve high levels of congestion, pollution, encourage use of different modes of transport, use of public transportation, reduce traffic accidents and encourage the use of Information Communication Technologies (ICT) to reduce the need to travel (Feikie, Das & Mostafa, 2017).

2.3.3 IMPLICATIONS OF SUSTAINABLE ROAD TRANSPORTATION

In order for a city to be sustainable, it has to in significant ways contribute to the sustainable development goals (Goldman & Gorham, 2006; Klopp & Petretta, 2017). Among the challenges faced by cities that are moving towards sustainability in the transportation sector, challenges relating to energy and environment have become a priority as these challenges, if not prioritised, might lead to irremediable situations in different cities that might affect the world globally. Other challenges relating to the social and economic aspect are also important in the journey of realising sustainable transportation systems, and all the implications of sustainable road transportation feed into those aspects (Mercier, Tremblay-Racicot, Carrier, & Duarte, 2019). There are many crucial implications of sustainable transportation, For example, through different policies, sustainable road transportation has the potential to reduce energy use and reduce environmental pollution through fuel economy improvement. Places like China have put in immense effort to reduce vehicle pollutants through imposition of strict emission standards, to cope with air quality (Banister, 2008).

Furthermore, effective public transport networks can bring about quality, sustainable, innovative and safe transportation systems (Das, 2015). Through different casual variables when interlinked, they demonstrate the implications of sustainable road transportation. Urban functions create a need for travel, and travel is done through public transportation network leads to the quality of public transportation that allows local accessibility. Local accessibility, if integrated with the effective use of ICT, leads to a reduction in local travel, and local travel, if joined with the use of economical cars, will consequently reduce carbon emissions. If there is a reduction in travel need, then the expected reductions in traffic volume will lead to greater traffic safety that will ultimately lead to sustainable, innovative and safe transportation (Gärling & Schuitema, 2007; Chapman, 2007; Wadud, Mackenzie, & Leiby, 2016).

2.3.4 INITIATIVES, FRAMEWORK AND TECHNIQUES USED FOR UNDERSTANDING SUSTAINABILITY OF CITIES AND TRANSPORTATION SYSTEMS

Various environmental tools and frameworks have been developed to ensure sustainability in cites. They aim to achieve this by influencing political decision-making, built environment, and the transportation sector. Other urban sustainable tools such as the Leadership in Energy and Environmental Design (LEED); Building Research Establishment Environmental Assessment Method (BREEEAM) and Comprehensive Assessment System for Building Environmental Efficiency are aimed at labelling (Sharifi & Murayama, 2013). On the other hand, Hedman, Sepponen, and Virtanen (2014) presented a tool that helps with the assessment of energy demand of buildings, as well as transportation systems. In addition, other frameworks such as the Partnership for Sustainable Urban Transport in Asia (PSUTA) (CAI-Asia Program) and the Bangalore Mobility Indicators focus on transportation in densely populated (Directorate of Urban Land Transport, 2011). However, the use of different approaches creates a problem, because it does not offer a holistic approach to solving sustainable challenges. As Tanguay (2010) suggest, this is caused by multiple interpretations of the sustainable development, which triggers an explosion of indicators (Tanguay, Rajaonson, Lefebvre, & Lanoie, 2010).

Developed and developing cities are experiencing transport problems, and the physical and mental health of the urban populations are affected by energy consumption, congestion, traffic crashes, land, noise and air pollution (Chakhtoura & Pojani, 2016). Even though steps have been taken to alleviate the problems, they have been subjective in nature. The definition of urban transport sustainability varies depending on the approach that is adopted (Mihyeon Jeon, & Amekudzi, 2005). Indicators are used to assess whether the approach adopted will lead to sustainability or not. Good targets and indicators are Specific, Measurable, Attainable, Relevant and Time-bound (SMART); and depending on a set of indicators, a desirable and realistic framework can be adopted.

Frameworks are chosen depending on the scale of plans to be evaluated; the physical, economic and environmental environment prepared, time; and the availability of outcomes (Scoones, 1998). A set of indicators adopted to make the city sustainable might differ from city to city, depending on the context and the needs of that city. The frameworks adopted are always based on a set of indicators, which aim to solve the transport challenges a city is facing. The right framework would be a framework that does not only focus on the tangible solutions, but a framework that aims at integrating the transportation solution with the social aspect to make sure that the new systems are realistic and user-friendly (Neves & Leal, 2010). Among the cities that have adopted frameworks, cities like Melbourne adopted a framework that is focused on environmental, social and economic issues, while cities like Lyon focused on the environmental, social, economic and mobility issues. Even though a city like Taipei does not have a structured framework like the others, the adopted framework includes important aspects such as having dedicated lanes for public transport buses, as a way of prioritising buses and encouraging the use of public transport (De Jong, Joss, Schraven, Zhan, Weijnen, 2015). The most important indicators for transportation system sustainability include fuel, access, congestion, emissions and safety (Mihyeon Jeon & Amekudzi, 2005). They have a variety of factors that influence them, e.g., vehicles and kilometres of travel affect safety, congestion, the environment and fuel consumption. The frameworks adopted are dependent on passenger factors that may affect sustainability indicators (Richardson, 2005).

2.3.5 POLICY INTERVENTION

Since the adoption of the Brundtland decision, Governments and planners have continue to implement different policies to allow for the achievement of sustainability in different areas. The increase in population and the increase in the number of motor vehicles on the roads are not making it easy for the planners, as there is an increase in challenges that are leading to unsustainable cities (Goldman & Gorham, 2006). Different scholars and authors argue and show that policies that will lead to sustainability are not only limited to infrastructure or noticeable solutions. They highlight that, since social and behavioural factors affect sustainability in cities, it is important to consider those factors when planning and adopting new policies. Many international organisations argue that sustainable road transportation indicators should be based on representative geographic or political systems (Litman & Burwell, 2006; Dobranskyte-Niskota, Perujo, & Pregl, 2007). Accordingly, indicators have been developed (May et al. 2005; Litman, 2007; Emberger, Pfaffenbichler, Jaensirisak, & Timms, 2008; Zhao, 2009; Haghshenas, Vaziri, & Gholamialam 2015). Accordingly, it is agreed that important indicators to measure sustainable road transportation should include carbon dioxide emissions from vehicles, per capita motor vehicle mileage, traffic crashes, land consumption due to transportation, and road conditions. (Litman & Burwell, 2006; Thynell, Mohan, & Tiwari 2010; Sietchiping, Permezel, & Ngomsi, 2012).

Further, as the objective of sustainable development is having systems around all spheres that promotes the quality of life without compromising the needs of the future generations, and as climate change is the greatest market failure the world has ever seen (Stern 2016), it is important to reduce emissions, especially from the transport sector. Classified policies in transportation can be categorised into three different groups, namely physical policies, soft policies and knowledge policies. It is however acknowledged that physical policies are the most important policies when it comes to adopting and implementing them and there are a lot of rules that need to be followed and all stakeholders need to be included in the process (Satterthwaite, 1999; Newman & Kenworthy, 2006). While soft and knowledge policies are not as important as physical policies, their contribution is important as they contribute to sustainability and they are not hard to implement (Newman & Kenworthy, 2015). Physical policies include public transport integration; land use; walking and cycling; road construction and expansion (Hopwood, Mellor, & O'Brien, 2005). The integration of public transport deals with how cities can have different modes of transport that are integrated with the land use and different policy makers. The integration of different modes of transport may be achieved through integrated ticket systems with park and ride facilities. The integration has to be efficient and should include the economic, environmental and health policies while focusing on the role of public transport in reducing CO_2 and achieving social inclusion through integrated transport policies (Satterthwaite, 1999). Also, it is argued that public transport should be subsidised to make sure that it is affordable and efficient, the initiatives in integration and subsidised public transportation can have a positive effect through a virtuous circle between congestion charging and public transport. This has been plausible in places like London, Singapore, Portland and Curitiba (Satterthwaite, 1999; Mori & Christodoulou, 2012).

Further, land use policies play crucial roles in sustainable development of both cities and transpiration. Land use policies are based on enhancing urban planning. Land use policies in existing cities include changing the way people travel. If the land use is planned in such a way that it limits the need for travel, then roads will be less congested, because all the needs of consumers can be reached with less trips (Hopwood, Mellor & O'Brien, 2005; Zucaro & Morosini, 2018). Limited parking spaces would also encourage the use of public transportation, for example limiting car parking will force people to resort to public transport. Even though it may be difficult to change land use of existing cities because of history and heritage, planning regulations and accessibility should be a priority and they should always be channelled to trying to alleviate the use of private transportation through land use policies that are integrated and easily accessible through public transport (Bettencourt & West, 2010). Furthermore, walking and cycling policies are options for short distance trips. The land use should have facilities for pedestrians and cyclists that allow safe and undisturbed manoeuvrability. Not only does this option have health benefits but it also has positive impacts on the environment through reduced emissions (Seyfang, 2010). Different cities in countries such as Netherlands, Denmark, Germany, and Colombia have adopted such policies. Other examples include OYBike in London, Velib in Paris and Bicing in Barcelona (Newman & Kenworthy, 2015).

In addition, road construction policies highlight the construction of new roads as a way of alleviating congestion, but caution is always taken as a new road construction may induce additional traffic, and the argument in this policy is always on whether cities should invest more on roads or railways (Stimmel, 2015). Soft policies include teleworking and teleshopping, car sharing and car clubs and information and advertising for behavioural change. Even though soft policies are not due to physical changes on the environment, they do contribute towards the sustainability of cities. Teleworking and teleshopping are aimed at reducing trip generation and the need for travel, and consequently reducing vehicles on the roads (Satterthwaite, 1997; Pugh, 2014). Cities like The Hague in Netherlands; Hokkaido, Tohoku, Kanto, Toka, Kansai and Kyushu in Japan; and California in the US have adopted these policies of teleworking and teleshopping (Newman& Kenworthy, 2015). Car sharing and car clubs are also a part of soft policies used in sustainable transport, instead of people using their private cars alone they are encouraged to share their trips either with friends or colleagues or have car clubs with people working in the same areas with them, by doing so the number of vehicles are reduced on the roads; this has been adopted in place such as Austria (Newman & Kenworthy, 2015). Beyond sharing vehicles, eco-driving and educational campaigns might be part of the solution towards sustainability. If eco-friendly cars are manufactured and eco driving is implemented, people are taught about the dangers of emissions and obligatory labelling is imposed so that people are able to choose cars they use knowing their effect on the environment (Satterthwaite, 1999; Spiegel, 2011). Information and advertising for behavioural change also has an effect, even though the effect or results are not always visible and quantified, but attitude, education and behaviour are important contributors to how people choose to travel and if this can be influenced then their choices may yield positive results towards sustainability (Newman & Kenworthy, 2015).

2.4 PRIORITISING PUBLIC TRANSPORTATION

Public transportation plays a role in enhancing mobility in cities, reducing traffic crashes, minimising congestion in roads, decreasing pollution and improving living conditions. In many cities, a high percentage of trips on public transportation are provided by the informal private sector services. In South African cities, population grows simultaneously with car ownership. This is a simple indication that rehabilitation and construction of new roads is not the only solution that must be implemented (Feikie, Das, & Mostafa, 2018).

Evidence from most cities in Africa, Asia and Latin America show that there is a slow supply of public transport by the formal sector, and this discrepancy is further widened because the larger the city grows, the greater the average length of travel (Newman 1996; Feikie, Das, & Mostafa, 2017; Feikie, Das, & Mostafa, 2018).

Therefore, the world's wealthiest cities, such as Los Angeles, Zurich and Singapore, have been rather focusing reducing the dependence on private automobile. Further, public transport in developing countries is mostly characterised by a lack of adequate financial resources to fund infrastructure and operational services. The demands for other needs such as housing, education and health services limits the funds that can be made available for public transportation development and support. However, some cities have proved that lack of funding for public transportation does not stop cities from developing public transportation (Newman, 1996; Walters 2008; Feikie, Das, & Mostafa, 2017; Feikie, Das, & Mostafa, 2018). Examples from different cities worldwide show that sustainable public transportation should be a priority in order for sustainability to be achieved.

2.4.1 Singapore and Hong Kong

Cities such as Singapore and Hong Kong had the challenge of dependence on individual privately driven automobiles. They solved this problem by providing public transit, which resulted in a successful transit system and a low car dependency. The cities now have rapid, comfortable and flexible transit system that are supplemented by non-motorised means such as walking and cycling (Newman, 1996; Walters 2008; Feikie, Das, & Mostafa, 2017; Feikie, Das, & Mostafa, 2018).

2.4.2 Curitiba

This city minimised the cost of public transit and invested in it, to make it a preferred mode of transport over private automobile use. This has helped the city to lower crash rates per vehicle, considerable savings on transport and low cost fares across the city, thus contributing to sustainable road transportation in the city (Newman, 1996; Walters 2008; Feikie, Das, & Mostafa, 2017; Feikie, Das, & Mostafa, 2018).

2.4.3 Surabaya

Surabaya has focused on non-motorised transportation facilities, which include bicycles and walking. Pedestrian facilities were improved through a programme which focused on the infrastructure (Newman, 1996; Walters 2008; Feikie, Das, & Mostafa, 2017; Feikie, Das, & Mostafa, 2018).

Thus, the success stories provide evidence that a public transportation system is a major driver for sustainable road transportation. Significant interventions have taken place in South African cities to improve public transportation, which is in fact a relevant and essential step towards achieving sustainable road transportation (Newman, 1996; Walters 2008; Feikie, Das, & Mostafa, 2017; Feikie, Das, & Mostafa, 2018).

2.5 INTEGRATING ICT WITH ROAD TRANSPORTATION

Professionals agree that ICT contributes significantly to sustainable improvement in cities. Various attributes of ICT such as extensibility, trackability and intelligence speeds up spatial interaction, improves trains and prompts data collection, processing and navigation (Neirotti, De Marco, Cagliano, Mangano, & Scorrano, 2014; Feikie et al., 2017). Use of ICT in public transportation for activities such as scheduling and route planning results in increased use of public transportation. ICT solutions also solve challenges for both operators and clients in public transportation (Bashingi, Masinde & Hassan, 2016; Cohen-Blankshtain & Rotem-Mindali, 2016). Further, Das (2014) highlights that mobility is influenced by accessibility and travel needs. Therefore, effective use of ICT can reduce the need to travel, as people can use ICT to perform urban functions without having to travel. Consequently, tis will lead to reduced trips, lower volume of vehicles on the road, lower levels of congestion and reduced traffic crashes, thus assist in achieving sustainable road transportation (Shapiro, 2008; Van Soom, 2009; Nijkamp & Kourtik, 2011; Lombardi, Giordano, Farouh & Yousef 2012; Das & Emuze, 2014). Thus, ICT integration with road transportation and socio-economic activities in South African cities, will contribute to sustainable road transportation significantly.

2.6 METHOD/MODELS TO ANALYSE SUSTAINABLE ROAD TRANSPORTATION

Through the years there have been methods and models used to analyse sustainable road transportation. Through indicators and concepts that are aimed at alleviating transportation challenges through factors such as socio-economic and environmental conditions. Different scholars highlight that lowering the levels of congestion on the roads and limiting CO_2 emissions will contribute positively towards sustainable road transportation (EC, 2005; Litman & Burwell, 2006; Thynell, Mohan, & Tiwari, 2010; Sietchiping, Permezel, & Ngomsi, 2012; Keetse, & Das, 2016)

Table 1: Models of analysing sustainable road transportation

Parameter	Model	Nomenclature	References
Level of Service (LOS)	LOS = V/C or AADT/C	V= total volume of vehicles AADT=Average annual daily traffic	HCM, 1985, 2000
Travel Time	TT= (Peak period travel time - free flow travel time) = (free flow travel; speed/ peak period travel speed)		Rao and Rao, 2012; Schrank and Lomax, 2005
Delay Time	Delay time = travel time (congested) - travel time (uncongested)		Lomax, Turner, Shunk, Levinson, Pratt, Bay. and Douglas, 1997; Rao and Rao, 2012.
Queue length (Ni)	Ni= (Di*Qi)/3600	Di = Average delay of vehicles in lane i in units of seconds/vehicle, excluding acceleration and deceleration delay Qi = Arrival flow rate in lane i in units of vehicles/hour/lane	Traffic Signal Design Volume 3, section 2.4.6, Road Traffic Signs Manual, South Africa, 2012

2.6.1 CONGESTION

Traffic congestion is one of the major challenges that cities have been trying to solve, including South African cities such as Cape Town, Johannesburg, Durban and Pretoria. Traffic congestion wastes time, causes pollution, has a negative impact on productivity and imposes costs on the society. Even though different cities are trying to alleviate the same challenge of traffic congestion, there are different practices in different cities to make sure that the level of congestion are reduced. Countries like the United States of America, South Korea, Japan, and India focus on either speed, travel time and delay, volume, level of service, and demand and capacity (Feikie et al., 2017).

2.6.1.1 TRAFFIC VOLUME AND LEVEL OF SERVICE

Most congestion measures use the level of service (LOS) concept introduced in the highway capacity manual. The LOS concept is defined in terms of densities on freeways and intersections, average stopped delay for intersections, and average speed for arterials. The LOS measure ranges from A (best service) to F (worst service). The LOS measure is also associated with volume to capacity ratios, as shown in Table 1, which assist in understanding the levels of congestion, through measuring delays. Measures of traffic volume and LOS are widely used because it is very easy to collect the data on the field, though some researchers criticise the method because sometimes it might be misleading, especially when conditions are near the threshold (HCM, 1985.2000).

2.6.1.2 TRAVEL TIME

Travel time is the time it takes to travel on a route from one point to another point. It is a very useful measure in transportation, useful for congestion management, transportation planning and traveller information. Travel time information is one of the most important measures in transportation as it offers real time information on the level of congestion on a segment of road. There are different techniques used to collect data for travel time, such as test vehicles techniques, license plate matching techniques, and ITS probe vehicle techniques. Some of the congestion measures, as shown in Table 1, include the following: travel time or difference in travel time (minutes or seconds); travel rate (minutes per kilometres); delay rate (minutes per kilometre); total delay (person hours, vehicle hours); relative delay rate; and delay ratio (Schrank & Lomax, 2005; Rao & Rao, 2012).

2.6.1.3. TRAVEL SPEED

Traffic speed at any section affects the quality of traffic at the time. Even though initiatives of alleviating congestion prioritise reducing the number of vehicles on the road, concerns are that high speeds on the road lead to the severity of traffic accidents, and slow speeds are associated with traffic congestion. In recent days, efficient monitoring is done through GPS and GIS. Different speed measure can be estimated depending on different classes of roads; some of the measures include average peak-hour speed, average travel speed and peak-hour travel speed. Speed measures are also important because travel speeds are used to assess the levels of congestion by doing a comparison between congested condition and free flow operating conditions (Falcocchio & Levinson, 2015)

2.6.2 CO_2 EMISSIONS

The transportation sector plays a major role in carbon dioxide emissions, because the emissions are dependent on traffic speed and the acceleration and deceleration of cars increase these emissions. Various initiatives have been encouraged worldwide to curb the levels of pollution. Policy makers believe that manufactures of cars should prioritise lighter and smaller vehicles and the integration of advanced technologies. Some researchers look at congestion, as a function of speed and total kilometres travelled in order to formulate solutions. Recent research has encouraged the prioritisation of public transportation in cities, especially where the use of private transportation is high; this decrease in the number of vehicles on the road will decrease congestion. If the levels of congestion in roads decrease, the vehicles will be experiencing average flow, leading to reduced changes in acceleration and deceleration, which will consequently lead to reduced levels of pollution (Muresan, 2016).

2.7 LINK BETWEEN ICT, URBAN DEVELOPMENT AND TRANSPORTATION

Urban growth has proven to be a major contributor to challenges the environmental, economic, and social sustainability of cities (Neirotti, De Marco, Cagliano, Mangano, & Scorrano, 2014). Urbanisation causes challenges such as increased energy consumption, high levels of congestion, high traffic volumes, pollution and depletion of non-renewable resources. ICT is part of urban sustainability debate due to the massive use. Information processing and data sensing are being incorporated into every detail of cities, and wireless networks are flourishing rapidly (Batty 2012; Bibri & Krogstie 2016). This is because cities are moving towards sustainability and this necessitates innovative technologies. Rapid growth in urbanisation provides new perspective on the transition towards achieving sustainable development goals (Batty, 2013a,b; Bibri & Krogstie, 2016a,b).

ICT can be used for the achievement of short and long-term goals. In fact, ICT is already the main solution in rapid urbanisation, transformation of cities and growing mobility. The urgent need for solutions seeks to solve challenges and find alternatives for existing methods (Nam & Pardo, 2011). Townsend (2013) highlights that there is a relationship between ICT development and urban growth, that requires collaboration. The planning of this cities requires new and innovative solutions, and techniques (Rotmans, van Asselt, & Vellinga, 2000; Kramers, 2013 & 2014; Shahrokni, Årman, Lazarevic, Nilsson, & Brandt, 2015). This entails the application of complex science upon which ICT is founded (Bibri & Krogstie 2016).

ICT refers to systems, software, networks, applications, and urban infrastructure that aim at providing data. The innovative technological components are used to sense, collect, store, coordinate, integrate, process, analyse, synthesise, manipulate, model, simulate, manage, exchange, share and plan for smart cities (Al-Fuqaha et al., 2015). The purpose of integrating ICT into urban areas and structures, and consequently using technological applications, is to better understand how cities function and how they can be managed, by analysing emerging theories and coming up with solutions to formalise and implement new methods. This involves ways to alleviate challenges in the cities and to promote greater efficiency and quality of life. Urban ICT includes hardware and software components. This includes sensors, internet, computers, phones, wireless communication, cloud systems, and database systems (Al-Fuqaha et al. 2015). The list includes all kind of software applications operating and running on hardware systems (Sundmaeker, Guillemin, Friess, & Woelfflé, 2010).

ICT comes in different forms and shapes, therefore it can be integrated in buildings, different kinds of infrastructure, networks, facilities, services, spatial organisations, physical objects and it can even be attached to individuals for monitoring as they carry on with their daily activities, such as transportation. In the transportation sector, ICT can best be associated with words like smart transport, smart mobility, and smart traffic. Even though ICT is normally aligned with urban computing, it should be clear that ICT in urban environments is strictly concerned with its application and the effect it might have on urban communities. Even though there has not been a clear and consistent understanding of the true definition of smart city, smart city concept is believed for its ability to promote efficiency with regard to energy, transportation, land use, communication, economic development, and service delivery.

2.8 ROLE AND INFLUENCE OF ICT ON SUSTAINABLE ROAD TRANSPORTATION

The development of transportation technologies represents intelligence that is aimed at providing advanced services across urban movement challenges. This includes challenges from the modes of transportation, to the management of traffic. Innovation in modern transportation design, with a view of creating healthy and more walkable cities, could solve transportation challenges such as congestion and public safety. When transportation is integrated with ICT in the planning stage, it helps in alleviating challenges relating to social policy, by addressing the 'urban food desert' and improving access to social services (Stimmel, 2015). ICT solutions could be used to solve mobility challenges for public transportation operators (Bashingi, Masinde & Hassan, 2016). Further, Das (2014) highlights that mobility influences travel needs.

The availability and effective use of ICT infrastructure can reduce travel needs, as a large portion of the urban functions can be performed by the use of ICT without the requirement of physical engagement. The effective use of ICT has the potential to reduce travel needs, which will result reduced trip generation, which will contribute to lower volumes on the roads. Ultimately, this reduces pollution and traffics crashes, thus assist in achieving sustainable road transportation (Shapiro, 2008; Van Soom, 2009; Lombardi, 2011; Nijkamp & Kourtik, 2011; Das & Emuze, 2014).

2.9 CHALLENGES OF APPLICATION OF ICT TO SUSTAINABLE ROAD TRANSPORTATION

Since the 1980s, the transportation sector has used the term "Information and Communications Technologies (ICT)" to precisely portray the different telecommunications and information technologies. Through time and research, there has been an introduction of "concepts such as "intelligent vehicle", "intelligent highway", "smart real time", "traffic monitoring and control". ICT is bringing enormous changes to people's lives in developing and developed countries, while in others people have hardly experienced the capabilities of new ICT applications, though some observers suggest that the market mechanisms are ensuring that everyone enjoys the benefits. Other scholars suggest that the implications of these technologies have been exaggerated (Shanker, 2008). They argue that the new ICT applications may destroy more jobs rather than create them and their usage may widen the gap between the poor and the rich (Heeks, 2010). Other experts and scholars urge decision makers to be cautious when embracing the new technologies, as they might be at risk if the applications do not solve their development problems (Mansell, 2012).

Technologies that have emerged and shaped traffic and traffic and transportation include the following: Systems for mobile communication technologies, broadband, and internet services. (Giannopoulos, 2004). One of the basic requirements for the successful system of information to the users is efficiency and simplicity (Harris, Wang, & Wang, 2015). The main objective of ICT integration is road safety, efficiency and environmental considerations. The data that can be collected using ICT include the following: congested areas; areas for accidents and incidents; road works areas; weather conditions; expected traffic volumes on roads at specific periods; existing speed limits; road fees; information on other modes; information on parking guidance and park and ride systems; and information on car sharing (Rathore, Ahmad, Paul, & Rho, 2016). The implementation of systems for supplying timely, reliable, and real time information brings about the advantages of reducing uncertainties relating to journey time; encouraging people to travel at non-peak hours; reducing congestion through real-time route changes; prioritising the use of public transport and different modes; and offering personalised travel information (Davis, 2015; Emmerink & Nijkamp, 2018).

Though the advantages are evident and encouraging, challenges relating to the application of ICT in the transportation sector are more inauspicious. The costs relating to building new information infrastructure are too high and developing countries normally do not have enough funds for the implementation and maintenance relating to the balance between hardware and software production and skills for sustaining the effective use of ICT. There are uncertainties as to whether success in export markets can be positively translated into the wider diffusion of ICT in the domestic markets, the cultures and business practices are compromised due to the anonymity of communication, while the rate of computerised crime is increasing and poses a risk especially to developing countries. The possibility of doing parts of the communication online does reduce the need for travelling and ICT is a medium of ecological communication, but it also contributes to environmental pollution due to the waste and emissions generated in the production process of ICT. Energy consumption in running computers and the Internet is high and other solutions may offer greater economic benefits. The considerable risks of unemployment, social and economic dislocation pose a much higher risk (Birkehag and Sohlman, 2015).

The success of the implementation of ICT in the transportation systems requires organisational change. Training and skills are needed to familiarise users with new systems. The size in the workforce may be transformed by the introduction of ICT and the application must always be accustomed to suit local needs. The boundary between the producers and users must be eliminated to avoid applications that are not user friendly, and to achieve this planners and designers must always engage with the users to ensure that the end product with be user friendly to all the users, especially to the elderly and those who are illiterate. Priorities should be on the awareness to the public, better education, user involvement in designing, public access to networks and a better approach to include all stakeholders and policy makers to come with more practical initiatives (Mansell, 2012).

2.10 SUSTAINABLE ROAD TRANSPORTATION IN SOUTH AFRICA AND AFRICA

Sustainable road transportation is a challenge in African cities and particularly in South African cities. The challenges are related to mobility and accessibility. Other challenges that the cities are facing include lack of public transportation, high congestion levels, traffic safety and predominant use of privately driven vehicles, high travel times and environmental pollution (Sultana, Salon & Kuby, 2019). Similarly, improved accessibility through sustainable road transportation remains a priority but the main question remains – are the current adopted policy measures such as urbanisation, building of new infrastructure, bus transit system (BRT) or introduction of congestion taxes answers to the current challenges that are hindering sustainable road transportation in cities? If so, despite the systems available, why are carbon emissions still worrying in some European countries and why is there still mobility challenges in cities like Stockholm and Delhi (Scheiner & Kasper, 2003; Zanella, Bui, Castellani, Vangelista, & Zorzi, 2014).

Similarly, Emuze and Das (2015) highlight that sustainable road challenges in South African city emanate from various factors. For instance, the necessity to travel is caused by a lack of the use of Information Communication Technologies (ICT) to perform socio-economic activities. High volumes of traffic on roads due to individual driven cars are caused by the lack of adequate and reliable public transportation and the need to travel. Consequently, high volumes of individual driven cars on the roads lead to increased levels of congestion, traffic accidents, and pollution, which ultimately leads to unsustainable road transportation (Metz, 2013; Wang, Xu & Qin, 2014; Vuchic, 2017).

In addition, some scholars argue that land use and social economic urban functions are the most important factors that encourage or discourages the use of individually car use (Nikitas, Kougias, Alyavina, & Njoya Tchouamou, 2017). Nonetheless, some cities in South Africa and in Africa at large have adopted the framework to transition towards sustainable transportation (Schneider, 2013; Das, 2014; Feikie et al. 2017). However, the critical challenge is to change the perception on private and public transportation, this involves encouraging use of public transportation and discouraging the use of unnecessary car use. In this regard, Banister (2008) highlights that discouraging unnecessary car use, does not necessarily mean that individual car use should be prohibited. Rather, cities should be planned and designed with quality and consideration to reduce the need for cars (Gehl, 2013).

It is believed that the improvement of cities and low emissions can be achieved by encouraging use of different modes of transport, as well as the usage of ICT for urban functions to reduce the need to travel (De Oliveira et al., 2013; Grant-Muller & Usher, 2014). This can be achieved by dedicated lines for public transportation, improved pedestrian facilities, usage of ICT to perform activities, without the need to travel (Huwer, 2000; Grazi & Van den Bergh, 2008). Cities such as Johannesburg and Cape Town have adopted some sustainable transportation strategies to improve their sustainability status. Johannesburg has integrated bus rapid transit (BRT) system, and electronic trains that are integrated with technological solutions (ICT, and ITS.) (Venter, 2013; Grant-Muller & Usher, 2014).

2.11 ICT IN AFRICA AND SOUTH AFRICA

In the early 2000s, Africa was still considered a region with poor internet connectivity marginalised ICT development. Mobile technologies and wireless technologies caused a rapid change that led to the connection of Africa to global communication. The Internet population in Africa was small due to low literacy rates and the lack of computer skills; for this reason the growth in technological awareness and growth was low in Nigeria, Rwanda, Central African Republic, South Africa and Egypt, as compared to other countries outside Africa. Even though the growth was small, in the southern part of Africa, South Africa has been leading in Internet penetration. The implications of the slow growth are evident in the present day because research shows that, as technology usage lags, so does per capita income, skills development and productivity (Guerriero, 2015). ICT has been adopted in Africa and has been integrated in different sectors such as health care, education, protection of the environment, and transportation. In South Africa the adoption of ICT has been believed to be influenced by exposure; by the capacity to adopt and use technologies; and by political factors and state policies. The adoption of ICT in South Africa has also been slow, considering the fact that South Africa has had a challenge of establishing its position in the global market while trying to address problems created by colonialism. The government and economist still look to ICT for better service delivery, skills development, better productivity and economic growth (Kyobe, 2011).

Even though the implications of ICT were believed to be exaggerated initially, there has been enormous positive outcomes from ICT initiatives. ICT has been the main hub of economic growth throughout the globe. ICT facilities that were initiated and developed throughout the world have increased efficiency and contributed to new business opportunities, new jobs, and improved the quality of life (Ponelis & Holmner, 2015). Therefore, focusing on the advantages of ICT, African countries stand to gain a lot if ICT can be prioritised and integrated in all the sectors that drive and develop the cities. Over the years, there has been an adoption of beneficial policies adoption by governments to ensure the improvement of ICT usage and sustainability (Kayisire & Wei, 2016).

2.12 INFLUENCE OF ICT IN ROAD TRANSPORTATION IN SOUTH AFRICA

Traffic congestion is a challenge which has undesirable consequences such as negative economic impact and pollution (Sorensen, 2008; Rao & Rao, 2012; Wang, Gao, Xu, & Sun, 2014). According to statistics in South Africa, provinces such as Gauteng, Western Cape and KwaZulu-Natal have shown population increases of 15%, 10.3% and 0.1% in 2007 to 2011, respectively. Their transportation systems aim to offer transportation services that are fast, affordable, reliable and efficient (BEPP, 2017/18). The characteristics of these systems are discussed as below:

2.12.1 Gauteng

Public transportation in Gauteng is going through a major development, with Rea Vaya BRT system and park and ride facilities. There is a rapid rail network, first of its kind in Africa, which started operating in 2010. Though there is availability of different modes of transportation, Gauteng still faces the challenge of congestion. Most commuters still prefer to use taxis because they are more flexible and save time. Through the National Household Travel Survey, which investigates travel patterns, and problems in cities, it was revealed that the main source of transportation in Gauteng is taxis (41.6%), followed by private cars (13.7%), buses (10.2%) and trains (4.4%) (Stats, S.A. (2014). Similarly, almost 46.8 hours are spent on traffic annually in Gauteng, which means that there are high levels of congestion (Feikie, Das, & Mostafa, 2018). Therefore, despite the measures put in place for public transportation, traffic congestion and sustainable road transportation remain a challenge in Gauteng.

The city has introduced some ICT initiatives, such as open online varsity by connecting fibre Internet to public libraries, free Wi-Fi hotspots in the city and training of youth in ICT on non-motorised transport. Other plans are also in place to offer free Wi-Fi at bus stations and across the city (Musakwa & Mokoena, 2017).

2.12.2 KwaZulu Natal: Durban

Durban has integrated rapid public transport network (IRPTN) which is aimed at ensuring that the city is Africa’s most liveable city by 2030. The city plans to be a multi-modal city with integrated transportation between – bus, rail, taxis, cycling and walking.

The city also plans to have Advanced Public Management Transport System the will provide passengers with real-time information. Information will be made available on electronic displays at stations, on buses and via Mobile Applications (Greyling & Smith, 2008; Petterson, 2017). The transportation system in the city predominantly consist of buses, rail, and taxis, which are not integrated with technological solutions, such as mobile applications, real-time information. There are other car-hailing applications such as Uber and Taxify, which are not entirely cost effecting because of the fluctuating prices that depend on distance and availability (Petterson, 2017). Similarly, almost 30.2 hours are spent on traffic annually, indicating significant traffic congestion challenges in the city (Feikie et al., 2018).

According to Statistics SA, Durban is one of the cities showing massive growth and development, even in the transportation sector. Different ICT initiatives have been adopted, from trying to create employment to enriching communities. The city embraces a multimodal transportation system with different projects and initiatives ahead to improve the efficiency and reliability (Odendaal, 2011).

2.12.3 Western Cape: Cape Town

Many commuters in the city of Cape Town use public transportation, as it is cheaper. Golden Bus service used in the city transports almost 48.5 million passengers per year (Cloete, 2014). There are 122 train stations in the province, and MyCiTi Bus Rapid Transit (BRT) system (Struwig, 2013). There are dedicated lanes for public transportation in the city, also a predominant use of minibus taxis and metered taxis for their local travel needs (Feikie et al., 2018). Almost 49.1 hours are spent on traffic annually, this shows that despite the interventions put in place, this city still has sustainable road transportation challenges (Strydom, 2010).

Some initiatives have already been adopted in the city, such as public Wi-Fi hotspots, improvement in the Internet access in the libraries and surveillance cameras around the city. The reliability and adoption of ICT in transportation is gaining popularity and some ideas have been integrated already (Mhangara, Mudau, Mboup, & Mwaniki, 2017; Musakwa, & Mokoena, 2017).

2.12.4 Free State: Bloemfontein

Mangaung Metropolitan Municipality has an integrated development plan that prioritizes transportation. A commuter rail is being explored with the aim of providing other modes of transportation. currently the transportation system is based on buses, taxis and private cars (BEPP, 2017/18). Almost 16.1 hours are spent on traffic annually. Although congestion levels are not as alarming in Bloemfontein as in other cities, it is still important to prioritise it to avoid high levels in the future. The city already introduced ICT initiatives such as a tag system in buses and access to Wi-Fi in the central business district.

The analyses of the above four cities revealed that availability of a public transportation system is not on its own able to alleviate traffic challenges in a city. The alternative option includes the use of ICT for socio-economic and transportation activities.

2.13 SYNTHESIS AND RESEARCH GAP

- The United Nations highlighted that the population in urban areas is increasing, and due to this, there is a serious need for solutions to challenges such as air pollution, traffic congestion, waste management and human health issues.
- Though researchers and experts have engaged in debates on the definition of sustainability or sustainable development, it is now understood that cities become sustainable when there is a balance between the development of the urban areas and protection of the environment
- The importance of sustainability initiatives is to ensure that natural resources are conserved for future generations.
- There is a consensus that the ultimate goal is to move cities and communities towards sustainability, but some authors critiqued the current approach arguing that they do not focus on alleviating the harm done on the environment, rather they just slow down the pace at which the harm is made, and for that reason they were advocating for a more integrative term of “regenerative term”

- Some authors believe that understanding the relationships between people, their activities and the environment, with the integration of diverse technologies, is the key to achieving sustainability.
- Sustainability was measured with a set of indicators, but other researchers highlight that efficient monitoring is dependent not only on a set of indicators, but on the need to visualise the achievement of initiatives. Therefore, indicators set on real-time information seem more plausible and practical as they give a more accurate scenario of different cities, because cities develop differently according to their needs. Despite the lack of, and controversy surrounding, systems to rank the sustainability of cities, researchers concur that ICT has the potential to transition cities towards sustainability.
- Cities face diverse challenges that are proving to be hard to solve as populations increase in cities and urban areas. The greatest challenge, according to researchers, is that dwellers have to see cities as laboratories for innovation. This may be used to inform future designs for the development of technologies that will ensure equity, efficiency, and sustainability.
- There are many crucial implications of the sustainable transportation. For example, through different policies, sustainable road transportation has the potential to reduce energy use and reduce environmental pollution through fuel economy improvement
- A large number of assessment tools and frameworks have been developed to ensure that the measures taken in the transportation sector are moving towards sustainability goals. The right framework would be a framework that does not only focus on the tangible solutions but aims also at integrating the transportation solution with the social aspect to make sure that the new systems are realistic and user-friendly.
- Public transportation plays an important role in enhancing urban mobility, reducing levels or road congestion, limiting emission and improving the lives of people.
- Increased use of public transportation can be achieved by the usage of ICT for scheduling, route changes and logistic information.
- ICT solutions solve the mobility challenges experienced by the public transportation operators and their clients.

- ICT can be used during travel for route planning and optimisation of travel distance, which essentially will assist in reducing travel time and travel distance.
- The integration of ICT with road transportation and socio-economic functions effectively in South African cities will contribute to sustainable road transportation.
- The purpose of integrating ICT to urban areas and structures, and consequently using technological applications, is to better understand how cities function and how they can be managed, by analysing emerging theories, and coming up with solutions to formalise and implement new methods.
- When transportation is integrated with ICT in the planning stage, it helps in alleviating challenges relating to social policy, by addressing the 'urban food desert' and improving access to social services.
- The challenges associated with ICT in transportation ranges from making people understand the implications of ICT to making sure that people are trained enough and understand what is to be adopted. One of the important factors surrounding this issue is also funding, which is proving to be a challenge, especially in the developing countries.
- However, through some difficulties and many trial and errors, some cities in South Africa have embraced the challenge of moving towards sustainability through the route of ICT integration. There have been positives and negatives and people are not sure if some decisions are the best for their cities. Particularly in South Africa, there is a serious need of remedial actions in different cities regarding transportation. The greatest challenge thus far has been in making sure that the public transportation is integrated and affordable.

The gap in the literature in South African cities is with regard the integration of ICT in transportation. Various studies have been focusing on sustainable parameters and actions that can be adopted to alleviate some of the challenges. These actions have included some cities introducing BRT systems, integrating transportation systems and building infrastructures for non-motorised transportation. Nevertheless, the challenge has been that, even after those initiatives, some of their problems such as congestion, carbon emissions and use of public transportation were not entirely solved. Further, studies on the integration of ICT in transportation and its impact are scarce. This study thus is focused on assessing the impact of ICT road transportation system of cities and making them sustainable. The other shortcoming that the literature has shown is that planners need to look at cities differently because they all have different needs and a solution that works for one city might not necessarily work for the other. Consequently, it is imperative for Bloemfontein to be considered as a case study, because as a developing city, the needs on this particular city needs to be addressed individually to avoid other challenges some cities have experienced.

2.14 CONCLUSION

This chapter has consisted of a discussion of the literature related to sustainable road transportation and its implications that are available in the mainstream literature. The focus on sustainable transportation has included a review of the indicators, implication, initiatives, framework, techniques, and policy interventions adopted in different cities. ICT integration in sustainable road transportation was critically reviewed, and literature showed that ICT might be a solution to the challenges faced by cities, both those that are developing and those that have already developed. The following chapter will be on the study area profile, where the analysis of the characteristics, current and imminent challenges and opportunities will be discussed thoroughly.

CHAPTER 3: PROFILE OF THE STUDY AREA

3.1 INTRODUCTION

The analysis of the study area profile provides a concise understanding to its characteristics, its current and imminent challenges, opportunities and plausible solutions, which are essential for the development of policy interventions in general and the formulation of plausible planning guidelines, in order to ensure sustainable road transportation as an integral part of sustainable development. Numerous factors such as socio-economic activities, infrastructural conditions, environmental and road conditions, economic issues, technological awareness and land use planning, influence individuals' decision-making processes regarding their mode of transport, time of travel, number of trips and activities to be performed, which in general influence the suitability of the road transportation system in a city. Therefore, this chapter aims at providing the current scenario of those attributes and parameters of the study area that have an impact on the sustainable road transportation. The parameters discussed include background of the area, demographic profile, socio-economic profile, land use, transportation system, access to the Internet and availability of technological gadgets.

3.2 BACKGROUND OF THE STUDY AREA

Bloemfontein city as shown in figure 1, situated in the Free State province, is in the centre of South Africa. It was selected as the study area for this investigation because among other reasons, it is a promising developing city. It is under the Mangaung Metropolitan Municipality (MMM), in the Motheo district. The vegetation surrounding the city is mainly dry grassland on a flat plateau bordered by the semi-arid region of the Karoo. Bloemfontein is known for its very cold winters and very hot summers. The rainy season is during the summer months and strong winds are experienced during the spring season (Department of Science and Technology South Africa, 2011).

Mangaung area has urban centres for both commercial and mixed farming. Due to the new recent demarcation, Mangaung municipal area now includes rural town such as Soutpan, De Wetsdorp, Wepener and Van Stadensrus. The N1 and N8 routes are national roads that link the municipal area with the rest of the country (IDP, 2018/2019).

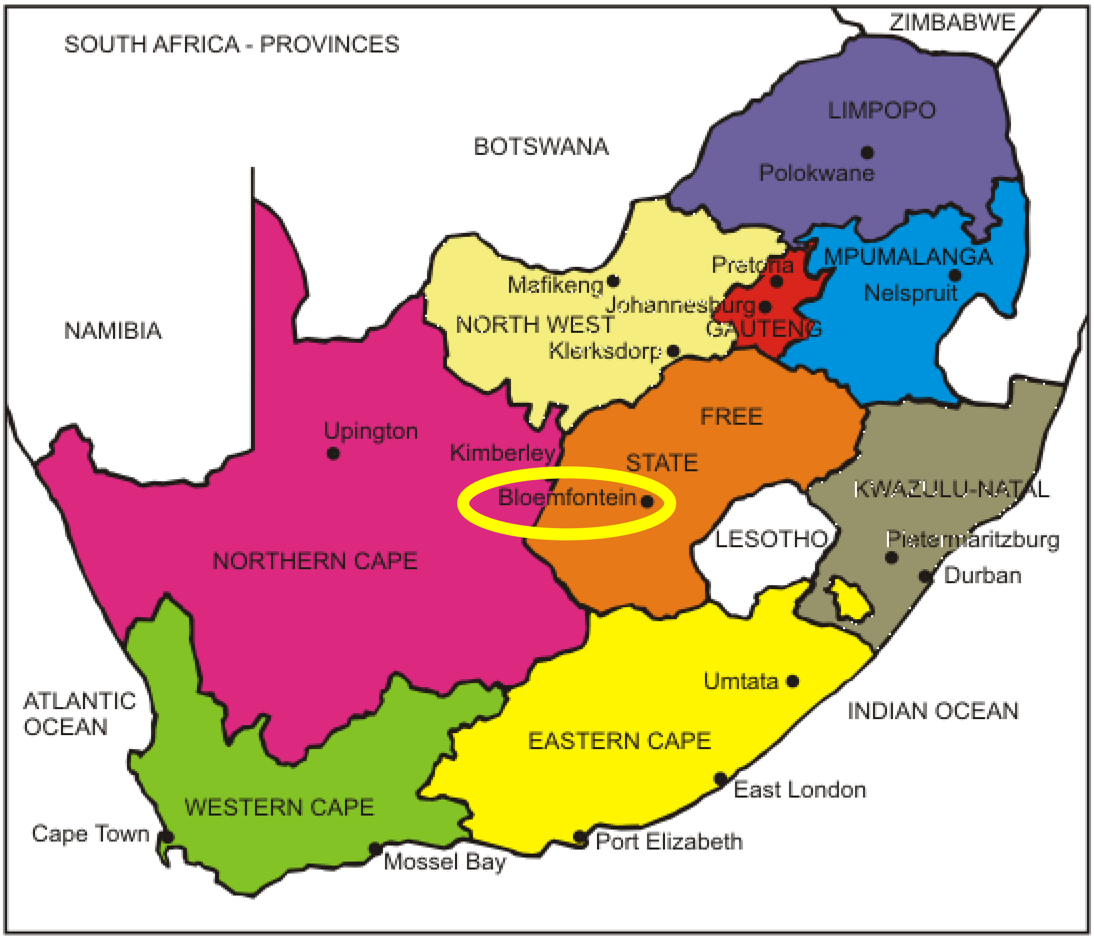

Figure 1: South African map showing the city of Bloemfontein

Note: Naledi Local Municipality was merged into Mangaung Metropolitan Municipality in 2016. Statistics prior to 2016 are not inclusive of the merge, unless stated otherwise.

3.3 DEMOGRAPHIC PROFILE

3.3.1 POPULATION

According to Statistics South Africa (2011), South Africa had a population of 51, 8 million, amongst which almost 2, 8 million resided in the Free State. According to a community survey 2016, MMM had a population of an average of 787 803, including people from the recently demarcated rural towns (IDP 2018/2019). Table 2 below shows the population of MMM in 2011 before the demarcation, and the number of people that moved from one area to another between 2007 and 2011. The Table 2 shows that almost 50 000 people migrated from Botshabelo to Bloemfontein, while Thaba Nchu township and the tribal villages experienced a combined negative growth of 187. Thaba Nchu appears to be more stable than Botshabelo in terms of emigration to other areas. This growth indicates that gradually cities like Bloemfontein will have to plan not only for people who reside in the city only but also for those that migrate from rural areas to urban areas (Statistics South Africa, 2011; Community survey, 2016).

Table 2: Population size of MMM, 2011- excluding new demarcated rural areas

<table>
<tr><td>Area</td><td>No of People</td><td>No of Migrants (2007-2011)</td></tr>
<tr><td>Bloemfontein</td><td>256 534</td><td rowspan="2">50 178</td></tr>
<tr><td>Mangaung Township</td><td>227 155</td></tr>
<tr><td>Botshabelo</td><td>181 712</td><td>-49 992</td></tr>
<tr><td>Thaba Nchu Township</td><td>70 118</td><td rowspan="2">-187</td></tr>
<tr><td>Tribal Villages</td><td>11 913</td></tr>
</table>

3.3.2 EDUCATION

The largest proportion of the population by age in the MMM is people aged from 15 to 64 with the lowest proportion is of people over 65 years of age (Table 3). Among the population aged 20 years and above, only 4.3% in 2011 and 5.2% in 2016 of the population have never been in school before (Table 4). There has been an increase in the percentage of people with matric and higher education training; this is a good indication of growth and development because with the adoption of technological advancements, at least minimum level of education/training is needed in order to comprehend and react accordingly to different transportation systems.

Table 3: Age structure for MMM (2011 and 2016)

Age Structure	**2016**	**2011**
Population under 15	29.7%	27.1%
Population 15 to 64	65.0%	67.6%
Population over 65	5.3%	5.4%

Table 4: Education (aged 20+) for MMM (2011 and 2016)

Education (aged 20 +)	**2016**	**2011**
No schooling	5.2%	4.3%
Matric	32.8%	29.1%
Higher education	13.3%	13.1%

3.3.3 EMPLOYMENT

According to Statistics SA (2011), the unemployment rate was 27.10% and 27.70% in South Africa and Bloemfontein respectively. Table 5 and Figure 2 show the trends of unemployment in MMM. Only 211 746 people are employed, while 195 707 people are not economically active. 81 225 people are unemployed and 18 244 are discouraged work seekers. These numbers clearly show that there is a high rate of unemployment in MMM, and this affects the rate at which the municipality is developing, in particular the city of Bloemfontein, as it is the main generator of income for the municipality.

Even though there is an increase in the unemployment rate in the province, statistics show that the average household income has increased. Table 6 and figure 3 show the average household income in MMM and Bloemfontein. MMM generally has a higher proportion, compared to Bloemfontein, of those households from no income to R76 400. For the average of R76 401 and above, Bloemfontein has the highest percentage. This shows that Bloemfontein is an important city in the municipality and its development and growth will not only benefit the city alone, but the municipality as a whole.

Table 5: Employment status in MMM (2011)

Employment Status	Number
Employed	211 746
Unemployed	81 225
Discouraged Work Seeker	18 244
Not Economically Active	195 707

Table 6: Average household income in MMM and Bloemfontein (Statistics SA, 2011)

Income	Percentage MMM	Percentage Bloemfontein
No income	11.40%	9.50%
R1 - R4,800	4.60%	2.80%
R4,801 - R9,600	6.80%	4.50%
R9,601 - R19,600	17.20%	11.10%
R19,601 - R38,200	20.20%	14.50%
R38,201 - R76,4000	14.10%	12.40%
R76,401 - R153,800	10.30%	13.30%
R153,801 - R307,600	8.00%	14.90%
R307,601 - R614,400	5.00%	11.30%
R614.001 - R1.228,800	1.60%	4.00%
R1,228,801 - R2,457,600	0.40%	0.90%
R2,457,601+	0.40%	0.80%

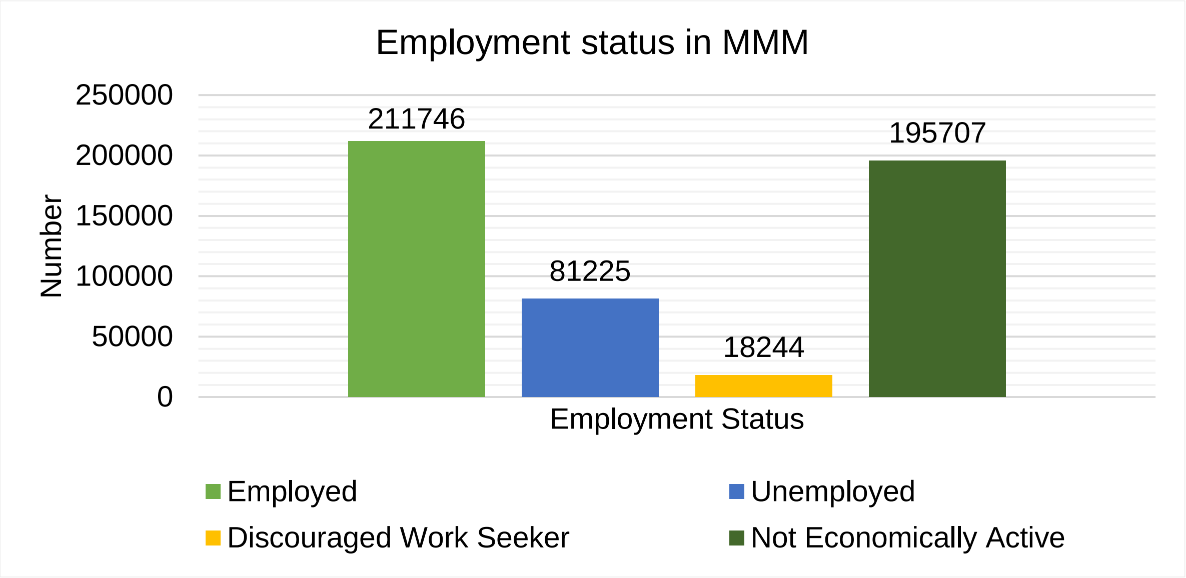

Figure 2: Employment status in MMM (Statistics SA, 2011)

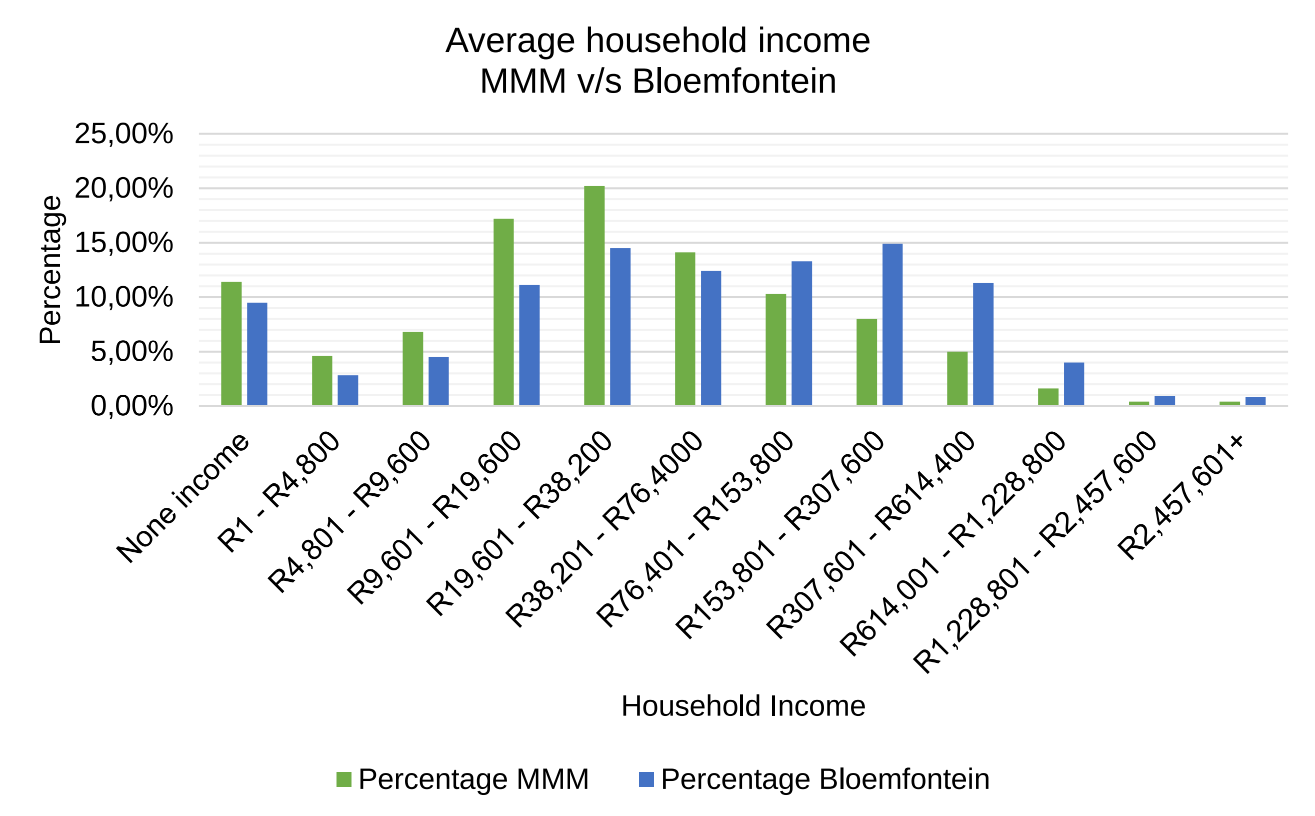

Figure 3: Average household income in MMM versus Bloemfontein (Statistics SA, 2011)

3.4 TECHNOLOGICAL AWARENESS

In MMM, 61.90% of people do not have access to the Internet, while in Bloemfontein only 46.30% of people do not have access to the Internet (Figure 4 & Figure 5). The percentages of access to the Internet are higher in Bloemfontein, with 20.90% of people accessing the Internet from their cell phones. There has been a massive change in technological advancements and accessibility to the Internet from 2011 until now. It is expected that this percentage of accessibility of Internet from cell phones both in MMM and Bloemfontein would have increased by 2021. Ownership of household goods seems to be at high percentages both in MMM and Bloemfontein. Even though the percentages of access to the Internet from cell phones were not that high, the majority of people in MMM do have cell phones, computer, television, satellite television, radio, telephone and motor car (Figure 6). Accessibility to the Internet may be low due to the costs associated with it, but in recent years the accessibility to free Wi-Fi and reduced data prices has improved and this might yield better accessibility in future.

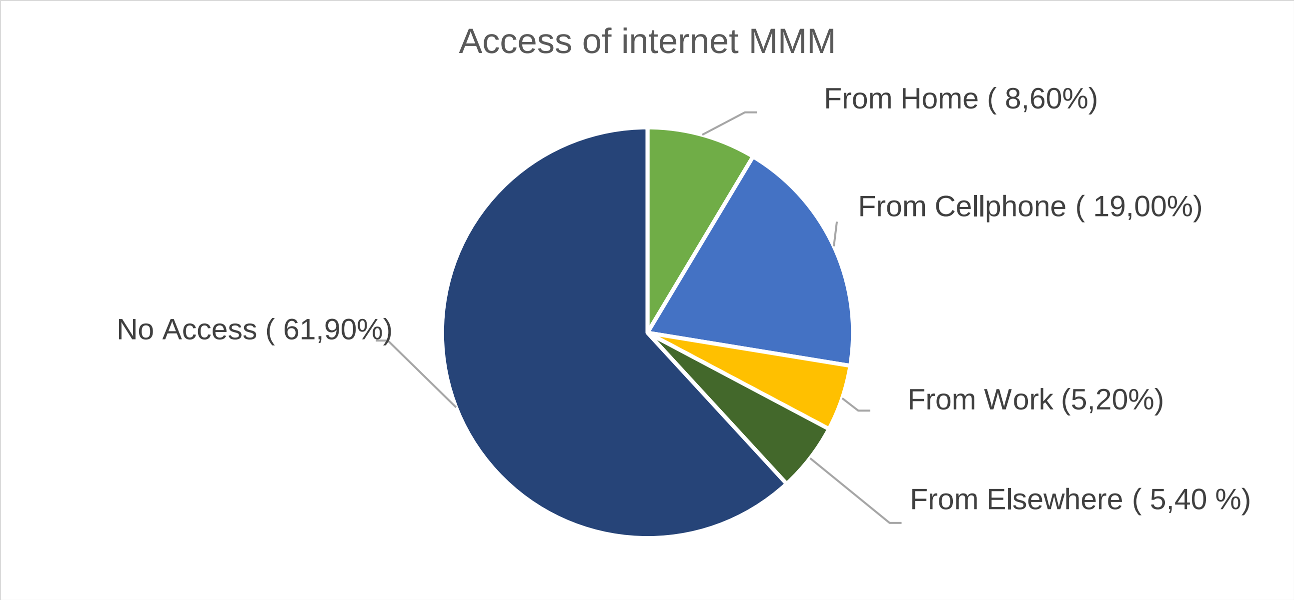

Figure 4: Access to Internet MMM (Statistics SA, 2011)

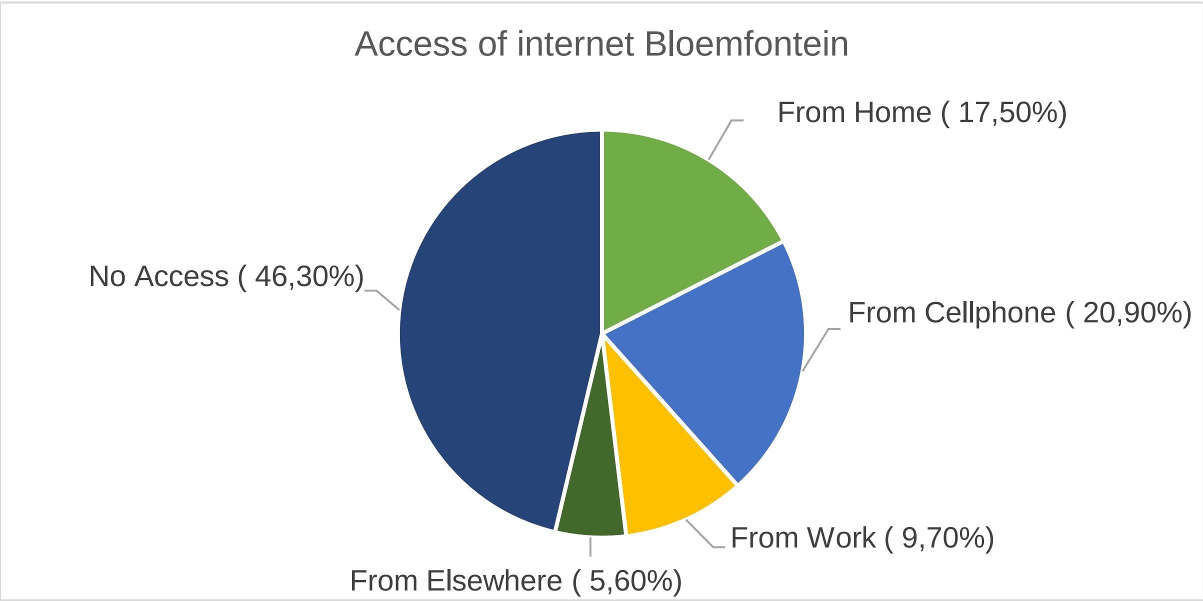

Figure 5: Access to Internet Bloemfontein (Statistics SA 2011)

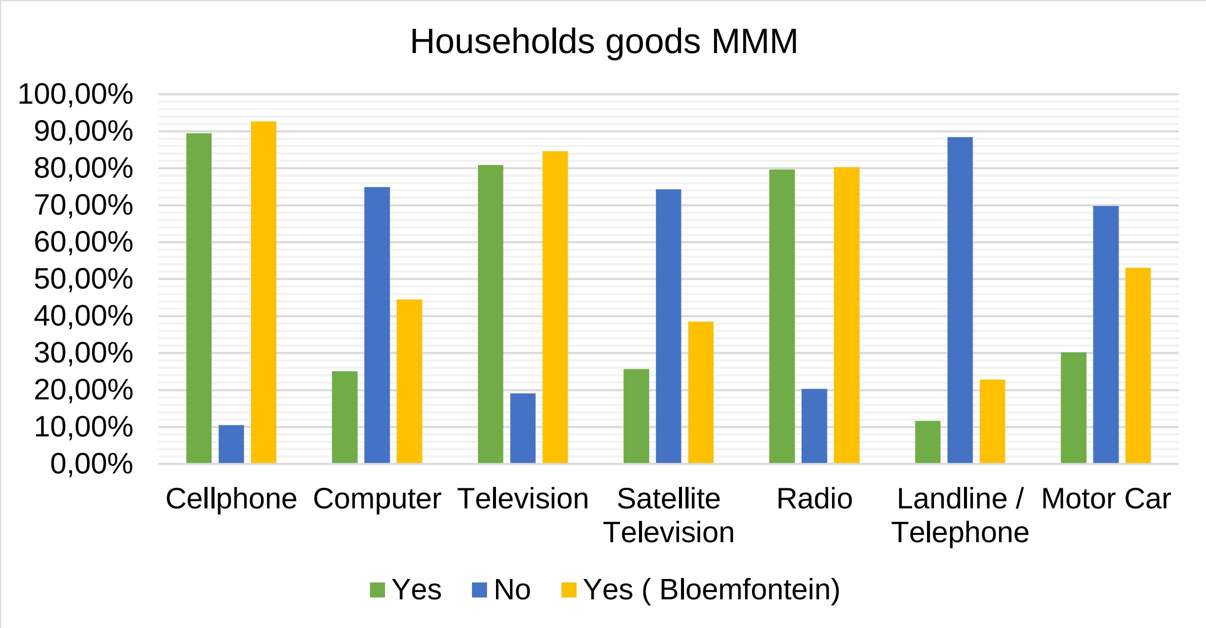

Figure 6: Possession of households goods for MMM and Bloemfontein (Statistics SA, 2011)

3.5 URBAN HABITATION PATTERNS

According to Statistics SA (2011), there are 231 931 households in MMM, with an average household size of 3.10 persons per household. Figure 8 shows that 90.60% of people in MMM, prior to the new demarcations, lived in urban areas, while only 6.90% and 2.50% dwelled in tribal/traditional and farms respectively. In Bloemfontein 100% of the population lived in urban areas. These statistics show that the migration of nearly 50 000 people from Botshabelo to Bloemfontein (Table 2) may be due to the fact that Bloemfontein city is growing at a faster rate than the other towns, and people are migrating for better living conditions. There are 81 286 households in Bloemfontein, with an average household size of 2.90 persons per household (Statistics SA, 2011).

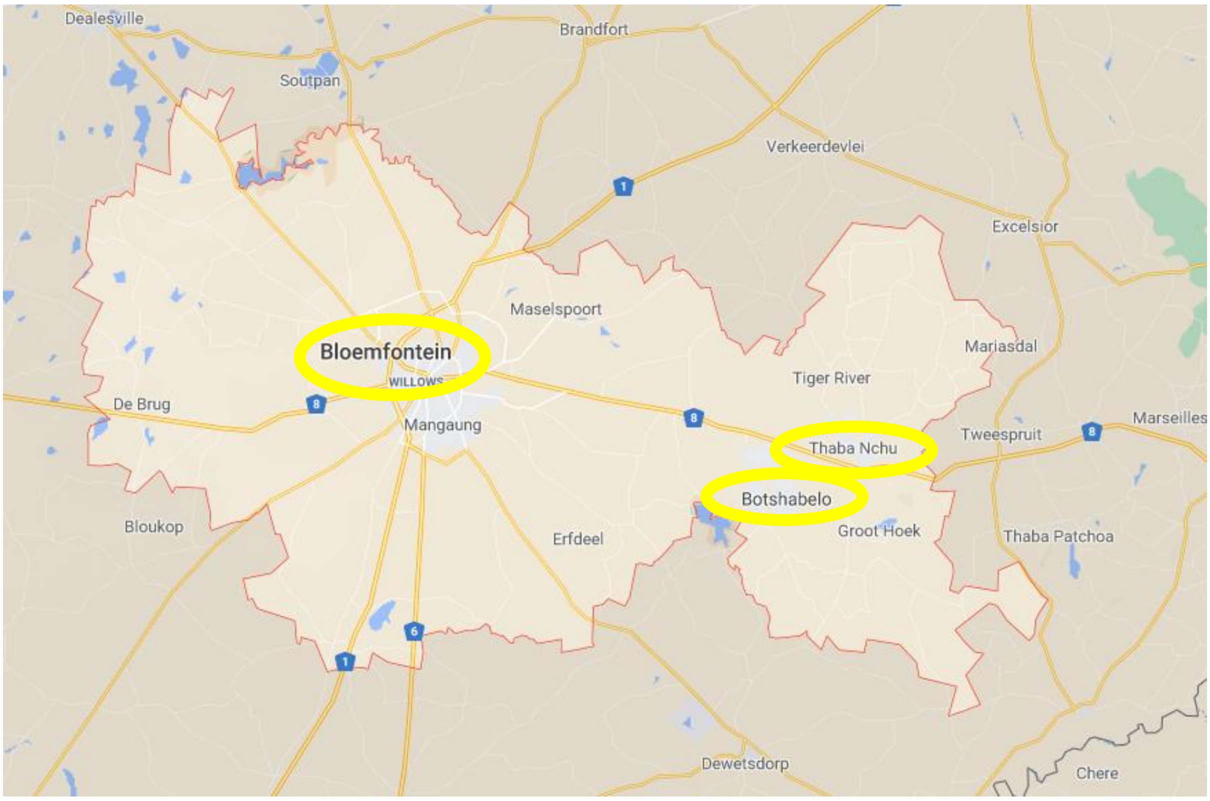

Figure 7: Mangaung Metropolitan Municipality Map showing surrounding towns (Source, Google Maps)

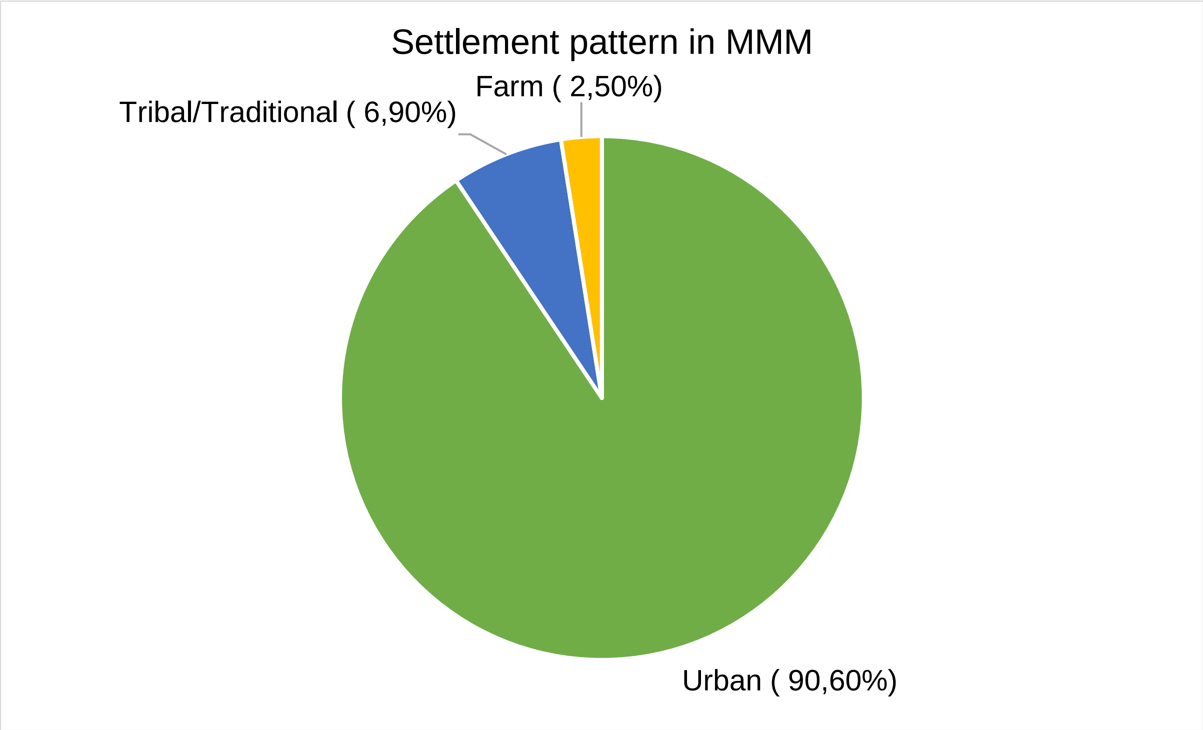

Figure 8: Settlement pattern in Bloemfontein (Statistics SA, 2011)

3.6 SPATIAL PATTERNS

Mangaung Metropolitan Municipality comprises of eight main cities/towns, which have sub areas. Bloemfontein covers the biggest area and has the highest number of households in the municipality. Mangaung area follows Bloemfontein in terms of the population, yet it only covers 35.83km², that is only 7% of the whole MMM area (Table 7). Botshabelo follows Bloemfontein, in having an area of 103.98 km², but has a smaller population compared to Mangaung area. Bloemfontein covers 48% of the total area, which is reasonable considering the population growth and number of households. Figure 10 shows the land use type in MMM, with the percentages in formal stands only in Bloemfontein, Botshabelo and Thaba Nchu. Figure 9 shows that only 3% of the total municipal area are urban areas, 97% of all residential properties are in urban areas. Farms and other types of dwellings cover the other space (IDP 2018/19).

Table 7: Cities/Town in MMM (Statistics SA, 2011)

Cities/Towns	**Area (km²)**	**Population**	**Households**
Bloemfontein	236.17	256 185	81 286
Botshabelo	103.98	181 712	50 593
Dewetsdorp	25.77	9 498	2 890
Mangaung	35.83	209 262	68 595
Soutpan	44.79	186	65
Thaba Nchu	36.39	70 118	21 792
Van Stadensrus	6.91	820	267
Wepener	36.3	1 281	447

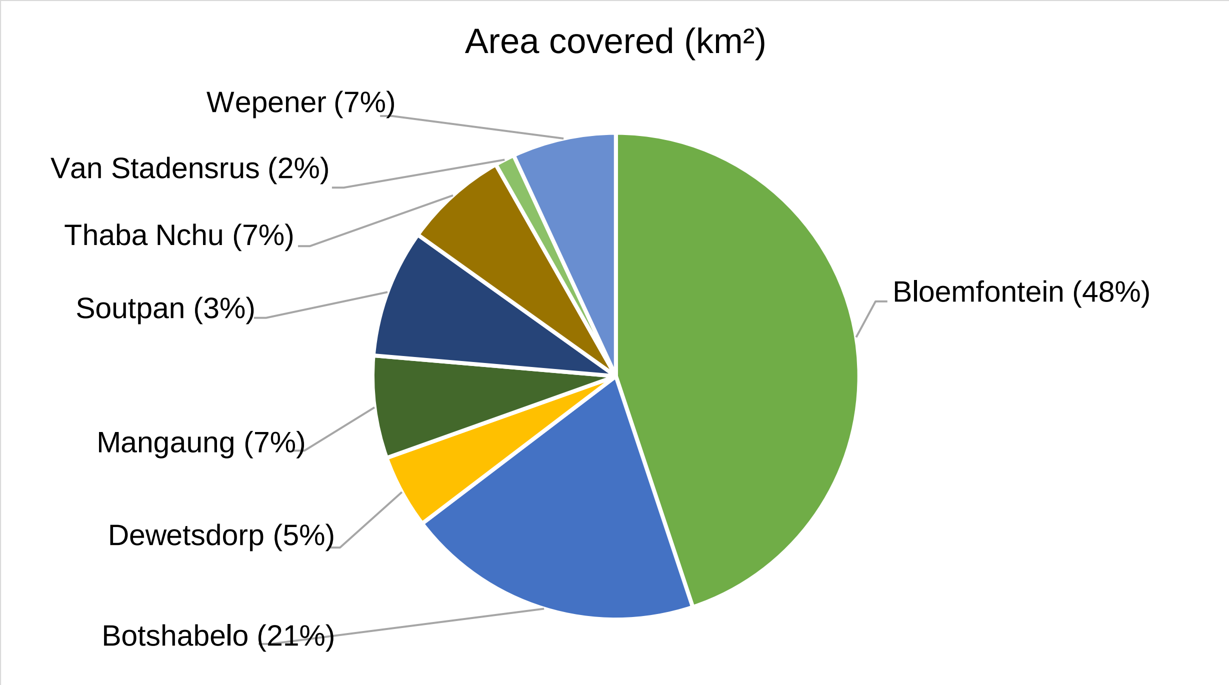

Figure 9: Percentage of area (km²) covered by cities/nearby towns (Statistics SA, 2011)

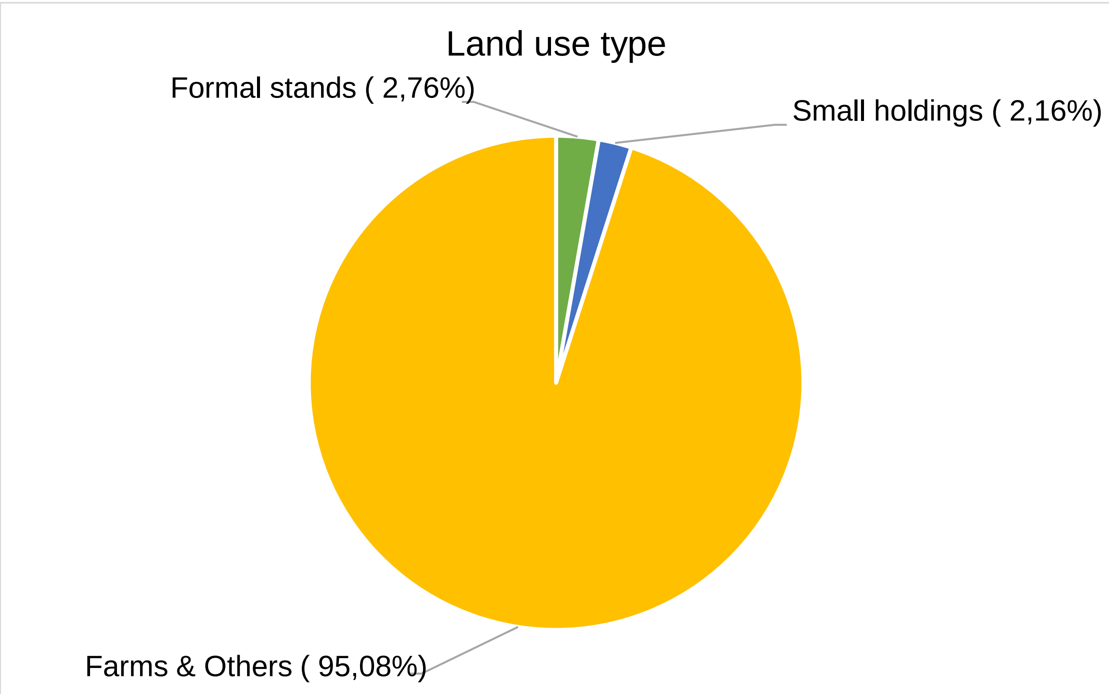

Figure 10: Land use type in MMM (Statistics SA, 2011)

3.6.1 Bloemfontein

Bloemfontein has a CBD that offers business and services, with various mixed activities facilities, two large shopping centres and three industrial areas. Bloemfontein is the most developed area as compared to Botshabelo, Thaba Nchu and other towns, with better higher education facilities and access to health care. Bloemfontein is the most profitable section of the municipal area. It is located at the centre of South Africa, being served by major roads such as the N1 which connects Gauteng with the southern and western Cape, the N6 which connects Bloemfontein to the Eastern Cape and the N8 which connects Lesotho in the east with the Northern Cape in the west via Bloemfontein. The areas surrounding the CBD have been developing, and now offer a mixed land use character. Table 8 shows different suburbs in the city of Bloemfontein and their population. Some of the suburbs having more population include these: Ashbury (11 478), Bloemfontein Central (7 578), Bloemside Phase 2 (6 594), Bloemside Phase 3 (5 249), Dan Pienaar (5 606), Fichardt Park (8 783), Grasslands (34 601), Heidedal (9 605), Langenhoven Park (11 368), Pellissier (6 129), Rodenbeck (46 566), Universitas (9 076), and Willows (6 150) having populations exceeding 5 000.

Table 8: Suburbs/areas in Bloemfontein (Statistics SA, 2011)

Suburb/Area	Population	Suburb/Area	Population	Suburb/Area	Population
Arboretum	266	Fleurdal	2 198	Noordhoek	2 128
Ashbury	11 478	Gardenia Park	1 633	Olive Hill SH	717
Baysvalley	763	Geluk SH	454	Oos-Einde	0
Bayswater	4 491	Generaal De Wet	2 627	Oranjesig	1 042
Bayswater Rural	763	Grasslands	34 601	Park West	4.07
Bloemfontein Airport	384	Grasslands SH	458	Pellissier	6 129
Bloemfontein Central	7 578	Groenvlei SH	360	Pentagon Park	2 263
Bloemfontein SP	481	Grootvlei Prison	5 586	Rayton SH	1 268
Bloemside Phase 1	3 644	Hamilton	67	Rodenbeck	46.566
Bloemside Phase 2	6 594	Heidedal	9 605	Shannon SH	1 435

Bloemside Phase 3	5 249	Helicon Heights	526	Spitskop SH	521
Bob Rodgers Park	377	Heuwelsig	2 596	Tempe	1 393
Brandwag	4 075	Hillsboro	282	Uitsig	4 313
Buitesig	529	Hilton	2 121	Universitas	9 076
Dan Pienaar	5 606	Hospitaalpark	2 923	Vredenhof SH	466
Deals Gift AH	1 067	Langenhoven Park	11 368	Waverley	2 738
Ehrlich Park	4 644	Linquinda	280	Westdene	4 117
Estoire AH	517	Lourierpark	3 177	Wilgehof	3 896
Fauna	4 576	Mandela View	854	Willows	6 150
Fichardt Park	8 783	Navalsig	2 375	Woodlands Estate	1 945

3.6.2 Botshabelo

Botshabelo is located 55km east of Bloemfontein; it has a weak CBD with the urban node designed along a linear major access route limiting the motion in a north/south direction through the centre of the area. The town is more developed on the northern parts, creating problems for the southern community, as they have to travel almost 8 kilometres to access the developed parts of the town. The area is characterised by an oversupply of school sites and public open spaces. The slow growth in development and employment opportunities are some of the factors that are forcing people to migrate out the area. Botshabelo also includes an industrial park with factories and infrastructure worth R500 Million. The current occupancy rate at the node stands at 89.54% and it employs 6 000 people. There are large open spaces that separate different residential areas, and plans for public amenities throughout the area have been planned. There is a sports stadium, which runs through town, but there are sign of overgrazing because many residents still keep cattle within the urban environment. The game reserve and the Rustfontein Dam are located towards the south with some potential for tourism. Table 9 shows all the areas around Botshabelo which follow an alphabetic method of identification, with Botshabelo F (21 259) being the most populated area, followed by Botshabelo K (15 206) and Botshabelo SP (13 043) (Statistics SA, 2011; IDP 2018/2019).

Table 9: Areas in Botshabelo (Statistics SA, 2011)

Area	Population	Area	Population
Botshabelo A	10 095	Botshabelo L	9 599
Botshabelo B	3 631	Botshabelo M	9 743
Botshabelo BA	27	Botshabelo N	8 765
Botshabelo C	12 978	Botshabelo R	7
Botshabelo D	8 398	Botshabelo S	4 490
Botshabelo E	8 752	Botshabelo SP	13 043
Botshabelo F	21 259	Botshabelo T	8 661
Botshabelo G	6 581	Botshabelo U	12 623
Botshabelo IA	106	Botshabelo V	4 594
Botshabelo J	12 429	Botshabelo W	10 725
Botshabelo K	15 206		

3.6.3 Thaba Nchu

Thaba Nchu is located 67 km east from Bloemfontein and has a more scattered development pattern, it is characterised by large stretches of communal grazing land utilised for cattle. There are 38 FDC factories with an occupancy rate of 65%. Due to the closure of many government departments and amenities, the town has little economic investment. The town has a very rich cultural history and emphasis is put on cultural tourism. The town has a casino, cultural centre, and a stadium, supplemented by sports fields and the recently completed Regional Park. Public facilities like the sanatorium, the military base, the college and the reformatory school have all closed down in Thaba Nchu (IDP 2018/19). The area that has the highest population in Thaba Nchu is Selosesha (12 358), followed by Mokwena (8 603), and Bultfontein 2 (7 115) (Table 10) (Statistics SA, 2011).

Table 10: areas in Thaba Nchu (Statistics SA, 2011)

Suburb/Area	Population	Suburb/Area	Population
Bultfontein 1	5 439	Moroka Ext	821
Bultfontein 2	7 115	Ratau	4 477
Bultfontein 3	6 001	Ratlou	4 454
Bultfontein 4	5 579	Selosesha	12 358
Bultfontein 5	3 330	Selosesha Ext 3	2 261
Flenter	100	Station View	551
Mokwena	8 603	Thaba Nchu 21	2 070
Moroka	6 916	Thabanchu 3	45

3.6.4 Soutpan

Soutpan is a very small located 52 km away from the town of Bultfontein to the north and 38km away from Bloemfontein to the south. It is widely known for the production of salt and most of its residents are employed by the salt production industry. The town has a population of 186 people, an anthropological area and a nature reserve. 5 km to the east of Soutpan is a centre called Ikgomotseng.

3.6.5 Dewetsdorp

Dewetsdorp is located 75km southeast of Bloemfontein. One attraction is the British War Graves and Monument. It has a population of 9 498 (Table 11).

Table 11: Areas in Dewetsdorp (Statistics SA, 2011)

Suburb/Area	Population
Dewetsdorp SP	833
Morojaneng	8 665

3.6.6 Wepener

Wepener is located 120km southeast of Bloemfontein and is situated next to Caledon River. There is a nature reserve about 15km south of Wepener on the R701. The town has a population of 1282 (Table 12).

Table 12: Areas in Wepener (Statistics SA, 2011)

Suburb/Area	Population
Ebenaeser	602
Wepener SP	680

3.6.7 Van Stadensrus

The town of is located 160km southeast of Bloemfontein and is one of the borderline towns on the border of South Africa and Lesotho. It has a population of 820 people.

3.7 THE CURRENT TRANSPORTATION SYSTEM

Globally, the best practice is the provision of seamlessly integrated modes of transport. These may include buses, light rail and non-motorised transport (walking and bicycles). The recent status of MMM is informed by various development priorities, which, among a few, include public transport. In order to address future developments, The MMM has prioritised sustainability and financial viability of the city; lack of spatial integration; ineffective public transport systems; climate change, and inadequate Information technology and communication. All these challenges/risks are linked to transportation in one way or the other, and the study seeks to address the issues of sustainability with the objective of contributing to the resolution of these challenges/risks. The transportation system in the whole of MMM is not fully integrated and other modes of transportation are not prioritised.

3.7.1 Road network

The National Household travel survey 2013 (NHTS 2013) revealed that Mangaung is a developing city. The highest number of trips are generated from Mangaung (91000), followed by Bloemfontein (45 454) and the Botshabelo/Thaba Nchu cluster (NHTS, 2013). Trips in Bloemfontein are mostly taken using private vehicles, whereas trips in Botshabelo/Thaba Nchu and Mangaung are mostly undertaken by walking and public transport. There are three urban nodes in MMM. Botshabelo and Thaba Nchu are located more than 55km from Bloemfontein. The primary node is Bloemfontein with different opportunities in retail, office, commercial and industrial activities. The movement in Bloemfontein is radial, with all the major routes converging in the CBD, which is the core area. Some businesses are moving towards the west. The apartheid spatial structure contributed to the segregation of middle and high-income development, expanding towards the west, while the low-income residents are developing towards the southeast. Because of this predicament, the average travel times of the different communities increase continuously. Job scarcity in Botshabelo and Thaba Nchu is not helping either, as people have to travel over 55km every day to get to Bloemfontein. Table 13 below shows different types of main roads in MMM.

Table 13: Important roads in Bloemfontein (MMM operational plan, 2016-2020)

Class 1: National Roads / Freeways	**Class 2: Arterials**
National Route N1 (connecting Gauteng to Cape Town)	Raymond Mhlaba Street (R30)
National Route N8 (connecting Botshabelo / Thaba Nchu, Bloemfontein and Kimberly)	Kenneth Kaunda Road (R700)
National Route N6 (connecting East London and Bloemfontein)	General Dan Pienaar Road
	Nelson Mandela Drive (R64)
	Walter Sisulu (N8 western extension)
	Jagersfontein / Curie / Kolbe Avenue (R706)
	Ferreira Road
	Church Street (M30 / N6 southern extension)
	Dewetsdorp Road (R702)
	Meadows Street
	Thaba Nchu Road

3.7.2 Other transportation infrastructure: Railways

Listed below are the current railway lines in MMM. They do not serve as public transportation within the Mangaung area. They are used for freight transportation and for long distance passenger transport along the Johannesburg – Bloemfontein – Port Elizabeth service, the Johannesburg – Bloemfontein – East London service and the Cape Town – Kimberley – Bloemfontein – Pietermaritzburg – Durban service.

1. The railway line from Bloemfontein to Maseru connects Thaba Nchu to Bloemfontein.
2. The railway line from Johannesburg crossing Bloemfontein to East London, crosses the Bloemfontein urban node in a north-south direction

To strengthen transportation in MMM a five-year plan was developed. Other modes of such as commuter rail are to be explored, to enable residents from nearby town such as Botshabelo and Thaba Nchu to better connect to Bloemfontein. The linkage of the rail to bus rapid transport (BRT) system and taxis will also form part of the solution (IPTN 2016/2020).

3.7.3 Modes of transportation

The transportation system in MMM consists of the following modes of transport:

Buses - Commuters from MMM use subsidised buses to commute to and around Bloemfontein every day. The buses have a set time schedule and selected routes that they follow. The buses have small tags that are used to load the number of trips to allow users to use buses without having to pay cash on every trip. These schedules are constant and, if there are delays, users do not get notifications or alerts, the only users that are notified are that are those on the main station only. The cost of usage is dependent on the number of trips a user loads on their tags.

Taxis - There are local taxis, which are minibus taxis, passenger cars that are used as taxis, and long distance taxis whose destinations include Botshabelo and Thaba Nchu. These taxis do not follow any type of schedule. They are always moving in/out/around the city until late at night. The local taxis start at a minimum amount of ten rand (R10) per trip; those going to Botshabelo and Thaba Nchu start at twenty-five rand (R25) per trip.

Railway - There is no commuter rail around MMM; the available railways are used for long distance travel and freight transport.

Walking and Cycling – Residents of Mangaung and Bloemfontein have the option to either walk or cycle to their desired destination, due to realistic distances. People from other towns/area can only walk/cycle within their areas, due to long distances to Bloemfontein. This option poses major limitations for them.

There are pavement sidewalks, pedestrian bridges, and pedestrian crossings in intersections. Nonetheless, these pedestrian facilities are not much of a priority in the city. Bloemfontein weather is extreme during summer and winter; there are no shades that are provided for pedestrian protection.

3.7.4 Public transportation system

The public transportation facilities around MMM predominately consists of minibus-taxi ranks and bus facilities. Interstate Bus Line (IBL) provides the subsidised public transport between Bloemfontein and Thaba Nchu, Botshabelo, Mangaung and

Soutpan. The distribution is operated from Central Park Terminus. The services are operated by 214 buses (203 peak and 11 spare buses). There are three taxi associations, which provide paratransit commuter services across the MMM. The taxi association covers 201 routes, with over 3 000 vehicles.

3.7.5 Challenges

Currently the city's transportation is based on the subsidised Interstate Bus Line (IBL) buses, taxis, minibus taxis, and metered (BEPP, 2017/18). Bloemfontein ranked number 470 worldwide, with 16.1 hours spent in traffic per year. Bloemfontein is the economic hub of the entire province, and people from surrounding area travel long distances every day to reach their different destination. The public transportation is not integrated, reliable, efficient, and cost effective. The study of the four cities (Durban, Cape Town, Pretoria and Johannesburg) revealed that these cities have multimodal system, public transportation system in terms of BRT, local and metro rail system. However, the roads of the cities are congested, leading to loss of valuable time. The use of private vehicles dominates in the city and this is leading to increased emissions in the city. It is evident that alleviation of traffic congestion is not only dependant on public transportation system such as BRT system and metro rail. Therefore, in order to reach sustainability solutions such as use of ICT during people's travel and socioeconomic activities need to be considered.

3.7.6 Future proposals

To successfully achieve a more convenient and cost effective integrated public transportation network, the municipality plans to improve residents' quality of life by making sure that the IPTN focuses safety, security, convenience, affordability and socially equitable by providing a fully integrated public transport network .According to the Spatial Development Framework (SDF), there is a proposal for a railway upgrade connecting Botshabelo to the Thaba Nchu-Bloemfontein Railway line section.

3.8 CONCLUSION

This chapter has focused on highlighting the current profile of MMM, prioritising the link between Bloemfontein and other towns/areas. Bloemfontein is the main contributor to the development of the MMM and the province as a whole, it is therefore vital for the planners to be prepared as there is an increase in urban sprawl, with anticipated population growth in the future. The current transportation systems are not reliable or efficient enough to contribute to sustainability and there is a need for integrated public transportation prioritisation in the city to better meet the needs of the users. It is argued that technological advancements such as ICT should be integrated in the systems to better manage the manoeuvrability of the users and to make sure that the introduced solutions do alleviate the current challenges the city is facing. The chapter that follows will focuses on the methodology that was followed in the study, highlighting the importance of the different roads and intersections surveyed.

CHAPTER 4: METHODOLOGY

4.1 INTRODUCTION

Research philosophy, which explains the way data about a particular aspect should be gathered, analysed and used, is the basis of every research. The study follows a quantitative approach through a positivist paradigm to attempt to formulate solutions on integrating ICT on road transportation, prioritising public transportation as a way of achieving sustainable road transportation. The study was conducted through primary and secondary data collected from different sources; surveys and questionnaires were compiled and analysed. The chapter details all the steps and methods followed to lead to policy analysis, and the development of strategic sustainable road transportation guidelines.

4.2 RESEARCH METHODOLOGY OUTLINE

The investigation followed a systematic methodology (Figure 11), which is shown in section 4.2.1 and the steps involved are listed below.

4.2.1 STEPS USED IN THE RESEARCH

Step 1: Problem identification, literature review, setting of objectives and hypothesis and research design

Step 2: Delineation of study area and selection of sample survey area and roads

Step 3: Collection of data

Step 4: Data analysis

Step 5: Application of empirical models

Step 6: Results and discussions

Step 7: Findings and inferences

Step 8: Policy analysis and evolving of strategic sustainable road transportation guidelines

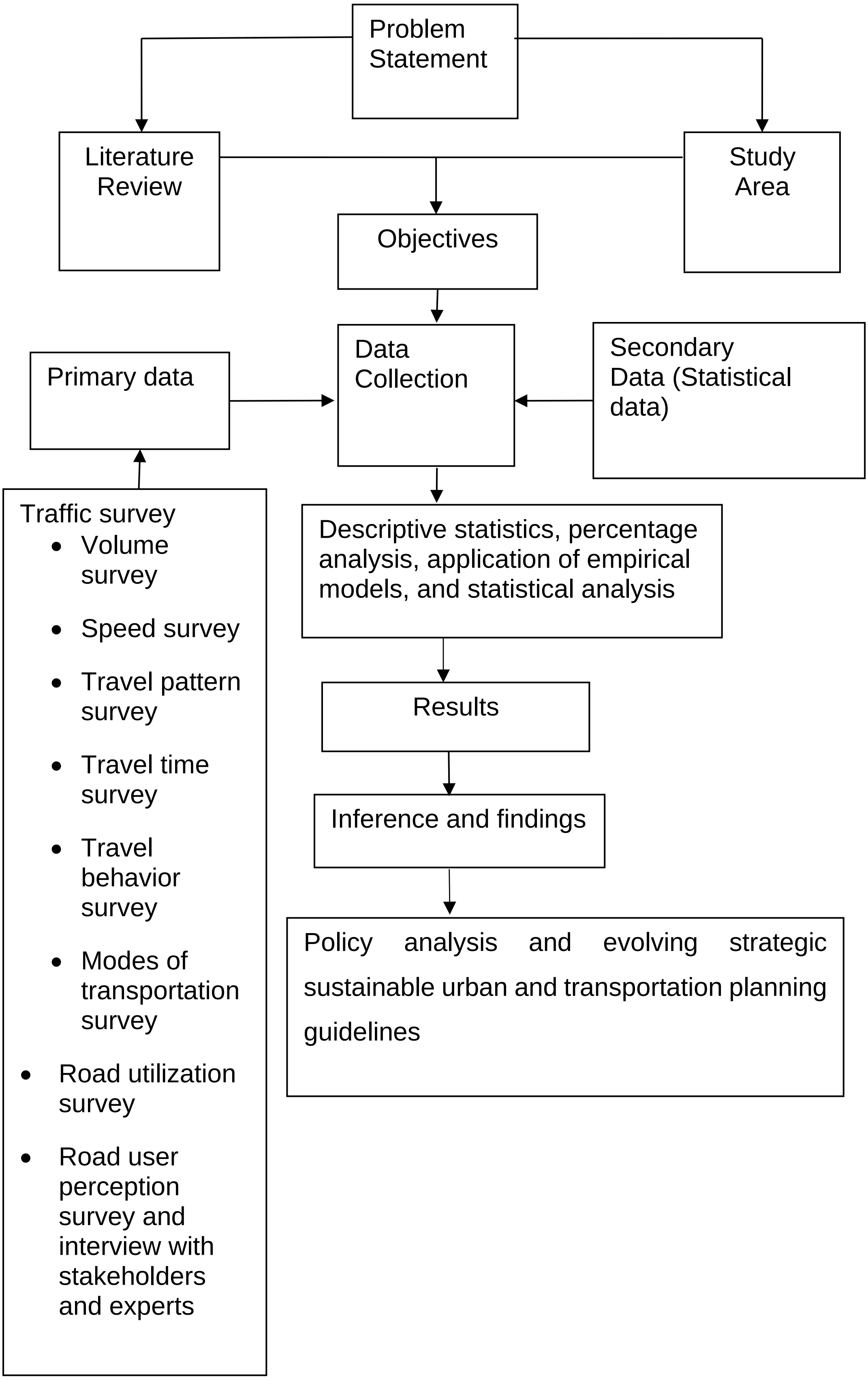

Figure 11: Methodology chart

4.3 DATA COLLECTION

Data for this investigation was collected from both primary and secondary sources. Primary data was collected at the grassroots, level such as roads and selected locations of the city, by using relevant survey methodologies. The secondary data, in terms of structured statistical data and other relevant information such as policies, rules, regulations, and standards, were collected from archival records and reports of authentic and established organisations located at the city, provincial and National level. All data collected from questionnaires will be placed under locked key and the names of participants will not be disclosed.

4.3.1 PRIMARY DATA

The data was collected in the city of Bloemfontein through traffic surveys and road user surveys (online surveys). The collection of primary data is essential as it gives a clear understanding of what the current scenario in the transportation system is, as well as investigating how different stakeholders and users would react to certain changes in their cities.

4.3.1.1 TRAFFIC SURVEY

Traffic survey was conducted by using standard templates of both the traffic count and road user surveys. Traffic volume, speed and mode of travel surveys was conducted by using standard traffic survey procedures and templates on selected roads of the study area (Kadiali, 2008; Richardson, Ampt & Meyburg, 1995; Talpur, Napiah, Chandio & Khahro, 2012). Travel pattern surveys in the form of types of vehicles, volume, speed, delay time and travel times; and travel behaviour survey were conducted among the road users by considering the travel parameters such as origin, destination, route choices and activity patterns of the road users.

4.3.1.1.1 SELECTION OF TRAFFIC NODE/INTERSECTIONS

For the purpose of this study, six (6) intersections and 10 roads were chosen. The intersections investigated were some of the most important intersections because of the land use either around them, or because of where they are situated around the city. Some of the challenges that led to the survey of these intersections includes congestion during peak hours; investigation of the type of modes of transport widely used around the city and checking the severity of other challenges such as the turning radius for trucks, as these intersections are important because of where they are situated around the city. The traffic survey data were collected from the following intersections: Nelson Mandela Drive – Furstenberg Road intersection (I1); the Kellner street – General Dan Pienaar Drive/Parfitt Avenue intersection (I2); the Harry Smith street/Union Avenue – Aliwal Street/Milner road intersection (I3); the Alexandra Avenue – Oos Burger/Raymond Mhlaba Street intersection (I4); the Fort Hare Road – Hamilton Road intersection (I5); and the Victoria Road – Walter Sisulu Road/Parfitt Avenue intersection (I6). Some of these intersections are not only important because of where they are situated or the land use around them, but they are also important because of the other roads and intersections they are connected to. Different roads that were surveyed include the following Nelson Mandela Drive; Aliwal Street; Raymond Mhlaba; Oos Burger Street; Fort Hare Road; Harvey road; President Boshof Street; Parfitt Avenue; Kolbe Avenue; President Avenue; General Dan Pienaar Drive. These roads were surveyed because they lead to the important intersections that were also surveyed and most of them are situated either at the entrance or exit point of the city. Other roads such as Nelson Mandela Drive, Aliwal Street, Raymond-Mhlaba, Oos Burger Street, Fort Hare Road, Harvey road, President Boshof Street, Parfitt Avenue, Kolbe Avenue, President Avenue and General Dan Pienaar Drive were chosen because of the land use around them, leading to them carrying high volumes of traffic, especially during peak hours.

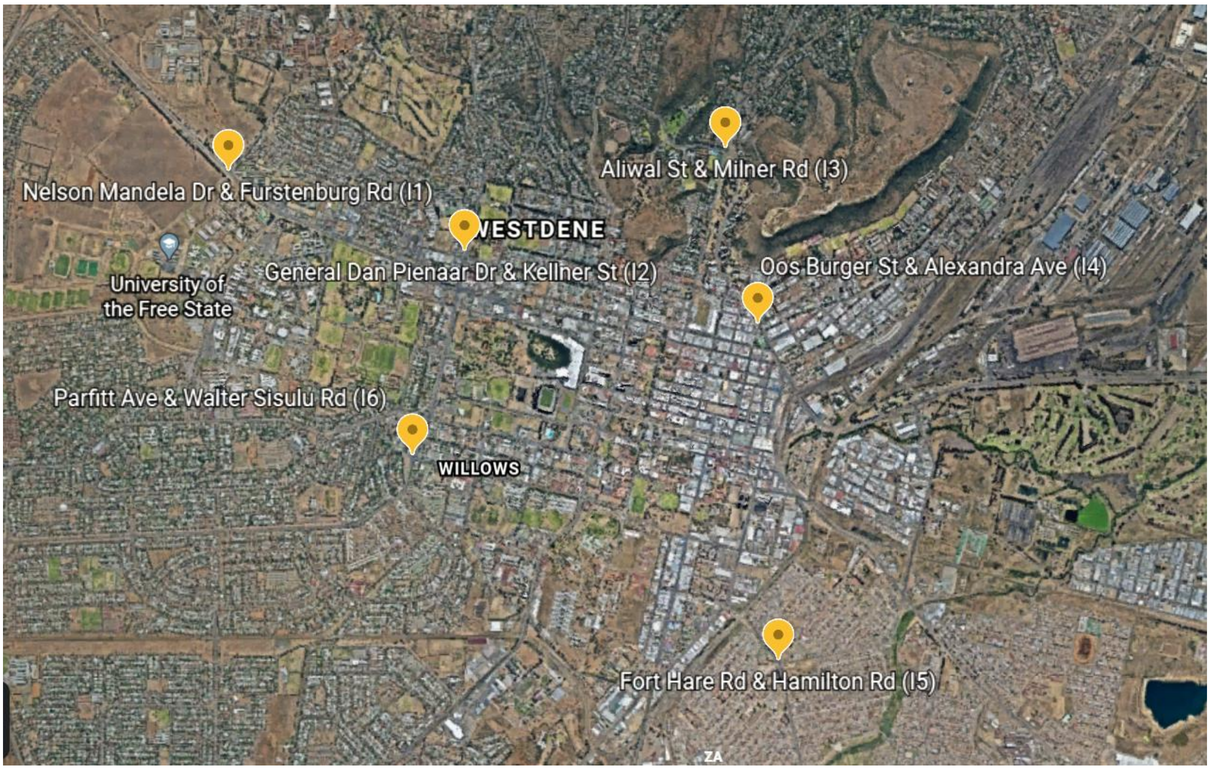

Figure 12: Intersections of Bloemfontein city

(Source: Google Earth)

4.3.1.1.2 TRAFFIC VOLUME SURVEY

A template was used to collect the data needed. The template included the types of modes of transport on the roads and at the intersections. These modes comprised of buses, cars (used as taxis) motorcycles, mini buses, trucks, taxis, bicycles. The traffic count was conducted for seven days (7) continuously, from 05:00 am to 20:00 pm; this duration was chosen because it is around these hours people normally commute to/from their workplaces. The period outside the stipulated period was not considered because of the insignificant amount of traffic volume observed on the roads during these periods. The volume was recorded on an hourly basic. The characteristics of the various intersection surveyed are discussed in the following sections.

Nelson Mandela Drive – Furstenberg Road intersection (I1)

Nelson Mandela Drive (N8) and Furstenberg Road are two of the most important roads in the city of Bloemfontein. The intersection is surrounded by suburbs such as Westdene, Brandwag and Universitas. The surrounding land use leads to the busy intersection situated 29°06’09”S 26°11’05”E, connecting with other important roads such as the N1 and R64 to allow traffic in and out of Bloemfontein. This intersection is a point of entrance and exit to Bloemfontein; therefore, there is a high traffic volume of cars and trucks. The intersection is connected to a dual carriageway that helps with the free flow. Moreover, the majority of traffic volume incudes passenger cars, taxis, and passenger buses. This is because the land use around the intersection and the fact that this intersection is connected to roads that lead to the central business district. Important buildings such as a shopping mall and other business centres are also located around the intersection. It is observed that large volumes of vehicles pass through this section both in the morning and in evening hours of the day; it is apparently congested.

Figure 13: Nelson Mandela Drive–Furstenberg Road intersection (I1)

(Source: Physical road and traffic system survey, 2017 & 2019 conducted by the investigator)

Kellner Street – General Dan Pienaar Drive/Parfitt Avenue intersection (I2)

This intersection is situated at 29°06’29”S 26°12’09”E at the corner of Parfitt Avenue and Kellner Street; it connects with General Dan Pienaar Road, which is also a dual carriageway. The roads and the intersection experience high volumes of traffic due to the active land use around it, and this includes the fact that the roads also lead to the centre of the city. The land use around this intersection includes Mimosa Mall, Medi-clinic, schools and other small businesses. The land use around this area leads to congestion during peak hours. Passenger cars, taxis and buses frequent this intersection and it is always busy, with many delays in the morning and in the afternoon. This intersection also connects with a major road that leads towards the city. Heavy vehicles and passenger vehicles also frequent this intersection.

Figure 14: Kellner Street – General Dan Pienaar Drive/Parfitt Avenue intersection (I2)

(Source: Physical road and traffic system survey, 2017 & 2019 conducted by the investigator)

Harry Smith Street/Union Avenue – Aliwal Street/Milner road intersection (I3)

This intersection is one of the most important nodes of the city, as it connects with R700 road, which connects to the N1. The intersection is at 29°06’04”S 26°13’20”E at the corner of Aliwal Street and Union Avenue. The intersection is surrounded by places like Waverley, Arboretum and Naval Hill. The intersection is connected to Aliwal Street that is a dual carriageway to assist with the free flow during peak hours. Heavy vehicles and passenger vehicles frequent this road as it connects to the city and the surrounding areas. The land use around this intersection includes several schools nearby, clinical and medical services, parks, coffee shop and restaurant. The land use and consequent urban functions make the intersection and the roads congested during peak hours.

Figure 15: Harry Smith Street/Union Avenue – Aliwal Street/Milner road intersection (I3)

(Source: Physical road and traffic system survey, 2017 & 2019, conducted by the investigator)

Alexandra Avenue – Oos Burger/Raymond Mhlaba Street intersection (I4)

The intersection is situated at 29°06’45”S 26°13’29”E, and it is surrounded by two suburbs, which are Hilton and Arboretum. The land use around this intersection includes car parts stores, warehouses and Econo Foods. Oos Burger Street leads directly to the centre of the city and leads to Bloemplaza, which is a shopping complex in the central business district. The intersection connects with road R30, which later connects with the N1, which is a national road. This road experiences a high flow of heavy vehicles because it also leads to the exit of the city. The intersection is part of the connector to the national route, therefore the double lanes helps with the free flow. Land use contributes to most of the flow, as it is closer to working and buying stations for people, and there are residential areas. The intersection is also mostly congested with private vehicles, as there is not an efficient public transportation for the residents and workers.

Figure 16: Alexandra Avenue – Oos Burger/Raymond Mhlaba Street intersection (I4)

(Source: Physical road and traffic system survey, 2017 & 2019, conducted by the investigator)

Fort Hare Road – Hamilton Road intersection (I5)

This intersection is situated at the corner of Fort Hare Road and Hamilton Road at 29°08'05"S 26°13'35"E. It connects with Harvey Road and Fort Street, and offers direct access to the Batho location. The intersection and the immediate road are important because they are double lanes, which is an indication that the road is made to assist with free flows during peak hours. Batho Location and Oranjesig surround it. The intersection is very busy due to the active land use around it, and the road that leads to the centre of the city. The land use around this road includes Home Affairs Department, stop shop Engen, hospital, schools, police station, community hall and Twin City Mall. Taxis and private vehicles frequent this intersection. Mornings are highly congested and turning vehicles are experiencing long waiting periods. However, the vehicles that are on the straight movement lanes, manage to move well even during peak hours without having to experience long waiting periods.

Figure 17: Fort Hare Road – Hamilton Road intersection (I5)

(Source: Physical road and traffic system survey, 2017 & 2019, conducted by the investigator)

Victoria Road – Walter Sisulu Road/Parfitt Avenue intersection (I6)

This intersection is situated at the corner of Parfitt Avenue and Walter Sisulu Road(29°07’16”S 26°11’55”E). It connects with Victoria Road and President Avenue. Heavy vehicles and passenger vehicles generally pass through this road, as it is a connecter to national roads like the N1 and N8. Commercial and business activities, residential areas and flats mostly surround the intersection

Figure 18: Traffic scenario on the roads of the city Bloemfontein

(Source: Physical road and traffic system survey, 2017 & 2019, conducted by the investigator)

4.3.1.1.3 ROAD USER SURVEY

The study area was chosen as the Bloemfontein city and the respondents of the road user surveys were residents from the city’s suburbs. Data was collected from residents who own/use their private vehicles for daily trips. Questionnaires from either residents who use public transportation or those who use walking as a mode of transport were circulated. The objective was to collect data for different modes of transport, so that a true representation of the current transport system around the city can be achieved.

A road user perception survey was conducted by using pretested questionnaires and following the random sampling survey method. Semi structured interviews were conducted among the road users for this purpose (Lambsdorff, 2006; Kadialli, 2008; Nardo, Saisana, Saltelli, Tarantola, Hoffman & Giovannini, 2005; Richardson, Ampt, & Meyburg 1995; Saltelli, 2007; Talpur et al. (2012). The sample size consist of 305 respondents who live in different suburbs around the city of Bloemfontein, which comprise the following: Arboretum; Bainsvlei; Batho; Baysvalley; Bayswater; Bloemanda; Bloemfontein Central; Brandwag; Ehrlich Park; Fauna; Grassland; Heidedal ; Heuwelsig; Langenhoven Park; Mandela View; Namibia; Navalsig; Noordhoek; Pellissier; Phahameng; Phelindaba; Rocklands; Turflaagte; Uitsig; Universitas; Westdene; Wilgehof ; Willows; and Woodland Hills. The suburbs were chosen randomly, but the objective was to get a sample from almost all the suburbs to ensure that a better understanding of the transportation system around the city can be analysed. The confidence level that was considered was 95% for a population of 256 185, and therefore 305 respondents would be an adequate sample size for a confidence interval of six. Of the 305 respondents, 60% were male and 40% were female. The respondents represent different racial groups in varying percentages such as: Asian (3%), African (67%), White (15%), Indian (3%), and coloured (12%). Educational levels of the respondents consisted of tertiary level (75%), secondary school education (20%) and primary education (5%). Some of the respondents, who were still studying in various higher education institutions, were counted with the respondents with tertiary qualification. The reason for this is that this part of the survey is highly linked with whether people of the city of Bloemfontein will be able to use ICT in their cell phones apps and understand real time information when shared. Information such as travel time, travel pattern, travel behaviour, and modes of transport are the major parameters, which were collected through the questionnaire survey. Parameters such as origin to destination, reasons for travel, and the number of activities performed were also collected through questionnaires. Besides, interviews with other stakeholders and experts such as transportation planners, Municipal officials, decision makers, and academicians, were conducted through non-structured interviews.

Table 14: Respondents' demographic attributes

Respondent category	Number	%	Educational level	Number	%
Male	183	60	Primary education	15	5
Female	122	40	Secondary school education	61	20
			Tertiary level	229	75

4.3.2 SECONDARY DATA

Secondary data relevant to this study was collected from a variety of sources, such as published and unpublished literature, documents from and relevant organisations such as Mangaung Metropolitan Municipality, Department of Road Transportation, Free State and Municipal Demarcation Board. Statistical secondary data was also collected from Statistics South Africa.

4.4 DATA ANALYSIS

The analysis of data was done by using statistical methods and empirical modelling. Below is the list of objectives and a discussion of how the analysis was done to satisfy the objectives.

Objective	Data	Data analysis and modelling approach
To assess the current scenario of road transportation system in terms of trip generation, traffic volume, speed, modes of transportation,	Primary data and secondary data	Traffic volume in roads and intersections (LOS), distance travelled per mode of

travel pattern and travel behaviour, vehicular distance travel (Vehicle – kms) and the current use of ICT in Bloemfontein city.		transport, speed data, travel time and travel delays (Application of empirical modelling and tabulations) Descriptive statistic and percentage analysis were used for the analysis of the current use of ICT in Bloemfontein city.
To examine the land use, urban function, road transportation inter-linkage in the city	Primary data and Secondary data	Investigation of different land use around the city, and how it influences traffic flow and route choice. (Descriptive statistic and percentage analysis)
To evaluate the sustainable road transportation indicators, such as congestion (LOS), travel time delay, use of public transportation, and carbon emissions level in the city.	Primary data and Secondary data .	Through questionnaire data, about trip generation from different suburbs (regression analysis and tabulation)
To establish the relationships between road transportation indicators such as use of public transportation, congestion and carbon emissions and evaluate their performance under different ICT usage levels.	Primary data and Secondary data	Queue length, LOS, travel delay, correlations and significance test (t test) (Correlations, tabulation and empirical modelling) Tabulation of use of ICT, for different purposes and how that influence trip generation

		around the city. (regression analysis and tabulation)
To evolve a set of plausible strategic urban and transportation planning guidelines to attain sustainable road transportation in the city.	Formulated from Primary data and Secondary data	Deductions were made from the analysis of p tests and results from correlations, and possible guidelines developed.

4.5 MODEL DEVELOPMENT, VALIDATION AND APPLICATION

Non-linear regression models (power and logarithmic) were developed and used to analyse and comprehend trip generation and influence of different urban functions, demographic, road transportation variables and ICT use on sustainable road transportation of the study area. Before applying the model, the validity of the model was checked by structure verification, checking the mathematical equations and behaviour test. The developed and validated model was applied to develop simulated scenarios under different conditions, so as to understand how the different urban functions, demographic variables road transportation variables and ICT use influence sustainable road transportation in the study area. Besides, empirical models such as Level of Service (LOS) were used to measure congestion on the roads of the study area. Carbon emissions were measured by using a model based on trip generation, vehicle kilometres travelled and carbon emissions from the vehicles.

4.5.1 APPLICATION OF EMPIRICAL MODELS

This section aims to highlight the empirical models, which were adopted to analyse the information gathered. The justification of the model and purpose is stated in section 2.6.

4.5.1.1 LEVEL OF SERVICE (LOS)

LOS = V/C or AADT/C …………………………………………………...Equation 1

Where:

V= total volume of vehicles on the road (lane)

AADT=Average annual Daily Traffic

C= Capacity of the roads (lanes)

4.5.1.2 TRAVEL TIME

TT= (Peak period travel time - Free flow travel time) = (Free flow travel; speed/ Peak period travel speed*)*………………………………………………………..Equation 2

Where:

TT= Travel time

4.5.1.3 Queue length at junctions (Ni)

Ni= (Di*Qi)/3600 ....Equation 3

Where:

Di = Average delay of vehicles in lane in units of seconds/vehicle, excluding acceleration and deceleration delay

Qi = Arrival flow rate in lane in units of vehicles/hour/lane

4.6 RESULTS

The results from different statistical analysis and model simulations, including the information from the surveys were discussed and analysed to satisfy the aim, and objective of the investigation.

4.7 INFERENCES AND FINDINGS

Inference were drawn from the results of the various analyses.

4.8 STRATEGIES AND GUIDELINES

Based on the results, discussions and inferences of this investigation, a set of policy interventions was developed and strategic guidelines to attain sustainable road transportation in the study area

4.9 CONCLUSION

This chapter's objective was to detail the methodology followed for the study, highlighting the types of data collected and the software used to analyse the data. It has addressed the different models adopted and how they were validated, to their ultimate use for the development of new models and strategic guidelines. The next chapter provides the analysis of the data collected from both primary and secondary sources, and the modelling and development of simulated scenarios.

CHAPTER 5: RESULTS

5.1 INTRODUCTION

The primary and secondary data collected from different sources, surveys and questionnaires was compiled and analysed and all the findings and results are discussed in this chapter under the following headings:

- Demographics
- Analysis of sustainable road transportation indicators of Bloemfontein
- Scenarios of information and communication technology
- Linkage between road sustainability parameters and use of ICT
- Linkage between ICT and carbon emissions
- Hypothesis testing
- Conclusion.

5.2 DEMOGRAPHICS

The demography of Bloemfontein city was conducted based on the parameters such as population, gender, and age. Analysis of demographic characteristic is essential to understand the age, gender, population structure, occupation structure of the people, which largely influence their behaviour. This analysis is based on 305 respondents of the questionnaire survey conducted, in the city of Bloemfontein. The analysis of the demographic information was used to better understand the various demographic characteristics such as age, gender, occupation, and income of the city. The income classification was used in the regression analysis, to comprehend how income affects trip generation and travel distance.

5.2.1 POPULATION

The population pyramid is made up of 305 respondents who took part in the survey. 40% of the respondents were females and 60% were male. The pyramid shows that the highest number of respondents were between ages 25-34. The number of people above the age of 55 was 35. This information shows that most of the respondents are employable and, because of fairly low age, the adaptability of ICT integration in transportation will be easier.

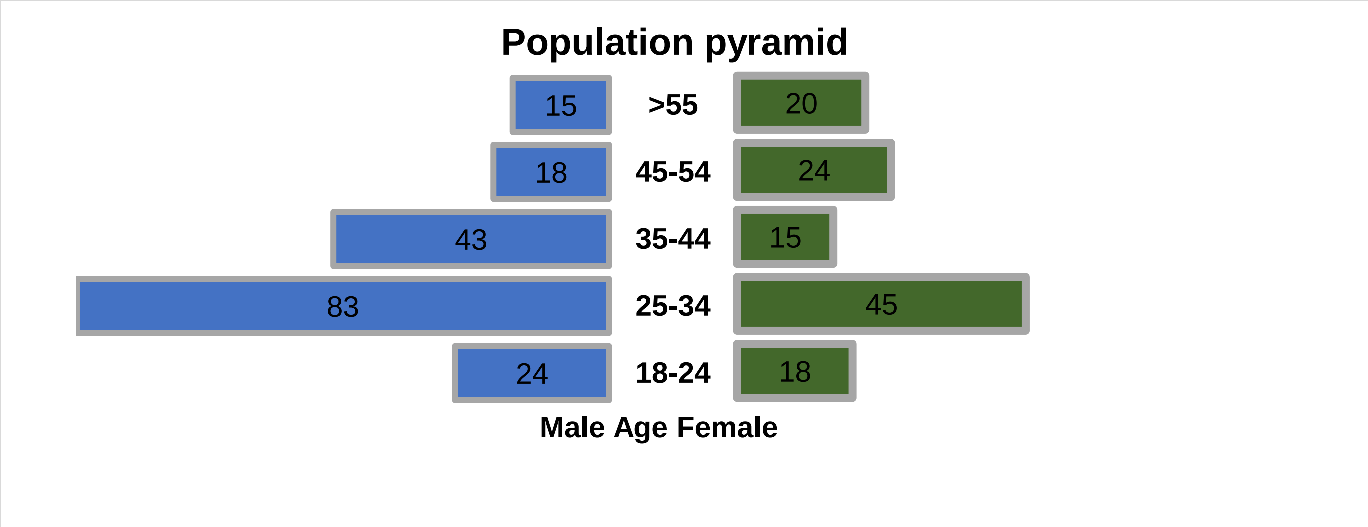

Figure 18: Population pyramid by age in Bloemfontein (Source: Primary survey, 2017)

5.2.2 GENDER

Gender is an important indicator of characteristics of the employable population as well as people who would need facilities for movement. Figure 19 presents the gender breakdown obtained from the primary survey. The survey revealed that 60% of the respondents were male and 40% were female.

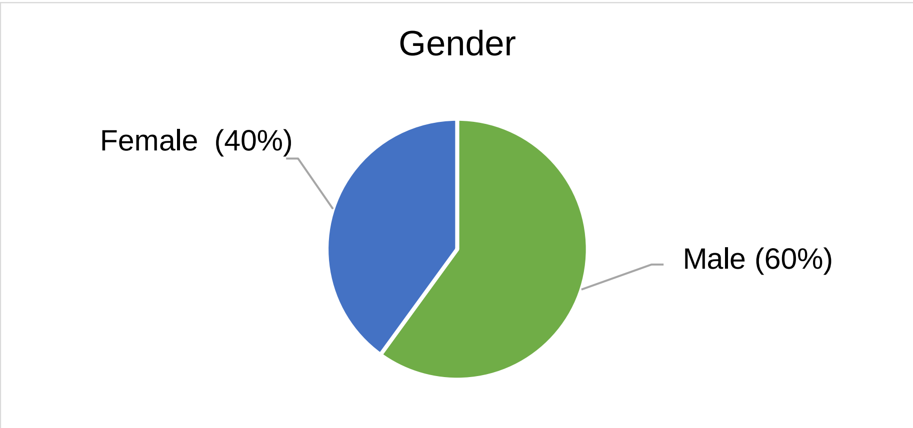

Figure 19: Population according to gender in Bloemfontein (Source: Primary survey. 2017)

5.2.4 EDUCATION

Educational level is also linked to employment and thus indirectly related to income as well as transportation needs of people. Figure 20 presents the educational level of the people in the city as observed from the survey. It is found that the majority of the surveyed have either secondary (60%) or tertiary education (35%). Consequently, most of the people are expected to be employable and thus need transportation facilities.

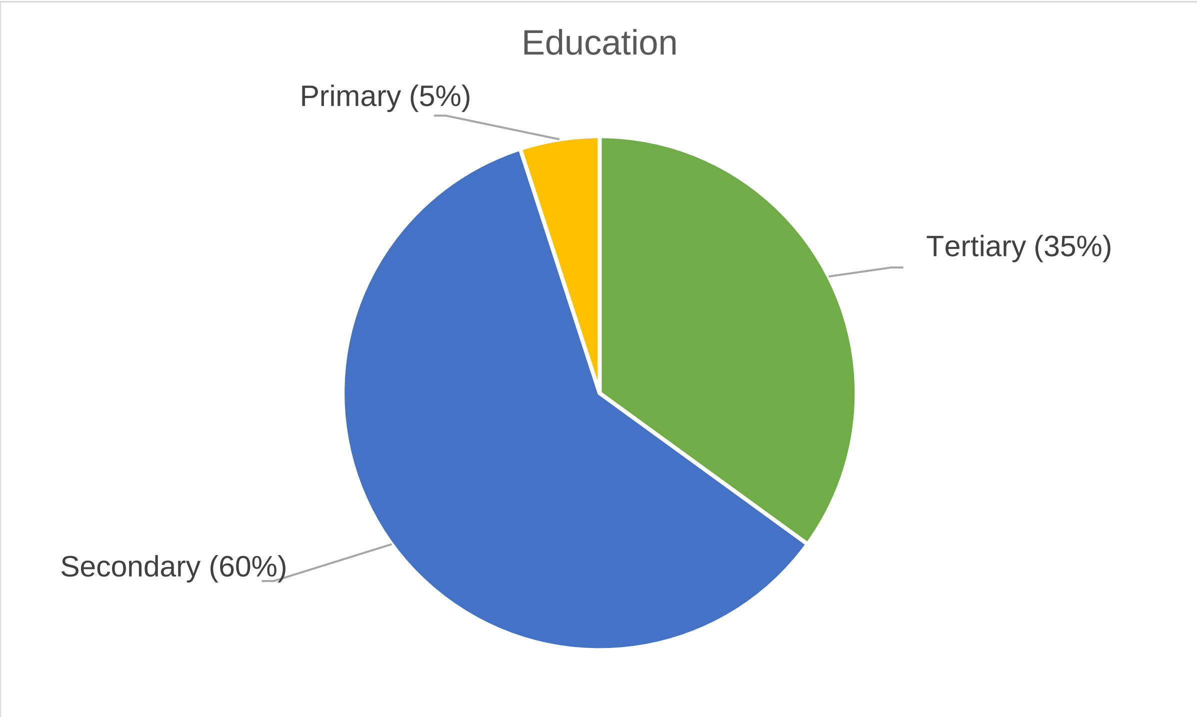

Figure 20: Education statistics for questionnaire respondents

5.2.4 OCCUPATION

Occupation categories in a city are important as they indicate different categories that have to be catered for in transportation. It also helps in forecasting the generation of trips, because, if the movement of a group of people can be forecasted precisely, then better facilities can be provided to suit the needs. Figure 21 shows the occupation categories of the respondents. The figure shows that 18% of the respondents were unemployed, 6% in accountancy, 6% in teaching and education, 5% are entrepreneurs, 5% in construction and building, 5% in retail, 4% in IT, 4% in sales, 3% in engineering, 3% in healthcare, 3% in import and supply chain, 2% in financial services, 2% in hospitality, 2% in management, 2% in property, 1% in consumer goods, 1% in Human resource and recruitment, 1% in investment and banking, 1% in management consulting, 1% in public services, 1% in science and research and the rest (18%) of the respondents were involved in others. The spread in categories show that, since the majority of the people are employed in different service activities, they are expected to travel to work in the morning and return to home in the afternoon. Consequently, the trips by the employees are generated both in the morning and during the afternoon when they go back to their respective destination. This indicates that the transportation system has to be available and reliable during these pick hours.

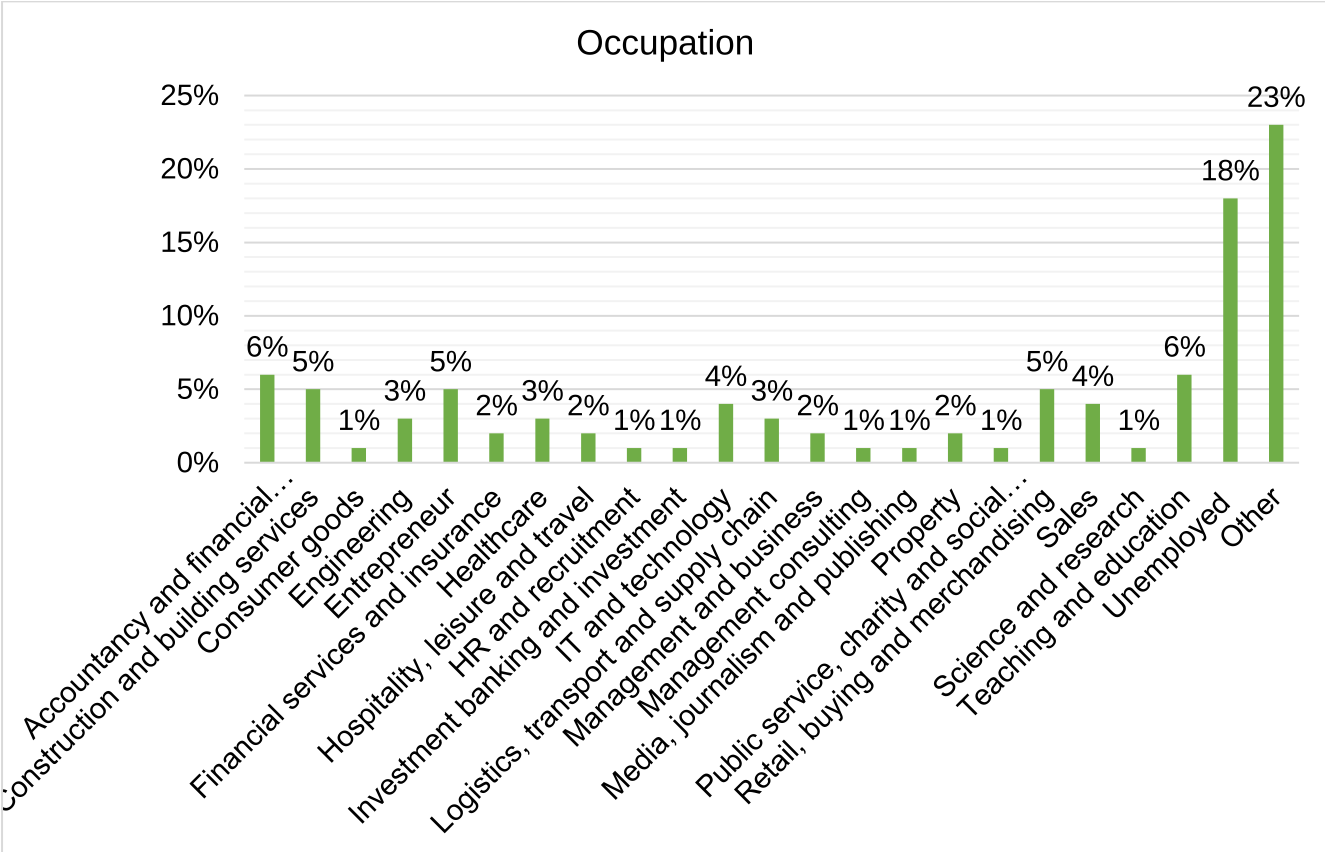

Figure 21: Occupation statistics for questionnaire respondents

5.2.5 INCOME

Figure 22 presents the annual income scenario of the people of Bloemfontein as obtained from the survey. The annual income levels of people were categorised under nine categories at a uniform difference of R50 000 such as R 0 - 50000, R50 000 – 100 000, R 100 000 – 150 000, R150 000 – 200 000, R 200 000- 250 000, R250 000-300 000, R300 000 – 350 000, R 350 000 – 400 000, and > R400 000. It is revealed that 35% of the respondents earn between R0 - R50 000, followed by 19% who earn between R50 000 - R100 000. 18% of respondents earn between R200 000 - R250 000. 7% earn between R100 000 - R150 000. The other 6% earn between R250 000 – R300 000, 7% earn between R200 000 - R250 000. The respondents who earn above R400 000 constitute 4% and the lowest were the groups of people earning between R350 000 - R400 000 and R300 000 - R350 000, constituting 2% and 3% respectfully. The findings reveal that the majority of people need reliable and cost effective transportation systems in order to travel to and from work.

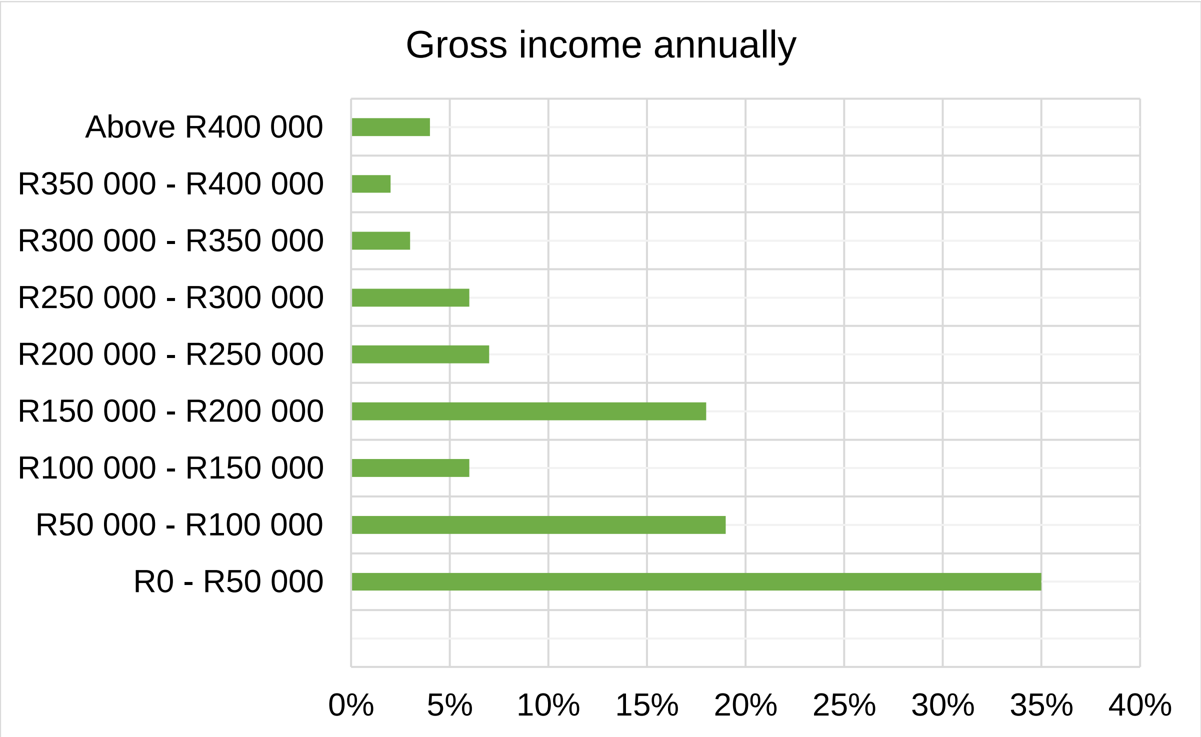

Figure 22: Gross annual income of people surveyed in Bloemfontein (Source: Primary survey 2017)

5.3 ANALYSIS OF SUSTAINABLE ROAD TRANSPORATION INDICATORS OF BLOEMFONTEIN

In this section, the analysis of the sustainable road transportation indicators of Bloemfontein city is presented. The indicators that were analysed and discussed include physical and geometrical parameters of the roads, and traffic related parameters such as travel pattern, trip generation, travel time, travel delays, current transportation systems, and congestion.

5.3.1 PHYSICAL AND ROAD GEOMETRY PARAMETERS

This sub-section focused on the characteristic of the roads and the intersections. This information is essential to understand the current scenario on the roads and challenges that drivers are facing.

5.3.1.1 CHARACTERISTICS OF ROADS

Table 15 presents the characteristics (physical and road geometry parameters) of the roads surveyed in Bloemfontein. The characteristics were aligned according to the definitions of the TRH26 (2012) (Appendix A).

The characteristics of the roads surveyed as discussed below:

- The roads surveyed are moving either away or into the city. They are classified according to either northern, southern, eastern or western direction.
- The majority of roads surveyed have two lanes, except Nelson Mandela Drive, Aliwal Street and President Boshof Street.
- The width of the road ranges between 6.4m to 10.8m depending on the number of lanes.
- The lane width ranges between 3.0m to 3.7m.
- The sight distance ranges from 100m to 200m.
- The road curvatures are gentle for all the roads.
- Some of the shoulders are paved and some are not paved.
- All roads have kerbs present.
- All roads have medians except President Avenue, Raymond Mhlaba Road, Oos Burger Street and Fort Hare Road.
- All roads are sealed and the road conditions are in either good condition or acceptable condition.

The road lanes are considered acceptable except on certain roads such as General Dan Pienaar Drive, Fort Hare Road and Oos Burger Street, where trucks overlap to the other lane because of narrow lanes; this causes delays especially during peak hours. No roads that were surveyed have on-street parking; this is a challenge for drivers because of the land use. Some facilities do offer parking but it not adequate, and drivers utilise the road lane for parking. This slows down movement and causes delays on the roads. This phenomenon was frequent on Harvey Road and General Dan Pienaar Drive.

1

Table 15: Characteristics of roads surveyed in Bloemfontein (Source: Primary survey, 2017)

Road	Direction	No of Lanes	Road type	Road width (m)	Lane width (m)	Sight distance	Road curvature	Availability of pavement,foot-path,shoulders Y/N (P/F-P/S)	Kerbs (Y/N)	Median	Type of road surface	Condition of road surface	On-street parking type Right angle/ inclined/ parallel
Nelson Mandela Drive	E	3	U3	10.8	3.6	>200	Gentle	Not paved	Y	Yes	Sealed	Good	NO
Nelson Mandela Drive	W	3	U3	10.8	3.6	>200	Gentle	Not paved	Y	Yes	Sealed	Good	NO
Aliwal Street	N	3	U3	10.8	3.6	>150	Gentle	Not paved	Y	Yes	Sealed	Good	NO
Aliwal Street	S	3	U3	10.8	3.6	>150	Gentle	Not paved	Y	Yes	Sealed	Good	NO
Raymond Mhlaba (two way)	N	2	U3	7.0	3.5	>200	Gentle	Y(P)	Y	No (line)	Sealed	Acceptable	NO
Oos Burger Street (two way)	S	2	U3	6.0	3.0	>200	Gentle	Y(P)	Y	No (line)	Sealed	Good	NO
Fort Hare Road	E	2	U3	6.4	3.2	>150	Gentle	Not paved	Y	No (line)	Sealed	Good	NO
Fort Hare Road	W	2	U3	6.4	3.2	>150	Gentle	Not paved	Y	No (line)	Sealed	Good	NO
Harvey road	N	2	U3	7.0	3.5	>100	Gentle	Y(P)	Y	Yes	Sealed	Acceptable	NO
Harvey road	S	2	U3	7.4	3.7	>100	Gentle	Y(P)	Y	Yes	Sealed	Acceptable	NO

President Boshof Street	N	3	U3	10.5	3.5	>200	Gentle	Y(P)	Y	Yes	Sealed	Good	NO
President Boshof Street	S	3	U3	6.9	3.5	>200	Gentle	Y(P)	Y	Yes	Sealed	Good	NO
Parfitt Avenue	N	2	U3	10.6	3.5	>150	Gentle	Y(P)	Y	Yes	Sealed	Good	NO
Parfitt Avenue	S	2	U3	10.5	3.5	>150	Gentle	Y(P)	Y	Yes	Sealed	Good	NO
Kolbe Avenue	N	2	U3	10.4	3.5	>150	Gentle	Not paved	Y	Yes	Sealed	Good	NO
Kolbe Avenue	S	2	U3	7.4	3.7	>150	Gentle	Not paved	Y	Yes	Sealed	Good	NO
President Avenue	E	2	U3	7.4	3.7	>100	Gentle	Not paved	Y	No (line)	Sealed	Good	NO
President Avenue	W	2	U3	7.4	3.7	>100	Gentle	Not paved	Y	No (line)	Sealed	Good	NO
General Dan Pienaar Dr (2 way)	N	2	U3	9	3.0	>200	Gentle	Not paved	Y	Yes	Sealed	Good	NO
Parfitt Avenue (2 way)	S	2	U3	10.3	3.4	>200	Gentle	Not paved	Y	Yes	Sealed	Good	NO

5.3.1.2 CHARACTERISTICS OF INTERSECTIONS

Table 16 presents the characteristics (physical and road geometry parameters) of the intersections surveyed in Bloemfontein.

The characteristics of intersections surveyed is discussed below:

- The width of the intersections ranged from 19m to 35m, with divisional islands available in all of them.
- All intersections had channelising islands and refuge islands, and all of them have automated signalling systems.

The width and number of lanes of the intersections show that these intersections accommodate large volume of vehicles, hence the availability of channelising islands. Even though the intersections are wide and have multiple number of ways, some intersections such as Alexandra Avenue - Oos Burger/Raymond Mhlaba Street intersection (I4) and Fort Hare Road - Hamilton Road intersection (I5) have problems of turning trucks because of the small turning radius.

Table 16: Characteristics of intersections (Source: Primary survey, 2017)

Intersections	No of ways	No of lanes	Width (m)	Divisional island	Channelising island	Refuge island	Signalling
Nelson Mandela Drive-Furstenberg Road intersection (I1)	2	21	35	Available (2)	Available (2)	Available	Automated Signalling
Kellner Street - General Dan Pienaar Drive/Parfitt Avenue intersection (I2)	2	24	34	Available (2)	Available (1)	Available	Automated Signalling
Harry Smith Street/Union Avenue - Aliwal Street/Milner road intersection (I3)	2	17	19	Available (4)	Available (4)	Available	Automated Signalling
Alexandra Avenue - Oos Burger/Raymond	2	18	34	Available (2)	Available (2)	Available	Automated Signalling

Mhlaba Street intersection (I4)							
Fort Hare Road - Hamilton Road intersection (I5)	2	16	19	Available (1)	Available (4)	Available	Automated Signalling
Victoria Road - Walter Sisulu road/Parfitt Avenue intersection (I6)	2	23	31	Available (4)	Available (2)	Available	Automated Signalling

5.3.2 TRAVEL RELATED PARAMETERS

This section discusses travel related parameters such as travel pattern, trip generation, travel time, travel delays and travel distance. This information is essential to understand how trips are generated, how people travel, how much distance they travel and how the travel delays affect travel time.

5.3.2.1 TRAVEL PATTERN

Travel pattern was analysed in terms of number of trips coming from different suburbs to the city in the morning and going back in the afternoon as shown in Figure 23 below. The greatest number of trips are generated as a result of people moving to the city and away from the city to their respective suburbs. Willows has trip numbers ranging from 2000-2500, followed by Brandwag, with trips moving towards and away from the city ranging from 1000-1500. Universitas had trips ranging between 800-1000, followed by Botshabelo and Heidedal with trips ranging from 400-600. Other trips fell in the category of 200-400; these suburbs are Noordhoek, Thaba Nchu, Langenhoven Park, Heuwelsig, Navalsig, Bloemanda, Batho and Rocklands. The lightest travel patterns in terms of trips generated were from Oos-Einde, Hilton, Woodlands, Bainsvlei, Pellisier, Ehrlich Park, Phahameng, Hillside, Turflaagte, Namibia and Bochabela, ranging between 0-200. It is expected that numbers of trips may be generated from Botshabelo and Thaba Nchu, as people commute daily from these townships, for work, school and other functions to Bloemfontein central area, which encompass a number of work places (commercial companies) and shopping centres (Waterfront and Mimosa mall). The study indicated that even though sometimes people move from one suburb to another, the highest volumes of traffic are generated from the suburbs, which move towards the city centre in the morning and vice versa in the evening hours.

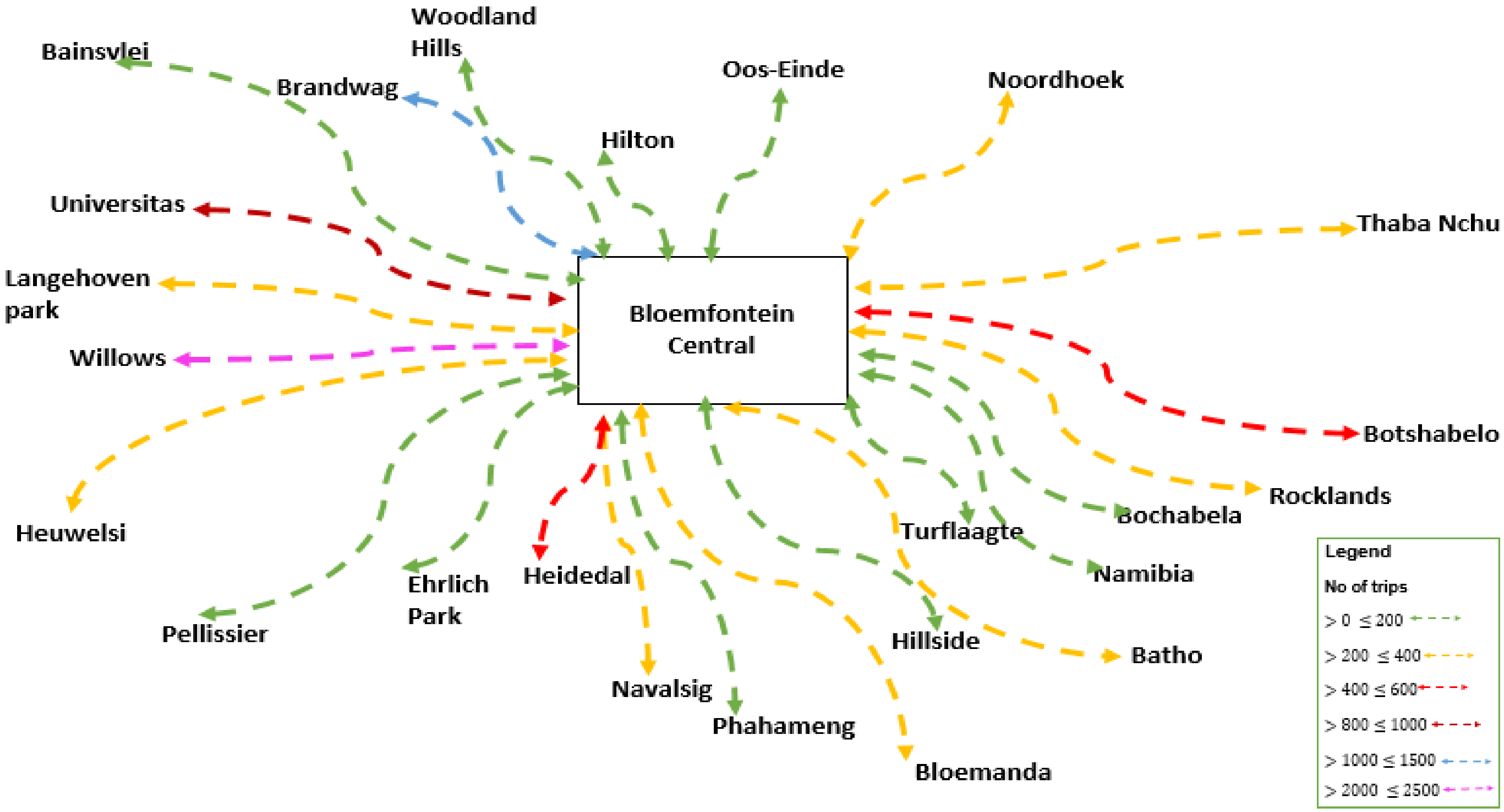

Figure 23: Traffic pattern for morning and afternoon coming from suburbs-city and city-suburbs(Source: Primary survey, 2017)

5.3.2.2 TRIP GENERATION

Figure 24 shows different suburbs and the number of trips generated from each of them. The suburbs where most trips are generated include Willows (2226), Universitas (1224) and Brandwag (960). Botshabelo (600) and Thaba Nchu (300) also generate substantial volume of traffic as many people commute daily from these areas to Bloemfontein for different activities. Other suburbs are Noordhoek (208), Langenhoven Park (300), Heuwelsig (234), Navalsig (266), Bloemanda (342), Batho (208) and Rocklands (324). The least number of travel pattern in terms of trips generated were from Oos-Einde (121), Hilton (121), Woodlands (154), Bainsvlei (192), Pellisier (196), Ehrlich Park (196), Phahameng (143), Hillside (168), Turflaagte (132), Namibia (168) and Bochabela (195). The figure of trip generation shows where most trips are generated, which assists in indicating which suburbs might need to be prioritised when planning public transportation.

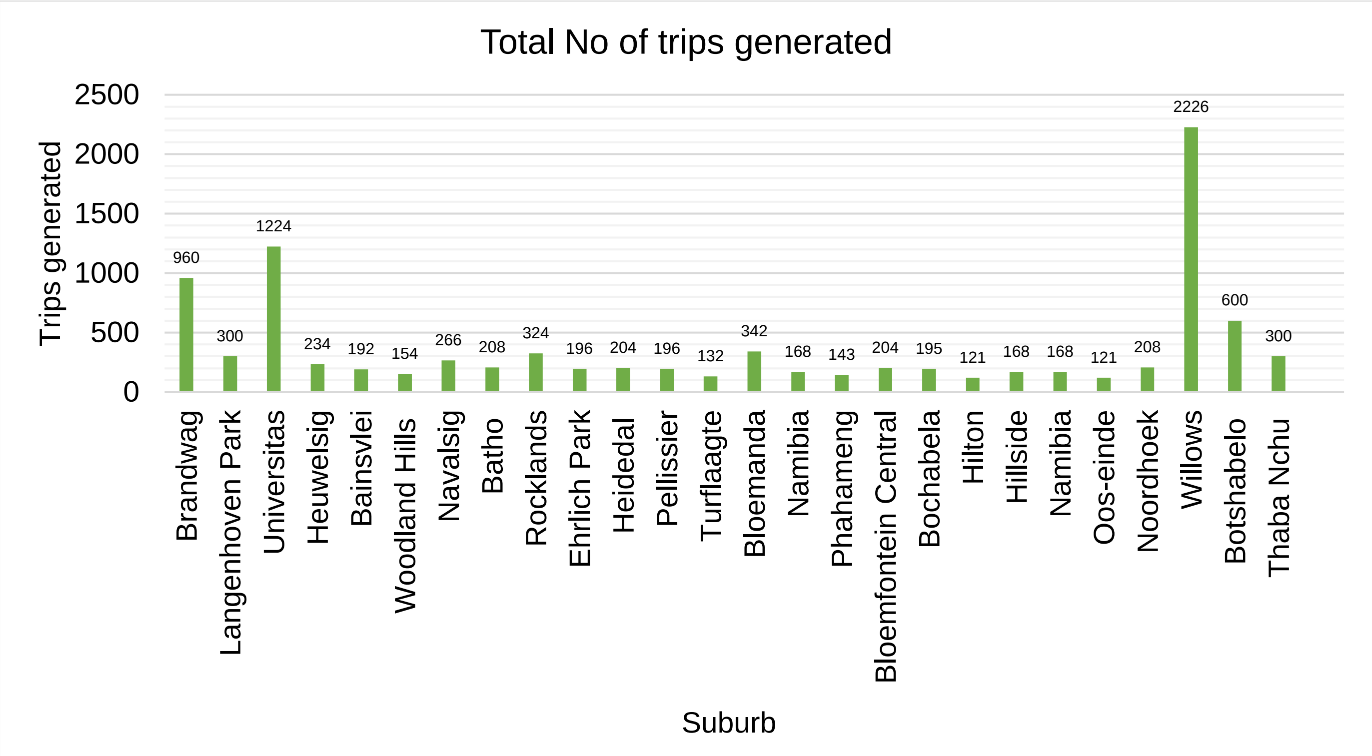

Figure 24: Total number of trips generated (Source: Primary survey, 2017)

5.3.2.3 TRAVEL TIME AND TRAVEL DELAYS

Table 17 presents the travel time on different roads in and around the city. This information is necessary as it gives an indication of which roads have the highest delays during travel. The travel times were computed by considering the minimum speed, average speed during normal hours and speed limit over a distance of 1 kilometre. The table shows that Hanger Street has the highest delays of 4.91min, followed by Raymond Mhlaba, Oos Burger Street, General Dan Pienaar Drive and Parfitt Avenue with delays of 4.67min. Nelson Mandela Drive has delays of 2.80min, Aliwal Street has delays of 1.67min, Fort Hare Road has delays of 2.67min, Kolbe Avenue has delays of 2.91min, and President Boshof has delays of 2.50min. President Avenue has the lowest delays of 1.50min. The high values of the travel delay indicate that travel delay is a challenge on the road of Bloemfontein.

Table 17: Travel time and delays for different roads (Source: Primary survey, 2017)

Road	Direction	Average Speed during normal hours (in km/ h)	Minimum Speed (in km/h)	Speed Limit (in Km/h)	Distance (1 km)	Travel time with minimum speed (min)	Travel Time with average speed (min)	Travel delay (min)
Nelson Mandela Drive	E	50	15	60	1	4	1.20	2.80
	W	50	15	60	1	4	1.20	2.80
Aliwal Street	N	45	20	60	1	3	1.33	1.67
	S	45	20	60	1	3	1.33	1.67
Raymond Mhlaba	N	45	10	60	1	6	1.33	4.67
Oos Burger Street	S	45	10	60	1	6	1.33	4.67
Fort Hare Road	E	45	15	60	1	4	1.33	2.67
	W	45	15	60	1	4	1.33	2.67
Hanger Street	N	55	10	60	1	6	1.09	4.91
	S	55	10	60	1	6	1.09	4.91
President Boshof Street	N	40	15	60	1	4	1.50	2.50
	S	40	15	60	1	4	1.50	2.50
Parfitt Avenue	N	40	10	60	1	6	1.50	4.50
	S	40	10	60	1	6	1.50	4.50
Kolbe Avenue	N	55	15	60	1	4	1.09	2.91
	S	55	15	60	1	4	1.09	2.91
President Avenue	E	40	20	60	1	3	1.50	1.50
	W	40	20	60	1	3	1.50	1.50
General Dan Pienaar Dr	N	45	10	60	1	6	1.33	4.67
Parfitt Avenue	S	45	10	60	1	6	1.33	4.67

5.3.2.4 TRAVEL DISTANCE

Figure 25 shows the total average distance in kilometres (km) travelled daily by a group belonging to a certain annual income range, according to the questionnaire survey around the city of Bloemfontein. For this study, the annual income of people earning a certain amount annually was compared with the kilometres they travel daily. The highest average kilometres travelled are for people who earn between above R400 000 (24,2 km/day), followed by people earning between R300 000-R350 000 (23,1km/day). People earning R300 000-R400 000 travel on average 22,8km/day. The lowest distance travelled is for people earning between R0-R50 000. In order for transportation to be efficient in the city of Bloemfontein, it should be reliable and cost effective to accommodate people with lower income in other for cities to be sustainable.

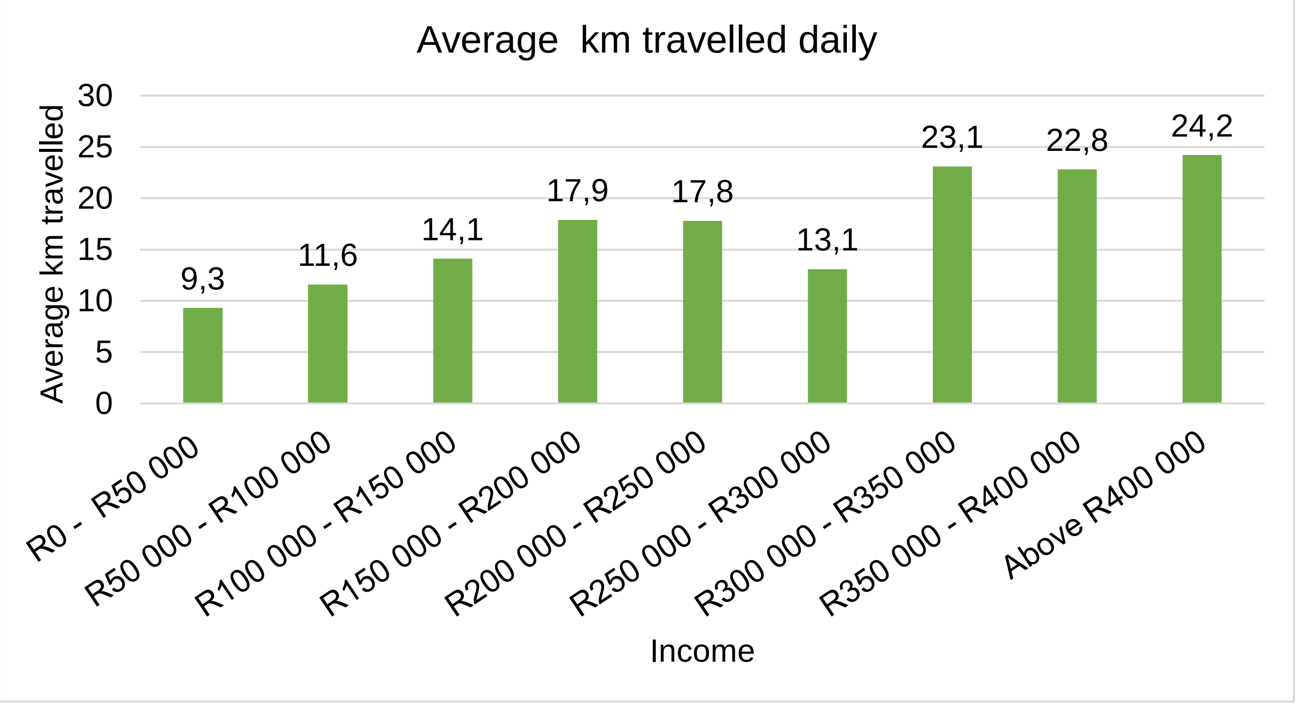

Figure 25: Average kilometres travelled by people according to annual income category (Source: Primary survey, 2017)

5.3.2.5 REDUCED TRAVEL DISTANCE

The Table 18 and Figure 26 show the distance travelled in the city of Bloemfontein, and the reduced distance travelled through the integration of Information and communication technology. Figure 26 shows the average distance travelled daily by individuals and the reduced average distance travelled per trip. Figure 27 shows the distance travelled daily by each household, and the reduced distance travelled by households per day in kilometres. The average distance travelled per trip in kilometres increases with the increase in income range. Figure 26 shows that there is a decrease in kilometres travelled per trip as a result of integration. The kilometres decrease as follows R0 - R50 000 (from 9.3 to 7.5km); R50 000 - R100 000 (from 11.6 to 9.3 km); R100 000 - R150 000 (from 14.1 to 11.3km); R150 000 - R200 000 (from 17.9 to 14.3km); R200 000 - R250 000 (from 17.8 to 14.2); R250 000 - R300 000 (from 13.1 to 10.5km); R300 000 - R350 000 (from 23.1 to 18.5km); R350 000 - R400 000 (from 22.8 to 18.2km) and above R400 000 (from 24.2 to 19.4 km).

Figure 27 shows that there is a decrease in kilometres travelled per trip as a result of integration. The kilometres decrease as follows: R0 - R50 000 (from 15.5 to 12.4 km); R50 000 - R100 000 (from 21.7 to 17.3 km); R100 000 - R150 000 (from 30.9 to 24.8 km); R150 000 - R200 000 (from 45.9 to 36.7 km); R200 000 - R250 000 (from 39.9 to 32 km); R250 000 - R300 000 (from 30 to 24 km); R300 000 - R350 000 (from 62.8 to 50.3 km); R350 000 - R400 000 (from 51.2 to 41.0 km) and above R400 000 (from 72.7 to 58.1 km).From both figures 25 and 26, it is revealed that the integration of ICT might have a positive impact on the total kilometres travelled daily.

This decrease in travel distance is an indication that, if kilometres are reduced, then there will be a reduction on the emissions and noise pollution, consequently decreasing the congestion levels and delays in the city.

Table 18: Reduced average distance travelled due to the integration of ICT (Source: Primary survey, 2017)

Income range (Rands)	Average distance travelled per trip in kms	Average distance travelled by households	Reduced Average distance	Reduced average distance travelled by

		per day in Km	travelled per trip in km	households per day in km
R0 - R50 000	9.3	15.5	7.5	12.4
R50 000 - R100 000	11.6	21.7	9.3	17.3
R100 000 - R150 000	14.1	30.9	11.3	24.8
R150 000 - R200 000	17.9	45.9	14.3	36.7
R200 000 - R250 000	17.8	39.9	14.2	32.0
R250 000 - R300 000	13.1	30.0	10.5	24.0
R300 000 - R350 000	23.1	62.8	18.5	50.3
R350 000 - R400 000	22.8	51.2	18.2	41.0
Above R400 000	24.2	72.7	19.4	58.1
Total average distance	17.1	41.2	13.7	32.9

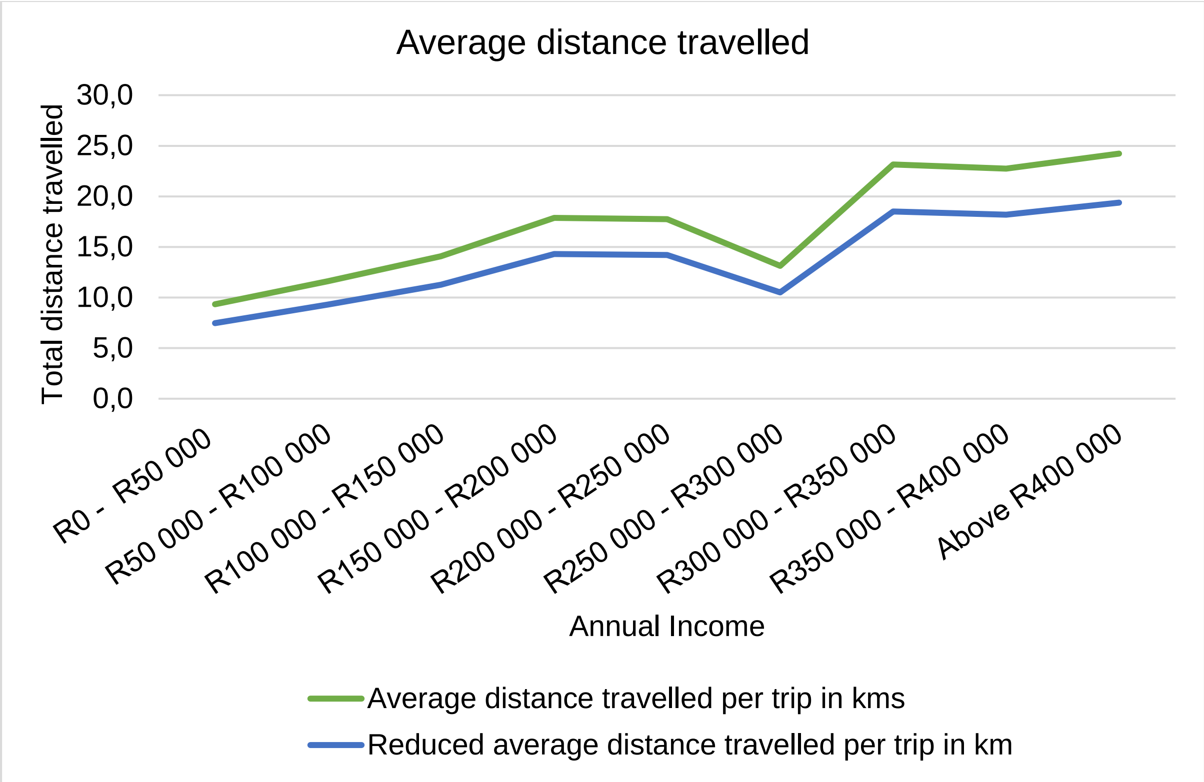

Figure 26: Average distance travelled and reduced average distance travelled daily across different annual earnings, per trip (Source: Primary survey, 2017)

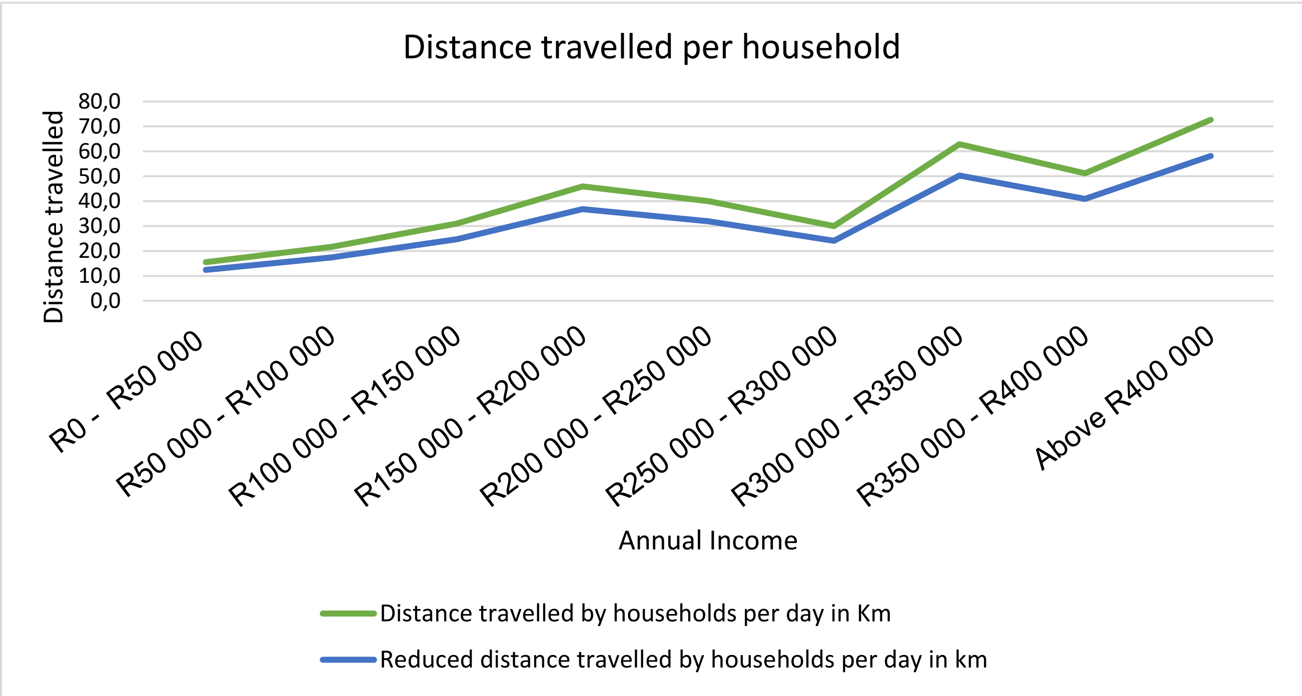

Figure 27: Distance travelled per household across different annual earnings (Source: Primary survey, 2017)

5.3.3 CURRENT TRANSPORTATION SYSTEMS

This section discusses the current transportation systems in the city of Bloemfontein. The modes of transportation used in the city are discussed.

5.3.3.1 PRIVATE TRANSPORTATION

Figure 28 show the use of private transportation in the city. The figure shows that 76% of people who use private transportation use their private cars, followed by 9% of people using company vehicles, 6% using shared vehicles, and 5% using private taxis/vehicle (pre-arranged transport either for staff). The use of private cars is the highest in the city. The study also revealed that less than 5% use non-motorised transportation.

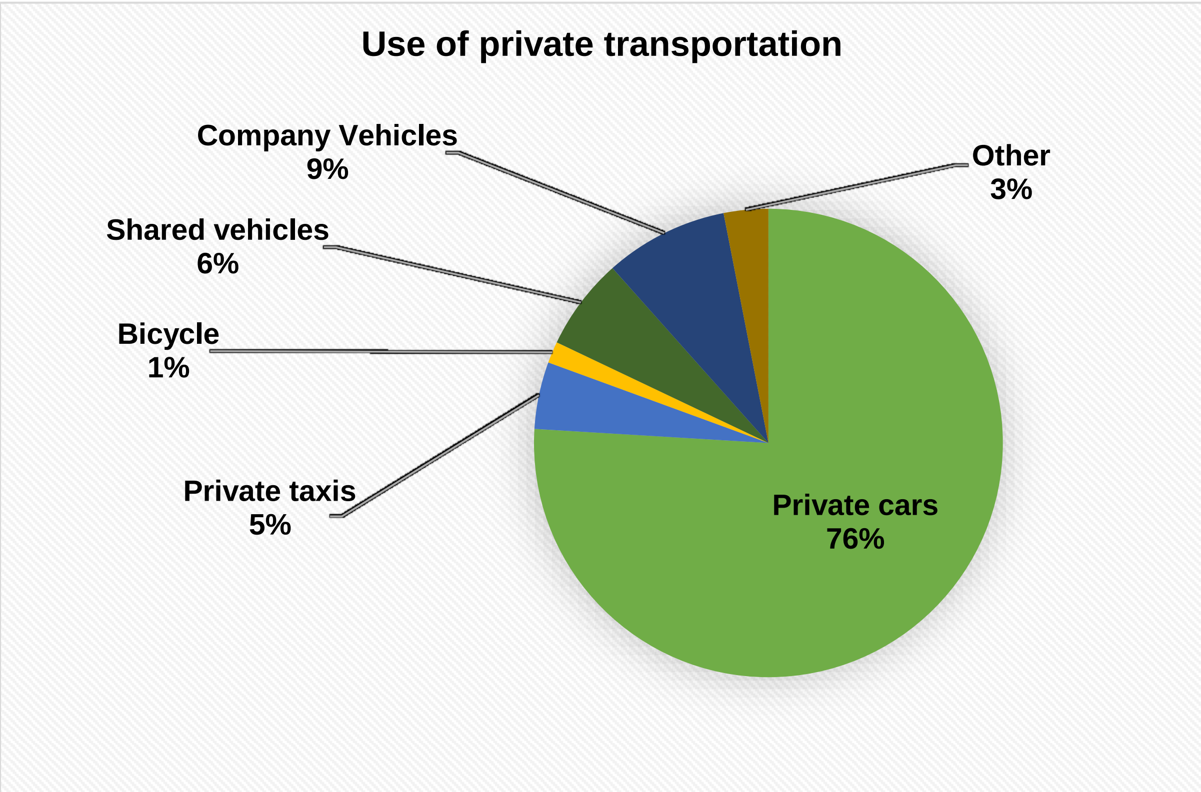

Figure 28: Types of private transportation used (Source: Primary survey, 2017)

The figure 28 shows the different types of private transportation, categorised according to annual income and kilometres travelled. The figure shows that, throughout all the categories, people prefer to use private transportation that they own (e.g. cars). The second mostly used type of private transportation is company vehicles. The figure 28 clearly shows that there is a high use of private cars in the city of Bloemfontein and, if any integration of public transportation is introduced, the big challenge would be to convince people to choose public transportation over private cars.

5.3.3.2 PUBLIC TRANSPORTATION

Figure 29 shows the total distance in kilometres travelled using public transportation. It is found that metered taxis and public taxis are the ones that are used mostly in the city. The use of public taxis (64%) is more visible in the people who earn between R0 - R50 000 and decreases as the amount earned annually increases, with only 20% of people earning above R400 000 using public taxis. The high use of metered taxis is visible throughout all the categories; this high use of metered taxis might be caused by their efficiency and reliability, even though their cost is much higher as compared to public taxis and the buses. Most kilometres travelled using public transport also reveal that people who earn between R300 000 - R400 000 and above travel less, when compared to people earning less.

Public transport used in and around the city includes buses, public taxis, and metered taxis. Trains are not used in the city as the services are not available. For the modes of transport that are used around the city, metered taxis and public taxis are used roughly equally; buses are used much less. This clearly indicates that even though the bus is cheaper than the public taxis, people still use taxis rather than buses.

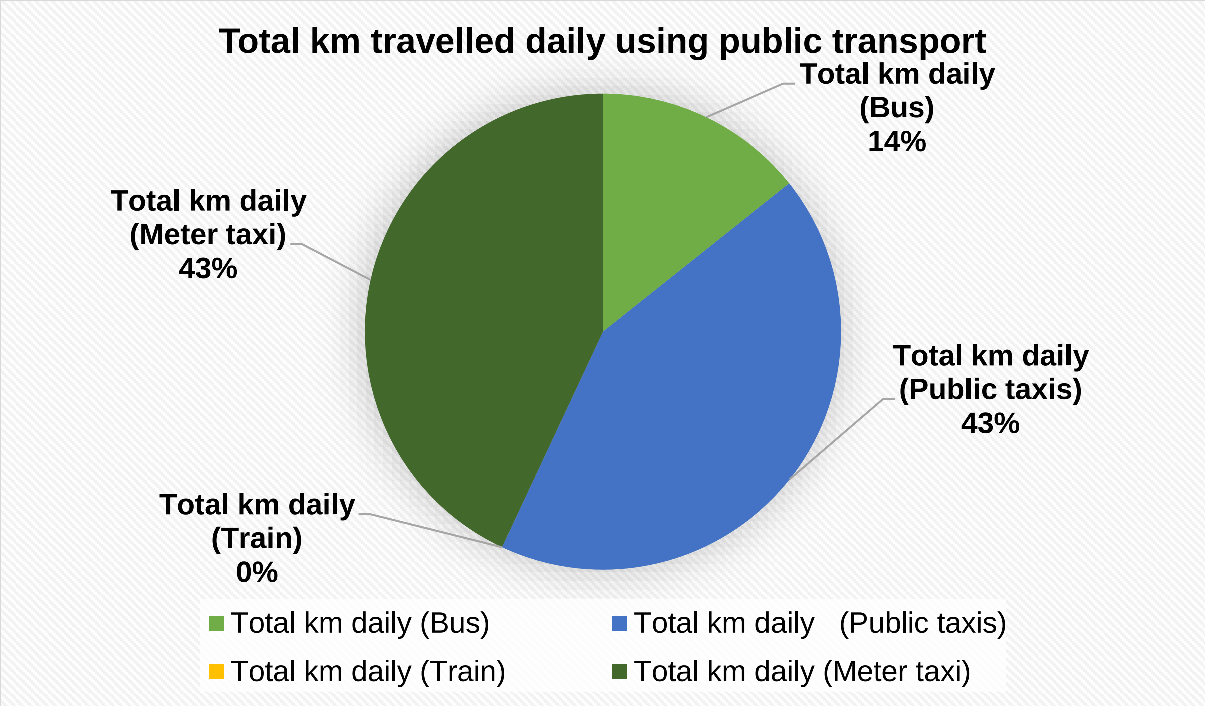

Figure 29: Different modes of public transportation (Source: Primary survey, 2017)

5.3.4 TRAFFIC RELATED PARAMETERS

This section discusses traffic related parameters such as traffic volume on roads and on intersections, traffic speed and the level of service as well as levels of congestion. This information is important because it gives an indication of how congested the roads and intersections are.

5.3.4.1 TRAFFIC VOLUME ON ROADS

Bloemfontein is a developing city with many growth potential and high expectations. For the purpose of this study, 11 roads were surveyed. Table 19 and Figure 30 represent the traffic volume scenario of the study area. The hours are separated into normal and peak hours. The data showed that the peak hours were between 06:30 - 08:30 in the morning and again at 16:30-18:30 in the evening as shown in figure 31. All the other hours are considered as normal hours, where a free flow of traffic can be expected. The traffic volume is analysed in terms of average hourly traffic volume (normal hours) and peak hourly traffic volume in equivalent passenger car units (PCU). The traffic volume was characterised as the one that is moving toward or away from the city from any direction (east, west, north and south). Higher traffic volumes were found to be experienced in certain roads such as Nelson Mandela Drive (14946 PCU), Aliwal Street (8889 PCU), Fort Hare Road (9744 PCU), Hanger Street (11131 PCU), Parfitt Avenue (8974 PCU), and Kolbe Avenue (12576 PCU), with the average Hourly Traffic Volume (in PCU) ranging from a minimum of 103 to a maximum of 1055. The Peak Hour Traffic Volume (in PCU) ranges from a minimum of 332 to a maximum of 2135, and Off-peak Hourly Traffic Volume (in PCU) ranges from a minimum of 17 to a maximum of 281. The maximum traffic volume is experienced in the morning between 06:30-08:30 when people are travelling towards the city, and again in the afternoon between 16:30-18:30 when they are travelling away from the city. The ratio of peak hour traffic volume to total traffic volume ranges from 0.06 to 0.15.

Table 19: Normal hourly and peak hourly traffic volume (Source: Primary survey, 2017)

Road	Direction	No of Lanes	Total Traffic Volume (in PCU)	Average Hourly Traffic Volume (in PCU)	Peak Hour Traffic Volume (in PCU)	Off-peak Hourly Traffic Volume (in PCU)	Ratio of Peak Hour Traffic Volume to Average Hourly Traffic Volume	Ratio of Peak hour Traffic Volume to Total Traffic Volume
Nelson Mandela Drive	E	3	14946	1055	2135	281	2.02	0.14
Nelson Mandela Drive	W	3	11682	824	1314	209	1.59	0.11
Aliwal Street	N	3	8889	623	1554	121	2.49	0.17
Aliwal Street	S	3	5914	418	793	84	1.90	0.13
Raymond Mhlaba	N	2	7057	493	762	105	1.54	0.11
Oos Burger Street	S	2	3532	250	447	58	1.79	0.13
Fort Hare Road	E	2	6614	465	859	86	1.85	0.13
Fort Hare Road	W	2	9744	687	1194	147	1.74	0.12
Hanger Street	N	2	11131	788	1379	202	1.75	0.12
Hanger Street	S	2	6542	464	797	119	1.72	0.12
President Boshof Street	N	3	6442	456	883	124	1.94	0.14
President Boshof Street	S	3	1462	103	332	17	3.21	0.23
Parfitt Avenue	N	2	8457	593	1077	102	1.82	0.13
Parfitt Avenue	S	2	5780	403	631	72	1.57	0.11
Kolbe Avenue	N	2	10910	403	631	72	1.57	0.06
Kolbe Avenue	S	2	12576	889	1538	178	1.73	0.12
President Avenue	E	2	2794	197	300	46	1.52	0.11
President Avenue	W	2	4787	337	557	68	1.65	0.12
General Dan Pienaar Dr	N	2	13194	933	2010	162	2.15	0.15
Parfitt Avenue	S	2	8974	633	1311	72	2.07	0.15

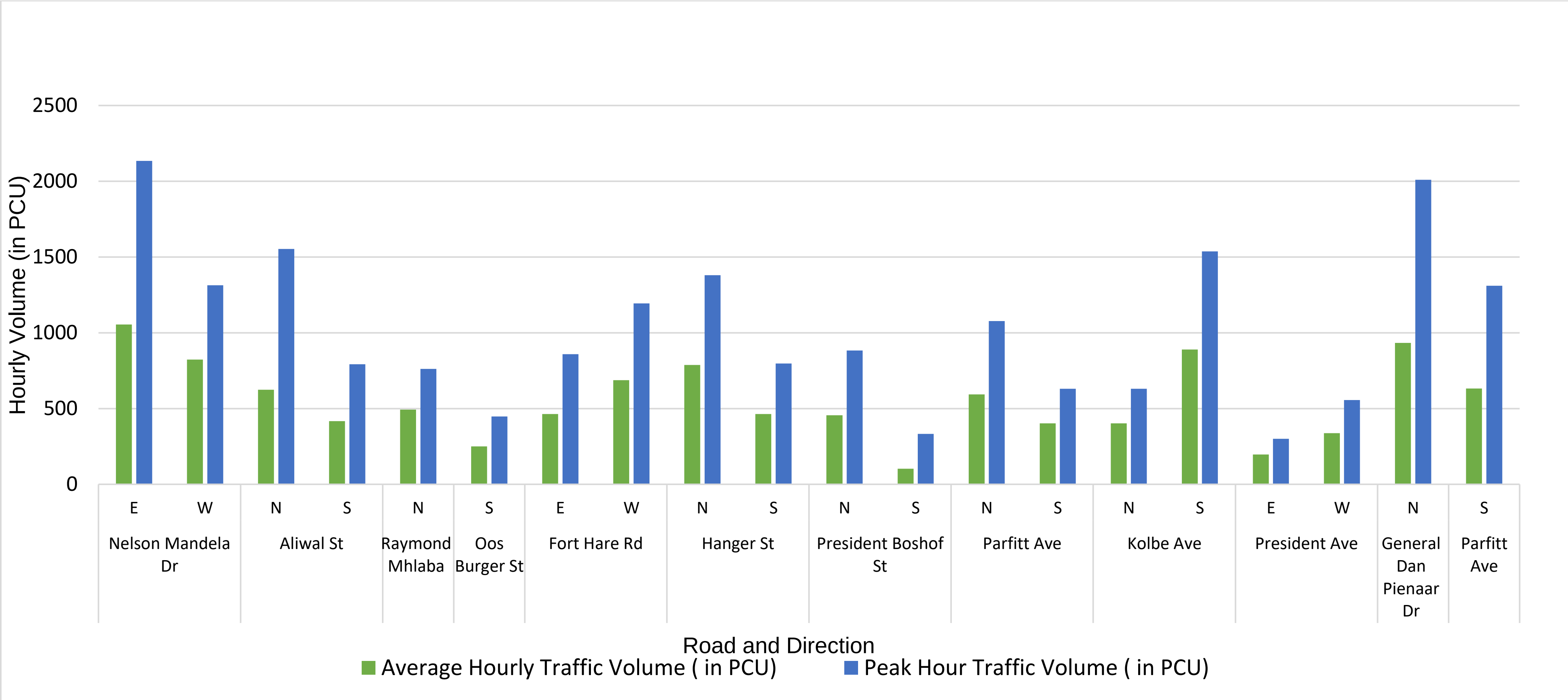

Figure 30: Normal hourly and peak hourly traffic volume (Source: Primary survey, 2017)

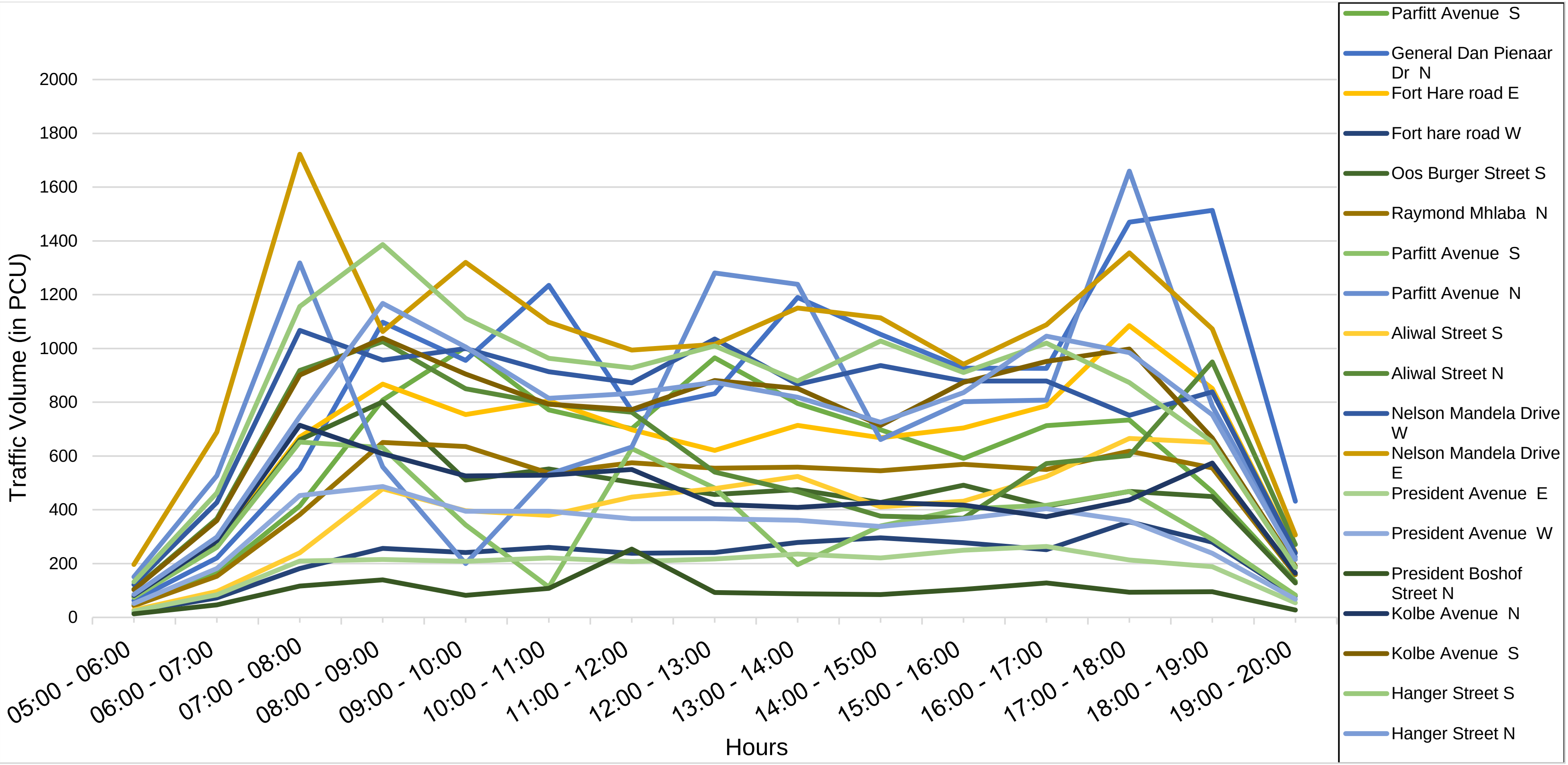

Figure 31: Average traffic volume in PCU (Source: Primary survey, 2017)

5.3.4.2 TRAFFIC VOLUME ON INTERSECTIONS

Figures 32 to 37 present the traffic volume at different intersections during peak hours. The six important intersections being considered are: the Nelson Mandela Drive–-Furstenberg Road intersection (I1); the Kellner street – General Dan Pienaar Drive/ Parfitt Avenue intersection (I2); the Harry Smith Street/Union Avenue – Aliwal Street/ Milner road intersection (I3); the Alexandra Avenue – Oos Burger/Raymond Mhlaba Street intersection (I4); the Fort Hare Road – Hamilton Road intersection (I5); and the Victoria Road – Walter Sisulu road/Parfitt Avenue intersection (I6). The arrows in the figures indicate the direction of flow and the numbers in the box indicate the traffic flow per hour during peak hours. The traffic flow is divided into left turning-, straight moving- and right turning vehicles.

5.3.4.2.1 Nelson Mandela Drive – Furstenberg Road intersection (I1)

The traffic flow in the intersection joining Nelson Mandela Drive and Furstenberg is presented in Figure 32. It shows that 24.0% of the traffic moves away from the city. 76.0% of the traffic moves away from the city. 33.0% of the traffic flow moving towards the city is distributed to Furstenberg Road while 67.0% of the traffic moves to the city. The peak flow that is moving towards the city distributed from Furstenberg Road is 13.0% from the south and 17.0% from the north. The peak flow that is moving away from the city distributed from Furstenberg Road is 23.0% from the south and 17.0% from the north. During peak hour volume, the intersection carries 5784PCU, and the average queue length value is 10. This shows that there are delays on this intersection, especially for turning vehicles.

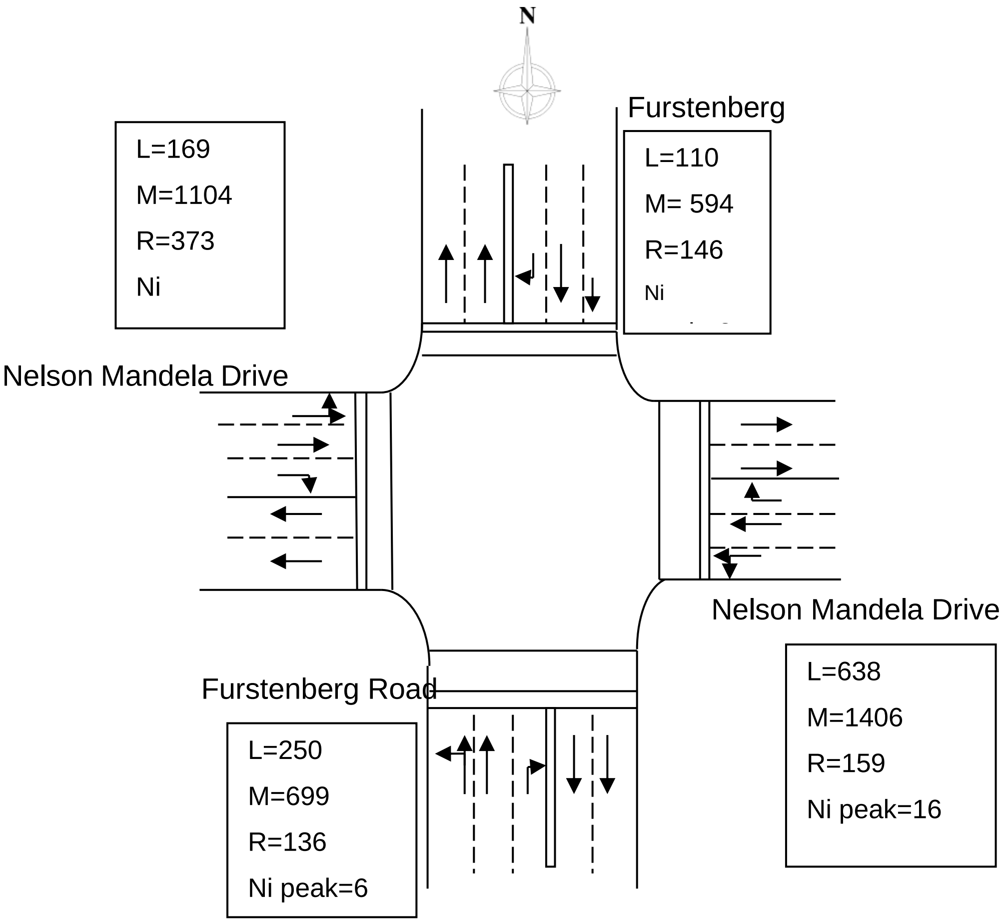

Figure 32: Peak traffic volume for Nelson Mandela Drive–Furstenberg Road intersection (Source: Primary survey, 2017)

5.3.4.2.2 Kellner Street – General Dan Pienaar Drive/Parfitt Avenue intersection (I2)

The traffic flow in the intersection joining Kellner Street and Parfitt Avenue-General Dan Pienaar Drive is presented in Figure 33. All the traffic flow that is coming from the North and West forms part of the flow that is coming towards the city. 62.0% of the traffic flow coming from General Dan Pienaar Drive is going towards the city, 12.0% is distributed towards the city and the remaining 25.0% is moving to the west/away from the city. From the traffic flow from Parfitt Avenue 62.0% moves to the north/away from the city, while 24.0% moves to the west/away from the city. Only 14.0% of the flow from Parfitt Avenue moves towards the city centre. From the flow coming from Kellner Street, 89.0% of the overall flow is moving towards the city, while 11.0% moves to the north. During peak hour volume, the intersection carries 5027 PCU and the average queue length value is 10.

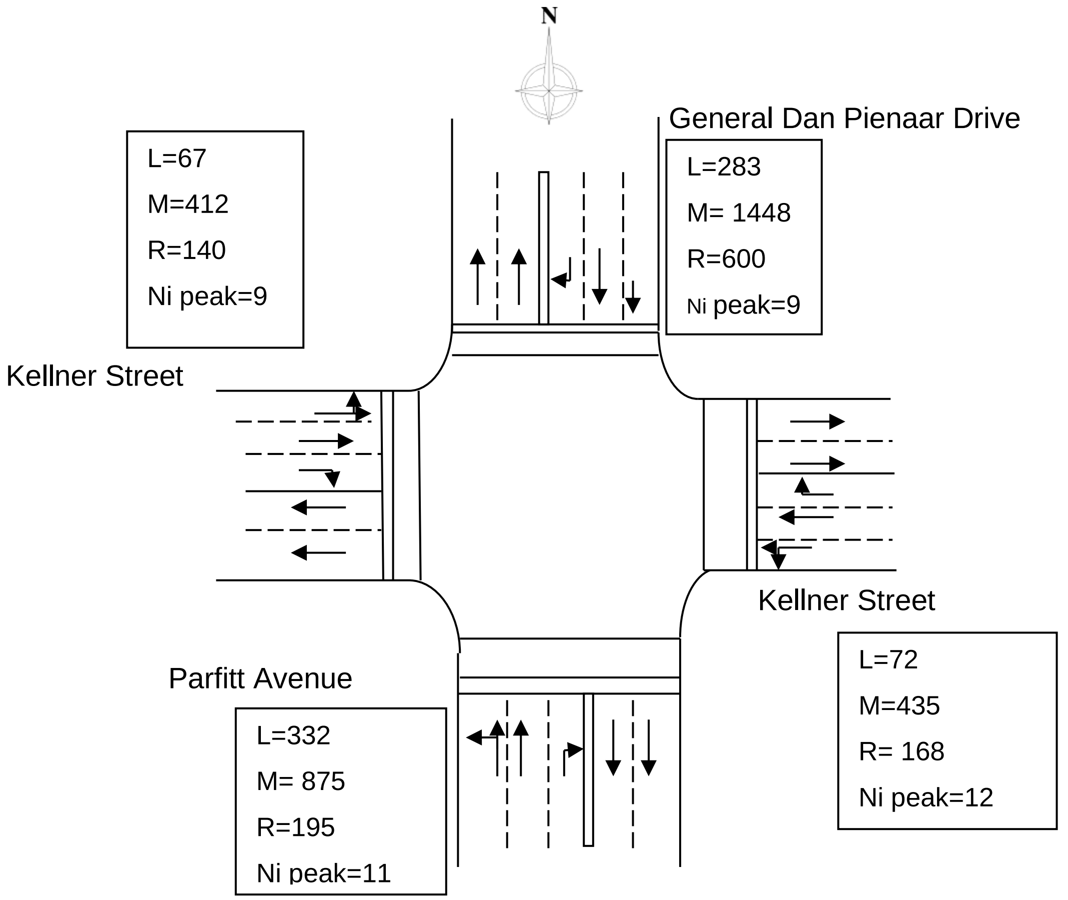

Figure 33: Peak traffic volume for Kellner Street – General Dan Pienaar Drive/Parfitt Avenue intersection (Source: Primary survey, 2017)

5.3.4.2.3 Harry Smith Street/Union Avenue – Aliwal Street/Milner road intersection (I3)

The traffic flow in the intersection joining Aliwal Street-Milner road and Harry Smith Street-Union Avenue is presented in the figure 34. 70.0% of the flow coming from Milner road moves towards the city, while 24.0% comes from Harry Smith Street and 22.0% comes from Union Avenue. 40.0% of the traffic flow from Aliwal Street is distributed to Harry Smith Street and Union Avenue, while 60.0% of the flow moves towards the north/away from the city. 30.0% of the traffic flow coming from Milner road is distributed to Harry Smith Street and Union Avenue. During peak hour volume, the intersection carries 4596PCU, and the average queue length value of 12. This intersection carried high volume, but the maximum delays are caused by the turning vehicles because of long queues.

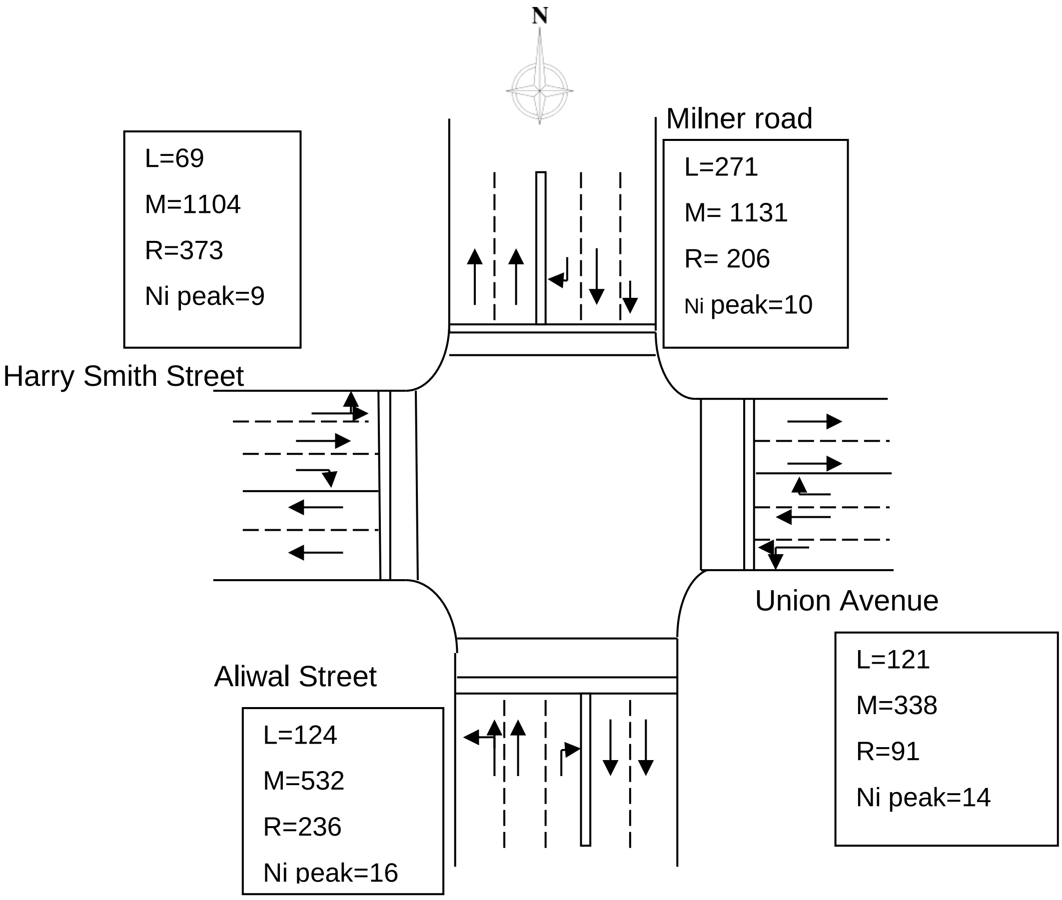

Figure 34: Peak traffic volume for Harry Smith Street/Union Avenue – Aliwal Street/Milner road intersection (Source: Primary survey, 2017)

5.3.4.2.4 Alexandra Avenue – Oos Burger/Raymond Mhlaba Street intersection (I4)

The traffic flow in the intersection joining Alexandra Avenue and Oos Burger-Raymond Mhlaba Street is presented in the figure 35. The traffic flow moving from the south to the north represents all the traffic moving away from the city. 15.0% of the flow from Oos Burger Street is moving to the west, while 26.0% moves to the east and 60.0% of that flow is the one moving away from the city. 17.0% of the flow coming from Raymond Mhlaba Street is moving to the east, 23.0% is moving to the west and 60.0% is moving towards the city. During peak hour volume, the intersection carries 2230 PCU, and the average queue length value of 9. This intersection does not carry high volume as compared to others.

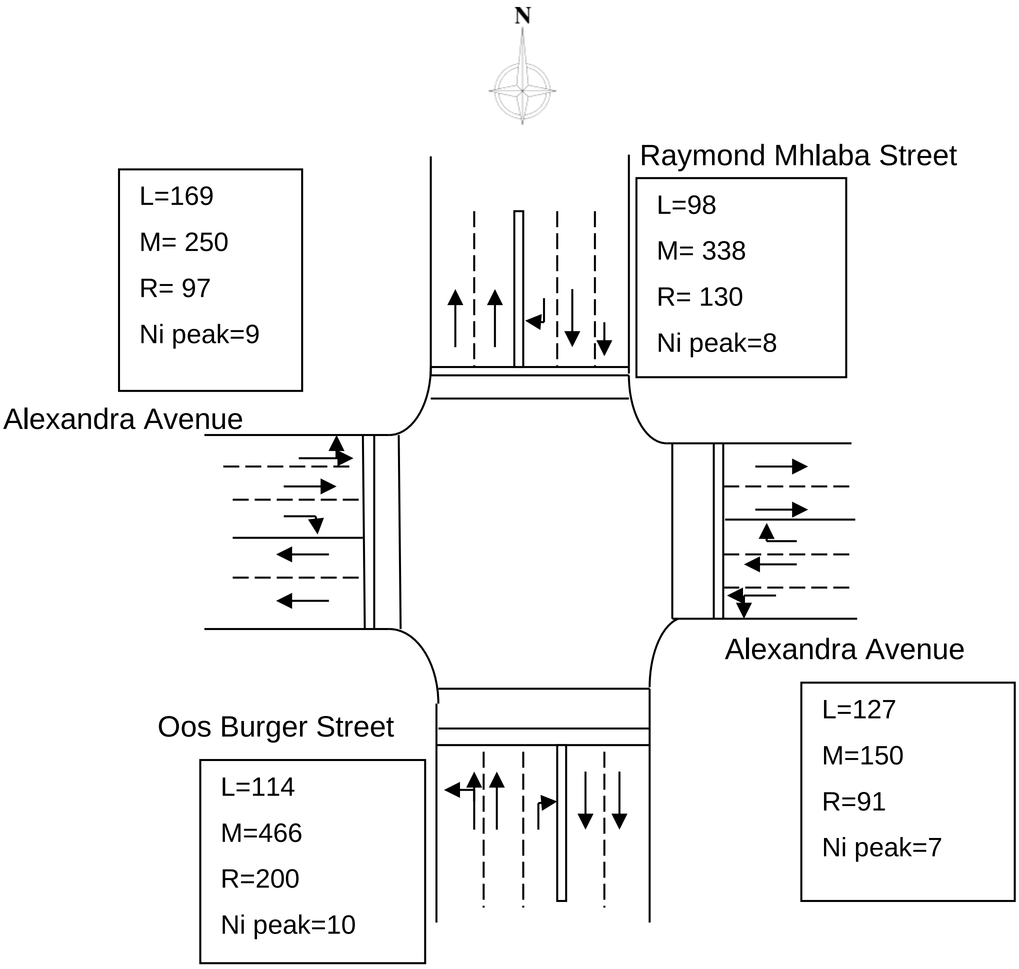

Figure 35: Peak traffic volume for Alexandra Avenue – Oos Burger/Raymond Mhlaba Street intersection (Source: Primary survey, 2017)

5.3.4.2.5 Fort Hare Road – Hamilton Road intersection (I5)

The traffic flow in the intersection joining Hamilton Road and Fort Hare Road is presented in the Figure 36. All the traffic flow moving to the west represents the flow going to the city. About 72.0% of the traffic coming from the Fort Hare Road goes towards the city. About 28.0% is distributed to Hamilton Road moving towards the south and 30.0% is distributed to Hamilton Road moving towards the north. Further, 31.0% of the traffic moving to the city comes from the north direction, while 34.0% comes from the south. During peak hour volume, the intersection carries 2912 PCU, and the average queue length value is 8.

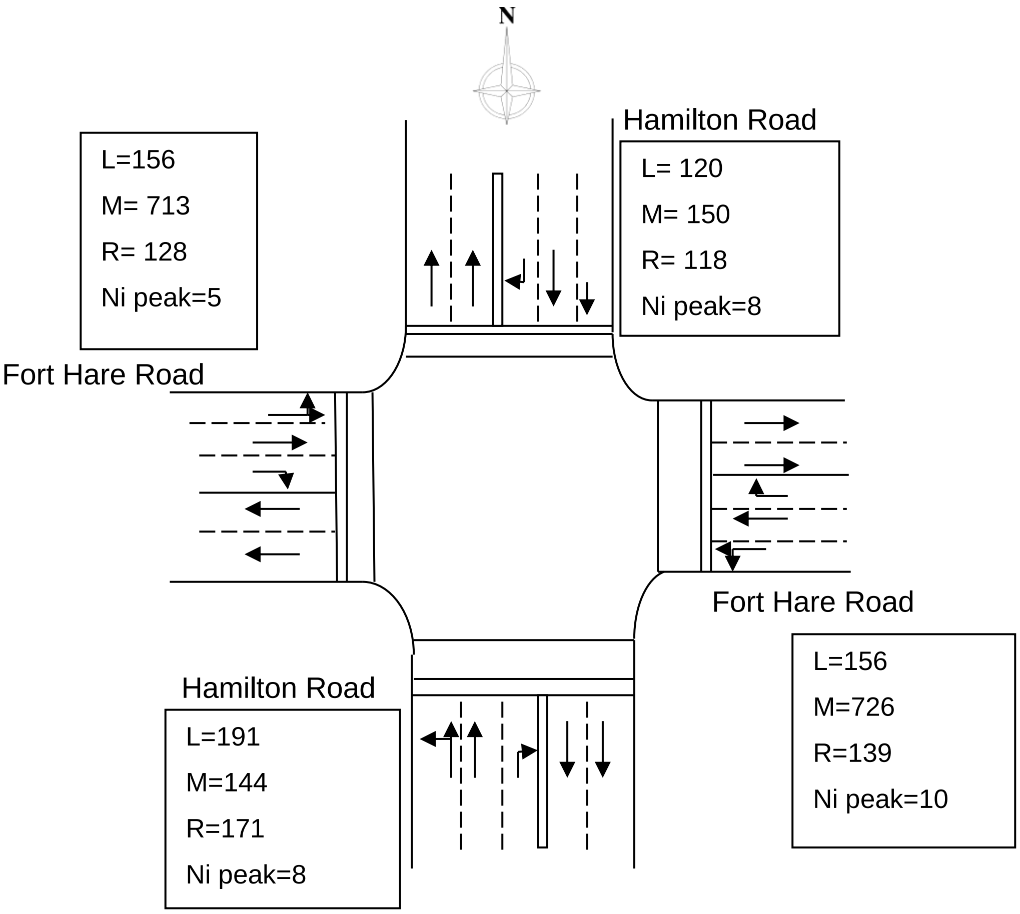

Figure 36: Peak traffic volume for Fort Hare Road – Hamilton Road intersection
(Source: Primary survey, 2017)

5.3.4.2.6 Victoria Road – Walter Sisulu road/Parfitt Avenue intersection (I6)

The traffic flow in the intersection joining Victoria Road and Walter Sisulu road-Parfitt Avenue is presented in the figure 37. All the flow moving to the south and East direction represents the flow going towards the city centre. The traffic flow moving to the south comprises 51.0% of Parfitt's Avenue traffic flow, 33.0% of Victoria's flow coming from the east, and 36.0% coming from the west. The traffic flow moving to the east comprises of 40.0% of Victoria Road's flow from the west, 24% coming from Walter Sisulu road and 19% coming from Parfitt Avenue. During peak hour volume, the intersection carries 2857 PCU, and the average queue length value is 10.

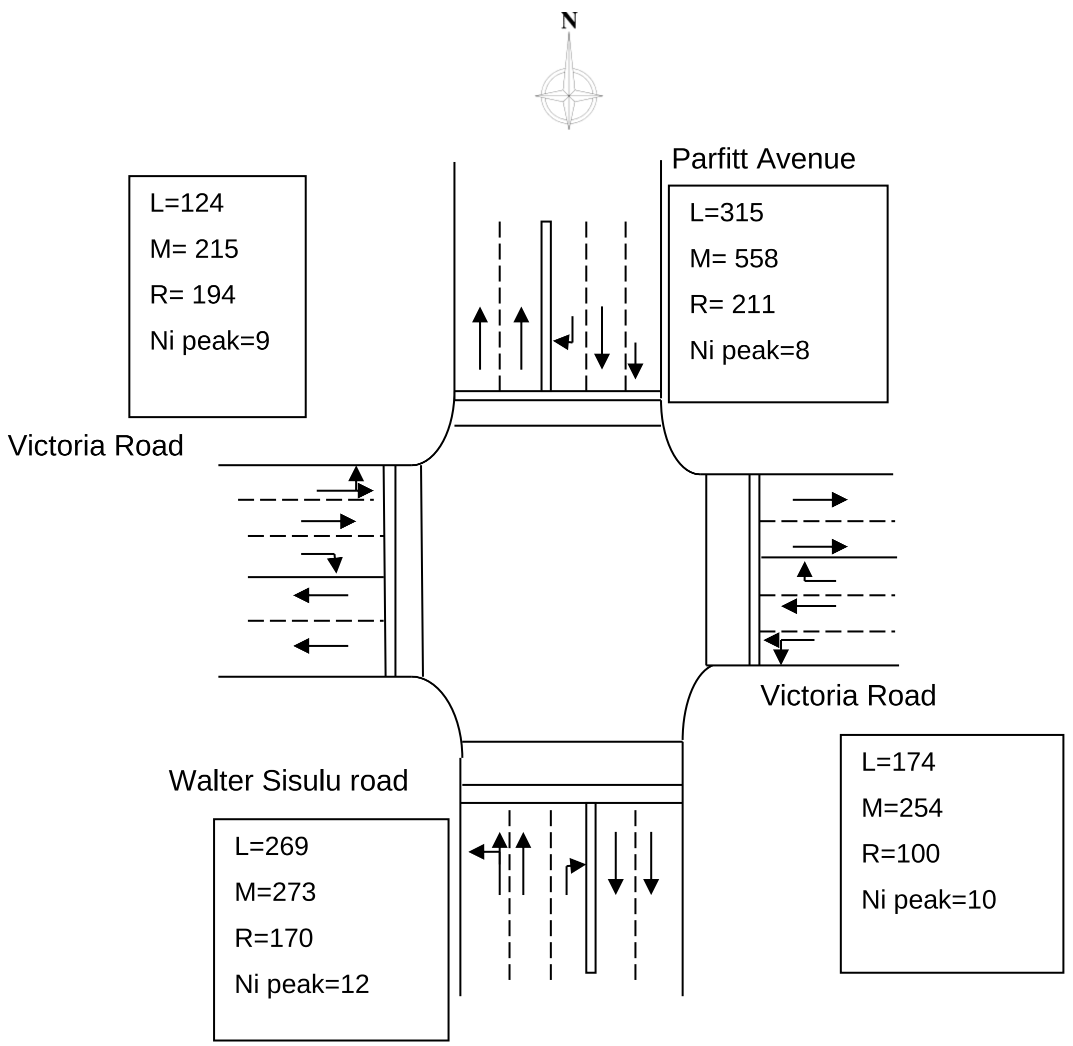

Figure 37: Peak traffic volume for Victoria Road – Walter Sisulu road/Parfitt Avenue intersection (Source: Primary survey, 2017)

5.3.4.3 TRAFFIC SPEED

For this study, the speed was analysed on all roads where the traffic volume was investigated. Figure 38 and Table 20 show the speed traffic on the roads surveyed. The average speed during normal hours in kilometres per hour (in km/ h) was found to vary between 40 km/h and 55 km/h. The average speed during peak hours (in km/ h) ranges from 18 km/h to 30 km/h. Comparing the speed during peak and normal hours, it can be seen that the roads carry high numbers of traffic volume during peak hours, therefore leading to delays due to high traffic volume. The minimum speed ranges from a minimum of 10 km/h to a maximum of 20 km/h, and the maximum speed ranges from a minimum of 80 km/h to a maximum of 100 km/h. Table 20 shows that there is a considerably high difference in speed between normal hours and peak hours, this shows that there is congestion on the roads during peak hours because the speed is too low.

Table 20: Maximum and minimum speed for different roads (Source: Primary survey, 2017)

Road	Direction	Average Speed during normal hours (in km/ h)	Average Speed during peak hours (in km/ h)	Difference in speed between normal hours and peak hours (In%)	Minimum Speed (in km/h)	Maximum Speed (in km/h)
Nelson Mandela Drive	E	50	25	50	10	100
	W	48	23	52	15	95
Aliwal Street	N	47	35	26	20	80
	S	45	30	33	15	85
Raymond Mhlaba	N	47	28	40	10	90
Oos Burger Street	S	45	30	33	10	95
Fort Hare Road	E	48	25	48	20	98
	W	45	27	40	15	100
Hanger Street	N	57	18	68	10	85
	S	55	20	64	15	90
President Boshof Street	N	42	27	36	20	100
	S	40	30	25	15	95
Parfitt Avenue	N	41	22	46	10	90
	S	40	20	50	15	95
Kolbe Avenue	N	55	18	67	10	110
	S	53	20	62	15	100
President Avenue	E	40	30	25	20	85
	W	41	35	15	15	80
General Dan Pienaar Dr	N	45	22	51	10	90
Parfitt Avenue	S	46	20	57	15	95

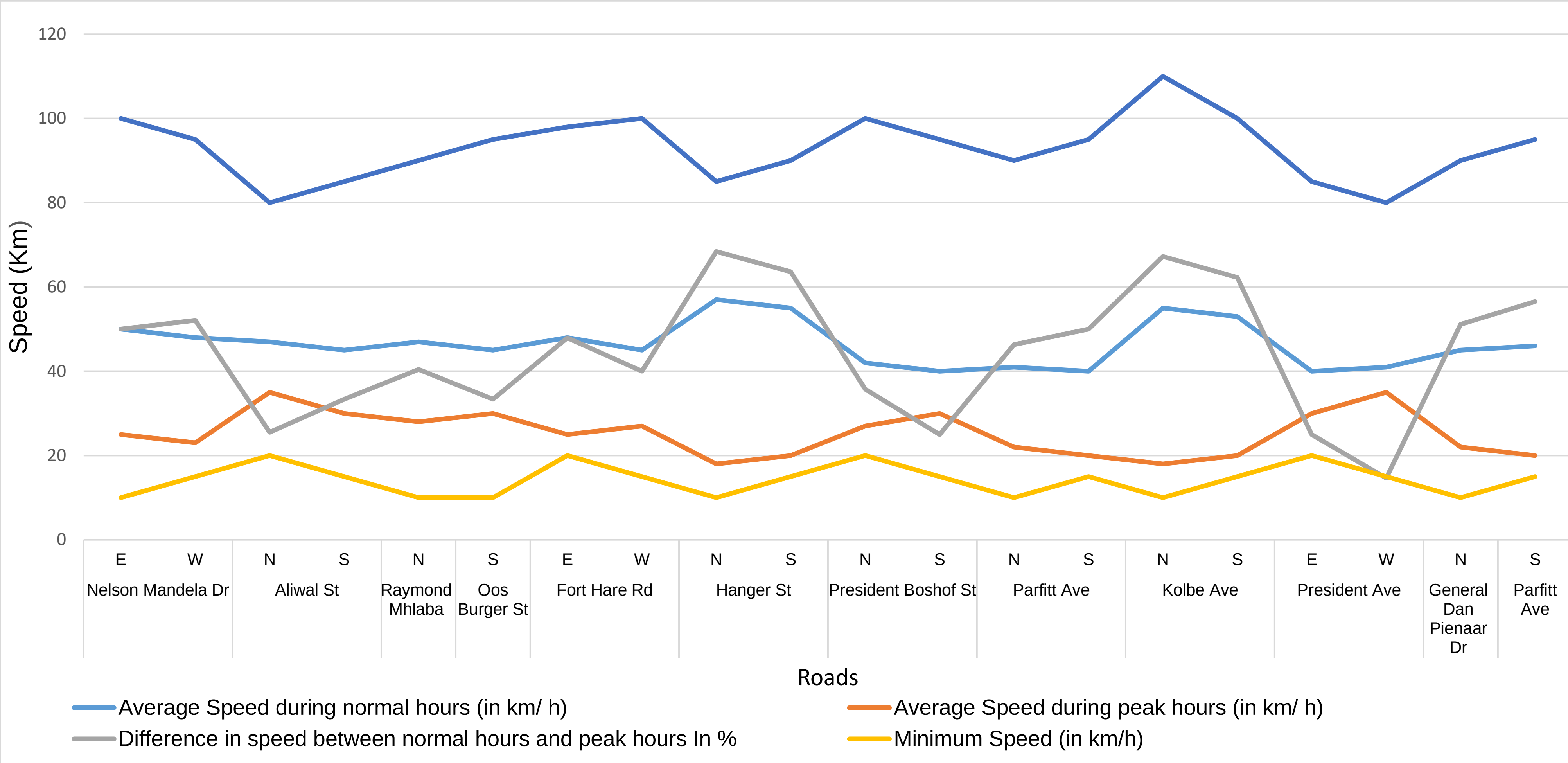

Figure 38: Speed of traffic on the surveyed roads of Bloemfontein (Source: Speed survey, 2017)

5.3.4.4 LEVEL OF SERVICE AND LEVEL OF CONGESTION

Table 21 shows the Level of Services (LOS) around the city on the surveyed roads, the following conditions were adopted while calculating the LOS of the roads.

- C= Capacity of the roads, as explained in Chapter 2, estimated to be 1 100 vehicles per hour per lane for arterial roads (Type II and III equivalent to U3-minor arterial roads and U4 roads in South African cities) (TRB, 1994; TRH26, COTO, 2012, p. 22). The capacity was estimated based on a saturation flow rate of 1 900 vehicles per lane per hour (TRB, 1994) and on the assumption that major roads would receive 60% of the green time and roads perpendicular to the major roads would receive 40% of the green time. Since almost 53-87% of the vehicles on the road are cars, the value 80% (with PCU 1) and 20% heavy vehicles (with average equivalent PCU of 2.5), the capacity of the roads/lane is estimated to be 1430 PCU/ hour rounded to 1400 PCU/hour (the capacity of the roads/lane = 1100*0.8*1.0+1100*0.2*2.5= 1430 PCU/ hour ≈1400 PCU/hour), and as the roads considered in the CBD area are of one way and two lanes system, the total capacity of the roads are estimated to be 2800 (2*1400=2800)PCU/hour *(*TRB, 1994, Appendix H -Traffic Level of Service Calculation Methods, B 4-5).
- The Nelson Mandela Drive is listed as a U2 road, but for the purpose of this study, its LOS will be calculated using the capacity of U3 road. This is because the part that was surveyed was in the city and therefore the maximum speed changes because of the area and traffic signals.

The LOS revealed the following:

- During normal conditions, the roads are well capacitated, and they are very much capable of accommodating the flows. LOS of all roads surveyed is at LOS A, during normal conditions with the volume to capacity ratio ranging from 0.04 to 0.38. However, the concern is the flow during the peak hours, as the ratio of volume to capacity ranges from 0.11 to 0.76, leading to a LOS ranging from level A to C.
- Nelson Mandela Drive is the most congested road. It has a total traffic volume (in PCU) of 14946, and a Level of Service C.

- General Dan Pienaar Drive, towards the northern direction, is congested, with a total traffic volume (in PCU) of 13194, and a Level of Service of C.
- Kolbe Avenue towards the southern direction is congested, with a total traffic volume (in PCU) of 12576, and a level of service of B.
- Aliwal Street towards the northern direction is congested, with a total traffic volume (in PCU) of 8889, and a level of service of B.

With the population of Bloemfontein growing every year, the conditions in public transportation not improving and with the increase in private car use, it could be a matter of a few years before the roads of Bloemfontein are over capacitated and the levels of congestion higher than expected. The high volumes carried by both roads and intersections inform this. The use of private vehicles is increasing with the increase in population and migration to the urban areas; this has a negative impact on traffic, as increased use of private vehicles will contribute to more congestion and delays.

Table 21: Level of services for normal and peak hour volume (Source: Primary survey, 2017)

Road	Direction	No of Lanes	Total Traffic Volume (in PCU)	Average Hourly Traffic Volume (in PCU)	Peak Hour Traffic Volume (in PCU)	Capacity of two lane traffic	V/C	LOS Normal	Vp/C	LOS (Peak)
Nelson Mandela Drive	E	2	14946	1055	2135	2800	0.38	A	0.76	C
Nelson Mandela Drive	W	2	11682	824	1314	2800	0.29	A	0.47	A
Aliwal Street	N	2	8889	623	1554	2800	0.22	A	0.55	B
Aliwal Street	S	2	5914	418	793	2800	0.15	A	0.28	A
Raymond Mhlaba	N	2	7057	493	762	2800	0.18	A	0.27	A
Oos Burger Street	S	2	3532	250	447	2800	0.09	A	0.16	A
Fort Hare Road	E	2	6614	465	859	2800	0.17	A	0.31	A
Fort Hare Road	W	2	9744	687	1194	2800	0.25	A	0.43	A
Hanger Street	N	2	11131	788	1379	2800	0.28	A	0.49	A
Hanger Street	S	2	6542	464	797	2800	0.17	A	0.28	A
President Boshof Street	N	2	6442	456	883	2800	0.16	A	0.32	A
President Boshof Street	S	2	1462	103	332	2800	0.04	A	0.12	A
Parfitt Avenue	N	2	8457	593	1077	2800	0.21	A	0.38	A
Parfitt Avenue	S	2	5780	403	631	2800	0.14	A	0.23	A
Kolbe Avenue	N	2	10910	403	631	2800	0.14	A	0.23	A
Kolbe Avenue	S	2	12576	889	1538	2800	0.32	A	0.55	B
President Avenue	E	2	2794	197	300	2800	0.07	A	0.11	A
President Avenue	W	2	4787	337	557	2800	0.12	A	0.20	A
General Dan Pienaar Dr	N	2	13194	933	2010	2800	0.33	A	0.72	C
Parfitt Avenue	S	2	8974	633	1311	2800	0.23	A	0.47	A

5.4 SCENARIOS OF INFORMATION AND COMMUNICATION TECHNOLOGY (ICT)

This section highlights the use and importance of ICT in the city of Bloemfontein. Sub-sections discussed below include the accessibility of ICT, where and how people access ICT, the availability of ICT, reasons for use of ICT and the preference of ICT integration in transportation. This information is important because it gives the indication of how currently ICT is used in the city, and how that can benefit the city, should there be an integration of ICT with transportation.

5.4.1 ACCESSIBILITY TO ICT

Table 22 and Figures 39 and 40 present the responses on accessibility of ICT. According to the survey, 73% of the respondents in Bloemfontein have access to ICT, while 24% of respondents have limited access and only 3% of the respondents do not have any access to ICT. The result indicates that even people with low income have access to ICT. This implies that if ICT is integrated with public transportation, people belonging to all economic strata, including people with low income, will be able to use it because they are already familiar with the technology.

Table 22: Availability of information and communication of technology (Source: Primary survey, 2017)

	Yes (%)	Yes (N)	No (%)	No (N)	Limited (%)	Limited (N)
Annual Income						
R0- R50 000	62%	59	4%	3	34%	35
R50 000 - R100 000	67%	34	8%	4	25%	13
R100 000 - R150 000	74%	17	4%	1	22%	5
R150 000 - R200 000	78%	35	2%	1	20%	9
R200 000 - R250 000	70%	14	5%	1	25%	5
R250 000 - R300 000	95%	21	0%	0	5%	1
R300 000 - R350 000	67%	6	0%	0	33%	3
R350 000 - R400 000	75%	3	0%	0	25%	1
Above R400 000	70%	7	0%	0	30%	3
Overall	73%	196	3%	10	24%	75

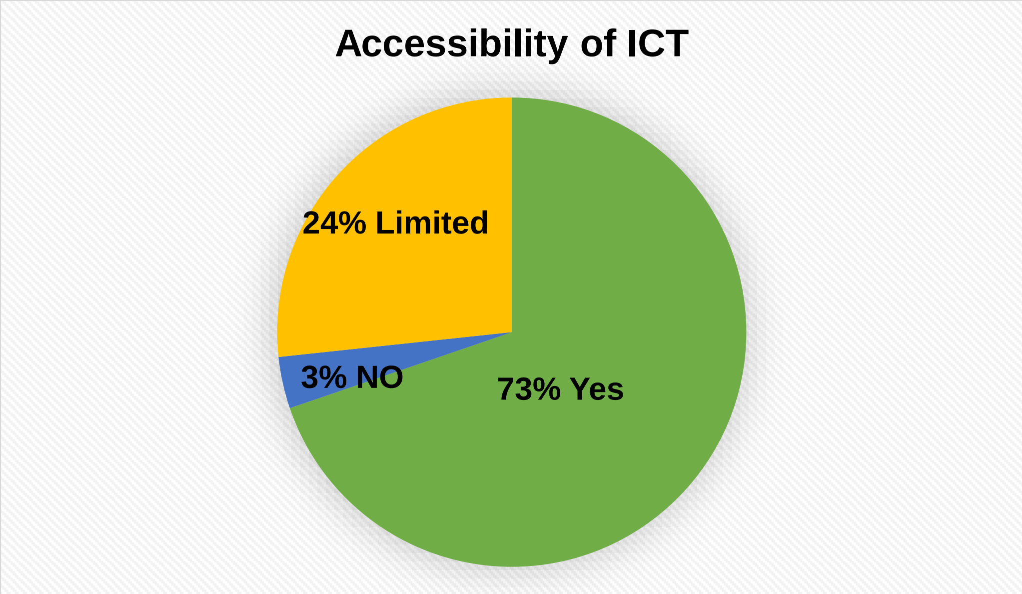

Figure 39: Accessibility of information and communication technology (Source: Primary survey, 2017)

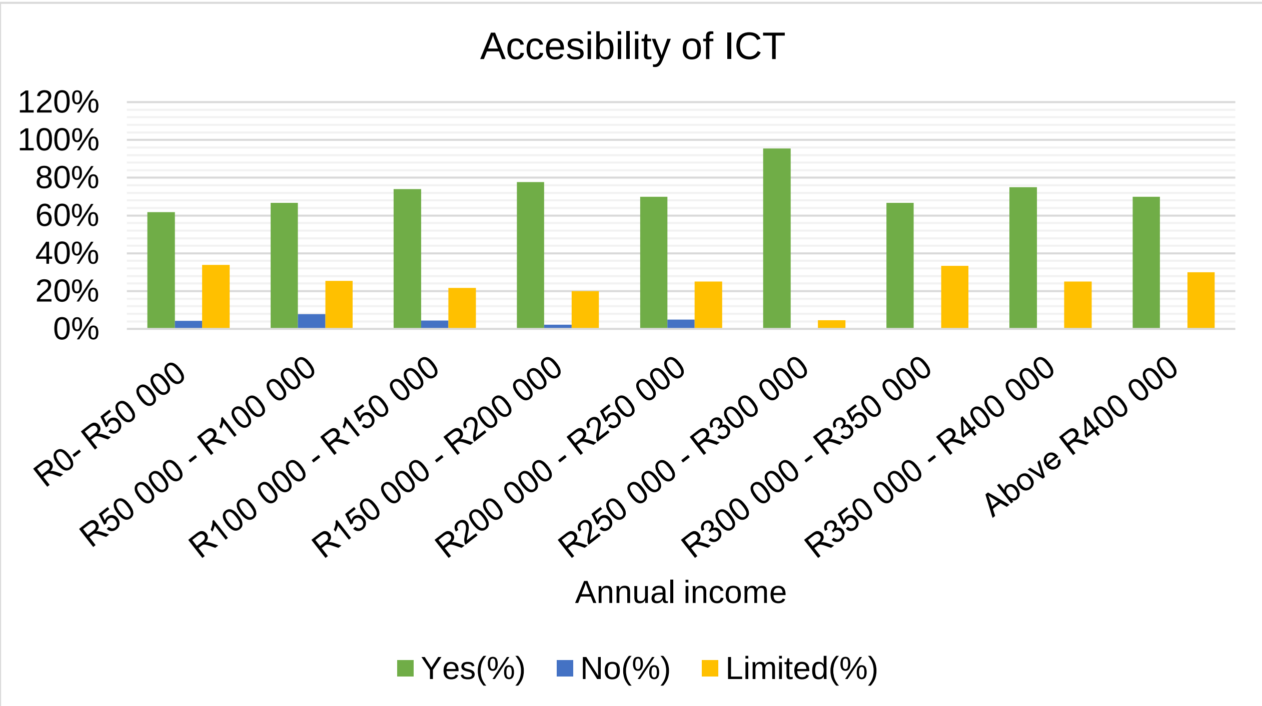

Figure 40: Accessibility of information and communication technology per annual income (Source: Primary survey, 2017)

5.4.2 POINT OF ACCESSIBILITY OF ICT

Table 23 and figures 41 and 42 show the results of the means and points of accessibility of ICT. It is found that the majority of people access ICT through their smartphones, 21% get access from their computers at home, 19% from computers at work and only 15% from tablets. Even though the majority of the people do not have access of ICT through computers, most of them do have access through smartphones and tablets. The high ICT accessibility through smartphones and tablets implies that there is a possibility that, if ICT is integrated in public transportation people can access it through their smart phones and tablets.

Table 23: Point of accessibility of ICT (Source: Primary survey, 2017)

	Computers at home (%)	Computers at home (N)	Computers at the office (%)	Computers at the office (N)	Tablets (%)	Tablets (N)	Smartphones (%)	Smartphones (N)
Annual Income								
R0 - R50 000	16%	23	6%	7	16%	20	62%	87
R50 000 - R100 000	18%	15	15%	12	16%	13	51%	42
R100 000 - R150 000	18%	7	23%	9	8%	3	53%	21
R150 000 - R200 000	27%	26	21%	20	11%	11	41%	39
R200 000 - R250 000	15%	5	12%	4	15%	5	58%	19
R250 000 - R300 000	26%	16	23%	14	19%	12	32%	20
R300 000 - R350 000	21%	5	21%	5	21%	5	38%	9
R350 000 - R400 000	20%	2	30%	3	10%	1	40%	4
Above R400 000	25%	7	25%	7	18%	5	32%	9
Overall	21%	106	19%	81	15%	75	45%	250

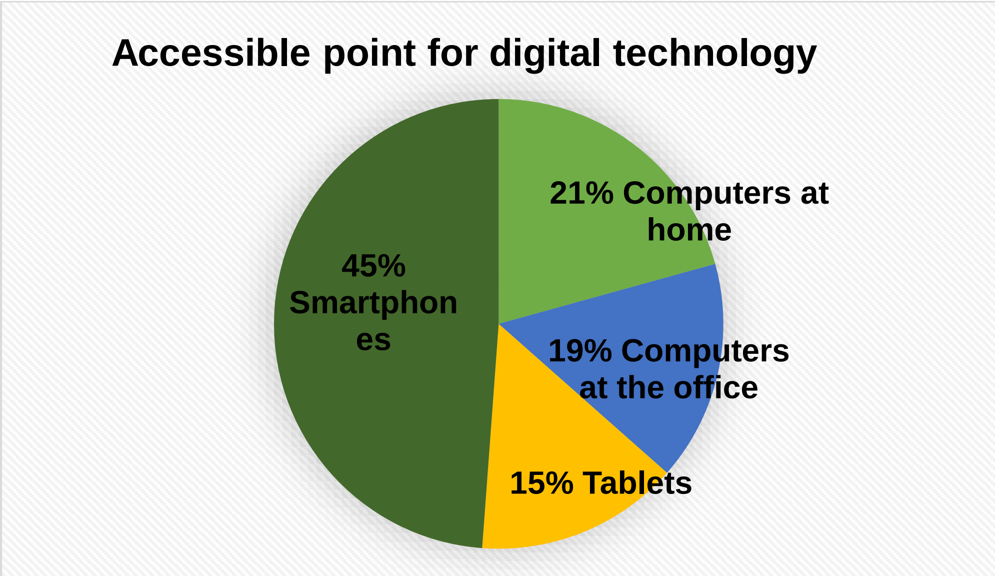

Figure 41: Point of accessibility of ICT (Source: Primary survey, 2017)

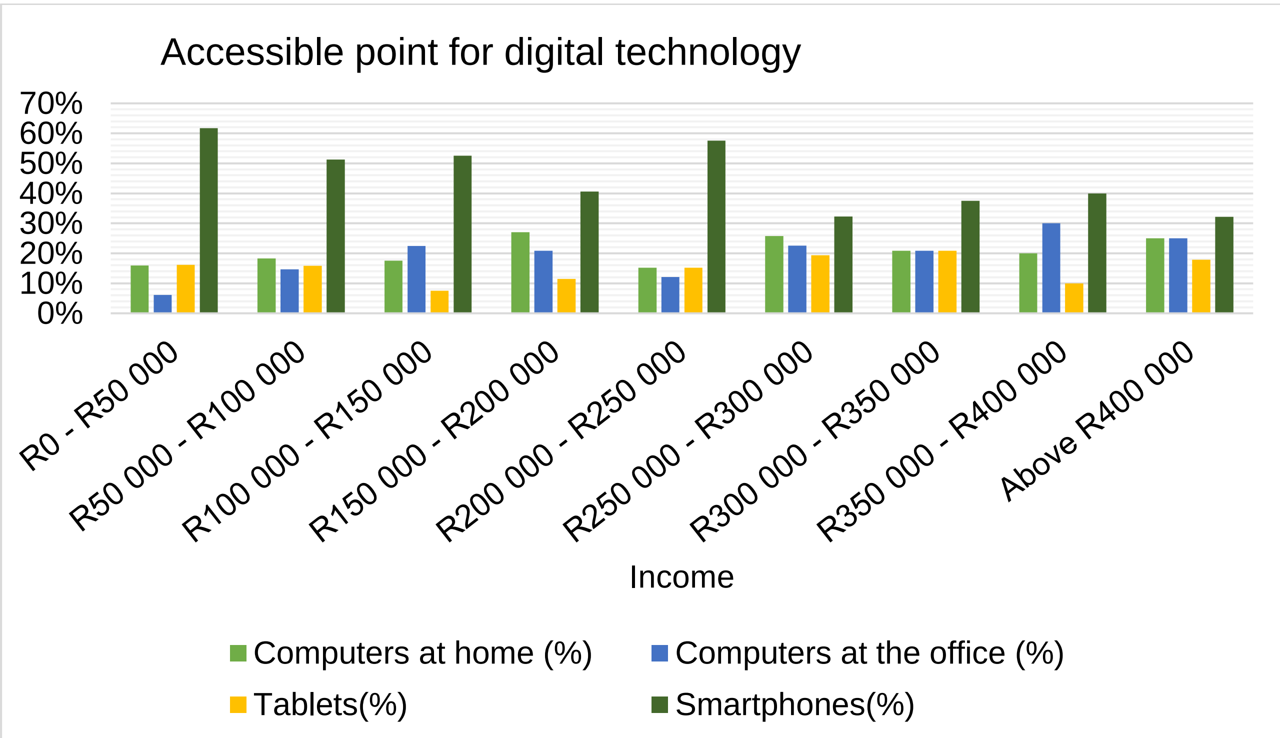

Figure 42: Point of accessibility according to different income categories (Source: Primary survey, 2017)

5.4.3 AVAILABILITY OF ICT

Table 24, and Figure 43 and 44 show the availability of ICT. Almost 97% of the respondents in Bloemfontein do have access to digital technology and only 3% do not have access.

Table 24: Availability of digital technology (Source: Primary survey, 2017)

	Yes(%)	Yes(N)	No(%)	No(N)
Annual Income				
R0 - R50 000	95%	92	5%	5
R50 000 - R100 000	94%	48	6%	3
R100 000 - R150 000	91%	21	9%	2
R150 000 - R200 000	98%	44	2%	1
R200 000 - R250 000	100%	18	0%	0
R250 000 - R300 000	95%	21	5%	1
R300 000 - R350 000	100%	9	0%	0
R350 000 - R400 000	100%	4	0%	0
Above R400 000	100%	10	0%	0
Overall	97%	267	3%	12

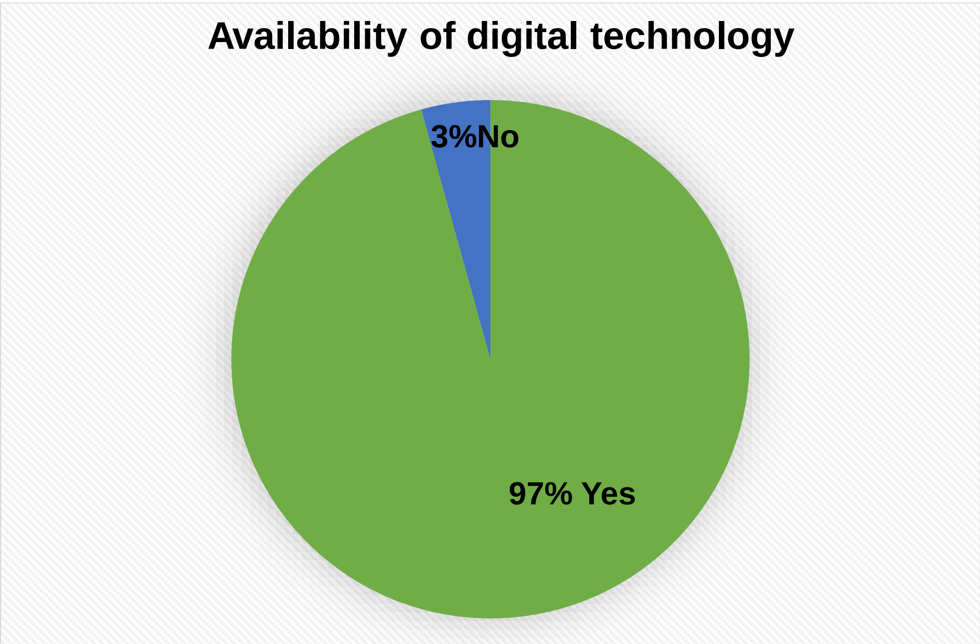

Figure 43: Availability of ICT (Source: Primary survey, 2017)

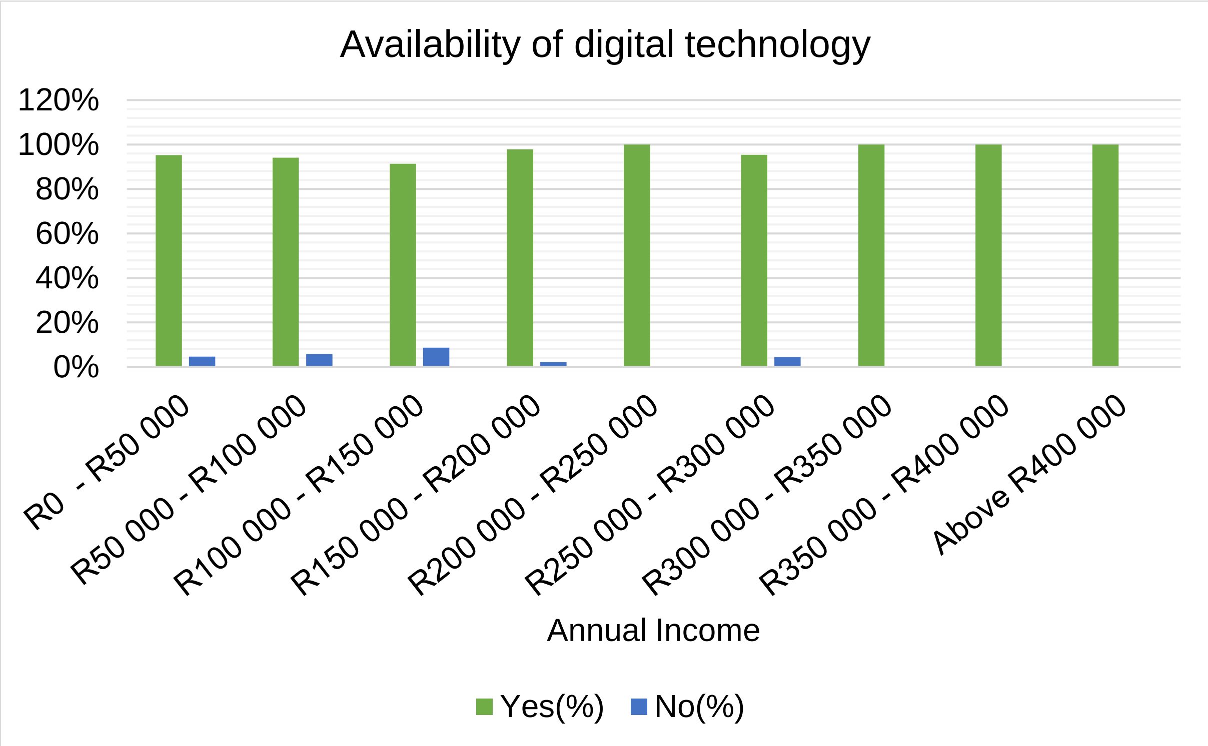

Figure 44: Availability of ICT (Source: Primary survey, 2017)

5.4.4 PURPOSE FOR USE OF ICT

When asked the reason for their use of ICT. 37% of respondents from Bloemfontein revealed that they use ICT for online communication, while almost 24% use it for work and 25% use it for online entertainment, and only 14% claim to use it for online shopping

Table 25: Purpose for using Information and communication technology (Source: Primary survey, 2017)

	Office work online(%)	Office work online (N)	Online shoppin g (%)	Online shoppin g (N)	Online entertainment (%)	Online entertainment (N)	Online communication (%)	Online communication (N)
Annual Income								
R0 - R50 000	10%	13	6%	9	24%	33	60%	86
R50 000 - R100 000	15%	14	10%	9	28%	26	47%	44
R100 000 - R150 000	31%	14	11%	5	24%	11	33%	15
R150 000 - R200 000	22%	24	15%	16	26%	28	37%	40
R200 000 - R250 000	24%	10	12%	5	24%	10	40%	17
R250 000 - R300 000	24%	14	21%	12	22%	13	33%	19
R300 000 - R350 000	26%	6	17%	4	26%	6	30%	7
R350 000 - R400 000	36%	4	9%	1	27%	3	27%	3
Above R400 000	23%	8	26%	9	26%	9	26%	9
Overall	24%	107	14%	70	25%	139	37%	240

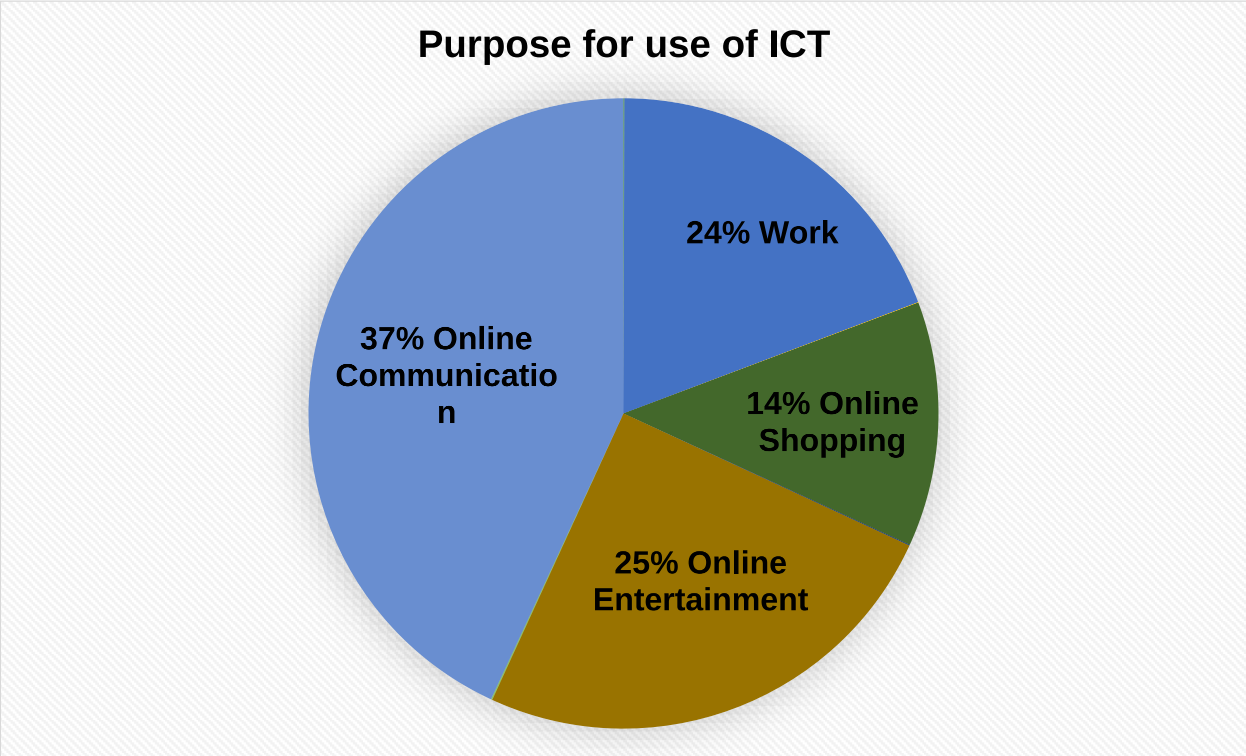

Figure 45: Purpose for the use of ICT (Source: Primary survey, 2017)

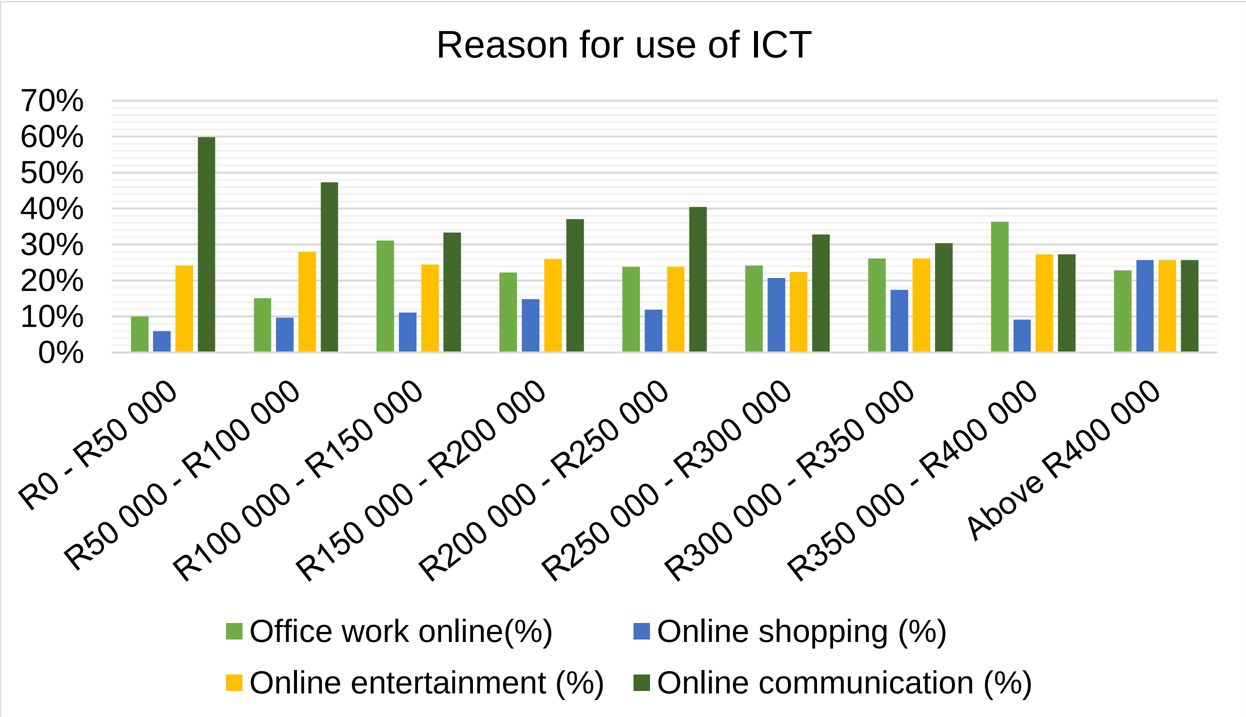

Figure 46: Purpose for use of ICT (Source: Primary survey, 2017)

5.4.5 CHALLENGES OF ICT IN BLOEMFONTEIN

The study revealed that people still do have some challenges they face when it comes to ICT (Table 26 and Figures 47 and 48). Some of the major challenges include connectivity speed, as 34% of the respondents highlighted this as a major challenge, and cost – 37% of the respondents highlight this as a worrying factor – while the minor challenges include technology awareness, since only 12% of the respondents highlighted this as a challenge. People who have low income are mostly affected by the cost, availability and connectivity speed, while people who earn higher income complain mostly about the connectivity speed.

Table 26: Challenges in information and communication technology according to different annual income categories (Source: Primary survey, 2017)

	Connectivity speed (%)	Connectivity speed (N)	Availability (%)	Availability (N)	Cost (%)	Cost (N)	Technology awareness/ literacy (%)	Technology awareness/ literacy (N)	Others(%)	Others(N)
Annual Income										
R0 - R50 000	34%	54	18%	25	40%	64	9%	13	0%	0
R50 000 - R100 000	33%	29	18%	16	36%	31	10%	9	2%	2
R100 000 - R150 000	36%	17	15%	7	36%	17	13%	6	0%	0
R150 000 - R200 000	34%	32	18%	17	33%	31	15%	14	1%	1
R200 000 - R250 000	44%	15	18%	6	26%	9	12%	4	0%	0
R250 000 - R300 000	24%	9	16%	6	41%	15	19%	7	0%	0
R300 000 - R350 000	29%	4	21%	3	50%	7	0%	0	0%	0
R350 000 - R400 000	22%	2	11%	1	44%	4	22%	2	0%	0
Above R400 000	50%	10	15%	3	30%	6	5%	1	0%	0
Overall	34%	172	17%	84	37%	184	12%	56	0%	3

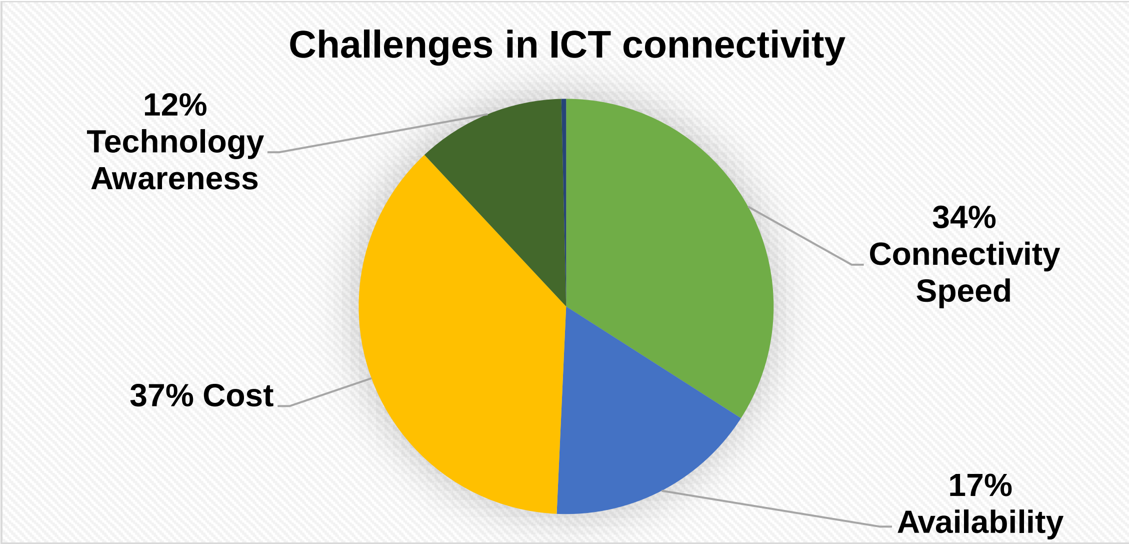

Figure 47: Overall challenges in ICT connectivity (Source: Primary survey, 2017)

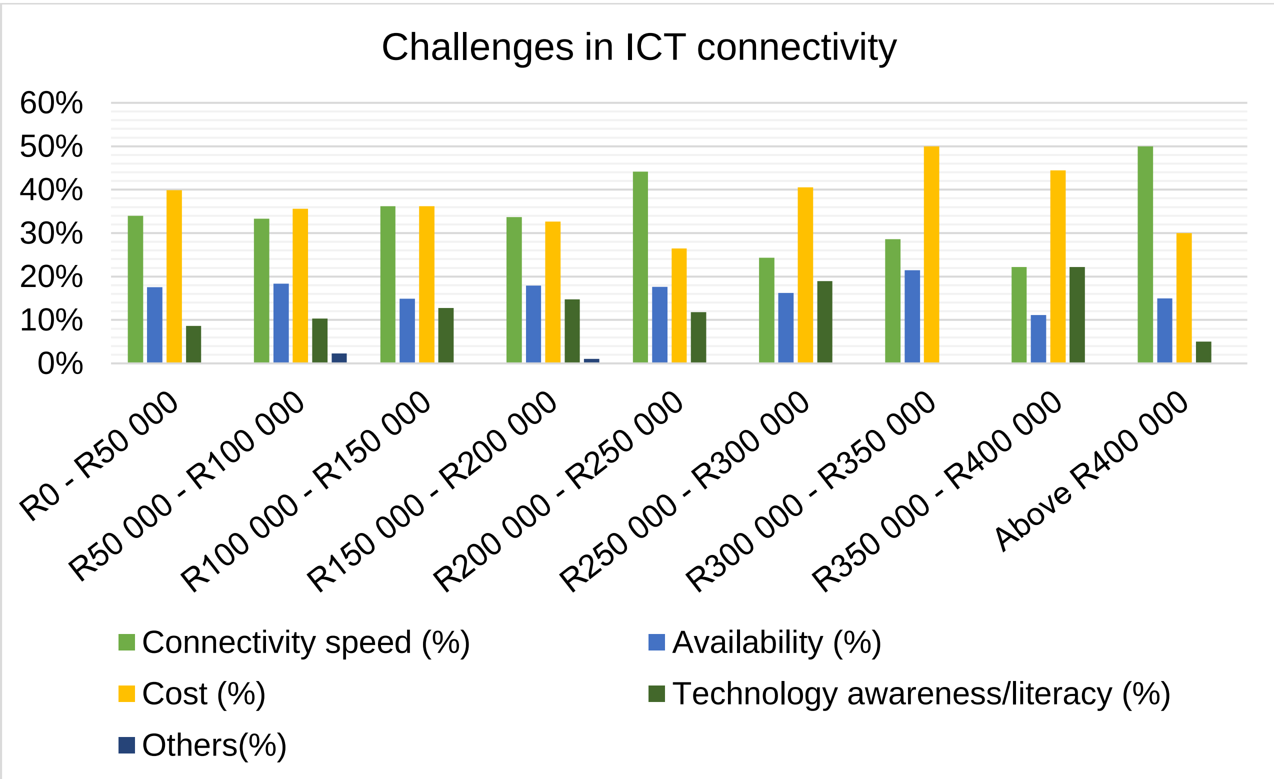

Figure 48: Challenges in ICT according to income categories (Source: Primary survey, 2017)

5.4.6 PREFERENCE OF USE OF ICT AT HOME AND WORK

According to the survey, most of the respondents (90%) will prefer to use ICT at their homes for work activities (Table 27 and Figure 49 and 50), while 10% of people are not interested in it. People with higher income seem to accept the idea of using ICT at home for work purposes. People with lower incomes are also keen on the idea, except the 10%.

Table 27: Preference for use of ICT for work at home (Source: Primary survey, 2017)

	Preferable (%)	Preferable (N)	Not Preferable (%)	Not Preferable (N)
Annual Income				
R0 - R50 000	85%	78	15%	13
R50 000 - R100 000	67%	33	33%	16
R100 000 - R150 000	78%	18	22%	5
R150 000 - R200 000	91%	40	9%	4
R200 000 - R250 000	95%	18	5%	1
R250 000 - R300 000	91%	20	9%	2
R300 000 - R350 000	100%	9	0%	0
R350 000 - R400 000	100%	4	0%	0
Above R400 000	100%	10	0%	0
Overall	90%	230	10%	41

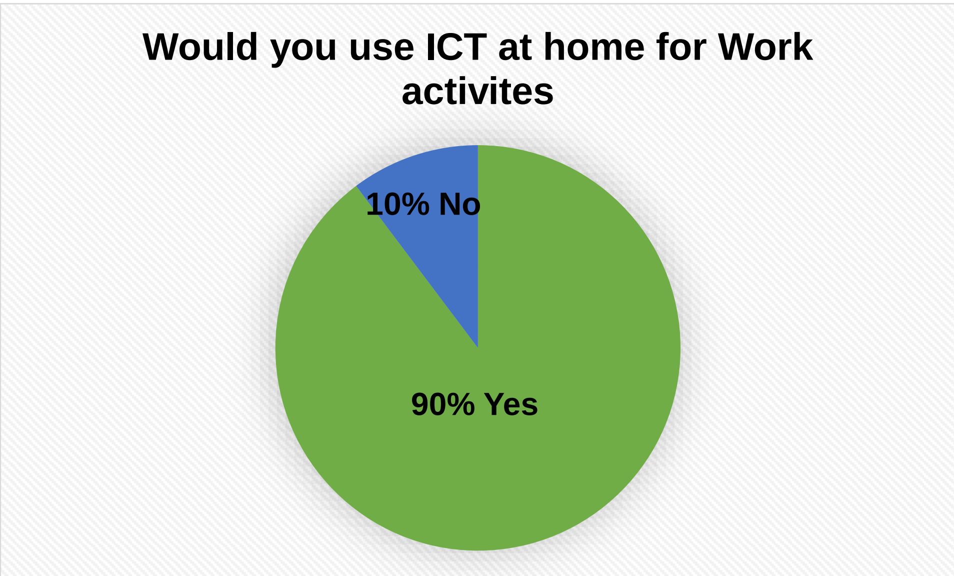

Figure 49: Preference of ICT usage at home for work activities (Source: Primary survey, 2017)

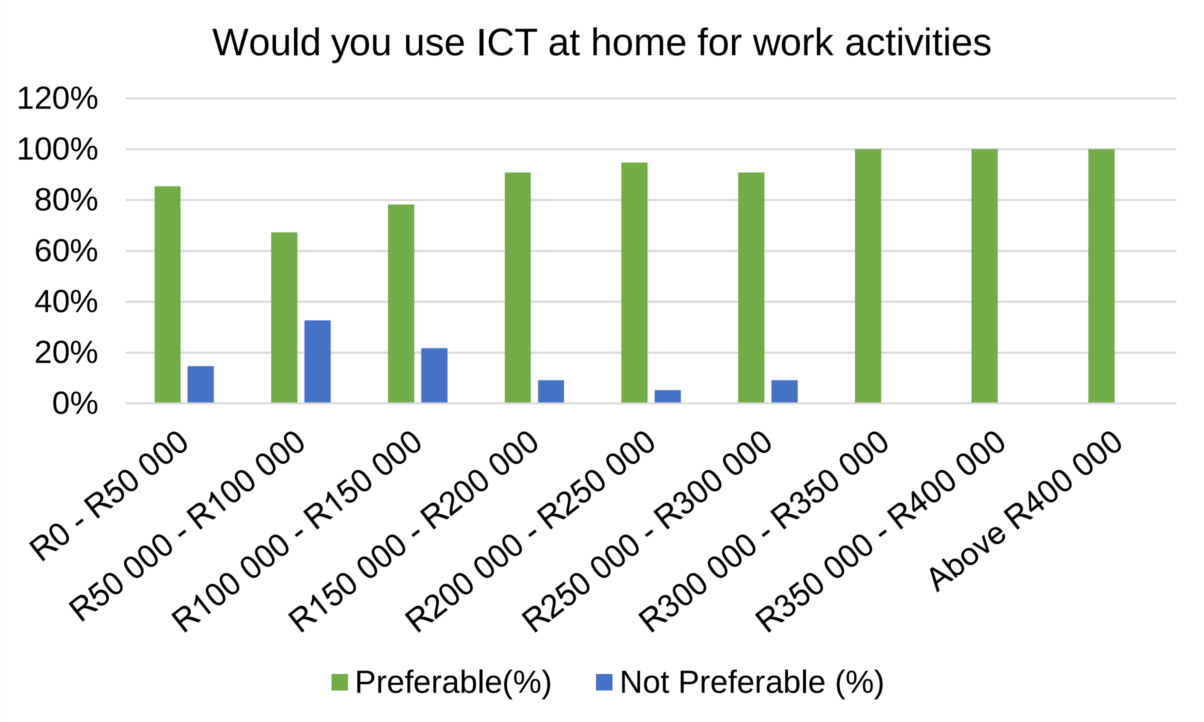

Figure 50: Respondents' percentage responses on the usage of ICT at home (Source: Primary survey, 2017)

5.4.7 DURATION AND TIME OF DAY OF USE OF ICT

Even though a high percentage of people around Bloemfontein have access to ICT and digital gadgets, only 46% of people claim to have accessibility to ICT all the time, according to Table 28 and Figures 51 and 52. About 19% use it only during the day, and 13% use it during night-time. Looking at the percentage of people accessing their ICT all the time (46%), during office hours (18%) and those that access it during the day (19%). It can be seen that almost 83% of people might be able to access ICT during the day; this means if ICT is integrated with public transportation people can use it to plan their trips.

Table 28: Duration of access to information and communication technology (Source: Primary survey, 2017)

	Limited period during office hours (%)	Limited period during office hours (N)	During the day (%)	During the day (N)	During night time(%)	During night time(N)	All the time (%)	All the time (N)	Never (%)	Never (N)
Annual Income										
R0 - R50 000	9%	9	30%	31	13%	15	46%	50	2%	2
R50 000 - R100 000	18%	10	27%	15	11%	6	38%	21	5%	3
R100 000 - R150 000	13%	3	8%	2	4%	1	71%	17	4%	1
R150 000 - R200 000	19%	10	15%	8	15%	8	50%	27	2%	1
R200 000 - R250 000	9%	2	22%	5	9%	2	61%	14	0%	0
R250 000 - R300 000	17%	4	8%	2	8%	2	67%	16	0%	0
R300 000 - R350 000	27%	3	18%	2	27%	3	27%	3	0%	0
R350 000 - R400 000	25%	1	25%	1	0%	0	25%	1	25%	1
Above R400 000	21%	3	21%	3	29%	4	29%	4	0%	0
Overall	18%	45	19%	72	13%	41	46%	157	4%	10

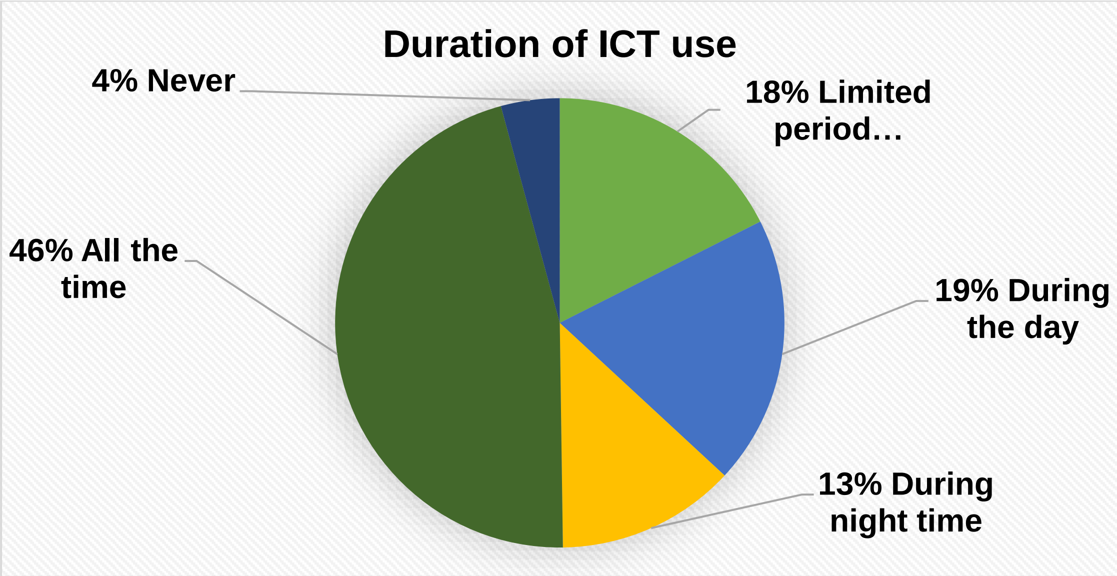

Figure 51: Duration of accessibility of ICT usage (Source: Primary survey, 2017)

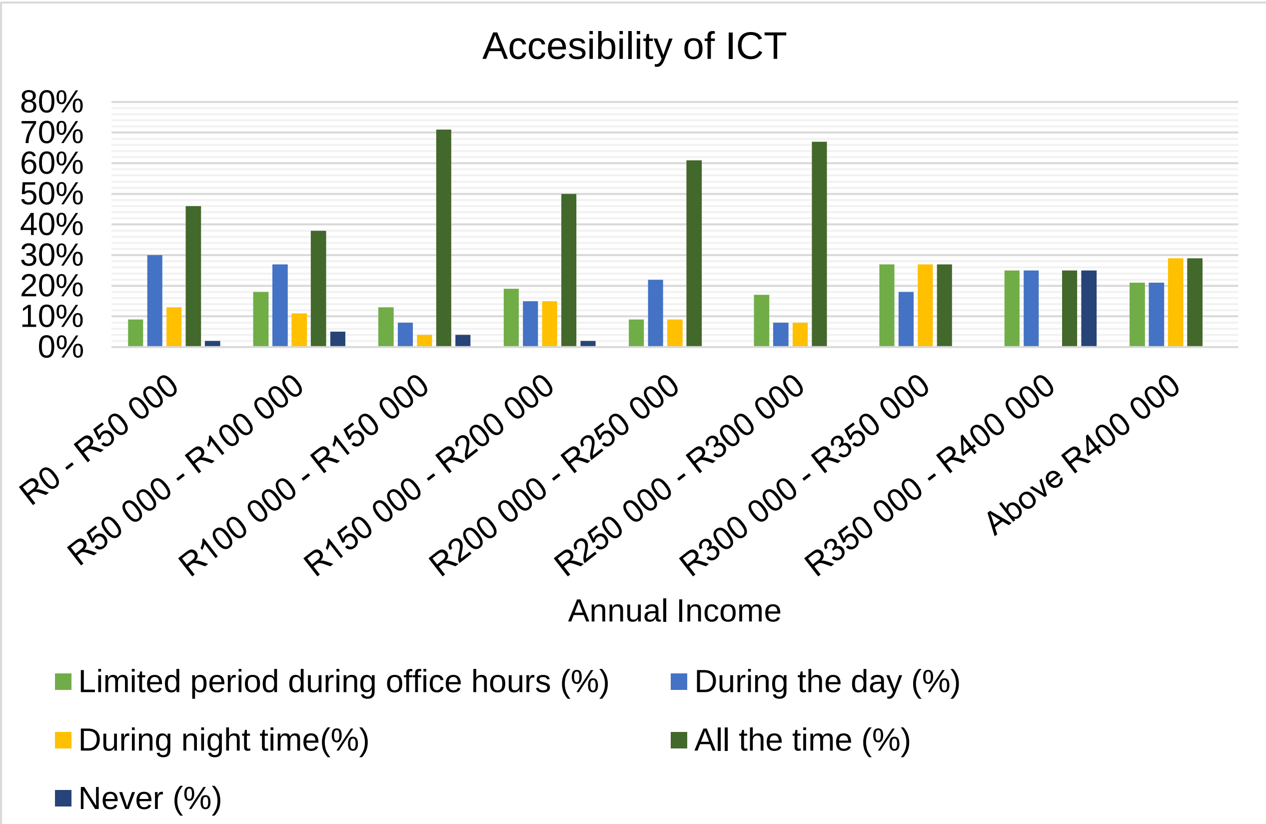

Figure 52: Duration of accessibility of information and communication technology across different annual earnings (Source: Primary survey, 2017)

5.4.8 PLACES OF ACCESS OF ICT

Even though the percentage of accessibility is not as expected, Figure 53 shows that there is accessibility to the Internet. ICT accessibility is dependent not only on availability, but also on choice. Table 29 and Figures 53 and 54 shows that people do have high percentages of Internet coverage during the day.

Table 29: Place of access of ICT (Source: Primary survey, 2017)

	At home (%)	At home (N)	Office/ work place (%)	Office/ work place (N)	Public places (%)	Public places (N)	Anywhere (%)	Anywhere (N)
Annual Income								
R0 - R50 000	19%	21	14%	13	13%	15	54%	64
R50 000 - R100 000	14%	9	21%	14	15%	10	50%	33
R100 000 - R150 000	11%	3	21%	6	7%	2	61%	17
R150 000 - R200 000	15%	8	13%	7	9%	5	63%	34
R200 000 - R250 000	28%	7	12%	3	8%	2	52%	13
R250 000 - R300 000	12%	3	12%	3	0%	0	76%	19
R300 000 - R350 000	23%	3	23%	3	0%	0	54%	7
R350 000 - R400 000	20%	1	40%	2	0%	0	40%	2
Above R400 000	29%	4	36%	5	0%	0	36%	5
Overall	19%	59	21%	56	6%	34	54%	194

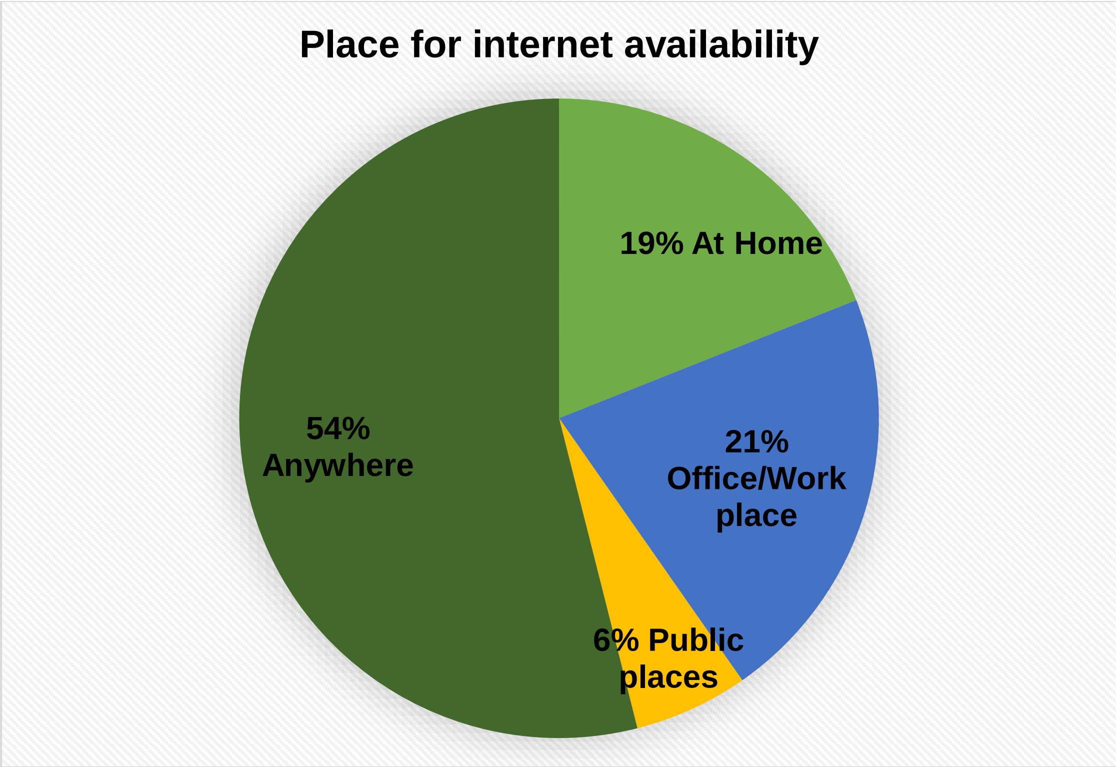

Figure 53: Place of accessibility of ICT (Source: Primary survey, 2017)

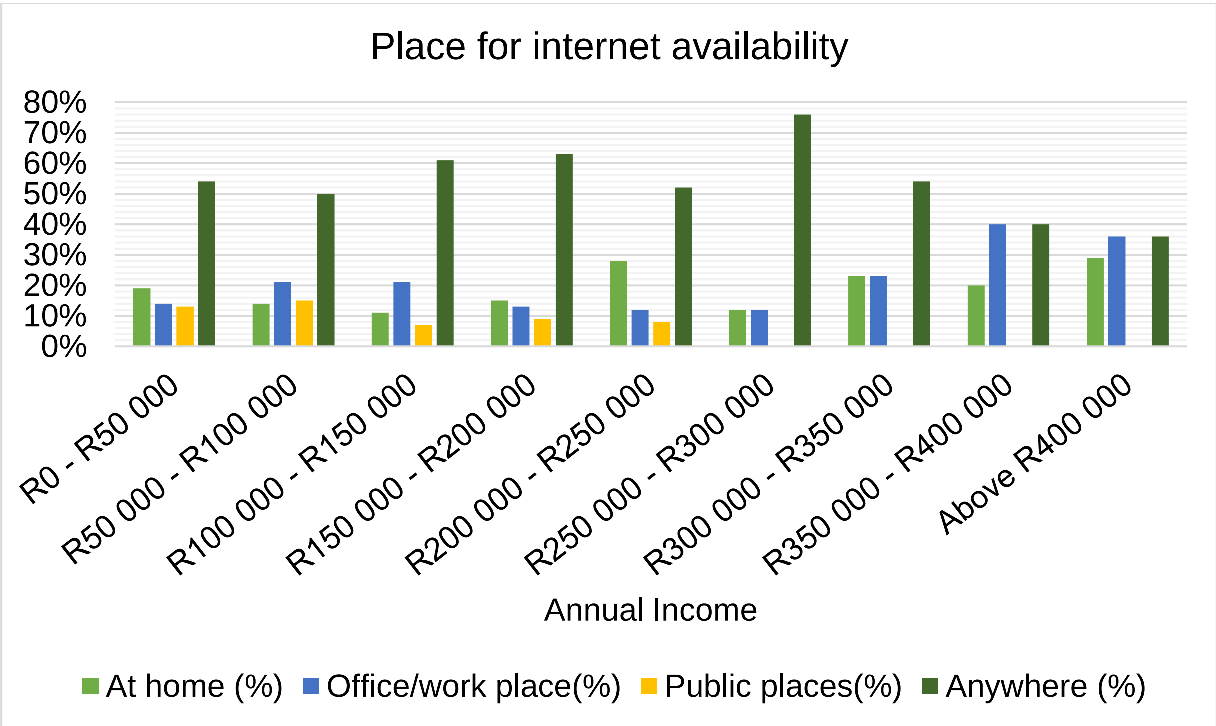

Figure 54: Place of access of ICT across different income categories (Source: Primary survey, 2017)

5.4.9 PURPOSE FOR USE OF ICT AT HOME

The survey revealed that some of the reasons that will make people use ICT at home for work purposes would include the possibility of limiting the need to travel and reducing the number of travelled kilometres. About 59% of people would use ICT to reduce the number of kilometres travelled. This simply means that, if circumstances allow, they will use ICT at home for their work purposes so that they reduce their travel distance and activities. About 41% would use ICT at home for work activities because that will limit the need to travel (Table 30 and Figures 55 and 56). It can be concluded that, with favourable and acceptable conditions, people from Bloemfontein seem not to have a problem with integrating ICT both with their transportation and with socio economic activities.

Table 30: Purpose for the use of ICT at home (Source: Primary survey, 2017)

	Limited need to travel work (%)	Limited need to travel to work(N)	Reduction of kilometres travelled (%)	Reduction of kilometres travelled(N)
Annual Income				
R0 - R50 000	33%	27	67%	62
R50 000 - R100 000	44%	21	56%	27
R100 000 - R150 000	37%	10	63%	17
R150 000 - R200 000	42%	22	58%	31
R200 000 - R250 000	48%	10	52%	11
R250 000 - R300 000	43%	10	57%	13
R300 000 - R350 000	64%	7	36%	4
R350 000 - R400 000	80%	4	20%	1
Above R400 000	46%	6	54%	7
Overall	41%	123	59%	179

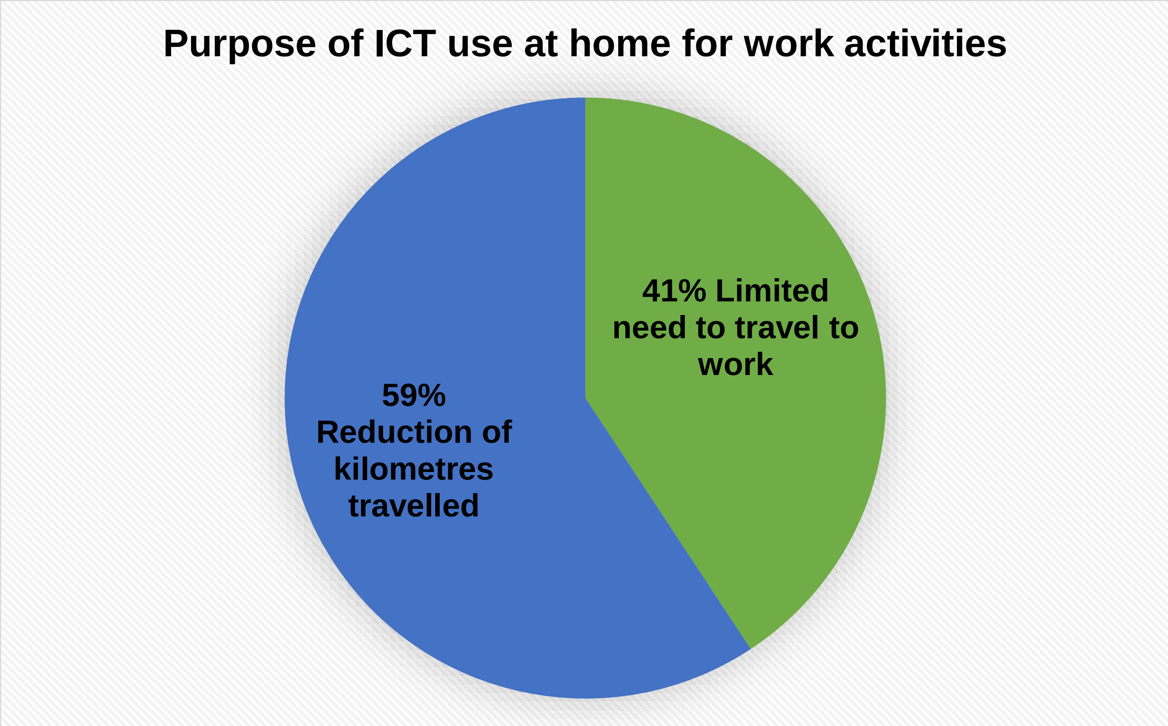

Figure 55: Purpose for ICT use at home for work activities *(Source: Primary survey, 2017)*

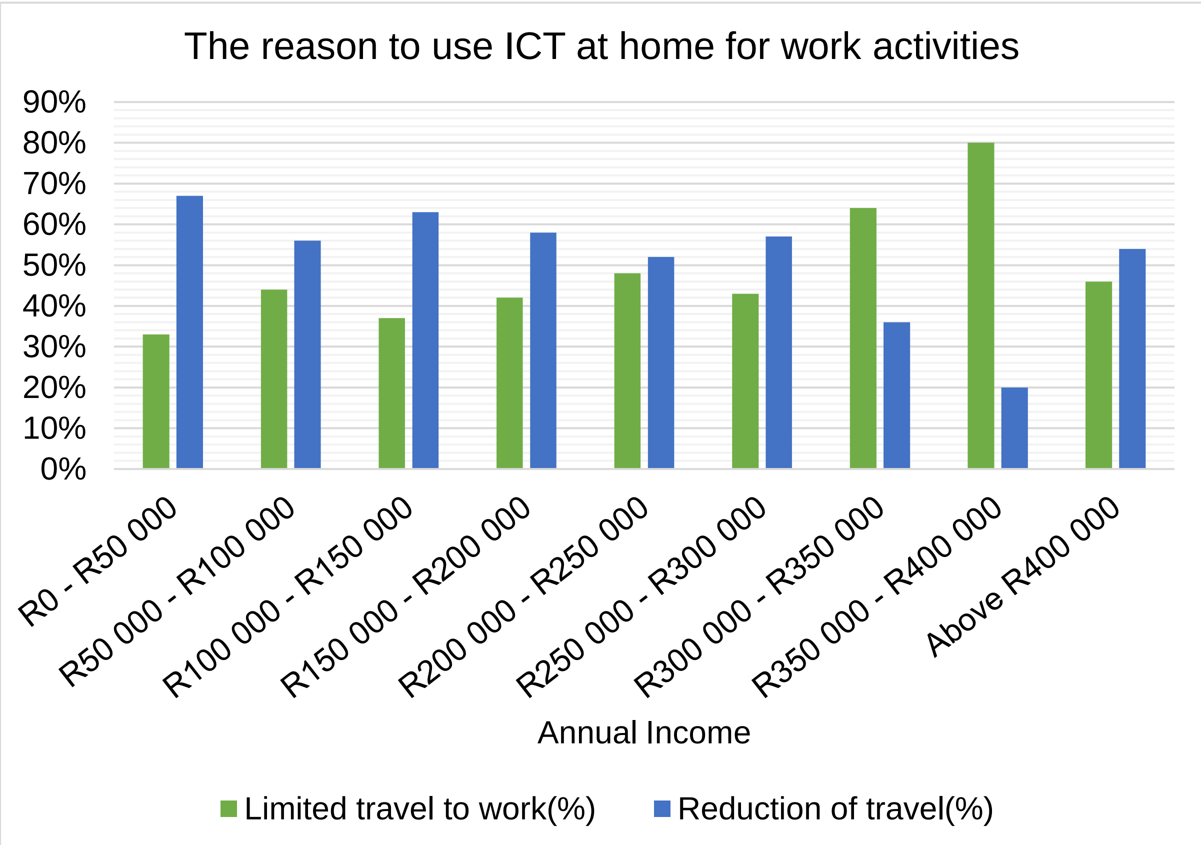

Figure 56: The reason to use ICT at home for work activities, according to income categories (Source: Primary survey, 2017)

5.5 LINKAGE BETWEEN SUSTAINABILITY PARAMETERS AND USE OF ICT

Statistical nonlinear regression models were developed and employed to understand trip generation and influence of different urban functions (ICT usage), demographic (Income), road transportation (distance travelled and trip generation) variables and ICT use on sustainable road transportation of the study area.

A summary of all the important factors that contribute towards sustainable transportation were considered and presented in Table 31. All grouping was made according to annual income, and important factors such as ICT usage, number of trips, and distance travelled daily were presented below. Table reveals the following:

- There is an increase in ICT usage in hours as income range increase. People earning between R0 - R50 000 have ICT usage of 0.50 hours. People earning between R50 000 - R100 000 have ICT usage of 0.52 hours. People earning between R100 000 - R150 000 have ICT usage of 1.00 hours. People earning between R150 000 - R200 000 have ICT usage of 2.00 hours. People earning between R200 000 - R250 000 have ICT usage of 3.00 hours. People earning between R250 000 - R300 000 have ICT usage of 5.00 hours. People earning between R300 000 - R350 000 have ICT usage of 4.00 hours. People earning between R350 000 - R400 000 have ICT usage of 7.00 hours. People earning above R400 000 have ICT usage of 6.50 hours.

- The number of trips increases as the income range increases. The lowest range of income R0 - R50 000, has the lowest number of trips of 1.7. This number, through the integration of ICT usage of 0.5 hours, reduces by 14%. For the income range of R50 000 - R100 000, there are 1.9 average trips generated per day and through the integration of 0, 52 hours in ICT there is a reduction of 15.5%. For the income range of R100 000 - R150 000, there are 2.2 average trips generated per day and through the integration of 1.00 hours in ICT there is a reduction of 15.4%. For the income range of R150 000 - R200 000, there are 2.6 average trips generated per day and through the integration of 2.00 hours in ICT there is a reduction of 19.5%. For the income range of R200 000 - R250 000 there are 2.3 average trips generated per day and through the integration of 3.00 hours in ICT there is a reduction of 21.7%.

For the income range of R250 000 - R300 000 there are 2.3 average trips generated per day and through the integration of 5.00 hours in ICT there is a reduction of 22.2%. For the income range of R300 000 - R350 000 there are 2.7 average trips generated per day and through the integration of 4.00 hours in ICT there is a reduction of 22.4%. For the income range of R350 000 - R400 000 there are 2.3 average trips generated per day and through the integration of 7.00 hours in ICT there is a reduction of 23%. For the income range above R400 000 there are 3.0 average trips generated per day and through the integration of 6.50 hours in ICT there is a reduction of 22.2%.

- The average distance travelled also increases as the income range increase. The lowest range of income R0 - R50 000, has the lowest average distance travelled of 9.3km. This number through the integration of ICT usage of 0.5 hours has a reduction of 33%. For the income range of R50 000 - R100 000, there is an average distance travelled of 11.6 km, and through the integration of ICT of 0.52 hours there is a reduction of 44% in the average distance travelled. For the income range of R100 000 - R150 000, there is an average distance travelled of 14.1 km, and through the integration of ICT of 1.00 hours there is a reduction of 37% in the average distance travelled. For the income range of R150 000 - R200 000, there is an average distance travelled of 17.9 km, and through the integration of ICT of 2.00 hours there is a reduction of 42% in the average distance travelled. For the income range of R200 000 - R250 000, there is an average distance travelled of 17.8 km, and through the integration of ICT of 3.00 hours there is a reduction of 48% in the average distance travelled. For the income range of R250 000 - R300 000 there is an average distance travelled of 13.1 km, and through the integration of ICT of 5.00 hours there is a reduction of 43% in the average distance travelled. For the income range of R300 000 - R350 000, there is an average distance travelled of 23.1 km, and through the integration of ICT of 4.00 hours there is a reduction of 64% in the average distance travelled. For the income range of R350 000 - R400 000, there is an average distance travelled of 22.8 km, and through the integration of ICT of 7.00 hours there is a reduction of 80% in the average distance travelled. For the income range above R400 000, there is an average distance travelled of 24.2 km, and through the integration of ICT of 6.50 hours there is a reduction of 46% in the average distance travelled.

- The distance travelled by households per day increases as the income range increase. The lowest range of income R0 - R50 000, has the lowest distance travelled per household of 15km.The integration of ICT in terms of mobile applications and real time information can help drivers use shorter routes that will help them reduce total kilometres they travel daily. While the use of ICT for socio-economic activities such as working from home, online shopping, and online entertainment reduce the need to travel, which consequently leads to reduced kilometres travelled. Through the integration of ICT usage of 0.5 hours has a reduction of 33%. For the income range of R50 000 - R100 000, there is 22 km of distance travelled per household, and through the integration of ICT of 0.52 hours there is a reduction of 44% in the distance travelled per household. For the income range of R100 000 - R150 000, there is 31 km of distance travelled per household, and through the integration of ICT of 1.00 hours there is a reduction of 37% in the distance travelled per household. For the income range of R150 000 - R200 000, there is 46 km of distance travelled per household, and through the integration of ICT of 2.00 hours there is a reduction of 42% in the average distance travelled. For the income range of R200 000 - R250 000, there is 40 km of distance travelled per household, and through the integration of ICT of 3.00 hours there is a reduction of 48% in the average distance travelled. For the income range of R250 000 - R300 000, there is 30 km of distance travelled per household, and through the integration of ICT of 5.00 hours there is a reduction of 43% in the average distance travelled. For the income range of R300 000 - R350 000, there is 63 km of distance travelled per household, and through the integration of ICT of 4.00 hours there is a reduction of 64% in the average distance travelled. For the income range of R350 000 - R400 000, there is 51 km of distance travelled per household, and through the integration of ICT of 7.00 hours there is a reduction of 80% in the average distance travelled. For the income range above R400 000, there is 73 km of distance travelled per household, and through the integration of ICT of 6.50 hours there is a reduction of 46% in the average distance travelled.

The integration of ICT in terms of mobile applications and real time information can help drivers use shorter routes and choose routes that are less congested. This will result in less congested and improved travel time. This will also give passengers notifications if there are delays, so that they will use alternative or other modes of transport. The reduction in travel time is a major benefit for lower income commuters. For those in the bracket R0 – R50 000 (who have ICT usage of .50 hours daily), the likely saving in time is 3.00 hours. For those in the bracket R50 000 – R100 000 (who have ICT usage of .52 hours), the saving is 3.42 hours. For those in the bracket R100 000 – R150 000 (who have ICT usage of 1 hour), the saving is 1.59 hours. For those in the bracket R150 000 – R200 000 (who have ICT usage of 2 hours), the saving is 0.85 hours. For those in the bracket R200 000 – R250 000 (who have ICT usage of 3 hours), the saving is 0.64 hours. For those in the bracket R250 000 – R300 000 (who have ICT usage of 5 hours), the saving is 0.35 hours. For those in the bracket R300 000 – R350 000 (who have ICT usage of 7 hours), the saving is 0.69 hours. For those in the bracket R350 000 – R400 000 (who have ICT usage of 7 hours), the saving is 0.71 hours. For those earning above R400 000 (who have ICT usage of 6.5 hours), the saving is 0.29 hours.

Table 31: Usage of information and communication technology, travel time and travel distance

Income range (Rands)	ICT Usage in hours per day	Number of trips per day per household	Average distance travelled per trip (in kms)	Reduction in number of trips per day in numbers and in (%)		Reduction in travel distance per trip (in kms)		Distance travelled by households per day	Reduction in travel Distance by households per day in kms and (in%)		Reduction in travel time by households per day in hours
R0 - R50 000	0.50	1.7	9.3	14.0%	0.23	33%	3.1	15	33%	5	3.00.
R50 000 - R100 000	0.52	1.9	11.6	15.5%	0.29	44%	5.1	22	44%	9	3.42
R100 000 - R150 000	1.00	2.2	14.1	15.4%	0.34	37%	5.2	31	37%	11	1.59
R150 000 - R200 000	2.00	2.6	17.9	19.5%	0.50	42%	7.4	46	42%	19	0.85
R200 000 - R250 000	3.00	2.3	17.8	21.7%	0.49	48%	8.5	40	48%	19	0.64

R250 000 - R300 000	5.00	2.3	13.1	22.2%	0.51	43%	5.7	30	43%	13	0.35
R300 000 - R350 000	4.00	2.7	23.1	22.4%	0.61	64%	14.7	63	64%	40	0.69
R350 000 - R400 000	7.00	2.3	22.8	23.0%	0.52	80%	18.2	51	80%	41	0.71
Above R400 000	6.50	3.0	24.2	23.4%	0.70	46%	11.2	73	46%	34	0.29

5.5.1 ICT versus number of trips

The number of trips generated influences the sustainability of road transportation. So an investigation was made to examine the interlinkage between ICT use and number of trips. There is a significant decrease in trips with significant increase and integration in ICT use. For example, use of ICT for about 7 hours on transportation and socio-economic activities significantly reduces trip generation, particularly for the higher income group people, the relationship is presented in Equation 4, which shows that ICT has a non-linear relationship with number of trips.

The linkage between ICT use and reduction in number of trips indicated a non-linear relationship with R^2 value of 0.8628. The relationship is presented in Equation 5. It is observed that reduction in number of trips increases with the increase in ICT usage. This is an indicator that to reduce number of trips in the roads of Bloemfontein, ICT usage will have to be one of the top priorities.

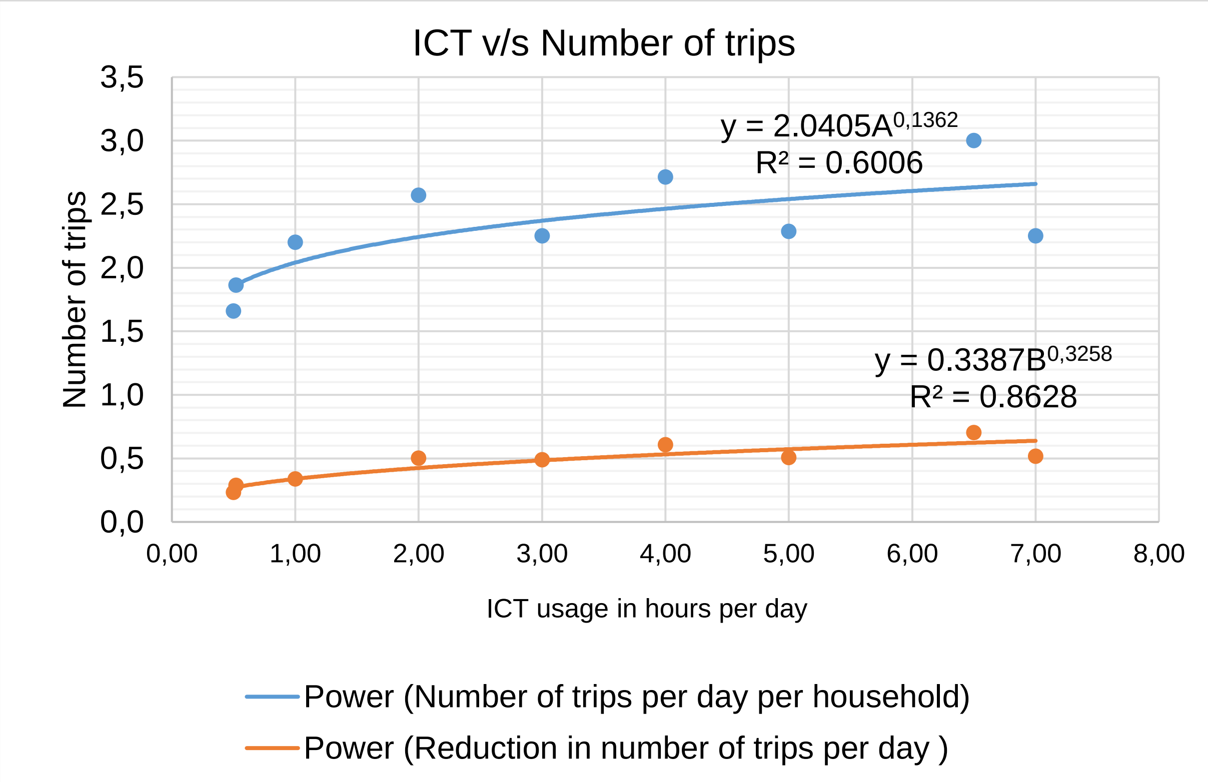

Figure 57: Linkage between ICT usage hourly and the number of trips daily

$y = 2.0405A^{0,1362}$ ....*Equation 4*

Where:

y = number of trips per day

A= ICT usage in hours per day

R^2 =0.6006

$y = 0.338B^{0,3258}$........................*Equation 5*

Where:

y = reduction in number of trips per day

B= ICT usage in hours per day

5.5.2 ICT versus average distance travelled per trip

The linkage between ICT and average distance travelled is presented in equation 6. ICT is observed to have a non-linear relation with the distance travelled by people (R^2= 0.6949).

Equation 7 indicates that the increase in ICT usage per hour also increases with the increase in the reduction in travel distance per trip. The reduction in travel distance per trip indicates that as the average distance travel decreases daily, the city of Bloemfontein benefits as it will lead to a reduction in traffic volume, traffic emissions, congestion, and travel delay.

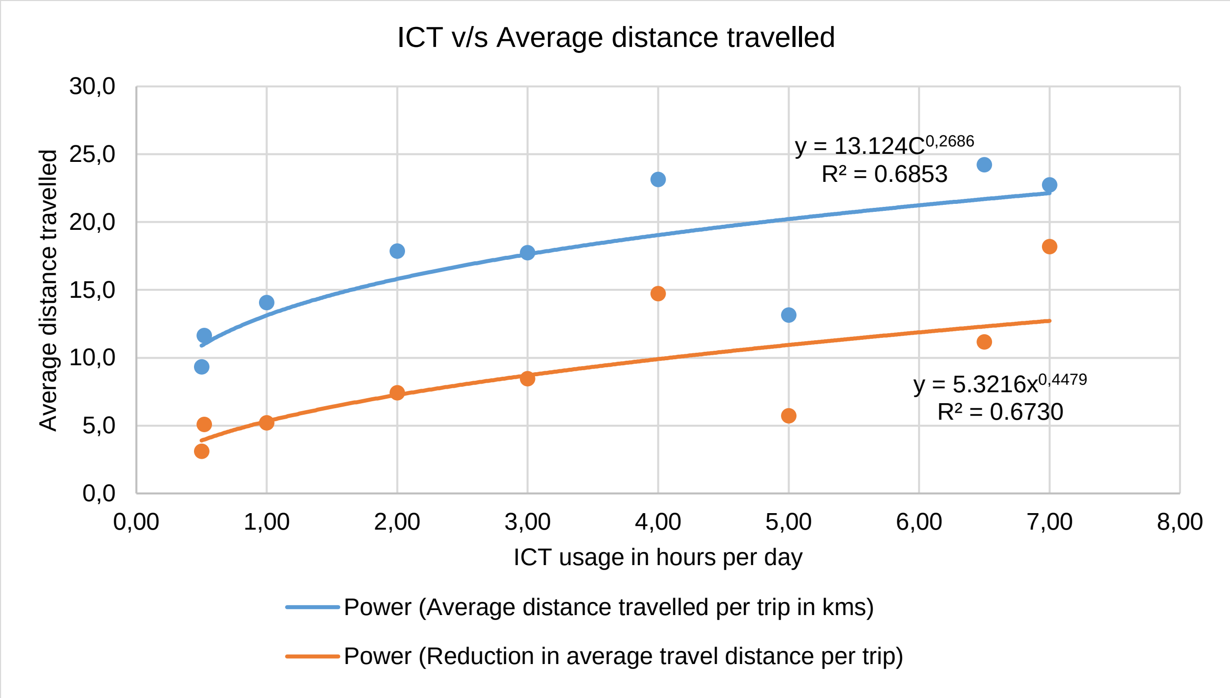

Figure 58: Linkage between ICT usage hourly and average distance travelled

$y = 26.78C^{0,4047}$……………………..*Equation 6*

Where:

y = distance travelled

C= ICT usage in hours per day

$y = 5.3261D^{0,4479}$.......................*Equation 7*

Where:

y = reduction in travel distance per trip

D= ICT usage in hours per day

5.5.3 ICT versus average distance travelled by households

The equation below demonstrates that the reduction in distance travelled increases as the ICT usage in hours increase. This indicates that the increase in ICT usage causes an increased reduction in travel distance per household. The reduction in travel distance will have a positive effect on sustainable road transportation.

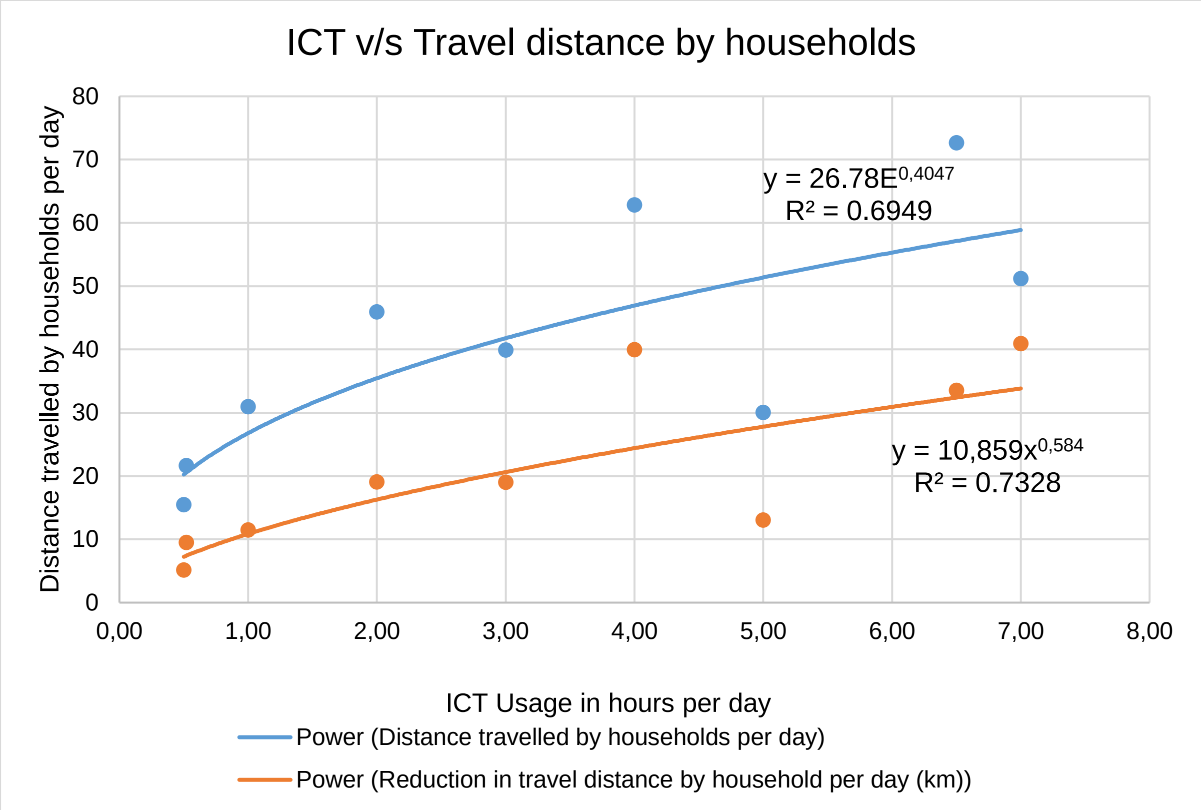

Figure 59: Linkage between ICT usage hourly and distance travelled by households per day

$y = 26.78E^{0,4047}$........................*Equation 8*

Where:

y = number of trips per day

E= ICT usage in hours per day

$y = 10.859F^{0,584}$……………………..*Equation 9*

Where:

y = Reduction in travel distance per household

F= ICT usage in hours per day

5.5.4 ICT versus reduction in travel time

The linkage between ICT and the reduction in travel time is presented in equation 10. ICT is observed to have a non-linear relation with the reduction in travel time by households per day in hours (R^2= 0.8772). Equation 10 indicates that the increase in ICT usage per hour decreases travel time.

$y = 1{,}7176G^{-0{,}784}$……………………..*Equation 10*

Where:

y = Reduction in travel time per household

G= ICT usage in hours per day

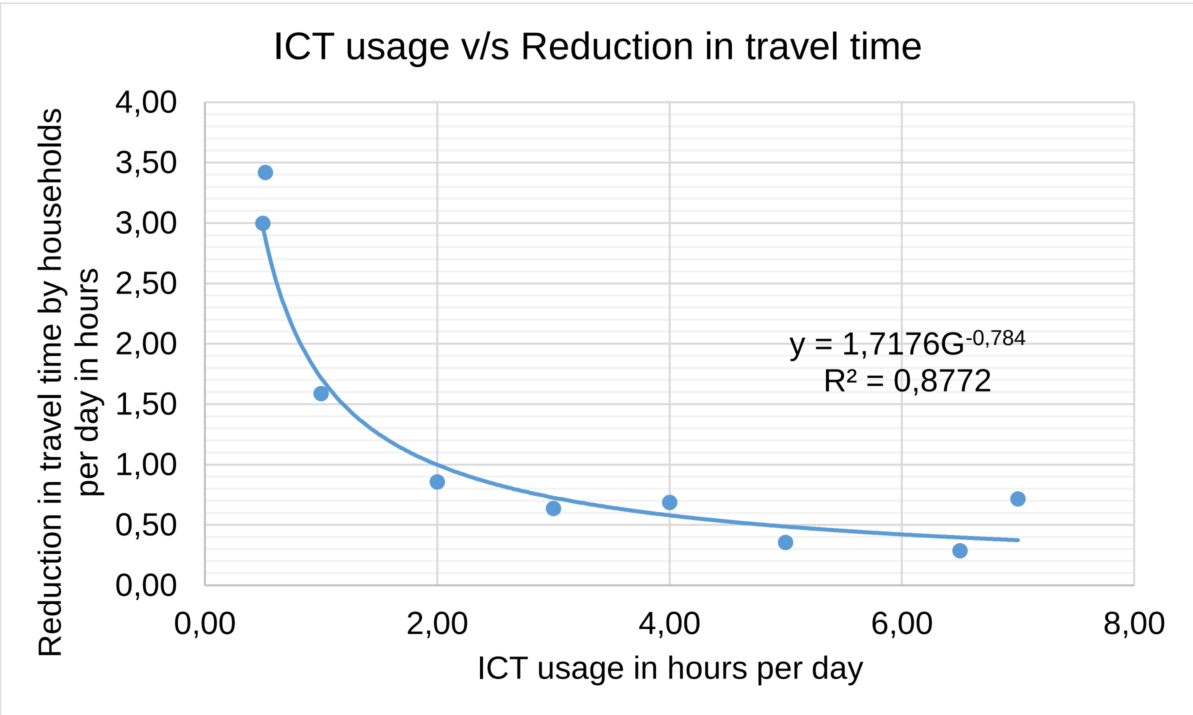

Figure 60: Linkage between ICT usage hourly and reduction in travel time by households per day in hours

5.6 LINKAGE BETWEEN ICT AND CARBON EMISSIONS

5.6.1 CARBON EMISSIONS FOR PRIVATE CARS

Table 32 shows the total average emitted by private cars. Figure 28 shows that 76% of private transportation is for private cars. The total average emissions were calculated from the average km travelled daily using private cars and therefore the emissions emitted daily because of the use of private transportation (cars). Table 32 shows that the total average daily carbon emissions due to private vehicles amounts to 17212.40g in the city of Bloemfontein. Figure 61, also show that the highest emissions are from the people earning above R400 000 emitting 2738(g) daily and the lowest emissions on private cars are for people in the bracket of R0-R50 000.

Table 32: Total carbon dioxide emitted daily due to private vehicles

Annual income	Total average km daily (Private cars)	Total average CO_2 emissions in (g)daily
R0 - R50 000	7	1036
R50 000 - R100 000	9	1332
R100 000 - R150 000	11	1628
R150 000 - R200 000	13	1924
R200 000 - R250 000	14	2072
R250 000 - R300 000	11	1628
R300 000 - R350 000	18	2634
R350 000 - R400 000	15	2220
Above R400 000	19	2738
Total average	116	17212,40

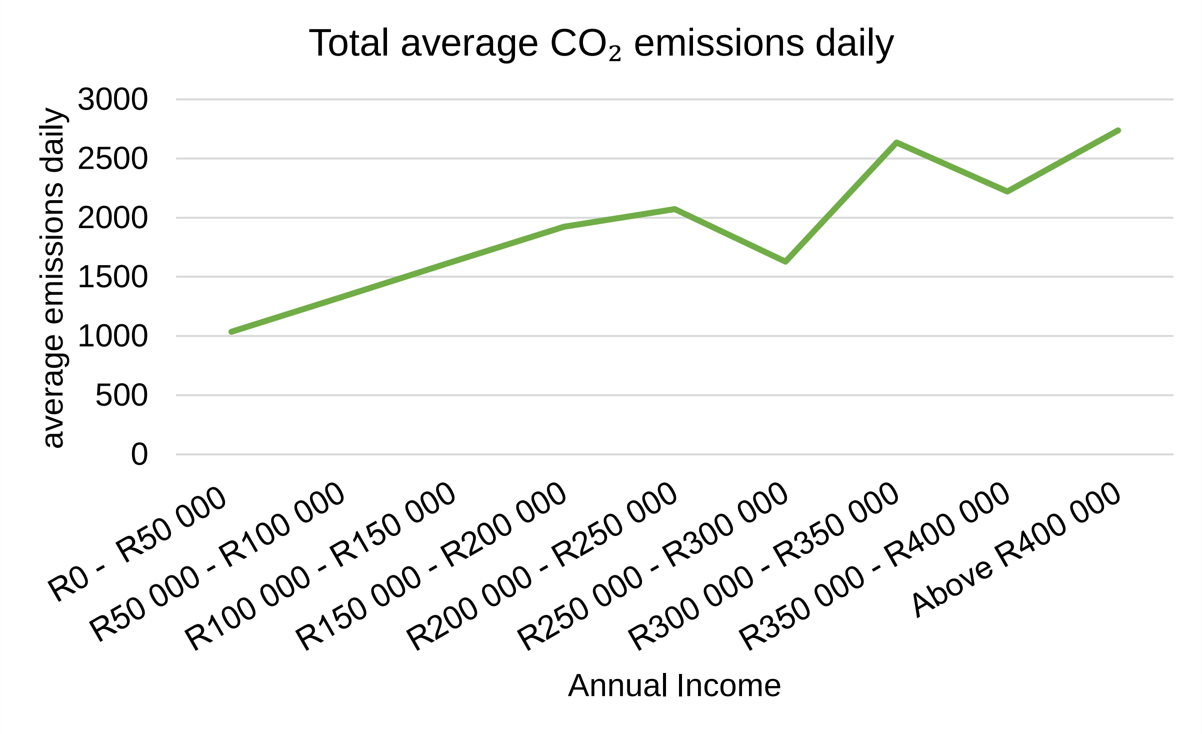

Figure 61: Total average carbon dioxide emitted daily across different annual earnings

5.6.2 REDUCTION IN CO_2 EMISSIONS

According to the respondents of the survey conducted, people are willing to reduce their trips by 20% on average, if they are given the opportunities and by performing transportation and socio economic activities by use of ICT. Consequently, there would be reduction in both travel distance and carbon emissions. The total average carbon emission reduction under different income categories are presented in Table 33 and Figure 62. It is observed that the carbon emission would be reduced by a quantity of 8262g per day on average.

Table 33: Reduced carbon dioxide emissions due to the integration of ICT

Annual income	Total average km daily (Private cars)	Total average CO_2 emissions in (g) daily	Average reduction in CO_2 emissions in (g) daily	Total average **CO_2'** emissions in (g) daily
R0 - R50 000	7	1036	497	539
R50 000 - R100 000	9	1332	639	693

R100 000 - R150 000	11	1628	781	847
R150 000 - R200 000	13	1924	924	1000
R200 000 - R250 000	14	2072	995	1077
R250 000 - R300 000	11	1628	781	847
R300 000 - R350 000	18	2634	1265	1370
R350 000 - R400 000	15	2220	1066	1154
Above R400 000	19	2738	1314	1424
Total average	116	17212,40	8262	8950

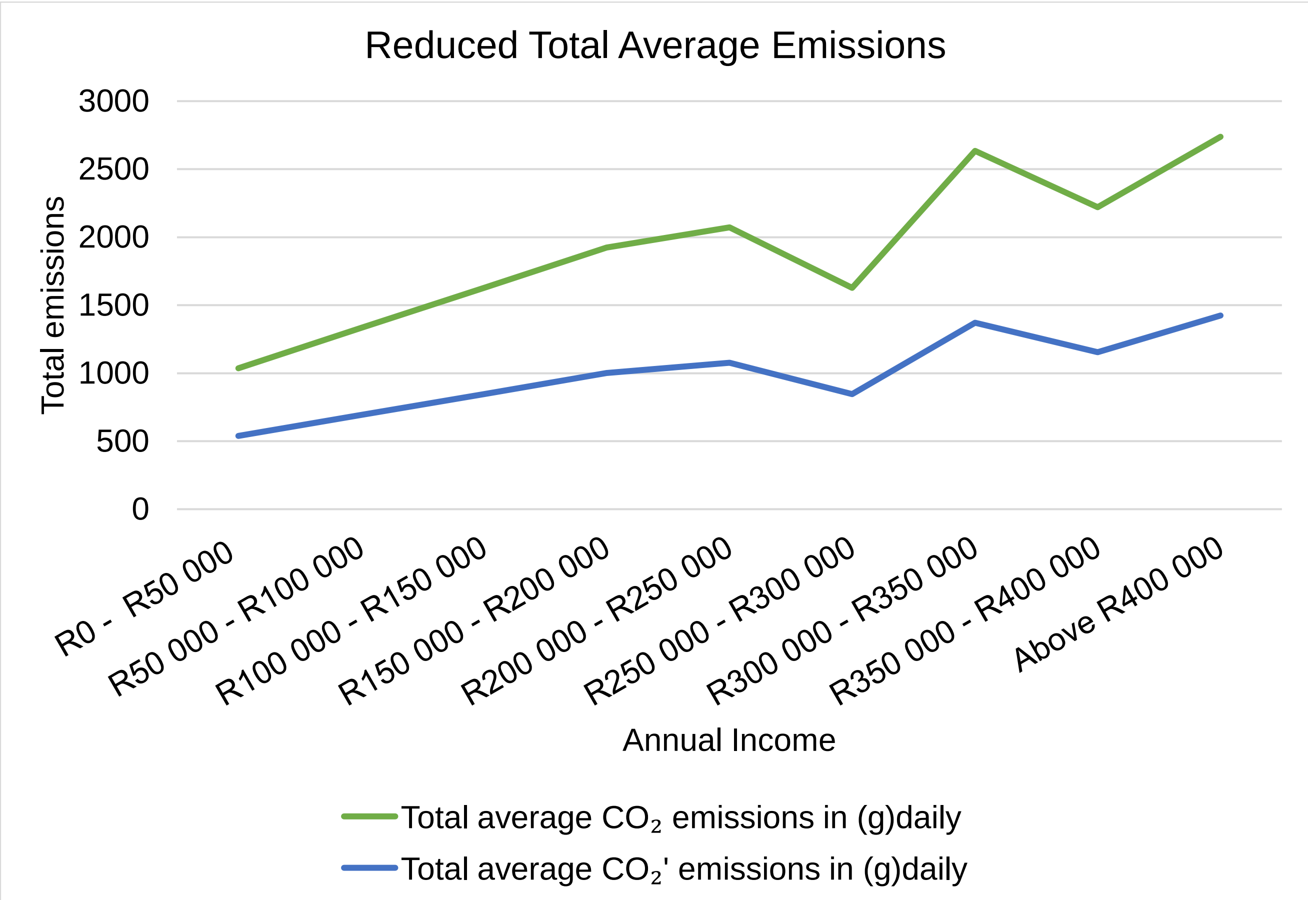

Figure 62: Total carbon dioxide emissions and reduced carbon dioxide emissions due to the integration of ICT

Figure 63 presents the relationship between ICT and CO_2 emissions. It is observed that a non-linear relationship exists between the use of ICT and CO_2 emissions. The relationship is given in the Equation 10 and 11. Equation 10 presents the linkage between current ICT use and total carbon emission. Equation 11 shows the linkage between reduced carbon emissions because of the intended higher use of ICT. It is revealed that, with the increase in ICT use, a reduction in carbon emission is expected.

$y = 4754.4H^{0,386}$........................*Equation 11*

Where:

y = CO_2 emissions

H = ICT usage in hours per day

The second line on the graph shows the reduced CO_2 emissions due to the integration of ICT.

$y = 543.71I^{0,3857}$........................*Equation 12*

Where:

y = CO_2 emissions

I = ICT usage in hours per day

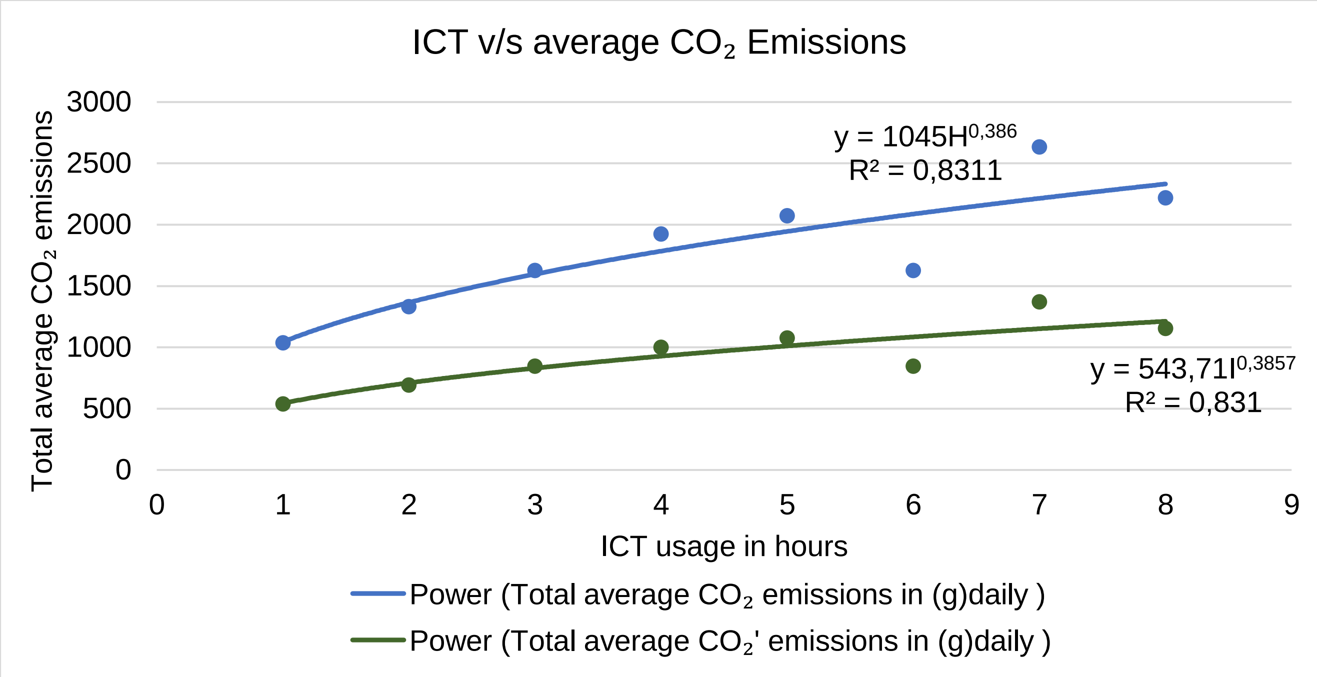

Figure 63: Relationship between ICT and CO_2 emissions

5.7 SIGNIFICANCE TEST

The results of the relationship between ICT and sustainability parameters is presented in sections 5.5 and 5.6, using non-linear regression analysis of power and logarithmic respectively. The section below summarises the findings of a t-test, which was used to test the hypothesis, which states that the use of ICT in day-to-day urban functions (household and professional activities) will reduce trip generations and consequent carbon emissions on the urban roads.

5.7.1 SIGNIFICANCE TEST AND HYPOTHESIS TESTING

Table 34 below shows the results of the t-test between parameters such as income, ICT usage and number of trips, against ICT usage, number of trips, average distance travelled, reduction in trips, reduction in travel distance and reduction in travel time. The significance level considered was 95%. The t-tests with p values ≤ 0.05 for both 1 tailed and 2 tailed tests revealed that there is statistical significance in the relationship between ICT usage and average distance travelled, reduction in trips, and reduction in travel distance. There is statistical significance between ICT usage and reduction in travel time. Lastly, it shows that there is statistical significance between numbers of trips against average distance travelled, reduction in trips, reduction in travel distance and reduction in travel time.

The significance test thus established the hypothesis that the use of ICT in day-to-day urban functions (household and professional activities) would reduce trip generation and consequently the distance of travel on the roads of Bloemfontein. As evidenced by the reduction in travel distance, there will be a reduction of carbon emission (Section 5.6).

Table 34: Significance tests between ICT use and different sustainable transportation parameters (number of trips, average distance travelled, reduction travel distance and reduction in travel time)

Parameters		t-Test results (T index values and p values at α≤ 0.05).					
		ICT usage	Number of trips	Average distance travelled	Reduction in trips	Reduction in travel distance	Reduction in travel time
Income		6.36935	6.36932	6.36908	6.36942	6.3692	6.36938
	1 tailed	5.04E-10	5.04E-10	5.05E-10	5.04E-10	5.05E-10	5.04E-10
	2 tailed	1.01E-09	1.01E-09	1.01E-09	1.01E-09	1.01E-09	1.01E-09
ICT usage				-8.34628	3.37372	-2.95725	1.34172
	1 tailed			2.48E-10	4.87E-03	5.99E-03	9.92E-02
	2 tailed			4.96E-10	9.73E-03	1.20E-02	1.98E-01
Number of trips				-9.73438	12.6085	-2.68584	3.18694
	1 tailed			8.87E-20	1.32E-28	1.25E-02	4.33E-03
	2 tailed			1.77E-19	2.63E-28	2.50E-02	8.65E-03

5.8 CONCLUSION

This chapter focuses on the data analysis, results and finding of the study. The analysis included demographics, sustainability analysis, information and communication technology, linkage between sustainability parameters and use of ICT such as physical and geometrical parameters of the roads, traffic related parameters such as travel pattern, trip generation, travel time, travel delays and the current transportation systems. It tested the significance of the hypothesis. The analysis shows that there is a statistically significant relationship between ICT usage and other sustainability parameters. The hypothesis stated that the use of ICT in day-to-day urban functions (household and professional activities) will reduce trip generations and consequent carbon emissions on the urban roads can be accepted. The following chapter, include the summary findings, discussions, recommendations and conclusion of the study.

CHAPTER 6: FINDINGS, RECOMMENDATIONS AND CONCLUSION

6.1 INTRODUCTION

This study aimed to examine the influence of ICT on sustainable road transportation. It followed a systematic quantitative approach to explore this influence and establish the linkages between ICT use and various sustainable road transportation indicators in the context of Bloemfontein city in South Africa. This chapter presents the summary findings and inferences from both global and South African literature on sustainable cities and ICT, inferences from the study profile, and the analysis and results of this study. Lastly, it also proffers a number of recommendations to attain sustainable road transportation in the cities of South Africa.

6.2 INFERENCES FROM LITERATURE REVIEW

The concept of sustainable road transportations started from developed countries, and was thereafter adopted by developing countries, including South African cities. This section highlights the findings from literature reviewed. The findings are:

- The Brundtland report increased attention to the importance of sustainable cities.
- Cities are experiencing extensive rises in the challenges regarding air pollution, congestion, waste management and human health.
- The indicators used to measure the sustainability of cities include such variables as CO_2 emissions, vehicle pollution emissions, per capita motor vehicle mileage, traffic crash injuries and deaths, transport land consumption, roadway aesthetic conditions, accessibility to and quality of public transportation, level of congestion, level of carbon emissions and polluting matters, road utilisation, facilities for pedestrian movement and traffic.
- Cities consist of important social, biological and physical components.
- Diverse technology needs to be intergraded in achieving sustainability.
- All stakeholders need to be consulted in the processes of planning.

- Efficient monitoring is dependent on an aggregated index to visualise the achievements.
- Real-time indicators are more plausible as they reflect practical scenarios.
- The planning and management of cities should be based on sustainable goals and smart targets..
- Challenges relating to energy and environment have become a priority
- Urban activities, land use and road transportation are complementary to each other.
- Proposed transportation policies should tackle transportation, socio economic and environmental challenges that are restricting the city from achieving sustainability.
- Public transport is not prioritised in many cities.
- Public transport plays a role in enhancing urban mobility, reducing congestion and emissions.
- Some cities progress and achievements have shown that financial resources are not a reason not to develop public transport.
- ICT can contribute significantly to sustainable improvements .
- Cities globally have also integrated ICT with land use policies to solve transportation challenges.
- The priority of the integration of ICT is aimed at solving congestion, pollution and delays, and increasing the use of public transportation.
- South African cities such as Cape Town, Pretoria and Johannesburg have adopted strategies to solve sustainability challenges and have started employing guidelines to improve their sustainability road transportation status.

Literature reveals the significance of issues surrounding the concept of sustainable road transportation, such as pollution that contributes to global warming. In order to achieve sustainability, it is important to always opt for a holistic approach, which considers the economic, socio-economic and environmental aspects. It is therefore imperative to include all stakeholders in the planning phase to better solve the day-to-day challenges that cities and people are face. Even though there are plans/solutions in motion, there are still challenges relating to energy and the impact on the environment, and therefore the need for the integration of ICT and other technological intelligence/solutions. Urban activities, land-use and road transportation are complementary to each other and current policies are focused on solving challenges with a holistic approach rather than treating them as independent. South African cities such as Durban, Johannesburg, Pretoria and Cape Town have advanced in terms of sustainability. Some of the major challenges that they still face include carbon emissions, lack of public transportation, and congestion. These challenges still pose as a threat to the attainment of sustainability, therefore proposals that include the integration of ICT are needed to solve these challenges.

6.3 INFERENCES FROM THE STUDY AREA PROFILE

The section below highlights the inferences from the study area profile. It focuses on the geographical area of the city, including the major roads that connect or pass through the city. The current transportation systems and the demographics, specifically looking at how the MMM has grown over the years, are relevant to the inferences:

- Bloemfontein situated in the Free State province is selected as the study area.
- In 2018 MMM had an average population of 787 803.
- Districts around Free State have been experiencing a decrease in population while Bloemfontein has experiencing an increase.
- The majority of the population are African (77.8%) and 13.8% of the people aged 20 years old and above have completed higher education training.
- In Mangaung alone the percentages of unemployment were very high in Botshabelo (56%) and Thaba Nchu (52%) and only 28% in Bloemfontein.
- Even though the unemployment rate was high, the average household income across districts had an average of R30 189 in 2001 and R75 312 in 2011
- In 2011 technological awareness was mostly restricted to cell phones 16.3%, while 64.8% had no access to the Internet.
- According to census 2011, 77, 6% of the population resided in formal dwelling and 0.9% in others. There was a decrease in traditional and informal dwelling at 7.9% and 13.6%, from 18% and 16% in 2007,
- According to South African Statistic, the city of Bloemfontein has shown significant growth between 2007-2012,
- Bloemfontein now houses two thirds of the entire Mangaung population,

- The transportation system comprises of taxis and buses that move around Mangaung,
- Non-motorised facilities comprise sidewalks, pedestrian bridges and pedestrian crossings,
- IDP in places has an objective of having integrated transportation systems that includes road and rail transport,
- The Mangaung Metropolitan Municipality has come up with areas that should be prioritised for future development, these include addressing threats to the sustainability and financial viability of the city; lack of spatial integration and built environment; ineffective public transport systems; climate change and environmental degradation and inadequate Information technology and communication.
- Trips in Bloemfontein are mostly taken using private vehicles, whereas trips in Botshabelo/Thaba Nchu and Mangaung are undertaken by walking and public transport.
- The public transportation around MMM predominately consists of minibus-taxi ranks and bus facilities.
- Currently the city's transportation is only based on subsidised Interstate Bus Line (IBL) buses, minibus taxis, metered taxis, and private cars that have been changed to operate as taxis
- The public transportation is not integrated, reliable, efficient, and cost effective.
- To successfully achieve a more convenient and cost effective integrated public transportation network, the metro municipality plans to improve residents' quality of life by making sure that the city offers fast, safe, secure, convenient, clean, affordable and socially equitable integrated public transport network covering the expanse of the Mangaung metro area with appropriate transport services based on rail, road and non-motorised options.

The findings from the study are profile show that even though Bloemfontein is a growing city, in has a lot of potential because of its location in South Africa. Neighbouring towns such as Botshabelo and Thaba Nchu contribute immensely to the traffic congestion of Bloemfontein, therefore the current and future public transportation is not only for Bloemfontein residents but also for those coming from neighbouring town. The initiatives taken by the metro municipality to improve transportation challenges have assisted in some areas, but the challenges around public transportation, congestion, pollution, delays, traffic crashes and road utilisation are still not solved. It is therefore important to analyse how the integration of ICT can help the city alleviate the challenges.

6.4 CHALLENGES THAT HINDER ROAD SUSTAINABILITY

This section highlights challenges that hinder sustainability in Bloemfontein city. The challenges are from the primary and secondary data. The challenges include the following:

- Restrictive commercial land-use that doesn't have parking
- Limited to none facilities for pedestrian movement
- Roads with small turning radius prohibiting heavy vehicles to make turns
- Congested roads during peak hours, that leads to high emissions and traffic delays
- Traffic crashes
- Non-integrated public transportation with fewer modes of transport.
- High use of private transportation
- Less efficient and non-reliable public transportation
- Non utilisation of all routes.

6.5 INFERENCES FROM ANALYSIS AND MODELLING

This section highlights the findings from the analysis and modelling. It focuses on the important aspects on all the primary and secondary data, and the findings thereof.

- All the roads surveyed are either major or minor arterials (U2) or minor arterials (U3)
- The main priorities served by the roads are accessibility and mobility
- Nelson Mandela Drive–Furstenberg Road intersection (I1): The finding shows that of the flow moving away from the city, 36% of the traffic flow is distributed to Furstenberg Road while 64% of the traffic moves away from the city. 28% of the traffic flow moving towards the city is distributed to Furstenberg Road while 72% of the traffic moves to the city.

- Kellner Street – General Dan Pienaar Drive/Parfitt Avenue intersection (I2): All the traffic flow that is coming from the north and west forms part of the flow that is coming towards the city. 62% of the traffic flow coming from General Dan Pienaar Drive is going towards the city, 13% is distributed towards the city and the remaining 25% is moving to the west/away from the city.
- Harry Smith Street/Union Avenue – Aliwal Street/Milner road intersection (I3): 70% of the flow coming from Milner road moves towards the city, while 27% comes from Harry Smith Street and 17% comes from Union Avenue. 33% of the traffic flow from Aliwal Street is distributed to Harry Smith Street and Union Avenue, while 67% of the flow moves towards the north/away from the city. 30% of the traffic flow coming from Milner road is distributed to Harry Smith Street and Union Avenue.
- Alexandra Avenue – Oos Burger/Raymond Mhlaba Street intersection (I4): The traffic flow moving from the south to the north represents all the traffic moving away from the city. 15% of the flow from Oos Burger Street is moving to the west, while 26% moves to the east and 60% of that flow is the one moving away from the city. 21% of the flow coming from Raymond Mhlaba Street is moving to the east, 6% is moving to the west and 73% is moving towards the city.
- Fort Hare Road – Hamilton Road intersection (I5): 79% of the flow coming from Fort Hare Road goes towards the city. 17% is distributed to Hamilton Road moving to the south direction and 4% is distributed to Hamilton Road moving to the north. 10% of the flow moving to the city comes from the north direction, while 6% comes from the south. Traffic flow moving from the west to the east/away from the city is distributed to Hamilton Road and 17% is moving to the north, 3% moving to the south and 79% moves away from the city.
- Victoria Road – Walter Sisulu road/Parfitt Avenue intersection (I6): The traffic flow moving to the south comprises of 38% of Walter Sisulu's traffic flow, 19% of Victoria's flow coming from the east, and 32% coming from the west. The traffic flow moving to the east comprises of 55% of Victoria Road's flow from the west, 24% coming from Walter Sisulu road and 29% coming

from Parfitt Avenue. The flow of traffic moving away from the city is represented by 13% coming from the west of Victoria Road and 33% coming from the east of Victoria Road, and 51% coming from Parfitt Avenue.

- Higher traffic volumes were found to be experienced in certain roads such as Nelson Mandela Drive, Aliwal Street, Fort Hare Road, Hanger Street, Parfitt Avenue, and Kolbe Avenue. With the average Hourly Traffic Volume (in PCU) ranging from a minimum of 103 to a maximum of 1055. The Peak Hour Traffic Volume (in PCU) ranges from a minimum of 332 and a maximum of 2135, and Off-peak Hourly Traffic Volume (in PCU) ranges from a minimum of 17 to a maximum of 281.
- The average speed during normal hours (in km/h) was seen to vary between 40 and 55, whereas the average speed during peak hours (in km/ h) ranges from 18 to 30. Comparing the speed during peak and normal hours, it can be seen that the roads carry high numbers of traffic volume during peak hours and therefore leading to delays due to high traffic volume.
- The study revealed that even though sometimes people move from one suburb to another, the highest volumes are for those moving from suburb to city. In most cases, even those moving from suburb to suburb using public transportation have to change either buses or taxis to the desired suburb/work place.
- Travel time when speed is at a minimum is higher than the travel time computed using the average speed. These high values in the travel delay indicate that there are delays experienced in the roads of Bloemfontein.
- For the modes of transport that are used around the city, the most frequently used was metered taxis, followed by the use of public taxis and the metered taxis. The survey revealed that 43% use public taxis, 43% use metered taxis and only 14% use a bus. This clearly indicates that, even though the bus is cheaper than the public taxi, people still use taxis than buses.
- The use of public taxi is more visible amongst the people who earn between R0 - R50 000 and decreases as the amount earned annually increases. The high use of metered taxis is visible throughout all the categories, this high use of metered taxis might be caused by their efficiency and reliability, even though their cost is much higher as compared to public taxis, and the buses.

- The second mostly used type of private transportation is company vehicles. There is a high use of private cars in the city of Bloemfontein and, if any integration of public transportation introduced, the big challenge would be to convince people to choose public transportation over private cars.
- According to the responses, 73% of people in Bloemfontein have access to ICT, while 24% of people have limited access and only 3% of the people do not have access.
- The majority of people's accessibility point is through their smartphones, while 21% get access from their computers at home, 19% from computers at work and only 15% from tablets.
- The high results on the accessibility through smartphones and tablets is a good indication of the positive results this might bring on the integration of ICT with public transportation, because people do carry their phones and tablets with them everywhere they go.
- Almost 97% of the respondents in Bloemfontein do have access to digital technology and only 3% do not have access.
- 37% of people from Bloemfontein revealed that they use ICT for online communication, while almost 24% use it for work and 25% for online entertainment, and only 14% claim to use it for online shopping.
- When analysing the use of ICT, most people who have low income are mostly affected by the cost, availability and connectivity speed, while people who earn higher income complain mostly about the connectivity speed.
- Most respondents (90%) would prefer to use ICT at their homes for work activities (Table 27 and Figures 49 and 50), while 10% of people are not interested in the use of ICT. People with higher income seem to accept the idea of using ICT at home for work purposes. People with lower income are not keen on the idea, and the decline is mostly based on the nature of their jobs.
- 59% of people would use ICT to reduce their travel, this simply means that where circumstances allow, they will rather use ICT at home for their work purposes so that they reduce their travel distance and activities. 41% would use ICT at home for work activities because they would love to reduce their travel to work

- With favourable and acceptable conditions, people from Bloemfontein seem not to have a problem with integrating ICT not only with their transportation but also for socio economic activities.
- Total emission daily is very high and is dependent on the trips generated daily.
- Number of trips generated influence the sustainable road transportation. ICT has a non-linear relationship with number of trips; there is a significant decrease in trips with significant increase and integration in ICT use.
- The linkage between ICT use and reduction in number of trips indicated a non-linear relationship with R^2 value of 0.8628. It is observed that reduction in number of trips increases with the increase in ICT usage.
- The linkage between ICT and average distance travelled has a non-linear relation with R^2 value of 0.6853.
- The reduction in travel distance per trip indicates that, through the integration of ICT, the average distance travel decreases daily.
- The increase in ICT usage causes an increase in the reduction in travel distance per household.
- ICT is observed to have a non-linear relation with the reduction in travel time by households per day in hours with R^2 value of 0.8772. ICT usage is shown to lead to a reduction in travel time.
- If the trips were reduced by 20% daily, it would have an effect on the carbon emissions emitted daily.
- It is clear that the integration of communication and information technology might have a positive impact on the total kilometres travelled daily. This decrease is an indication that, if kilometres are reduced, then there will be a reduction in congestion levels and delays in the city, consequently decreasing emissions and noise pollution.
- The analysis shows that there is a statistical significance between ICT usage against average distance travelled, reduction in trips, and reduction in travel distance. There is a statistical significance between ICT usage and reduction in travel time. Lastly, it shows that there is a statistical significance between numbers of trips against average distance travelled, reduction in trips, reduction in travel distance and reduction in travel time.

The analysis shows that the majority of the residents of Bloemfontein city uses public transportation; it also shows that the use of ICT even though not used for transportation currently can be of significant help if integrated in transportation. The use of ICT is seen to reduce trip generation and need to travel, therefore reducing congestion and carbon emissions in the city.

6.6 STRATEGIES FOR SUSTAINABLE ROAD TRANSPORTATION IN BLOEMFONTEIN CITY

The study focused on the influence of information and communication technologies on sustainable road transportation in Bloemfontein city. This study was to be achieved by analysing the current transportation and all the other challenges as stated in section 6.4 that affect the sustainability of the road transportation. In order to evolve a set of policies interventions and guidelines the following strategies have been adopted:

- Integration of ICT on transportation to reduce travel distance.
- Reduce the usage of private transportation.
- Divert traffic to other routes, based on real time information obtained from ICT use.
- Provide free WI-FI connectivity around the city for transportation.
- Reduce the number of trips/need to travel to decrease carbon emissions around the city.
- Integrate public transport with ICT to reduce number of trips.

6.7 ALTERNATIVE PLAUSIBLE POLICY GUIDELINES

Based on the concept above, and the analysis on different scenarios relating to sustainable urban transportation and use of ICT, the following alternative policies were formulated and are presented below:

- Policy 1 - Integration of ICT on transportation to reduce travel distance.
  Figure 26 shows that there is a decrease in kilometres travelled per trip as a result of integration of ICT in transportation and socio economic activities. The

kilometres decrease as follows R0 - R50 000 (from 9.3 to 7.5km); R50 000 - R100 000 (from 11.6 to 9.3 km); R100 000 - R150 000 (from 14.1 to 11.3km); R150 000 - R200 000 (from 17.9 to 14.3km); R200 000 - R250 000 (from 17.8 to 14.2); R250 000 - R300 000 (from 13.1 to 10.5km); R300 000 - R350 000 (from 23.1 to 18.5km); R350 000 - R400 000 (from 22.8 to 18.2km) and above R400 000 (from 24.2 to 19.4 km).This decrease is an indication that if kilometres are reduced then there will be a reduction on the emissions and noise pollution, consequently decreasing the congestion levels and delays in the city. This can be achieved by integrated transportation and cell phone applications to provide real time information about the flow of traffic.

- Policy 2 - Reduce the usage of private transportation.
  76% of people who use private transportation use their private cars, followed by 9% of people using company vehicles, 6% using shared vehicles, and 5% using private vehicle (pre-arranged transport either for staff) in the city of Bloemfontein. The use of private cars is highest in the city. The study also revealed that less than 5% use non-motorised transportation. Reduction of the use of private vehicles will maximise the use of public transportation and consequently contribute towards the sustainability of the city. This can be achieved by providing affordable public transportation that is efficient and reliable at all times.

- Policy 3 - Divert traffic to other routes.
  Higher traffic volumes were found to be experienced in certain roads such as Nelson Mandela Drive (14946 PCU), Aliwal Street (8889 PCU), Fort Hare Road (9744 PCU), Hanger Street (11131 PCU), Parfitt Avenue (8974 PCU), and Kolbe Avenue (12576 PCU). With the average Hourly Traffic Volume (in PCU) ranging from a minimum of 103 to a maximum of 1055, the Peak Hour Traffic Volume (in PCU) ranges from a minimum of 332 and a maximum of 2135, and Off-peak Hourly Traffic Volume (in PCU) ranges from a minimum of 17 to a maximum of 281. The maximum traffic volume is experienced in the morning between 06:30-08:30, when people are travelling towards the city, and again in the afternoon between 16:30-18:30, when they are travelling away from the city.

Therefore, other roads that are not utilised during peak hours can be used to reduce congestion on the heavily congested roads during peak hours. Real time traffic information signs can be used to inform drivers about roads that are less congested.

- Policy 4 - Provide free WI-FI connectivity around the city for transportation.

  The study revealed that even though transportation in Bloemfontein is not integrated with ICT, people still do have some challenges they face when it comes to ICT. Some of the major challenges include connectivity speed and cost, while the miner challenges include technology awareness. People who have low income are mostly affected by the cost, availability and connectivity speed, while people who earn higher income complain mostly about connectivity speed. Therefore, the integration of ICT with transportation should come with free Wi-Fi around the city to allow passengers to get information regarding public transportation.

- Policy 5 - Integrate public transport with ICT to reduce carbon emissions.

  The usage of private cars is a challenge in many cities. The integration of public transportation with ICT leads to the reduction in number of trips. The reduction in number of trips/need to travel leads to reduced carbon emission. The total average carbon emissions of private vehicle amounts to 17212, 40g daily. It is also observed that people belonging to middle- and higher-income groups travel using private transportation (in number of kilometres) by use of private cars and thus emit more carbon emissions. Therefore, the need to reduce carbon emissions, especially in the group belonging to middle- and higher-income groups, will be dependent on the real time information to reduce long queues in traffic, reduce the need to travel using private transportation and therefore consequently reduce carbon emissions.

6.8 STRATEGIC SUSTAINABLE URBAN AND ROAD TRANSPORTATION PLANNING GUIDELINES

Based on the detailed survey analysis of various spatial-, land use-, traffic- and road related factors, and in addition to the policy alternatives mentioned above, the various plausible policy guidelines to achieve sustainability through ICT are:

- Public transportation in the city need to be reinforced.
- Introduce other modes of transport such as trains, and promote cycling and walking.
- Introduce cell phone applications to provide real time information.
- Installation of real time traffic information signage.
- Use ICT for other socio-economic activities to reduce the need to travel.
- Redirect traffic to less congested roads during peak hours.
- Improve pedestrian facilities to promote non-motorised transportation.

6.9 CONCLUSION, LIMITATIONS AND FUTURE RESEARCH

Sustainable road transportation is a challenge in most of the South African cities. Initiatives and model have been initiated and developed to address the issue, but the solutions seem to not be addressing the challenges. The literature provide an extensive background to the concept of sustainability and shows that the gap in the literature regarding South African cities concerns the integration of ICT in transportation. Various studies have been focusing on sustainable parameters and actions that can be adopted to alleviate some of the challenges. These actions have included some cities introducing BRT systems, integrated transportation systems and building infrastructures for non-motorised transportation. Nevertheless, the challenge has been that, even after those initiatives, some of their problems such as congestion, carbon emissions and use of public transportation were not entirely solved. Therefore, the study aimed a different approach of examining the current scenario of the road transportation system in Bloemfontein city and explore how sustainable road transportation in the city can be achieved by use of relevant innovative systems like Information and Communication Technologies (ICT) in the daily personal and professional activities of people and travel needs in and around the city.

To achieve this, a systematic approach was followed and primary and secondary data was collected. The data included road surveys, traffic count, speed surveys, road characteristic investigations. In total 6 intersection and 10 roads were surveyed. The data collected from questionnaires consisted of 305 respondents. The analysis included demographics, sustainability analysis, information and communication technology, linkage between sustainability parameters and use of ICT such as physical and geometrical parameters of the roads, traffic related parameters such as travel pattern, trip generation, travel time, travel delays, current transportation systems, and congestion. The hypothesis was tested and found to be valid.

The findings of the study show that most of the roads are in good condition, but the parking facilities do not accommodate the land use, this is evident as most of the roads surveyed do not have on-street parking, and for this reason, drivers use the road for parking, which cause congestion especially during peak hours.

Travel delays are a serious issue in the city. Hanger Street has the highest delays of 4.91min, followed by Raymond Mhlaba, Oos Burger Street, General Dan Pienaar Dr and Parfitt Avenue with delays of 4.67min. President Avenue has the lowest delays of 1.50min.

Even though distance travelled seems to be an issue, the integration of ICT for transportation and socio economic activities reduces travel distance. The highest reduction (4.8km) in travel is for people earning above R400 000. The decrease in travel distance can be achieved by integrated transportation and cell phone applications to provide real time information about the flow of traffic.

Public transportation seem to be the biggest challenge in the city because of other lack of modes of transportation, which lead to unreliability. This inadequacy is causing people to opt for private transportation.

Roads and intersections are congested during peak hours. Intersections such as Alexandra Avenue - Oos Burger/Raymond Mhlaba Street intersection (I4) and Fort Hare Road - Hamilton Road intersection (I5) have problems of turning trucks and busses. Higher traffic volumes were found to be experienced in certain roads such as Nelson Mandela Drive (14946 PCU), Aliwal Street (8889 PCU), Fort Hare Road (9744

PCU), Hanger Street (11131 PCU), Parfitt Avenue (8974 PCU), and Kolbe Avenue (12576 PCU). High volumes and challenges experienced on roads cause major delays and contribute to congestion.

The use of ICT is increasing around the city and, even though currently it is not used for transportation, the survey shows that 73% of the respondents in Bloemfontein have access to ICT, while 24% of respondents have limited access and only 3% of the respondents do not have any access to ICT. Some of the major challenges include connectivity speed and cost, while the minor challenges include technology awareness. People who have low income are mostly affected by the cost, availability and connectivity speed, while people who earn higher income complain mostly about the connectivity speed.

Linkage between reduction in number of trips and ICT showed a non-linear relationship with R^2 value of 0.8628. A reduction in number of trips increases with the increase in ICT usage. This is an indicator that to reduce number of trips in the roads of Bloemfontein, ICT usage will have to be one of the top priorities. Linkage between ICT and reduction in travel distance showed a non-linear relationship with R^2 value of 0.6853. Increase in ICT usage per hour, also increases with the increase with the reduction in travel distance per trip. The reduction in travel distance per trip indicates that as the distance travel decreases daily, the city of Bloemfontein benefits as it will lead to a reduction in traffic volume, traffic emissions, congestion, and travel delay. Linkage between ICT and reduction in travel distance by household showed a non-linear relationship with R^2 value of 0.7328. Total average daily carbon emissions of private cars amounts to 17212.40g, which can be reduced by a quantity of 8262g per day on average.

T-test between parameters such as income, ICT usage and number of trips, against ICT usage, number of trips, average distance travelled, reduction in trips, reduction in travel distance and reduction in travel time, were analysed. The significance level considered was 95%. The t-tests with p values ≤ 0.05 for both 1 tailed and 2 tailed test revealed that there is a statistical significance between ICT usage against average distance travelled, reduction in trips, and reduction in travel distance. There is a statistical significance between ICT usage and reduction in travel time. Lastly, it shows that there is a statistically significant relationship between numbers of trips against average distance travelled, reduction in trips, reduction in travel distance and reduction in travel time. The significance test thus established that the use of ICT in day-to-day urban functions (household and professional activities) would reduce trip generations and consequent distance travel on the roads of Bloemfontein. As evidenced reduction in travel, distance will reduce carbon emission. Therefore, it can be concluded that there is a need for the integration of ICT on day to day urban function, with transportation as a priority.

The investigation has a few limitations. The analyses were carried out on certain roads and junctions by primarily using traffic data collected through surveys. Some of the other roads and junctions also need to be investigated. In addition, a larger data set could provide further insight. The scope of the study was also limited to the roads in and around the CBD area of Bloemfontein City and therefore the results cannot be generalised for other cities of South Africa.

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Appendix A
(TERMINOLOGY)

Road: A wide way between places.

Urban area: An urban area is an area, which has been subdivided into even, whether formal or informal. It includes formal and informal rural settlements of one hectare or less.

Urban road: Any roads located in an urban area, excluding Throughways and Bypass.

From the roads condition survey tabled below the following characteristics were found;

- All the roads surveyed are either major arterials (U2) or minor arterials (U3). The main priority served by the roads are concerned with mobility.

- All the roads have two lanes that increase as the intersection is approached.
- All the roads are selected were some of the major/important roads around the city of Bloemfontein, because the carry traffic towards or away from the city centre.
- The roads are all sealed with bitumen, and others are paved while others are not paved on the sidewalks, and the all have kerbs.

Environment: The natural world, as a whole or in a particular geographical area, especially as affected by human activity.

Information and Communication Technology (ICT): infrastructure and components that enable modern computing.

Public transport: a system of transport, in contrast to private transport, for passengers by group travel systems available for use by the general public, typically managed on a schedule, and operated on established routes.

Travel time: A period of time spent traveling

Appendix B
(QUESTIONNAIRE)

INVESTIGATION OF INFLUENCE OF INFORMATION AND COMMUNICATION TECHNOLOGIES ON SUSTAINABLE ROAD TRANSPORTATION IN BLOEMFONTEIN CITY, SOUTH AFRICA

Sustainable road transportation is a challenge in most of the South African cities. Bloemfontein in South Africa is such a city experiencing the challenges of unsustainable transportation in a large scale. It is one of the fast growing cities of the country, which offers higher order socio-economic and infrastructural facilities to the people of the central region of the country. The current road transportation system is found to be inadequate, overcrowded during peak period, unsafe, inconvenient and often unreliable (IDP 2011/2012).Thus, the purpose of this questionnaire is gather information about the current scenario of the road transportation system in Bloemfontein city and explore how sustainable road transportation in the city can be achieved by use of relevant innovative systems like Information Communication Technology (ICT) in the daily personal and professional activities of people and travel needs in and around the city.

DEMOGRAPHICS

First Name

Last Name

Phone

Email Address

Which suburb do you live in?

1. Arboretum
2. Arboretum
3. Bain's Vlei
4. Bainsvlei
5. Batho
6. Baysvalley
7. Bayswater
8. Bayswater
9. Bloemside
10. Bloemanda
11. Bloemfontein Central
12. Bloemside phase 2
13. Bloem-spruit

14. Bochabela
15. Brandwag
16. Brandwag
17. Chris Hani
18. Dan Pienaar
19. Dan Pienaar
20. Ehrlich Park
21. Fauna
22. Ferreira
23. Fichardt Park
24. Fichardt Park
25. Fleurdal
26. Fleurdal
27. Gardenia Park
28. Generaal De Wet
29. Glen
30. Grassland
31. Groenvlei
32. Grootvlei
33. Heidedal
34. Helicon Heights
35. Heuwelsig
36. Heuwelsig
37. Hillsboro
38. Hillside
39. Hilton
40. Hospitaalpark
41. Hospital Park
42. JB mafora
43. Joe slovo
44. Kagisanong
45. Kiepersol
46. Kloofeind
47. Kopanong

48. Lakeview
49. Langenhoven Park
50. Langenhovenpark
51. Loerier Park
52. Mandela view
53. Namibia
54. Naval Hill
55. Navalsig
56. Navalsig
57. Noordhoek
58. Oos-einde
59. Panorama Park
60. Park West
61. Parkwest
62. Pellissier
63. Pellissier
64. Pentagon Park
65. Pentagon Park
66. Phahameng
67. Phelindaba
68. Quaggafontein
69. Rayton
70. Rocklands
71. Rodenbeck
72. Roodewal+C18:C38
73. Sperville
74. Spitskop
75. Turflaagte
76. Uitsig
77. Universitas
78. Universitas
79. Vallombrosa
80. Vallombrosa
81. Waverley

82. Waverley
83. Westdene
84. Westdene
85. Wildlife Estate
86. Wilgehof
87. Willows
88. Willows
89. Woodland Hills
90. Others: Specify

____

Date of birth

- ___________

Age

Gender?

1. Male
2. Female

Educational level?

1. Primary
2. Secondary
3. Tertiary

Occupation?

1. Accountancy and financial management
2. Civil and structural engineering
3. Construction and building services
4. Consumer goods
5. Engineering
6. Entrepreneur
7. Financial services and insurance
8. Healthcare
9. Hospitality, leisure and travel
10. HR and recruitment
11. Investment banking and investment
12. IT and technology
13. Law barristers
14. Law solicitors
15. Logistics, transport and supply chain
16. Management and business
17. Management consulting
18. Marketing, advertising and PR
19. Media, journalism and publishing
20. Property
21. Public service, charity and social work
22. Quantity surveying and building surveying
23. Retail, buying and merchandising
24. Sales
25. Science and research
26. Teaching and education
27. Unemployed
28. Other
29.

Annual income?

1. R0 - R50 000
2. R50 000 - R100 000
3. R100 000 - R150 000
4. R150 000 - R200 000

5. R200 000 - R250 000
6. R250 000 - R300 000
7. R300 000 - R350 000
8. R350 000 - R400 000
9. Above R400 000

Please allocate 100 points on how you spend your income:

- Essentials (Gas, Grocery etc.) __________
- Entertainment (Movies, Clubs etc.) __________
- Other _________

TRANSPORTATION

Challenges faced during trips?

1. Congestion
2. Accidents
3. Delay
4. Pollution
5. Diversion of routes
6. Change of mode

What kind of vehicles do you use for your trips?

1. Public transportation
2. Private transportation
3. Both

To what extent you would like to reduce number of trips?

1. Less than 20%
2. 20% - 40%
3. 40%- 60%
4. 60%- 80%
5. 80%- 100%

What are the reasons of public transportation use?

1. Availability

2. Cost effective
3. Easily accessible
4. Efficient
5. Reliable
6. Secured

What kind of public transport (local) you use?

1. Bus
2. Train
3. Public taxis
4. Meter taxi

Types of private transportation used?

1. Private cars
2. Private taxis
3. Bicycle
4. Shared taxis
5. Car
6. Office vehicles
7. Other ____

If you will be given an opportunity to reduce use of private vehicles?

1. Yes
2. No

What are the reasons for using private transportation?

1. Cost
2. Safety
3. Psychological feeling (relax)
4. Efficiency
5. Stick to schedule
6. Other ____

What are the sustainable transportation challenges you face?

1. Congestion

2. Fuel consumption
3. Cost(high)
4. Accidents
5. Delay
6. Reliability
7. Safety and security(fear of crime)
8. Carbon emissions
9. Distance travel
10. Traffic control and management
11. Road related challenges: condition, type, configuration
12. Others ____

What are your opinion to improve sustainability?

1. Use of public transportation
2. Use of ICT
3. Green cars
4. Improved roads
5. Improved transportation environment
6. Traffic control and management
7. Congestion tax
8. Vehicle tax
9. Road tax
10. Work and job
11. Use of ITS with GPS for advance information

ICT AND ACCESIBILITY

Availability of digital technology?

1. Yes
2. No

Accesible point for digital technology?

1. Computers at home
2. Computers at the office
3. Tablets

4. Smartphones

Place for Internet availability?

1. At home
2. Office/work place
3. Public places
4. Anywhere
5.

Accessibility of ICT?

1. Yes
2. No
3. Limited

Duration of ICT connectivity?

1. None
2. 0 - 5hr
3. 5hr - 10hr
4. 10hr - 15hr
5. 15hr - 20hr
6. 20hr - 24hr

Accessibility of ICT during the period of the day?

1. Limited period during office hours
2. During the day
3. During night time
4. All the time
5. Never

Use of ICT for activity purposes?

1. Office work online
2. Online shopping
3. Online entertainment
4. Online communication

Would you prefer to use ICT at home for Work activities?

1. Preferable
2. Not Preferable

Purpose of ICT use at home for work activities?

1. Limits the need to travel to work
2. Reduction of kilometre travel

Challenges in ICT connectivity

1. Connectivity speed
2. Availability
3. Cost
4. Technology awareness/literacy
5. Others ____

Types of ITS system??

1. Road based
2. Vehicle based
3. Environment based
4. All

Information transfer system(Real time)?

1. GPS
2. Radio
3. Television
4. Sms
5. Warning signs in vehicles
6. Warning signs on road signs
7. Others ____

What kind of ITS system would you use?

1. real time information
2. GPS system
3. Early congestion warning
4. Early parking warning

5. Road condition warning
6. Accident occurrence warning
7. Speeding warning
8. Environmental condition warning
9. Navigation warning
10. All
11. Nothing

Prefered travel information system?

1. Radio at home
2. TV at home
3. Car radio
4. Sms
5. Internet
6. Roadside LED boards
7. Road signs
8. Manual

On average how many km do you travel daily

On average how many activities do you do daily

On average, how many trips do you do daily

Appendix C

Traffic Congestion scenarios

On what days congestion occurs: weekdays/ weekends

On what period of the day congestion occurs

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	22.00-24.00	Any other specific period
No congestion										
Appreciable										
Close to maximum										
Maximum										

Appendix D

INVESTIGATION OF INFLUENCE OF INFORMATION AND COMMUNICATION TECHNOLOGIES ON SUSTAINABLE ROAD TRANSPORTATION IN BLOEMFONTEIN CITY, SOUTH AFRICA

Template for physical and road geometric parameter survey

Physical characteristics of the roads in the CBD area of Kimberly city

Name of the roads	Road type	Road width	Number of lanes	Lane width	Availability of pedestrian/ bicycle lane	Pavements/ footpaths /shoulders width	Kerbs	Median width	Sight distance	Radius of Curvature	Type of Road surface	Condition of road surface	Availability of Traffic control system	On street parking type
Nelson Mandela Drive E														
Nelson Mandela Drive W														

Aliwal Street N														
Aliwal Street S														
Raymond Mhlaba N														
Oos Burger Street S														
Fort Hare Road E														
Fort Hare Road W														
Hanger Street N														

Hanger Street S														
President Boshof Street N														
President Boshof Street S														
Parfitt Avenue N														
Parfitt Avenue S														
Kolbe Avenue N Kolbe Avenue S														

President Avenue E														
President Avenue W														
General Dan Pienaar Dr N														
Parfitt Avenue S														

N= North (Towards inside of the city)

S = South (Towards outside of the city)

E= East (Towards inside of the city)

W = West (Towards outside of the city)

Appendix E

Data collection proforma for traffic volume survey on road sections

Road Classification……………………….

Date and day of the week:

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

Name of the road ………………..road section …………………………………. Close to land mark if any:

Hour of count	**Types of vehicles**						
	Cars	Buses	Trucks	Motor-cycles	Bicycle	Other(Specify)	Remarks,including weather conditions
6h00- 6h30							
6h30- 7h00							
7h00- 7h30							
7h30- 8h00							
8h00- 8h30							
8h30- 9h00							
9h00- 9h30							
9h30- 10h00							
10h00- 10h30							

10h30- 11h30							
11h30- 12h00							
12h00- 12h30							
12h30- 13h00							
13h00- 13h30							
13h30- 14h00							
14h00- 14h30							
14h30- 15h00							
15h00- 15h30							
16h00- 16h30							
16h30- 17h00							
17h00- 17h30							
17h30- 18h00							
18h00- 18h30							
18h30- 19h00							
19h00- 19h30							
19h30- 20h00							

Name of enumerator:

Name of supervisor:

Signature:

Signature:

Date:

Date:

Appendix F

Data collection proforma for traffic volume survey at intersections

Date and day of the week:

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

Name of the road ………………..road section …………………………………. Close to land mark if any:

Traffic entering intersection from

Name of approach road:

Travelling (Compass direction):

Time of the day:

Direction of Flow	**Types of vehicle**						
	Cars	Buses	Trucks	Motor-cycles	Bi-cycles	Others(Specify)	Remarks, including weather conditions
Vehicles turning left							

Vehicles proceeding straight ahead							
Vehicles turning right							

Appendix G

Speed survey schedule

Name of the surveyor:

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																			
		Carwa				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
6h00-6h30																					

6h30-7h00																					
7h00-7h30																					
7h30-8h00																					
8h00-8h30																					
8h30-9h00																					
9h00-9h30																					
9h30-10h00																					
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17h30 - 18h00																					
18h00 - 18h30																					
18h30 - 19h00																					

19h00 - 19h30																					
19h30 - 20h00																					

Appendix H
Level of service (LOS) criteria

Table B-4
Level of Service Criteria for Arterials

Arterial Class	I	II	III
Range of Free-Flow Speeds (mph)	45 to 35	35 to 30	35 to 25
Typical Free-Flow Speed (mph)	40 mph	33 mph	27 mph
Level of Service	**Average Travel Speed (mph)**		
A	≥ 35	≥ 30	≥ 25
B	≥ 28	≥ 24	≥ 19
C	≥ 22	≥ 18	≥ 13
D	≥ 17	≥ 14	≥ 9
E	≥ 13	≥ 10	≥ 7
F	< 13	< 10	< 7

mph miles per hour
≤ less than or equal to
≥ greater than or equal to

Source: Transportation Research Board, *Highway Capacity Manual, Special Report 209* (Washington, D.C., 1994), pp. 11-4.

B-7

Table B-5

CMP Level of Service Criteria for Arterials[a] Based on Volume-to-Capacity Ratios

Level of Service	Description	V/C[b]
A	Free-flow conditions with unimpeded maneuverability. Stopped delay at signalized intersection is minimal.	0.00 to 0.60
B	Reasonably unimpeded operations with slightly restricted maneuverability. Stopped delays are not bothersome.	0.61 to 0.70
C	Stable operations with somewhat more restrictions in making mid-block lane changes than LOS B. Motorists will experience appreciable tension while driving.	0.71 to 0.80
D	Approaching unstable operations where small increases in volume produce substantial increases in delay and decreases in speed.	0.81 to 0.90
E	Operations with significant intersection approach delays and low average speeds.	0.91 to 1.00
F	Operations with extremely low speeds caused by intersection congestion, high delay, and adverse signal progression.	Greater Than 1.00

[a] For arterials that are multilane divided or undivided with some parking, a signalized intersection density of four to eight per mile, and moderate roadside development.
[b] Volume-to-capacity ratio.

≥ greater than or equal to.
< less than.

Source: Transportation Research Board, *Highway Capacity Manual, Special Report 209* (Washington, D.C., 1994).