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Title:

Investigating the possibility of electronic intermodality and interoperability of innovative urban public transport systems in the City of Tshwane

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DATE: 31 OCTOBER 2019

DECLARATION

By submitting this dissertation, I declare that the entire work contained therein is my own original work, that I am the sole author thereof, that reproduction and publication thereof by University of Johannesburg will not infringe any third party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification or examination at any other university. Any work done by other persons has been properly acknowledged and referenced.

Signature Date: **31 October 2019**

DEDICATION

The research work is sincerely dedicated to my family, in particular, my mom whom is my number one supporter and she always gave me 100% support to make sure I succeed in what I do, whenever I feel tired she will always motivate me by saying to me *kubamba ezingelayo* “hard work breeds success”. I thank the almighty God for my existence, the strength, protection and blessings he afforded to me. Further, my ancestors to look upon me every day since my existence.

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ABSTRACT

Urban areas have the purpose of satisfying citizen's needs to interact and conduct different activities such as work, study or leisure. Public transport systems are designed to allow the efficiently and reliable movement of people within the city (Amaya et al. 2017). Globally, developed countries always work on different methods in order to have the best formal urban public transportation system. This involves integration of various modes of public transport including technological innovations such as integrated e-smart cards and information dissemination. In South Africa, there has been the development of innovative urban public transport to enhance the public transport network and eliminate negative impacts on the road. Within Gauteng province in the past 10 years, the City of Tshwane has introduced innovative Formal Urban Public Transport (FUPT) systems that will convey commuters efficiently to desired locations with no delays and at more frequent intervals through an effective public transport network. However, the innovative FUPT network is fragmented and departments do not work with one other in any form. The aim of the study was therefore to investigate the state of electronic integration of the formal urban public transport operations. It advanced a possible model that can be used to identify areas suitable for stations and stops in order to integrate innovative urban public transport modes in the City of Tshwane. A case study research design used a mixed method approach consisting of spatial, quantitative and qualitative approach. The BRT and Gautrain systems in the City of Tshwane were the focus area of the study where explorative data analysis was used to explore the payment systems and information distribution of innovative FUPT. Consequently, the existing spatial integrated areas in the city were explored regarding how these systems can connect to one another. Further, experimental analyses were used through social media data to identify spatial location for areas of expansion, including areas that will allow switch in-betweens from Gautrain system to A Re Yeng system. Consequently, social media data were used for word cloud to predict the possible concerns and views of the commuters. Interviews with relevant commuters and key officials were conducted to discover whether there were any payment and information systems shared by the innovative FUPT, and the possibility of integrating the two innovative FUPTs. Further, questions posed to officials included the policies and legislative frameworks that inform integrated public transport in the city. The results revealed that there is spatial integration in the Hatfield and Pretoria CBDs between the Gautrain and A Re Yeng systems. Further, both systems use e-smart cards, but Gautrain system has more advance tools for information dissemination. However, the Gautrain system and A Re Yeng system are not electronically integrated. Consequently, in the City of Tshwane, policies and legislative frameworks support the development of integrated urban public transport. The conclusion drawn from the study indicates that it might be possible to integrate the two systems since both use e-smart cards for fare collection. There are also elements of online information distribution by the Gautrain and A Re Yeng systems, with a few locations presenting availability of spatial integration. Additionally, maps were presented to assist in identifying areas for possible future development of bus stations and stops to enable these systems to service most areas of the City of Tshwane, and a model was created indicating how Gautrain system and A Re Yeng system can be integrated. The study recommends that the present integrated spatial location of the innovative FUPT in the city can be used as the starting point. There of electronical integration is possible, since both systems use e-smart cards and a development of one integrated e-smart card. Further, integrated online information dissemination applications in real time can be accessed through mobile smart phones for convenience purposes.

Keywords: integration, formal urban public transport, spatial, e-smart card, information dissemination.

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ACRONYMS AND ABBREVIATIONS

BRT	Bus Rapid Transit
IRPTN	Integrated Rapid Public Transport Network
NLTA	National land transport act
IDP	Integrated Development Plan
CITP	Comprehensive Integrated Transport Plan
DoT	Department of Transport
GTS	Green Transport Strategy
GHG	Greenhouse gas emissions
RSA	Republic of South Africa
PICC	Presidential Infrastructure Coordinating Commission
NATMAP	National Transport Master Plan
NDP	National Development Plan
ITS	Intelligent Transport Systems
COT	City of Tshwane
CBD	Central Business District
ORTIA	O.R.Tambo International Airport
GMA	Gautrain Management Agency
SATAWU	South African Transport and Allied Workers Union
SANTACO	South African National Taxi Council
UPT	Urban Public Transport
FUPT	Formal Urban Public Transport
NDoT	National Department of Transport
IT	Information Technologies
MRTS	Mass Rapid Transit System
DART	Dar es Salaam Bus Rapid Transit
PT	Public Transport
VV	Verkehrsverb€unde
TTC	Toronto Transit Commission
TMB	Transports Metropolitans de Barcelona
ICT	Information and Communications Technology
SC	Smart cities
ICM	Integrated Corridor Management
GPS	Global Positioning System
CVO	Commercial Vehicle Operations
ARTS	Advanced Rural Transportation Systems
EM	Emergency Management
APTS	Advanced Public Transport Systems
AVCSS	Advanced Vehicle Control and Safety Systems
ATIS	Advanced Traveller Information Systems

ATMS	Advanced Traffic Management Systems
CV	Connected vehicle
MPO	Metropolitan Planning Organization

CHAPTER 1: SETTING THE SCENE

Urban public transport (UPT) is important as it allows all individuals to be transported from point A to B in a flexible manner daily. Each day, around 10 million commuters use UPT per country. For commuters, the attractiveness of UPT (buses and trains) depends on the degree of comfort they offer. However, the link quality and the convenience of getting timetable information and buying tickets are also particularly important to passengers.

1.1 INTRODUCTION

Movement of people takes place every day and every minute, therefore availability of transportation to cater for all persons is needed. Public transport is a system available for use by all individuals and is globally recognized and used (Vuchic 2005). It therefore must be efficient for convenience purposes to all people. In developing countries, however, insufficient and ineffective urban public transport is a common challenge (Gwilliam 2003). Disconnected UPT has a negative impact on quality public transport desired by all commuters as it can cause delays; commuters do not switch smoothly from one UPT mode to the other; this results in an unreliable urban public transport system. Connected and integrated UPT systems are therefore urgently required (Chowdhury et al., 2017).

The twenty first century has introduced a generation that uses advanced technology to make life easier for themselves, and technological innovations have also increased convenience in UPT. Technologies such as big data generate a large amount of information which traditional data are unable to generate (Ruiz et al. 2016). Consequently, more technology innovations such as Intelligent Transportation systems (ITS) are deployed in UPT operations. The use of ITS assists public transport to be able to sense prevailing conditions and react to them in real-time (Vanderschuren 2006). These technological innovations improve customer satisfaction such as knowing the times of transport, reducing delays by assisting with knowing congested routes in real-time, providing alternative routes and offering smartcard operations for UPT (Mezghani 2008).

In South Africa, Gauteng province has introduced the Bus Rapid Transit (BRT) and Gautrain systems (Speed train and Bus) in order to provide a formal urban public transport (FUPT) that is efficient, effective, reliable and satisfactory to commuters. These two systems of UPT use advanced technologies. The current study area is within the context of the City of Tshwane Municipality and the BRT system, and Gautrain system. The historical context of South African transport is clouded by planning that was aimed to providing services unequally, which is one of the factors that has led to disintegrated UPT. Internationally, the BRT and the speed train has proven to be good and it may thus yield benefits in South Africa. Therefore, the study attempts to investigate the possibilities of integrating the Gautrain and A Re Yeng formal urban public transport electronically. This is achieved through investigating the spatial integration of the Gautrain and A Re Yeng to ensure the feasibility of electronic integration between the two UPT systems.

1.1.1 Background

Post -1994, South African cities and various role players faced the mounting challenge by using public transport systems to overcome the barriers of the apartheid spatial legacy. This was accomplished through reconnecting isolated nodes and communities disconnected from economic opportunity (SATC_CSRI 2017). The process of local and global urbanization to South African cities since post-1994 has thus put pressure on available transport infrastructure. However, the governments at all spheres- national, provincial and local have responded by making huge investments in UPT to ease the challenges of the unstable public transport systems. The bus rapid transit (BRT) and Speed trains were therefore implemented as part of the solution. The first bus rapid transit implemented in South Africa has been developed in the City of Johannesburg and is known as "Rea Vaya" which means we are going (Adewumi and Aloppi 2013). Consequently, Gauteng province implemented the second BRT system in 2014 known as A Re Yeng (Let's Go) in the City of Tshwane (Browning 2013). Furthermore, the speed train implemented in the province is Gautrain which services the City of Tshwane, the City of Johannesburg and Ekurhuleni.

The past years have shown a rapid increase in the use of private mobility and informal urban public transport. This seen an increasing number of cars on the roads, more traffic congestion and air pollution. Van Oort et al., (2010) states that ensuring accessibility and liveability of our cities for future generations means a substantial quality leap is needed in formal urban public transport. This will facilitate a desired modal shift from car traffic towards urban public transport, which is safer, cleaner and produces less congestion. Further, the use of technology is essential to assist urban public transport operations to be effective.

South African public transport first introduced the use of technology by improving the payment systems from a paper ticket to an electronic smart card (e-smart card) for convenience purposes. According to Dydkowski (2015), modern systems which are based on electronic tickets (e-ticketing) give much wider possibilities of efficient management of process and transport services offered. Mezghani (2008) supports the above mentioned by stating that e-ticketing systems are not only a means of payment but process huge amounts of information which offer a large range of possibilities to make public transport easier to use and to manage. Further, the uptake of mobile technology with online UPT information dissemination applications have rapidly increased globally, and this has changed how commuters manage their travel time. According to Julsrud and Denstadli (2017), studies have documented that the use of mobile information and communication technology (ICT) while travelling has the potential to enrich the use of travel time and in some cases, strengthens positive attitudes towards formal urban public transport.

Integration of different modes of formal urban public transport using a single e-ticket system is not common in South Africa. Nevertheless, interoperability of the formal urban public transport system is possible in the republic with the use of one electronic single ticket/smart card to connect to different modes of transport. Furthermore, integrated online information dissemination is displayed by developed countries, since e-ticket systems and online information dissemination exist. This allows easy ridership for commuters and makes it convenient for a person to make a journey that involves changing from one transport mode to the next (Nielsen & Lange 2007). Therefore, the use of mobile technology with online information dissemination application and integrated smartcards could bring more efficiency, reliability and effective UPT. In particular, the City of Tshwane metropolitan calls for a systematic and more interoperable approach in urban public transport (Acharya & Morichi 2012).

1.2 RATIONALE OF THE STUDY

In developing countries, insufficient and ineffective UPT is common (Gwilliam 2003), and South African cities are similarly challenged with ineffective UPT. Urban public transport networks are disconnected which disturbs smooth travelling for commuters who cannot switch from one transport mode to the other leading to an unreliable UPT network. Through improving integration aspects in UPT such as spatial, information dissemination and payment methods, urban public transport can attract more current private vehicle users thus reducing congestion in the roads and provide quality services. Further, developing attractive and marketable public transport is an urgent requirement. South African cities will otherwise suffer high levels of congestion and negative causes relating to car user preferences. By limiting private vehicles on the roads, there will also be fewer vehicle accidents.

1.3 RESEARCH PROBLEM

In the past 10 years, the City of Tshwane has introduced innovative formal urban public transport systems. These include the BRT (A Re Yeng) and Speed train systems (Gautrain and Gaubus). These two systems of UPT have increased the frequent movement of urban public transport and reduced delays for commuters in the city. However, commuters in the City of Tshwane are still challenged by delays caused by numerous factors. For example, the Gautrain and A Re Yeng one systems of formal public transport are not connected to each other. Therefore, commuters are unable to switch smoothly from one mode of transport to the next, and this increases ineffective, inefficient and unreliable FUPT. As a result, half of the commuters use informal public transport while others prefer private vehicles, which creates myriad challenges on the road. Therefore, the study investigates the possibilities of integrating the existing formal urban public transport operations in the City of Tshwane electronically in the hope of achieving efficient, effective, frequent movement and reliable urban public transport to attract more ridership.

1.3.1 Main research question

What is the state of electronic integration of Gautrain and A Re Yeng public transport operations?

1.3.1.1 Sub-questions

1. What are the policies and legislative frameworks on formal urban public transport integration in South Africa?
2. Are there any information systems that are shared by innovative urban public transport modes in the City of Tshwane?

3. Are there any payment systems that are shared by innovative urban public transport modes in the City of Tshwane?
4. Can there be a theoretical framework or model that explains strategies of integrating innovative urban public transport modes in the City of Tshwane?

1.4 RESEARCH AIM AND OBJECTIVES

Related to research questions are study aims and objectives. Aims and objective assist the research to have direction and purpose.

1.4.1 Aim

The aim of the study is to investigate the state of electronic integration of the formal urban public transport operations and create a model that can be used to integrate innovative urban public transport modes in the City of Tshwane.

1.4.2 Objectives

1. To review the policies and legislative frameworks on integration of formal urban public transport modes in South Africa.
2. To investigate the information systems that are shared by innovative urban public transport modes in the City of Tshwane
3. To assess the payment systems that are shared by innovative urban public transport modes in the City of Tshwane.
4. To advance a theoretical framework or model that explains strategies of integrating innovative urban public transport modes in the City of Tshwane.

1.5 SCOPE OF THE STUDY

The scope of the dissertation is in three forms: these are spatial scope, temporal scope and conceptual scope.

1.5.1 Conceptual scope

The study relies on theories and models that are relevant to formal urban public transportation, more precisely the integration and operation of intermodal urban public transport electronically.

1.5.2 Temporal scope

High-speed trains were introduced in 2009 in the Gauteng province. Subsequently, the A Re Yeng bus project was implement in 2014. Therefore, the focus timeline of the study is from 2009 till 2017.

1.5.3 Spatial scope

Gauteng is the smallest province in the republic but with the highest population and the study is limited to one city. The focus study area is the City of Tshwane which is located in Gauteng. The City of Tshwane is the capital of the republic. Accordingly, the study focus is on the formal urban public transport moving within the City of Tshwane, specifically Gautrain, Gaubus and A Re Yeng bus.

1.6 STUDY AREA

The study area is in Gauteng province as mentioned earlier. This affords many economic opportunities with a land cover area of 18 178 km^2 and the province is the heart of economic activity. The City of Tshwane was established in 1855 and has the reputation of being the academic city with three Universities and the Council for Scientific and Industrial Research (CSIR). Furthermore, the City of Tshwane affords twenty four percent (24%) of job opportunities in the province.

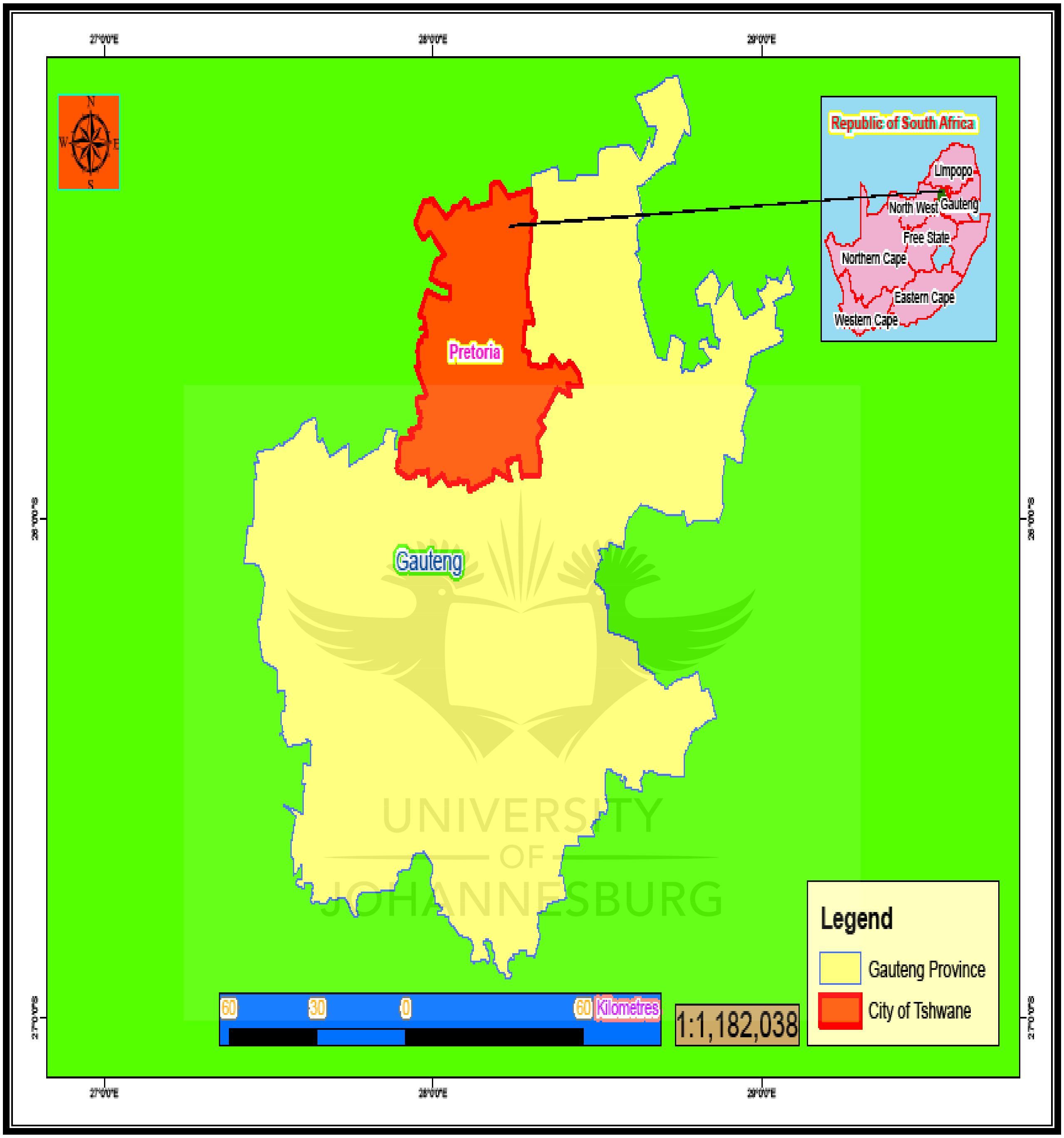

Figure1.1: Gauteng Map [Source: Author 2017]

According to Stats SA, the city population in 2011 was 2.921.488 (Stats SA 2011), and the map above indicates the study area which is the City of Tshwane. The study focuses on the formal urban public transport in the city, specifically the Bus Rapid Transit (BRT) and Gautrain systems. The Gautrain operates in selected locations in the province; however, it services the City of

Johannesburg, City of Tshwane and Ekurhuleni. The City of Tshwane and the City of Johannesburg are serviced by the BRT system (Rea Vaya and A Re Yeng). These BRT systems operate in their respective cities and designated locations.

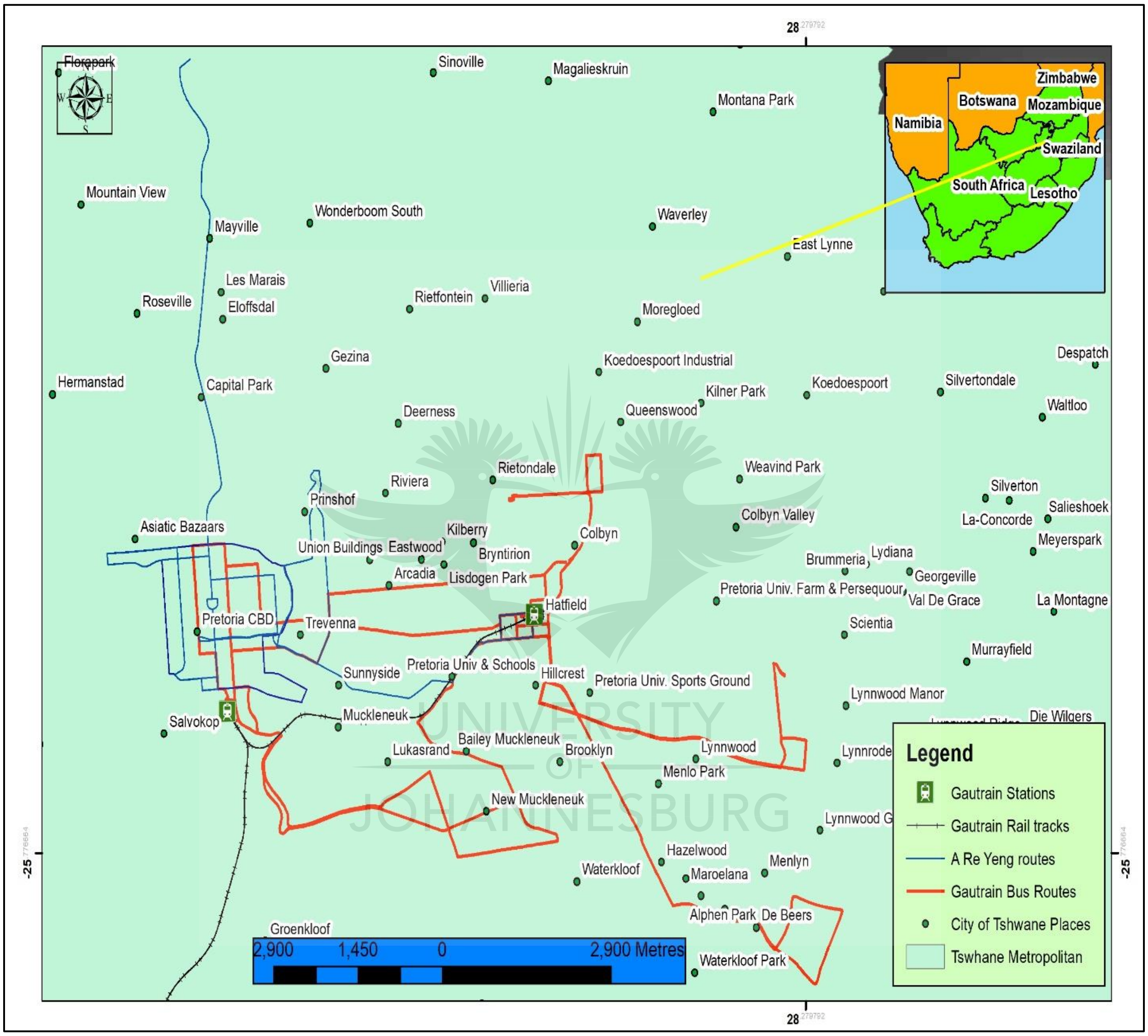

Figure 1.2: Study Integrated network routes [Source: Author, 2019]

The above map shows the integrated network routes found in the City of Tshwane. Only two Gautrain stations showed on the above map which are Pretoria station and Hatfield station, reason being, the study focuses on integrating Gautrain system and A Re Yeng system, A Re Yeng system services mostly areas around the CBD. Further, this map shows that both systems serve a role.

There is spatial connectivity in some locations and the routes serviced by both systems are different. Connecting both systems will create seamless travelling around the City of Tshwane.

1.7 OPERATIONALIZING RESEARCH

A research study must adopt a suitable methodology. According to Midgley (2000, p. 105), "A 'method' is a set of techniques operated in a sequence (or sometimes iteratively) to achieve a given purpose. Thus, a 'methodology' is the set of theoretical ideas that justifies the use of a particular method or methods." Further, Henning (2004) states that methodology identifies various procedures and strategies and sources that will be used to gather information. Therefore, the research methodology adopted for this study was a mixed method approach which consisted of both qualitative, quantitative and spatial data.

Larger databases used were Scopus, Science direct, Sage and Google scholar. Secondary data sources used were journal articles, newspaper articles, textbooks and documents of companies. The publications of authors featured in many journal articles were studied for any relevant information. For preparation of this study, 300 publications were reviewed, and only relevant publications were used. Further, up-to-date conference proceedings were examined to assist with the current awareness and improvements from industry practitioners and researchers. Secondary data was important in supporting the study based on what other studies revealed. Further, crowd source data obtain from Echo-social was used to ensure a large sample size and to strengthen the data; this includes data received from facebook and twitter. Accordingly, the data was used to advance a model that explains strategies of integrating innovative urban public transport modes in the City of Tshwane.

1.8 RESEARCH STRUCTURE

Figure1.3: Research Structure [Source: Author 2017]

Chapter 1: Introduces and gives a short background to the study. Consequently, outlines the purpose of the study highlighting its aim and questions that will direct it. The chapter briefly indicates techniques used in order to achieve the objectives of the study. The structure of the dissertation to demonstrate the flow of the research is described.

Chapter 2: Reviews the literature based on the concepts relating to the objectives of achieving the study. It uses journals articles and various works of scholars regarding methods of integrating urban public transport.

Chapter 3: International studies regarding integrated public transport systems are identified; specifically, studies based on electronic integration and different studies are used to support the main study. The studies identified indicate that the study was feasible, as there are countries globally with integrated UPT. Further, in African countries, only innovative public transport mode studies are identified, as integrated public transport systems of rail and road do not exist currently.

Chapter 4: Existing various formal and informal UPT modes are identified. Accordingly, innovative Urban Public Transport of both rail and road in the republic are also identified and the need to integrate the Bus Rapid Transit system and the Gautrain system in the City of Tshwane was indicated. Further, policies and legislative framework are reviewed.

Chapter 5: The study has several different objectives. To reach the objectives of the research, there are suitable methods that need to be adopted for a smooth operation of the study. The study has adopted a mixed method approach which includes gathering, analysis and presentation of qualitative, quantitative and spatial data. The spatial analysis conducted through Focal statistics, and Kriging interpolation results in producing a model that identifies areas for future extensions.

Chapter 6: The research findings and analysis are presented on this chapter. Interviews conducted with various urban public transport officials and commuters of A Re Yeng system and Gautrain system are analysed. Consequently, the payment methods and information distribution to commuters in line with the objectives of the study are analysed and presented. Further, the existing spatial integration is identified that can make possible smooth switching between the A Re Yeng and Gautrain systems.

Chapter 7: The social media data (Facebook and twitter posts) are used for different analysis. Word cloud identified words that are mostly used by commuters through posts, and these words predicted concerns and possibly link the solution of the concerns to the study objectives. The social media data is attached with coordinates system of where every post was made. This data is used for focal statistics analysis and kriging interpolation analysis to identify cold and hot spots of the commuters for possible development of stations and stops to give commuters easy access.

Chapter 8: The previous chapters indicated different views of the study, indicating the purpose of why the study need to be conducted, and whether the study is feasible or not, the techniques used to achieve the study objectives etc. Therefore, this chapter gives the summary of the whole study. Consequently, it provides the conclusions and recommendations to the study. Further, areas of expansion to provide efficient, reliable and effective Urban Public Transport to all users are identified and presented.

1.9 CHAPTER SUMMARY

The chapter introduced the study with a brief background of the republic and highlighted the main purpose and need for the research. The main question, aim and objectives are clearly stated. Further, the chapter highlighted the use of technological innovations in this study, as they are key factors in assisting the prime objective of formal urban public transport to be efficient and reliable for commuters satisfactory. Consequently, the selected study area is indicated which provides both innovative FUPT systems. Further, the following chapters 2, 3 and 4 will discuss previous studies conducted on integrating urban public transport operations electronically.

CHAPTER 2: LITERATURE REVIEW & CONCEPTUAL FRAMEWORK

Different modes of UPT working together produce quality public transport services. There are several promising opportunities that exist to improve service reliability and efficiency, these being the most important quality aspects of urban public transport (Van Oort 2011). Technology is important as a tool to make viable UPT. Integration of formal urban public transport through technology makes travelling easier, as many individuals have access to tools that use technology such as mobile phones, computers etc., and technology also simplifies data collection for analysis of urban public transport. This chapter therefore reviews techniques to integrate UPT electronically and the need to integrate the UPT network.

2.1 INTRODUCTION

Urban areas have the purpose of satisfying the citizen's needs to interact and conduct different activities such as work, study or leisure. Transport systems are designed to allow the required movements within the city efficiently and effectively (Amaya et al. 2017). Globally, developed countries always work on different methods in order to have the best formal urban public transport. Several developed countries have good roads; this allows them to develop decent road public transport. Formal public transport such as Bus Rapid Transit (BRT) systems, other formal bus modes, road public transport modes such as trams are subsequently developed and other good public transport services such as high-speed trains. Most countries with such formal urban public transport integrate these modes in order to make travelling faster and easier for commuters, with different techniques used to integrate two or more transport modes. Integrating formal urban public transport electronically using smart cards and information sharing systems enables urban areas to have efficient, reliable and effective UPT. Accurate information also needs to be collected regarding locations that need more urban public transport services, and peak hours should be considered as well. Tools such as big data can give enough information. Furthermore, Intelligent transport systems (ITS) make use of UPT interesting in such a way that they assist with traffic flow, knowing a certain public transport mode's location in real time etc.

2.2 PURPOSE OF URBAN PUBLIC TRANSPORT MODES (UPT) SERVICES

Urban Public Transportation can be described as systems that are available for use by all persons who pay the established fare. These modes, which operate on fixed routes and with fixed schedules, include bus, light rail transit, metro, regional rail and several other systems (Di Pietro et al. 2015). Paulovičová et al., (2015) state that UPT systems may serve us as a useful model of spatial interaction, with a multidimensional complex web of links varying in intensity and regularity over various frequencies, probably most importantly a daily 24 hours long. There are many reasons for travelling; people travel to go to work, school and to meet with other people for different reasons. In order to travel, means of transport is essential, and the two types are public and private transport. Public transport includes buses, train, taxis and airplanes. Buses are convenient as the pick-up spots or bus stations can be found inside every neighbourhood corner, can carry many people, and an individual can move inside the bus. Taxis are convenient in most occasions; however, everything has its weaknesses; an individual does not wait for a long time to get a taxi and this public transport has a maximum of 16 seats for passengers. Trains carry many people in nature, and they are spacious. Airplanes are for travelling to far places, and overseas and they are very fast in nature. On the other hand, private transport includes cars, motor bikes and bicycles. Cars are comfortable and give an individual a private space. Motorbikes are very quick and allow a maximum of two people on it. Bicycles is a source of transport that can be used by one person and it is slow but faster than walking. However, the study focuses on urban public transport, specifically the Bus Rapid Transit (BRT) system and Gautrain system.

The role of UPT makes movement easy for all people, regardless of conditions, as most types are affordable. Many people around the Republic of South Africa use UPT for different reasons as some use it to reduce traffic congestion, while for some it is the only mode of transport accessible. Promoting the use of UPT is urgent because it provides a sustainable, effective and efficient citizen’s mobility, while simultaneously having a positive effect in air pollution and energy costs reductions (De Pablos et. al 2011). UPT has positive benefits, which include tackling congestion by transporting large numbers of people efficiently (Hidalgo and King 2014). It also has a major role to play in alleviating congestion, improving traffic flow and cutting energy bills, as public transport offers energy-efficient transport solutions. With the number of trips made in urban areas set to rise exponentially in the years to come, governments will need smarter mobility solutions. If these new trips are made by private vehicles, governments will see a significant hike in their energy bills, and a greater dependence on fossil fuels and imported oil (Booth and Richardson 2001). Further, cost to the economy is affected, as in cities with a high share of public transport, walking and cycling, the cost of transport for the community can be as much as 50% lower. This is in comparison with cities where the private car dominates and the creation of job opportunities as public transport is also a major contributor to national and local economies through the jobs it provides directly (All together for public transport growth 2013). Therefore, the above-mentioned benefits outline why the use of urban public transport should be encouraged and why the need for a good functioning urban public transport that is integrated and functions as one system.

2.2.1 Bus Rapid Transit (BRT) system operations

Deng and Nelson (2010) defines Bus Rapid Transit (BRT) as a form of mass transport (public transport) that combines speed and reliability of a rail service with flexible service and lower operating costs. It is based on dedicated road lanes that cannot be used by vehicles other than large buses operated by BRT companies (Labour Impact Assessment 2018). BRT involves building new roads, interchanges, terminals and modern stations along the routes. According to Adewumi and Allopi (2013), the large-scale development of BRT systems started in Curitiba (Brazil) in 1974, before which there were several smaller-scale projects". Venter (2013) mentions that the introduction of the BRT is a response to the challenges from the informal public transport that has evolved and been used of decades. All over the world countries are affected by traffic congestion. The World Bank and national governments therefore encourages the implementation of BRT, as it is believed that it will ease congestion, increase efficiency, and reduce air pollution (Labour Impact Assessment 2018).

The Curitiba master plan envisaged transport orientated development, and a railway system was one of the options to consider for a public transport system (Hidalgo and King 2014). The railway was aimed to accommodate the envisaged population growth. The cost of the railway system was however not affordable, and the concept of BRT worked out to be cheaper, more effective and flexible, allowing transport to be integrated with development (Burgess and Ordiz 2010). The more effective and flexible from the previous sentence implies that, even if the funds were available for the railway system, the BRT would have been a logically best choice. The BRT proved to be good not only in terms of costs but the desired transport system that is flexible and integrated to the city's development is, reliable, comfortable and attractive. In addition, the environmental benefits set Curitiba's system as a model in efforts to reduce fuel emissions. The BRT system reduced use of fuel by 30% per capita (Goodman et al. 2005).

2.2.2 High-speed train

Globally, there is a preference in the use of public transport due to their nature as some transport few people and other many people. Most preferable public transport modes are train and bus. The High-Speed Rail (HSR) is defined differently around the world. Outside the United States, HSR generally refers to trains that travel above 150 miles per hour (250 kilometres per hour). The European Union defines HSR as newly built lines equipped for speeds of greater than 155 miles per hour (250 km per hour) or upgraded lines equipped for speeds of greater than 124 miles per hour (200 km per hour) (Todorovich and Hahler 2011). This train is one of a kind. It is comfortable and much faster than normal traditional trains. The high-speed train moves smoothly and is designed to beat traffic. It only stops in designated train stations and has accurate travel times. The first speed train was developed in Japan in 1964 and was known as a bullet train. High-speed trains can be found in many counties around the world and connect major cities. Countries such as Austria, Belgium, China, France, Germany, Italy, Japan, the Netherlands, Poland, Portugal, Russia, South Korea, Spain Sweden, Taiwan, Turkey, the United Kingdom, the United States and Uzbekistan have implemented this mode of urban public transport to establish a swift movement for commuters. This mode of UPT is popular in most developed countries; it uses its own designated rail track from other light rail services as it is very fast in nature. Its coordination is also different from other rail services, as it does not have delays and coordinates its departure, and arrival times (Loubinoux 2018).

2.3 IMPORTANCE OF TRANSPORT PLANNING

The US Department of Transport (2014), defines Transport planning as a cooperative process designed to foster involvement by all users of the system. This includes the business community, community groups, environmental organizations, the traveling public, freight operators, and the general public. It operates through a proactive public participation process conducted by the Metropolitan Planning Organization (MPO), state Department of Transportation (state DOT), and transit operators. Transport planning and design choices have a direct influence on development patterns, travel mode choices, infrastructure costs, redevelopment potential, the health of natural resources, and other community concerns. Transport planning/evolution and demand usually responds to how communities' function spatially (Holzer et al. 2003). In some cases, transport planning can be used to force spatial change (Wegener & Fürst 2004). Further, transport helps shape an area's economic health and quality of life. Not only does the transport system provide for the mobility of people and goods, it also influences patterns of growth and economic activity by providing access to land. Transport planning is more than listing highway and transit projects. It requires developing strategies for operating, managing, maintaining, and financing the area's transport system to achieve the community's long-term transport goals (US Department of Transportation 2014).

According to Lucas (2006), the planning phase is more critical, as a system can be referred to as part of planning. The design element is tied to a management plan, as it will involve planning of routes and stops integrated with frequencies. In line with the above, at the strategic level of planning the public transport system, long-term stability of a high service quality is required for the system to influence urban development and to create more sustainable transport patterns (Nielsen & Lange 2007). Consequently, Schöbel (2016), states that planning public transport is a multi-objective problem that includes line planning, timetabling, and vehicle scheduling. For each of these planning stages, models are known, and advanced solution techniques exist. Some of the models focus on costs, others on passengers' convenience. Setting up a transport system is usually done by optimizing each of these stages sequentially.

In some instances, the challenge is with physical connectivity, as some transport modes do not enter in certain locations, and the problem is in the planning phase in some cases. However, this research will look further than physical connectivity and use intelligent transport systems to integrate different modes of urban public transport so that it is easily accessible to its commuters. For UPT to function well, there are certain elements that need to be considered. In the planning process, there is a need to determine the current demand and the relationship of movements of different transport modes and environmental demands. There is also a need to predict future travel demand and make a recommendation to fulfil challenges which might occur. Further, it is important to assess whether the proposal makes a satisfactory demand and provides maximum benefit to the community. Monitoring existing conditions such as forecasting future population and employment growth includes assessing projected land uses in the region and identifying major growth corridors. It identifies current and projected future transport problems and needs and analyses, through detailed planning studies, various improvement strategies to address those needs.

Urban Public transport planning in South Africa has been improving over the years as more strategies from around the world are adopted by the republic. Several transport modes have been implemented in order to improve the state of public transport in the country. For example, Bus Rapid Transit & Speed trains have been implemented in order to boost quality, efficiency, effectiveness and reliability of the public transport network.

2.4 INFORMATION DISSEMINATION AND PAYMENT SYSTEMS

The increasing development of big data technology has brought great opportunities and challenges to innovation of complex systems such as Intelligent Transportation Systems (ITS) (Zeyu et al., 2017). The emergence of ITS has paved the way for new innovative prospects for improving the safety, operation, and environmental impact of transport networks. Connected vehicle (CV), a ground-breaking initiative of “intelligent vehicles”, is emerging as the next wave of technology to further empower travellers (Jadaan 2017). According to Suen et al. (1998; 386) “Intelligent Transportation Systems is the term used to describe the application to road transport of advanced technologies including computing, sensors, communications, and controls”. In accordance with the above, Intelligent Transportation Systems are designed and developed as a response to existing challenges related to management of road traffic, pedestrian and passenger flows in large cities (Agureev et al. 2016). Further, the European Union (2010) supports the above statement by defining ITS as application of information and communication technologies in the field of road transport. This includes infrastructure, vehicles and users, and in traffic management and mobility management as well as for interfaces with other modes of transport.

Developed countries use these technologies, and the rate of application has increased dramatically in the past years. Real-time display of information in public transport systems is becoming common, and multimodal information terminals are starting to appear (Liu and Ceder 2017). ITS's are playing a big role, as governments around the world are employing them for improving the functioning of transport system (ITS Technologies) due to the problem of increasing population and congestion in cities. This tool makes a huge difference in transport and it could be applied in many ways with different models one of these is the Advanced Traveller Information System (ATIS), which monitors the movement and location of a certain source of transport (car, bus etc.) in real-time and keeps a watch on the condition of the transport network (Briem et al. 2017).

In addition, Mitchel (1997) states that "The areas of application of ITS are usually listed as Advanced Traffic Management Systems (ATMS), Advanced Traveller Information Systems (ATIS), Advanced Vehicle Control and Safety Systems (AVCSS), Advanced Public Transport Systems (APTS), Emergency Management (EM), Advanced Rural Transportation Systems (ARTS) and Commercial Vehicle Operations (CVO)". Functioning of Intelligent Transport Systems are intended to improve the safety, efficiency and capacity of the roads. The use of ITS to monitor urban public transport users provides better information before and during a journey. It includes the use of e-smart cards to pay public transport fare, all of which reduces stress and increases security for travellers and directly improves safety (De Grange et al., 2013)

2.4.1 Integrated e-Smartcard for urban public transport

According to Evans et al. (2015), e-Smartcard technologies offer the potential for bringing transport and citizen services onto a single smartcard platform, referred to henceforth as an integrated 'Transport- Citizen' (TranCit) card. The wider integration of different services has been a key aspiration within the public transport sector, as it has potential to deliver numerous benefits which will ultimately make public transport more attractive to users (NEA 2003). Smartcards are not a new creation but have existed for more than 40 decades. The first integrated circuit smartcard patent was successfully filed in Germany by Jürgen Dethloff and Helmut Göttrup in 1969 (Goethe-

Institute 2015). Throughout the 1970s, the technology gradually developed and by 1977, Motorola and Bull had successfully developed the mass production of a product which we would now consider to be a smartcard (Blythe 2000; Shelfer and Procaccino 2002). E-Smartcards have become a regular feature of many peoples' daily lives, but they typically only provide access to a single service and/or are used in a restricted place, existing in isolation from other potential opportunities. The most outstanding examples of a single service smartcard are those deployed for public transport services (e.g. Oyster in London, Navigo in Paris, Octopus in Hong Kong). Bank cards are used for payments/cash withdrawal or in numerous organisations where members use their smartcard as a proof of ID for building access control and as a bespoke key to other available services.

The idea of combining services onto a single card is not new: major schemes have been experimenting with multi-application citizen cards since the late 1990s (Blythe 1999; Blythe, Lawther, and Shield 2000; Evans et al. 2015), whilst the early integration of the smartcard for public transport ticketing purposes were proven on a multi-operator or multi-modal basis (Giuliano, Moore, and Golob, 2000). Early field operational trials of e-smartcard systems suggested that such systems were favoured by passengers and operators alike, saving time during boarding and being more convenient than cash-based transactions (Chira- Chavala and Coifman 1996). However, in many cases, early attempts to develop integrated schemes failed due to the lack of a sustainable business case. These were a result of limitations of the state-of-the-art technologies, no robust definition of the roles and responsibilities required for running a single system and a general lack of understanding surrounding the complexity of demands being made on the technology (Giuliano et al. 2000). Further, e-smartcards are more convenient than paper tickets and paying hard cash to board in a certain public transport. Public transport systems with electronic fare collection devices continuously store data related to trips taken by users, which contain valuable information for planning and policy analysis (Amaya et al. 2017).

2.4.2 Urban public transport operations using big data

The U.S Department of transportation (2014) defines big data as an approach to generating knowledge in which a number of advanced techniques are applied to capture, manage and analyse very large and diverse volumes of data – data so large, so varied and analysed at such speed that it exceeds the capabilities of traditional data management and analysis tools. Further, Big data has been described as "data sets whose size is beyond the ability of commonly used software tools to capture, manage and process the data within a tolerable elapsed time" (Forsyth Communications 2012, pp.5). Big data improves efficiency, decreases costs, increases revenue and assists organizations with decision-making; however, some organizations yet do not know the benefits of this tool. Many organizations in the Republic of South Africa use this tool to market their brands by accessing individual's private information such as mobile numbers and calling or texting them. Furthermore, big data is not a new concept but exists in every era, where the tools for data processing are always being stretched by increasing size (Batty 2013).

Big data represents the information assets characterized by such a high Volume, Velocity and Variety (the three Vs) to require specific technology and analytical methods for its transformation into value (de Mauro et al. 2016). In line with above mentioned, Ruiz et al., (2016) state that big data sources for transport planning applications include: GPS traces (smart phones, etc.), cell phone traces, transit smart card transactions, and other count and sensor data (including on-board vehicle sensors). They include online Social Media/Networks, credit card transactions (travel-related activities) and RFID traces. The role of big data can be of great assistance by capturing locations that are desperately in need for more public transport. The following diagram illustrates the process of big data.

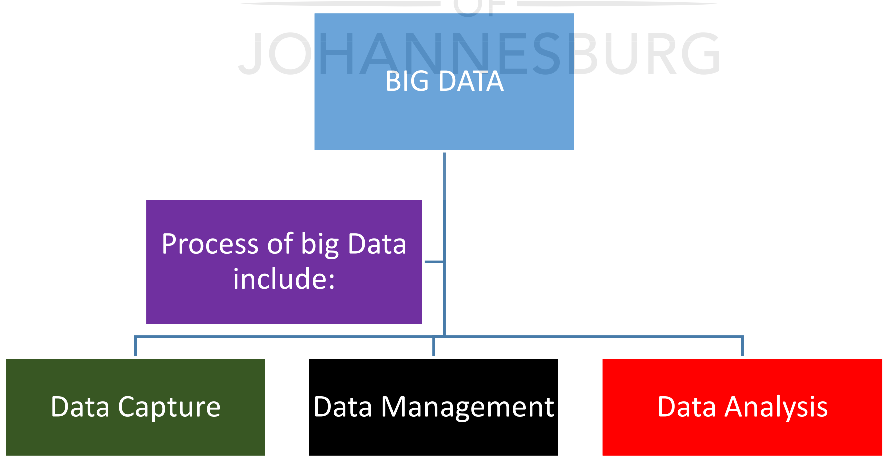

Figure 2.1 Big Data process [Source: Author 2017]

The above shown diagram indicates how big data functions. Data Capture includes massive datasets encompassing all or most of the population being studied (as opposed to small samples). Data are used from both purpose-specific and repurposed data collection; and utilization of crowd sourced and “electronic breadcrumb” data (Ferreira et al. 2017). Further, data management features storage in decentralized and virtual locations (i.e., the cloud) and handles both structured and unstructured data. Finally, data analysis it is often automated, with computers doing more of the work to find complex patterns among many variables.

Examples of big data approaches or techniques being used in transport operations are limited. Several current projects feature approaches common to big data. These are the Integrated Corridor Management (ICM) systems in San Diego and Dallas and several Michigan Department of Transportation agency fleets connected vehicle projects, (Borges and e Cunha 2017). Although very valuable, they do not illustrate the full potential for big data, which can be realized by applying big data when connected vehicles are widely deployed across the country. Big data examples are somewhat more prevalent in the private sector. Although big data approaches are not yet common, these sorts of examples of big data in suggest that a great deal of potential exists for applying data in the coming traveller data-rich connected vehicle environment (US Department of Transportation 2014).

2.4.3 Mobile technology

The introduction of cell phones was to serve the purpose of passing a certain message through phone calls through a phone that is portable. Technological advancement has contributed in helping by decreasing travelling hours and in some cases, technology has managed to eliminate the need to travel. According to Riggs and Gordon (2017), mobile technology is changing cities in ways we are only beginning to understand. For example, internet-enabled mobile devices incorporating GPS allow for location-based, social networking content, which can increase awareness of user activity, movements, and behaviours in real-time conditions and specific contexts (Kwak et al. 2010). Communication through smart phones simplifies many challenges, as the world is moved by technology advancement. Furthermore, demand and supply are both relevant for travel time in public transport, while it is obvious that the supply side in form of the timetable corresponds directly to the travel time, and demand influences the travel time only partially but in critical moments (Briem et al. 2017). Consequently, through smart phones most things are accessible as the device is portable and can be carried anywhere. In accordance with the mentioned, there is a need for an online application that can be accessed through smart phones in order to assist with the availability of urban public transport now. The online application assists with time saving, as commuters do not need to get to a certain station to get a timetable of the UPT and with online application commuters can be able to view real-time movement of a certain mode of UPT.

2.4.4 Smart Cities concept (Smarter Mobility)

The term "smart city" was coined towards the end of the 20th century. It is rooted in the implementation of user-friendly information and communication technologies developed by major industries for urban spaces. Its meaning has since been expanded to relate to the future of cities and their development. The term is not easy to be define, but Airaksinen and Kokkala (2015, pp. 8) indicate that "The impression is often that a smart city is the same as a digital city, and sometimes its meaning is close to that of a sustainable city". Further, Frith (2017, pp.176) supports the above mentioned by stating that "the term smart cities is broad and resists simple definition, but it mostly refers to the use of digital technologies to produce data to increase cities' efficiency, improve their liveability, and promote their safety".

According to Dameri and Benevolo (2016), Smart Cities (SCs) are a recent but emerging phenomenon, aimed at using high technology and especially information and communications technology (ICT) to implement better living conditions in large metropolises, to involve citizens in city government, and to support sustainable economic development and city attractiveness. Cities have been implementing innovative public transport which uses technology such as ICT and ITS thus producing smarter mobility (Gruen 2013; Hancke, Silva, & Hancke 2013; Hashem et al. 2016; Zanella, Bui, Castellani, Vangelista, & Zorzi 2014). These technologies assist UPT to be safe, efficient and reliable and contribute to smart cities and incorporate new energy, traffic and transport environment concepts. Formal urban public transport such as BRT and high-speed trains also contribute in creating smart cities which these systems are a concept of smarter mobility. These two modes of public transport aim to reduce traffic congestion, air pollution, car accidents and provide reliable, attractive, efficient, and effective formal urban public transport. They transport people into different spaces of socio-economic activities and produce a compact chain between public transport, residential areas and socio-economic areas.

2.5 INTEGRATED TRANSPORT APPROACH

Transport systems are complex with many parts that comprise the whole. The objective of integrated transport planning is to find balance among these dimensions so that planning and investment decisions contribute optimally to the economic, social, cultural and physical potential of the transport system and society in general. Integration is a concern with the whole, with common objectives and agreed desired outcomes. The different options, goals and points of view must be integrated to identify realistic solutions to community problems. Integrated transport planning is about more than coordinating transport. It integrates multiple and sometimes-conflicting objectives to reach more sustainable transport outcomes that contribute to community, industry and government priorities. Further, it is significant that the transport network is well established from the beginning of the development. Designs should allow roads to link and need enough space for vehicles movement and for potential development of potential smart transport. In South Africa, Gauteng has implemented smart UPT such as the BRT system in the City of Tshwane (A Re Yeng bus) and City of Johannesburg (Rea Vaya bus). The development of this concept played an important role as it brought more alternatives in UPT; however, it has reduced the width of the roads for both public and private transport leading to traffic congestion on certain peak hours. Hence, environmental challenges may arise and increase human health risk due to time spent on the road by cars releasing noxious gases.

UPT should not be an independent phenomenon but should be viewed as dependent, as there is one prime objective which is efficiency, safety, reliability and effectiveness. This means, UPT should connect modes of transport for necessary switching between modes by commuters. However, transport related innovations should not come only from the office of the transport department or experts in design for current needs and accommodating future transport needs in response to existing and expanding patterns. The possibility of introduction of a transport system capable of connecting public transport to function as one transport mode would be difficult however, it is possible. Currently there is a high need of effective public transport to reduce the number of transport challenges. Physical connectivity in South African UPT is however lacking, hence, this study focuses on integrating transport electronically.

2.5.1 Need for integrated Urban Public Transportation

Integrated public transport is a structural practice by which fundamentals of the commuter public transport systems (network and infrastructure, fares and ticketing systems, information and marketing components) and a variety of carriers who serve different transport modes, interact more closely and efficiently. This generates an overall improvement in service quality level and enhanced performance of the combined public and individual transport (Solecka and Zak 2014). In general, the implementation of different transport integration solutions may result in decreased time spent traveling, public transport prices/costs, traffic jams and environmental and pollution (Prospects 2003).

According to Chowdhury and Ceder (2016), transfers are a key component in the successful operation of an integrated system. The roles of transfers are twofold. Firstly, they increase the accessibility of various destinations for users. Secondly, interchanges that facilitate transfers need to be provided in the network at strategic locations to reduce duplication of the public transport routes to improve the reliability of the network. Urban public transport integration solutions may improve the UPT network accessibility and overall competitiveness as well as assure better utilization of different transport means and infrastructure. Integrated urban public transport delivers a system to commuters that has alternatives which do not limit desired travel routes and offer an appropriate, accessible, efficient, safe, effective and reliable system (Ibrahim 2003; Luk and Olszewski 2003; Ulengin et al. 2007; Chowdhury et al. 2017). Numerous research studies have revealed that integrated urban public transport systems can draw more users. For example, Ibrahim (2003) stated that in Singapore, where urban public transport use is considerably high at 60% of mode share, the government aimed to increase the mode share to 75% through integration. Matas (2004) examined the important rise of urban public transport use (>40%) in Madrid, Spain from 1986 to 2004 and discovered the reasons to be the changes made for integration. Further, electronic integration is common in developed countries. In the City of Cracow, Poland, integrated payment systems and integrated information distribution through timetables, transfer points and riding times has improved the smooth movement of public transport (Solecka and Zak 2014).

2.6 Chapter Summary

The literature has unpacked how concepts such as big data, Intelligent transportation systems and smart mobility can be utilized in the Integration of existing public transport systems whilst also highlighting new possibilities of electronical integration through the use of payment systems and information dissemination.

CHAPTER 3: INTEGRATED URBAN PUBLIC TRANSPORT SYSTEMS INTERNATIONAL EXPERIENCES

The lack of integration in the public transport system has long been a major complaint in passenger satisfaction surveys. To reach a destination, for example, a rider is often forced to take multiple routes, each with different schedules and transfer stations but without coordination of passenger information. As a result, the rider may have to take a long walk to make transfers and pay multiple fares. It also creates overlapping services and discourages ridership. Therefore, UPT runs efficiently when it operates as a seamless, integrated system. By analysing previous studies that have been documented, this chapter will discuss the countries that have implemented innovative UPT and countries that have integrated UPT.

3.1 INTRODUCTION

The population explosion in cities leads to travel demand. Provision of decent UPT is therefore very crucial for customer satisfaction. For example, Indonesia is one of the most populated countries in the world after China, India, and the USA and faces a large travel demand (Friman 2009). However, Germany, Austria, Switzerland, the United Kingdom, Australia, Spain etc. have responded well to public transport issues. These countries have introduced innovative methods that use Curitiba transport systems (ITS), Information Communication Technology, Big data and other technologies. Further, these methods have been used to connect and integrate urban public transport electronically. The use of well-planned public transport networks, spatial connectivity, payment methods and information distribution are the key elements in integrating UPT as demonstrated by the developed countries.

3.2 UNIVERSAL PRACTICES OF INNOVATIVE URBAN PUBLIC TRANSPORT

According to Liu and Ceder (2017) state that ITS plays a very big role in streamlining the movement of public transport vehicles in big cities which must cope with the variable traffic volume. This is true especially in Poland where the motorization levels are greater than, for example, in the USA (based on information from Poland Central Statistical Office) (Chmiel 2016). The Automotive Industry Standard (2016) supports the above-mentioned role of public transport by highlighting that Intelligent Transport Systems are globally proven to optimize the utilization of existing transport infrastructure and improve systems in terms of efficiency, quality, comfort and safety. An example is India, which has realized the potential of ITS, and Government bodies and other organizations in India are presently working towards implementing various ITS services across the country. The first steps taken for creation and implementation of ITS was a National Workshop titled "User Requirements for Interactive ITS Architecture", which was conducted as a collaboration between SIAM and ASRTU on 26th -27th February 2015. This was primarily for Public Bus Transport. Nevertheless, the workshop helped to create the "National Intelligent Transport System Architecture and Policy for Public Transport (Bus)", which was submitted by ASRTU and SIAM to the government.

3.2.1 Development of Bus Rapid Transit systems and High-speed trains globally

In Brazil, Curitiba was one of the first cities to develop a Bus Rapid Transit (BRT) system. The decision to rely on buses was perceived as a more flexible and affordable public transport solution than rail transit for a medium-sized developing city (Hook 2009). The popularity of Curitiba's BRT system has attracted motorists to it, despite a high rate of automobile ownership relative to the rest of Brazil. The BRT in Curitiba is effectively coordinated with land development; it is heavily patronized, and it operates quickly and reliably. Curitiba city in Brazil can therefore be regarded as the birthplace of the BRT system. Curitiba wished to develop a mass public transport system, but despite budget constraints, innovation from the mayor who was an urban designer/architect led to the idea of a transport orientated development. A cheaper transport system but capable of carrying many people at a less cost was finally created and integrated with the development of a master plan (Gustafsson & Kelly 2016).

The need for the economy of Curitiba to grow was linked with the need to grow the population and therefore the planned transport system catered for this. With the known facts about the train capabilities, the ideal of the BRT was appealing because it was cheaper. The BRT was approved and implemented to change and shape the town towards functional transport orientated development (Zheng 2015). The system resulted in the economy and business activities in the area growing and property rental values increasing (Goodman et al. 2005). Also, the BRT had advantages over a train system as it could penetrate in the city as well as drive on lanes being dedicated to the BRT. Furthermore, the environmental benefits prepared Curitiba's system to be a model in efforts to reduce fuel emissions. The BRT system reduced use of fuel by 30% per capita (Goodman et al. 2015). The BRT was a success, mainly because all its citizens benefited without having to address issues pertaining to unequal treatment history. Today more than 70 percent of Curitiba's population is successfully using the BRT (Hidalgo and King 2014).

In 2000, the city of Bogotá, Colombia embarked on a grand land use and transport system experiment. The transformation of Bogotá included building the city wide TransMilenio Bus Rapid Transit (BRT) system which offered speed and convenience like that of an underground metro (Heres 2013). Further, countries such as Beijing, China has implemented the BRT system in their transport planning strategy. Beijing is one of the cities that has the highest population in the world and therefore suffers from congestion. Unlike Curitiba, where the city's population densities increased because of the success of the BRT, China has implementing the BRT system to solve an old congestion problem (Deng and Nelson 2010). Accordingly, many countries have implemented the system after the success of BRT in certain countries.

Advancement of transport has also led to speed trains that are a very popular around the world. One of the first countries to have such trains is China, and today they are in many countries in Europe, and China's high-speed rail operation is ranked as one of the best globally. Cities that are densely populated need high-speed passenger dedicated lines (Liu and Ceder 2017). The design and efficiency of such trains is informed by the rapid transit concept, which aims to reduce traffic congestion and encourage the use of public transport systems. Consequently, the train is tailored to achieve smart mobility (Liu & Teng 2014).

3.3 CASES OF INTEGRATED URBAN PUBLIC TRANSPORT SYSTEMS GLOBALLY

Demands for urban public transport in different countries are caused by different reasons. For example, the demand for urban public transport services in Kuwait emerged as a direct result of rising immigrant labour in the Country which experienced sudden oil wealth in the early 1950s. Absence of effective urban public transport could worsen the quality of urban life for the unprivileged groups of the society in particular, therefore, a need for implementing good, easily accessible UPT has arisen. When it is accessible, different techniques to make UPT viable should be implemented as well.

3.3.1 Integrated urban public transport in developed countries

In Barcelona, Spain, metro buses and trams belong to one integrated transport system operated by Transports Metropolitans de Barcelona, or TMB. This means that passengers can buy integrated tickets from TMB points of sale which allow them to travel on all modes of transport. Barcelona's transport system is well served by frequent metro trains, buses and trams, so passengers normally don't have to worry too much about timetables. The metro, bus and tram services run every few minutes throughout the city's centre, especially Zone 1. If passengers want to consult timetables or find out journey times, they can do this very conveniently on the TMB website's Journey Finder page. Here they can simply enter their departure location, the destination, the date and the approximate time they wish to travel – the website calculates the best route options and times. Consequently, Barcelona has a well-developed and relatively modern transport network covering all modes, including rail- and bus-based public transport and a network of motorways/expressways developed between the 1970s and early 1990s. The 1992 Olympics had a major impact on infrastructure provision within the central area. Integrated fares and ticketing were introduced across all public transport modes from 2001. Real-time public transport information on metro, rail and bus networks, travel information is available via the internet with Barcelona offering regularly updated road camera images on the web, and both cities provide public transport routing information electronically and via phone hotlines.

Another example is Toronto, Canada, where the public transport service is called the Toronto Transit Commission (TTC). This covers the entire city and uses a subway (metro) and a bus network. There is also a free 'transfer' ticket, which is used to move from the subway to the bus and vice versa without paying an extra fare for a continuous trip. This transfer must be obtained from red machine dispensers on the subway stations or from the bus driver. If passengers do not obtain the transfer ticket, they will be required to pay another fare. Toronto's subway consists of 3 lines. The Bloor-Danforth line crosses the city from east to west. This line has an extension in the Scarborough area of the City of Toronto, operated with LRT (Light Rapid Transit) trains, and operates in the easternmost part of Toronto. The Yonge-University line is U-shaped and operates from Ontario Lake to the northern parts of Toronto in a north-south direction. The Sheppard line is the latest addition to the Toronto subway system, and it travels in the east direction from Yonge Street along the Sheppard Avenue. Full schedules and maps can be found on the TTC website.

In Western Australia, the Mandurah line was opened in December 2007. This 72-kilometre railway line, with 11 stations, connects Perth with Western Australia's second largest city, Mandurah. The opening of the new line saw the introduction of partial network integration and fare integration to Perth's transport network. The construction of the Mandurah line is coupled with the creation of 62 new feeder bus routes which connect the suburbs surrounding the Mandurah line with its 11 stations. The bus feeder services have train service integrated timetables, meaning that the buses and trains are co-ordinated at interchange points, reducing the time-cost of modal interchange for passengers. The integration of these two modes is supported by the introduction of fare integration in Perth. Rather than being mode specific, public transport fares in Perth are based on movements between zones; this means that a ticket is purchased for a time period of access to Perth's transport services. The integration of fares is coupled with the introduction of the SmartRider card, which allows passengers to pre-load value onto their cards which is then deducted from the card when passengers tag off at the end of their multi-modal journey. In addition, most transit authorities in Australia offer a smartphone app that will help passengers find their way around the city using public transport. The apps allow them to access service updates (cancelled, rescheduled or late services), find out estimated arrival times, and assist where to find closest bus stop, train station, wharf or light rail stop. Therefore, commuters can plan their journey from wherever they are to wherever they need to go.

3.3.2 Integrated public transport adopted by other countries with success in developed countries

Over the past five decades, Germany, Austria, and Switzerland have also successfully implemented regional public transport (PT) associations, called Verkehrsverb€unde (plural), which coordinate PT planning, services, fare structures, ticketing, marketing, and customer information throughout entire metropolitan areas, and in some cases, entire states (Buehler et al. 2015; Homburger and Vuchic 1972; Pucher and Kurth 1996; Topp 1989; VDV 2009). Verkehrsverb€unde (VVs) facilitate the collaboration of PT operators with state, regional, district, and city governmental jurisdictions throughout the service area. Unlike regional PT organizations in most other countries, VVs include both PT operators and government representatives in the process of making policy decisions about services and fares (Eno Foundation 2014; Koch and Newmark 2017; VDV 2009). Moreover, the overall degree of integration provided by a

Verkehrsverbund (singular) is greater, offering one unified route network (all modes, all lines), fully coordinated schedules, and one fare structure and ticketing system.

VVs have provided better PT services by fully integrating them across modes and operators over entire metropolitan areas, and even beyond that, including entire surrounding states. Its success is most evident in the spread of VVs to encompass almost all of Germany, all of Austria, and the largest urban area in Switzerland (Buehler et al., 2019). Other indices of success include increased quantity and quality of service, rising passenger levels, reduced subsidy needs as a percent of operating costs, and an overall PT mode share which has been stable or rising in spite of increasing rates of car ownership and driver licensing of the German, Austrian, and Swiss populations. Fitzroy and Smith (1998) as well as Buehler and Pucher (2011b) emphasize the crucial role of Freiburg's VV in providing fully integrated, multimodal, regionwide ticketing, which also facilitates meaningful discounts for regular riders using monthly, semester, and annual PT tickets. Cervero (1998) found that VV coordination was key to the success of the PT systems in Munich and Zurich, especially in terms of providing high-quality service at attractive fares, increasing passenger trips, and competing effectively with the private car.

Another indicator of success is the falling frequency of trips by car, a key goal of urban transport policy in European cities. Car trips have dropped from 40% to 27% in Vienna; 39% to 30% in Zurich, 40% to 33% in Munich, 48% to 42% in Hamburg, and 35% to 30% in Berlin (Buehler et al., 2019). Those declines would not have been possible without an attractive package of well-coordinated PT, cycling, and walking alternatives to car usage. The VV model has spread quickly because it is adaptable to the different types of integration needed in different kinds of situations. The six VVs examined in this article are all fully integrated systems but serve different areas. The urban and suburban service areas of the Munich and Hamburg VVs are more narrowly delineated and more compact than the large, sprawling service areas of the Vienna and Berlin VVs, which include extensive rural areas (Buehler et al., 2019). Rhine-Ruhr is extremely polycentric while the other five VVs are monocentric.

VVs also vary in their internal organization, with state and local governments running the decision-making VV boards in almost all large urban areas, while PT operators run VV boards in smaller cities and towns. Thus, the VV model is a range of organizational structures but with the same outcome of fully integrated services, fares, and ticketing. The flexibility of its internal organizational form makes it more adaptable, helping to explain its widespread adoption. One puzzling issue remains: Why has the VV model not spread beyond German-speaking countries? To some extent, regional PT organizations have simply taken a different form and name in other countries (Hrelja et al. 2016; Sørensen and Longva 2011; UITP 2014; van de Velde 1999 2001; VDV 2009). Danish and Swedish metropolitan areas, for example, also have integrated PT, but coordinated and dominated at the county level by government. In the Netherlands, coordination is at the national level, made possible by the much smaller size of the country. There is some national coordination in Switzerland for the same reason. Except for the VV in Zurich, most Swiss regions are served by less fully integrated Tarifverb€unde, which coordinate fares and ticketing (Vollmer and Schiesser 2009). That limited regional coordination is however supplemented by the Swiss federal government, which provides discounted nation-wide annual tickets and coordinates schedules for intercity and regional rail services (Petersen 2016; VDV 2009).

American metropolitan areas have similar federal structures to those in Germany, Austria, and Switzerland, with spatial fragmentation among different cities, counties, administrative regions, and states. Political scientists have documented much greater independence and rivalry among American local and state governments compared to the cooperation and consensus-seeking characteristic of the German federal structure (DiGaetano and Strom 2003; Doering 2000; Kelemen 2015). That may explain the unwillingness of local and state governments in the USA to cooperate as closely as necessary in a VV. The resulting lack of PT integration in American urban areas has seriously harmed the overall quality and effectiveness of PT, while helping to explain its enormous subsidy requirements (APTA 2017; Buehler and Pucher 2011a; TRB 2001). As exemplified by the USA, full integration of PT is not always possible despite the VV's flexibility to adapt to very different situations. The crucial precondition for a VV is the willingness of local governments to work together to improve PT services in their region. Provided that precondition is met, however, VVs would be feasible in many of the world's metropolitan areas.

3.3.3 Integrated public transport in transitional countries

Integrated public transport has received attention in recent years to improve public transport services and reduce reliance on car travel. Cities such as Singapore and Hong Kong already have high modal shares in public transport (63% and 90% of all motorised trips, respectively) (Petersen 2016). Car-ownership in Hong Kong is very low at 50 cars per thousand population, and the public transport systems account for 90% of motorised trips. Better modal interchanges, e-smart cards and information integration are the key measures that benefit the public in the local context.

A single fare card usable on all public transport modes greatly facilitates integrated transport. Singapore introduced a magnetic stripe, stored value TransitLink fare card in 1990 for bus/rail travel. A contactless smart card, called the EZ Card, was introduced in 2002 as a common fare card for all bus, Mass Rapid Transit (MRT) and Light Rapid Transit (LRT) services. The EZ card project was designed by the same company (the ERG Group of Australia) that implemented the Hong Kong Octopus Card (contactless) and the Melbourne Metcard (magnetic stripe). Other applications suitable for the EZ card include park-and-ride and small retail purchases. The impacts of such a system are efficiency gain and operating cost reduction. In a trial study on the use of the EZ Card, the boarding time of a bus was found to decrease by 62% compared with cash payment, and 34% compared with magnetic transit cards (Petersen 2016). In Hong Kong, it was also found that the cost of coin collection and counting was about 8% of the revenue, and this cost has been substantially reduced (Buehler et al., 2019). Each day's taking can now be reconciled within 24 hours instead of the usual three-day delay when cash constituted a significant portion of the revenue. With a single fare card, it is also easy to encourage using public transport by introducing rebates for intermodal transfer. Using the EZ card and the earlier TransitLink card, a rebate of up to S$0.25 is given to an individual passenger who transfers from an MRT station to a bus within 30 minutes. Fare integration and rebates are powerful tools to achieve a high transit modal share.

A service company, TransitLink, was formed in 1989 to produce a transit travel guide and coordinate transit travel information such as routes, timetables and multi-modal data at interchanges. The TransitLink Guide provides coordinated and comprehensive information on all aspects of travelling on bus, MRT and LRT in a single book. It is updated every year and remains in use today. An electronic version is also available through the Internet. With an expanding

MRT/LRT network, it becomes necessary to employ a good signage system to facilitate multi-modal travel. New colour coding for MRT/LRT lines has recently been introduced. Each MRT/LRT station employs consistent new alphanumeric codes. The signage system is progressively extended to bus interchanges, bus stop and taxi stands. It provides a consistent identity for all public transport modes. Real-time information is provided through an 'i-Transport platform'. This is an IT platform that integrates traffic information from road based ITS measures (signal system, freeway monitoring system, road pricing system) and transit-based measures (GPS-equipped taxis and buses, MRT/LRT locations). A traveller can use this real-time information to make decisions on modal choices, trip start times and route planning.

3.3.4 Innovative Urban Public Transport Systems in developing countries

The Lagos BRT development was one of the earliest in Africa and began operations on 17 March 2008. Called "BRT-Lite", it is a form of BRT, but not of the highest specification. It was quick and cheap. It took only 15 months from conception to operation and cost only $1.7 million per kilometre (Mobereola 2009). After the elections in 1999, transport was identified as one of the most pressing issues in Lagos. The newly- elected Lagos State governor appointed a special adviser on transport and sought development assistance from the World Bank Group. The Lagos Urban Transport Project was initiated and, in 2002, the Lagos Metropolitan Area Transport Authority (LAMATA) (Labour Impact Assessment 2019).

Another example was the Tanzanian government launch of DART, a new BRT system in Dar es Salaam in 2016, after years of delay. First announced in 2002, the DART project was supported by a World Bank loan of USD 150m.From the outset, there was considerable skepticism about the ability of DART to smoothly integrate daladala operators into the new system, however, the Tanzania BRT has proved to be a huge success in reducing traffic. Further, Tanzania's Dar es Salaam city has won a global award for its Bus Rapid Transit (BRT) system. In conjunction, the city won the Sustainable Transport Award for the Dar es Salaam Bus Rapid Transit (DART), which has eased public transport and enhanced safe movement for vulnerable road users.

In 2015, the government of Kenya continued with serious plans to launch the Mass Rapid Transit System to de-congest the capital city of Nairobi. The rail and road system was set to be a great and final solution to the city's public transport chaos (Bury 2019). The Bus Rapid Transit (BRT) system has been delayed for years, and there are certain questions in place as to whether and when the BRT will be implemented in Nairobi, as is the meaning of "BRT" in this context. According to the ITDP, a full "gold standard" BRT system would cost a minimum of Ksh 100bn (Business Daily 2018b). However, the authorities are also considering other means of improving public transport. For example, various versions of cheaper "BRT-lite" systems, perhaps similar to the model adopted in Lagos, light rail and other infrastructure projects. At a minimum, "BRT" could simply be the reorganisation and branding of new fleets of large buses using the existing road infrastructure (Labour Impact Assessment 2019).

The Nairobi Metropolitan Area Transport Authority (Namata) made proposals for construction of BRT stations along the marked superhighway as well as park and ride facilities at Ruiru, Githurai and Kasarani. A total of 150 high capacity buses would use the dedicated lane, and 30 high capacity buses had already been ordered and would be in operation (Xinhua 2019). Planning is being done in several phases similar to the infrastructure plans undertaken by the road agencies, which is coordinated by Namata. The service plans and business plans are being created by consultancy services through development partner assistance.

Egypt is to develop a high-speed train within the next two years, and the line will be used by passenger and freight trains, as well. The network includes three lines that will be executed in order of priority. The first links Ain Sokhna to New Alamein. It will start from the New Administrative Capital (NAC) passing through Ain Sokhna and 6th of October City until New Alamein. There will be a branch at NubaRea that extends to Alexandria through Borg al-Arab city. The high-speed railway will connect the Mediterranean and the Red Seas.
Tariq Abu Al-Wafa, head of the Central Planning Department of the National Authority for Tunnels, said that the Authority is in the process of finalizing the feasibility study for the 500 kilometres project, and the first section of the line will have 12 stations.

The first phase of that line will stretch from NAC until the 6th of October City over 122 kilometers and be linked with the Rod al-Farag Axis. The second phase will extend from 6th of October City until New Alamein over 210 kilometers passing in parallel to Rod al-Farag - Dabaa axis. That phase will have a branch line that starts from NubaRea at Beheira governorate and end in Alexandria passing through Borg al-Arab over 99 kilometers. The third phase links NAC with Ain Sokhna and lies over 92 kilometers. Further, the second line will link 6th of October City with Upper Egyptian governorates until Aswan. The third line will start from Ain Sokhna and pass through Marsa Alam and Hurghada until it ends in Luxor. Ain Sokhna and Luxor will be the junction stations of the first and third lines. The speed of passenger and freight trains will be 250 km/h and 160 km/h respectively.

3.4 URBAN PUBLIC TRANSPORT INTEGRATION APPROACHES

3.4.1 Physical integration

The proximity and ease of access at mode interchanges will greatly enhance public transport services. Walkways should be carefully designed for passengers to change mode. Passengers should be within a short walking distance from their residences to a transit stop". Cities like Hong Kong and Singapore have been able to build mass transit stops in the heart of neighborhoods, thereby providing proximity to residences, offices and retail outlets.

3.4.2 Network integration

Bus and rail systems should be an integrated network, and these separate networks should further complement one another. Feeder services using buses, trams or light rail should be designed to maximize the patronage of the trunk routes (Liu and Ceder 2017). Network integration is closely linked to physical integration and both contribute towards the integration of infrastructure. For instance, it is relatively easy to change between different lines on the London Underground (tube) network, as tube stations have been designed with several interchange points between lines (Briem et al. 2017). Cities such as Hong Kong, Singapore and Kuala Lumpur have been able to redesign bus routes so that they feed into and support the mass transit/metro lines (Luk and Olszewski, 2003). Similarly, London's underground and buses connect with the above ground heavy rail network to take passengers to their final destinations. An essential part of network integration involves timetabling services so that intramodal and intermodal services connect efficiently and effectively.

3.4.3 Fare integration

A single fare card for multiple transit services will facilitate the transfer between modes. Rebates can be implemented as an inducement for those who transfer from one mode to another, e.g. zonal rebates in Vancouver (Liu et al. 2019). Whilst electronic ticketing is not a prerequisite for integrated ticketing, it does provide a very powerful mechanism to efficiently and effectively operate an integrated fares structure. For example, Hong Kong, Singapore and London all have a smart card system in place which has underpinned the increase of public transport usage (Borges and e Cunha 2017). For example, public transport in Hong Kong accounts for approximately 85 percent of all main mode trips respectively. In London, journey stages by public transport modes (defined as bus, tram, underground, DLR, rail, taxis and private hire vehicles) increased in share from 30 per cent in 1993 to 34 per cent by 2000, and to 41 percent by 2008 and 2009. The 7 per cent increase in the share of public transport usage between 2000 and 2009 is equivalent to a 5 per cent increase in trip-based mode share for public transport in London (Transport for London 2010). While other factors have driven patronage growth in these examples, fare integration has underpinned and supported integration in the networks. Recent examples of fare integration in Australia are represented by the introduction of the Go Card in Brisbane, the MyMulti card in Sydney, the Myki card in Melbourne and the Metroticket in Adelaide (Van Nes 2002).

3.4.4 Information integration

A comprehensive, easy to use passenger travel guide is critical to successful multi-modal travel. The signage at rail and bus stations should be properly designed to convey effective information to travelers (Ferreira et al. 2017). Information Technologies (IT) and Intelligent Transport Systems (ITS) can play important roles in integrated transport and information integration in general. For example, at the major railway stations in Japan, they have very clear signs differentiating directions to the high-speed rail network, the intercity train's network and the suburban/local trains network (Wagner and Zundorf 2017). In addition, websites provide public transport users with information on the multi-modal transport options available and the related details.

3.5 CHAPTER SUMMARY

The chapter presented various examples of international best practice for integrated multi-modal transport. The key ingredients of public transport integration were explained in detail and how different modes of transport work together in order to successfully deliver services for the user. Various cities as identified above have delivered integrated transport by achieving integration at both the strategic and practical level of transport planning and service delivery. Identified areas are fare integration, whereby the integration of fares is a fundamental aspect of delivering a systems approach to passenger transport. Global experience has shown that integration of fares across public transport modes, through technologies such as electronic smart cards, makes mode switching more seamless from a customer viewpoint and ensures common pricing across the transport network, removing price disadvantages that might exist under current arrangements.

Consequently, physical integration is an important aspect, as developing an integrated transport network demands that modes seamlessly connect, making journeys intuitive and 'pain free' for commuters. Examples of physical integration include interchange facilities that provide covered walkways, transport hubs, park-and-ride facilities and the integration of transport hubs and commercial precincts. Further, for a successful network, physical integration must be supported by a full integration of transport networks and modes. Examples might include bus services that are timetabled to connect to rail services, or a move to 'turn up and go' rather than timetabled frequency, ensuring that different transport modes complement each other as part of a whole network, rather than competing. In addition, information integration encourages commuters to travel across public transport modes while being aware of travelling schedules and where switches between modes can be made without being delayed. A much smarter approach to journey information is required; electronic signage, easy to access smartphone apps and uniform, high grade signage across all modes ensures that journeys are intuitive and easy for commuters. Real time transit information, such as next service countdown timers are equally important to provide journey time certainty to commuters.

Additionally, it has been identified that in African counties, integrated public transport of rail and road are yet to be developed. Most of the countries such as Nigeria and Tanzania are still challenged by the available BRT system that exist, and Kenya is challenged with the implementation of the system. Egypt is working on implementing its own high-speed train system. This indicates that African countries are still focusing on developing formal urban public transport systems that only focuses on a single mode.

CHAPTER 4: LOCAL EXPERIENCES

Urban public transport (UPT) in South Africa is available in every province which includes both formal and informal urban public transport. Commuters in all the nine provinces prefer both formal and informal UPT due to certain reasons. The study focuses on identifying solutions to improve the formal UPT in the Gauteng province. It specifically focuses on the Gautrain and A Re Yeng bus (BRT) in the City of Tshwane Metropolitan Municipality (COTMM). Formal urban public transport loses attractiveness when it is not reliable. Therefore, identifying solutions to assist formal urban public transport to be reliable, efficient, effective and more attractive in the City of Tshwane is desirable. The use of policies and legislative frameworks to support the study are highlighted in this chapter.

4.1 INTRODUCTION

Urban public transport makes movement of all people easier regardless of the conditions as in general, most of them are affordable. Many people in the republic use UPT for different reasons, some people use it to reduce traffic congestion as roads on certain hours are congested. For some, it is the only mode of transport accessible for travelling. Promoting the use of UPT is urgent with a sustainable, effective and efficient citizen's mobility, and simultaneously with a positive effect in air pollution and energy cost reduction (Aziz et al. 2018). UPT has a major role to play in alleviating congestion and improving traffic flow and reducing other negative impacts that can be caused (De Pablos et. al 2011).

South African UPT history is dominated by its historical development policies. Some formal public networks were planned and implemented by government and they were not enough for the growing population and urbanisation. Inadequate provision of UPT together with the fact that communities in marginalized areas could not afford private transport resulted in the evolution of other forms of UPT which addressed the greater need of the transport of marginalized South Africans (Khosa 1998). The formal planned transport system was therefore not adequate in meeting the travelling demands of the growing population which was also fuelled by the failure of policies to regulate urban immigration (Adewumi et al. 2013). An effective transport system that adapted to the travelling needs of commuters on the ground was born but poorly regulated and thus associated with negative structures, standards and safety related issues (Walters 2008).

4.2 URBAN PUBLIC TRANSPORT IN SOUTH AFRICA

South Africa has different modes of UPT which all are unique and effective in their own way. Each province in South Africa has their own UPT modes which do not differ that much between each province. These kinds of public transport include minibus-taxis which are said to be an informal sector. There are bus transport modes which differ and include such types as the BRT, City buses (public sector), private sector buses. They all function in different ways, but all operate according to a schedule (Weakley & Bickford 2015). The innovative urban public transport developed in various cities of South Africa is the BRT system. These cities are Cape Town (My CiTi), Rustenburg Rapid Transport and Durban (GO!Durban). The operation of BRT systems in these cities has been successful regarding providing its services to commuters, as there are phases that are being implemented to improve the bus network.

4.2.1 Urban Public Transport in Gauteng province

In Gauteng province, there are various alternatives of urban public transport which include both informal and formal urban public transport. The use of taxis, busses and trains services are in operation. Commuters using the City/Municipality bus services are currently subsidized based on multi-journey ticket sales by Gautrans in terms of an interim contracts. The subsidy funds originate from the budget of the National Department of Transport (NDoT) (Joburg 2014). Both the City of Johannesburg and the City of Tshwane have implemented the BRT system to improve the state of formal urban public transport in the province. Further, the trains include such types as Metrorail and Gautrain. Metrorail have schedules which are slow but very cheap and on the other hand Gautrain is very quick in terms of the operating schedules but expensive to use. Implementation of the Gautrain system was to improve the state of urban public transport as well as connect the three metropolitan municipalities.

4.3 URBAN PUBLIC TRANSPORT IN THE CITY OF TSHWANE METROPOLITAN MUNICIPALITY

The service levels in terms of safety affected by taxi fights has been an ongoing concern, thus giving the industry a negative image (Patel 1997). The fights are not understood, but they have impacted on the growth and popularity of the taxi industry (Dugard 2000). Within the correct context that favours the passengers and government objectives, BRT is implemented to be the future UPT of choice from a cost and effectiveness perspective (Biegler 2011).

4.3.1 Informal urban public transport sector: Taxis dominance

These are one of the dominant modes of UPT in the republic. They do not operate according to timetables, but a taxi departs from the starting point (taxi rank) when it is full and not according to a schedule, and most vehicles used are 16-seater minibuses. Further, taxis do not always start from the starting point (taxi rank), but they pick up passengers on the main routes in any streets, unlike bus or train where there are demarcated stops. Routing is very structured (by the taxi associations to which all operators belong), and operators are assigned to a route or group of routes.

According to the South African National Taxi Council (SANTACO) statistics, it has a collective national fleet of more than 250,000 minibuses with 123,000 owners (Competition Commission 2018). The government's official statistics put the number of minibus taxis at 130,996 (Grice and Oldjohn 2018). These are almost certainly an underestimate of the total numbers, with many taxis still unregistered. The deregulation of the industry in the 1980s had unleashed uncontrolled growth and provided fertile ground for conflicts ("turf wars") over routes and ranking facilities. During the same period the industry boomed into a giant sector and became unmanageable in the absence of any form of regulatory framework. After a long and intensive government consultative process with taxi operators, the South African National Taxi Council (SANTACO) was established in 2001. This was an umbrella body governing the industry and acting as the principal representative body for taxi owners. It was formed from 34 taxi federal organisations and three national bodies. It brought a significant amount of unity to the industry but didn't completely end the conflicts (Labour Impact Assessment 2018). Further, the government also attempted to modernise and regulate the industry through a programme of "taxi recapitalisation", whereby smaller vehicles would be phased out, and new larger and safer minibuses would be introduced with an electronic fare system. If they were properly registered and members of a recognized taxi association, owners were given the option of getting cash compensation for scrapping their old vehicle, or a deposit for a new vehicle (Wang et al., 2011).

In many cities, especially developing countries, regular public transport systems do not meet all the demands of the marketplace. The reasons for this shortfall often vary. It can result from an insufficient response to constantly changing travel and settlement patterns, poor attendance to service places (speeds, levels of service, job changes), or purely from a lack of total capacity (Golub 2003). Cervero (1991) states that regular public transport services normally employ full size vehicles. Many times, these are poorly connected and coordinated, and the vehicles cannot always serve residential areas with narrow entryways, poor roads and at times difficult terrain. In many of these cases, informal modes of transport illegally enter the market to fill the gaps that are left open by the regular public transit system.

According to Statistics South Africa report on measuring household expenditure on public transport (2015), 51, 1% of public use taxis, and followed by busses at 18, 1% and then trains 7, 6%. It can be argued that, while bus and train services were the first to be formally introduced to the public, despite criticisms, the taxi industry it remains the most popular mode of transport. There two possible reason of which (1) being that it is a transport of choice and more convenient or (2) it is the most easily accessible even if not preferred. It should be noted that while bus and train services are the formal modes of transport and cheaper, these are not the most popular, even though the taxi customer service has been under criticism for many years (Gauteng Government 2013).

4.3.2 Bus Rapid Transit (BRT) system

The demand for urban public transport services in Gauteng emerged as a direct result of rising immigrant labour in the Country (Abu-Ayyash et al. 1986). The City of Tshwane adopted the BRT system in order to have smart, efficient, effective public transport for the city commuters and to avoid the pressure caused by urbanization. Venter (2013) sees the introduction of the BRT as a response to problems from informal public transport that has evolved and been used for decades. The taxi industry is informal and therefore formalizing it by introducing the BRT can also be a movement to replace the termed informal public transport (Venter 2013). Further, in the mid-2000s, the government began to promote Integrated Rapid Public Transport Networks (IRPTNs) with Bus Rapid Transit (BRT) as the core. Disappointment caused by the failure of earlier government plans prompted SATAWU to support BRT to formalize the informal transport industry.

The BRT objective in South Africa is to provide road based public transport. This should move many passengers, effectively from a cost, time and comfort point of view, while overcoming the traffic congestion and safety matters. A total number of 120 buses were acquired on lease in 2013 in order to make the bus system effective and avoid delays (Mostert 2013). However, there were challenges faced in urban public transport as confirmed by the minister of transport Joe Maswangayi on 10 July 2017 at the 36th Southern African transport conference. The minister stated that the BRT public transport implemented was a mammoth flop. He further mentioned that lot of money was spent, but still the desired/imagined role that is supposed to be played by BRT system was failing (Mabena 2017). Browning (2017) supports the above by stating that when the public transport strategy was launched in 2007, the mini-bus taxi carried 70% of all public transport users, and mini-bus taxis still carry 70% a decade later.

4.3.2.1 BRTS as a solution in the City of Tshwane

If a solution is brought at wrong time, it may be a problem and at a wrong place it may be waste as it will not work. Taking into consideration that the BRT is a new transport system and service provider leads us to look at the historic private and public transport modes and systems. At the level they operated, the introduction of the BRT may be a complement to the existing systems, or a competition (fair or unfair). The problem may arise if the BRT becomes an obstacle to the existing and historic transport systems while it has to cater for the transport demand and general needs. This would imply that the system has created problems and not solutions. By being an obstacle, it means the previous and historic transport systems may be operating at a slower rate (taking longer to reach their destinations) and more passengers are travelling longer to reach their destinations. Arguments around consultation with all the stakeholders do not take away the resultant outcome and realities of the new system's impact (Schalekamp & Behrens 2010).

Once the infrastructure is developed for the systems, there is always a risk of it not working or being supported. As a result, development of policies that would manipulate the system to work may be developed and imposed on departments which should have been key role players in the consultation process at the planning stage. Examples are where high densities are encouraged along the BRT routes in order to support the public transport system. Depending on where the planning comes from, this argument can advantage or disadvantage both ways. The solution can be to develop transport infrastructure which is ready for the coming and desired densification and business opportunities around the stations.

4.3.3 High-speed train (Gautrain system)

The first rapid transit train in Africa known as Gautrain was launched in South Africa (Gauteng) during the 2010 football world cup. The Gautrain has been effective since then and has also expanded into many other areas which initially it did not reach. (Gautrain Management Agency 2013). The main objective of this transport mode was to reduce traffic congestion and enable quick travel times from origin to destination, and the development of the Gautrain was to encourage the use of public transport. This concept is tailored to achieve smart mobility and it is very fast in nature (Liu & Teng 2014). The Gautrain project as it was established, a bus system was developed which as well is known as Gaubus and these two are interdependent. Gaubus is developed to penetrate in the areas that the Gautrain cannot. This strategy was aiming to bring about effective, efficient formal urban public transport through integration between trains and busses to show that the two public transport modes can work hand in hand. These services are fully integrated and may be used separately or jointly by transferring from one to another. The Gautrain system provides a safe, comfortable and reliable train service between O.R.Tambo International Airport (ORTIA) and the Sandton CBD ('Airport Service') and between Johannesburg Park Station and Tshwane's Hatfield Station ('Commuter Service').

4.4 PAYMENT SYSTEM AND INFORMATION DISSEMINATION

The city of Tshwane metro bus upgraded the fare collection mechanism from using paper ticket collections and coupons to e-card (Makgoo 2018). The e-card method in the City of Tshwane eliminated challenges that led to bus stoppages which were a nuisance to metro and passengers. Accordingly, A Re Yeng bus uses an e-smart card for fare collection. Further, the Gautrain system also use an e-smart card known as a Gold card. The Gold card allows seamless transfers between Gautrain's train, bus (Gaubus) and parking services. Once a commuter has purchased the gold card, one can use it to access and pay for either the train or the bus services. This clearly indicates that the city is moving towards electronic payment method trying to resolve paper ticket, hard cash payment challenges and so forth.

Information sharing in urban public transport is very crucial and is accurate as ridership will escalate. Information distribution of public transport that services commuters in the city mostly have fixed timetables at dedicated stations. This can become a challenge on some occasions when a certain mode does not arrive. Informal urban public transport does not have timetables at all, but taxis leave a taxi rank when it is full, or when a number of certain passengers are in a taxi according to the taxi association agreement.

4.5 USE OF TECHNOLOGICAL INNOVATION IN URBAN PUBLIC TRANSPORT OPERATIONS

Big data is used toward improving customer satisfaction such as: knowing the times of the transport and delays. Further, a single smart card for Gautrain, Gaubus and A Re Yeng is used to assist commuters to switch smoothly between public transport modes. In South Africa, government at all spheres- National, Provincial and Local are trying to find innovative ideas to improve public transport systems. The introduction of the Gautrain and A Re Yeng Bus in the City of Tshwane was a good initiative, as this has managed to fill other challenges of urban public transport in the Capital city.

Public transport must be made more attractive and user friendly in relation to improved service, travel information, reliability, safety and the upgrade of infrastructure such as waiting stations (Adewumi et al. 2013). Cost is an important factor that influences the demand for public transport in relation to the time spent waiting, boarding and alighting from vehicles coupled with the risks and inconveniences involved in those actions. It has also been suggested that commuters and business users board the fastest and most direct routes. The information distributed to commuters through smart phone applications can assist them to make informed decisions about the available public transport mode. Gautrain has an application that provides information about the travel times of the train. If this application can be used to give schedules for both Gautrain and A Re Yeng, it can improve efficiency in the cities' formal urban public transport. Payment systems and information distribution in the City of Tshwane are operated and managed technologically with the use of both ITS and big data. Therefore, the public transport that operates in the city could be integrated, the movement of transport can be fast, and delays can be reduced.

4.6 POLICIES AND LEGISLATIVE FRAMEWORK OF INTEGRATED URBAN PUBLIC TRANSPORT

Transport plays a significant role in any country, and the National Government of the Republic of South Africa (the Government) has recognized transport as one of its priority areas for socioeconomic development. The effectiveness of the role played by transport is however dictated to a large extent by the soundness of the transport policy and the strategies utilized in implementing the policy. The Constitution of the Republic of South Africa act 108 of 1996 outlines the important of public services of the Republic to which must function, and be structured, in terms of the national legislation, and which must loyally execute the lawful policies of the government of the day. Therefore, the study is in line with the Constitution as there are policies and legislative frameworks supporting.

4.6.1 National Development Plan (NDP) 2030

The National Development Plan offers a long-term perspective for the entire country. It aims to eliminate poverty and reduce inequality by 2030. The plan identifies the improvement of the quality of public services as critical to achieving transformation. This requires provinces to focus on identifying and overcoming the obstacles to achieving improved outcomes, including the need to strengthen the ability of local government to fulfil its developmental role. Transport planning aims of the NDP 2030 are focused on addressing inherited spatial divisions. They call for a strategy that focuses on the space economy to address the legacy of the apartheid geography and create conditions for more humane and environmentally sustainable living and working environments by defining a spatially targeted approach.

The need for a modal shift from private transport in the long term is highlighted. Behavioural change is critical in reducing environmental, social and economic costs by shifting user and supplier decisions about movement, travel and sources of energy. While some forms of private transport, such as the car will still be used in 2030, a marked change to PT will emerge through concerted effort, strong leadership, consistent messages and actions, and public system alternatives that work. By 2030, PT will be user-friendly, less environmentally damaging, cheaper and integrated or seamless.

4.6.2 Draft Revised White Paper on National Transport Policy 2017

Integrated transport planning has experienced limited success with difficulties in implementation, in that it is subservient to prioritised public transport and associated planning, and land use and transport integration is missing from current practices. An integrated transport planning framework should therefore be established that integrates planning for infrastructure and operations across modes for both freight and passenger transport. Through using shared data and information, it should integrate the transport system with other sectors, and foster integrated transport planning between the DoT and other departments within the three spheres of government.

The part of the policy's mission is to provide integrated, well-managed, viable and sustainable transport planning and infrastructure meeting national and regional goals in the 21st century. This will help to establish a coherent base to promote accessibility and the provision of safe, reliable, effective and efficient transport services. Accordingly, the strategic objectives for ITP are as follows:

- To establish sound integrated intermodal coordinating structures and promote the provision of seamless intermodal services;
- To promote seamless integration and harmonization of standards with neighbouring member states; and to develop a comprehensive transport data and information system to inform integrated transport planning decisions;
- To find a practical and reasonable solution that leads to an equitable distribution of infrastructure capital, management, operating and maintenance costs across transport modes;
- To encourage more urban land use densification, correcting spatial imbalances and reducing travel distances and times for commuting to a limit of about 40 km or one hour in each direction;
- To promote a strong, diverse, efficient and competitive transport industry within the limits of sustainable transport infrastructure;
- To enhance the competitiveness of South African industry and the quality of life of its citizens by providing protection of consumers, safety and security, and meeting accessibility, reliability and mobility needs by providing transport infrastructure to serve the purpose;
- To ensure that the transport needs of persons with disabilities are considered when new infrastructure and operations are planned and designed;

- To advance human resource development in the provision of transport infrastructure and management of operations.

4.6.3 Green Transport Strategy for South Africa: (2018- 2015)

South Africa launched a Green Transport Strategy in June 2019 (GTS). This promotes a transport system that is environmentally friendly and helps boost economic growth and create jobs. It minimizes the adverse impact of transport on the environment, while addressing current and future transport demands, and encourages electric vehicle use and public transport enhancement. Fundamental to the greening of the transport sector is the seamlessly integrated functioning of the transport system. These integration policies and strategies have been defined in all transport sector planning, policy and strategy documents. Integration is the key principle on which all transport strategy rests for successful execution and functioning. In terms of the GTS, the modal shifts to rail and away from private vehicle use are premised on integrated transit and feeder systems that make far greater use of public transport and non-motorised transport.

GTS acknowledges the importance of advanced technology in integrated transit systems, as it notes that Intelligent Transport Systems have the potential to reduce GHG emissions and can be used through transport planning processes to provide advanced data via digital connectivity such as signal timing, real-time traveller information, incident management, etc. Transport planning and investment decisions can improve the operational efficiency of multi-modal transport networks and integrated transport and land use planning to reduce travel time. The DoT in consultation with National Treasury will provide a national team of experts to consult to all spheres of Government as infrastructure expands. The team of green transport integration experts will also consult to the Strategic Integrated Projects throughout their planning and execution.

4.6.4 National Land Transport Act of 2009

The National Land Transport Act 5 of 2009 ("NLTA") provides for the development and implementation of the Integrated Rapid Public Transport Network ("IRPTN") plans by the metropolitan cities in order to provide uninterrupted public transport services to commuters. The City of Tshwane consequently initiated the implementation of the IRPTN plan to improve the quality of lives of its commuters through facilitating affordable and safe public transport services that will reduce the daily travel time between home and work. Bus travel time is naturally unstable since a small disturbance, such as a delay in boarding or alighting, can start a vicious cycle that results in bus unpunctuality. Further, buying a ticket for every public transport mode is costly and takes time. This reduces the attractiveness and the competitiveness of public transport (Giffinger et al. 2007).

4.6.5 Gauteng 25-Year Integrated Transport Master Plan (2013)

The 25-year Integrated Transport Master Plan (ITMP25) will contain a full Implementation Strategy for the transformation of the transport system in Gauteng over the next 25 years. However, given the current state of transport in the Gauteng City Region and the associated pressing problems and challenges, some urgent interventions are required. A few initiatives have been identified in order to integrate urban public transport in the Gauteng province. Regarding the study, integrated public transport ticketing and information are identified as one of the key initiatives.

4.6.5.1 Integrated public transport tickets

In April 2011, the Gauteng Department of Roads and Transport undertook the completion of Public Transport Systems Planning and Development of an Integrated and Interoperable Fare Management Framework. The objective of Integrated Fare Management (IFM) is to enable seamless travel and transfer across an entire journey using a single fare media (and possibly a single fare) for different operators and modes of transport. Furthermore, it promotes an integrated fare collection system that will improve the transit experience and convenience for commuters. The IFM approach is to make public transport systems more efficient by reducing the need for cash and cash management and improving boarding times, which in turn reduces delays leading to better schedule adherence.

IFM relates to multiple operators (and multiple modes such as bus, rail, taxi) who deploy and accept the same fare collection mechanism for public transport services within a defined region. This type of system allows customers to travel throughout the region in a seamless manner. At a minimum, the use of a common fare media permits commuters to load individual Transit Products (e-Tickets or passes) from multiple operators as well as e- Money (electronic cash for fare payment) onto a single card. The purpose of the IFM Framework is to establish a common basis and vision from which to promote and execute Integrated Fare Management, towards establishing an integrated public transport system in Gauteng. The framework is being developed on a provincial level (to ensure consistency for strategic components), although operational components of the framework will be carried out primarily at a municipal level.

4.6.5.2 Integrated public transport Information

The potential for collecting and integrating passenger travel information has always existed but has never been realized, because complex surveys were necessary to record this data. However, this problem has been resolved with the advent of Integrated Fare Management and the requirement for fare collection systems to comply with National AFC Regulations through the of use bank issued fare media. Many such electronic fare collection systems calculate and deduct a passenger's public transport fare through a "tap on tap-off" process. With the aid of vehicle satellite tracking systems, this data translates into information on passenger travel patterns and volumes. A central data warehouse is required to be established in order to collect and collate this passenger travel data from different operators. The data can then be analysed to produce passenger travel information and real-time data for schedule information systems at stations and on-board busses. The advent of fast, reliable and affordable wireless/Internet communication has made it possible for travel information to be disseminated timeously and reliably via mobile phone (SMS or social media), web sites and electronic signs. The use of an integrated, bank issued fare media must be established, through compliance with National AFC Regulations, followed by a Provincial Public Transport Data Warehouse. This will ensure the centralized collection of passenger data to be disseminated as required once analysed. A Passenger Information Call Centre would be one means of co-ordinating the dissemination of such travel information.

4.6.6 Tshwane Comprehensive Integrated Transport Plan (CITP) 2015- 2020

The CITP for Tshwane for the period 2015 to 2020 addresses all the chapters specified by the Department of Transport (DoT) CITP Minimum Requirements. The CITP is a statutory plan required by the National Land Transport Act No. 5 of 2009 (NLTA) and the Gauteng Transport Framework Revision Act. The CITP forms an integral component of the Integrated Development Plan (IDP). The CITP formulates Tshwane's vision, mission, policy and objectives for transport, consistent with the NLTA. The scope of the CITP has gone beyond what is required by the DoT in its minimum requirements, including aspects such as sustainable transport, aviation, road and public transport safety and security, intelligent transport systems, and micro-simulation of traffic in congested areas.

The city's goal and objective are to develop a transport system that improves accessibility and mobility whilst enhancing social inclusion and provides a fully integrated public transport system. This will drive economic growth, improve the safety and security of the transport system, be an efficient, effective, growth orientated public transport system and integrate land use and public transport plans.

4.7 CHAPTER SUMMARY

South Africa has numerous modes of urban public transport which include both Formal Urban Public Transport and Informal Urban Public Transport (IUPT). There is a domination of IUPT (Taxis), this is due to services provided by these modes being in favour of commuters, as taxis service every main route in an area, it is easy to access and operates for 24hrs. There are other modes of urban public transport in the republic such as railway trains which are very cheap, but it is very populated during peak hours and this is risky for passenger's safety. Consequently, there are more private and municipality busses which, however, transport workers and students during certain hours in the morning and late afternoon to the evening.

Further, the innovative FUPT in the form of the Bus Rapid Transit has been implemented in different cities such as Cape town (My CiTi), City of Johannesburg (Rea Vaya), City of Tshwane (A Re Yeng), Durban (GO! Durban) and Rustenburg. The Gautrain in the Gauteng province services the Cities of Tshwane, City of Johannesburg and Ekurhuleni. These two innovative FUPTs use advanced technology for commuter convenience regarding payment systems and information distribution. The drive behind the advanced technology is to provide efficient, reliable and effective transport to commuters. The BRT system has its own dedicated lanes to avoid traffic congestion, and Gautrain uses its own rail tracks.

Improving the reliability of UPT services is a key priority and primary focus for the Gauteng Province Roads & Transport as stated in the Gauteng 25- year Integrated Transport Master Plan. The City of Tshwane FUPT, Gautrain system and A Re Yeng BRT system are the focus areas of the study. The aim of the study is to investigate the state of electronic integration of the formal urban public transport operations and create a model that can be used to integrate innovative urban public transport modes in the City of Tshwane. This will assist to integrate Gautrain systems and A Re Yeng system. This is in line with the national transport act 5 of 2009 ("NLTA") which provides for the development and implementation of the Integrated Rapid Public Transport Network ("IRPTN") plans. Accordingly, the City of Tshwane consequently initiated the implementation of the Integrated Rapid Public Transport Network plan. This improves the quality of lives of its commuters through facilitating affordable and safe public transport services that will reduce the daily travel times between home and work. Therefore, this highlights that the study is in line with the future public transport planning of the city. Non-integrated transport planning across various modes has resulted in modes that are not sufficiently customer-focused, that are inefficient, and have poor levels of reliability, predictability, comfort and safety. Such planning does not reflect the world-class aspirations of the NDP 2030. The fragmented nature of institutional governance over public transport is also not helpful. Consequently, policies and legislative frameworks support the integration of urban public transport, as their strategies of improving the public transport are focusing on integration.

CHAPTER 5: OPERATIONALIZING RESEARCH

The chapter describes how the research was conducted, and the tools and strategies used. Consequently, the study adopted different methods in order to achieve the main objectives of the research and various analysis to solidify the results.

5.1 INTRODUCTION

A mixed method research design was adopted where qualitative data, quantitative data and spatial data analysis was used. Various research instruments such as interviews were employed in the study, as they assisted to give insight into both commuters and the authorities/ officials views. ArcGIS assisted with creating Gautrain/ Gaubus route maps showing locations serviced and the physical integration of the FUPT modes. Consequently, participant observations gave the researcher an opportunity to understand the two public transport systems without the decisions being influenced. The A Re Yeng system, Gautrain system commuters and officials, Crowd source data obtained from social media posts and documented studies relating to this study were the source of data. Experimental analyses were used in order to develop a model that explains strategies of integrating innovative Urban Public Transport in the City of Tshwane. Comparative analysis highlighted the different methods of payment systems, information systems and locations serviced by both UPT systems. The comparative analysis was further used to ensure that the results obtained from Kriging interpolation and Focal statistics analysis produced equivalent results to confirm that the model was suitable and correct according to the study. Furthermore, content analysis was employed to review previous documented studies. The study took account of ethical considerations but had limitations, as there were challenges encountered.

5.2 RESEARCH DESIGN

A research design is a detailed plan of how a research study is to be completed, involving the sample selection and data collection as well as analysis of the gathered data (Thyer 1993). Labaree (2013) indicates that a research design is the overall approach selected to assimilate the various constituents of the research in a comprehensible and rational manner, thus ensuring the research objectives are achieved. The study adopted a case study research survey and experimental research design that used a mixed method approach to glean spatial, qualitative and quantitative data to achieve the objectives of the study. Further, the use of an exploratory approach was convenient for the study to understand the current challenges of the investigation and how a solution can be identified. The research designs adopted for the study were selected based on the suitability of answering the research questions and meeting the research objectives to achieve the aim of the study.

5.2.1 Case study survey design

A case study survey design was deployed to outline the extent of electronic integration among innovative UPT systems. According to Kohlbacher (2006), the case study research strategy involves an empirical enquiry of complex social phenomena within a real-life context which borrows some aspects of qualitative and quantitative approaches. The case study was based on an empirical enquiry and analysis of policy directives and interventions outcomes, for instance the planning and development practises within the City of Tshwane urban public transport. The case studies were also used to explore the relatively new concept of the applicability of geolocation data as techniques to describe the state of public transport integration. Further, payment methods and information dissemination of specific innovative UPT in the City of Tshwane was explored. The objective of this survey design was to reach a theory of how to integrate the A Re Yeng and Gautrain systems through payment methods and information distribution to commuters.

5.2.2 Experimental case study design

Experiments were conducted in the study using the geolocation data acquired from social media platforms (namely Twitter and Facebook). These explored the state of spatial integration, visualized commuter concentrations and tracked the movement patterns of Gautrain and A Re Yeng commuters. Using an experimental design, the researcher was able to repeatedly conduct the prediction analysis. This ensured that the results were more accurate relative to only conducting the analysis once. Critics outlined that experiments rarely confirm that a theory may be true, as they can be rejected later. The value of adopting a research design which is experimental in nature is that it permits the researcher to conduct tests on a said hypothesis or assumption hence testing a relationship between cause and effect of a set or subset of variables (Moyo & Musakwa 2016).

For instance, independent variables were measured using interpolation analysis, whilst the dependent variables were calculated using the geo-tagged commuter data. Subsequently, experimental techniques were chosen to develop the model, as these serve as a suitable adoption when the researcher does not have control of the variables (Campbell & Stanley 1966). In terms of this aspect of the research, the researcher could not influence when people posted Tweets or Facebook posts or switched on their locations on their mobile devices.

5.3 RESEARCH APPROACH

Myers (2009) describes the research approach as being the strategy of inquiry which links the underlying assumptions to data collection whilst remaining within the scope of the research design. The commonly used research approaches are qualitative and quantitative; the two approaches can either be considered, depending on how the researcher interprets the phenomenon. The approaches determine whether statistics alone can best interpret worldly phenomenon or whether a socio-economic viewpoint represents a more realistic interpretation. The study adopted a case study research survey design and experimental research design that used a mixed method approach to glean spatial and qualitative data to achieve the objectives of the study.

5.4 DATA COLLECTION TECHNIQUES

This section highlights the data collected within the study area with respect to allocated sample size. Various data collection methods were used as indicated in the research design matrix (table 5.2). Both primary and secondary data collection were employed for this study.

5.4.1 Desktop studies

This technique is adopted by many scholars for research; it is convenient, very useful and reduces time. Data on UPT planning and operations was gathered from various major sources including existing literature, policy documents and reports of national, provincial and local organisations. Different themes relating to integrated urban public transport planning in the COT (such as urban public transport, transport planning, integrated public transport systems (spatially and electronically), transport management processes, geolocation-based services) were identified and used in carrying out the web search in major electronic databases. Larger databases used were Scopus, Science direct, Sage and Google scholar. Secondary data sources were used such as journal articles, newspaper articles, textbooks and documents of companies. The publications of authors featured in many journal articles were studied for any relevant information. For preparation of this study, 350 publications were reviewed, but only relevant ones were used. Further, up-to-date conference proceedings were reviewed to assist with the current awareness and improvements in industry practitioners and researchers. Secondary data supported this research as it was based on other studies (Mbatha and Gumbo 2018).

5.4.2 Key informant interviews

Interviews provide a qualitative method of gathering data or information. According to Valenzuela and Shrivastava (nd), interviews are particularly useful for getting the story behind a participant's experiences, because the interviewer can pursue in-depth information around the topic. Interviews may enable a follow-up to certain respondents to questionnaires, e.g., to further investigate their responses (McNamara 1999). Twenty (20) interviews were conducted with relevant officials from the Department of transport, COT Metropolitan Municipality representatives, Gaubus/Gautrain and A Re Yeng. The questions asked were based on policies and legislative framework, possibilities of connecting innovative urban public transport modes electronically in the COT, and possibilities of integrating public transport with the current conditions of available spatial integration between the Gautrain and BRT systems. The data collected from the interviews assisted to strengthen the results and allowed another dimension for reaching the aim of the study.

5.4.2.1 Primary data collection

Primary data are collected for a specific research problem at hand using procedures that fit the research problem best (Hox & Boeije 2005). The techniques involve gathering information through both formal and informal interviews with the relevant transport officials from various departments. A field survey enabled analysis of the different public transport modes operations specific to Gautrain/Gaubus, A Re Yeng. Therefore, collecting data using these methods assists with gathering concrete knowledge by getting first-hand information.

5.4.2.2 Secondary data collection

According to Hox and Boeije, (2005), "On every occasion that primary data are collected, new data are added to the existing store of social knowledge". As this increase, this material created by other researchers is made available for reuse by the general research community; it is then called secondary data. The above mentioned, include the use of previous journals and books that have been used for almost similar study. Further, relevant websites are used to get a wider view about transport planning operations.

5.4.2.3 Observations

Observation is a complex research method because it often requires the researcher to play a number of roles to collect data and to use a number of techniques; including the five senses. In addition, despite the level of involvement with the study group, the researchers must always remember their primary role and remain detached enough to collect and analyse data relevant to the problem under investigation (Baker 2006). Gorman and Clayton define observation studies as those that "involve the systematic recording of observable phenomena or behaviour in a natural setting" (Gorman and Clayton 2005, pp. 40). The researcher spent more time at the different public transport platforms (A Re Yeng, Gaubus and Gautrain station) to get first-hand experience, a period of 14 days was spent onsite, and notes were taken. Open conversations with commuters obtained truthful answers before narrowing it down to interviews.

5.4.3 Geolocations face book and twitter data (Echo-Echo)

Echo-Echo collects data from different social media platforms then analyses the data into meaningful information, using semantics and sentiments analysis. It is an independent private company that uses sentiments and semantics analysis, and the results are collected in-real time (Moyo & Musakwa 2016). The geolocation social media datasets received from Echo-Echo included labelled time-series data with fields including the user, coordinates, message, source and date. Preparation of the data required the use of ArcGIS to convert the Excel social media data into a shapefile format. Through the data preparation, social media posts without X and Y coordinates were eliminated to generate more accurate information. Hence 19717 Gautrain and A Re Yeng geolocation social media datasets were generated for use in the study. Further, with the correct generated coordinates the process of creating shapefiles was conducted.

	Message	Social User	Latitude	Longitude	City
2	Happy Youth day from @A_RE_YENG https://t.co/HSRF1qeiGo	A_RE_YENG	-25.6051205	28.3929417	The City of T
3	RT @carly_maeko: The 1st BRT in SA to offer Free WiFi in the station and aboard @A_RE_YENG @sontondlovu @Freetshwifi @sustaincities https:/...	A_RE_YENG	-25.6051205	28.3929417	The City of T
4	RT @carly_maeko: The 1st BRT in SA to offer Free WiFi in the station and aboard @A_RE_YENG @sontondlovu @Freetshwifi @sustaincities https:/...	Freetshwifi	-25.6975497	28.1590786	Tshwane
5	June 16 commemoration with colleagues #Amandla @CityTshwane @A_RE_YENG https://t.co/xiFrnsk5yP	telltumi	-25.73134	28.21837	Pretoria
6	@Thobela_Moshate E le gore BRT ye ya Tshwane, e tlo tswa neng ka gare go toropo go isha banamedi gae? @AReYeng_	NamanyanaKgaph1	-25.73134	28.21837	Pretoria
7	I travelled on @ReaVayaBus (bad experiences especially on F11). @A_RE_YENG & @TheGautrain Proud of our cities improving #publictransport	kitty46kat	-25.73134	28.21837	Pretoria, Sou
8	The @A_RE_YENG buses announce clearly the next bus station. Functional tag machines in the buses. Fast wi-fi too at the bus stations	kitty46kat	-25.73134	28.21837	Pretoria, Sou
9	@A_RE_YENG not only is the bus stations clean and neat the staff is so professional and so too is the bus drivers #publictransport	kitty46kat	-25.73134	28.21837	Pretoria, Sou
10	Public transport system in Gauteng @A_RE_YENG versus @ReaVayaBus such a vast difference. Guess which one 1. Clean 2. Best customer service	kitty46kat	-25.73134	28.21837	Pretoria, Sou
11	No more using project cars @giz_gmbh SA, we will connect you to all your offices through the use of @A_RE_YENG https://t.co/frvmYiG9sW	A_RE_YENG	-25.6051205	28.3929417	The City of T
12	Official handover of @A_RE_YENG cards:Encouraging @giz_gmbh SA to reduce carbon foot print by using public transport https://t.co/uJL4PsSC4o	A_RE_YENG	-25.6051205	28.3929417	The City of T
13	@giz_gmbh South Africa purchased @A_Re_Yeng Connector cards that were handed out to staff members #EnvironmentWeek https://t.co/rqHjPtDElN	A_RE_YENG	-25.6051205	28.3929417	The City of T
14	RT @DA_GautengNorth: .@SollyMsimanga meeting #AreYeng bus drivers and promising that @Our_DA will not cancel that service #VoteForChange ht...	SollyMsimanga	-25.6975497	28.1590786	Tshwane
15	RT @DA_GautengNorth: .@SollyMsimanga meeting #AreYeng bus drivers and promising that @Our_DA will not cancel that service #VoteForChange ht...	Our_DA2016	-30.559482	22.937506	South Africa
16	RT @DA_GautengNorth: .@SollyMsimanga meeting #AreYeng bus drivers and promising that @Our_DA will not cancel that service #VoteForChange ht...	Independent1965	-18.97476	32.65556	Mutare, Zim
17	RT @DA_GautengNorth: .@SollyMsimanga meeting #AreYeng bus drivers and promising that @Our_DA will not cancel that service #VoteForChange ht...	Kwena_94	-25.73134	28.21837	Pretoria, Sou
18	.@SollyMsimanga meeting #AreYeng bus drivers and promising that @Our_DA will not cancel that service #VoteForChange https://t.co/o2jWbqjwCx	DA_GautengNorth	-25.73134	28.21837	Pretoria, Sou
19	We are so close to using one card on all modes of transport as I can now use my @ReaVayaBus card to travel with @AReYeng_ and @MyCiTiBus	takatso_moloi	-26.2574817	27.8282121	Soweto,Nale
20	I should just take an areyeng bus to somewhere this weekend, never been on those	saint_caroll	-23.8961708	29.4486263	Polokwane
21	#ANCGPManifesto Tswane has introduced BRT areyeng	MySouthAfrica94	-30.559482	22.937506	South Africa
22	@A_RE_YENG #CNG buses have priority seating for people who are on wheelchair #SWeek16 https://t.co/X5T8GsVNHD	A_RE_YENG	-25.6051205	28.3929417	The City of T
23	Day 3 of @SustainWeekSA: Learn more about @A_RE_YENG bus powered by #CNG #SWeek16 https://t.co/Fl0vOu6Ba9	A_RE_YENG	-25.6051205	28.3929417	The City of T

Gautrain | Rea Vaya | A Re Yeng

Figure 5.1: Excel data format from Echo-echo [Source Author: 2017]

Figure 5.1 highlights the summary of the Gautrain and A Re Yeng, crowd-sourced, geolocation social media posts (Facebook and Twitter) data records that were received from Echo-Echo in Excel format and which are also attached in Annexure C. A total of 19617 Gautrain social media posts were received and only 100 A Re Yeng social media posts were received. This data is meaningful in the study to derive information of the whereabouts of the commuters. It assists in identification of commuter hotspots when the Neighbourhood analysis and Kriging interpolation was conducted. Further, the data assist with identifying concerns raised by the commuters related to the study.

The aim of this conversion of geographic social media co-ordinates into shapefiles was to create maps through the kriging interpolation method and neighbourhood analysis. The execution of the different analyses of the data depended on the reliability of the information recorded which meant that all potential errors had to be minimized. Despite quality assurance being embedded in all the analytic processes, such as data collecting and editing, errors may still have existed (Moyo and Musakwa 2016).The editing process was therefore conducted more than once to avoid errors from increasing, the editing process was repeated until the researcher was satisfied that all the records reflected a true representation of the real world feeds. Maps were used to visualize high and low commuter concentration zones and to track the movement patterns of commuters using the A Re Yeng, Gaubus and Gautrain. Table 5.1 summarises the information analysed during the study.

Datasets	Quantity	Formats
Gautrain Stations	3 train stations	Esri shapefile
Gaubus stops	245 bus stops	Esri shapefile
A Re Yeng bus stops	209 bus stops	Esri shapefile
Gautrain commuters	19 617 posts with geolocation co-ordinates	Microsoft Excel
A Re Yeng commuters	100 posts with geolocation co-ordinates	Microsoft Excel
Gautrain and A Re Yeng Social Media posts	19 391 posts with geolocation co-ordinates	Microsoft Excel

Table 5.1: Summary of datasets collected [Source: Author 2018]

Tab1e 5.1 indicates the summary of the Gautrain and A Re Yeng, crowd-sourced, geolocation, social media (Facebook and Twitter) data records that were received from Echo-Echo in Excel format. Further, 3 Gautrain stations, 245 Gaubus stops and 209 A Re Yeng bus stops were identified that are currently operating in the City of Tshwane. Accordingly, the echo-echo data were used in forming word clouds. The words used by commuters though posts were identified and then analysed to produce meaningful information relating to the study.

5.5 SAMPLING DESIGN

Sampling is concerned with the selection of individuals or various stakeholders for a certain study to participate and represent the whole population instead of selecting everyone. This study adopted purposive sampling, random sampling. Snowball sampling was also employed in the study to obtain data from recommended officials. According to Creswell (2008), "purposive sampling is a kind of sampling where the researcher intentionally selects individuals and sites to learn or understand the central phenomena". This type of sampling was used for the selection of relevant transport officials. Consequently, random sampling was employed to select commuters for interview questions to understand how different individuals feel about the current formal urban public transport. Lastly, snowball sampling is a technique for finding research subjects. One subject gives the researcher the name of another subject, who in turn provides the name of a third and so on (Vogt 1999). Therefore, sampling selection for research work is important as it enables enough data to be collected about a certain population without using all the population. In accordance with the mentioned above, not all commuters can be interviewed or go through questionnaires as well as the officials, hence the sampling is necessary.

Purposive sampling was conducted for both commuters and officials of Gautrain/Gaubus and A Re Yeng. It is crucial to interview daily commuters as they have a daily experience of what happens during journeys by these modes of public transport. Further, relevant information can be acquired from experienced officials of the Gautrain/Gaubus and A Re Yeng. Thus, forty interviews were conducted with current users of the Gautrain, Gaubus, and A Re Yeng in the City of Tshwane. The main questions asked were about the Gautrain/Gaubus and A Re Yeng information distribution and payment systems. The questions included the following: How easily do commuters access information about the time schedules of transport? Do they switch smoothly from one mode of transport to the other immediately with the current information supplied if they are travelling to areas that need them to switch public transport? What do they use to board public transport? What kind of payment system do they use and is it convenient? Information also included their needs and preferences as well as the availability of information about the options and how one can connect the various modes. More details were asked on the possibilities of developing composite and integrated apps that provide real time information as well as the integrated smart card for both urban public road and rail transport. Such data was analysed to provide guidelines and policy recommendations on rail and road integration purposes.

5.6 DATA ANALYSIS

The study followed an inductive approach to data analysis by way of identifying the state of spatial integration within themes of urban mobility. The analysis started by exploring findings under each theme before confirming the findings based on analytical principles, and not necessarily following a set of rules (Labaree 2009). Accordingly, content analysis, thematic analysis and spatial analysis were adopted as the techniques to assess all the spatial and qualitative primary and secondary data collected during the study. All the above-mentioned analysis techniques were purposefully chosen, as they could be used for studying the efficacy of electronically integrated, reliable and convenient innovative urban public transport systems consistent with the inductive approach to data analysis.

5.6.1 Correlational analysis

In research "the movement of interpretation is constantly from the whole to the part and back to the whole" (Gadamar 1976b, p 117). This illustrates that a relationship of elements exists at various levels and should not only be understood as singular. Generally, correlation research refers to conditions in which a presumed cause and effect are identified and then quantified, whilst other fundamental features of experiments are absent (Brown, et al. 1999). The correlation process is similar to observational research, as the researcher only observes the relationship of the data sets, such as changes in quantity or movement patterns. With regards to the social media big data, the researcher used correlation to assess how proximity affects the commuter's choices. For this reason, a linguistic analysis was done to monitor the trends and patterns imbedded in the social media big data.

5.6.2 Content analysis

As a means of controlling public opinions and facilitating public participation, the GMA has engaged with the public from the initial development process of the Gautrain. This social media presence that has been growing over the years led to the Gautrain having more than 120000 twitter follows and having an average feed rate of over 75000 posts for the period January to June 2017. Consequently, the GMA now uses social media as a mitigation and evaluation tool for their operations.

5.6.3 Time series

The principle of the time-series technique is based upon a periodic assessment of elements, with investigations being made at set times to see any trends or patterns that exist within the data set. "Time series are classified as dynamic data since their characteristics change over time, subsequent values are linked in some way to the previous values, and their order is important. Clustering of time series can pose a significant challenge, because it requires the detection of patterns and relationships in large volumes of data" (Luczak 2016: p 2-3). Regarding clustering, it is notable that the time-series techniques allow for various clustering of themes to be introduced in the research such as seasonal; weekly or monthly. These results can later be compared with historical data, to assess any developing patterns or changes in trends (Creswell 2007). Consequently, geo-location data for Twitter and Facebook users was collected for a 6-month period between January and June, July to December 2016 and 2017. Through clustering the researcher monitored and identified cause and effect relationships within the public transport system and hence determined the factors which caused fluctuating trends in commuting volumes.

5.6.4 Kriging interpolation

Spatio-temporal patterns can be approximated using interpolation (Moyo and Musakwa 2016). Interpolation is a prediction of surface values at unobserved locations based on the observed surface values of neighboring locations (Colin, et al., 2004). Using spline and kriging techniques, interpolation has been used to predict weather patterns, animal migration patterns and for agricultural studies, In this research kriging was utilized within the model as it is "a powerful statistical interpolation method used for diverse applications which assumes that the distance or direction between sample points reflects a spatial correlation that can be used to explain variations in the surface" (Colin, et al., 2004, p 3). The elevation or 'z' value was extracted from the DEM using the ArcGIS spatial analyst tool to determine values to points of geographical locations from the social media posts. This was then used as the inputs of the kriging operation to predict spatial patterns of the data records.

The rationale of utilizing the interpolation technique (kriging) was to analyse similarities over time; the degree of the spatial phenomenon to space; the level of interdependence; and finally, the nature and strength of the interdependence in the predicted surface. Kriging was subsequently used to analyse the variations in density for the recorded sites in the social media data obtained from Echo-echo. Before performing the above, the data was analysed for any pre-existing patterns using the histogram and semi-variogram for the 'z' value of the social media big data.

5.6.5 Focal statistics analysis

Focal statistics estimates attributes of what is adjacent or nearby a location using data from surrounding points. In this research, the neighborhood analysis was conducted using fiscal statistics. This allowed for the assessment of the proximity of one feature to another. Often proximity is referred to as the capacity to classify the spatial distance between corresponding features. The neighborhood analysis was conducted using the City of Tshwane data. The social media data was laid over the City of Tshwane data to assess the spatial pattern variation which existed in the City. Further, the study area was divided into 25km^2 areas using the data management tool *create fishnet.* This was done to ensure a uniform analysis could run for the whole study area, as it is characterized by irregular shapes.

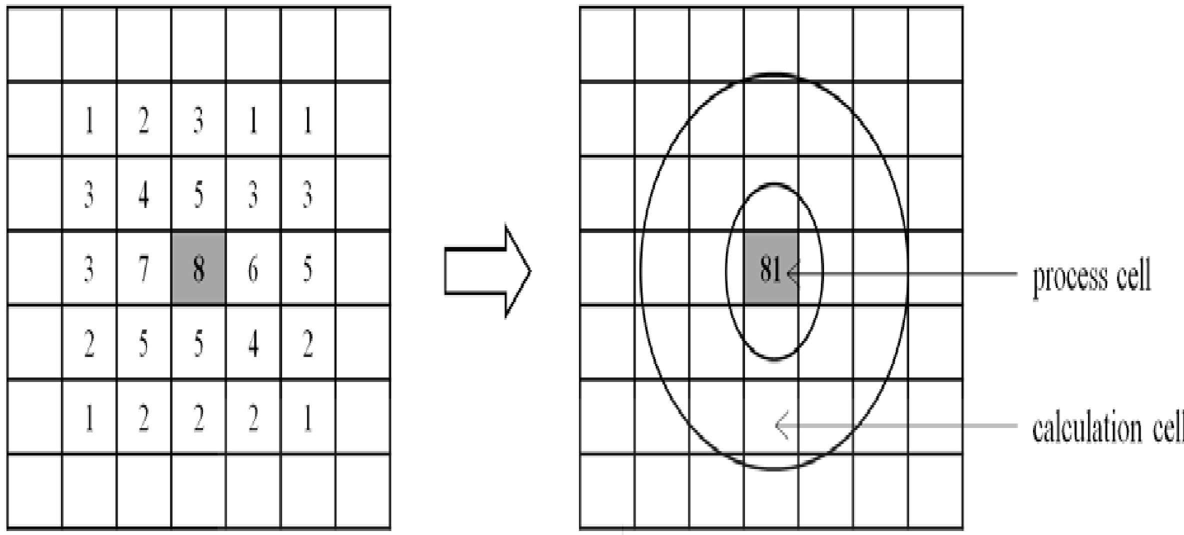

Figure 5. 2: Focal Statistics Analysis diagram [Source: picture modified after ESRI 2012]

The Geospatial Modelling Environment is a suite of numerous analytic and modelling tools, which was used to *create a count in polygon* field for the fishnet data. "This tool counts the number of points that overlap each polygon and writes the result to a field in the polygon attribute table. Each polygon is processed consecutively and independently of any other overlapping polygons. Thus, if there are overlapping polygons, a single point may contribute to the count of more than one polygon, and the count for a polygon that is 'underneath' an overlapping polygon will not be influenced by this overlap" (Beyer 2015, p 41). In fiscal statistics, the functions are based on the geometric configuration of the raster data, the spatial coincidence of each cell, as well as on the attributes that they depict, for the calculation of fiscal statistics was premised on the results from the count in polygon for the fishnet. For the geolocation analyses, only 45.70%, or 9633 posts were valid and considered in the analyses. To conduct the neighborhood analysis using the fishnet data, the spatial analysis focal statistics tool was used. Initially, a fishnet of 5 kilometres by 5 kilometres was created for the City of Tshwane using the data management extension tool.

5.6.6 Software applied

ArcGIS is a geographical information system, which can be described as a combination of packages which assist decision makers to monitor, analyse and measure spatial phenomena (Longley et al. 2010). The version used during the research was ArcGis 10.3, which like previous versions has various packages, which assist for various geographic analyses. These are ArcMap;

ArcGlobe; ArcCatalog; and ArcScene. ArcMap was used in the research to analyse the big social data. Also, the analysis was undertaken using the geographic data view window, whilst map creation was developed using the layout view. The potential unlimited use of ArcGis consequently relies on how it can access GIS data in numerous formats, whilst using multiple databases and file-based datasets concurrently (Longley et al. 2005 2010)

The Geospatial Modelling Environment (GME) is a stand-alone program which can be used in conjunction with other applications such as ArcGIS and R. In principal, GME is a platform intended to facilitate rigorous spatial analysis and modelling (Beyer 2015). Besides the software's numerous analysis and modelling tools, GME supports batch processing, hence offering new graphing functionality. The count in polygon feature in GME also stands out in that it can facilitate the neighborhood analysis in ArcGis, as the ArcGIS extension for counting has limited functions which the GME offers.

5.6.7 Crowd sourcing

Crowds can generate massive amounts of information, and sometimes it takes the power of a crowd to sift through it all. Interestingly, just as we can use a crowd to gather information, we can also use a crowd to rate information for relevance and value (Benkler 2007; Howe 2009; Malone, Laubacher, & Dellarocas 2009). This approach can be employed passively, such that the crowd does not even know that its behaviours are being used to rank information (e.g., Google's PageRank or Amazon's collaborative filtering algorithms). Large amounts of data are being collected effectively through the assistance of crowd sourcing. Further, the use of crowd sourcing for this study was very important, as a lot of people use urban public transport. Hence, many views from different individuals has solidified the data for the certain objectives of this study to be achieved. Thus, collection of data through social media allowed commuters who were not interviewed to add their views.

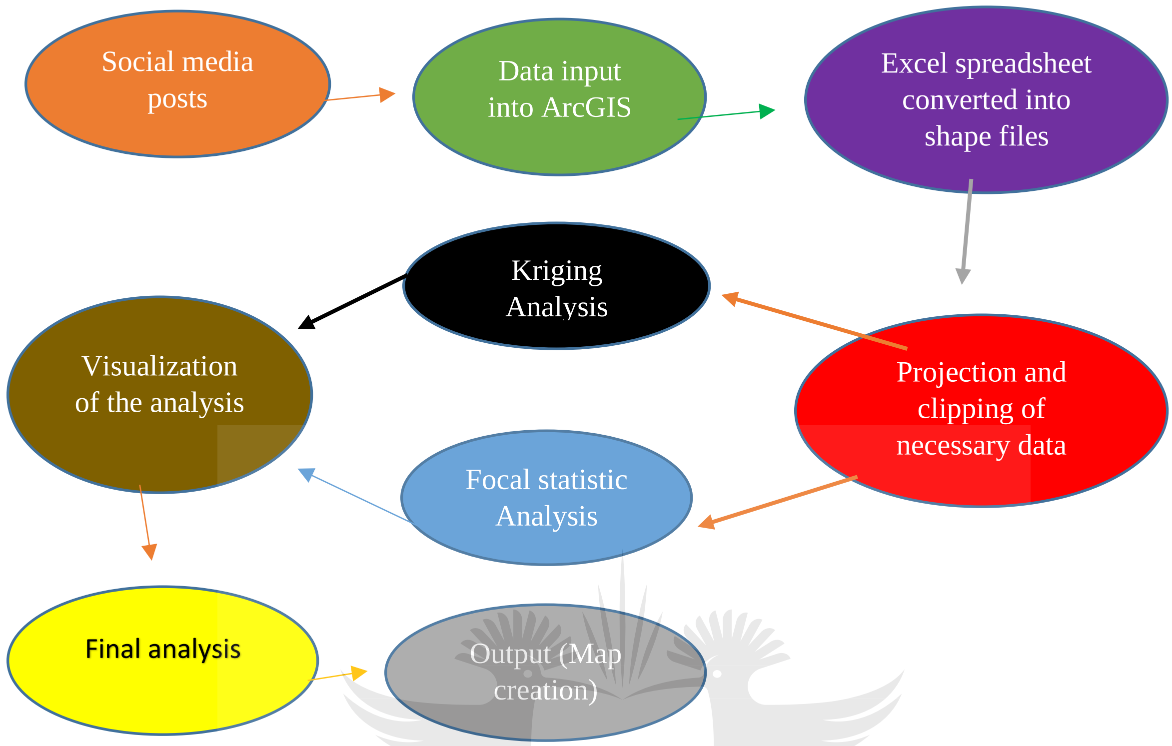

Figure 5.3 Format of map creation [Source: Author 2018]

Figure 5.3 indicates the preparation of Kriging interpolation analysis. Focal statistics analysis and all Gautrain system and A Re Yeng maps were created. Social media data posts were obtained in a excel spread sheet which were input into ArcGIS as data. These data were then created into shapefiles which were projected to a common coordinates system for a defined reference. Necessary shapefiles were clipped such as province layers, BRT routes, Gautrain routes and stations etc. to GCS Haartebeeshoek 1994. The social media shape files were then inserted in the Focal statistics and Kriging interpolation tools for the analysis. Visualization of the analysis by the researcher was conducted where all error information was removed, and more refined analysis was conducted. With the final analysis conducted, the output resulted in a map creation.

Research Objectives	Sources of Data	Data Analysis	Data Presentation
To review the policies and legislative frameworks on integration of formal urban public transport modes in South Africa.	City of Tshwane Municipality website and relevant internet websites, Articles, Journals. Relevant Department of transport officials and relevant City of Tshwane Municipal officials.	Content Analysis	Text (Paragraph explanation)
To investigate the information systems that are shared by innovative urban public transport modes in the City of Tshwane	City of Tshwane Municipality website and relevant internet websites, Journals. Relevant Department of transport officials and relevant City of Tshwane Municipal officials,	Thematic analysis, Word cloud Content Analysis Highlighting the current methods of information distribution, the needs and users preferences, and how UPT can be integrated through information dissemination	Images, Text (Paragraph explanation), Graphs, Clouds
To assess the payment systems that are shared by innovative urban public transport modes in the City of Tshwane.	City of Tshwane Municipality website and relevant internet websites, Journals, Gautrain/Gaubus and A Re Yeng officials, Dept of Transport officials, A Re	Thematic analysis, Word cloud, Content Analysis Highlighting the current methods used for FUPT fare, the needs and users preferences, and how FUPT can be integrated through information dissemination	Images, Text (Paragraph explanation), Graphs, clouds

	Yeng and Gautrain system users.		
To advance a theoretical framework or model that explains strategies of integrating innovative urban public transport modes in the City of Tshwane.	Journals, GIS data, Echo-echo (Social media data)	Word cloud, time series, ArcGIS tools (Kriging interpolation and focal statistics analysis highlighting the spatial penetration, spread of public transport in the COT, population densities, current and future hot and cold spots and places needing public transport connection	Maps (Raster and vector data), Clouds, Text (Paragraph explanation)

Table 5.2: Research design matrix [Source: Author 2017]

Data set	**Data Type**	**Source**	**Analysis**
points at A Re Yeng stations and routes	Shapefile	Gauteng Management Agency	ArcGIS- Map
Cadastral: -Gautrainrail reserves - Gautrain bus stops - Gautrain rail tracks - Gautrain/ Gaubus stations - SA Towns	Shapefile	Gauteng Management Agency	ArcGIS- Map
-Twitter posts (Locations of stations and routes) - Facebook posts (Locations of stations and routes)	Excel	Geolocation based services: posts	ArcGIS-Map Word Cloud
-Towns layer data -Land Use data -Province layer data	Cadastral shapefile	City of Tshwane metropolitan municipality	ArcGIS- Map

Table 5.3: Dataset [Source: Author 2017]

The objectives of the study were met by means of data in Table 5.2 representing the research design matrix. Table 5.3 indicates the data used to create maps and word cloud. The maps created through cadastral shapefiles shows the movement of both Gautrain and A Re Yeng systems in the City of

Tshwane Metropolitan Municipality and consequently the spatial integration of both systems. The maps further, assisted with the build-up of the model by identifying cold and hot spots of potential development required by the commuters.

5.7 LIMITATIONS

It refers to all the envisaged objectives to be achieved by the researcher that could not be accomplished due to certain reasons. This may include time; the period for the study may not be enough to collect all the data needed. Furthermore, interviews were not clearly answered due to respondents not understanding or lacking clarity/good explanation of questions from the researcher. Some respondents wanted to give their opinions on what they feel about a certain urban public transport mode. Consequently, some data through kriging interpolation and neighbourhood analysis could not be analysed as there were errors in the data processing stages.

Due to time constrain the number of participants to be interviews were scaled down, not all public transport users were interviewed, only daily commuters as they might have more information regarding challenges of commuting. Responses that were not relevant to the study were left out as they will make the results weak. Further, errors in data processing stages were left out and the successful completed data was used for the analysis.

5.8 ETHICAL CONSIDERATIONS

A researcher who was fully aware of the following ethical considerations conducted this study. Important considerations such as informed consent, privacy, anonymity and confidentiality were addressed (Nachimias 1981). Informed consent was valued in this study in the sense that the researcher made sure that all the participants were aware that their involvement was voluntary. At all times, a thorough explanation of the research was given.

5.9 Chapter Summary

This chapter indicated how the research was conducted with the use of different techniques. Consequently, how the collected data was analysed. Further, limitations of the study were outlined such as accessibility to spatial data of UPT and ethics of the participants were considered such as the information shared was confidentially.

CHAPTER 6: STATE OF PHYSICAL INTEGRATION OF INNOVATIVE FORMAL URBAN PUBLIC TRANSPORT IN THE CITY OF TSHWANE

For smooth movement in UPT, easy access to different modes is vital. Spatial connectivity needs to be present and for potential electronic integration between different modes, physical integration is required for commuters to switch in between modes of UPT. The chapter highlights locations serviced by both the Gautrain and A Re Yeng systems. The chapter further indicates the physical integration between the two systems.

6.1 INTRODUCTION

Urban Public Transport (UPT) services are very important as they play a key role in moving a large percentage of individuals globally, and this apply locally as well. Many residents in the City of Tshwane use public transport and this could be in different forms. For example, (i) individuals drive from home to a certain station then use UPT, (ii) individuals who do not own private vehicles use UPT, and (iii) Some private vehicle owners use UPT depending on acceptable reasons. To all commuters, the UPT services are expected to be efficient and reliable. Accordingly, the public transport network needs to function in a manner that satisfies all commuters. This chapter presents the results of the research regarding the state of spatial integration of innovative FUPT in the COT.

6.1.1 Innovative FUPT in the City of Tshwane Metropolitan Municipality

COT is the chosen study area. It is the capital city of the Republic of South Africa and it is in the Gauteng province. The Republic of South Africa has nine provinces of which Gauteng is the smallest. The province affords more job opportunities than any other province in the Republic of South Africa, thus attracting many people both international and locally. It is the heart of the country and is the economic hub. There are three metropolitan municipalities in the province, which are the City of Tshwane, the City of Johannesburg and the City of Ekurhuleni. This is the indication of economic concentration in the province. The City of Tshwane contains several institutions and its population is around 2,921, 488 square metres (Stats SA 2016).

6.1.1.1 Gautrain operations

Gautrain is the high-speed train system implemented in South Africa, specifically, in Gauteng. However, it is desired by all three spheres of the government that the Gautrain should grow and operate in all nine provinces within the Republic of South Africa. The Gauteng Provincial government formed a partnership with local and international experts to build a modern transport network, which is the biggest public-private partnership in Africa.

Figure 6.1: Gautrain [Source: Author 2018]

The above-depicted image indicates the Gautrain. This system currently covers a rail track of 80-kilometres network and provides significant economic and transport related benefits to the province (Gautrain Management Agency 2018). The existing network was already close to 80 million commuting trips by the years 2017 and 2018. Gautrain ridership currently hovers around 60 000 people on a weekday (Venter 2019). Further, the Gautrain service delivers 98.6% punctuality and 95% availability. Therefore, Gautrain commuters know that they have a better chance arriving at their desired destination in time rather than using a private motor vehicle. Below is the Gautrain province map showing the current the locations serviced by the Gautrain.

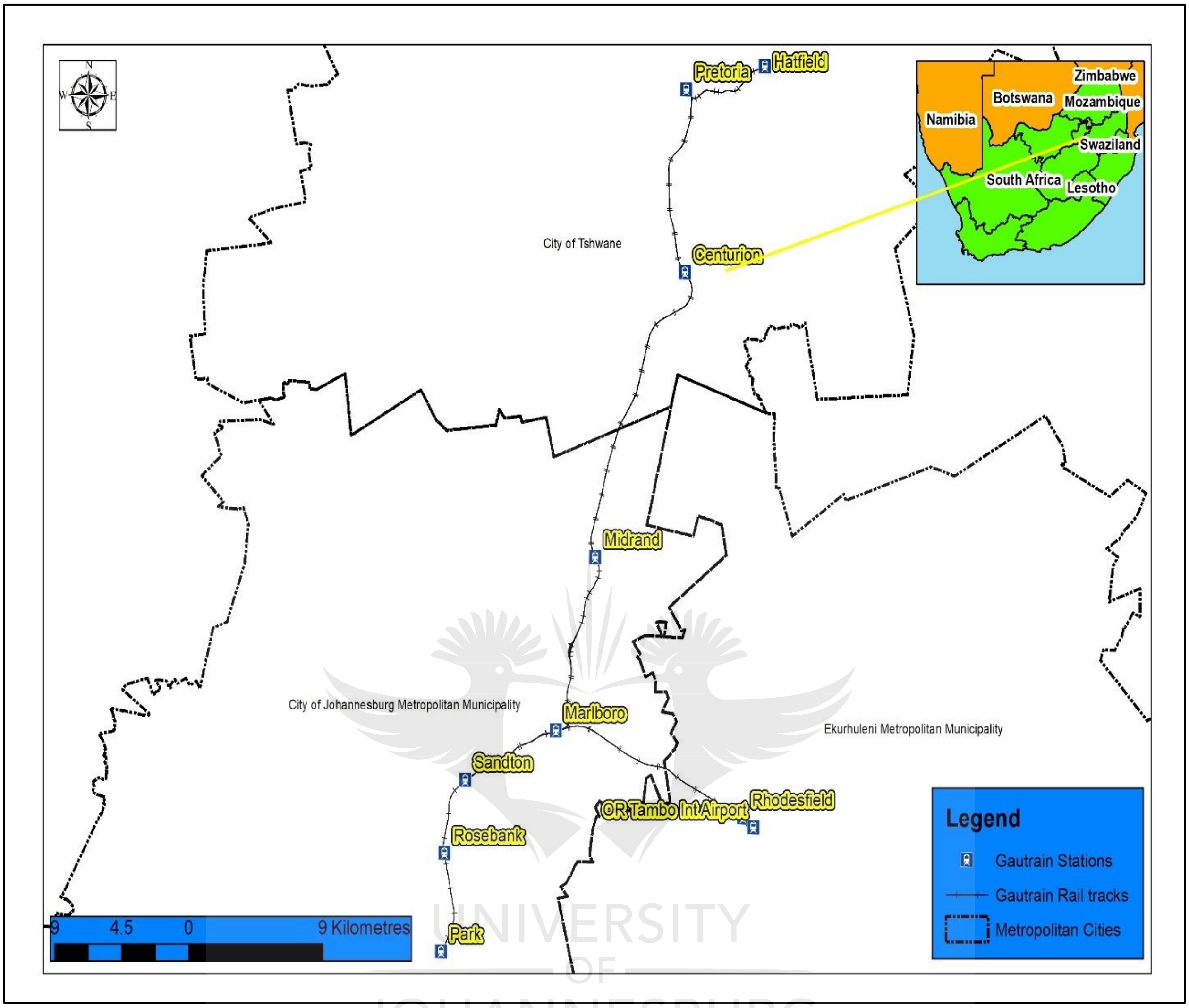

Figure 6.2: Gautrain network map [Source: Authors 2018]

The above-depicted map in Figure 6.2 indicates the operation of Gautrain within the three Metropolitan Municipalities. The study focuses in the City of Tshwane which is also known as Pretoria. The implementation of an innovative FUPT system in the city creates smart mobility which is part of the smart cities concept. As shown on Figure 6.2, the Gautrain operates from the City of Tshwane, to the City of Johannesburg and to Ekurhuleni. The Gautrain has been operating for 9 years, and there are plans in place for it to grow further and be accessible from more locations in the Gauteng province (Mbatha and Gumbo 2018). The Gautrain operates using 10 train stations. However, only three stations are available in the City of Tshwane which are Hatfield station, Pretoria station and Centurion. The areas with train stations afford most job opportunities to many individuals.

6.1.1.2 Gaubus operation (routes serviced)

As a high-speed train was developed, a bus FUPT mode named the Gaubus that is compatible with the high-speed train was developed.

Figure 6.3: Gaubus [Source: Author 2018]

The above Figure 6.3 indicates the implemented FUPT bus mode that is developed with the Gautrain. The Gaubus penetrates the areas where there is no train station to provide efficient and reliable transport for commuters. The strategy of the Gautrain and Gaubus is important to cover lot of ground in the Gauteng Province, as there are locations that do not have train stations, hence, the provision of Gaubus.

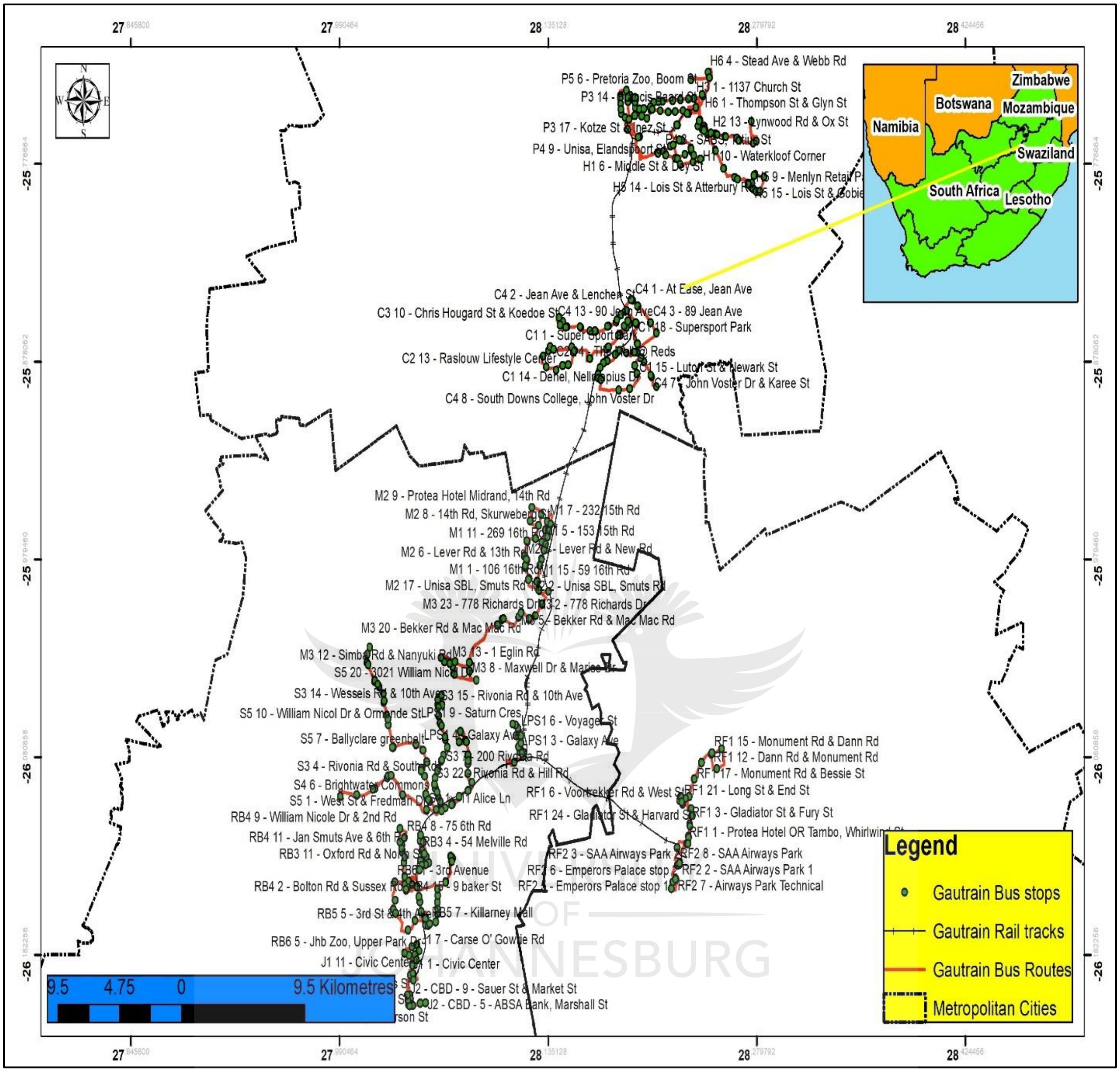

Figure 6.4: Gaubus stops and routes Map [Source: Author 2018]

Figure 6.4 shows all the bus stops and routes available for Gaubus. All the Gautrain stations in the City of Tshwane have Gaubus stops outside the station. This makes the Gautrain system effective and attracts more commuters as there are alternatives provided, which also allow switching between Gaubus and Gautrain. This is the first system of such a kind in the Republic of South Africa and Africa as a whole (Mbatha and Gumbo 2018).

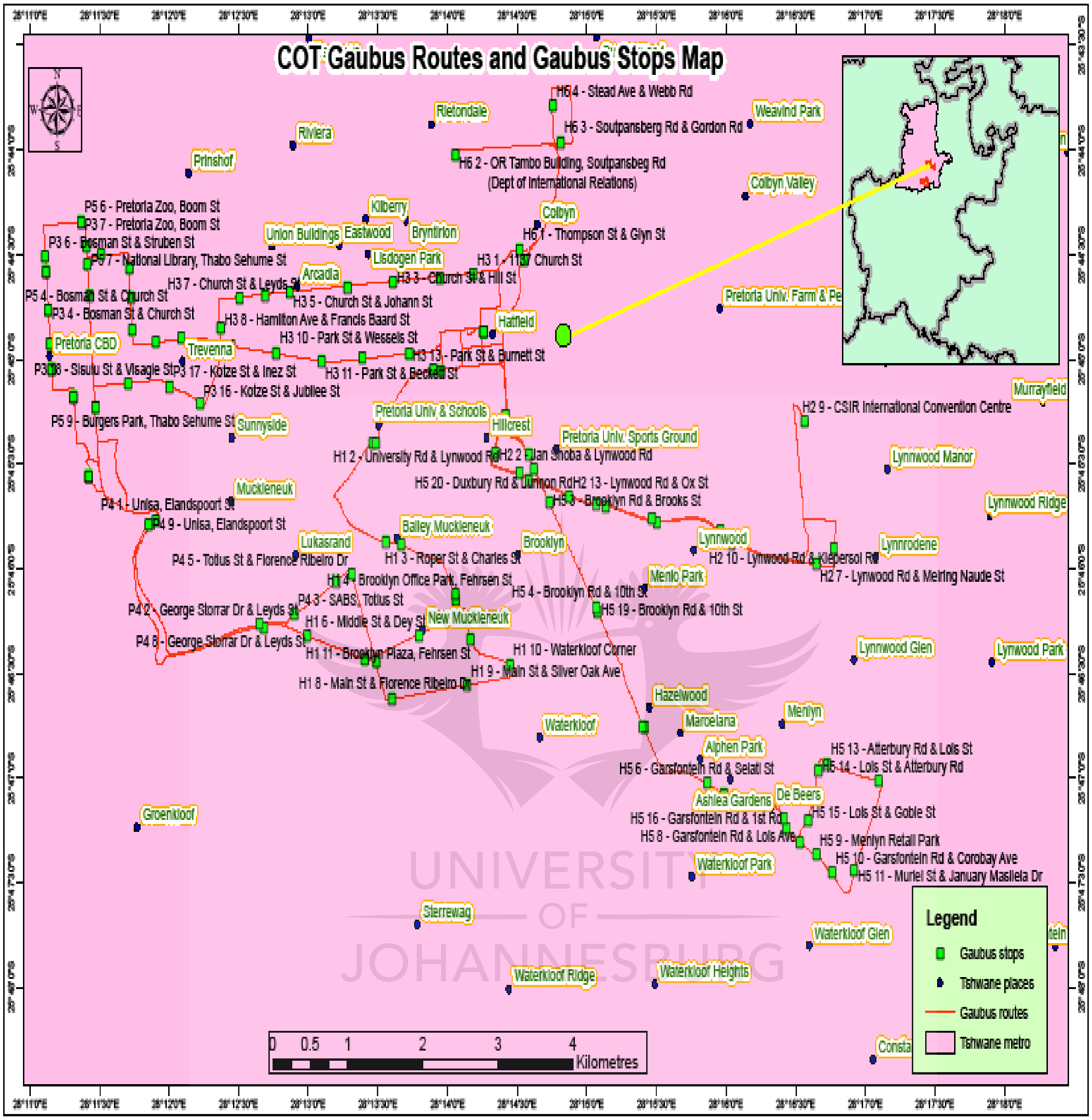

Figure 6.5: Gaubus stops and routes Map [Source: Author 2018]

Figure 6.5 shows all the bus stops and routes in the City of Tshwane (centre) available for the Gaubus operating from the CBD to Hatfield, excluding the operations of the system in Centurion. The Gaubus services many areas in the city as shown on the map Figure 6.5, Table 6.1 and Table 6.2.

PRETORIA CBD- P3 PRETORIA ZOO- P5

Bus type	Bus stop & routes serviced	Bus type and stops	Bus stop & routes serviced
P3-1	Transvaal Museum, Paul Kruger St	P5-1	Transvaal Museum, Paul Kruger St
P3-2	Bosman St & Nana Sita St	P5-2	Bosman St & Nana Sita St
P3-3	Bosman St & Pretorius St	P5-3	Bosman St & Pretorius St
P3-4	Bosman St & Church St	P5-4	Bosman St & Church St
P3-5	Bosman St & Johannes Ramokhoase St	P5-5	Bosman St & Johannes Ramokgoase St
P3-6	National Department of Transport, Struben St	P5-6	Pretoria Zoo, Boom St
P3-7	National Library, Thabo Sehume St	P5-7	National Library, Thabo Sehume St
P3-8	National Treasury, Thabo Sehume St	P5-8	State Library, Thabo Sehume St
P3-9	Sammy Marks, Madiba St	P5-9	Burgers Park, Thabo Sehume St
P3-10	South African Reserve Bank, Sisulu St		
P3-11	Louis Pasteur Hospital, Sisulu St		
P3-12	Sisulu & Visagie Str		
P3-13	Burgers Park, Thabo Sehume Str		

Table 6.1: Spatial locations of Gaubus in Pretoria CBD [Source: Author 2018]

In the City of Tshwane CBD, P3 Gaubus services Bosman Street and there are three bus stops found along the street see Table 6.1. There are two bus stops in Madiba Street but only two streets long are serviced in Madiba Street. On Sisulu Street, there are three Gaubus stops, and the Gaubus services six streets long. Paul Kruger Street and Thabo Sehumo Street, each have one bus stop and each service four streets long. Further, Struben Street and Visagie Street also have one Gaubus stop and each service three streets long.

The Table 6.1 further shows that the P5 Gaubus services eighteen streets long in Thabo Sehumo Street with three bus stops. Four bus stops are provided on Bosman Street, and the Gaubus services 11 streets long. One bus station is found in Boom Street that provides direct access to the National Zoo. On Paul Kruger Street, there is one bus stop and the Gaubus services four streets long. Both P3 and P5 Gaubus use Gaubus stops on Bosman and Thabo Sehumo Streets.

Hatfield-Brooklyn H1 Hatfield-Lynnwood H2 Hatfield-Arcadia H3 Hatfield-Menlyn H5

Bus type	Bus stop & routes serviced	Bus type	Bus stop & routes serviced	Bus type	Bus stop & routes serviced	Bus type	Bus stop & routes serviced
H1-1	Burnett St & Festival St	H2-1	Duncan St & Duxbury Rd	H3-1	1137 Church St	H5-1	Jan Shoba & Duxbury Rd
H1-2	University Rd & Lynwood Rd	H2-2	Duncan St & Lynnwood Rd	H3-2	Church St & Festival St	H5-2	Duxbury Rd & Lunnon Rd
H1-3	Roper St & Charles St	H2-3	Hillcrest Blvd, Lynnwood Rd	H3-3	Church St & Hill St	H5-3	Brooklyn Rd & Brooks St
H1-4	Brooklyn Office Park, Fehrsen St	H2-4	Lynnwood Rd & Kings Highway	H3-4	Church St & Eastwood St	H5-4	Brooklyn Rd & 10th St
H1-5	Middel St & Brooklyn Circle	H2-5	Hoërskool Menlopark, Lynnwood Rd	H3-5	Government Ave & Beckett St	H5-5	Dely Rd & Elandslaagte Rd
H1-6	Middel St & Dey St	H2-6	Lynnwood Rd & Kiepersol Rd	H3-6	Union Buildings	H5-6	Garsfontein Rd & Selati St
H1-7	Middel St & Florence Ribeiro Dr	H2-7	Lynnwood Rd & Meiring Naude St	H3-7	Hamilton St & Edmon St	H5-7	Garsfontein Rd & Mante St

H1-8	Main St & Florence Ribeiro Dr	H2-8	Daventry St & Hallisham Ln	H3-8	Hamilton Ave & Francis Baard St	H5-8	Garsfontein Rd & Lois Ave
H1-9	Main St & Silver Oak Ave	H2-9	Innovation Hub	H3-9	Park St & Cilliers St	H5-9	Menlyn Retail Park
H1-10	Waterkloof Corner	H2-10	CSIR Gate 2	H3-10	Park St & Wessels St	H5-10	Garsfontein Rd & Corobay Ave
H1-11	Brooklyn Plaza, Fehrsen St	H2-11	CSIR (International Convention Centre)	H3-11	Park St & Beckett St	H5-11	Muriel St & January Masilela Dr
H1-12	Fehrsen St & Muckleneuk St	H2-12	Lynnwood Rd & Kiepersol Rd	H3-12	Park St & Eastwood St	H5-12	Atterbury Rd & January Masilela Dr
H1-13	Charles St & Roper St	H2- 13	Hoërskool Menlopark, Lynnwood Rd	H3-13	Park St & Burnett St	H5-13	Atterbury Rd & Lois St
H1-14	University Rd & Lynwood Rd	H2-14	Lynnwood Rd & Kings Highway			H5-14	Lois St & Atterbury Rd
H1-15	Burnett St & Festival St	H2-15	Lynnwood Rd & Ox St			H5-15	Lois St & Gobie St
		H2-16	Lynnwood Rd & Pienaar St			H5-16	Garsfontein Rd & Ist Rd
		H2-17	Duncan St & Duxbury Rd			H5-17	Garsfontein Rd & Matroosberg Rd
						H5-18	Elandslaagte Rd & Dely Rd

						H5-19	Brooklyn Rd & 10th St
						H5-20	Duxbury Rd & Lunnon Rd
						H5-21	Jan Shoba & Duxbury Rd

Table 6.2: Spatial locations of Gaubus in Hatfield [Source: Author 2018]

Table 6.2 indicates the Gaubus stops and routes serviced by the Gaubus at Hatfield (see Figure 6.5). The Gaubus is differentiated into four types according to locations serviced from the Hatfield Gautrain station. These are Hatfield to Brooklyn (H1), Hatfield to Lynnwood (H2), Hatfield to Arcadia (H3) and Hatfield to Menlyn (H5). From the Hatfield Gautrain station H5, the Gaubus transports commuters to Menlyn through different routes from H1, H2 and H3. Jan Shoba has two bus stops and services four streets long. Jan Shoba connects to Duxbury Road which has two Gaubus stops, and Duxbury Road connects to Garsfontein Road which has five Gaubus stops and connects to other streets and roads in Menlyn. From Hatfield Gautrain station H1, the Gaubus transports commuters to Brooklyn through Burnett Street which has two Gaubus stops. In the line, Burnett Street connects to University Road that also has two Gaubus stops. University Road connects to Charles Street that has two Gaubus stops as well. Charles Street connects to Fehrsen Street, and Fehrsen has one Gaubus stop connecting with other streets in Brooklyn. Consequently, from the Hatfield Gautrain station, H2 transports commuters to Lynnwood through Duncan Street which has three Gaubus stops. Duncan Street connects to Lynnwood Road which has 9 Gaubus stops, and Lynnwood Road connects to other streets and roads in Lynnwood. Further, from the Hatfield Gautrain station to Arcadia, H3 transports commuters through Church Street that connects to Beckett Street, Beckett Street connects to Hamilton Street and Hamilton Street connects to Park Street which has five Gaubus stops. Gaubus goes around Arcadia.

6.1.1.3 A Re Yeng bus rapid transit operations (routes serviced)

The new City of Tshwane A Re Yeng BRT system is designed to transport commuters across the city efficiently by making use of specially designated lanes with enclosed bus stations. The hub is located at the corner of Nana Sita and Paul Kruger streets in the city centre. The network features two circular routes traversing the Pretoria CBD and various trunk routes linking up to Pretoria's different university campuses, with further routes currently under construction. The significance of the development of this system is to assist in transforming the spatial apartheid planning. Further, to use the bus, commuters need to register for a connector card (for a once-off fee of R25) at any A Re Yeng bus station (Mbatha and Gumbo 2018). They then proceed to the turnstile and after swiping the card commuter receive a paper ticket that is later shown to conductors during the journey.

Figure 6.6: A Re Yeng [Source: Author 2018]

Figure 6.6 shows an example of a BRT system bus operating in the City of Tshwane. The design of the bus is to produce fast, public transport which escapes traffic congestion on the road, and provides the bus with its own lanes. Good BRT bus stops are provided for this mode with innovative technology such as smartcards, and a tap in and out system to enter and exit the station. Information is provided in the bus such as alerting commuters regarding the station approaching. Information is provided at the stations, and people with disabilities have seats provided for them in the bus.

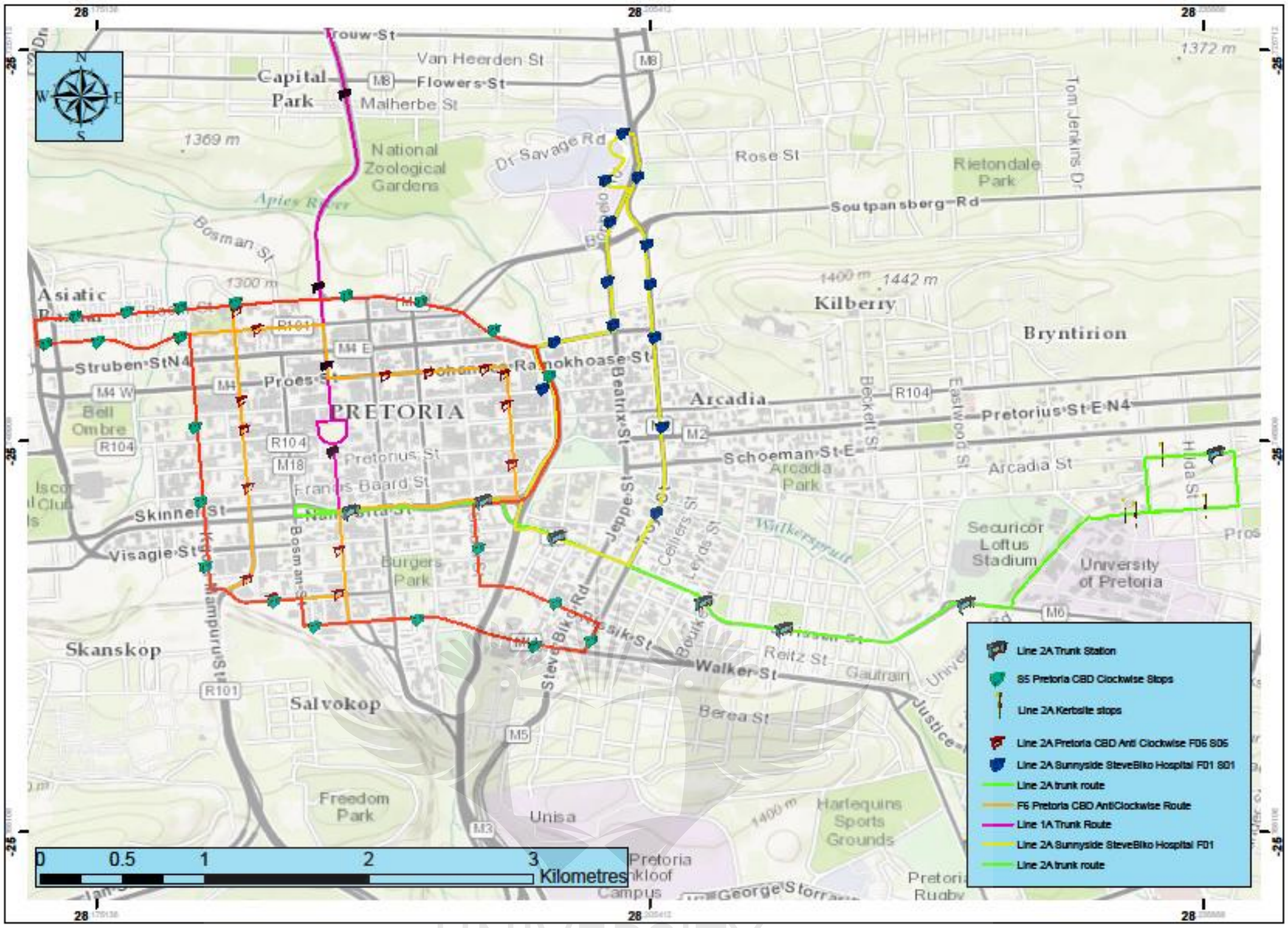

Figure 6.7: A Re Yeng Map routes and Stations [Source: Author 2018]

The A Re Yeng bus has the T1 and T2 Trunk routes, the above Figure 6.7 indicates the routes and stops of A Re Yeng. The different colours represent certain routes and locations serviced by A Re Yeng busses as shown on the map. Each bus has a certain identity, for example T1 represents the green route. T1 only operates from the CBD to Sunnyside and Hatfield (or Hatfield to Sunnyside and the CBD), and there are other stops in between. T1 services ten A Re Yeng bus stations. T2 is represented by colour red and only moves within the CBD. Therefore, if a commuter is interested in travelling to a certain location, it is important to take the correct bus to get to a desired destination.

The T1 transports commuters from Pretoria Central to Sunnyside and Hatfield and services ten A re Yeng bus stations. T2 transports commuters from Wonderboom to Capital Park and the Pretoria

CBD. T2 services six bus stations. These are Hector Pieterson, Moses Mordu, Enoch Sontonga, Anton Lembede, Rivonia Trial and Pretoria Central.

Bus stops	Routes Pretoria CBD Clockwise feeder	Bus stops	Routes Pretoria CBD Anticlockwise feeder
1	Bosman Street between Nana Sita and Francis Baard Street	1	Du Toit between Francis Baard Street and Pretorius Street
2	Bosman Street between Pretorius Street and WF Nkomo Street	2	Du Toit between Pretorius Street and Stanza Bopape Street
3	Madiba Street between Bosman Street and Paul Kruger Street	3	Du Toit between Stanza Bopape Street and Madiba Street
4	Madiba Street between Paul Kruger Street and Thabo Sehumo Street	4	Johannes Ramokhoase Street between Du Toit and Sisulu Street
5	Madiba Street between Lilian Ngoyi Street and Sisulu Street	5	Johannes Ramokhoase Street between Sisulu Street and Lilian Ngoyi Street
6	Du Toit Street between Stanza Bopape Street and Pretorius Street	6	Johannes Ramokhoase Street between Lilian Ngoyi Street and Thabo Sehumo Street
7	Pretorius Street between Du Toit Street Sisulu Street	7	Johannes Ramokhoase Street between Paul Kruger Street and Bosman Street

8	Sisulu Street between Pretorius Street and Francis Baard Street	8	Sophie De Bruyne between Johannes Ramokhoase Street and Madiba Street
		9	Sophie De Bruyne between Madiba Street and WF Nkomo Street
		10	Sophie De Bruyne between Francis Baard Street and Nana Sita

Table 6.3: Pretoria CBD Clockwise and Anti-Clockwise Feeders [Source: Author 2018]

The Pretoria CBD clockwise feeder starts from Central station and proceeds in a westerly direction, turning right into Bosman Street, and turning right in Madiba Street. It proceeds further and turns right into Du Toit Street, proceeds and turns right into Pretorius Street. It proceeds further and turns left into Sisulu Street, proceeds and turns right into Nana Sita Street. It then proceeds up to Central Station. Further, the Pretoria CBD anti-clockwise feeder starts from the Central station and proceeds in an Easterly direction on Nana Sita station. It proceeds further on Nana Sita Street turning left into du Toit Street. It then proceeds and turns left into Johannes Ramokhoase Street proceeds and turns left into Sophie de Bruyne Street. It proceeds further and turns left into Nana Sita Street and then proceeds up to Central station.

Bus stations/ stops	Routes	Bus stations/ stops	Routes

	Pretoria CBD/Steve Biko Academic Feeder		Muckleneuk Feeder
1	Bosman Street between Nana Sita and Fransis Baard Street	1	Troye Street between Jorrisen Street and Rissik Street
2	Bosman Street between Pretorius Street and Stanza Bopape Street	2	Troye Street between Rissik Street and Justice Mahomed Street
3	Bosman Street between Madiba Street and Johannes Ramokhoase Street	3	Steve Biko Street between Justice Mahomed and Ridge Streets
4	Bosman Street between Struben Street and Bloed Street	4	Elandspoort Street between Justice Mahomed and Ridge Streets
5	Boom Street between Paul Kruger Street and Thabo Sehumo Street	5	Willem Punt Avenue between Mears and Leyds Streets
6	Boom Street between Lilian Ngoyi Street and Thabo Sehumo Street	6	Leyds Streets between George Storrar and Sibellius Streets
7	Dr Savage Road between Soutpansberg Road and Steve Biko Street	7	Totius Street between Dr. Lategan and Steger Streets
8	HF Verwoerd Road between Dr Savage Road and Malan Street	8	Florence Riberio Avenue between Totius Street and Sibellius Street

9	Malan Street between Dr Savage Road and Johan Heyns Streets	9	Sibellius Street between Lingbeek Street and Dr. Lategan Street
10	Johan Heyns Drive between Rose and Annie Botha Street	10	Leyds Street between Sibelius and Prelier Streets
11	Soutpansberg Road between Hamilton Street and Steve Biko Street	11	Bourke Street between Ridge and Berea Streets
12	Soutpansberg Road between Steve Biko and Theodore Hove Avenue		
13	Sisulu Street between Bloed Street and Struben Street		
14	Struben Street between Sisulu Street and Du Toit Street		
15	Nelson Mandela Drive between Madiba Street and Stanza Bopape		

Table 6.4: Pretoria CBD and Muckleneuk Feeder [Source: Author 2018]

The Pretoria CBD/Steve Biko Academic feeder forward route starts from Nana Sita station, situated in Nana Sitastreet, proceeds in a westerly direction and turns right into Bosman Street. It proceeds further and turns right into Boom Street. It proceeds along Boom Street bearing left and turns into Soutpansberg Road. It proceeds further bearing left into Dr. Savage Road. It continues along Dr. Savage Road and turns left into HF Verwoerd Road. It proceeds further takes the second off ramp under Bephelo Road and continues to the terminus in Malan Street. The Pretoria CBD/Steve Biko Academic feeder return route departs from its terminus in Malan Street and proceeds east. It turns right into Johan Heyns Drive, proceeds bearing right and turns into Soutpansberg Road bearing left into Dr. Savage Road. It then turns left into Sisulu Street, proceeds further and turns left into Struben Street. It continues with Struben Street and turns right into

Nelson Mandela Drive. It then proceeds with Nelson Mandela Drive and turns right into Nana Sita Street up to the Nana Sita bus station.

The Muckleneuk forward route, this starts from Mahatma Ghandi station, situated in Kotze Street at Bourke Street intersection, and proceeds westerly to Troye Street and Turn left into Troye Street. It proceeds with Troye Street up to Justice Mahomed Street, proceeds and turn left into Mears Street. It continues southwards into Elandspoort Street, then proceeds and turns left into Ridge Street and then turn right into Mears Street. It proceeds with Mears Street and turns left into Willem Punt Avenue proceeding with Willem Punt Avenue up to the T-junction with Leyds Streets. It turns right into Leyds Street and proceeds up to the terminus at the main entrance to the University of Pretoria, Groen Kloof Campus.

The Muckleneuk forward route

This departs from the terminus in Leyds Streets at the main entrance next to the University of Pretoria, GroenKloof campus. It continues and then turns left into George Storrar Drive, proceeds with Totius Street and turns left into Florence Ribeiro Avenue. It proceeds further with Florence Riberio Avenue and turns left into Sibelius Street, continuing with Sibelius Street up to the T-Junction with Leyds Street and turns right into Leyds Street. It then proceeds and turns right into Bourke Street and continues in a northerly direction. It proceeds with Bourke Street and turns left into Kotze Street towards Mahatma Ghandi station.

6.2 SPATIAL INTEGRATION OF FORMAL URBAN PUBLIC TRANSPORT (FUPT) SERVICES

UPT spatial integration is important to allow commuters to have alternatives for choosing the best mode for travelling and assist commuters to switch in-between smoothly when necessary.

Figure 6.8: Spatial integration in Hatfield [Source: Google earth 2018]

Spatial integration of urban public transport makes it easier for commuters to switch smoothly from one mode to another and it gives commuters alternatives to use the available transport mode at the time convenient to them. At Hatfield in the COT, there is spatial integration as indicated in figure 6.8. The Gautrain/Gaubus and A Re Yeng are close to each other. For example, the A Re Yeng and Gaubus are 25 metres away from each other. Both the Gaubus and A Re Yeng are 100 metres away from the Gautrain station, which therefore is convenient for commuters to walk the distance (Mbatha and Gumbo 2018). However, timetabling could be a factor between Gautrain, A Re Yeng and Gaubus, as the times might not allow the immediate transporting of commuters.

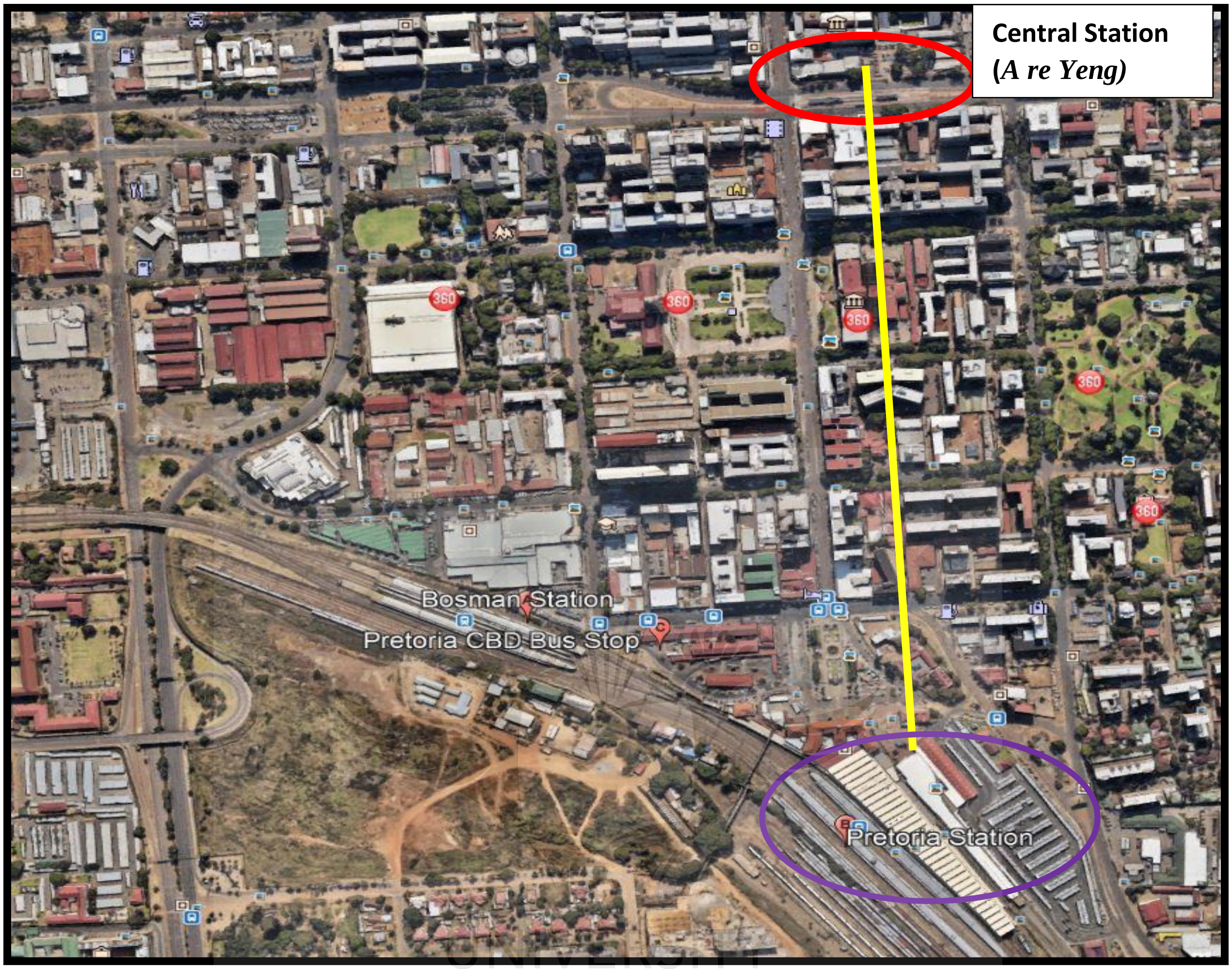

Figure 6.9: Spatial integration in Pretoria Station [Source: Google earth 2018]

In Pretoria station in Bosman Street, the Gaubus is immediately outside when commuters exit the Gautrain station. This distance is close enough for smooth switches between the Gautrain and Gaubus for commuter convenience purposes, and the system functions well. The Central station (A Re Yeng) on Skinner Street is approximately 800m away from the Pretoria station (Gautrain/ Gaubus) as shown on Figure 6.9. Therefore, the planning of the FUPT in this location indicates that all stakeholders involved in the planning process considered integrating the A Re Yeng, Gautrain and Gaubus spatially in order to make the movement of commuters easier (Mbatha and Gumbo 2018).

6.3 INTERVIEW FINDINGS ANALYSIS

Interviewing is one of the most important techniques to collect data, as a researcher can gather views of some of the important role players involved. Figure 6.10 indicates the feedback from the interviews conducted with officials and commuters.

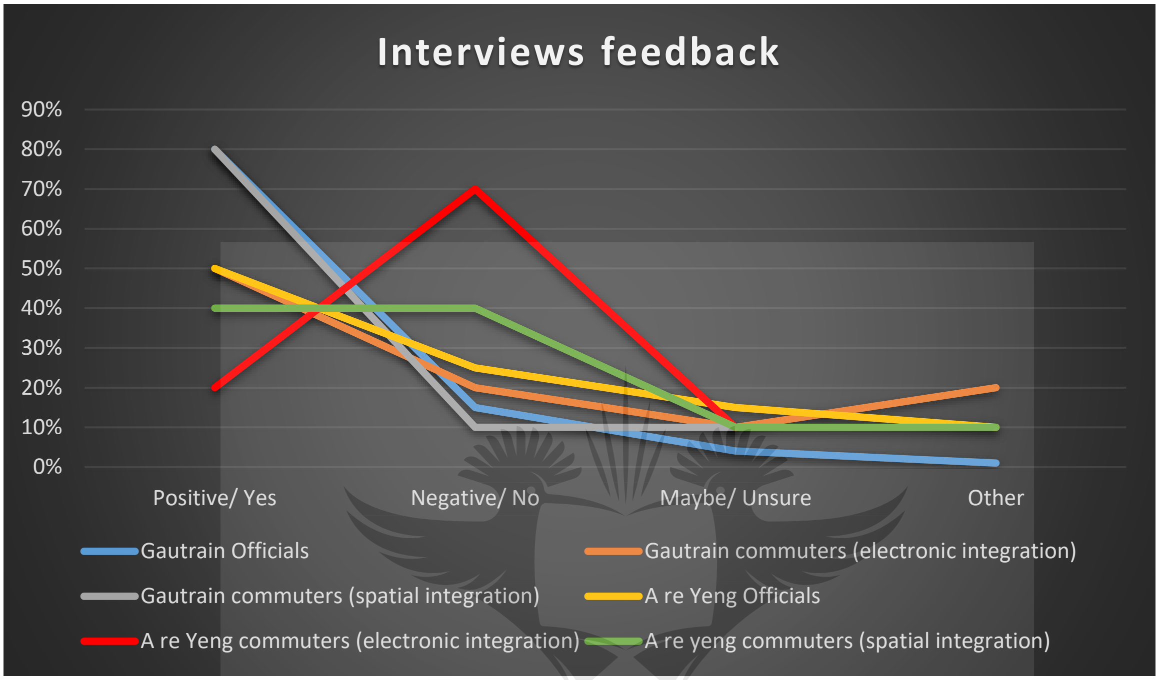

Figure 6.10: Interviews feedback [Source: Mbatha & Gumbo 2019]

About 80% of Gautrain/ Gaubus officials gave a positive response regarding both physical and electronic integration. Officials indicated that Gautrain stations are next to Gaubus stations or bus pick up spots. This strategy makes the system more efficient and reliable. Further, officials highlighted that the Gautrain/ Gaubus services operate electronically. For fare collection, only an e-smart card is acceptable to board the Gautrain and Gaubus. There are also numerous platforms for information distribution such as online information and timetables found at all Gautrain station. The online application distributes information for both the Gautrain and Gaubus. Approximately 50% of Gautrain/ Gaubus commuters interviewed shared positive views regarding the services provided by the system. Commuters indicated that information distribution is good; both Gautrain/ Gaubus are at the stations corresponding to the time provided. The payment system is always online at the counters and there is provision of alternative machines for loading money into the e-smart cards. Gautrain/Gaubus commuters are positive towards integrated UPT services as they indicated that it creates seamless travelling. Commuters do not encounter challenges when they switch from Gautrain to Gaubus, as most stations are 100m or less apart from one another. Approximately 10% of the Gautrain/Gaubus commuters, agree that integrating the two systems (Gautrain and A Re Yeng) could benefit commuters of both systems as they are within a good walking distance at certain locations.

Accordingly, A Re Yeng officials are positive about the services provided. Approximately 50% of the responses indicate that commuters have access to information about time schedules. Maps are provided at the A Re Yeng stations for commuters to plan trips properly, and there is provision of information on the A Re Yeng website online. Consequently, officials indicated that bus fare collections are electronic using e-smart cards deployed through tag in and tag out at the bus stations. About 25% of responses were negative indicating that there are challenges on the road such as traffic congestion resulting in the bus delays. On a few occasions, the system of loading money on the e-smart card goes offline due to system maintenance, which restricts commuters to load money on the e-smart cards. Further, officials highlighted that the routes serviced by the busses are mostly the busier routes. Hence there are potential routes extensions planned to increase the A Re Yeng bus services to other locations in the City of Tshwane.

About 70% of A Re Yeng commuters gave a negative feedback that both payment systems and information distribution is inadequate. Bus arrivals at the stations do not correspond to the bus timetable schedules provided. This can be frustrating for commuters as they are not able to use the A Re Yeng at that moment, and commuters must use alternatives to get to their desired destinations. Spatially, 40% feedback from the commuters was positive. Commuters indicated that A Re Yeng transports them to the desired locations around the CBD. These were mostly from the University of South Africa (Unisa) students and residents residing and working in the City of Tshwane. About 40% of the feedback from commuters indicated that A Re Yeng does not go to the desired locations and integrating it with Gautrain/Gaubus is not going to make much of a difference, as the routes that are used by both systems do not service their locations. Approximately 10% of A Re Yeng commuters are unsure about the positive change made by the integration of A Re Yeng and Gautrain/ Gaubus. However, they feel like it is a good initiative, as on some occasions such alternatives are necessary for travelling to other locations.

6.4 CHAPTER SUMMARY

The City of Tshwane has the presence of innovative FUPT services, which include the Gautrain, Gaubus and A Re Yeng bus. Regarding the spatial aspects of the location of stations and stops, in each Gautrain station there is a Gaubus stop/ station. On some locations there is physical integration between the Gautrain, Gaubus and A Re Yeng busses, and these locations include the CBD and Hatfield, allowing commuters to switch between the transport modes smoothly and seamlessly. Further, it has been identified that these locations service high income and working-class areas. With the spatial connectivity identified between A Re Yeng, Gautrain and Gaubus, integration of these two systems can be a possibility

CHAPTER 7: STATE OF ELECTRONIC INTEGRATION AND SOCIAL MEDIA DATA ANALYSIS FOR FORMAL URBAN PUBLIC TRANSPORT SYSTEMS IN THE CITY OF TSHWANE

Commuter's views regarding a certain mode of Urban Public Transport (UPT) are important as they assist in identifying needs and wants of commuters, which enables the UPT operators to have information about how to strengthen that certain mode. Collecting such information requires social media platforms, as commuters are not asked questions or to partake in some sort of a survey, but they just post different kinds of views based on individual experiences. With technology advancement, this sort of data can be used in various ways for analysis purposes. A software such as ArcGIS is deployed to assist with the analysis by identifying locations that have low, adequate and high commuter concentrations to be able to predict areas that need attention of innovative UPT services where possible future extensions could be made.

7.1 INTRODUCTION

This chapter looks beyond physical integration and towards electronic integration. Information distribution is important to keep commuters updated with the information concerning a certain mode, and payment methods bring significant elements in ensuring smooth operations in public transport. Consequently, social media is one of the important aspects of data collection for any phenomenon, as it allows individuals to pose views and concerns. For this study, the data collected from the social media was used through different kinds of analysis. Kriging interpolation and focal statistics was used in order to identify areas that have most commuter concentrations in various locations for the A Re Yeng, Gautrain and Gaubus. These two methods of analysis were both used to ensure that the results received from each technique were aligned to the others to achieve correct results. Further, word cloud was used for a direct analysis of social; media data through identifying most frequent words used about the concerns and views raised by the commuters of the BRT system and Gautrain system.

7.2 INFORMATION DISTRIBUTION TO THE USERS

Information distribution to commuters is important in UPT services, as it assists commuters with planning for trips. In line with this, information provided to commuters needs to be correct and if there are changes commuters need to be updated (Mbatha and Gumbo 2017). Up-to-date information for customers retains the current users and attracts more ridership.

7.2.1 Gautrain/Gaubus information dissemination

Gautrain/ Gaubus have innovative ways of information provision to commuters, and different techniques are deployed.

Figure 7.1: Gautrain information distribution [Source: Mbatha & Gumbo 2017]

Gautrain is one of the FUPTs with good information distribution services globally. Figure 7.1 presents the information distribution by Gautrain to commuters. The Gautrain has an online application that shows the real time information of the Gautrain/ Gaubus, and the information provided is mostly correct. The Gautrain is always on time in the station, departs exactly on the time given and gets to its destination as provided on the timetable. For individuals who cannot access the information online, there are printed timetables in all platforms to update commuters. Consequently, there are electronic machines in all the stations that a commuter can use to check the real-time information of the Gaubus/Gautrain (Mbatha and Gumbo 2017). Further, the use of Real Time Public Information Display Systems (PIDs) are a part of the Gautrain services, as they show the departure times and stops of the next train as well as the location.

7.2.2 A Re Yeng information provision to the commuters

The information provided must be precise for commuters to trust the public transport services. Commuters must always be informed about changes and delays taking place or which are to take place.

Figure 7.2: A Re Yeng information dissemination [Source: Mbatha & Gumbo 2018]

Information distribution in all A Re Yeng stations is available. Accordingly, on the online page of the A Re Yeng there is information provided of buses operating times. Public Information Display Systems are deployed in all the stations which show the arrival and departure times of the bus. Figure 7.2 also indicates how commuters can make their trip. There are different route maps provided at the stations and where switches between modes of transport are allowed depending on which A Re Yeng bus a commuter is using. With the A Re Yeng, it is difficult to track real-time information, as the system has no online application, but there are timetables in all stations provided which in most cases are not reliable (Mbatha and Gumbo 2017).

7.3 GAUTRAIN/GAUBUS AND A RE YENG PAYMENTS SYSTEM

The development of electronic fare collection technologies records currently considerable progress in many types of payments, including the application in transport. Use of new technologies in UPT contributes to higher customer satisfaction, smoother movement of passengers and increases the efficiency of collection of fare compared to the current payment method (Olivkova 2017). The introduction of the electronic payment systems has assisted with the availability of great amounts of e-smart card data, which can be used to analyze current travel patterns and to predict the effect of structural network changes on future public transport usage.

7.3.1 Gautrain/ Gaubus payment system

These two modes of UPT use the same e-smart card to board the Gautrain or the Gaubus, and they are compatible with each other both spatially and electronically.

Figure 7.3: Gautrain system payment method [Source: Mbatha & Gumbo 2018]

The use of e-smart cards for applicable fare payment by commuters in UPT operations is a method that is used globally. COT innovative FUPT services have adopted the same technique to manage and operate the fare collection which is also convenient for customers. The Gautrain/ Gaubus both use a smart card called the Gautrain Gold for payment as shown on Figure 7.3. To load the money on the smart card there are counters at all stations, and there are alternatives in order to manage long queues as there are machines used by individuals to load money on their e-smart cards. Securities are found at all stations for necessary assistance (Mbatha and Gumbo 2017).

7.3.2 A Re Yeng payment system

The first BRT (Rea Vaya) system in South Africa used paper tickets for fare collection. This meant that commuters had to buy a ticket every time they used the bus or had to buy lot of paper tickets. The introduction of e-smartcards in South Africa's BRT system has ease the pressure on data collection by officials and fare operations. It has reduced the illegal paper tickets sold by people outside stations.

Figure 7.4: A Re Yeng payment method [Source: Mbatha & Gumbo 2018]

The A Re Yeng is another mode of FUPT that uses e-smart cards for fare collection in the COT, and there are four types of these smart cards. The first type is a Silver e-smart card which is used by normal adult class whereby rates are charged normally. The second is for people living with disabilities and students who use a green e-smart card, and a flat fee of only R7.00 is applicable for all trips on A Re Yeng. The third is a purple e-smart card for pensioners over 65 years old. They can get discounts when using the bus outside peak hours and travel free during eligible periods. The last type is a blue e-smart card used by pensioners between 60- 65 years old; this card qualifies for a 25% discount during eligible periods. With this smart card, there are numerous benefits when an individual load more than R60 on the card. For example, they receive more points which are converted to a free journey (Mbatha and Gumbo 2017).

7.4 KRIGING INTERPOLATION

This technique assists with the identification of areas where most commuters are located for the A Re Yeng, Gaubus and Gautrain using social media posts. It further identifies suitable locations for future extensions of these innovative FUPTs. Further, it is one of the important ways to identify hotspots and cold spots of commuter concentration. The index was used to show the cold and hot spots of commuter concentration using different colours.

7.4.1 A Re Yeng Commuter Posts

The A Re Yeng BRT system network is being implemented in several phases to provide an extensive high-quality integrated transport network which is stimulating and supporting social economic development. Social media data was used in the experiment to identify geo-location areas that are in demand for the system's expansion.

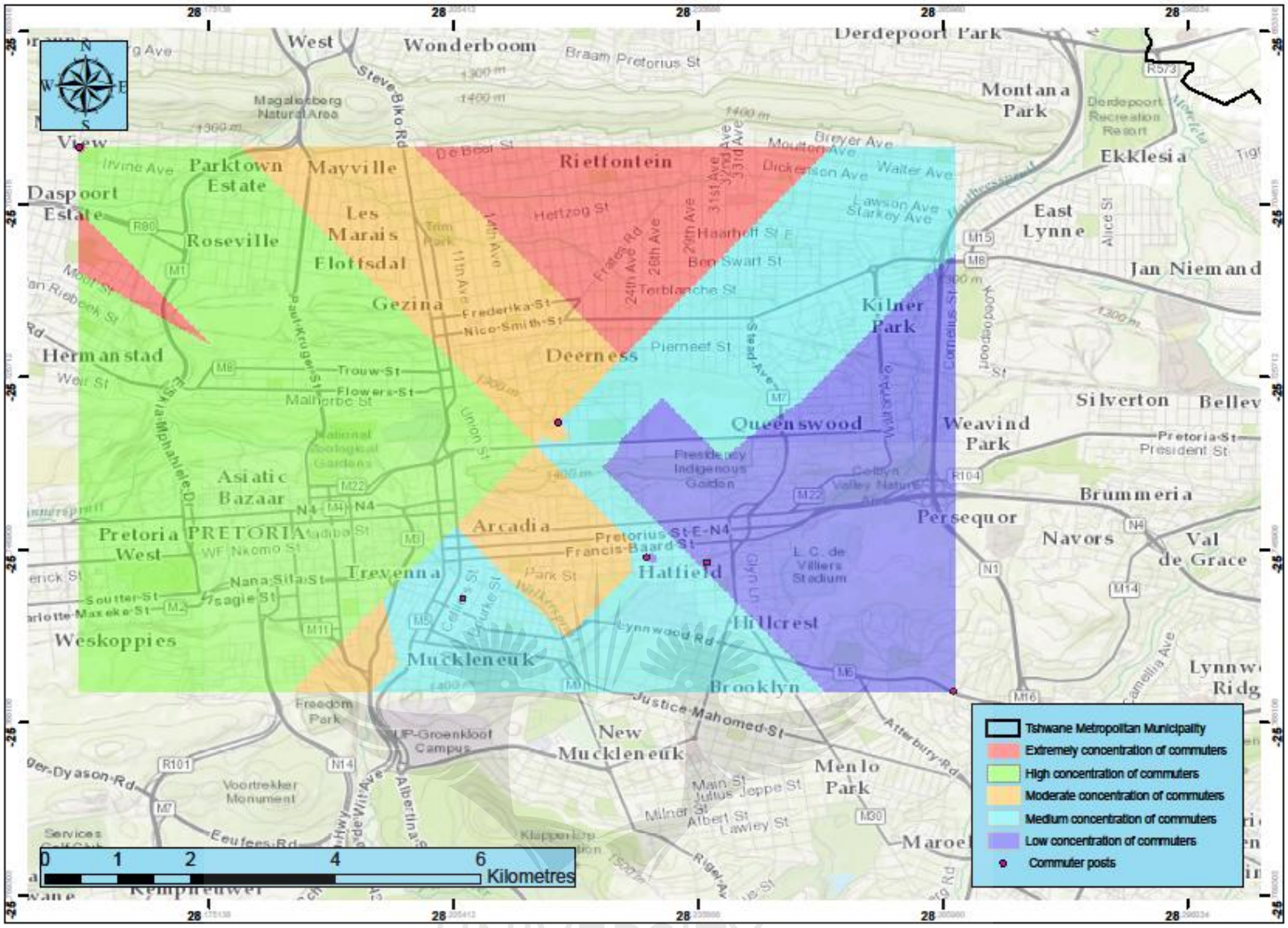

Figure 7.5: A Re Yeng commuter posts concentration [Source: Author 2018]

The A Re Yeng bus services do not have a great ridership, as it currently services most of the routes found in the CBD and not very far from the CBD. The map in Figure 7.5 indicates the A Re Yeng commuter post concentrations. This shows locations where (i)commuters post when they are waiting for the bus, (ii) when they are in the bus, and (iii) commuters location (live/ work/ places of interest etc.).There is an extreme concentration of commuters in Rietfontein, according to the analysis conducted. This is, followed by the CBD with a high concentration of commuters. This shows that many commuters of the A Re Yeng are located within these areas, and there is a low concentration of commuter posts in areas such as Hillcrest and Queenswood. These areas with low commuter's concentration posts are located when moving away from Hatfield where there are A Re Yeng bus stops.

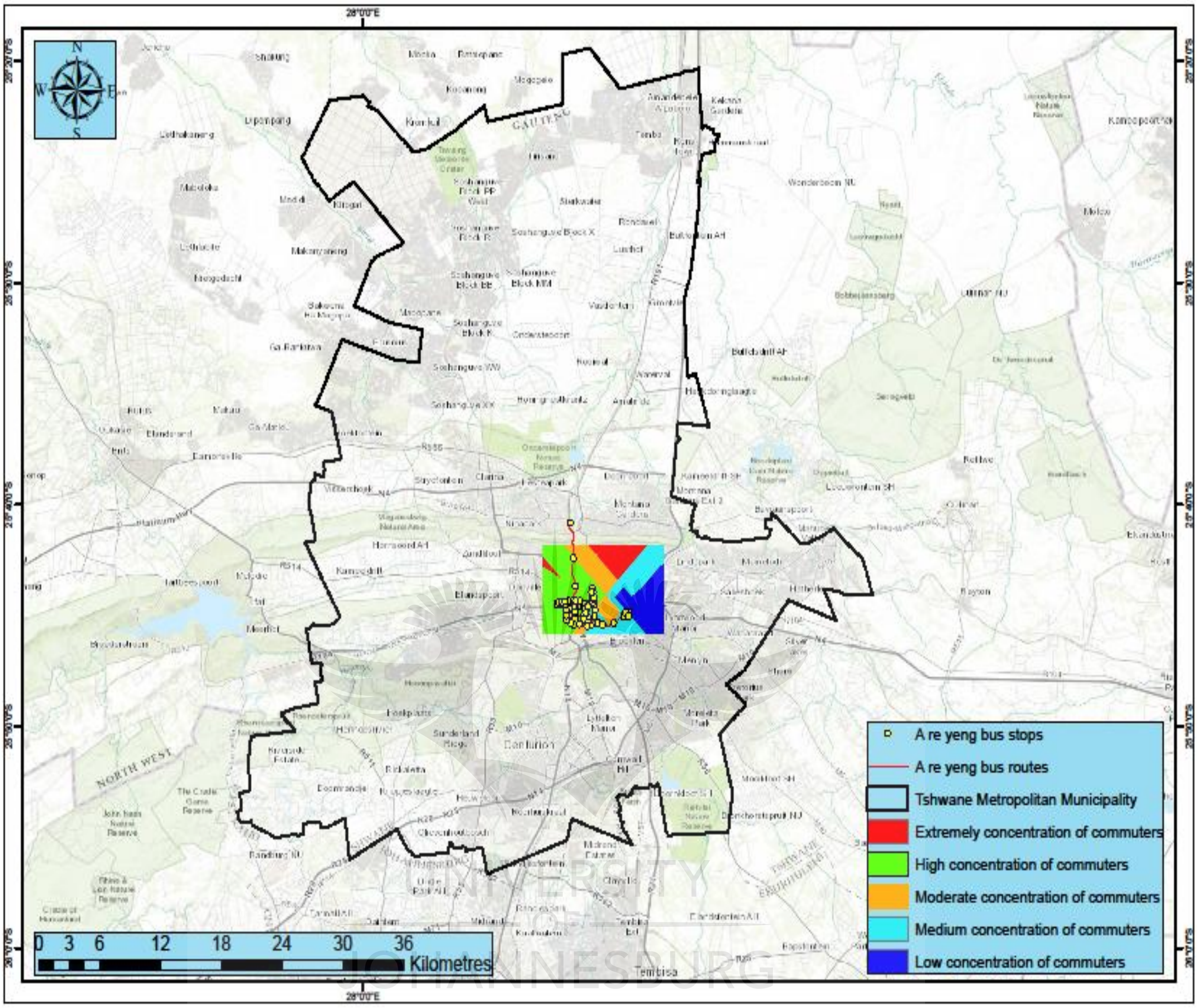

Figure 7.6: A Re Yeng commuter posts concentration in COTMM [Source: Author 2018]

The above map indicates commuter concentration of the A Re Yeng in the whole of the City of Tshwane. This shows that many users of the A Re Yeng are in the areas close to the CBD, to Hatfield and surrounds. In the entire city, there are less or no posts of about this mode of FUPT services. This does not mean that people in the City of Tshwane are less interested in the A Re Yeng. The challenge might be that currently areas serviced by this mode are from the CBD to Hatfield and around, and that this mode is still new in the COT.

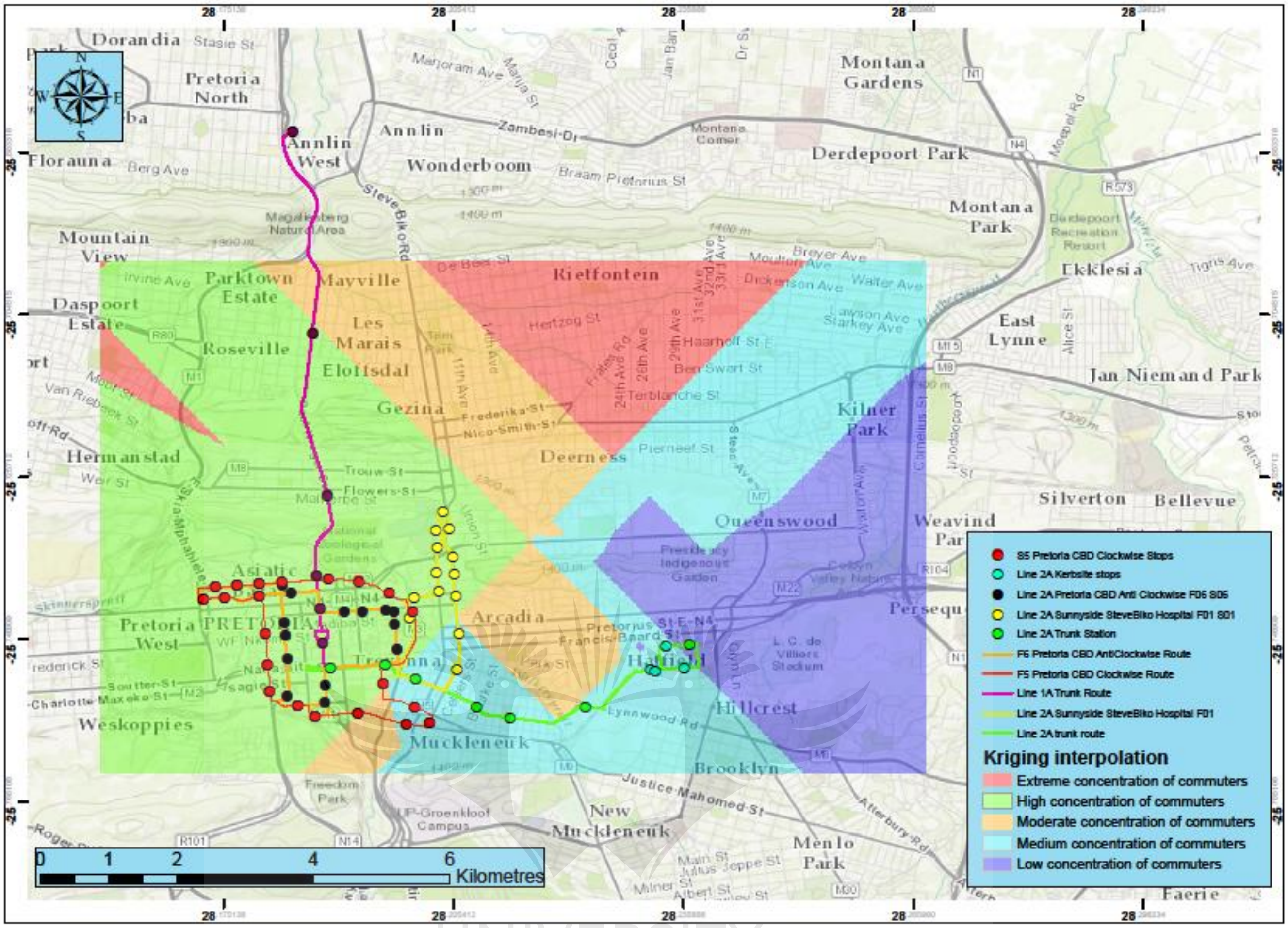

Figure 7.7: A Re Yeng commuter concentration [Source: Author 2018]

Figure 7.7 indicates where most of the A Re Yeng bus stops are located and the routes serviced. Rietfontein is one of the locations with extreme concentration of commuters; however, there is a lack of provision of the services. In the CBD, there is a high concentration of commuters and this location is serviced well. Therefore, this shows that most of the commuters interested in A Re Yeng are located around Rietfontein areas and the CBD. As shown on Figure 7.7, all the busses go to the CBD and then spread to other nearby locations. Within these locations, there are there are bus stations designated for switch in-betweens. Therefore, because one bus is designated to only operate on certain routes, commuters can make switch in-betweens from one bus to the next to reach the desirable destination

7.4.2 Gautrain system commuter posts

Effective commuter communication through the social media benefits commuters without them noticing that they are providing data that can assist with the provision of a more suitable urban public transport system.

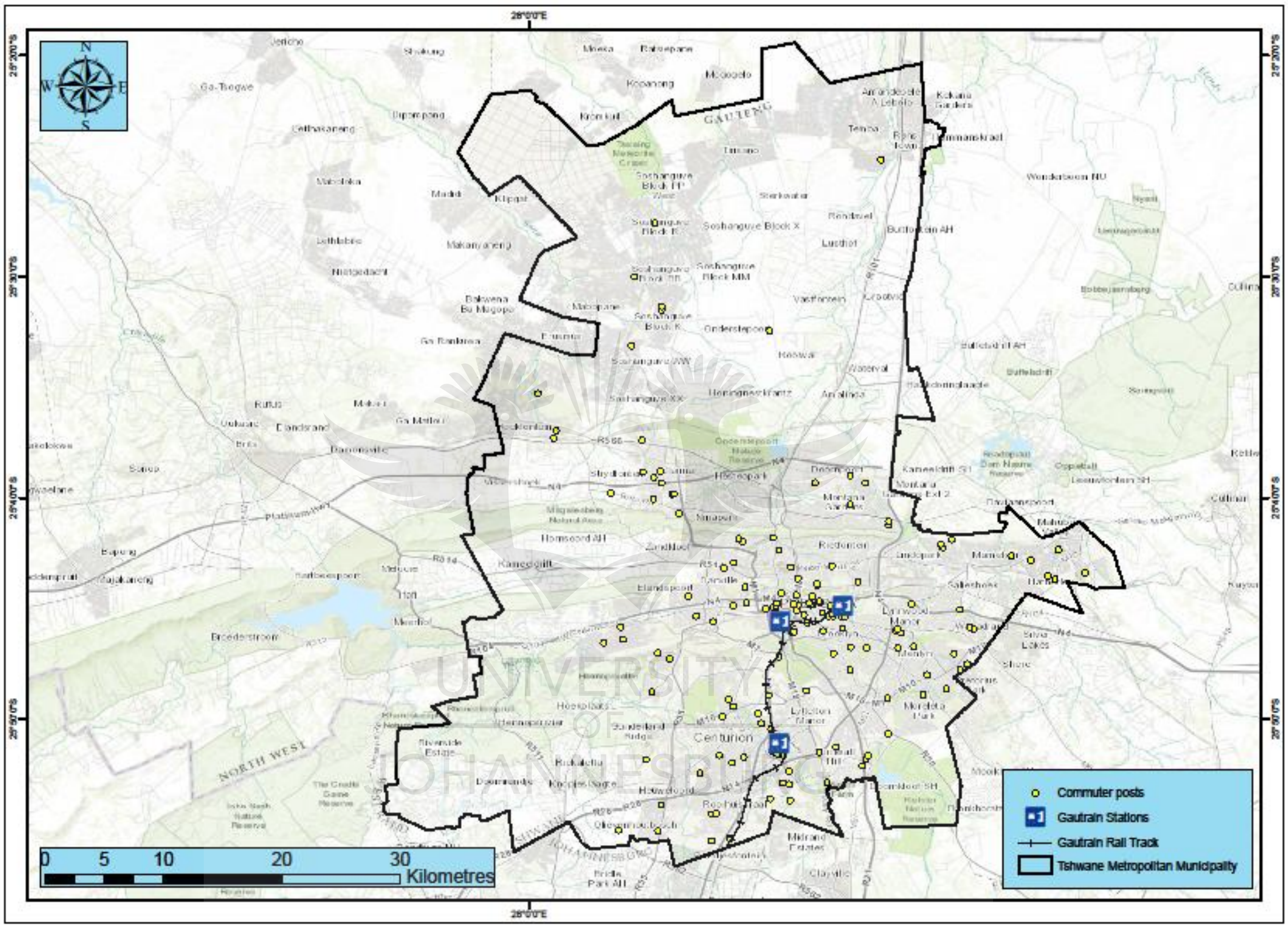

Figure 7.8: Gautrain commuter posts in the COTMM [Source: Author 2018]

Figure 7.8 shows the social media posts by commuters of the Gautrain and Gaubus in the entire COTMM. The above map shows that the commuters of this UPT system are found everywhere around the city. However, the social media posts differ from area to area. These posts reveal areas where commuters are situated when posting. Locations that do not have social media posts of the Gautrain and Gaubus show that there are less people interested in these modes of UPT or the area is not serviced by the Gautrain/Gaubus. This does not mean, however that they might not need such a service. In the locations where there are posts, this shows that there are individuals interested in these modes of UPT even if its 1% of the posts.

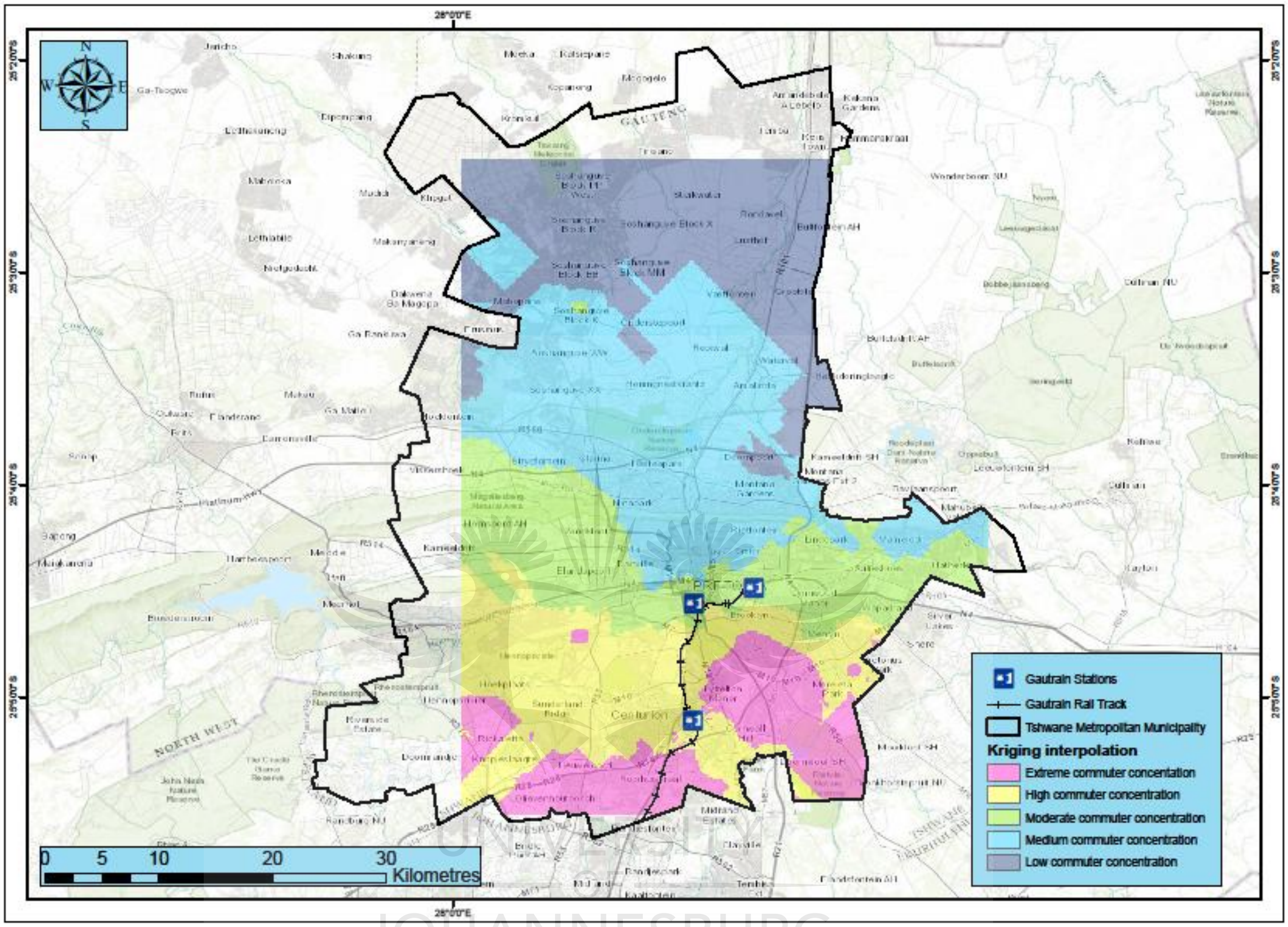

Figure 7.9: Gautrain commuter concentration [Source: Author 2018]

The above map shows the concentrations of Gautrain commuters in the entire COTMM. This is indicated in five different types. These are extreme, high, moderate medium and low commuter concentrations. Figure 7.9 shows that there are moderate concentrations of commuters in the CBD Gautrain station, the Hatfield Gautrain station indicated in green and a high concentration in the Centurion Gautrain station indicated in yellow. According to the social media post analysis, the commuters that use the Gautrain services are situated in the locations where there are no stations, thus indicating the need for provision of the service. Therefore, future extension of Gautrain stations must consider the areas indicated with pink with an extreme Gautrain concentration of commuters.

7.4.3 Integrated commuter posts

Integrated commuter posts broaden the idea of how the two systems can service the City of Tshwane. These show areas using x and y coordinates where Gautrain and A Re Yeng system posts are mostly done. Below it is the map showing all posts done by the two Formal Urban Public Transport (FUPT) systems.

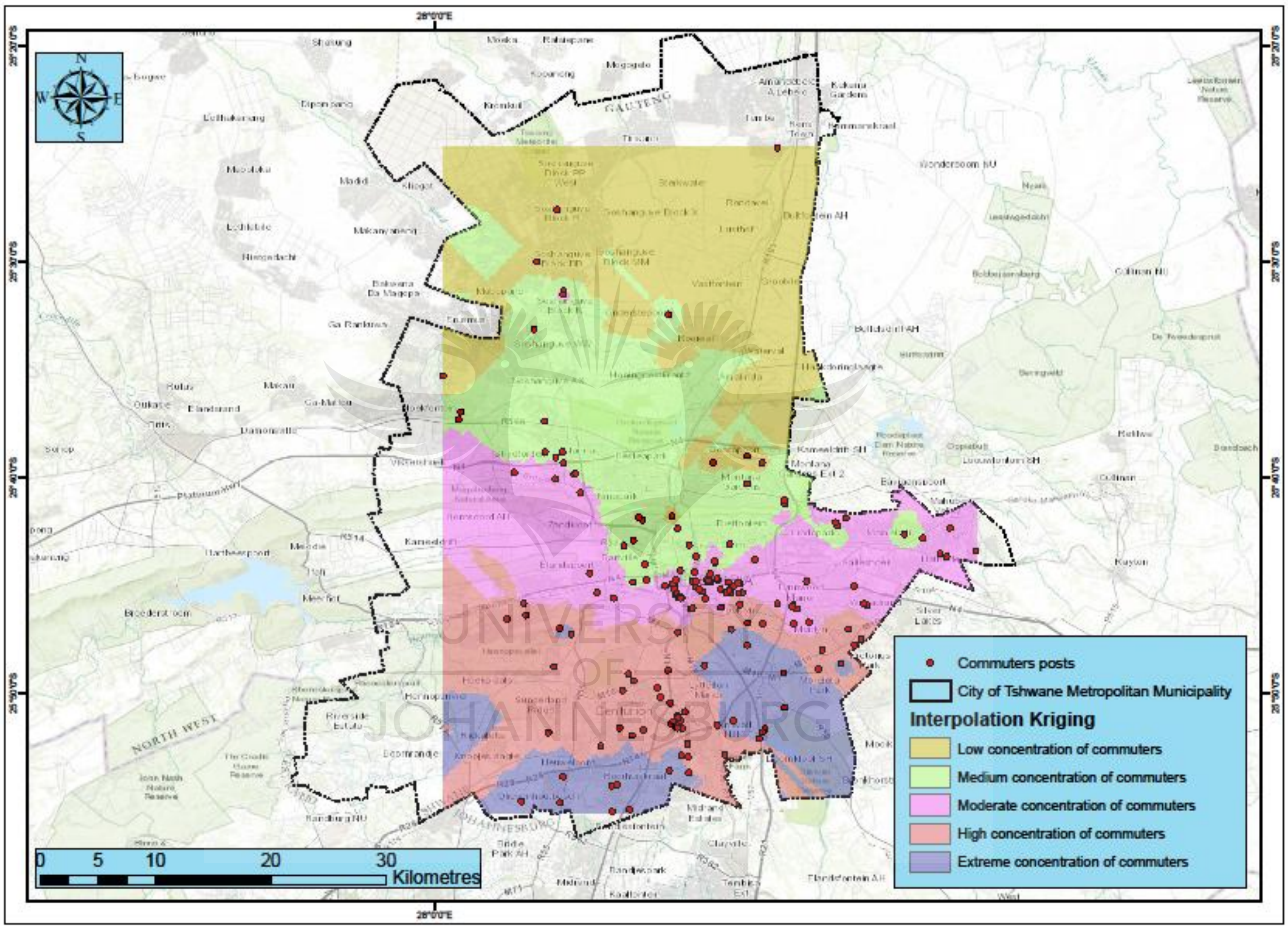

Figure 7.10: Gautrain and A Re Yeng Integrated commuter posts [Source: Author 2018]

The above map Figure 7.10 shows the overall posts of the Gautrain, Gaubus and A Re Yeng. It further shows the commuter concentrations in different locations. Interpolation using kriging analysis shows the lack of the two FUPT services in the north areas of the City of Tshwane, while in the south areas, there is a high concentration of commuters. Consequently, in the south of the City of Tshwane there is an extremely high concentration of commuters for these FUPT services, although the Gautrain, Gaubus and A Re Yeng is absent. Currently, these systems service a small portion of the City of Tshwane.

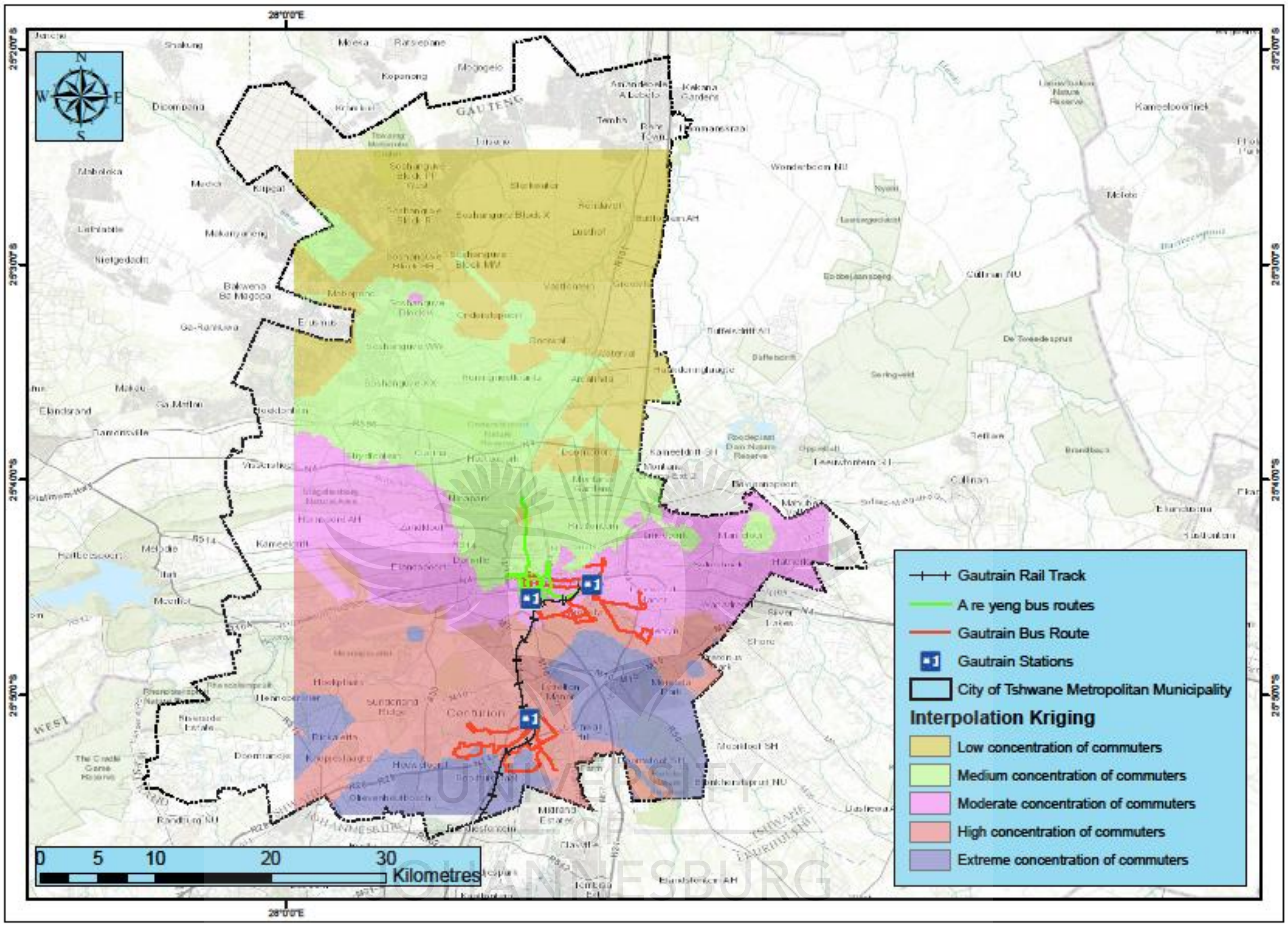

Figure 7. 11: Integrated routes Kriging Interpolation [Source: Author 2018]

Figures 7.11 reveals the commuter concentrations of Gautrain, Gaubus and A Re Yeng. The map clearly shows that the A Re Yeng bus service only operates in the CBD and Hatfield of the COTMM, highlighted in dark green. The Gaubus operates in the CBD, Hatfield and Centurion as well as the areas close to the Gautrain stations. From the CBD Gautrain station to Centurion Gautrain station there is a demand for Gautrain or Gaubus stations. As indicated on the above map, there is a high concentration of commuters in these locations. In some other areas in the north (Soshanguve), there is a moderate concentration of commuters indicating that there is a need for

FUPT services. Where the integration of the Gautrain, Gaubus and A Re Yeng exists, there are more areas covered in the CBD of the COTMM.

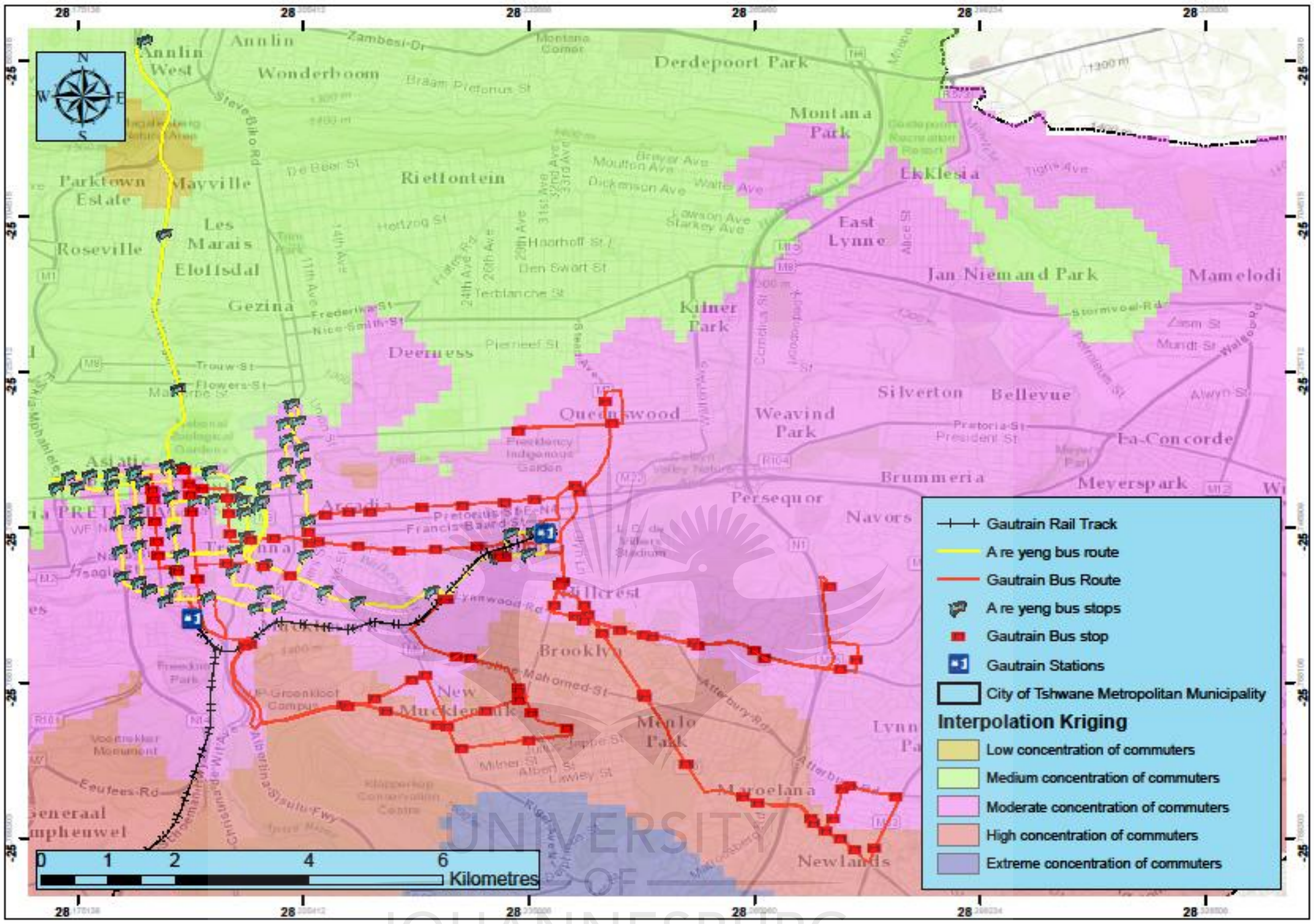

Figure 7.12: CBD movement of Gautrain and A Re Yeng systems [Source: Author 2018]

Figure 7.12 reveals a close view of the areas that are fully serviced by the Gautrain, Gaubus and A Re Yeng. The above map shows that where there is an extreme concentration of commuters there is no provision of the Gautrain, Gaubus and A Re Yeng services. Menlo Park, Maroelana, Brooklyn, Newlands, Muckleneuk and Groenkloof however have a high concentration of commuters, which have enough service by the Gaubus. From the CBD to the Hatfield Gautrain station there is an adequate service of the Gaubus, Gautrain and A Re Yeng. There are several bus stops and these areas have a moderate concentration of commuters. From the CBD to Annlin West there is a provision of the A Re Yeng bus with few bus stops.

7.5 FOCAL STATISTICS (NEIGHBOURHOOD ANALYSIS)

The application of focal statistics allowed more refined results of locations that have a higher to a lower commuter concentration within a 10hectares per block. This technique enables exact identification of which areas need special attention for future extensions and areas that need more busses or trains.

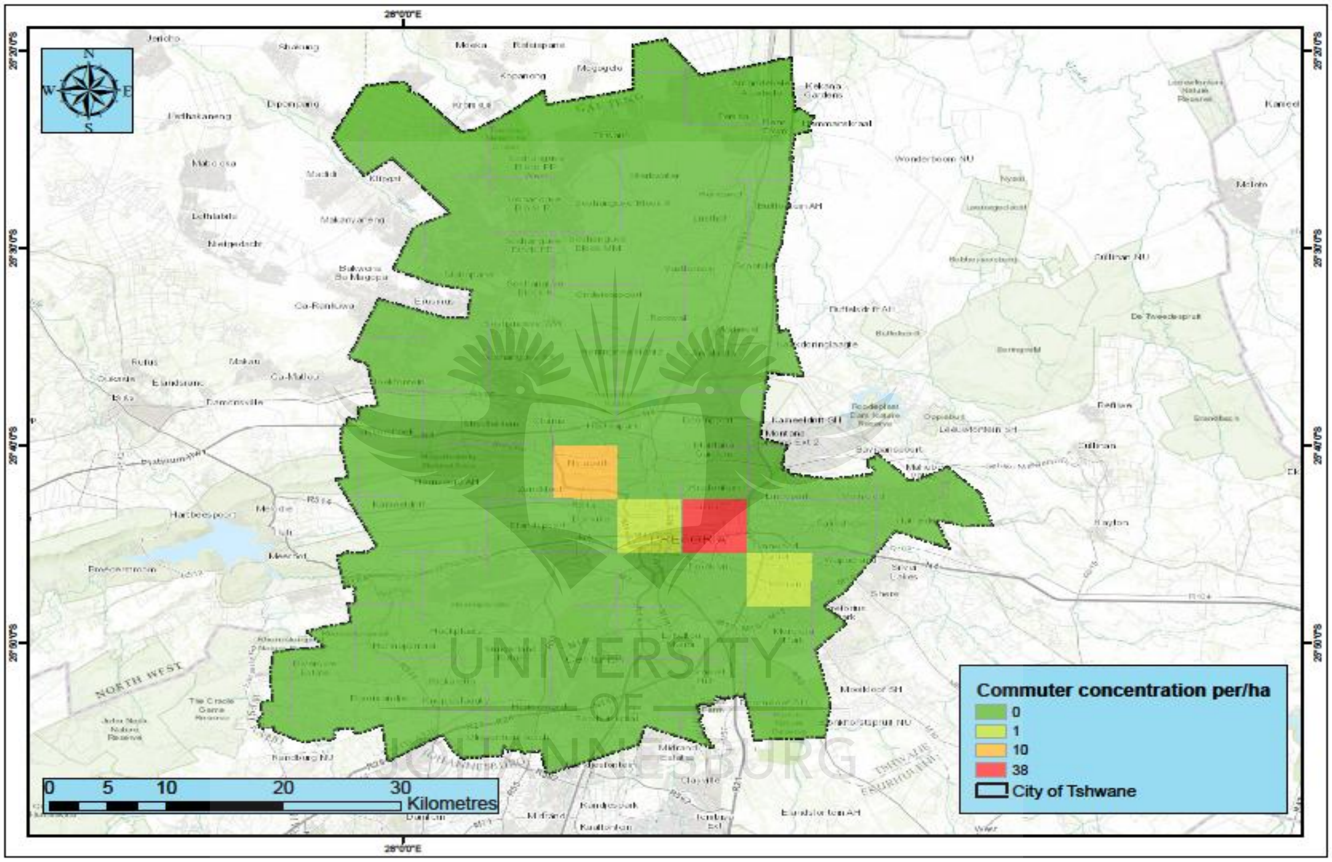

Figure 7.13: A Re Yeng commuter concentration (Focal statistics) [Source: Author 2018]

The above Table Figure 7.13 shows the commuter concentrations through analysed social media posts. All areas that have social media posts related to A Re Yeng are serviced by A Re Yeng buses. Hatfield has a high concentration of A Re Yeng commuters followed by Wonderboom with a moderate concentration. Consequently, all locations highlighted in green have no social media posts related to A Re Yeng, and these locations are not serviced by the A Re Yeng bus.

Integrated Social Media Concentration	Percentage of Social Media Posts%	Commuter Concentration
Green	0	Low Concentration
Yellow	14	Medium Concentration
Orange	20	Moderate Concentration
Red	76	High Concentration

Table 7.1: Focal Statistics A Re Yeng commuter concentration map [Source: Author 2018]

Figure 7.13 and Table 7.1 indicate that the A Re Yeng has fewer commuters. This is because it is a new system that was developed a few years ago. Further, as it is depicted from the map that low concentration areas lack the presence of A Re Yeng services. However, around the CBD, there is a certain interest showed by commuters indicating that if the services of the A Re Yeng could be expanded, more data could be generated to identify areas in need for this mode of transport through the neighbourhood analysis.

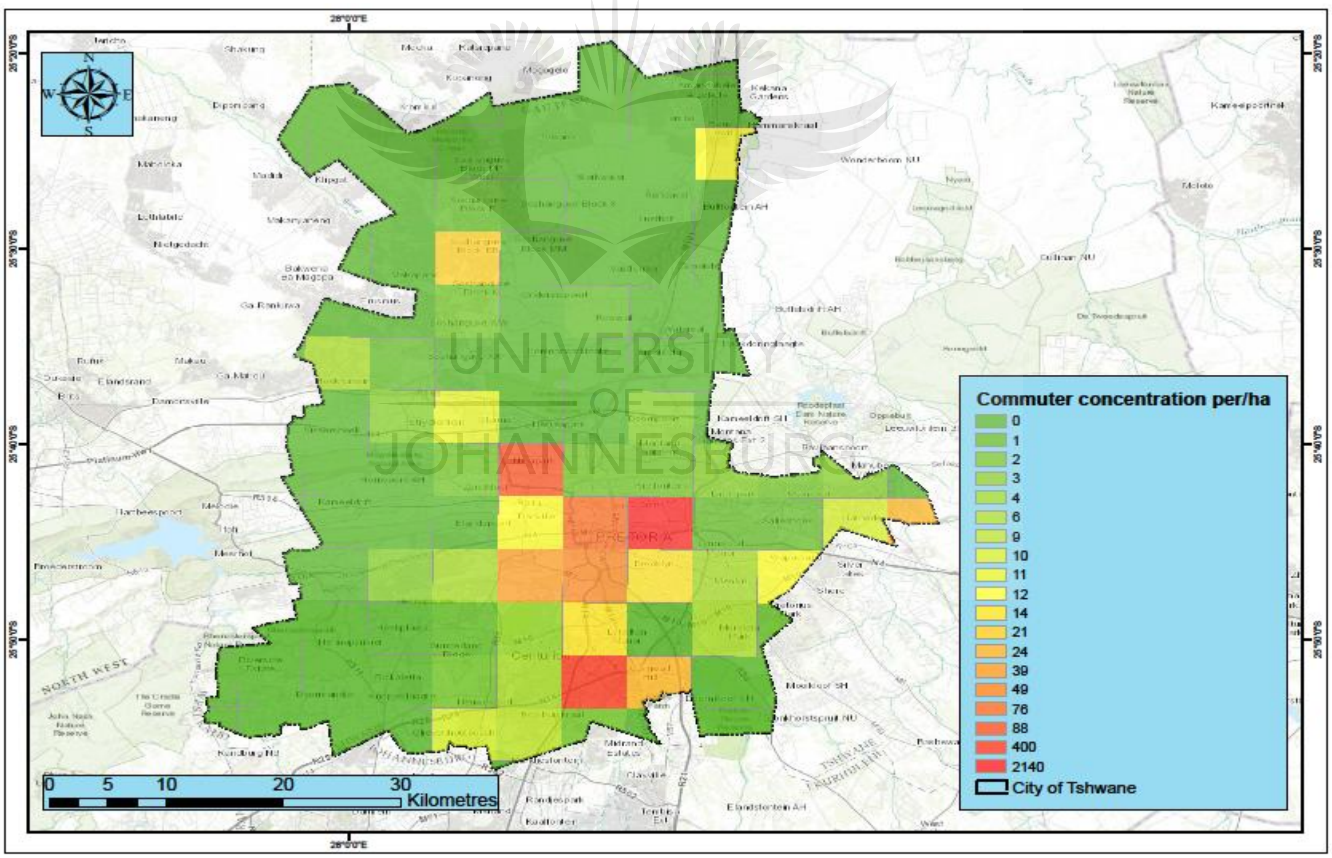

Figure 7.14: Focal Statistics Gautrain commuter concentration map [Source: Author 2018]

The above map Figure 7.14 reveals the analysis for the Gautrain and Gaubus. All locations highlighted in red and orange indicate that there is a high concentration of commuters. This includes include Hatfield, the CBD and Centurion. These locations mentioned are fully serviced by the Gautrain and Gaubus. The analysis indicates that the Gautrain and Gaubus services are in high demand in most sections of the City of Tshwane.

Gautrain Social Media Concentration	**Number of Social Media Posts**	**Commuter Concentration**
1	0-7	Low Concentration
2	9-14	Medium Concentration
3	21-49	Moderate Concentration
4	77-98	High Concentration
5	400-2140	Extremely High Concentration

Table 7.2: Analysis of Gautrain system commuter concentration [Source: Author 2018]

Figure 7.14 and Table 7.2 highlights that the entire City of Tshwane Metropolitan Municipality has commuters, and most areas that are not serviced by Gautrain system have a low and medium commuter concentration. With the development of train and bus stations in such locations the interest of commuters can be high. This could improve the data from the areas used for the analysis and identify more areas that need the services of this mode. This mode of transport can provide easy access to commuters for travelling to desired locations, as the network will spread to the entire city, and movement for commuters will be viable and reduce the use of informal public transport by providing more safe, effective and efficient FUPT services.

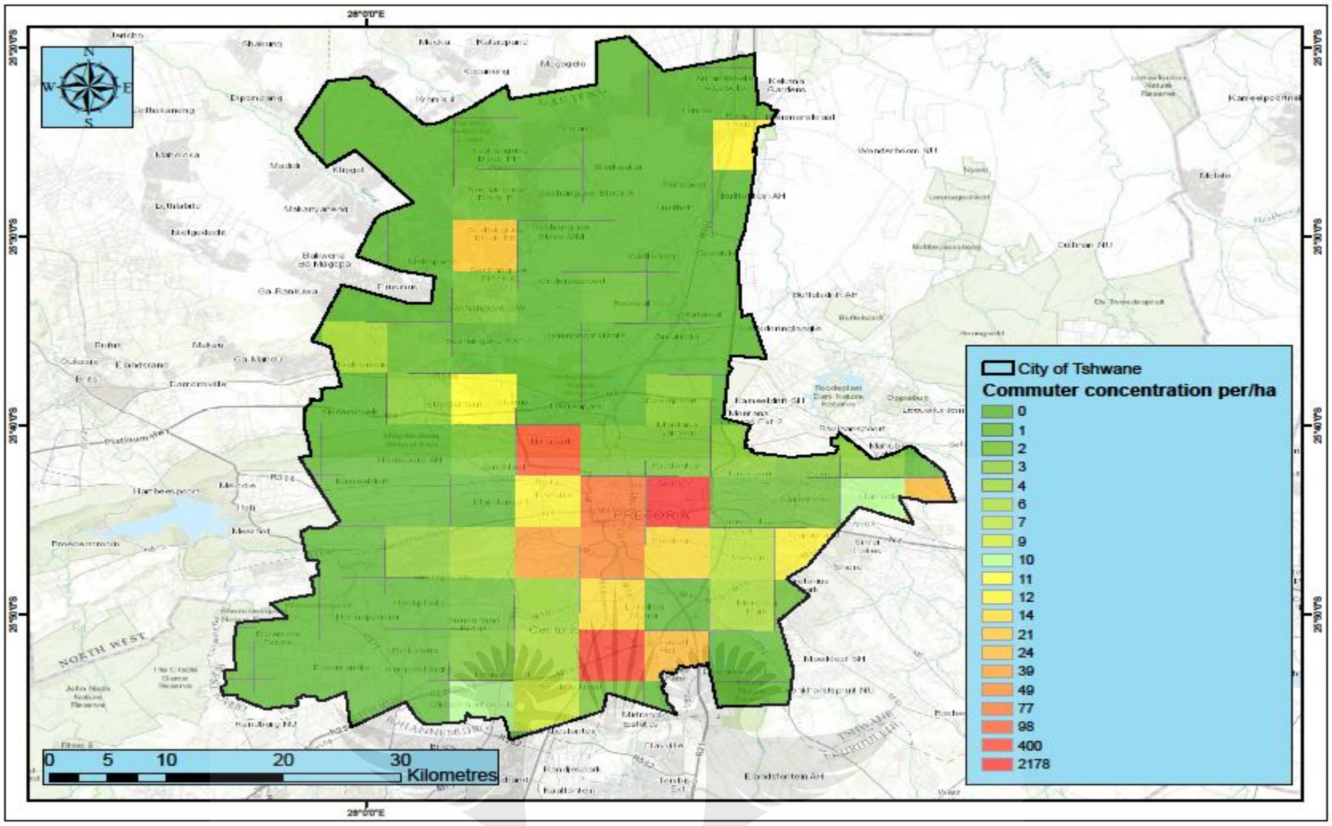

Figure 7.15: Gautrain and A Re Yeng commuter concentration [Source: Author 2018]

With an integrated commuter concentration, the number of posts increases which strengthens the data of the FUPT in the city. However, it can be noticed that more of the increase of commuter concentrations is around the CBD. Locations that are close by as the A Re Yeng system service dominates the CBD.

Integrated Social Media Concentration	Number of Social Media Posts	Commuter Concentration
1	0-7	Low Concentration
2	9-14	Medium Concentration
3	21-49	Moderate Concentration
4	77-98	High Concentration
5	400-2178	Extremely High Concentration

Table 7.3: Analysis of Gautrain and Rea Vaya commuter concentration [Source: Author 2018]

Figure 7.16 and Table 7.3 indicate the integrated analysis of the A Re Yeng and Gautrain systems. With the combined social media posts, the data indicates that the entire city requires attention for expansion of these modes of FUPT. However, the Gautrain social media dominates the above analysis. This this indicates that both systems can be integrated and service different routes. This will result in the network being expanded to the entire city through the shared responsibilities of providing a sustainable, efficient, safe and effective formal public transport system.

7.6 A PROPOSED INNOVATIVE URBAN PUBLIC TRANSPORT NETWORK (GAUTRAIN, GAUBUS AND A RE YENG)

The proposed network of FUPTs in the Gauteng province aims to improve the challenge of the growing problem of traffic congestion on the roads. The implementation of these two innovative FUPT systems is to get people out of their private motor vehicles and revitalise the Gauteng cities.

7.6.1 Gautrain proposed Urban Public Transport network

The Gauteng high-speed train has proposed to increase its network services with the addition of 150km of rail track to the existing 80km rail track. This wide expansion of the rail network will require twelve new high-speed trains (Gautrain Management Agency, 2013). The feasibility study conducted by the Gautrain Management Agency during the modelling made it clear that if nothing is done, the province will suffer to road congestion by the year 2037, as the number cars will double on the roads and travel 15 km per hour. Further, the increase will also affect peak-hour traffic, which will slow to 41km/h by 2025, and 23km/h by 2037. Therefore, chaos on the road will be a result, which indicates an urgent need for an increase in UPT options in the Gauteng.

Gautrain services has proposed the implementation of 19 Gautrain stations. The development of the new stations will be at Mamelodi, Hazeldene, Tshwane East, Irene, Samrand, Olievenhoutsbosch, Sunninghill, Fourways, the Cradle of Humankind, Lanseria Airport, Jabulani, Little Falls, Roodepoort, Cosmo City, Randburg, Sandton (second station), Modderfontein, East Rand Mall and Boksburg (Linder 2018). The feasibility study identified the following main links and stations of the Gautrain rail network extensions:

- On the link between Jabulani via Cosmo City and Samrand to Mamelodi, stations include Roodepoort, Little Falls, Fourways, Sunninghill, Olievenhoutsbosch, Irene, Tshwane East and Hazeldene.
- The link between Sandton and Cosmo City has a station at Randburg.

- On the link between Rhodesfield and Boksburg there will be a station at East Rand Mall and possible a link-up with the OR Tambo International Airport Midfield terminal development.
- A future link from Cosmo City to Lanseria Airport.

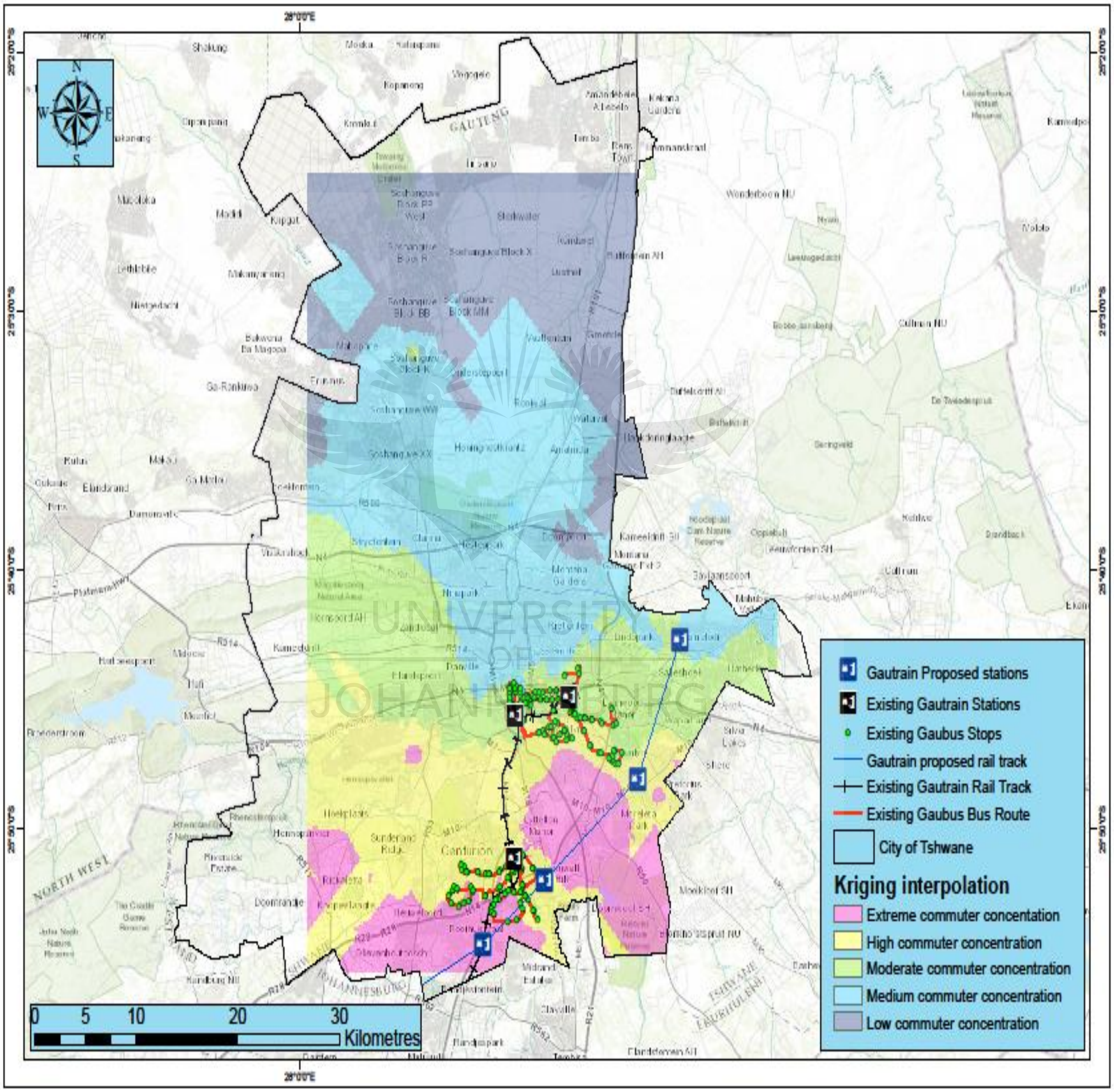

Figure 7.16: Existing and Proposed Gautrain Stations [Source: Author 2018]

The City of Tshwane has three Gautrain stations currently. These are Hatfield, Pretoria and Centurion. Figure 7.16 indicates the existing and proposed stations in the city namely, Mamelodi station on the top followed by Hazeldene station, then Tshwane East station not very far from Centurion station and Irene station. There will be seven Gautrain stations after the development of the proposed stations in Tshwane.

The proposed Gautrain stations will service the east and south east of the COT from the CBD (Pretoria and Centurion). Kriging interpolation estimations show that the new proposed Gautrain stations are located on the extreme, high and moderate commuter concentration areas. Mamelodi station is located on the moderate concentration area while both Hazeldene and Tshwane East stations are located on the high commuter concentration areas. Irene station is located on the extreme commuter concentration area. In the north and west of COT, Gautrain stations are yet to be proposed. Western areas of the COT have high, moderate and extreme commuter concentration. The northern areas of the COT have medium, and low commuter concentrations. According to the above kriging interpolation, there are no Gautrain services on medium and low commuter concentration areas.

7.6.2 A Re Yeng proposed Urban Public Transport network

The A Re Yeng is a BRT system developed in the City of Tshwane to improve the formal UPT services. The development of this system is to provide positive services for commuters such as efficiency, safety, comfort, reliability etc. However, there is a need for more routes to be serviced for the operation to be more efficient and give access to more commuters from different locations around the city.

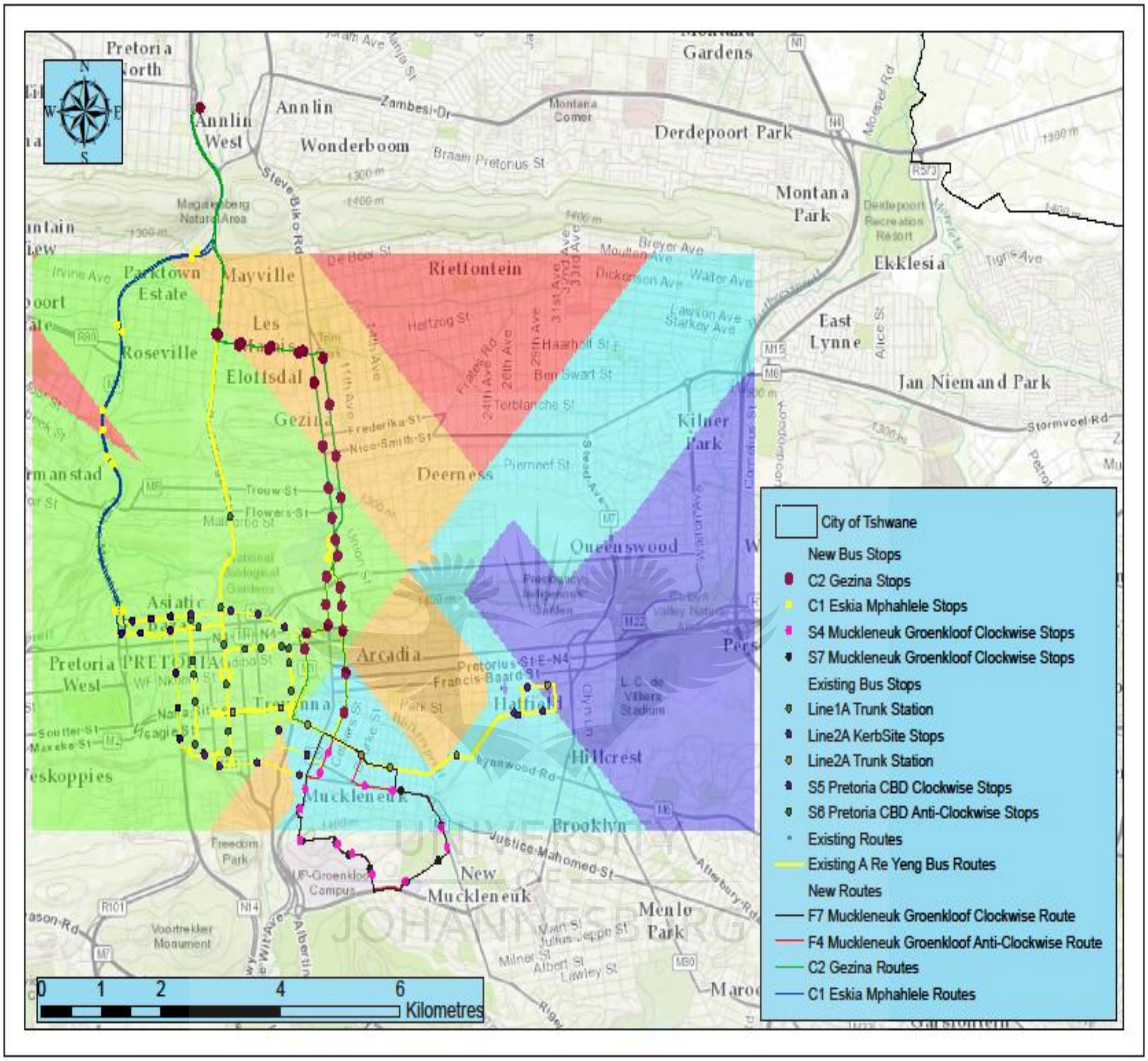

Figure 7.17: Existing and Proposed A Re Yeng routes and stops [Source: Author 2018]

The existing, A Re Yeng routes are highlighted in yellow and the new proposed routes are highlighted in different colours. The existing routes focus more on the Pretoria CBD to Hatfield stations, while the new proposed stations expand a little out of the CBD but not far from the CBD. The development of the C1 Eskia Mphahlele routes and stops will service Parktown Estate, Roseville, Herman Stad and Mountain View which are in high commuter concentration areas, and Daport Estate is in the extremely high commuter concentration areas. The development of the C2

Gezina routes and stops will service Les Marais, Eloffsdal, Gezina which are in the Moderate commuter concentration areas. The F7 and F4 Muckleneuk is in medium commuter concentration areas and is spreading out south east from the CBD to service areas far from the centre. Kriging interpolation has shown areas of concern according to the social media data used. The overlay method of kriging has shown that the new proposed routes and stops are within the areas that are more commuter concentrated. Further, more phases have been approved such as phase 5 that will service the Mamelodi areas to the CBD.

7.7 COMMUTER MOVEMENT PATTERN OF INNOVATIVE URBAN PUBLIC TRANSPORT NETWORK (GAUTRAIN, GAUBUS AND A RE YENG)

Organised distribution of UPT networks determine the efficient use of certain modes of UPT. The closer the UPT network is located to commuters and travels to commuter's desired destination, the more it becomes efficient. The UPT services are mostly located near to areas that will have large numbers of commuters to economic areas. Certain modes of UPT stations and stops are located according to means of affordability and a suitable strategy is designed for the movement of UPT modes to reach destinations.

Social media posts were used to identify the patterns of commuters from the locations of the posts to innovative FUPT stations/stops. This indicates areas where most of the users of certain modes are located, mostly because individuals cannot talk/post about something that they do not use. The origin and destinations of commuters were traced in the ArcGIS application through digitizing to create commuter pattern maps. This assisted with the identification of the locations where possible commuters are and the distance they travel to commute.

7.7.1 Gautrain and Gaubus commuter movement pattern

Kriging interpolation was used to indicate clear patterns of movement by commuters if there is a need for development of stations to be in areas that have high and extreme commuter concentrations. Further, in areas with low and medium commuter concentrations a few bus stop/ stations can be developed, as every area needs good FUPT services.

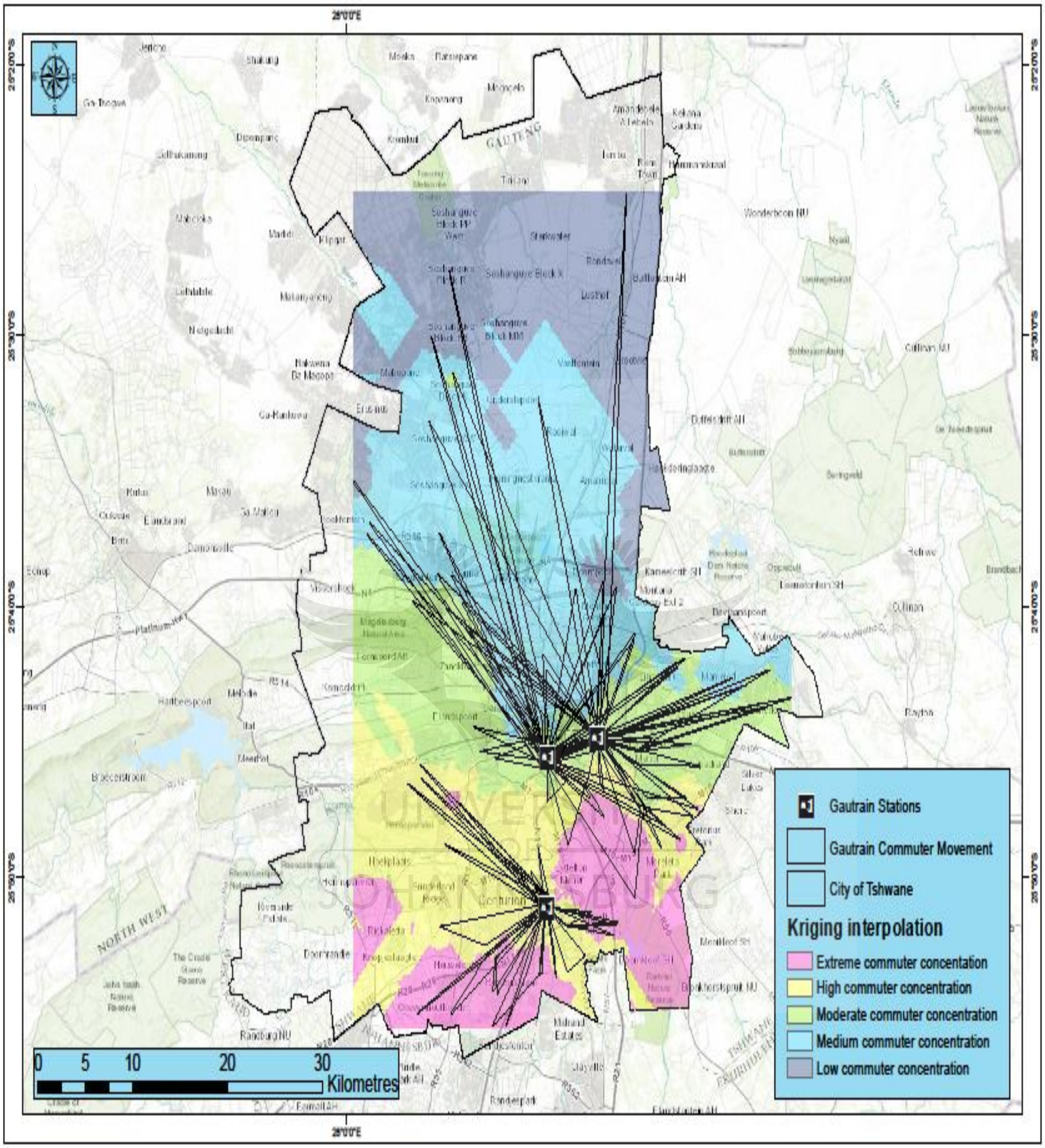

Figure 7.18: Gautrain and Gaubus movement pattern in Tshwane [Source: Author 2018]

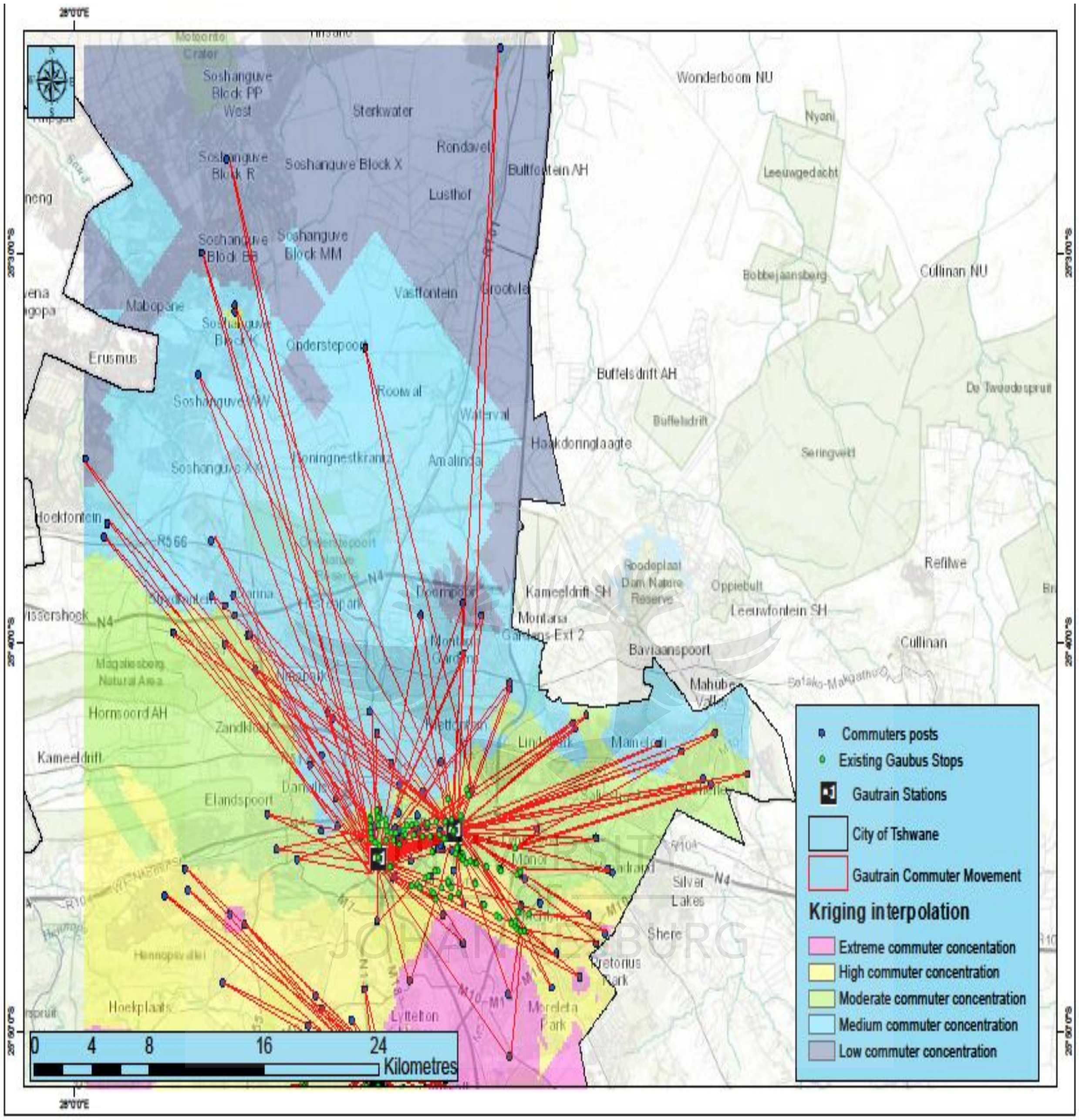

Figure 7.19: Gautrain and Gaubus movement of commuters [Source: Author 2018]

Figure 7.18 indicates the commuter movements of the Gautrain and Gaubus in the entire COT. Figure 7.19 indicates the commuter movements of Gautrain and Gaubus not in the entire COT but focusing on the Pretoria and Centurion Gautrain and Gaubus stations/stops. Commuter's movement on the above two maps shows that most of the posts are outside of the economic areas which are Hatfield and the Pretoria CBD. High income areas such as Garsfontein, Lynwood, Moreleta Park, and Menlo Park etc. have lots of posts indicating that this mode of transport is mostly used by individuals from high income areas. Consequently, townships in the City of Tshwane such as Mamelodi, Soshanguve etc are not serviced by the Gautrain/ Gaubus. However, there are commuter movement patterns from these locations, and commuters travel a long distance to use the Gautrain/Gaubus, indicating the need for their availability.

7.7.2 A Re Yeng commuter movement pattern

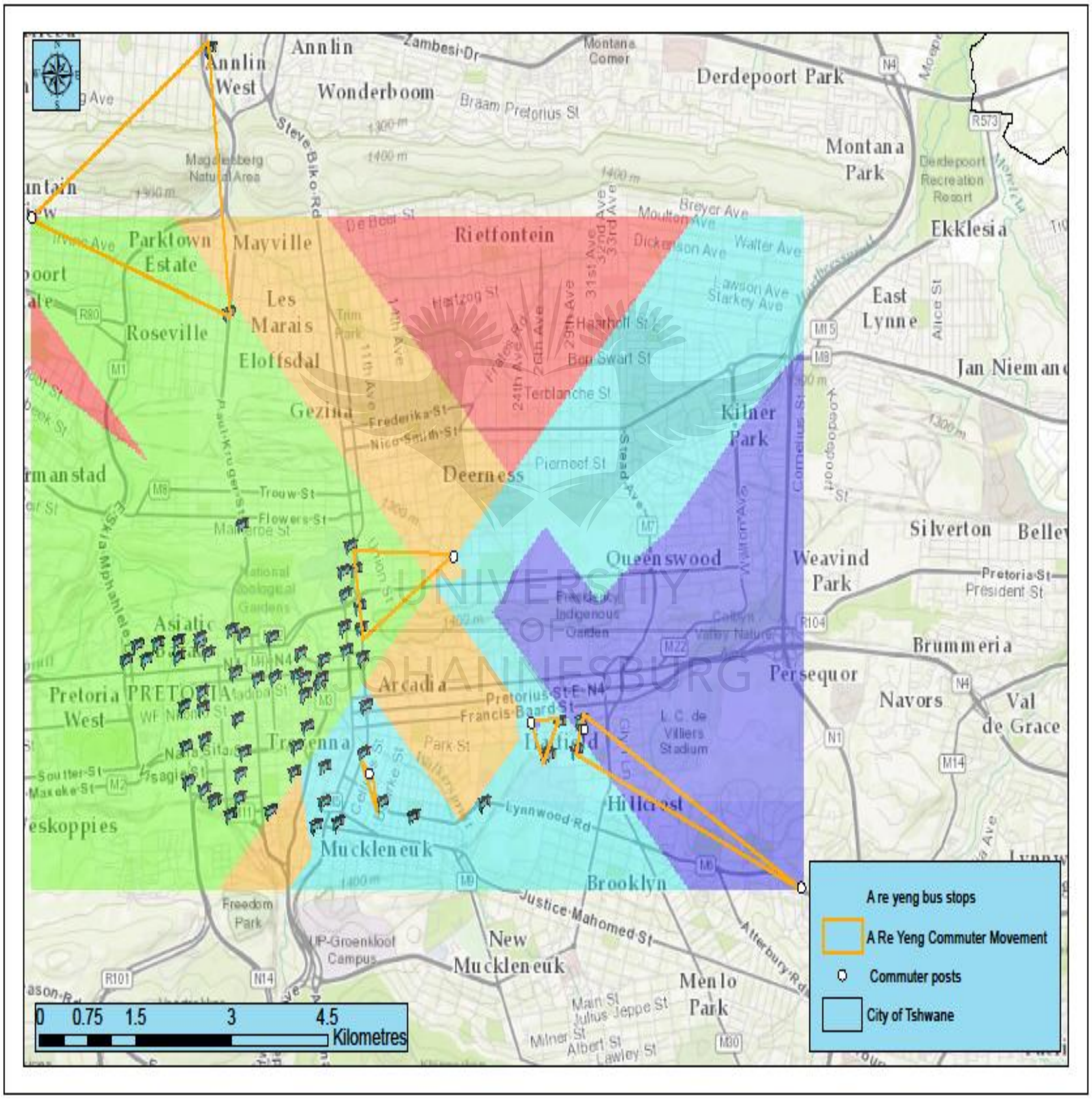

Figure 7.20: A Re Yeng commuter movement [Source: Author 2018]

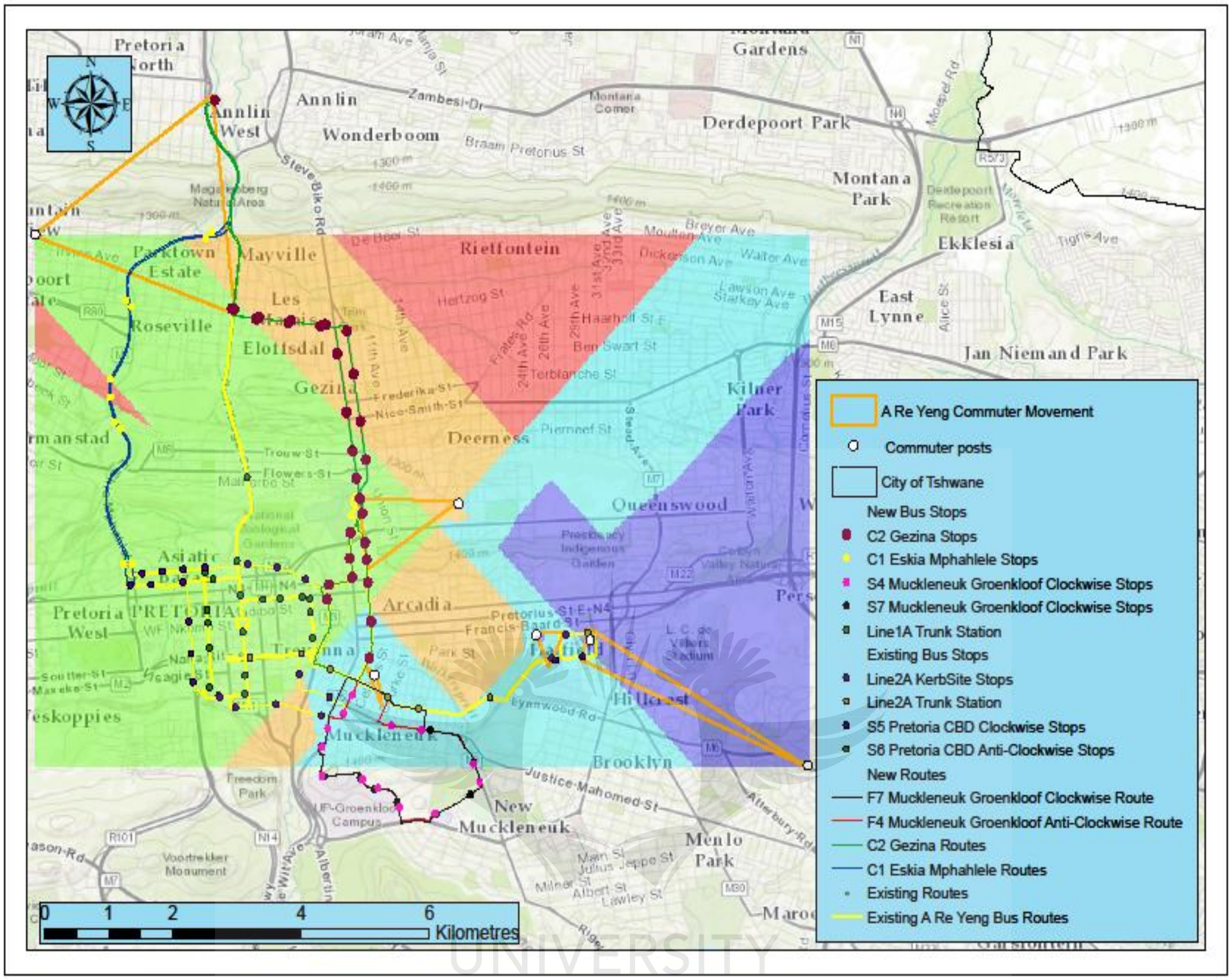

Figure 7.21: Integrated A Re Yeng routes and stops commuter movement [Source: Author 2018]

Figure 7.20 shows a map of A Re Yeng commuter’s movements before the new proposed bus stations. Figure 7.21 shows a map of A Re Yeng commuter’s movements with the existing and new proposed bus stations. As mentioned earlier in the chapter, the movement is derived from the commuter’s posts to relevant bus stations/stops. With the new proposed routes and stations, commuters from Mountain View and Daspoort can easily access the C1 Eskia Mphahlele stops as they are close by. Furthermore, commuters from Rietfontein where there is an extreme concentration of commuters will be able to access the proposed C2 Gezina stops as they are close by. However, there is still a need for bus stops and routes servicing the Rietfontein area. On the other hand, Gezina, Eloffsdal and Les which are in a high commuter concentration area will be serviced by the proposed routes and stations. This indicates a positive shift whereby movement of commuters will require short distance travelling from home to bus stations with more alternatives.

7.7.3 Integrated commuter pattern of Gautrain, Gaubus and A Re Yeng

This highlight areas serviced and not serviced by both the A Re Yeng and Gautrain systems as movement of commuters to stations/stops indicating the distance of commuters to stations/ bus stops. The purpose of this is to identify areas requiring immediate attention.

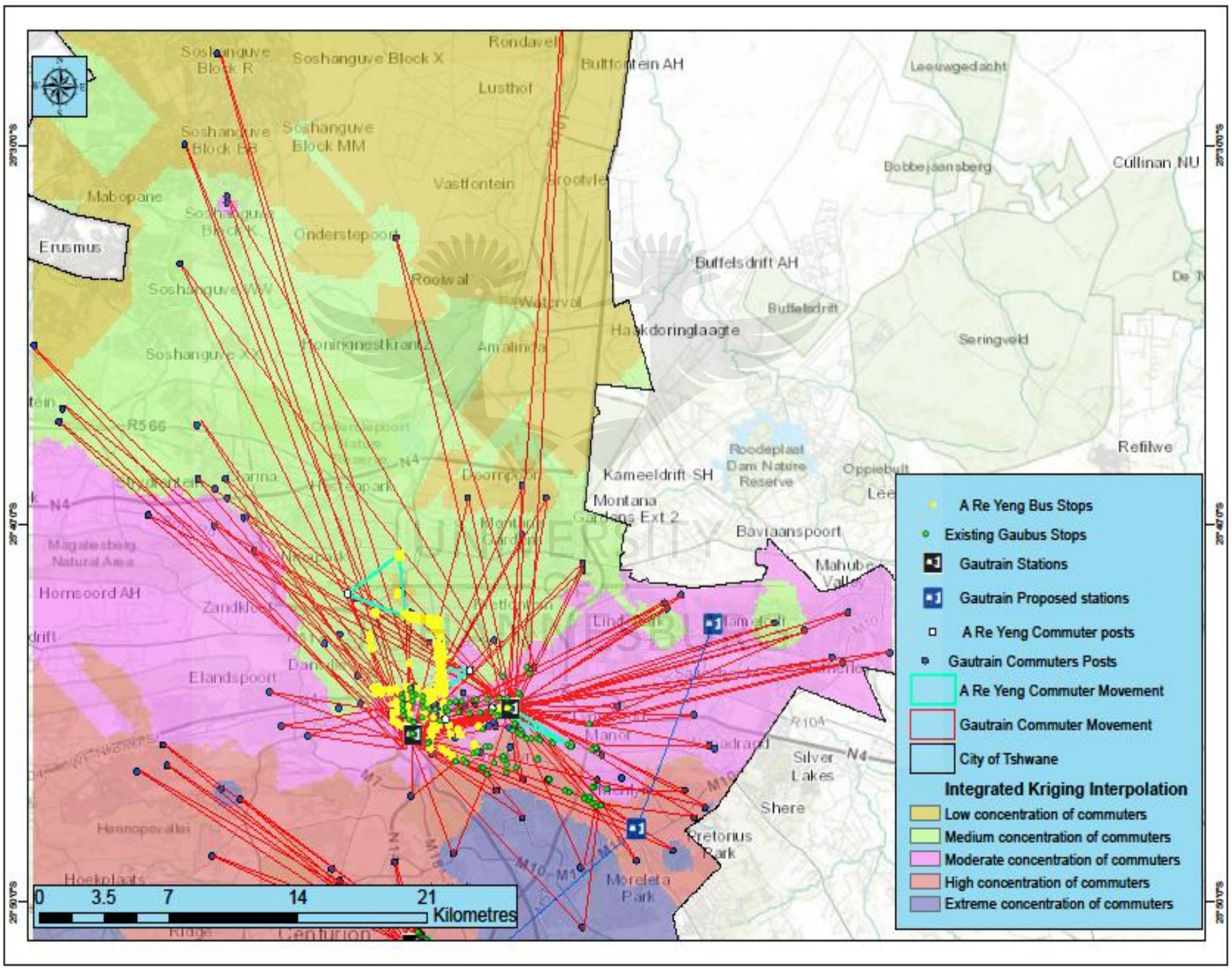

Figure 7.22: Commuter movement of Gautrain and A Re Yeng [Source: Author 2018]

Figure 7.22 indicates that the commuter movement of the Gautrain/ Gaubus is busier than the A Re Yeng. This is revealed by many social media posts of the Gautrain system received, as the above maps were created based on these posts. From these posts it can be observed that Gautrain system has many commuters. Furthermore, it is noticeable that commuters have alternatives routes that can be used to reach desired destinations by A Re Yeng or Gautrain.

Integrated Kriging interpolation was used for creating the above map. The proposed Gautrain stations are in Mamelodi and Tshwane East. The Mamelodi Gautrain station is in a moderate concentration of commuter's area, while the Tshwane East Gautrain station is located on a high concentration of commuter's area. From Mamelodi and Tshwane East both Gautrain and A Re Yeng commuters can use Gautrain to the CBD, However, if these systems were integrated, movement will be easier. The A Re Yeng dominates more on the northern side of the CBD, and there are more Gautrain commuters from the north travelling a long distance to use the Gautrain/ Gaubus who must pass A Re Yeng stations close by. However, with the integration of both the Gautrain and A Re Yeng, Gautrain commuters from the north can use the A Re Yeng stations close by and can switch in-between along the trips if necessary. These two systems dominate in the CBD areas and the locations just outside the CBD. This indicates the need for further stretches of these two systems all over the City of Tshwane. Integration of the A Re Yeng, Gautrain and Gaubus can therefore assist commuters to cover more ground in the City as these modes of the urban public transport can be assigned in different locations around the city. Further, these commuter movement patterns assist with identification of where new stations and bus stops can be developed.

7.8 WORD CLOUD

Currently, social media is one of the influential platforms through which different topics are shared for information distribution and communication. For this study, word art analysis assisted to identify words that are regularly posted by commuters related to the Gautrain, Gaubus and A Re Yeng bus. The analysis links the most used words to identify commuters' concerns.

7.8.1 Word count: Time series analysis

The Gautrain, Gaubus and A Re Yeng distributed more than 3000 social media posts every 6 months. All the posts are processed and the words that appear mostly become bolder than other words. The analysis indicate that these posts are not the same every 6 months. Very large amount of data is captured and analysed to give appropriate information that can be used to hypothesise the comments of the commuters in order to make sense regards to the study. The social media posts can be used to spread the word about how the services of these modes of transport are, and attract more users, further, assist on how the services can be strengthen. Consequently, it is easier for officials to identify challenges regards to the services provided when they raised than decisions made without noting concerns.

Figure 7.23: A Re Yeng Most used word June to December 2016 [Source: Author 2018]

During the period between June to December 2016, the most used words are A Re Yeng bus, new please, Road, services, Taxi, station and strike. This indicates that the concerns raised by commuters are the provision of A Re Yeng services to other roads, because other commuter’s desired locations are not serviced, and they are forced to use informal public transport (taxis). Therefore, they are pleading for new roads to be serviced by this mode and provision of stations in those locations.

Figure 7.24: Gautrain most used words June to December 2016 [Source: Author 2018]

During the period between June to December 2016, the most used words are Gautrain, bus out, wait more, time, take, taxi, uber, car, station, work. The analysis indicate that the concerns raised by the Gautrain/ Gaubus users are taking a taxi, uber and using cars after alighting from the station to reach desired destinations as some of the routes are not serviced. Further, most of the commuters use Gautrain/ Gaubus to go to work; however, they must wait more time than expected for the bus or train.

Figure 7.25: A Re Yeng most used word January to June 2017 [Source: Author 2018]

During the period of January to June 2017 most used words are A Re Yeng, strike, taxi, service, card, part, staff, busses, *hle* (please). This indicates that during this period, A Re Yeng commuters were affected by the bus strike taking place which forced them to use informal UPT such as taxis. The challenge is that taxis do not use smart cards but cash, as most commuters load weekly and monthly fare in their smart cards. Consequently, there is a need to increase the capacity of busses and staff, as the movement of transporting commuters is not efficient.

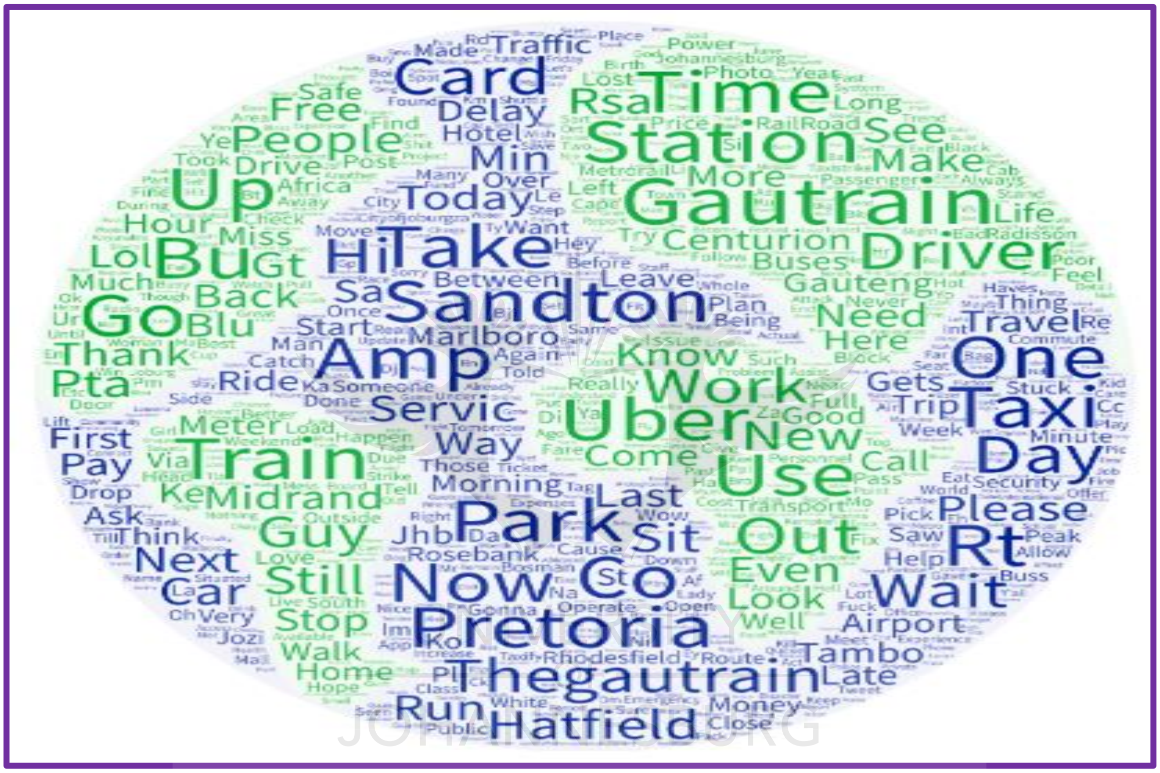

Figure 7.26: Gautrain most used words January to June 2017 [Source: Author 2018]

During the period of January to June 2017, the most used words are traffic, time, station Gautrain, taxi, trip, work, Pretoria, Sandton, Hatfield Park, service, need here. This indicates that during this period some of the commuter's conversations were positive as they were based on that. The Gautrain reduces delays, as it is not slowed by traffic when they use it to travel to work, home (Pretoria, Centurion, Sandton, Park etc.). Commuters reach their destinations in time. However, some of the concerns raised by the users are that when they reach their destinations at some stations, they must take an uber and taxi to get home.

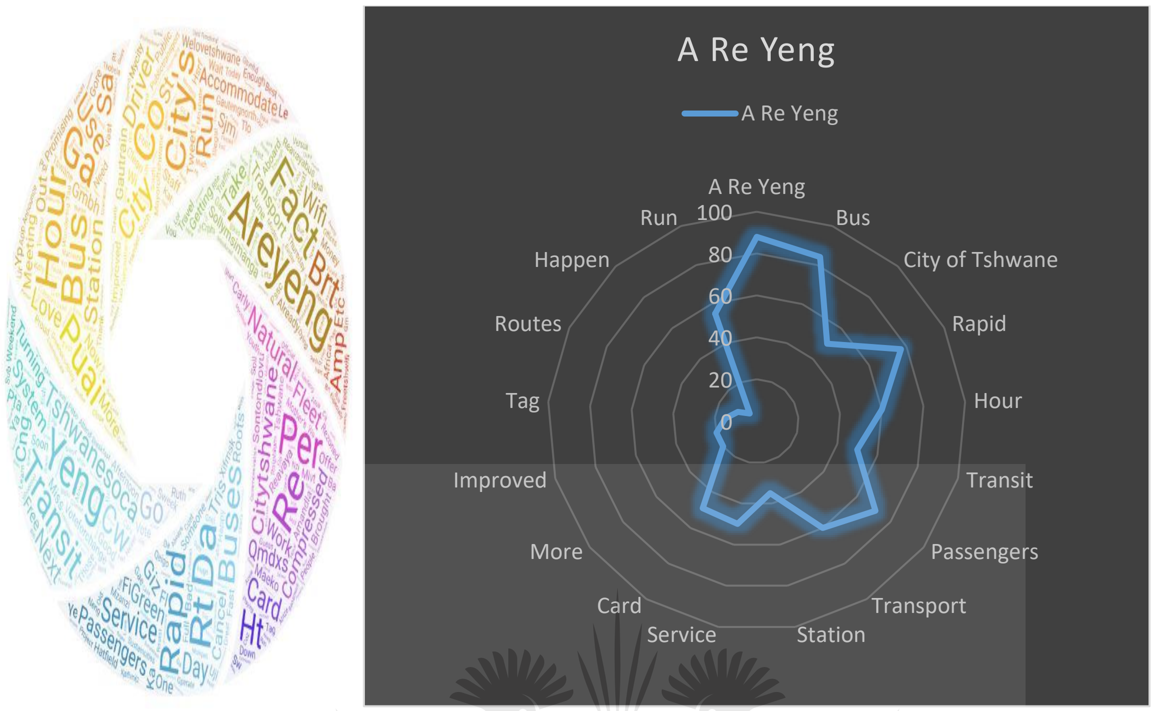

Figure 7.27: A Re Yeng most used words June to December 2017 [Source: Author 2018]

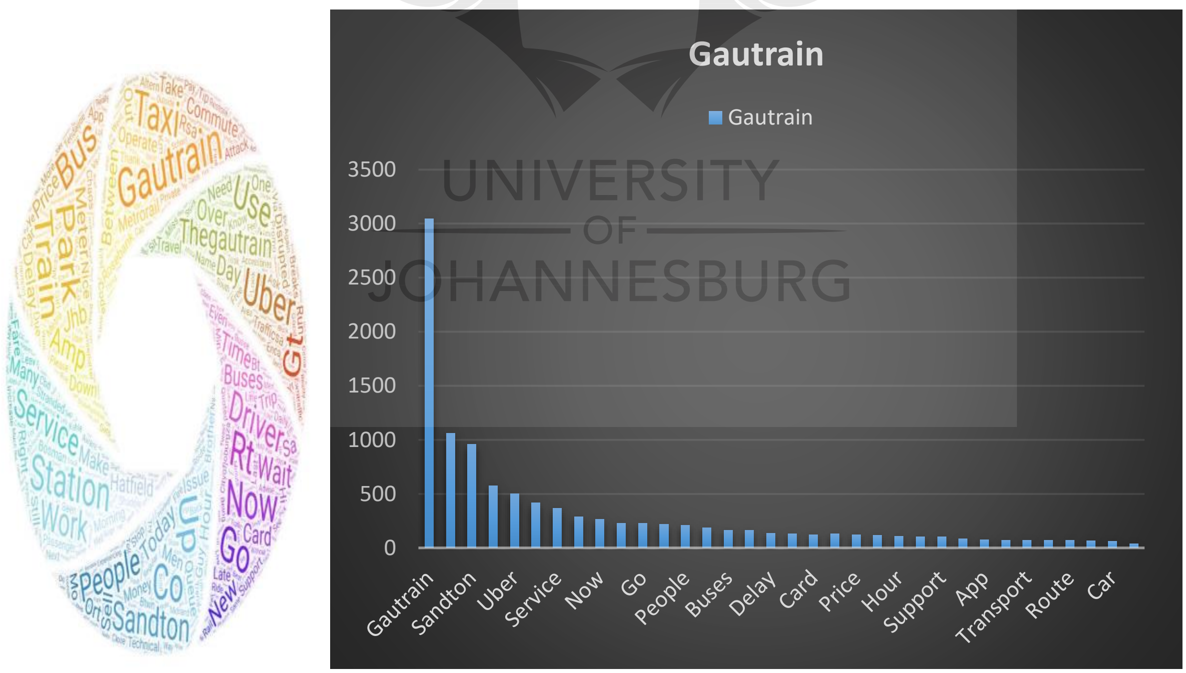

Figure 7.28: Gautrain most used words June to December 2017 [Source: Author 2018]

During the period of January to June 2017, most used words are indicated in Figure 6.28. This indicates that most of the commuters that use the Gautrain travel to Sandton, which is in

Johannesburg. Due to Gautrain and Gaubus not servicing other routes, commuters must use an uber. Further, the Gautrain has an online application that is used for information distribution in order to reduce delays when commuters reach the desired station and want to leave immediately to another or destination.

7.9 CHAPTER SUMMARY

Regarding electronic integration of these two systems, the chapter reveals that the Gautrain and Gaubus use one e-smart card for bus and train payments. Consequently, there is a good link in timetable scheduling between both modes of FUPT to reduce delays. The information is easily accessible through the Gautrain/ Gaubus application Similarly, A Re Yeng service has its own e-smart card for payment which cannot be used to board any other UPT mode. Information distribution, timetables are provided inside the stations and on the A Re Yeng website. However, the A Re Yeng, Gautrain and Gaubus are not electronically integrated regarding payment methods and information distribution. The use of kriging interpolation and Focal statistics (neighbourhood analysis) were used in this chapter to identify areas in demand for the Gautrain/ Gaubus and A Re Yeng services. The locations with high to low concentrations of commuters were highlighted together with localities serviced by Gautrain, Gaubus and A Re Yeng.

The commuter movement patterns were created by mapping to identify distances to be travelled by commuters in order to reach bus or train station. The analysis assisted with identifying locations that need attention, future extensions, and how the integration of these modes can strengthen the FUPT services. Further, the use of word cloud for both A Re Yeng and Gautrain system was deployed for the analysis based on the concerns raised by the commuters. The use of these techniques is important, as the analysis indicated that most commuters were concerned about the transport that they need to use from the station to home and the routes that are serviced by the Gaubus and A Re Yeng, These results therefore highlight the need for FUPT integration, as most commuters are forced to use uber and taxis.

CHAPTER 8: SUMMARY OF RESULTS, CONCLUSION AND RECOMMENDATIONS

Formal Urban Public Transport (FUPT) is important as it provides organized services to commuters and it is safe. When the FUPT system such as Gautrain and Gaubus is integrated both spatially and electronically, the movement of public transport becomes easy and convenient. Users rate reliable departure and arrival times as more important than journey time. As customers come to rely more on public transport, its reliability becomes more critical. Hence, improvements to reliability require enhancements to operations. Further, easy urban public transport payment methods and good information dissemination makes ridership more convenient with minimal delays.

8.1 INTRODUCTION

In the City of Tshwane, services of a BRT and Gautrain system are currently operating to service commuters and offer potential to deliver efficient, reliable service in an effective manner. These two systems of FUPT service different routes in the city. They operate separately; the Gautrain has its own customers. The Gautrain services such as mobile app and e-smart card (Gold card) can only be used for this system, and it is not connected to any other urban public transport services. The A Re Yeng (BRT system) services can only be used by its customers, and it is not connected to any other urban public transport mode. This creates a gap for commuters who might need to use both modes to reach their desired destination. In addition, disconnected urban public transport does not give alternatives for commuters to travel smoothly on numerous occasions. This sometimes results in commuters having to walk long distances after using a certain mode of urban public transport when in fact there are other modes travelling in their direction. Integrated formal urban public transport is a crucial factor to produce a sustainable FUPT services. Based on the research results, the chapter recommends areas that need further expansion and future study research areas.

8.2 SUMMARY OF THE RESULTS

Both results chapters indicate that the Gautrain/ Gaubus system is physically and electronically integrated. All Gautrain stations have Gaubus stops, but the Gaubus services certain locations and does not go deep inside Pretoria townships and many other areas. The Gautrain and A Re Yeng are spatially connected at the Hatfield station and Pretoria Central. The Gaubus and A Re Yeng are connected on some locations such as Hatfield, Arcadia, Sunnyside, Lukastrand, Pretoria Central, and Trevena. However, they do not service the same routes. As there is spatial integration on some locations, there is a need to continue with such direction and the introduction of electronic integration. Consequently, information distribution and payment methods for both systems are disintegrated

8.3 CONCLUSIONS

Prediction applications are globally used for planning purposes which assists identification of areas that can be digitally identified and gaps that need to be filled (Moyo 2016). Thus, a need exists for technologically advanced tools such as big data and ITS to link different public transport modes. Each study differs from another, as objectives differ. Hence the methods used to carry out the research by the scholars are not the same. Accordingly, the research objectives were based on integrating the Gautrain and BRT systems (electronically) in the City of Tshwane. It was important for the study to also focus on exploring the physical integration of Gautrain and BRT systems as the ability of commuters to switch between modes should be smooth, and platforms/stations should be close to one another. Further, methods were identified which are used for payment and information dissemination to commuters by service providers.

8.3.1 Conclusion on physical integration for Gautrain/Gaubus and A Re Yeng

The findings revealed that A Re Yeng currently services locations in and around areas close to the CBD. At least, two locations in the City of Tshwane which are physically integrated are Hatfield (Hatfield station) and the CBD (Pretoria station). In Hatfield, the Gautrain/Gaubus and A Re Yeng are close to each other. For example, the A Re Yeng and Gaubus are 25 metres away from each other. In the CBD, Gaubus is immediate outside when commuters exit the Gautrain station and Central station (A Re Yeng) on Skinners Street. This is about 800m away from Pretoria station (Gautrain/ Gaubus). Therefore, these locations are perfectly placed for integration to improve good UPT functionality.

8.3.2 Conclusion on integrated payment systems for Gautrain/Gaubus and A Re Yeng

The findings revealed that the Gautrain/ Gaubus and A Re Yeng use e-smart cards for payment. The Gautrain and Gaubus show that a bus and a train can use one e-smart card for payment without challenges in South Africa (Gauteng Province). However, it is a different case for the A Re Yeng and Gaubus/Gautrain to use one e-smart card, as they are different service providers. Nevertheless, in developed countries, it is possible for different service providers of public transport to use one e-smart for payment, and there are agreements that can be met in order to separate the payments.

Trips for travelling are charged according to the distance travelled by a passenger; the further the distance the higher the amount. There are various challenges with the A Re Yeng payment method. For example, when commuters want to load money on the e-smart cards for a journey(s), the system is offline. As well, the shortage of money loading counters to e-smart cards creates frustration for commuters. This forces them to take an informal mode of urban public transport such as taxi and on some occasions, queues are long which causes them to miss busses that they anticipated to take. Accordingly, the Gautrain/ Gaubus commuters are satisfied with the payment methods as there are alternatives of loading money in the Gold card for both modes.

8.3.3 Conclusion on integrated information dissemination for Gautrain/Gaubus and A Re Yeng

The findings revealed that the Gautrain and Gaubus use online applications to provide information to commuters. This makes it easy for commuters to know which train/ bus to take at a certain time and how to connect from one mode to the other. Consequently, the A Re Yeng bus service does not have an online application for information distribution. It only has a timetable on the website or in the bus station which is not reliable at most times.

8.4 URBAN PUBLIC TRANSPORT INTEGRATION MODEL

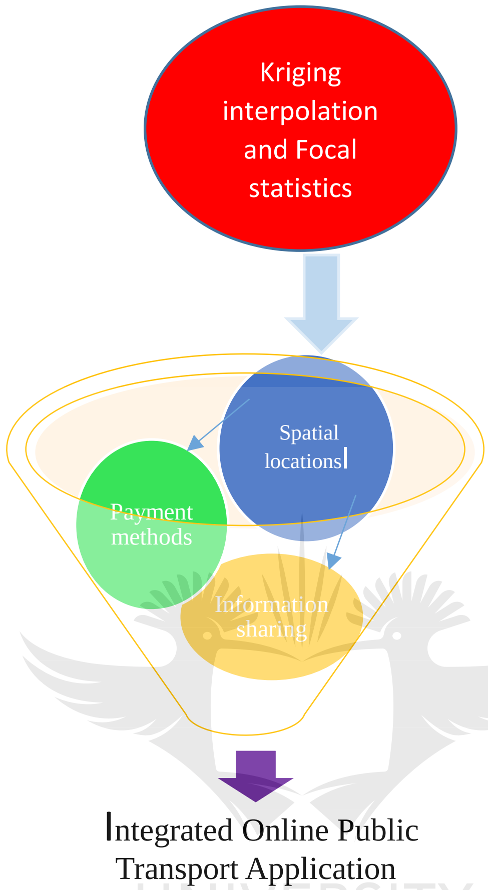

Figure 8.1: FUPT Integration model [Source: Author 2018]

Figure 8.1 explains the model of how to integrate the Gautrain and BRT systems (A Re Yeng) electronically. Kriging interpolation and Focal statistics identify cold and hot spots of locations that need formal urban public transport services, thus informing spatial locations. Accordingly, identified integrated spatial locations of both the Gautrain and A Re Yeng systems informs electronical integration. With spatial integration identified, urban public transport can be easily integrated electronically through information sharing and payment methods. A single integrated e-smart card can be used for payments to both systems, since the fare collection facilities are available. Consequently, integrated information dissemination can be used to share compatible timetabling scheduling through an online application in real time. The integrated online public transport application can identify the movement of the public transport mode in real time. It can show compatible times corresponding to certain modes as per bus or train taken and allow 5 to10 minutes intervals for switching between modes, thus reducing delays. This could make commuters feel less need to use cars and more of the FUPT.

8.5 RECOMMENDATIONS

8.5.1 Recommendations on physical integration for the Gautrain/Gaubus and A Re Yeng

The physical integration found in the city between the two systems indicates that transport authorities, urban planners and other officials consider integration of urban public transport as a crucial factor for smooth movement. Commuters do not need to struggle when they want to switch between different modes of urban public transport. As indicated on Figure 6.8 and Figure 6.9 that some locations of Gautrain, Gaubus and A Re Yeng are spatially connected.

Public transport capacity today cannot meet demand. To meet the future demand from projected growth, especially at peak times, the capacity of the system will need expansion and significant upgrades. The routes used by Gaubus and A Re Yeng are different. Therefore, connecting these modes will strengthen the network, as more routes can be serviced, assist commuters to reach places of interest reliably, and have more alternatives to choose from. This will help them to make informed decisions and plan well for smooth travelling.

8.5.2 Recommendations on integrated payment systems for Gautrain/Gaubus and A Re Yeng

A Gauteng ITS Plan can assist with the planning, funding and deployment of ITS technology. This will facilitate the integration of urban transport systems and promote the best possible utilization of existing and future transport networks (Gauteng province department of roads and transport 2013). Fare integration is possible to enable commuters to make journeys from origin to destination by using the same amount of money for any mode or the operator used. They will retain all allocated rights amongst the modes and operators, as this strategy is used in developed countries. This strategy does not apply different fares according to modes or operators. E-ticketing makes ticket integration easier to implement because it can manage a more complex fare system without necessarily harmonizing amongst fares of different operators or modes. Each operator or mode keeps its own single fares, and the smartcard acts as a unique means of payment. In addition, the system can include rules for transfer rights in order to be more attractive.

8.5.3 Recommendations on integrated information dissemination for Gautrain/Gaubus and A Re Yeng

ITS plays a critical role in helping the online information application keep track with real-time of the urban public transport. Gautrain and Gaubus have deployed such technology and big data also can be collected in real time rather than normal traditional data. These strategies have showed that it is working, as Gautrain/Gaubus commuters are happy with the information provided to them. Commuters have access to the exact time of the Gautrain/Gaubus arrival and can plan their journeys. They can make informed decisions about switching between Gautrain/Gaubus. The time spent waiting for a certain public transport mode either at a bus station or at a train station is not acceptable to the commuters.

8.5.4 Need for integrated Formal Urban Public Transport (FUPT)

Public transport plays a vital role in maintaining quality of life and enhancing attractiveness for industry development and investment. Therefore, the urban public transport system must be maintained effectively and enhanced through an integrated planning approach (Louw 2003). Further, a world class formal urban public transport system in a dense, integrated, mixed-use city provides users with good access to a wide range of destinations at most times of the day and week. By integrating the urban public transport network, the integrated system would provide very good to excellent accessibility over a much larger area. With this degree of accessibility, users would be able to go anywhere, anytime using the formal urban public transport system much as they would use their car.

An integration of schedules means all routes serving a certain stop or terminal are in operation during the same hours so that no rider is left "stranded." Coordination is thus particularly needed to minimize the transfer time for less-frequently used routes connecting at the same transfer station. In addition, fare setting, and payments should be convenient for passengers. An integrated electronic fare payment system, for example, can charge by distance or time, regardless of the number of transfers passengers make. It also allows different public transport operators to divide their revenues equally according to the distance travelled in a certain public transport type. It's also important to provide comprehensive, easy-to-understand and access trip planning information. This should be made available for users at home, work or school, buses and trains, and at terminals and transfer stations.

8.6 INTERPOLATION KRIGING AND FOCAL STATISTICS (NEIGHBOURHOOD ANALYSIS) SUMMARY

Different analyses were done in order to solidify the results, as the interpolation kriging and focal statistics were adopted for the study. The use of interpolation kriging and Focal statistics revealed the hot and cold spots of the commuters. The results from both above-mentioned analyses produced similar results on most locations. The analysis indicated that the locations with high commuter concentrations are currently serviced by A Re Yeng, Gaubus and Gautrain. The A Re Yeng commuter concentration is only in the Pretoria CBD, Hatfield and the locations around. The reason might be that the BRT system in the City of Tshwane is only in the CBD and the locations close by. However, the Gautrain and Gaubus commuter concentration are all over the City of Tshwane Metropolitan Municipality with different commuter concentrations. Locations that are not serviced by the Gautrain and Gaubus have commuters that are interested in the system, and some areas have high, moderate and low commuter concentrations.

8.7 WORD CLOUD SUMMARY

It was used in the study to indicate what A Re Yeng, Gaubus, Gautrain commuters raise and comment about regarding the modes of formal urban public transport. This assisted by indicating what were the most words used and the researcher manage to predict what were the most concerns of the commuters allowing to find areas that need to be strengthened in order to make the UPT effective.

8.8 AREAS OF EXPANSION AND FUTURE STUDIES

The Gautrain and A Re Yeng system already have plans that are put in place as indicated on the future extension maps. Both public transport service providers realize a need for the extension of routes to service more locations. Accordingly, the Kriging interpolation analysis and Focal statistics analysis has shown the bus stations with more commuter concentrations which might need attention during certain hours/ peak hours. Furthermore, the proposed routes for both the Gautrain and A Re Yeng systems does not service most of the locations that the Kriging interpolation and Focal statistics analysis indicated. Therefore, it is recommended that public transport service providers of these two systems consider such locations for future extension as these locations highlight that there are commuters in those locations.

Integrated urban public transport in South Africa is not common, as public transport providers operate as separate entities thus leaving a huge gap for smooth travelling. Provinces like Gauteng have developed FUPTs to deliver organized and convenient urban public transport. The Gautrain and BRT are an existing example. In the City of Tshwane there is the A Re Yeng (BRT system) and the operation of the Gautrain. In the City of Johannesburg there is Rea Vaya (BRT system) and the Gautrain. The Gautrain system and BRT existing in the City of Tshwane and the City of Johannesburg are not linked. Therefore, integrating the BRT system in the City of Tshwane and the City of Johannesburg with the Gautrain system could create seamless travelling between the two cities and with further expansion to the province. The Gautrain system can be the connector of the two cities, as the existence of Gautrain travels from the City of Johannesburg to the City of Tshwane.

Commuters located in the City of Johannesburg townships (Soweto) and other areas travelling to different areas in the City of Tshwane can therefore use Rea Vaya from the townships and other areas. They can then switch to the Gautrain in Park station (City of Johannesburg CBD), alight in the Pretoria or Hatfield station and then board A Re Yeng to travel to the desired destination smoothly. Further, the use of mobile technology could be key in integrating these modes of formal urban public transport by introducing the integrated payment method using a mobile phone for both systems. It could reduce time for uploading money in the e-smart cards at the counters and provide loading money machines into e-smart cards. Consequently, this will enable integrated mobile phone information dissemination indicating real time information. This will be compatible for both urban public transport systems, with the allowance of certain time intervals to allow commuters to be able to switch smoothly between the two systems and create a convenient transport network.

8.9 SUMMARY OF THE STUDY

There is a presence of the Gautrain, Gaubus and A Re Yeng (BRT) in the City of Tshwane services that functions well. However, there are elements of integration lacking between the two systems. There is slight availability of integration on the spatial level, but no integration on electronical aspects (payment and information distribution). The study has shown that there exists a knowledge gap, therefore investigation of the UPT integration in City of Tshwane is necessary. The use of big data is useful as large amounts of data can be collected to identify the real time movements of the UPT. A large amount of data can thus be collected from stations when commuters tap in and out to identify areas that are mostly used by them and if necessary, add more capacity of a certain UPT mode. Consequently, the use of ITS such as Advanced Traveller Information Systems (ATIS), which monitors the movement and location of a certain source of transport in real-time and keeps a watch on the condition of the transport network can be one of the crucial elements.

The Gautrain/ Gaubus and A Re Yeng are not connected through their payment systems, information distribution and timetabling. Payment systems and information distribution in the City of Tshwane are operated and managed technologically with the assistance of ITS. As shown in the results, both A Re Yeng and Gautrain/Gaubus use smart cards already. Therefore, it is possible to develop an integrated information application and one electronic smart card to establish seamless travelling in the City of Tshwane. The study has suggested that the use of electronic integration is should be introduced in order to support the areas that are spatially connected. This can strengthen the overall urban public transport to service more locations and routes. Further, the study showed that bus and train can be integrated. These modes can be compatible with one another if the system is designed in such a way that the two modes are not far apart, and there are elements such as payment, and information distribution systems linked together as is the case of Gautrain system. Integrating FUPTs in the Gauteng Province with the assistance of electronic elements including some of the existing public transport and future developed public transport will lead to a transparent FUPT network and make travelling convenient for commuters to all areas of the province.

Consequently, the movement of urban public transport can be fast, and unnecessary delays can be reduced. New customers can be attracted, and the current users can confidently use the urban public transport. Integrating the two modes of rail and road urban public transport electronically can produce effective, efficient and reliable urban public transport. As both operators are working on growing the two systems, integrating these modes could enable the system to service more locations, as both operators could come to an agreement of which townships or areas can be serviced. Further, in Centurion, City of Tshwane, there is availability of Gautrain/Gaubus, and this could give alternatives to A Re Yeng users who want to go to Centurion. Commuters favour public transport modes which do not delay in any form.

The data collected through smart cards can assist authorities to understand customers to be impacted regarding where more capacity of urban public transport be increased its cost. Consequently, introduction of an integrated information application can allow authorities to determine what alternatives can be used. This will be a good platform for commuters to post their views and queries directly for an integrated system.

In addition, investment in the existing bus and train systems can be a cost-effective way of improving urban public transport service provision. Enhancing existing bus routes or adding new routes to the network can also act as a precursor to future rail network extensions. The initiatives proposed to integrate Gautrain and A Re Yeng need to be implemented. Some of the network changes and additional bus network alterations are possible.

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