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In

THE FACULTY OF ENGINEERING AND THE BUILT
ENVIRONMENT
DEPARTMENT OF QUALITY AND OPERATIONS
MANAGEMENT

Title:

Applicability of geo-location data to delineate the state of spatial
integration of urban public transport operations in the City of
Johannesburg

Name: Brightnes Risimati  Registration Number: 201308075

We accept this report as conforming to
the required standard

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THE UNIVERSITY OF JOHANNESBURG

DATE: 15 JANUARY 2018
DEDICATION

The research work is sincerely dedicated to my family, particularly my wife Nyiko Chabalala and my daughter Masungulo Prosperity. My parents have taught me that anything is possible if one tries hard enough. I thank you for instilling in me the virtues of discipline and hard work. I give all glory to Jesus Christ, my Lord who always takes centre stage in my life.
ACKNOWLEDGEMENT

Hard work and long hours contributed towards the fulfilment of this dissertation. My gratitude therefore goes to all the participants who have contributed to making this an interesting research project. I am especially gratefully to the following personnel who played a crucial role in the fulfilment of this dissertation:

My academic supervisor, Prof Trynos Gumbo diligently guided me through this research, and gave precise, prompt and realistic feedback. He has been a pillar of strength and inspiration, and his words of wisdom, continuously pushed me to go the extra mile.

The officials at the Gautrain Management Agency, Rea Vaya BRT agency, Johannesburg Road Agency and City of Johannesburg were always willing to provide both data and insight on how the spatial integration of Gautrain and Rea Vaya can be defined through the applicability of geolocation data services.

I am grateful to the personnel at the Department of Quality and Operations management, University of Johannesburg, particularly Dr Pule Kholopane the Head of Department and Ms Khathutshelo Mushavhanamadi, My Co-supervisor. I earnestly give thanks for their useful early advice and encouragement as I was conceiving the research project. You have given me the opportunity to challenge myself and seek new ways of understanding urban challenges and public transport operations.

Finally, I acknowledge my loving family, Nyiko my wife and tower of support, whose tender words of encouragement helped me and my closest friends for the emotional, financial and spiritual support, which I will always cherish.

I am also grateful to Doctor Neil Barnes for proof reading the entire dissertation.

May God Continue to Bless You All…
ABSTRACT

The emphasis on developing well-integrated urban public transport systems has become a top priority in cities worldwide. In the past decades, most cities such as Johannesburg in South Africa have also prioritised improvements in urban mobility through mega investments in innovative urban public transport systems and strategic policy instruments. For example, the City of Johannesburg has invested in the Gautrain and Rea Vaya public transport modes. The Gauteng province and City of Johannesburg have further formulated relevant polices and legislative frameworks to inform the development of well-integrated urban public transport systems. However, the extent of spatial integration between the two urban public transport modes over the years has not been properly documented. In this study the extent of spatial integration of the Gautrain and Rea Vaya public transport modes has therefore been explored.

A phenomenological case study survey and experimental research design were adopted which applied a mixed-method to collect spatial and qualitative data. Key informant interviews were used to unpack the status quo of the two public transport modes and the effectiveness of policies and legislation frameworks governing public transportation in Johannesburg. Crowd sourced datasets from Facebook and Twitter enabled visualisation of commuters’ movement patterns. It was found from the novel data analysed that there have been spirited efforts in Johannesburg to not only formulate relevant transport policy and legislative frameworks but also to facilitate the development of efficient and integrated modern public transport systems. The results however further reveal that the existing urban public transport networks are spatially disintegrated. There is little to no collaboration between the Gautrain and Rea Vaya, as they operate separately. In addition, the results reveal that the high commuters concentrations are situated near the stations, as current stations are located in the melting points of commuters. The highest commuter social media concentrations emerge from the city centre, particularly from Park Station stretching towards the western areas, into the residential spaces of the City. A comprehensive integrated transport planning framework is proposed to inform the spatial integration of the existing urban public transport systems and promote their efficiency.

KEYWORDS: City of Johannesburg, urban public transport, smart mobility, Gautrain, Rea Vaya, spatial integration, efficiency, multimodal.
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# ACRONYMS AND ABBREVIATIONS

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<tr>
<td>ArcGIS</td>
<td>Aeronautical Reconnaissance Coverage Geographic Information System</td>
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<td>BRT</td>
<td>Bus Transit Systems</td>
</tr>
<tr>
<td>BUI</td>
<td>Bilhete Único Integrado</td>
</tr>
<tr>
<td>CBD</td>
<td>Central business District</td>
</tr>
<tr>
<td>CoJ</td>
<td>City of Johannesburg</td>
</tr>
<tr>
<td>GCR</td>
<td>Gauteng City-Region</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographic Information System</td>
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<tr>
<td>GMA</td>
<td>Gauteng Management Agency</td>
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<tr>
<td>GPS</td>
<td>Global Positioning System</td>
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<td>GRRL</td>
<td>Gautrain Rapid Railway Link</td>
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<td>HDFS</td>
<td>Hadoop Distributed File System</td>
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<td>ICTs</td>
<td>Information and Communication Technologies</td>
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<td>IDP</td>
<td>Integrated Development Plan</td>
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<td>ITMP</td>
<td>Integrated Transport Master Plan</td>
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<td>ITP</td>
<td>Integrated Transport Plan</td>
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<td>IoT</td>
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<td>IRPTN</td>
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<td>LECT</td>
<td>Light Express City Train</td>
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<td>MSA</td>
<td>Moving South Africa</td>
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<tr>
<td>NLTTAA</td>
<td>The National Land Transport Transition Amendment Act</td>
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<tr>
<td>NLTTA</td>
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<tr>
<td>PT</td>
<td>Public Transport</td>
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<tr>
<td>SPLUMA</td>
<td>Spatial Planning and Land Use Management Act</td>
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<tr>
<td>SPTN</td>
<td>Strategic Public Transport Network</td>
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<tr>
<td>CBD</td>
<td>Central Business District</td>
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<td>RDBMS</td>
<td>Relational Database Management Systems</td>
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CHAPTER 1: SETTING THE SCENE FOR THE STUDY

1.1. INTRODUCTION

In most cities of the African, Latin American and Asian continents, there have been growing concerns because of the lack of well-integrated, efficient and reliable public transport systems. This is mostly so in city centres, due to rapid growth of the urban population coinciding with the end of colonialism, and giving rise to large scale spatial, economic and structural transformation of urban landscapes (De Noronha et al., 2012; Taubenbock et al., 2012). This consciousness of the need for well-functioning, innovative public transport systems by all spheres of government and private sector institutions has prompted precipitate action in the past decades to invest in such systems. Just like other rapidly growing municipalities in developing and emerging economies, the city of Johannesburg has not been free from continuous public transport challenges. It is the political and economic capital of the Republic South Africa, thus it has experienced fast urban population growth and pressure on its contemporary public transport infrastructure. Subsequently, there have been collaborative efforts from both public and private stakeholders to invest massively in both innovative road and rail transport systems in the past decade.

This chapter focuses on the background of the study, that is public transport and spatial planning, from the apartheid to the post-apartheid era, and prominent policies introduced to support public transport planning and management. The problem statement to be investigated, and research questions that need to be answered are also outlined within this chapter. Related to the problem statement are the aim and objectives to be achieved which are clearly developed and spelt out. The location of the study area is presented, particularly the position of the City of Johannesburg within the country itself. In addition, the rationale and significance of the study are briefly presented. Lastly, the structure of the dissertation and a chapter outline are described.
1.2. RESEARCH CONTEXT: BACKGROUND

The political history of South Africa has had a significant impact on the shaping of public transport in City of Johannesburg. The apartheid system which was in place from 1948 until 1994 influenced spatial planning. It was designed to keep the pool of African labour living in townships located sufficiently far away from the economic hub and traditional white areas but still close enough to low paid jobs so that the labour pool could be used as and when needed (Peters et al., 2013). Planning was based on racial segregation, control and deliberate dispossession and socioeconomic marginalisation of black people. Black people were forcibly removed from urban land and had no legal claim to land or property ownership rights outside of the homelands (Mitchell, 2003). Housing for black families was created on the periphery of cities, and access of black labourers to the city was limited.

Transport services were designed to control access to urban areas, with commuter flows that brought people over long distances in the morning and took them home in the evening (Comscore, 2011). At the same time, the government invested heavily in road infrastructure for private vehicles and neglected public transport, which paved the way for the eventual growth of the minibus taxi industry (Barrett, 2003). Moreover, little investment was made in infrastructure for pedestrians and other non-motorised transport (NMT) users. This was especially true in poorer peripheral locations where walking is the dominant mode of mobility (Mitchell, 2003). The reality for many South Africans was displacement, marginalisation, inadequate shelter, tenure and asset insecurity, and poor access to socioeconomic opportunities (Landman and Badenhorst, 2015).

However, after the end of the apartheid regime, many South African cities have drastically scaled up their city size and opened avenues in terms of economic growth and population expansion. This is recognisable in the Gauteng metropolitan region, particularly the City of Johannesburg, as it is coined a ‘World Class African City’. This urban expansion has contributed to an explosive increase in the transportation volume and worsening traffic congestion (Hasan & Ukusuri, 2014).

The government is therefore aiming to enhance the urban public transportations system to alleviate congestion and to cater to the needs of captive riders (Comscore, 2011). To address this problem, the current public transport systems have been devised and implemented. These
include rail transit system and auxiliary bus systems such as the Gautrain and Rea Vaya in the hope of rapidly dispersing and streaming commuter flows (Hasan & Ukusuri, 2014). Mega investments in strategic policy instruments have been prioritised, and increasing the efficiency of urban transport systems has become a major issue for cities under expansion in order for them to have viable alternative transportation. One way to measure efficiency of the urban public transport systems is integration. This implies availability of the entire public transport system across a local or regional area independently of transport modes, tariffs, schedules, and ticket systems (Nyerges et al., 2013). The other alternative is non-integration of urban public transport systems which neglects the needs of customers, which ultimately results in a decrease of ridership.

In particular, the absence of an integrated public transport system causes problems and inconvenience for customers and authorities. These include lack of clear information, where the customers face a non-transparent jungle of traffic systems; travel times, whereby timetables and connections between operations are not harmonised; and cost, because in some relations, parallel, competitive services exist (Comscore, 2011). Ultimately, the main tools of an integrated public transport system are network integration. This means a more attractive system, because commuters can use the public transport with the vision ‘one network, one timetable’. As such, this study aimed to explore the extent of spatial integration of innovative urban public transport systems in the City of Johannesburg and create a comprehensive integrated transport planning framework which could inform the spatial integration of the existing urban public transport systems.

1.3. RESEARCH PROBLEM

It has been observed that globally, we are now living in an innovative era of urban public transport systems that extends beyond mere transportation of commuters (Fenta, 2014; Litman, 2013). This perceives integrating and improving public transport modes as a desirable method for enhancing the use of multi-mobility and promoting transit ridership. It endorses lessening of the negative impacts of automobile dependence, improves quality of life, enhances social inclusion, and provides a more environmentally-friendly and healthier activity pattern (Lopez-Iglesias et al., 2018). Contemporary urban public transportation is also seen as a vibrant infrastructure with long-lasting impetus on the morphology and dynamics of urban expansion and on sustainable and resilient urbanisation. Public transport integration encompasses
interdependent factors which when facilitated and coordinated, lead to inevitable best practices and to socio-economic transformation (Potter & Skinner, 2000).

At international level, there are successes that have recorded the achievement of integrated urban public transport systems in countries such as England, China, Brazil and Austria (Gould & Schmalbruch, 2015; Babinard, 2012; Klementschitz & Stark, 2009). However, in cities of the developing countries, particularly in Africa and Latin America, there are growing concerns about the state of urban public transport systems. One of the main issues is the lack of well-integrated and efficient public transport. This is particularly so in urban centres, due to rapid growth of the urban population which has coincided with the end of colonialism and given rise to large scale economic, spatial and structural transformation of urban landscapes. This consciousness of the need for well-functioning innovative public transport systems by all spheres of government and the private sector, has prompted precipitate action in the past decades to invest in innovative transport systems.

It is evident that the South African government has made a priority of improving public transport systems through mega investments in innovative systems and strategic policy instruments. These systems and polices of investment however leave much to be desired in terms of spatial integration and efficiency of public transportation. The operations and management of well-integrated, efficient, affordable and reliable modern public transport systems in South African cities are critical in ensuring smart cities and mobility within them. In the past decade, the City of Johannesburg has actively contributed through the implementation of the Gautrain fast innovative train system in conjunction with the Cities of Tshwane and Ekurhuleni within the Gauteng Province. In support of the innovative Gautrain system, the City of Johannesburg has also invested in and implemented the Rea Vaya rapid bus system. The Gauteng province and City of Johannesburg have also formulated relevant polices, strategies and frameworks such as the Gauteng 25-Year Integrated Transport Master Plan, the City of Johannesburg Strategic Integrated Transport Plan, and the City Of Johannesburg Strategic Public Transport Network. All these seek to inform the development and operation of efficient urban public transport systems. Nevertheless, the extent of spatial integration between the Gautrain and Rea Vaya has not been properly documented. There have been limited studies focusing on delineating the extent of spatial integration of public transport
systems as well as the effectiveness of the policy and legislative frameworks in informing the integration and efficiency of these systems.

1.3.1. Problem Statement

Integrated urban public transport has remained one of the major policy agendas for a long time in the City of Johannesburg, and increasing the efficiency of such transport systems has become a major issue. However, there seems to be a challenge in delineating the extent of spatial integration of the various modes and route networks within the Johannesburg public transport network system, as their market base is generally dispersed. This study therefore explored the extent of spatial integration of public transport systems as well as the effectiveness of the policy and legislative frameworks in informing their operation. The analysis of study results helped to derive a comprehensive integrated transport planning framework. This could inform the spatial integration of the existing urban public transport systems within the City of Johannesburg.

1.3.2. Main Research Question

The implementation of innovative urban public transport systems and formulation of relevant policies, strategies and legislative frameworks seeks to inform the efficient operation of such transport systems in the City of Johannesburg. The main question that comes to the fore is: what is the extent of spatial integration of Gautrain and Rea Vaya operations within the City of Johannesburg?

1.3.2.1. Sub-questions

To answer the research question, four sub-questions were identified as follows:

- How effective are the policy and legislative frameworks governing public transport infrastructure and operations in the City of Johannesburg?
- To what extent are the spatial patterns and routes networks integrated between the Gautrain and Rea Vaya?
- Is it possible to visualise commuters’ concentration patterns of the Gautrain and Rea Vaya through social media data?
Is there any possibility of developing a comprehensive integrated public transport framework that can be used to integrate the existing urban public transport systems?

1.3.3. Aim of the Study

As raised by the research problem and main research question, it appears that the extent of spatial integration between the Gautrain and Rea Vaya have not been properly documented. Thus the aim of this study was to explore the extent of spatial integration of innovative urban public transport systems in the City of Johannesburg and create a comprehensive integrated transport planning framework that can inform the spatial integration of these existing systems.

1.3.3.1. Objectives of the study

In an attempt to achieve the aim of the study, the following specific objectives were identified:

- To examine the efficiency of policy and legislative frameworks governing public transportation in the City of Johannesburg.
- To unpack the status quo in terms spatial patterns and routes network integration between the Gautrain and Rea Vaya.
- To visualise commuters’ concentration patterns of the Gautrain and Rea Vaya through social media data.
- To develop a comprehensive integrated transport planning framework that can be used to integrate the existing urban public transport systems.

1.4. SCOPE OF THE STUDY

The scope of the study was concerned with delineating clearly the extent of work covered and of the content explored in the research project (Nenty, 2009). This was necessary at the early stages of the study to operationalise it successfully. The spatial, conceptual and temporal extent of the study was determined, and the theoretical and empirical data collection strategies were adopted accordingly. This enabled a more logical investigation, results, conclusions and recommendations with clear and satisfactory study outcomes.
1.4.1. **Spatial Scope**

Within the City of Johannesburg urban public transport system, the study mainly focused on two modes of urban public transport which are the Gautrain and Rea Vaya. These are key means of achieving reliable, safe and affordable public transport and have become a catalyst for integrated public transportation. The Gautrain operates within the Gauteng metropolitan region which includes the City of Johannesburg, City of Tshwane and Ekurhuleni Metropolitan region in the East Rand. The Rea Vaya also operates under the jurisdiction of the City of Johannesburg. The three metros, as outlined, form the region which is the economic hub of the Republic of South Africa and are the only cities in the entire African continent which have a rapid transit train. These two modes of urban public transport began operating during the 2010 FIFA World Cup hosted by South Africa. They also operate along mixed land use as well as major economic, institutional and social nodes such as Johannesburg Park Station, OR Tambo International Airport, FNB Stadium, Emirates Airline Park Stadium and Sandton.

The City of Johannesburg is a well-developed economic hub and the fastest growing city in terms of its population, economy and development. The city covers an area of approximately 1,645 square kilometres (Risimati & Gumbo, 2018). It is divided into Regions A, B, C, D, E, F and G. Johannesburg is the over populated and economic engine of South Africa. It shares the most innovative transportation modes, along with its neighbouring metropolitan cities (City of Tshwane and Ekurhuleni Metropolitan Municipality). The Gautrain connects these three functional cities into one capital and economic region (figure 1). Perpetuated by demand, networks of urban public transport systems, commuter movement patterns and accessibility have become central issues within the City of Johannesburg.
The City of Johannesburg has been defined as a world class African city which means that the city will strive to become a smarter city. However what is it to be ‘smart’? Does it only involve decision-making or the use of advanced technology? Scholars have over the years defined the core of smart cities as the need for improvements in the quality of life of their citizens (Ferreira et al., 2017; Kummitha & Crutzen, 2017; Bakici et al., 2013). At present, the City of Johannesburg is promoting transit oriented developments (TOD) in previously marginalised spaces by focusing on economic and business nodes (figure 1). Nevertheless, the existing urban public transport network is spatial segregated. There is little to no clear collaboration between the various public transit providers namely the Rea Vaya, Gautrain or Gaubus, Metrobus or Metrorail and Mini-bus taxi, as they are developed and operate separately. This means that a knowledge gap exists of how to connect commuters and these places of economic and business activities. Urban public transport is at the heart of the City of Johannesburg’s agenda which has resulted in efforts to create Transit Oriented Development (TOD) Urban renewal and corridors of freedom (Steer, 2012).
1.4.2. Conceptual scope

The study focused on delineating the state of spatial integration between Gautrain and Rea Vaya operations within the Johannesburg Metropolitan City. The study took cognizance of the key concepts of international strategies applied to urban public transport infrastructure investment and innovative approaches to transport planning and development. The existing knowledge shows that urban public transport investments have evolved from a traditional approach. Recent developments incorporate innovative strategies for improved urban mobility for an integrated spatial form that facilitates access to economic opportunities and urban amenities. The main concepts of innovative urban public transport systems, urban mobility and integration through urban transport systems set the focus of the study.

1.4.3. Temporal scope

This study was consistent with the period in which the implementation of innovative urban public transport systems was concluded within the City of Johannesburg. The research period for geo-location based data was for a year (from January to August 2017), and the spatial and qualitative analysis were triangulated to yield viable results.

1.5. RATIONALE AND SIGNIFICANCE OF THE STUDY

Urban public transport systems are geared towards attaining integrated, efficient, liveable, safe, convenient, reliable, accessible, viable and cost effective public transport systems (Risimati & Gumbo, 2018). The above mentioned principles are often used as indicators to monitor the sustainability and functionality of public transport systems. Consistent with the above mentioned principle, is a need for bringing together the role players in transport planning and interdependent disciplines to facilitate economic transformation. All public transport infrastructure initiatives should build stakeholders consensus for an integrated multimodal public transport network that is efficient and affordable.

Notably, South Africa has witnessed massive public transport infrastructure investments, especially in metropolitan cities such as Johannesburg, Cape Town and Ekurhuleni. However, the question remains as to whether innovations and investments in urban public transport systems within the City of Johannesburg are actually contributing towards spatial integration.
There seems to be a trend in South Africa, where development takes place without rigorous research. This has been evident through the planners’ disregard of literature that can guide public transport investments towards spatial integration (Rode et al., 2014).

The study explored the extent of spatial integration resulting from innovative public transport systems. A framework which highlights the current state of rail and road public transport integration has been produced to inform the City of Johannesburg and Gauteng provincial government of what has been achieved so far and what needs to be improved in the urban public transport systems. The study focused on innovative strategies to enhance the role of innovative urban public transport systems in anchoring integrated urban public transport in the City of Johannesburg. Mulenga (2013) argues that public transport systems have a critical role to play in spatial integration and socio-economic development. Thus, public transport infrastructure is of paramount importance for South Africa, given the apartheid inherited, fragmented spatial form and prevailing socio-economic disparities (Todes, 2012). The role of the transport sector in integrating other sectors of the economy through spatial and modal integration is described.

The study explored the extent of collaboration by public institutions when investing in public transport infrastructure and whether adequate research is conducted to inform implementation that is responsive to local challenges. The study also investigated whether innovative urban public transport systems contribute to spatial integration and socio-economic transformation. Observations outlined by Wray and Gotz (2014) suggest that the City of Johannesburg transport planning policy narratives are in keeping with the global phenomenon for improved urban mobility that translates to socio-economic transformation. It is with this premise that this study investigated whether implementation of innovative urban public transport within the City of Johannesburg is meaningfully contributing to improved urban mobility.
1.6. STRUCTURE OF THE DISSERTATION

The dissertation is comprised mainly of eight chapters and these will consist of the following:

**SETTING THE SCENE FOR THE STUDY**

(CHAPTER 1)
- Introduction
- Research Context: Background
- Research Problem (problem statement, main research question, sub-question, aim and objectives of the study)
- Scope of the study (spatial scope, conceptual scope and temporal scope)
- Rationale and significance of the study
- Structure of the dissertation
- Conclusion

**CONCEPTUAL AND THEORETICAL FRAMEWORK**

(CHAPTER 2)
- Introduction
- Smart Cities (Smart Mobility)
- Public transport (Transportation planning)
- Urban public transport systems (innovative approaches to urban public transport transport. Types of innovative urban public transport systems, innovative public transport systems and urban mobility)
- Emerging approaches and social media big data (Analysis of social media data, web 2.0, crowd sourcing, big data and transport planning, multifaceted big data and internet of things)
- Conclusion

**GLOBAL EXPERIENCES IN URBAN PUBLIC TRANSPORT INTEGRATION**

(CHAPTER 3)
- Introduction
- The origin of integrated transport systems
- Global perspectives on public transport infrastructure and systems
- Case study of City of Linz, Austria
- Case study of Cracow, Poland
- Case study of Bogota, the Capital of Colombia
- Addis Ababa, Ethiopia
- Conclusion

**OPERATIONALISING RESEARCH**

(CHAPTER 4)
- Introduction
- Research Design (Phenomenological case study design and Experimental research design)
- Research Approaches
- Data Collection (Desktop study, key informant interviews, geolocation Twitter and Facebook data (Echo-echo)
- Data analysis (Content analysis, thematic analysis, spatial analysis)
- Limitations and challenges
- Ethical considerations
- Conclusion

**POLICIES AND LEGISLATIVE FRAMEWORKS GOVERNING PUBLIC TRANSPORTATION**

(CHAPTER 5)
- Introduction
- Post-apartheid South African policies and legislative framework governing transportation.
- Gauteng public transport infrastructure policy directives (25 year Integrated transport management)
- Strategic Integrated transport plan frameworks for the City of Johannesburg
- City of Johannesburg strategic public transport networks
efficacy of post-apartheid policy interventions
- Conclusion

**SPATIAL PATTERNS AND ROUTES NETWORK INTEGRATION BETWEEN GAUTRAIN AND REA VAYA**

(CHAPTER 6)
- Introduction
- Gautrain spatial pattern within Johannesburg (Gautrain commuters experience on the service provision)
- Spatial pattern of Rea Vaya within Johannesburg (Gautrain experience on the service provision)
- Spatial connectivity of public transport systems (analysis of Gautrain and Rea Vaya network integration, the function of urban public transport integration point A, B and C.
- Conclusion

**URBAN PUBLIC TRANSIT SYSTEMS COMMUTER PATTERN THROUGH GEOLOCATION SOCIAL MEDIA**

(CHAPTER 7)
- Introduction
- Gautrain commuters social media concentration analysis
- Rea Vaya commuters social media concentration analysis
- Gautrain and Rea Vaya commuters social media concentration analysis
- Commuters movement patterns of public transport systems
- Conclusion

**SUMMARY OF RESULTS AND CONCLUSIONS RECOMMENDATIONS**

(CHAPTER 8)
- Introduction
- Summary of results
- Conclusions
- Towards a comprehensive integrated transport planning recommendations
- Suggestion for future research
- Conclusion remarks

Figure 2: Dissertation layout (Source: Author, 2018)
Chapter 1: This chapter focus on the background of the study, that is public transport planning, and spatial planning from the apartheid to the post-apartheid era, whilst prominence of policies introduced to support public transport planning and management are presented. The problem statement to be investigated and research questions that need to be answered are also outlined within this chapter. Related to the problem statement is the aim and objectives to be achieved which are clearly spelt out. The location of the study area is presented, particularly the position of the City of Johannesburg within the country itself. In addition, the methods of data collection and analysis in brief is reported. Lastly, the structure of the dissertation and a chapter outline are described.

Chapter 2: This chapter provides a relevant background to literature concerning smart cities and integrated urban public transport systems. The chapter begins with a comprehensive discussion of smart cities and smart mobility. This continues with detailed definitions of public transport while providing an overview of transportation planning and highlights integrated urban public transport planning. In addition, this chapter discusses the applicability of Geolocation data services in urban public transportation systems. It concludes by providing a comprehensive discussion of Geographic Information Systems in public transport planning and management.

Chapter 3 In this chapter experiences of public transportation in cities of the developed, transitional and developing countries are presented. Firstly, this chapter traces the origin of integrated public transport systems development in various cities. The chapter provides a synthesis of urban public transport infrastructure and systems for the developed and developing worlds and transitional market countries. The focus is on case studies such as the City of Linz, Austria; Cracow, Poland; Bogota, Colombia; Addis Ababa, Ethiopia; Nairobi, Kenya; and the City of Cape Town in South Africa.

Chapter 4: The chapter spells out the methodological premises and research design process related to this study. It describes the development of the research from the inputs, to how it is based on the potential of using social media big data to define the state of urban public transport integration in the City of Johannesburg. The resulting model, though having limitations and challenges, had the potential to reveal the points of interests of the commuters, as presented in
the coming chapters. The chapter closed with the ethical considerations of the research methodology.

**Chapter 5**: this chapter reviews the development in policies and legislation governing public transport systems since the emergence of democracy in 1994. The Gauteng province and City of Johannesburg’s specific policy interventions on public transport infrastructure are also discussed, with a closer look at the level of collaboration between the provincial and national departments and between provincial and municipal departments. This is essential, since the provincial government is the link between national government which sets out policy directives and the municipal sphere where actual implementation takes place. In addition, the chapter outlines the effectiveness of government legislative frameworks and policy interventions.

**Chapter 6**: This chapter focuses on data representation and key findings, given the City of Johannesburg’s innovative urban public transport systems and the impact of these systems on urban mobility, particularly spatial integration. The spatial pattern of innovative urban public transport systems have been developed consistent with the Integrated Rapid Public Transport Network (IRPTN) national strategy for spatial integration and modal upgrading of urban public transport systems. Accordingly, vigilat consideration has been given as to whether the implementation of innovative urban public transport systems has contributed to improved urban mobility. Specific reference is made to efficiency and the inclusion of the urban poor and previously disadvantaged communities through a spatially integrated urban form.

**Chapter 7**: This chapter presents the applicability of location based services to reveal public transport commuters’ concentrations and movement patterns of commuters within the City of Johannesburg. Crowd sourced data from social media posts (Twitter and Facebook) were collected from Echo-Echo, a private company that collects and analyses social media information from a variety of web 2.0 platforms. A total of 39391 Gautrain and Rea Vaya geolocation social media datasets were received in an Excel format from the Echo-Echo. Crowd-source data is still a novel research activity, and this chapter shows the value of this real-time data for understanding system integration. Crowd sourced data is able to measure transit coverage areas, reveal high and low commuter concentration zones, and also track the movement patterns of commuters.
Chapter 8: The integration of urban public transport systems has the potential benefit of creating sustainable urban mobility and enhancing social inclusion. Conversely, the disintegrated public transport concomitant with an imbalanced distribution of public transport services across the population results in adverse effects for some social groups and their quality of transit ridership. In this context, this chapter presents the study recommendations for promoting the provision of well integrated and efficient public transport. This is because the provision such systems can help in reduction of energy consumption and carbon footprints as well as mitigating traffic congestion and accidents. As integrated modes of urban mobility, public transport can improve the quality of life, enhance social inclusion and also provide a more environmentally-friendly and healthier activity pattern (Lopez-Iglesias et., 2018). In addition, this chapter identifies possible future research and also brings the study to a conclusion.

1.7. CONCLUSION

This chapter presented the introductory aspects of the dissertation. It started by tracing the background of South Africa planning, from the apartheid to the post-apartheid era whilst highlighting policies introduced to support public transport planning and management. This chapter also clearly depicted the problem statement, research questions and sub-questions as well as the aim and objectives of the study. The chapter outlined the scope (conceptual, temporal and spatial scope) of the study consistent with the discussions of chapters in this dissertation. It further reviewed the significance of the study consistent with global trends and discussions on innovative urban public transport systems, urban mobility and socio-economic transformation. This chapter concluded by provided a chapter outline.
CHAPTER 2: CONCEPTUAL AND THEORETICAL FRAMEWORK

2.1. INTRODUCTION

Mobility in urban contexts is continuously adapting and transforming to everyday challenges, as can be perceived with the global shift towards smart city planning. This shift towards encouraging communities to utilising multi-mobility modes and public transport in their everyday commuting has led to a lessening in the negative impacts of private-car-dependence such as congestion (De Freitas Miranda & Rodrigues da Silva, 2012). This chapter provides a relevant background to literature concerning smart cities and integrated urban public transport systems. The chapter begins with a comprehensive discussion of smart cities and smart mobility. This continues with detailed definitions of public transport, while providing an overview of transportation planning and highlights integrated urban public transport planning. It discusses the applicability of Geolocation data services in urban public transportation systems and concludes by providing a comprehensive discussion of Geographic Information Systems in public transport planning and management.

2.2. SMART CITIES

Currently the notion of ‘smart city’ has vastly been used in academia to determine variations in developmental practices and in relating these developments to how the city functions (Letaifa, 2015). There are several perspectives offered, for example, a smart city can ultimately entail a network of infrastructures which facilitate the political, economic, cultural and sociological factors leading to city growth (Hollands, 2008). These have been perceived as a solution to problems emerging from rapid urbanisation and a way to achieve sustainable development (Datta, 2015). It is interesting to note how the emergence of Information and Communication Technologies (ICTs) have become the cornerstone of the smart city discourse. Contemporary developments based on ICT highlight the importance of the mobility, ecological, socio-economic and competitive performance of cities (Kourtit & Nijkamp, 2012).
2.2.1. Smart Mobility

Urban public transport as a catalyst for urban development in the era of smart mobility is well recognised (Banister, 2005). Typically, smart mobility describes movement patterns or city transport networks which are utilising active travel modes; information and technology; energy efficient renewable forms of energy; or shared vehicles wherever possible, resulting in low carbon output per passenger journey (Banister, 2005). Integrated multimodal-networked public systems have emerged as a smart mobility paradigm. They use transfer potential to provide a maximal service for a reasonable and efficient operating budget and a genuinely feasible alternative to automobile travel within urban areas (Goodwin et al., 1991). Mobility is the essence of modern life in urban areas. Nevertheless, it creates serious social, economic, and environmental problems. In a situation of growing car ownership, public transport services are facing tough competition from private automobiles (Letaifa, 2015).

The continuous increase in the number of vehicles on the road network poses further threats to traffic movements. This is evidenced by traffic congestion, slower flow, more accidents, and waste of time, money and efforts (Bauer et al., 2012). Severe traffic conditions reflect on the efficiency of public transport systems which causes people to become dissatisfied with these inconveniences. The reasonable solution to these acute traffic problems lies in developing efficient transport systems which can provide an attractive and convenient alternative to the private car. Such services are badly needed by the most vulnerable groups of the communities including the poor, the old, children, and the handicapped. The absence of effective urban public transport could worsen the quality of urban life for unprivileged groups in particular. “Experience in South African perspective has shown that, in the absence of sound transport system, the situation can arise where the urban poor are isolated in town centre ‘ghettos’ without access to employment and with deteriorating education, and social opportunities” (Letaifa, 2015:11).

The quality of a public transport system is among other items controlled by efficiency, flexibility, high mobility, regularity and reliability (Bauer et al., 2012). Public transportation should satisfy the requirements for access to centres of activity and population. This means that public transport must access key points of interest such as commercial, residential and recreational areas in the city. Modern Southern African society’s mobility needs are focused on future urban growth and survival rather than luxury. Planners, officials, and community
developers have given considerable attention to public transport and mass transit schemes (Wechsler, 2014). However, the unfulfilled public expectations of mass transport have triggered questions about the logic of present public transport arrangements, and the need to look for more effective alternatives. Appraisal of mass transit programs in many cities around the world has convinced planners of the need for a fundamental restructuring and reform of public activities in urban areas.

2.2.2. Mobility as a Service (MaaS)

Mobility as a Service (MaaS) is a recent innovative transport concept, anticipated to induce significant changes in the current transport practices. The innovative Mobility as a Service (MaaS) concept combines different transport modes to offer a tailored mobility package, similar to a monthly mobile phone contract and includes other complementary services, such as trip planning, reservation, and payments, through a single interface (Hietanen, 2014). This bundling of mobility modes presents a shift away from the existing ownership-based transport system toward an access-based one. It offers users a tailored hyper-convenient mobility solution, with a promising perspective to substitute private car.

It can be thought of as a concept (a new idea for conceiving mobility), a phenomenon (occurring with the emergence of new behaviours and technologies) or as a new transport solution (which merges the different available transport modes and mobility services). The first comprehensive definition of MaaS is offered by Hietanen (2014). He describes MaaS as a mobility distribution model that deliver users’ transport needs through a single interface of a service provider. It combines different transport modes to offer a tailored mobility package, like a monthly mobile phone contract. This interpretation encompasses some of the core characteristics of MaaS: customer’s need-based, service bundling, cooperativity and interconnectivity in transport modes and service providers. Cox (2015) adds to this definition, by emphasizing the similarity with the telecommunication sector. Being based on the same definition, Finger, Bert and Kupfer (2015) envisioned MaaS to integrate transport modes through the internet.
2.3. PUBLIC TRANSPORT

Public Transport can be defined as “all modes available to the public, irrespective of ownership. It includes road-based modes such as conventional buses, Para-transit vehicles, human and animal powered vehicles, cycles and walking; rail-based models such as heavy rail system, light rail transit, street tramway, and rapid transit systems” (Filippia et al., 2016: 190). Among these modes, the conventional bus is the most common public transport mode in developing countries mainly due to its low running and initial costs, route flexibility and permeability into town and city centres (Meyer and Miller, 2014). Public transport services are essential for city development as they provide mobility for those who cannot drive their own car. They relieve highway congestion, help in creating and maintaining liveable communities and assure long-term sustainability in terms of resource consumption and the environment (Datta, 2015). They also provide a very efficient means of moving large numbers of people with considerable flexibility in order to meet demand throughout the city. Perhaps, transport is the backbone of urban life, because it determines the form, and socio-economic development of a city. Mobility and accessibility provided by the transport system have played a major role in shaping countries. They have influenced the location of social and economic activity, the form and size of cities, and the style and pace of life. This has been through facilitating trade, permitting access to people and resources, and enabling greater economies of scale, worldwide and throughout history.

2.3.1. Transportation Planning

Transportation planning is a critical element in the evolution and growth of metropolitan regions. Such planning takes into account trip purpose, temporal and spatial distributions of trips and modal splits of travel and costs (Meyer and Miller, 2014). These considerations influence current and future infrastructure as well as the environment. This big picture perspective suggests influences on mobility, and fits into a more general interpretation of sustainability which includes social, economic and environmental factors (Datta, 2015). Transportation systems form the basis on which economic development can occur and the means by which society interacts (De Abreu Freire & Painho, 2014). However, an ineffective transport system and associated urban forms will limit economic and social opportunities.
Transportation planning is a strategic aspect of regional growth and prosperity that is intimately connected to policy formulation and implementation (Kourtit & Nijkamp, 2012). It is therefore essential that approaches exist for monitoring, evaluating and modelling system performance in order to better inform policies and regulations associated with transport services (De Abreu Freire & Painho, 2014). For example, in the United States the Clean Air Act and subsequent amendments to this act are policy-based regulations aimed at reducing the environmental impacts of emissions (Hanson, 2017). Associated with this has been the continued development of analysis approaches for identifying and assessing alternatives for achieving mandated reductions in emissions.

Another example is the urban transportation modelling system, which consists of interrelated models for helping to predict travel demand (Meyer and Miller, 2014). This is essential for evaluating impacts on facilities and various modes of travel resulting from regional growth. A final example is the interaction between land use and transportation which has been the subject of modelling efforts. A key component in the emerging methods and the techniques for better understanding transportation processes is geographical information systems (GIS) (Kourtit & Nijkamp, 2012). Whether it is the assessment of broad scale regional policies or linking specific capacity, GIS are proving to be valuable transportation management and modelling platforms. Thus, significant investment has been made to establish transport planning approaches and relevant data for assisting the monitoring, evaluation and modelling process.

Planning for smart cities development calls for the integration of land use and transportation, thus creating a compact city design which limits automobile use and encourages walking and the use of public transport and bicycles (Kourtit & Nijkamp, 2012). In general, integration implies the opportunity to use the entire public transport system across a local or regional area independently of transport modes, tariffs, fares, schedules, ticket systems (De Abreu Freire & Painho, 2014). To benefit the public, the planning of urban development and transport should be integrated in such a way that new development takes place in locations which are good for public transport (Hidalgo and King, 2014). A large customer base can also be created by building densely and by intermingling housing and workplaces. Alternatively, non-integrated public transport systems tend to neglect the needs of customers, which ultimately results in a decrease of ridership and problems for customers and authorities (Datta, 2015). These include a lack of comfort, as more than one ticket is needed for a single-trip ride. Lack of information
means that customers face a non-transparent jungle of traffic systems, and travel times, timetables, and connections between operators are not harmonised. Costs are a factor because in some situations, parallel, competitive services exist (Wechsler, 2014).

2.4. URBAN PUBLIC TRANSPORT SYSTEMS

Urban public transport systems are arguably the lifeblood of cities and towns, as centres of interaction and economic activities are essential for connecting places and people (Mazaza, 2002). The importance of urban public transport systems means that for urban development planning to effectively meet its intended needs, provision of adequate public transport infrastructure should be a top priority for cities worldwide. Thus, the pressing need for having an efficient urban public transport system that addresses the socio-economic needs of the people through an integrated network has influenced the nature of urban planning for developing countries. These have to deal with the challenge of managing rapid urbanisation against their constraints and at times decaying public transport infrastructure (Albalate & Bel, 2009).

Notably, urban public transport systems play a critical role in transporting high volumes of people for varied day to day transportation needs, access to economic prospects and transporting of goods (Kahn Ribiero, et al., 2007). Through fully functional and efficient systems, cities can attend to issues of access to economic opportunities, congestion and pollution. On the other hand, public transport inefficiency interferes with citizens’ quality of life and productivity rates. Urban public transport systems have earned recognition as a solution to congestion and road traffic management (Pojani & Stead, 2015). Therefore fully functional, efficient systems reduce congestion on public roads, where an alternative is provided and where people travel to their respective destinations more quickly and timeously.

People have different travel patterns and preferences which influences the public transport network pattern and makes possible the interchange or transfer between different modes of transport (Guo, 2008). The common multimodal systems of a public transport network include bus services (including mini-buses or taxis), rail transport, subways and cycling, with the main alternatives being bus systems and rail transport. The common trend is that in major urban areas there are different service providers some of which can be formal or informal. Buses and rail transport are the most common modes of urban public transport systems (Vuchic, 2002). It
is not surprising therefore that Bus Transit Systems (BRT) and advanced train systems have formed the core of innovation over the past 20 years (Wright, 2005).

Urban public transport is key, as it provides access to markets, employment opportunities, education, health care and recreation for the wellbeing of the people economically and socially. It is also critical in helping the developing world achieve its millennium goals, through meeting needs of the poor and vulnerable groups (Hook & Howe, 2005). Through a regulatory framework, the state may coordinate operations in the urban public transport system, as it has in places like the Rio de Janeiro city region (Zottis, 2015). Reasonable progress has also been witnessed in countries like China, where the state has provided adequate policy instruments complemented by the political will to improve public transport (Jones, et al., 2014).

The monopoly in space and time by transport operators cannot be ignored, as it may result in some services being offered at higher fares and therefore excluding some poorer members of the public (Anderson & Wilson, 2014). This means that a lack of comprehensive management by the government of urban public transport operations may result in social and economic exclusion and negatively impact people’s quality of life (Markovich & Lucas, 2011). Zottis (2015) argues that a lack of regulatory measures and enforcement therefore contributes to market failures. Litman (2012) also observes that transport planning should be done in a sustainable manner where its future impacts are considered when doing trade-offs in desired transport planning outcomes. Cerna (2013) also argues that political will plays a critical role in urban public transport systems interventions. Here, decision makers play a critical role on shaping the direction of these systems by enacting innovative policies that redress socio-economic disparities.

According to Mulenga (2013), it is essential that both soft and hard infrastructure is given cognizance in development processes and projects. Hard infrastructure relates to the railway lines and highways or BRT routes, whereas soft infrastructure implies the secondary institutional or market orientated development (Fung, García-Herrero, Iizaka & Siu, 2006). These observations are also acknowledged in the Gauteng 25-Year integrated transport master plan of 2013 focusing on intelligent transport systems. This outlines the Province’s plans to develop sustainable transport systems that will anchor the economic, social, cultural and environmental objectives of Gauteng.
2.4.1. Innovative Approaches to Urban Public Transport Systems

Investments in urban public transport infrastructure have emerged as an integral part of improved access to economic opportunities (Litman, 2017). Furthermore, the deficiencies in urban public transport infrastructure have driven innovative strategies to urban mobility and public transport infrastructure development (Gakenheimer, 1999). Given the sustainable development agenda and the need for creation of efficient and reliable urban public transport systems, integration of the public transport network has formed the core of the urban public transport infrastructure for multi-modal transport (Marrian, 2001). This takes account of the socio-economic needs of the people served by the public transport network as well as careful consideration of environmental constraints.

According to the Vasconcellos (2004), innovative urban public transport system integration is a response to market failures as well as the need to improve consumer experience. A spatial development pattern of any city is strongly influenced by the transport network which is a result of its planning (Clark, 2000). This suggests that a lack of integration in transport planning has a negative effect on building sustainable, compact and integrated cities and therefore results in market failures. Pardo-Martin, et al. (2010) observe that cities with vibrant economies have identified innovative urban public transport systems as focus points. One of the challenges tackled through innovative public transport systems is traffic congestion problems and increased travel times (Vasconcellos, 2004).

The fragmented nature and spatial form of urban public transport networks operated by various service providers has meant that public institutions responsibility goes beyond public transport infrastructure. Thus, the need to bring together all stakeholders directly and indirectly involved with public transport infrastructure has led to improvement in urban public transport operations. The different service providers often use different billing systems service patterns, some with distinct technological tools and service patterns. This complicates things for the commuters (Vermesan & Friess, 2013). Lack of integration and cooperation amongst service providers leads to increased travel times and costs, as people take more than one mode of transport to get to their destination. This has led to innovative strategies for integrated billing systems.
2.4.2. Types of Innovative Urban Public Transport Systems

The need for innovative approaches to planning and implementing urban public transport systems, and provision of adequate infrastructure that will improve the quality of such services has been established (Redman, et al., 2013). On this basis, it is important to define characteristics of innovative urban public transport systems in their varied forms. Adequate policy instruments should then be derived such that investments are channelled accordingly, considering the public transport needs of that specific city or town (Karim, 2017). Hence, innovative public transport systems can be defined as new practices that seek to provide better solutions to existing challenges and traditional measures in urban transport planning and mobility (Polis, 2015).

Innovative urban public transport systems allow for interdependent stakeholders and service providers to effectively respond to public transport challenges (Page, 2012). In this regard, the end goal should be a multimodal network that brings together the operations of all public transport modes that are responsive to local issues (Litman, 2014). Accordingly, innovative urban public transport systems create a much-needed platform for multimodal public transport coordination (Karim, 2017). Such innovations range from technologically inclined, high quality passenger transportation, stakeholders’ cooperation and integrated billing systems across all modes of public transport systems. The common goal is always providing, efficient, reliable and affordable urban systems.

The said innovative urban public transport systems characterised by rapid rail transport, light rail transport and Bus Rapid Transit (BRT) systems have since been the major investment pillars for most governments at local and international level (Tsay & Herrmann, 2013). The major investments associated with these innovations are understood to be key drivers of economic growth. It is therefore important to understand each type of innovative urban public transport system, the type and quantity of passengers it carries, and the role they play in socio-economic transformation, given prevailing circumstances in a given city. The most important consideration for developing countries is ensuring that they do not adopt public transport options that will be too costly. Rather they must seek innovations that are within their financial capabilities.
2.4.3. Innovative Public Transport Systems and Urban Mobility

The primary objective of public transport infrastructure is to facilitate urban mobility by way of improving the movement of people, goods and services within a particular space (Department of Transport, 1996). Given the prominent spatial disparities in the developing world, it is important that innovative transport systems policy interventions seek to improve urban mobility by effectively facilitating spatial integration of various land uses, thereby creating a vibrant socio-economic environment within cities (Jennings, 2015). Thus, densification along main public transport corridors has been advocated as a mechanism to redress the spatial imbalances of the past (Wilkinson, 2006). Even in the developed world, rapid urbanisation and population growth has meant that the provision of adequate public transport is a top priority for urban growth management (Aljoufie, Zuidegeest, Brussel & van Maarseveen, 2011).

In a nutshell, urban mobility is concerned with the time spent travelling, and distance covered is central to the state of mobility within the urban environment (Lucas, Tyler & Christodoulou, 2009). However, Peng (2005) argues that urban mobility policy interventions should look beyond addressing issues of traffic problems. They should be responsive to people’s day to day needs and not neglect or systematically exclude the urban poor. Accordingly, when deliberating on innovative urban transport systems, one cannot neglect the demand for improved urban mobility characterised by improved access to opportunities, affordable public transport systems and efficient and reliable service at the core of improving urban public transport infrastructure (Boscetti et al., 2014).

The existing body of knowledge reveals that four interlinked and interdependent main themes exist which serve as performance indicators of the public transport systems. These are accessibility, affordability, efficiency and reliability or convenience (Peng, 2005). Urban public transport systems that reflect a cross-balance across these four main themes can be deemed to have met the minimum requirements for improved urban mobility through an integrated urban public transport network (Rodrigue, Comtois & Slack, 2009). Subsequently, innovative urban public transport systems policy interventions should strive to achieve these main principles to ensure fully functional and economically viable cities.
2.4.3.1. Accessibility through urban public transport systems

The day to day activities within an urban setting consist of varied social and economic travelling needs, where people require easy access to economic opportunities and other urban amenities (Pernegger & Godehart, 2007). Such accessibility is concerned with people’s ability to easily connect to various opportunities in the form of goods and services in a given city, having reduced travel times and walkable access to human settlements as key indicators of improved urban mobility (Litman, 2017). Central to attaining accessibility is the provision of a variety of modes of public transport that are operationally integrated to enhance connectivity of various nodes. Commuters are thus able to travel directly to their desired destination without experiencing unnecessary delays due to limited public transport options, (de Stasio, Fiorello & Maffii, 2011).

According to Verseckienė, Meškauskas and Batarlienė (2016), improved accessibility through public transport cannot be achieved if public transport systems neglect people’s needs and travel costs. In relation to people’s needs, the principle of accessibility goes beyond access to economic opportunities. It emphasises the importance of providing public transport systems which are user friendly to the elderly and people living with disabilities (Ormerod, et al, 2015). Non-Motorised Transport (NMT), through pedestrian corridors and cycling routes, also forms the core of accessibility through innovative urban public transport systems (Wray & Gotz, 2014). Such systems should facilitate all travel needs through public transport corridors that which bring about socio-economic vibrancy to city life.

In spite of the shortfalls observed in traditional approaches to public transport in relation to the mobility principle of accessibility, improvements in the efficacy of innovative urban public transport systems will improve access levels. Innovative approaches have been adopted which are essential for attainment of accessibility. Through these, all people regardless of their physical, economic and social backgrounds are able to move around and enjoy opportunities available within the urban setting. Innovative approaches examine all components that are central to achieving a fully functional urban public transport network. This makes it easier for people, goods and services to move while also fostering integration of economic and residential opportunities.
2.4.3.2. Affordability: Cost-effective urban public transport systems

In the developing countries characterised by a fragmented spatial form, it is often the case that modes of public transport do not take commuters directly to their respective place of work or residence. As a result, this necessitates commuters’ use of two or more modes of public transport before getting to their intended destination (Guo, 2008). Further, the urban poor are often the main users of public transport, but due to their financial constraints they are sometimes unable to afford public transport fares and are forced to walk long distances to obtain access to various opportunities (Roux et al., 2012). Increased travel times and costs have a negative impact on the productivity of workers. In some cases, these may lead to low income earners (the urban poor) giving up their jobs or may discourage them from looking for employment opportunities completely (Pettinger, 2011).

Urban mobility policy interventions through innovative urban public transport systems must see to it that affordability for all is enhanced, especially for the poor (Pojani & Stead, 2015). Since the colonially inherited spatial form in most developing countries cannot be reversed, integrated billing systems and cooperation amongst stakeholders may help improve the situation. For example, in Rio de Janeiro (Brazil), introduction of the integrated billing system of one travel card Bilhete Único Integrado (BUI) or Integrated Ticket Fare meant that commuters could use one card to pay for all modes of public transport (Mashwama et al., 2017). As such, this helped facilitate affordable multi-nodal public transport operations and ensured reduced travel times which were very beneficial to the low-income earners.

2.4.3.3. Reliability of public transport systems

Urbanisation and rapid population growth means that availability of reliable public transport systems is of paramount importance to avoid congestion on public roads (Padam & Singh, 2001). In the 21st century, people are not easily persuaded to get rid of private cars unless they are more than satisfied that they can rely on public transport for their social and economic needs without having to endure inconvenience (Monchambert & De Palma, 2014). People’s having to rely on urban public transport for commuting purposes while being concerned about the punctuality of such public transport systems cannot boost commuters’ confidence in public transport (Prim, 2016).
Intelligent Transport Systems (ITS) have been introduced to strengthen the reliability of urban public transport systems through constant updates and communication about such services (Civitas, 2015). Through ITS communication channels, people are able to plan their business and day to day trips through the information provided by the channels (Houghton, 2009). ITS even enables tourists to navigate through the city using public transport. They can go wherever they want while being guided by the ITS linked to innovative urban public transport systems. These clearly communicate the mode of public transport to take them conveniently to their destination.

2.4.3.4. Integration of public transport systems

The term transport integration denotes such economic, technical, organisational, policy-based and informational concepts and solutions that pledge the continuity of travel from door to door (Janic & Reggiani, 2001). The term means connecting various transportation modes operating in certain transport systems which provide solutions to facilitate commuters between different modes and assuring a smooth, safe and efficient flow of commuters from their origins to their destinations (Ibrahim, 2003). Integration of urban public transportation is defined as an organisational process. Through this, components of the commuter public transportation system (Network and infrastructure, information and marketing components, fares and ticketing systems) and a variety of carriers who serve different transportation modes interact more closely to generate an overall enhanced performance of the combined public and individual transportation (Kourtit & Nijkamp, 2012). In particular, the implementation of various transport integration solutions may result in reduction of travel times, transportation costs, environmental pollution and traffic congestion (Paulley & Webster, 2017). Transport integration leads to the improvement of urban public transport system accessibility and overall competitiveness. It assures better utilisation of different transportation means and infrastructure.

Moreover, integration of urban public transportation is mostly determined by the pattern of land use, the nature of the transportation systems, and the characteristics of the traveller (Hidalgo and King, 2014). Travel cost, time, distance and the choice of travel mode are all important. The closer the origin and destination are to the main transportation system the higher
the level of connectivity (De Abreu Freire & Painho, 2014). Also, the wider the variety of modes for travelling between a given origin and a particular destination, the greater the connectivity. In addition, the less time and money spent in travel, the more places that can be reached within a certain budget and the greater the connectivity (Datta, 2015). In order for the concept of connectivity to be useful for evaluation of the need for and effectiveness of transportation and land use planning policies, it needs to be translated into measures of connectivity.

There are different types of transport integration in the urban areas. These include the integration of different modes of public transportation and integration of public and individual transportation. They also include the integration of transportation policy with other policies concerning spatial planning and city management, and spatial integration based on the application of efficient land use strategies (such as multimodal terminals and interchange platforms, and shared lanes for means of public transportation) (Paulley & Webster, 2017). Furthermore, they include infrastructural integration based on the development of various technical solutions in transportation infrastructure (for instance passageways connecting public transportation stops, overpasses, underpasses, shared stops for public transportation). Other types of integration are organisational integration (for instance metropolitan tickets various transportation modes and coordinated timetables) and economic integration focused on introduction of various measures supporting sustainability and efficiency of the public transportation systems (for example integrated tariffs). Informational integration includes passengers’ information systems; web pages and electronic travel planners (Kourtit & Nijkamp, 2012).

Urban public transport spatial integration is focused on connecting various transportation modes operating in a certain transportation system. It provides solutions to facilitate commuters’ transferring between the modes and assures safe, smooth and efficient flow of commuters from their origins to their destinations (Brahim, 2003). Integration of urban public transportation is defined as an organisational process combining components of the commuter public transportation system (network and infrastructure components) (Datta, 2015). Through this, a variety of carriers who serve various transportation modes interact more efficiency and closely to generate an inclusive enhancement in service quality level and improved performance of the public transportation (Luk & Olszewski, 2003, Ulengin et al., 2007). Spatial
integration based on the application of efficient land use strategies include multimodal terminals, shared lanes for means of public transportation and interchange hubs.

2.4.3.5. Efficiency of public transport systems

To ensure improved urban mobility, innovative urban public transport systems should be anchored through application of analytical methods to achieve best practices. These should be characterised by best consumer experience and socio-economic vibrancy, thereby optimising efficiency of the public transport systems (Preston, 2012). Therefore, efficiency of public transport systems is where public transport service providers see to it that service provided is of a high quality. The safety and security of commuters should be a priority, and each mode of public transport should be consumer friendly and effectively managed (Abreha, 2007). However, modes of public transport cannot run efficiently when operating independently from each other. Therefore the integrated multimodal urban public transport network is the heartbeat of efficiency, as it enables people to connect to every part of the city through high quality public transport systems.

Spatial integration is central to the principle of efficiency, where various innovations can be undertaken to facilitate trade, tourism, commerce, services and education to the benefit of commuters while also boosting the local economy. Therefore, efficiency goes beyond the quality of service provided by urban public transport systems. It also extends to designing stations and connector points as activity nodes, either as green space plazas for leisure and recreational purposes, or socio-economic nodes with vibrant small scale economic activities (Han, 2000). At an advanced level, efficiency can even involve a combination of recreational and socio-economic activities, where people can relax, enjoy and operate their small businesses in a healthy, refreshing and vibrant environment.
2.5. EMERGING APPROACHES AND SOCIAL MEDIA BIG DATA

In contemporary research, there has been a rapid growth in efforts to unpack web 2.0 big data. Most smart devices are evolving and now have GPS technology integrated into them. Moreover, location based services have advanced immensely, with the rapid investment in Web 2.0 platforms such as Strava Metro, Here and Foursquare (Bricka et al., 2016). As Web 2.0 promises to be a new untapped data source, new research paradigms are currently being studied. These data have been utilised in transportation, sociology and tourism, with key focus on location and data velocity (Chowdhury et al., 2016). Data velocity refers to the frequency with which data is collected and analysed (such as real-time) (Brambilla, et al., 2013). Using Twitter API, one can identify trending topics at any given time, because as various users post comments, the search engine identifies common words or phrases, and these are highlighted as the trending topics (Moyo and Musakwa, 2016). Facebook also offers a similar service, being their ‘Live Feed’, which allows users to share their experiences on real-time (Amiegbebhor, 2015). Web 2.0 has enabled users to share their lived experiences on real-time through posts including either video, images or text. Some platforms such as Foursquare have rapidly grown due to allowing users the option to ‘check in’ at various points of interest.

Another interestingly popular platform similar to Foursquare which has recently emerged is Gowalla. This has been developed with the key focus on utilising the potential GPS services on smart phones to allow users to ‘check-in’ at spots within their district (Estellés-Arolas et al., 2012). As part of the exploitation of real-time sharing of data capabilities by smart devices, Clixtr, automatically geo-tags posts by users, hence other uses within the proximity can access this information. Yelp is another new platform which promises to enhance data sharing capabilities for Web 2.0 users, as they seek to tap into this rapidly growing business. Thus, social media networks are websites and applications or software programs that permit people to create, interact, share and exchange information. People around the world post over 400 million tweets daily on Twitter, add 350 million photos to Facebook and view over 4 billion videos on YouTube (Amiegbebhor, 2015). Locally, fifty seven percent of the over sixteens in South Africa generate vast quantities of data through the use of some form of social media. This has prompted the development of new technical and methodological (big data) approaches to capture, process and analyse large and complex data sets (Chowdhury et al., 2016).
Big data approaches to analysing social media information can increase understanding of how people think and act. Organisations can use this material to inform their activities, improve decision-making, target products and services more effectively and to try to influence users’ behaviours in the future. For instance, in the United Kingdom in 2012, the government allocated £189 million to big data, with a further £73 million announced in February 2014 (Bricka et al., 2016). The Economic and Social Research Council is investing £64 million in the Big Data Platform which includes funding to facilitate access to social media data and further research on its use.

### 2.5.1. Analysis of Social Media Data

The data generated by mobile applications which rely on locations sensors, such as Facebook, Instagram, Strava Metro or Google Maps have the potential to analyse the day-to-day movement networks of commuters. However, in analysing this data, setbacks were identified by Lorenzi-Cioldi, (2014). For example, the information measured was subject to noise and uncertainties hence leading to imprecise results if these were not excluded in the analysis (Amiegbebor, 2015). The analysis of social media data can best be expressed through an insight into data analysis, which has evolved over the years. Moyo and Musakwa (2016:55) mentions that “scholars between 1995 to 2009 analysing data as a means to an end and those between the years 2009 to 2013 analysing data as both a means to an end and also as the end”. In contemporary years, there has been a paradigm shift, with scholars from 2013-2016 analysing data as ‘the end’ and those post-2014 analysing data as a service. Figure 3 illustrates the analysis of social media data evolution over the years.
According to Moyo and Musakwa (2016: 144), “This move from data as an end to empowering cities as a service opens new possibilities. As data is no longer only viewed as a means either to an end or just the end, but as an enabler for decision-making and collecting feedback for development, by offloading the risks and burdens of data management to a third-party cloud-based provider”. The evolution of analytics has greatly changed the manner in which data is managed, as it has led to improvements in data quality, agility and reduction of cost. Moreover, these analytical tools seem to be a viable resource that will improve operational efficiency whilst boosting the quality of city planning and transport management.

Figure 3: The analysis of social media data evolution over the years [Source: Moyo and Musakwa, 2016]
2.5.2. Web 2.0

The concept of Web 2.0 began with a conference brainstorming session between O’Reilly and Media Live international (Bricka et al., 2016). “The notion of web 2.0 initiated, when academics realized that the second generation of the web had emerged, which introduced new possibilities that were previously unattainable” (Moyo & Musakwa, 2016: 144). O’Reilly VP and Dale Dougherty, web pioneers, noted that far from having ‘crashed’, the web was more important than ever, with exciting new applications and sites popping up with surprising regularity. This growth on the web has led to new technological advancements and an incorporation of smartphones and web 2.0 services (Instances include Twitter and Instagram). Web 2.0 is the term describing a variety of web sites and applications which allow anyone to collaborate, share and communicate online information, or materials which they have created. Web 2.0 varies from other types of websites, as it does not require any web design or publishing skills to participate (Bricka et al., 2016).

The nature of this technology makes it an easy and popular way to communicate information either to a particular group of people or to a much wider audience. Universities can also make use of these tools to communicate with staff, students and the wider academic population (Brambilla, et al., 2013). It can be an effective way for staff to communicate and interact with students and research colleagues. There are number of different types of web 2.0 applications including wikis, blogs, social networking, podcasting, folksonomies and content hosting services (Amiegbebhor, 2015). Many of the most popular websites are web 2.0 sites such as YouTube, Myspace, Wikipedia, and Flickr. Cheng et al. (2011) furthermore demonstrate how human mobility can be understood using spatial temporal and societal data from location-sharing services. These researchers collected check-in data from Foursquare, Gowalla, and Facebook places to investigate factors that influence human mobility. Important lessons were learnt from their findings, through comparison of population density and income density. These showed how communities in high-density locations have to travel further than communities which are dispersed (Cheng et al., 2011). The variations in connectivity level within the study area could be a possible explanation for this phenomenon.

Further research by Hasan and Ukkusuri (2014) used web 2.0 data. They tested their hypothesis of whether mining data from different social media platforms would enable an analysis of a larger study area whilst saving on human resources, as data would be recorded on the internet
and sent to the analyst. Results from their study showed that data which are temporal and spatial have the potential to map out the movement patterns of people at either a global or a local scale. While such data generated automatically have limitations, the sheer granularity has the potential to open new research possibilities which were previously unattainable through data acquired from field surveys (Bauer et al., 2012). For example, Thurstain-Goodwin and Unwin (2000) used the Kernel density estimation technique to convert geo-tagged pictures to spatial points to map out the city core. Hollenstein and Purves (2010) also used web 2.0 in their research to delineate the core of a city. The study involved analysing Flickr data, which consists of picture tags which contained the following categories, namely: ‘Central Business District’; ‘Downtown’ and ‘City Centre’. This technique could be adopted in the current research, in that the geo-tagged data from web 2.0 could be mapped to create a continuous spatial density displaying the state of public transport systems.

2.5.3. Crowd Sourcing

Crowdsourcing involves leveraging the combined intelligence, knowledge or experience of a group of people to answer a question, solve a problem, or manage a process (Bricka et al., 2016). The concept, ‘crowdsourcing’ is relatively new, however the basic idea is not. Crowdsourcing is a natural solution to problems inherent in the management of complex systems. As social, political, technological, and other dimensions of society have grown increasingly complex and connected, crowdsourcing has emerged as a powerful tool in the management of various systems and has the potential to become even more useful in the future. It refers to a phenomenon in which a large group of people engage in a given task in order to harvest usable information (Estelles-Arolas, et al., 2012). The activity of crowdsourcing acts as a modus operandi to disentangle the multifaceted issues that exist in the real world. The abundance of data on the web, coupled with the ability to acquire feedback from crowds has the perspective of altering the manner in which data is synthesised and decisions are made.

Brambilla, et al. (2013) have outlined that “crowdsourcing can be used to answer questions that are inherently hard for machines but can be handled relatively easily with human input”. This exploratory technique is generally an information-seeking activity, where people gradually acquire knowledge about issues of interest. For instance, a metro council could ask the ‘crowd’ to post on the council’s social account their views relating to issues surrounding service delivery improvement. Tamilin et al., (2012) propose Sensor Civico a context-aware system to
enable mobile phone users to contribute towards public participation in developmental issues in the city. Crowdsourcing was undertaken by running a prototype connected to a central server. The data obtained was categorised according to the context, (geographical, temporal, demographical profile and activity) so as to inform the authorities of the people’s views. Authorities such as the City of Cape Town in 2014 used crowdsourced data collected through Google Waze to give residents the opportunity to use numerous multimedia data as a means of answering questionnaires and adding their opinions about various issues that affected them (Brambilla, et al., 2013).

2.5.4. Big Data and Transport Planning

Big data has been defined as emerging technologies designed to extract value from data having four V’s characteristics; volume, variety, velocity and veracity (Bujari & Palazzi, 2014). It contains large pools of unstructured data that can be stored, managed, and analysed. Big Data has also been characterised by High volume, Velocity and Variety (the three Vs) which require specific technology and analytical methods for their transformation into value (De Mauro et al., 2016). Big data sources for Transport Planning applications include GPS traces (smart phones), cell phone traces, transit smart card transactions and other count and sensor data (including on-board vehicle sensors), online Social Media or Networks, credit card transactions (travel-related activities) and RFID traces (NFC) (Bricka et al., 2016). Besides the three Vs, Social Network related big data usually are characterised by individual data, spatio-temporal data, socioeconomics and demographics, information shared, messy or disorganised data, multi-parametric data, event-oriented data and type of social link or tie data (depends on the data source). Khan et al. (2014) defines big data logistics as the modelling and analysis of urban transport and distribution systems through large data sets. These are created by GPS, cell phone and transactional data of company operations combined with human generated activity (for example social media, public transport). Big data analytics is therefore the process of examining large amounts of unstructured data to uncover hidden patterns, unknown correlations and other useful information (Bricka et al., 2016).

The logistics industry is also undergoing a fundamental shift from ‘product-related’ to ‘information related’ services (Bryant, et al., 2008). This industry demand and requirements are literally changing on a daily basis because of the innovations in technologies with smart computing. Thus, increasing the real time tracking of vehicles could facilitate more accurate
resources pooling and capacity sharing. Big data is seen as central to smart cities, because large datasets would provide information about the activities of different city actors. Integration of city systems is an important sub-task of city government led smart city visions and plans. Currently activities though, seem to pool data rather than integrate them. Analyses therefore need to establish interaction patterns rather than be based on how actors actually interact.

Big data analyses bring meaning to the data through interlinking it, while its capturing is unstructured and connected. The logistics aspect could be seen as a move from individual firms optimising their transport operations to collaborative, or system level analyses of flows, redrawing the landscape and focusing on local production, and thereby foremost short-distance transportation. Ideas are radical changes driven by or leading to local production, thus rather going from centralised transport solutions to distributed (Estellés-Arolas et al, 2012). Logistics firms would in a sense lose business, while companies utilising their offering would change interaction partners to more local alternatives. These changed interaction patterns would hence transform entire interaction systems with geography increasing the impact on interaction decisions. The logistics or transport aspects also point to how transportation would need to be reorganised so as to deal with their CO2 footprint (Bryant et al, 2008).

The emergence of big data is thus providing innovative opportunities for citizen engagement. City authorities and communities can also use ever-growing bodies of data to improve understanding of citizen behaviour and service usage. They can build transparency and accountability by opening up their records and statistics for public consumption, thus leading to the growth of ‘open data’. With the growth of technology and datasets also come new piracy surveillance and data misuse challenges for future cities. Such challenges are data quality, comprehensiveness and data collection and analysis. These include in particular, aligning data from data sources and managing the sheer volume of data which is produced. Big data must be robust, accessible, and ‘interpret-able’ if they are to provide cities and companies with meaningful opportunities and solutions (Bujari & Palazzi, 2014).

Smart cities provide an ideal background for exploitation of big data, and various interactions in the value chain can generate ‘exhaust data’ (Riggins & Wamba, 2015). Indeed, many big data applications are implemented far from the purposes for which the data was collected. For instance, location information that cell companies gather (so that they can efficiently route
calls) can be used to make predictions (Bujari & Palazzi, 2014). The transport network applications of big data can be utilised to improve key operational processes. For instance, big data is useful to define mobility strategies based on actual consumer patterns (for example, location based data generated by mobile phones) rather than through surveys Estellés-Arolas et al., 2012). Additionally, transport planners can use big data algorithms, instead of small data samples to fine tune mobility planning based on real-time in store and online sales.

2.5.5. Multifaceted Big Data

Although managing and processing of large data sets is not fundamentally new, during the past years a range of technologies have emerged which facilitate the efficient storage and processing of big data sets (Chatzimilioudis & Zeinalipour, 2013). While big data technologies such as Map Reduce and Hadoop are the products of big internet companies such as Google and Yahoo!, the need to handle large data sets is quickly extending to other sectors (Riggins & Wamba, 2015). For instance, the varied amount of patient data in the health sector offers new opportunities for better treatment, while the advent of smart meters, allows utility providers to better cope with the instability of the grid caused by renewable energy sources. From a technology perspective, Big Data challenges and technologies can best be described along the so-called 3 V’s: Volume, Velocity and Variety.

2.5.5.1. Volume

Volume refers to storing, processing, and quickly accessing large amounts of data. While it is hard to quantify the boundary for a volume challenge, common data sets in the order of hundreds of Terabytes or more are considered to be big (Farooq et al., 2015). In contrast to traditional storage technologies such as relational database management systems (RDBMS), new Big Data technologies such as Hadoop are designed to easily deal with the amount of data to be processed (Chatzimilioudis & Zeinalipour, 2013). In its most basic form, the Hadoop system uses its Hadoop Distributed File System (HDFS) to store raw data. Parallel processing is facilitated by means of its Map Reduce framework which is highly suitable for solving any awkward parallel processing problems (Big Data report, 2014). With Hadoop, it is possible to scale by simply adding more processing nodes to the Hadoop cluster without the need to do any reprogramming, as the framework takes care of using additional resources as they become available.
Summarising the trends in the volume challenge, one can observe a paradigm shift with respect to the way data are handled (Farooq et al., 2015). In traditional database management systems, the database design is optimised for the specific usage requirements. For example, data is pre-processed, and only the information that is considered relevant is kept. In contrast, in a truly data-driven enterprise that builds on Big Data technologies, there is awareness that data may contain value beyond its current use (Chatzimilioudis & Zeinalipour, 2013). Thus, a master data set of the raw data is kept that allows data scientists to discover further relationships in the data which may reside beyond the requirements of today. As a side effect, it also reduces the costs of human error such as erroneous data extraction or transformation.

2.5.5.2. Variety

In a data-driven economy, the objective is to maximise business value by considering all available data (Brambilla, et al., 2013). In practice, however, this approach confronts the challenge of using heterogeneous data sources ranging from unstructured textual sources such as social media data, to a wide diversity of sensor data (Riggins & Wamba, 2015). Traditionally, various forms of data integration address this challenge. In the context of big data a new dimension to the integration challenge is the large number of different data sources that need to be integrated. Social media open data or governmental data sources, and data platforms and markets result in a data ecosystem of significant variation (Bryant et al, 2008). As the integration of new data sources requires manual work to understand the source schema, to define the proper transformations and to develop data adapters, existing approaches do not scale effectively.

2.5.5.3. Velocity

Velocity refers to the fact that data are streaming into the data infrastructure of the enterprise at a high rate and must be processed with minimal delay (Big Data report, 2014). To this end, different technologies are applicable depending on the state and complexity of analysis. Complex Event Processing (CEP) engines offer efficient solutions for processing incoming data (Brambilla, et al., 2013). In contrast, when each new incoming data set needs to be related to a large number of previous records, but only simple aggregations and value comparisons are required, NoSQL databases offer the necessary write performance (Riggins & Wamba, 2015). The required processing performance can then be achieved by using a streaming infrastructure such as Storm.
2.5.5.4. Veracity

Veracity relates to the trustworthiness and truthfulness of the data. Data may not be fully dependable because of the way it has been acquired, for instance by unreliable sensors or imperfect natural language extraction algorithms, or because of human manipulation (Farooq et al., 2015). Assessing and understanding data veracity is therefore a key requirement when deriving any insights from data sets.

2.5.5.5. Visualisation

Visualisation of big data is particularly important for data scientists who try to discover new patterns in the data that can be exploited for creating new business value (Big Data report, 2014). This may involve creating new services by combining seemingly unrelated data sets.

2.5.6. Internet of things

The Internet of things is an innovative trendy field fuelled by the hype in big data, the proliferation of digital communication devices, the emergence of network science and the universal internet access for the common population (Chatzimilioudis & Zeinalipour, 2013). The 21st century generation has now become reliant on the internet, since masses of people upload and share information on a daily basis (Riggins & Wamba, 2015). Thus, the “Internet of things has made it possible for societies and devices to stay connected and build relationships from far distances, from meetings being moved from the normal traditional boardrooms to being held via Skype or directions being given via Tom-tom instead of paper maps” (Moyo & Musakwa, 2016: 333).

The origins of the concept Internet of Things can be traced back to 1982, when a modified Cola-Cola dispenser could give information on the temperature of the Coca-Cola inside (Moyo & Musakwa, 2016). This was made possible by the dispenser being connected to the internet (Farooq et al., 2015). Then decades later, Joy (1999) hinted at the possibility of inter-device ‘connectivity’, and Ashton (2009) proposed the term Internet of Things. Shen and Liu (2011) have outlined how the IoT is founded on the idea of allowing the autonomous transfer of useful data through invisibly embedded, diverse devices. This expresses how data is transferred and analysed almost automatically through ‘machine to machine ‘interaction, with small to no human interface. The Internet of Things shows how technology has advanced in the past years, with different devices currently being able to share information with each other through the use
of embedded sensors. For instance, mobile phones, smart televisions and cars, which are linked to different communication systems (Moyo & Musakwa, 2016). Thus, the internet has evolved into a platform for conveying, receiving, amassing and analysing data. This new manner of exchange of information has increased connectivity, leading to improved public participation in decision-making processes. The emergence of the IoT allows for the tracking of any tagged mobile object as it moves through its surrounding environment, or a stationary device that monitors its changing surroundings (Riggins & Wamba, 2015).

In the Internet of Things, various sensors and actuators are connected via a network to different computing systems, thus providing data for actionable knowledge. In this way, the IoT, big data and network science are all related, however, interoperability of data between one system and another is a potential challenge in the way of IoT expansion. IoT finds its application in healthcare monitoring systems. Data fed in real-time to computing systems by sensors and actuators can revolutionise maintenance tasks in industries, with a significant reduction in system downtimes. This opens up new possibilities in integration analysis, as people move around with numerous mobile devices which are constantly sending information to the internet. This will allow for the location of trip distribution and trace the numerous movement networks. The IoT has almost resulted in devices and human beings becoming locatable and interlinked (Farooq et al., 2015). This has greatly simplified peoples’ lives and transformed how decision-making is done, as information is now shared also instantaneously and automatically. However, this interconnectivity of information has raised concerns about security and has initiated calls for new means to ensure data are secure (Farooq et al., 2015).

2.6. CONCLUSION

The chapter presented a significant background to literature concerning smart cities and smart mobility. Comprehensive definitions have been presented in this chapter of public transport, integrated transportation planning, and urban public transport spatial integration based on the application of land use strategies. In addition, the chapter discussed the applicability of Geolocation data services and Geographic Information Systems in urban public transport planning and management. The chapter also presented a background to the social media big data. Emerging trends in social networks and analysis of social media data is presented in this chapter. It has discussed literature on web 2.0, crowd-sourced data and Internet of Things. In addition, bid data and transport planning; and the various faces of big data are presented.
CHAPTER 3: GLOBAL EXPERIENCES IN URBAN PUBLIC TRANSPORT INTEGRATION

3.1. INTRODUCTION

The urban public transport sector has become a common phenomenon in the world, particularly in developing countries. However, there are differences in the magnitude and types of urban public transport systems within developed, transitional and developing countries. Developed countries have well-integrated public transport systems, when compared to transitional and developing countries which are characterised by dispersed urban public transport systems. Such public transport systems fail to provide well-functioning commuters flows, as urban expansion is rapidly taking place in cities. This urban growth leads towards an explosive upsurge of transportation flows which worsens traffic congestion. In this chapter, experiences of public transportation in cities of the developed, transitional and developing countries are presented. Firstly, it traces the origin of integrated public transport systems development in various cities. It then provides a synthesis of urban public transport infrastructures and systems for the developed world, transitional market countries and the developing world. Focus is then placed on case studies such as the City of Linz, Austria; Cracow, Poland; Bogota, Colombia; Addis Ababa, Ethiopia; Nairobi, Kenya; and City of Cape Town in South African.

3.2. THE ORIGIN OF INTEGRATED TRANSPORT SYSTEMS

The original concept of developing an integrated public transport system started with countries such as Switzerland, Austria and Germany. For example, Hamburg in Germany was the first city to establish an integrated public transport system in 1965, and the first innovative fare system was develop in Basel in 1984 (Bauer et al., 2012). Most of these integrated public transport systems functioned as extensions of the municipal transportation to the surrounding spaces, or they solved the transportation challenges between the main city and its hinterland. One of the main motives was to improve integration of public transport in Germany. Five types of transport integration have to be entirely achieved for smooth transfers in an integrated public transport system to be regarded as being ‘planned’. Otherwise the transfers will be regarded as ‘unplanned’ (Bauer et al., 2012).
A planned transfer is defined as an integration which has been purposefully designed by network planners and policy makers in the multimodal network development stage. A ‘unplanned’ transfer is shaped by public transport operators from existing services without additional guidance from policy makers and network planners. For example, Matas (2005) discovered that the massive increase of public transport commuters in Madrid, Spain was due to the integration of mobility modes (De Grange et al., 2016). The current study discourse is that network integration and integrated fare systems have a huge influence on ridership. Brambilla et al (2013) created a framework to measure the price gradient of an integrated transport system and showed that when there is an increment in a particular fare, commuters are more enthusiastic to switch the mode of their journey rather than the time period (De Grange et al., 2016).

The comparison between Germany and the USA by Buehler (2014), revealed viable transport in Germany to be superior, since 40% of Germany commuters used viable modes (98% for public transport). A mere 11% of American commuters used viable modes for public transport (Ferrari et al, 2013). De Grange et al. (2016) illustrate that network integration for public transport is more essential than information integration for modern commuters of transfer routes that are unplanned. In a global context, urban planners and policy makers are developing urban public transportation strategies to advance the integration of their systems. The tool developed by Chowdhurry et al. (2016) provides a score of how well the transport plan or strategy is capable of delivering full integration. Thus, this tool can be utilised to assess and compare regional plans for integration. Brambilla et al. (2013) reveal that some of the countries might prefer a gradual application of integration systems. The above study investigated Cali and Bogota’s integration process and commented that the greatest issue for implementation was the transition from a variety of operators to a single city-wide regulation.
3.3. GLOBAL PERSPECTIVES ON PUBLIC TRANSPORT INFRASTRUCTURE AND SYSTEMS

Efficient urban public transport systems with an integrated public transport network are essential in addressing the global phenomenon of socio-economic challenges. They include provision of affordable public transport, access to economic opportunities and more efficient business operations to improve lives of the urban poor (Fenta, 2014). A global shift is noticeable from the old perspective of public transport based on physical travelling (mobility) to more comprehensive innovative urban public transport systems which consider their socio-economic and environmental impact (Litman, 2013). Thus, transport infrastructure has become an integral part of development across the world, with most countries putting emphasis on urban public transport as essential to sustainable development.

In the context of improved urban mobility, challenges of congestion during peak hours associated with most people commuting between places of residences has been a common trend across developed, transitional market and developing countries (Gwee & Currie, 2013). Despite the complexities and challenges associated with the urban public transport infrastructure, the intent is to prioritise mass rapid public transport in various forms or options in accordance with the needs of the people. However, regulatory frameworks, approaches to transport planning and delegation of powers differs between countries. This depends on administrative structures, distribution of resources and capacity of state departments in a given country to provide adequate infrastructure and an enabling environment to meet peoples’ socio-economic needs.

In some countries, particularly the developed world and some transitional market countries, it has been evident that where there is a healthy working relationship between the state as the regulatory and enabling authority, the public transport operators and the general public. Comprehensive, efficient urban public transport systems characterised by an integrated urban public transport network are possible (Gil and Biesek, 2016). In these instances, actions are coordinated to formulate a collective integrated strategy for public infrastructure investments with the buy in of all relevant stakeholders. Furthermore, sustainable human settlements characterised by reduced travel times, affordable transport fares and improved access to economic opportunities are developed (Patel et al., 2001).
Urban public transport systems in the developed world are arguably at an advanced stage. They are already moving towards incorporating economic growth, improved business operations and employment creation resulting from transport infrastructure investments. The sampled cities of Cracow and Linz represent comprehensive, fully functional and well planned public transport systems. This is more so in the City of Linz, where the railway station was transformed to a place of economic opportunities and social interaction, promoting improved business operations and social cohesion. The Cracow system has a few standards to adhere to before being completely sustainable, but it is also economically viable, efficient and accessible to the public. The integration of different modes of urban public transport is also a predominant feature of innovative urban public transport systems in the developed world. For example, the integration of rail transport with bus services and the availability of cycling options at the connector points have proven to be comprehensive in providing an efficient service for consumers.

The development potential in transitional markets countries is huge, and parallel to this is the need for institutional capacity to deal with the pressure as a direct result of rapid urbanisation. Accordingly, transitional countries have been characterised by a demand for a comprehensive urban public transport system that is accessible and affordable by all. The example of Colombia brings hope to the rest of the transitional market countries. Their progress has highlighted critical aspects to attend to in order to attain a fully functional, comprehensive innovative urban public transport system to deal with the challenges of rapid population growth, poverty and unemployment. The critical aspect in the case of Colombia in Bogota is the key role the state plays in regulating all forms of urban public transport while creating an enabling environment that encourages all relevant stakeholders to work together.

The case of Bogota further shows that people will always be welcoming of efficient services and legislative frameworks which enable them to interact and operate their businesses efficiently. Integrated billing systems and easy access to economic opportunities, health facilities, social facilities and education facilities made possible through the integrated transport system have proved to be critical for the transitional market countries. The common challenges facing the developing countries however are the minimal state involvement in the urban public transport systems’ operations and a lot of work still needs to be done to cater for
the needs of the people. It is evident though that a form of urban public transport exists in the developing countries and that the desire exists to improve the state of affairs.

However, it remains to be seen whether the comprehensive visions for urban public transport can be translated into meaningful progress. There is no proper coordination and management of different modes of transport, and challenges of limited access and high travel costs persist in the developing world. Though the need for innovative approaches to implementation of urban public transport systems is evident, it is important for developing countries not to duplicate public transport systems being implemented in developed and transitional market countries. Developing countries must therefore investigate innovative urban public transport systems without spending massive public funds which only cover a few areas and will not even be fully transformative there. Transit Orientated Development, where main public transport corridors are identified and used as densification opportunities provide housing options closer to opportunities. This will enable integration of various land uses and thereby improve the spatial form of cities while also enhancing functionality of urban centres and economic nodes available in these cities.

3.4. CASE STUDY OF CITY OF LINZ, AUSTRIA

The City of Linz is the capital of the Austrian Province of Upper-Austria located in the inter-modal transport corridor connecting Western Europe and Central Eastern Europe and which has a moderate population growth (Klementschitz & Stark, 2009). The City of Linz has successfully implemented comprehensive transport systems following an integrated approach to transport planning and addressing of socio-economic needs of the local residents (Vougioukas & Bochtis, 2008). The matrix table 1 below provides a synthesis of the City of Linz Innovative Urban Public Transport System:
Public transport needs and challenges

- Lack of integration in the transport infrastructure investments and urban regeneration
- Improving Economic productivity
- Maintaining competitiveness
- Environmental protection and improving public health
- Integrating different public transport modes.

Interventions to enhance Public Transport Systems

- Holistic concept: combining investments in infrastructure with urban development (urban regeneration, urban development and creation of workplaces).
- Redesign of main railway station, optimizing the interchange between regional and urban public transport
- Transforming the inner-city railway network such that all railway lines have an underground stop as a link to the railway station
- Integration of the central bus-station within the railway building.

Benefits/Positive outcomes of integration

- Railway Station turned into a social and economic facility that enhances social cohesion and creates business opportunities for entrepreneurs.
- Improved business operations and employment creation.
- All relevant stakeholders worked collectively to realise the goals and objectives of a comprehensive innovative urban public transport network.
- Successful implementation of pedestrian routes and cycling routes.
- Support for pedestrian access and creation of quality life for the citizens.

Table 1: Synopsis of the City of Linz Public Transport Innovations [Source: Author, 2018]

As depicted in the table above, the City of Linz transport system integrates transport planning and socio-economic facilities to cater for the needs of the broader community, and not just transport needs. In the same vein, Mäntynen and Myllärniemi (2007) observe that Linz is one of the few cities in the world that has successfully implemented a comprehensive urban public transport system through a collective effort by all relevant stakeholders, with the state as the enabling agent and regulatory institution. The City of Linz has a wide transport network connecting the central business area to surrounding neighbourhoods through a demand responsive system (Klementschitz & Stark, 2009). Innovative urban public transport systems options at Linz include inner-city light rail/trams covering 18.9 km; conventional busses covering 128.6 km and trolley busses covering 18.7 km. The most impressive concept realised was the creation of social cohesion and economic opportunities within the main railway station (Vougioukas & Bochtis, 2008). The City of Linz transport network thus is by far the most comprehensive illustration of the potential of an integrated approach to public transport planning and economic transformation.
3.5. CASE STUDY OF CRACOW, POLAND

Another contextual analysis of the developed world is the medium-sized public transport system in the City of Cracow, Poland for which diverse forms of public transport integration were proposed (Khan et al., 2014). The current urban public transport system in the city comprises of tram and bus networks critically managed by private and public administrators. The urban transport system ensures service for around 1 million commuters. It has about 190 thoroughfares comprising 79 urban bus routes, 24 tram routes, 22 mini bus routes and 65 commuters’ bus routes (Hasan & Ukkusuri, 2014).

This system is maintained by a variety of service suppliers, such as public private operator Mobilis LTD, public operator (Cracow Urban Transportation Company) and other numerous small private carriers (Gao et al., 2013). Within the Cracow metropolitan city, the railway network covers up to 127 km of train lines. There are 19 commuter’s stops, 7 active sidings and 4 commuter freight stations in this network (Kerr & Hiltz., 2013). The railway network has remained unavailable for local urban traffic (Haller, 2016). The suburban public transport in the city is accompanied by national road transportation and microbus transportation services offered by private operatives.

3.5.1. Variant V0

The Variant V0 is presented by partial transport integration focused on the spatial, organisation and economic information connectivity. This variant is characterised by the following integration aspects of urban public transport system:

(i) 11 kilometres of integrated tram-bus routes and 27 shared tram-bus stops;

(ii) 6 integrated interchange hubs, including 3 interchange hubs in the city centres (labelled 1, 2, 3 in figure 2), only one in the north, one in the west and one in the South-west part of the city (respectively, labels 4, 5, 6 in figure 3) (Hasan & Ukkusuri, 2014). “In these interchange hubs, commuters have accessibility to 3-10 tram routes and 4-10 bus routes.
(iii) Multimodal public transportation fares combined with the integrated ticket that covers all public transportation modes and 5 major railway entry lines (Khan, 2014:15). The ticket presents 2 traffic zones, namely zone 1 (city centre) and the zone 2 (Suburban spaces of the city) (Gao et al., 2013). “It is estimated that 30% of transferring commuters are covered by an integrated ticket;

(iv) 35% of the vehicles and 30% of the stops are equipped in a common, integrated commuter information system that includes timetables, transfer points and riding times;

(v) Common headway on principal and major subordinate bus or tram routes resulting in a certain (limited) coordination of the timetables of various different public transportation modes at the origin and destination stops” (Haller, 2016).

The announced rules indicate that intervals equal 10 min on the main tram or bus routes during peak hours and its promotion on the reduction routes and/or in the off-peak period (usually 30 min). The majority of tram and bus routes function closely with headways of 10, 12 and 15 minutes (Khan, 2014). The graphical illustration of the present public transport system is showed in figure 4. The figure 4 illustrates the present tram and bus network, with major tram and bus routes; shared or common tram and bus ways and integrated, multimodal interchange hubs (public transport terminals). It also illustrates the traffic flows and volumes on major routes of urban public transport systems.
3.5.2. Variant V1: Integration of railway-oriented public transport

The Variant V1 is an investment intensive, radical, railway-oriented amendment of variant V0 (Khan, 2014). It is created on the present suburban and urban public transport systems and the primer of 2 lines of the Light Express City Train. It services the City of Cracow and its contiguous spaces, with 2 subway lines, namely: L1 and L2 intersecting the Cracow metropolitan area vertically and horizontally (Hasan & Ukkusuri, 2014). The Light Express City Train line 1 (LECT 1) is 47 kilometres long, and operates from south-west in Skawina to north-east in Zastow. As illustrated in figure 4, LECT 2 is 37 kilometres long from the south in Wieliczka to the north-west in Krzeszowice (Haller, 2016). Both the two LECT lines operate with headways of approximately 15 minutes. However, 10 and 12 stops are situated respectively on the LECT line 1 and 2 (Gao et al., 2013).

The subway lines of the City of Cracow are illustrated in figure 3. Subway line 1 operates from the east in Bronowice to the west in Nowa Huta, while subway line 2 operates from the south
in Biezanow to the north in Piastow (Gao et al., 2013). Respectively, their intervals are approximately 16 kilometres and 22 kilometres. On subway lines 1 and 2 respectively, the 18 and 25 subway stops have an average distance between stops of 0.9 kilometres throughout the entire subway system (Haller et al., 2016). The subway lines function with headways of about 4 minutes. For variant V1, several bus routes are either shortened or closed to eradicate duplication of the presented subway and the LECT lines and the present bus system (Schneider, 2013). In other situations, new bus routes are presented as the feeder integration from either interchanges to suburbs or suburbs to interchanges.

Nevertheless, the following transport integrating solutions are the designed variant: (i) 39 shared tram-bus stops (increased by 12 stops) and 11 kilometres of disconnected, common tram-bus routes; (ii) 10 integrated transfer nodes (interchanges) (Gao et al., 2013). Six of the interchanges are exactly the same as of variant V0. Although, one of the transfer hubs (labelled 4) has been rebuilt and extended due to the setting up of integration of the present public transport modes and the subway line L2 (Haller et al., 2016). The recently introduced transfer hubs (numbers 7, 8, 9, 10) create multimodal appeal. In interchange hub 7 the commuters have accessibility to 12 tram routes, 19 bus routes, 12 tram routes, one subway route and 2 LECT routes (Schneider, 2013).

However, in interchange hub 8, commuters interchange between 4 bus routes, 6 tram routes and 1 LECT route (Schneider, 2013). Respectively, in transport hubs 9 and 10, commuters have accessibility to the tram routes, 2 subway, 1 LECT route and 1 subway. The shared multimodal urban public transport fare joins with the integrated ticket system that covers trams, buses and subways (Haller et al., 2016). The projected regional system is the same as the variant V0. It is envisioned that approximately 30% of the interchanging commuters are covered by the integrated ticket system. A total of 45% of vehicles and 40% of stops are prepared in an integrated commuters’ information structure which encompasses transfer points, timetables and riding times (Bojanova et al., 2014). Approximately 10% increment of the information connectivity is anticipated in Variant V1 (Khan et al., 2014). Figure 5 illustrate the subway lines of City of Cracow
3.6. CASE STUDY OF BOGOTA, THE CAPITAL OF COLOMBIA

Bogota, Capital city of Colombia is situated adjacent to the centre of the country, approximately 2,640 metres above sea level (Deloitte, 2014). Bogota is the biggest metropolitan city in Colombia, with an estimated populace of approximately 8.2 million in 2014 and a density of 3,912 residents per square kilometre (Kerr & Hiltz, 2013). Over the past two decades, Colombia has experienced an ever-growing population in urban centres influenced by economic and social factors. The city has absorbed a great portion of people who have migrated from the rural to the urban spaces, and the increasing population has produced a variety of major challenges for the city. These include the transport sector, heavy traffic congestion influenced by the abnormal use of private vehicles and the necessity for an effective-cost means of urban public transportation for the urban poor (Yuan et al., 2015). While automobiles occupied 64% of road usage, their residents demonstrated only 19% of the populace, with a day-to-day average commuting time of 80 minutes each way (Bauer et al., 2012). Other concerns involved a variety of air pollution in peak hours’ travel and a high rate of accidents.
Bogota’s public transport systems were used by few residents, with a low quality of service and convenience. The average speed of urban public transport systems remained about 10 kilometre per hour, and decreased to 5 kilometre per hour during peak hours because of heavy traffic (Deloitte, 2014). This led to increasing frustration of commuters because of the long waiting times for buses. To reduce time spent waiting for public transport, commuters therefore shifted from public transport to automobile travel. According to Brambilla et al. (2013:16) “Without price regulation, private bus operators were free to hike up prices and charge far more than public bus operators”. In 1998, Bogota Metropolitan City initiated a long-term plan for urban mobility as part of the urban renewal approach. Its ideals were to limit private vehicle travel, improve public transit by partially financing infrastructure development and promote non-motorised transport (Yuan et al., 2015).

After the new State Government prohibited plans for a train system in 1999, Bogota’s mayor announced the mobility plan for a BRT system, built on an effective practise in Curitiba (Kerr & Hiltz., 2013). Curitiba is well-known globally for having the first full bus rapid transit (BRT) framework. Today, the Curitiba integrated public transport network spreads over 14 of the 26 urban communities of the metropolitan region (Deloitte, 2014). The city’s integrated public transport network is the mainstay for the city’s transit-oriented development (TOD) model. Furthermore, it was envisioned by the national government that Bogota’s BRT system would help to realise major goals by: (a) reducing private automobile travel; (b) upgrading the urban public transport system with regard to safety, comfort, reliability, convenience, efficiency (c) increasing and refining bicycle paths; and (d) ensuring the availability of public spaces (Yuan et al., 2015).

3.6.1. Project Design and Description

The first proposition for a public transit framework included a network of buses and heavy Metrorail, however, this was abandoned in light of the fact that it cost multiple times that of the envisaged BRT. The Bogota mayor imagined the BRT as the focal point of an integrated urban mobility strategy. This however necessitated giving attention to the institutional issues that prompted price increases by small private transport companies (Kerr & Hiltz, 2013). The small bus proprietors and drivers opposed the proposition by facilitating protests which attempted to restrict its ratification.
The Bogota, TransMilenio BRT connects four components to provide functional efficiency:

a) **Infrastructure**: the BRT system is comprised of terminal stations, 22 central trunk corridors, feeder zones, pedestrian overpasses, plazas and sidewalks (Khan et al., 2012). Dedicated bus lanes, including new bus stations and integration stations at the end of the lanes ensure a smooth transfer to feeder lines. Traditional buses are banned from operating in trunk corridors (Brambilla et al., 2013).

b) **The Fare system**: Ticket office stations enable commuters to pre-pay for fare cards (smart Cards) that use a magnetic device, streamlining the ticketing and boarding processes (Bauer et al., 2012). Commuters can change from a local to an express bus, as well as from one route to another while using the same electronic fare card that is automatically debited at turnstiles (Deloitte, 2014). Revenue from card sales is deposited in a trust fund from which operators are paid according to rules in their concession contracts.

c) **The Bus Technology**: The innovative buses utilise Euro 2 and 3 technology and function on dedicated lanes 18 hours a day (Kerr & Hiltz, 2013). Each bus has a capacity of 160 individuals with platform level access, including space for disabled persons. There are new feeder buses that run on local streets and have a capacity of 70-90 individuals. Trunk buses use the central lanes of existing streets, longitudinally segregated from the general traffic.

d) **The Transit Management**: The tasks fleet centre informs commuters of schedule changes and other updates, produces reports, and maintains records. All buses are equipped with Global positioning system (GPS) devices linked to the operations centre (Yuan et al., 2015). Under a centralised system of integration, monitoring is done via eight substations (80 buses per station), and communication is established to schedule services and provide real-time responses to contingencies (Kerr & Hiltz, 2013).

The Bogota BRT system utilises different structures to accommodate high commuter demand. These incorporate the utilisation of high-capacity public transport, restrictive running ways, level boarding, off-board charge payments, and continuous public transport benefits allowing as much as 13 second lower headways on busy segments of the 388 kilometre system. Including the 8 stages of the TransMilenio BRT Masterplan, the development of the initial two have been
The TransMilenio Bus Rapid Transit (BRT) system provides the city with effective and safe mass travel systems supporting high commuting. Approximately 1.5 million commuters presently use the system consistently following achievement of the initial two stages (Deloitte, 2014). The BRT framework, through coordination of cutting edge Euro 2 and 3 innovative operational efficiencies has clearly contributed to lessening traffic congestion throughout the city. Bogota’s residents and tourists currently experience decreased travel time, fewer accidents and cleaner air. There has been a 32% decrease in general travel time and a 40% decrease in air emission because of the elimination of 2,100 old public buses in service. There has also been a 92% decrease in accident levels in passageways where the TransMilenio BRT system works (Deloitte, 2014). Post-BRT, Bogota has recorded critical fuel saving of 47%, while expanding throughput by 60% (Kerr & Hiltz, 2013).

3.7. ADDIS ABABA, ETHIOPIA

In the City of Addis Ababa (Ethiopia), complex urban public systems and networks are prevalent similar to those of other developing countries (third world) countries in the world (Gebeyehu & Takano, 2007). Most commonly observed amongst these challenges is overcrowding of pedestrian and modes of public transport due to a limited supply of public transport. This exists against a background of high demand, with no pedestrian walkways for a city that predominantly has a high volume of pedestrians. Fenta (2014), and Gebeyehu and Takano (2007) observe that buses (40%) and taxis (60%) are the only modes of transport available to provide urban public transport services, as there is no rail network. Taxis in Addis
Ababa are the most commonly used mode of transport, yet are not affordable by the urban poor (Fenta, 2014). Although the buses are the cheapest option, due to unreliability, overcrowding and the uncomfortable nature of the government buses, some people, especially the youth resort to minibus taxis even though they are expensive. The table 2 below provides a synopsis of the urban public transport network in Addis Ababa, Ethiopia:

<table>
<thead>
<tr>
<th>Public Transport Needs and Challenges</th>
<th>Interventions towards transformation of urban public transport operations</th>
<th>Outcomes the initiatives or transformation strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>o Limited urban public transport supply against high demand of public transport</td>
<td>o Addis Ababa Transport Plan which entails: - Bus Rapid Transit’ and/or Light Rail Transit along major corridors - Minibus taxis promotion.</td>
<td>o The Implementation of the Addis Ababa Urban Public Transport Plan is still a work in progress.</td>
</tr>
<tr>
<td>o High costs or unaffordable transport fares affecting mostly the urban poor</td>
<td></td>
<td>o The light rail is making steady progress in improving urban mobility though the demand for multimodal public transport systems is evident,</td>
</tr>
<tr>
<td>o Lack of cooperation from transport operators coupled with public authorities’ minimal role in public transport operations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>o High volumes of pedestrians with minimal pedestrian walkways</td>
<td></td>
<td></td>
</tr>
<tr>
<td>o Informal and non-regulated public transport operations</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Synopsis of the Addis Ababa Urban Public Transport System Operations [Source: Author, 2018]

Given the fragile state of institutions, Fenta (2014) questions the possibility of effective coordination and management of different modes of public transport operations proposed in the Urban Public Transport Plan, especially since the public authorities play a minimal role in the public transport operations. It is evident that the state has not done enough to strengthen its institutions, thereby creating an enabling environment and bringing all stakeholders to work together in Addis Ababa. Though the partnership with the China Railway Group Limited saw successful implementation of light rail, this did not bring together all relevant stakeholders (See Table 2).
Institutional capacity development is essential, especially since urban public transport infrastructure requires institutional coordination amongst interdependent stakeholders. Without effective coordination of stakeholders, chances of formulation of a collective strategy for an integrated multi-modal urban public transport network are limited. Thus, disjointed urban public transport systems characterised by unaffordable and poorly coordinated public transport, as it is the case in Addis Ababa, may persist if a variety of public transport modes is not catered for. There is also a need for Addis Ababa public transport interventions to incorporate elements of non-motorised transport like pedestrian walkways and cycling routes, especially for short distance trips.

3.8. NAIROBI, KENYA

The Nairobi Spatial form is embedded in the colonial era of planning characterised by segregation according to race and spatial fragmentation, where people are located far from places of employment (Howe & Bryceson, 2000). The spatial form is such that local people, especially the urban poor are in desperate need of an efficient urban public transport network that will help integrate the spatial imbalances of the past. The state has attempted to redress the ills of the past, but challenges of affordability and congestion persist in terms of extended travelling time and public transport cost. This is especially true when people must use more than one mode of transport to commute from places of residence to obtain access to their work and other urban amenities (Gonzales et al., 2009). These necessitate more innovative and institution integrated approaches when planning urban public transport infrastructure policies and strategies.

The most common mode in Nairobi is road transport, although there are rail operations available in limited quantity (Roux et al., 2013). The road layout of Nairobi was initially planned without considering future public transport needs. Thus rapid population growth and overcrowding on the roads have overshadowed the grid pattern of the Nairobi road network (Gonzales et al., 2009). The average travelling time to work in Nairobi is said to be between 2 to 4 hours which negatively affects productivity in the work place and family life (Howe and Bryceson, 2000). The need for an efficient multi-modal public transport network is therefore apparent to enable residents to effectively participate in the economy without stressful travel experiences which can also be unaffordable. The Bus Services and Matatu Share Taxis are the
main providers of public transport in Nairobi with minimal coordination between the two (Howe & Bryceson, 2000). Both these operations are privately owned, while railway operations are administered by the state in conjunction with Kenya Railway Corporation (Le Roux, 2013). The private sector is the main role player, as government has minimal involvement in the public transport operations. Table 3 provide synopsis of the Nairobi Urban Public Transport System Operations

<table>
<thead>
<tr>
<th>Problems associated with transport system, its planning and operations</th>
<th>Interventions towards transformation of urban public transport operations</th>
<th>Outcomes of the initiatives or transformation strategies and prevailing circumstances</th>
</tr>
</thead>
<tbody>
<tr>
<td>o Long travelling hours</td>
<td>o No studies and Recommendation have been carried out and no records exist of interventions or projects.</td>
<td>o The Kenya government only formulated a vision and mission with no implementation since 2004.</td>
</tr>
<tr>
<td>o Overcrowding and high traffic volumes on the roads.</td>
<td>o Kiiru (2015) observed that there is minimal comprehensive planning being directed towards urban public transport improvement with the last Public Transport Master Plan for Nairobi dating as back as 1970.</td>
<td>o Vision “a world-class transport system that is integrated and responsive to the needs of people and industry”.</td>
</tr>
<tr>
<td>o Limited urban public transport supply against high demand of public transport.</td>
<td></td>
<td>o Mission: “to develop, operate and maintain an efficient, cost effective, reliable, safe, secure and integrated transport system and link transport policy with other sectoral policies, in order to achieve national and regional development aspirations in a socially, economically and environmentally sustainable manner”. (NTPC, 2004)</td>
</tr>
<tr>
<td>o Lack of cooperation from transport operators coupled with public authorities’ minimal role in public transport operations.</td>
<td></td>
<td>o The urban public transport challenges in Nairobi persist despite the 2004 said vision and mission.</td>
</tr>
<tr>
<td>o High volumes of pedestrians with minimal pedestrian walkways.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>o Informal and non-regulated public transport operations.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Synopsis of the Nairobi Urban Public Transport System Operations [Source: Author, 2018]
As depicted in the matrix above, Kenya still has a long way to go to improve the state of its public transport system operations. The government have not done enough in providing and implementing a regulatory framework as well as creating an enabling environment. Access to public transport as well as affordability is still a major challenge. It is clear from the Nairobi case that a comprehensive vision on its own, without commitment and collective effort by the state and other relevant stakeholders to achieve the said vision as well as goals and objectives is not assisting with alleviating the challenges in public transport operations. The political will to accelerate efforts towards a multimodal urban public transport network responsive to the needs of Nairobi people is critical to see development of sustainable urban public transport systems (Table 3).

3.9. CONCLUSION

This chapter has provided a brief overview of the state of innovative urban public transport systems in cities of the developed, transitional and developing world. There is a clear distinction between the levels of innovation and the standards of urban public transport operations for the three worlds indicated above. The review shows that the different modes of urban public transport are readily integrated, fully functional, easily accessible by all, affordable and provide an efficient service. The main focus of the developing world has now shifted towards ensuring sustainability and improving the level of integration of transport nodes with social and economic facilities. This chapter has discussed the commendable progress of innovative urban public transport systems made by Colombia, illustrating the potential which transitional countries including South Africa could achieve. In spite of the developing world’s realisation of the need to improve their urban public transport systems, there is still a long way to go, with institutional coordination and adequate investments being major concerns. The cases of Addis Ababa and Nairobi discussed in this chapter provide evidence of the challenges which lie ahead for the developing world, given the persistent challenges and poor management of public transport operations.
CHAPTER 4: OPERATIONALISING RESEARCH

4.1. INTRODUCTION

This study adopted a mixed-method approach which consisted of a phenomenological case study survey design and experimental research design using spatial and qualitative methods of data collection and analysis. The study explored the extent of spatial connectivity of innovative urban public transport systems in the City of Johannesburg. The spatial approach required crowd sourced data from social media (twitter and Facebook) collected from Echo-Echo. The qualitative method was based on data from key informant interviews and field observations. Accordingly, this chapter clearly outlines the research design, sampling design, research approaches, data collection instruments and data analysis tools used when investigating the four (4) set research questions. The chapter further outlines the validation of the study results model, and the limitations as well as challenges of the study.

4.2. RESEARCH DESIGN

A research design is a road map for steering the research whilst controlling elements that may hinder the validity of the results (Burns & Grove, 2003). The research design establishes the blueprint of the study from onset to conclusion (Chatzimilioudis & Zeinaliopour-Yazti, 2013). It allows the researcher to approach data collection in a manner that will enable logical unpacking of the research problem by specifying the type of information essential for the analysis of the main subject(s) being studied. This study adopted a phenomenological case study survey and experimental research design that used mixed-methods approaches to gather spatial and qualitative information. An exploratory approach was applied to articulate the study problem for comprehensive investigation, while a descriptive approach was used to collect complete and more accurate information for the study. Accordingly, the two mentioned research designs were structured in accordance with the main research question and sub-questions which were aligned to the research objectives to achieve the aim of the study within the scope of the defined objectives.
4.2.1. Phenomenological case study survey design
The research made use of a phenomenological case study survey design to delineate the extent of spatial integration among public transport systems. According to Kohlbacher (2006), the cased 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. In this study, the phenomenological case study was based on an empirical enquiry and analysis of policy directives and interventions outcomes, for instance the planning and development practices within the City of Johannesburg public transportation. The case studies were also used to explore the relatively new concept of the applicability of geolocation data as techniques to delineate the state of public transport integration.

4.2.2. Experimental Research Design
The study made use experiments to determine whether geolocation data derived from social media platforms (namely Twitter and Facebook) could be used to explore the state of spatial integration, visualise commuter concentrations and track the movement patterns of Gautrain and Rea Vaya commuters. With an experimental research design, the researcher was able to repeatedly conduct the prediction analysis, thus to ensure 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 creating a relationship between cause and effect of the variables in the set or subsets (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.
4.3. RESEARCH APPROACHES

Myers (2009) describes the research approach as being the strategy of inquiry which links the underlying assumptions to data collection whilst still remaining within the scope of the research design. The commonly used research approaches are qualitative and quantitative; the two approaches can either be viewed as how the researcher interprets the phenomenon. Whether statistics alone can best interpret worldly phenomenon or whether a socio-economic viewpoint represents a more realistic interpretation of the phenomenon. This study used mixed methods, which consisted of spatial and qualitative approaches to achieve the aim and four (4) objectives of the study.

The study used spatial and qualitative approaches, since it sought to explore the extent of spatial integration between the Gautrain and Rea Vaya modes of public transport. Key informant interviews were used to unpack the status quo of the two public transport modes. Crowd sourced datasets from Facebook and Twitter were collected from Echo-Echo, and analysed using the kriging interpolation method and descriptive statistics. Echo-Echo is an independent private company that collects and analyses social media information from variety of web 2.0 platforms. Using sentiments analysis and semantics analysis, Echo-Echo untangles the big data social media to derive meaning from large quantities of text (Moyo & Musakwa, 2016).

The results were captured live and analysed through Echo-Echo. The geographic locations co-ordinates of where the social media posts were made were converted into shapefiles and spatially interpreted using the Geographic Information Application (ArcGIS 10.3). The aim of the conversion of these geographic social media co-ordinates into shapefiles was to create maps through the kriging interpolation method. The maps were also used to visualise high and low commuter concentration zones and to track the movement patterns of commuters who were using Rea Vaya and Gautrain. The period of the study was from January 2017 to August 2017 and the analyses were triangulated to yield viable results. This approach used a high temporal and spatial resolution as a means to ensure a large sample size during the research.
4.4. DATA COLLECTION

In this study, data was collected through a desktop study, key informant interviews and Echo-Echo. Primary and secondary data were used in the study. The merit of using secondary data, was that big data could be analysed in volume. Also with primary data collection the interviewer could explore the veracity of the data by querying responses from different interviews.

4.4.1. Desktop Study

The desktop study was informed by data collection based on a review of relevant, related and available literature on urban public transport provision, transportation planning and management in the City of Johannesburg. Data on the City of Johannesburg public transport planning and management were gathered from various major sources such as existing literature, policy documents and reports of National, Provincial and Local organisations. Various themes relating to integrated urban public transport planning and management in the City of Johannesburg (such as urban public transport, transport planning, integrated public transport systems, transport management processes, geolocation based services and the policies and legislatives framework governing transportation in Johannesburg) were identified and used in carrying out the web search in major electronic databases. These databases included Scopus database, Sage journal online, Science Direct journal online and other catalogues from the University of Johannesburg library.

Secondary data collected through the use of the desktop study played a vital role in guiding the geography of the topic. It also unpacked the status quo in terms of the effectiveness of the policies and legislations governing public transportation in the City of Johannesburg. It further revealed what the study area was like in the past in relation to the present and displayed the actual and potential relationship between the Gautrain and Rea Vaya. In addition, it provided the context into which the primary data fitted and provided an overlap in types of contexts. Using the secondary data in a comparative context was also useful in understanding the policy frameworks and trends in public transport provision within the city.
4.4.2. Key informant interviews

The key informant interviews were semi-structured, using open-ended questions to guide the conversations. Questions were guided by the main research question and sub-questions as well as the objectives of the study (See Annexure B for an example of the questionnaire). In-depth key informant interviews were held with officials from the Johannesburg Roads Agency (JRA), Gautrain Management Agency (GMA), Gauteng Department of Roads and Transport and City of Johannesburg. Interviews continued until data saturation was obtained. These interviews enabled accurate information to be obtained on the extent of spatial integration of the Gautrain and Rea Vaya public transport modes. The interviews were semi-structured, using open-ended questions to guide the conversations; and questions were guided by the four study objectives. Interviews were recorded on a smartphone with the permission of the interviewee.

The key informant interviews were useful in making sense of behaviour without mandating categorisation which would limit the scope of inquiry. They were relatively formal, taking on the format of face-to-face discussions at their places of work. This methodology is a useful way of getting to grips with people’s constructs, mentalities, perceptions and definitions of situations and realities. As such, the interviews provided distinctive empirical data, and understandings were compared to the empirical data gathered from other sources. The interviews were also used to gain better understanding of the lived experience of the commuters using the studied modes of public transport.

4.4.3. Geolocations Twitter and Facebook Data (Echo-Echo)

42630 Gautrain and Rea Vaya crowd-sourced geolocation social media (Facebook and Twitter) data records were received from Echo-Echo in Excel format (Annexure C). Echo-Echo is an independent private company which collects and analyses social media data from a variety of web 2.0 platforms. Using sentiments analysis and semantics analysis, Echo-Echo untangles the social media data to derive meaning from these large quantities of text (Moyo & Musakwa, 2016). The results are captured live and analysed through Echo-Echo. The geolocation social media datasets received from Echo-Echo included labelled time-series data with fields including the user, coordinates, message, source and date. The first steps in data preparation involved cleaning the social media data in Excel before converting it into a shapefile format. During the data preparation it was found that some social media posts did not have X and Y
coordinates, thus only 39391 Gautrain and Rea Vaya geolocation social media datasets were used in the study.

In this study, coordinates of geographic locations of the social media posts were converted into shapefiles and spatially interpreted using the Geographic Information Application called ArcGIS 10.3. The aim of this conversion of geographic social media co-ordinates into shapefiles was to create maps through the kriging interpolation method. The execution of the different analyses of the data relied on the reliability of the information recorded which meant that all potential errors had to be minimised. Despite quality assurance being embedded in all the analytic processes, such as data collecting and editing, errors may still have existed. To prevent errors from accumulating, the editing process was repeated until the researcher was satisfied that all the records used in the analysis reflected a true representation of the real world feeds. Maps were used to visualise high and low commuter concentration zones and to track the movement patterns of commuters using Rea Vaya and Gautrain. Table 4 summarises the information analysed during the study.

<table>
<thead>
<tr>
<th>Datasets</th>
<th>Quantity</th>
<th>Formats</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gautrain Stations</td>
<td>5 train stations</td>
<td>Esri shapefile</td>
</tr>
<tr>
<td>Gautrain bus stops</td>
<td>245 bus stops</td>
<td>Esri shapefile</td>
</tr>
<tr>
<td>Rea Vaya bus stops</td>
<td>209 bus stops</td>
<td>Esri shapefile</td>
</tr>
<tr>
<td>Gautrain commuters</td>
<td>27 967 posts with geolocation co-ordinates</td>
<td>Microsoft Excel</td>
</tr>
<tr>
<td>Rea Vaya commuters</td>
<td>11 424 posts with geolocation co-ordinates</td>
<td>Microsoft Excel</td>
</tr>
<tr>
<td>Gautrain and Rea Vaya Social</td>
<td>39 391 posts with geolocation co-ordinates</td>
<td>Microsoft Excel</td>
</tr>
</tbody>
</table>

Table 4: Summary of datasets collected [Source: Author, 2018]

4.5. 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 well-integrated, reliable and convenient innovative public transport systems consistent with the inductive approach to data analysis.

4.5.1. Content Analysis

Relevant, related and available literature on urban public transport provision, transport planning and management was collected through a desktop study. Content analysis was adopted to unpack the status quo in terms of the effectiveness of the policies and legislation governing public transportation in Johannesburg. Using the secondary data in a comparative context assisted in understanding the spatial, historic, social differences and trends in public transport provision within the City of Johannesburg. Further examination of data over 8 months was used to demonstrate social media interactions as a critical control feature.

4.5.2. Thematic analysis

Data was then classified into two main clusters namely innovative urban public transport systems and spatial connectivity of these systems. Under the cluster of innovative urban public transport systems, data was analysed in accordance with themes of improved urban mobility such as efficiency, accessibility, affordability and reliability. For the spatial connectivity of urban public transport systems cluster, data was analysed in line with themes such as spatial patterns routes networks of urban public transport systems, networks integration of urban public transport systems, visualisation of commuters concentration zones and commuters movement patterns. This was essential to ensure that data interpretation and analysis was aligned to the aim and four objectives in the study, and was able to perform credible analysis of the extent of spatial integration amongst the urban public transport systems. Lessons learned from the content analysis on international case studies in the developed world, transitional market countries and developing world were also used as points of reference in performing the content analysis.

4.5.3. Spatial analysis

Spatial concentration analysis can be undertaken through numerous indictors. This is because the social media data is unique in that it provides unprecedented opportunities to investigate commuter thoughts and feelings which are difficult to collect using conventional means such as questionnaires. The spatial phenomenon in the real world is made up of three spatial
dimensions, namely: the X and Y coordinates for geographical coordinates and Z values representing elevation. Thus incorporate these data in the study were very fundamental. Conception of an environment which can be used for the visualisation of the interchange nodes of the Gautrain and Rea Vaya had the potential for increasing integration within the urban sphere. While exploring big data, the transformation of big data into a meaningful representation of the spatio-temporal structures requires reduction through aggregation or selection in a manner that suits the requirements of the analyst (Wood, et al., 2011).

Initially after activating the spatial analysis extension in Arc GIS 10.3, the researcher set the environment for the analysis in the model. This was done to control the areas for spatial analysis examination and the magnitude of the results. The environment setting included the working directory, results directory, extent, and cell size. All these had to be set before each analysis was carried out in the model. Moreover, in assembling the data for analysing, the initial step was establish a set of rules. This was crucial to ensure that at the closing stages of the prediction model, the results would be a realistic presentation of the spatial patterns of the web 2.0 data. Consequently, the proposed criteria for delineating the state of urban public transport integration was established using the model rule set. This was developed through strenuous trials of various analytic and visualisation modus operandi, until one which showed real life interpretation of the data was found. Furthermore, the model used was relevant for distinguishing patterns of spatial associations (clusters and atypical spatial locations outliers for the various hubs).

4.5.3.1. Time Series

The main principle of time-series is the episodic assessment of elements, with investigations being made at set times to see any patterns or trends that exist within the data set. According to Luczak et al. (2016: 3), “Clustering of time series can pose a significant challenge, because of the detection of patterns and relationships in large volumes of data”. Colin et al. (2004) defines interpolation as the prediction of surface values at unobserved locations, based on observed surface values of neighbouring locations. In terms of clustering, it is notable that the time-series techniques allow for numerous clustering of themes to be initiated in the research such as seasonal, weekly or monthly. These outcomes can later be compared with historical data to evaluate any developing patterns or changes in trends (Moyo & Musakwa, 2016).

Therefore, geolocation data for Facebook and Twitter users was collected for 8 months in 2017.
Through clustering one was able to identify cause and effect relationships within the urban public transport systems and thus determine the factors which cause inconsistent trends in commuting capacities.

4.5.3.2. Kriging interpolation

Spatio-temporal patterns could be approximated using interpolation. Colin (2004) defines interpolation as the prediction of surface values at unobserved locations based on observed surface values of neighbouring locations. Historically, interpolation through use of spline and kriging techniques has been used to predict animal migration patterns, weather patterns and for agriculture studies. In this study kriging interpolation was used to analyse the social media data for the various months within the model. This is a “powerful statistical interpolation method used for diverse applications, which assumes that the distance or direction between sample points reflects a spatial correction that can be used to explain variations in the surface (Colin, 2004: 3). The elevation or ‘Z’ value was extracted from the City of Johannesburg Digital elevation model using the Arc GIS spatial analyst tool to extract values to points of geographical locations from the web 2.0 posts. This was then used as the points of the kriging interpolation operation to predict spatial patterns of the data.

The rationale of using the interpolation technique was to analyse similarities over time; the degree of the spatial coverage; the level of interdependence; and finally the nature and strength of the interdependence in the predicted surface. The basis of using the interpolation technique (kriging) was to analyse similarities in a time series analysis; the degree of the spatial clusters; percentage of interdependence; and finally the nature and strength of the interdependence in the predicted surface. Kriging was also used to analyse the variations in density for the various recorded sites in the social media data obtained from Echo-Echo. First, before performing the kriging analysis, the data was analysed for any pre-existing patterns, as displayed in the previous section using histograms and semi-variation for the ‘z’ value of the social media big data.

4.5.3.3. Visualisation

Through brainstorming and a review of the literature, an evaluation criterion for the model was developed (table 5). Accordingly reclassification was carried for the spatial analysis results so as to be able to compare the results using the criterion. Tools such as list reduction and multi-
voting helped to assess which criterion could be used to establish the extent of the clusters and outliers. A respective ranking based on the criterion was then developed, with 5 representing areas of extremely high commuter concentration and 1 representing areas with low to no commuter concentration. The integrated commuter index value was calculated to determine the overlay (that is how close the Gautrain and Rea Vaya commuter concentrations are towards each other). Table 5 illustrates the criteria for the commuter concentration index.

<table>
<thead>
<tr>
<th>Social Media Concentration</th>
<th>Commuter Concentration Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Low Concentration</td>
</tr>
<tr>
<td>2</td>
<td>Medium Concentration</td>
</tr>
<tr>
<td>3</td>
<td>Moderate Concentration</td>
</tr>
<tr>
<td>4</td>
<td>High Concentration</td>
</tr>
<tr>
<td>5</td>
<td>Extremely High Concentration</td>
</tr>
</tbody>
</table>

Table 5: The commuter concentration index [Source: Author, 2018]

4.6. LIMITATIONS AND CHALLENGES

Errors: When using interpolation techniques, the values are generally estimated in an objective manner using the probability theory. This implies that prediction errors would occur in the analysis of findings. Thus to validate the findings of the analysis, a measurement of the error had to be undertaken during a cross-validation exercise.

Data quality: Analyses run in GME and Arc GIS completely rely on the quality of input data. However, if the data are obtained from an unreliable source, the predictions will have numerous errors leading to misleading results. Therefore, the researcher had to ensure the social media data collected were obtained from an independent source with no affiliation with the GMA. Moreover, the research had to ensure that minimum errors were made during the data filtration exercise so as to note records with missing geographic coordinates.

Model Validity: as the research followed an experimental approach, a means of validating the results was needed. This was attained through the use of location maps from Echo-echo and numerical data on the volumes of commuters entering the various stations. This data would show whether the findings of the model accurately represented variations existing in the hubs.
This validation exercise was further used to identify and explain the reasons why the hubs had varying volumes of commuters.

4.7. ETHICAL CONSIDERATIONS

This study was premised on the utilisation of social media big data to define the state of spatial integration existing in the Rea Vaya and Gautrain public transport systems. Through the demarcation of the sphere of influence of the Gautrain and Rea Vaya, it becomes evident that privacy concerns arise. The data analysis carried sensitive personal data of the users, such as the user’s name and unfiltered Facebook and Twitter posts. Therefore it was ensured that the data was only used for academic and planning purposes. However, privacy anxieties subsequently arose due to the nature of this big data, as it could be misused to profile specific users or be sold for private gain. Moreover, another ethical issue of confidentiality arose because, whilst information on social media platforms is public knowledge, the researcher still could be held liable for any misuse of the data, especially the geographic locations of the posts. The study therefore utilised the university’s ethics and code of conduct policy to inform how the data would be safeguarded to protect the interests of the Rea Vaya and Gautrain and also social media users.

4.8. CONCLUSION

The chapter spelt out the methodological premises and the research design process related to the study. It described the development of the research from the inputs to how it is based on the potential of using social media big data to define the state of urban public transport integration in the City of Johannesburg. The resulting model though having limitations and challenges, had the potential to visualise the points of interests of the commuters, as presented in the coming chapters. The chapter closed with the ethical considerations of the research methodology.
CHAPTER 5: POLICIES AND LEGISLATIVE FRAMEWORKS GOVERNING PUBLIC TRANSPORT SYSTEMS

5.1. INTRODUCTION

Ever since the emergence of a democratic South Africa in 1994, the post-apartheid government has embarked on transforming the country’s public transport systems and operations through policies and legislative frameworks. It is evident that the South African government has made a priority of improving public transport systems through mega investments and strategic policy instruments. These policies and effectiveness of such investments leave much to be desired in terms of spatial integration and efficiency of public transportation. Prim (2016) observes that the South African urban public transport system has reached a crucial stage, with major cities (supported by national and provincial governments) already geared up to the implementation of innovative urban public transport systems. South African metropolitan cities seem to be the ones at the centre of innovative urban public transport system initiatives (mostly BRTs), while other cities and towns have lagged. This is understandable, given the population concentration and major economic activities in metropolitan cities.

For this study, it was very critical to examine the effectiveness of the commonly followed top-down approach to post-apartheid South African policy and legislative frameworks governing public transportation. Thus, this chapter reviews the development in policies and legislation governing public transport systems since the emergence of democracy in 1994 at national spheres of government. The Gauteng province and City of Johannesburg’s specific policy interventions on public transport infrastructure are also discussed with a closer look at the level of collaboration between the provincial, national and municipal departments. This is essential, since the provincial government is the link between national government which sets out policy directives and the municipal sphere, where actual implementation takes place. In addition, the chapter outlines the effectiveness of government legislative frameworks and policy interventions.
5.2. POST-APARTHEID SOUTH AFRICAN POLICIES AND LEGISLATIVE FRAMEWORK GOVERNING PUBLIC TRANSPORT SYSTEMS

The South African approach to spatial planning is often a top-down approach, where the national government sets a framework through policy directives which provincial and municipal departments must work towards. The provincial departments are then tasked with the responsibility of regulating provincial specific matters. Though the policy directives are set at national level, with provinces setting legislative frameworks and policy directives in line with provincial differentiation, the actual implementation takes place within the Municipal sphere of Government. The general expectation is that the three spheres must work together, with the national and provincial spheres playing a support and monitoring role. There is no exception with the public transport infrastructure, where the national government has been at the centre of setting the tone and direction for growth and development.

It is evident that public transport policy in South Africa gives a useful synopsis of what had transpired in the policy field. Since the 1996 White Paper on National Transport Policy, several empowering policies and legislative instruments have been adopted in South Africa to promote integrated, efficient, reliable, convenient and safe urban public transport systems. These started with the 1996 National Constitution; the 1996 Green Paper on National Transport Policy. More recently, the Green Paper on the National Rail Policy was implemented in 2015, and the Gauteng’s 25-year Integrated Master Plan in 2013. These helped to identify perspectives and methods of facilitating the planning, development and management of enhanced railroad transport systems in the Gauteng metropolitan region and the country. The National Land Transport Act (Act 22 of 2000) was a significant milestone by the national government, post the White Paper. This was followed by the introduction of the Integrated Rapid Public Transport Network (IRPTN) initiative, a more sophisticate approach which employs innovative approaches to urban public transport systems (Van Ryneveld, 2008). As part of the innovations, the Gautrain and Bus Rapid Transit (BRT) were introduced, with the BRT being the commonly adopted form of public transport across the country.
5.2.1. The 1996 White Paper on National Public Transport Policy

The white paper on national public transport policy is perceived as the key building block of the urban public transport systems transformation in the democratic era (Dawood & Mokonyama, 2015). The conception to develop the 1996 White Paper on National Transport Policy started in 1995, with consultations which resulted in the adoption of a Green paper on National Transport Policy in March 1996 (Department of Transport, 2007). The White Paper was reacting to the national transport policy approach developed in the 1980s. This had seen noteworthy deregulations of the taxi business, which before that time had worked under tight limitations, as government endeavoured to shield the financed transport industry from rivalry.

The white paper identified the need for a pro-active approach to deal with the prevailing circumstances and rising challenges facing the country. It managed all features of transport and pronounced the vision for transportation. This was to ensure reliability, safety, efficiency, effective and well integrated transport set-ups and infrastructure that would best address the requirements of commuter and freight customers. Its purpose was to improve services provision and cost in a manner which underpinned government strategies for socio-economic development whilst being economically and environmentally sustainable (Department of Transport, 2007).

The White Paper set up two key thrusts to realising the aims of better customer oriented transport services. These included the promotion of inter-modalism and integration. By inter-modalism, the 1996 White Paper empowered utilisation of the most suitable modes of transport for a specific purpose. This was not to be accomplished through regulation, but rather by making the correct incentives with the goal that every mode could finish based on its innate qualities (Walters, 2012). These thrusts translated into strategic objectives, for instance, ensuring integration in transport modes in terms of scheduling, ticketing and routes systems. Institutional, planning, spatial and modal integration was pursued with the purpose of incorporating the private sector, state departments and consumers to creatively develop resolutions for deficiencies (Van Ryneveld, 2008).
5.2.2. Moving South Africa Project

The 1996 White Paper addressed the National Transport Policy needed to improve the analyses of the abundant experimental information (Walters, 2012). The strategy was required to detect and make key decisions with a 20 year time horizon. Subsequently the Department of Transport set up an approach known as the Moving South Africa (MSA) project. This intended to establish a common vision, clear decisions, and reliable choice standards for all members in the transport industry. The MSA project set up an urban commuters’ action agenda, as a way to achieve the vision as outlined above and switch from customer-based to commuter-based modal transport (Meyer & Miller, 2014). The main thrusts for this were to meet the mass of public transport demand, to optimise the utilisation of modes for a given distance and demand and to enhance firm-level efficiency to meet the developing needs of customers. This stopped the historic legacy which prevented further scattering of development, adequately regulated all suppliers as far as transport designs planned by client requirements for local areas, and started to authorise customers to request better service.

5.2.3. The National Land Transport Transition Act, 2000

The National Land Transport Transition Act (Act 22 of 2000) focused mainly on the public transportation operations. The Act is well-crafted and articulates the policies settled upon in the 1996 White Paper and the Moving South Africa project in comprehensive legal terms (Hanson, 2017). The legislation set up principles such as (i) land transport operations have to be integrated with land use and economic planning and development corridors, and infilling, densification and transport planning should guide land use and spatial planning (Letaifa, 2015); (ii) the drives of the provision of land transport infrastructure and land transport planning should be given a higher priority than private transport. The Act within the framework of the Republic of South Africa’s Constitution therefore aims to build institutions suitable for the effective authority of public transportation. Presumably the greatest challenge that the Act encountered was the formation of structures situated in local government which could oversee public transport in an integrated manner across adequately operational transport locales.

Strategic plans are obligatory to create the transport constituents of Integrated Development Plans needed in terms of the municipal systems Act, 2000 (Letaifa, 2015). For example, in Section 18 (1), land transportation planning should be integrated with land use and spatial
development processes. Transport strategies needed for implementation of this legislation are planned to operationalise municipal planning outlined in the Schedule 4, part B of the Constitution. These should form a critical part of integrated development strategies in terms of relevant sections of the Local Government (Pycroft, 2016).

The National Land Transport Transition Act, 2000 aims to form instruments for management of the transformation of the public transport division into a more effective system, as highlighted in strategies set up by public transport planning structures (Walters, 2012). These have to be located within broader integrated strategies which focus on the entire transport division within the planning sector. The functioning license plans and the rationalisation strategies are needed for coordinating the events of private operatives with the public transport strategies. These strategies are centred on the approach of managed rivalry, which comprises taking the minibus taxi industry under more productive regulation (Banister, 2005).

5.2.4. The National Land Transport Act, 2009

The National Land Transport Act, 2000 focused mainly on further the process of transformation and restructuring the national land transport system initiated by the National Land Transport Act and to provide for meters connected therewith (Hanson, 2017). The Act give effect to national policy; and to prescribe national principles, guidelines, requirements, frameworks and national norms and standards that must be applied uniformly in the provinces and to consolidate land transport functions and locate them in the appropriate sphere of government. The National Land Transport Act 5 of 2009 (NLTA) regulates and monitors the transportation of public passengers for reward. In fact, the Act aims to form instruments for management of the transformation of the public transport division into a more effective system, as highlighted in strategies set up by the National Land Transport Transition Act, 2000 (Department of Transport, 2014).

5.2.5. National Land Transport Strategic Framework (NLTSF), 2015

The National Land Transport Strategic Framework (NLTSF) is not a Transport Strategy or a Transport plan; conversely it is a framework for Transport Planning effectively for all tiers of Government and sets the overarching vision, goals and objectives for each element of the transport system which would be reflected in the provincial Land Transport Frameworks (PLTFs) and Integrated Transport Plans (ITPs) (Department of Transport, 2014). It embodies
the overarching, national five-year (2015 to 2020) land transport strategy, which gives guidance on transport planning and land transport delivery by national government, provinces and municipalities for this five-year period (Letaifa, 2015). The recent development in the transport environment at national, provincial and local level as well as the new strategic objective of the current administration dictates the proposed review and update of the NLTSF. The development of the NLTA of 2009 and its related legal requirements, the Public Transport Strategy and the Action Plan, the approval of the National Development Plan (NDP) by government, Draft scholar transport policy, National Transport Master Plan 2050 (NATMAP) which is currently under review, including the strategic imperatives of the current administration that might have an impact on the development of the NLTSF five year horizon and many other developments in the transport environment needed to be considered in the review and update of the Framework (Pycroft, 2016).

The NLTSF sets out strategic priorities to apply transport planning in achieving social, health, economic and environmental outcomes. The identified strategic priorities and outcomes link the Framework to the NDP, NATMAP, provincial transport and spatial planning, and broader strategies and plans at Local Government level. The purpose of the NLTSF is to serve as a five year framework for integrated land use transport planning; to serve as an enabler of land use and transport planning aspects as guided by the National Development Plan (NDP) 2030; to provide the guiding principles that integrates various modes of land transport within the planning context of the NDP and support wider relevant national legislation and policy; to provide clarity and certainty about the transport planning priorities to enable effective decision-making about programmes and initiatives at all levels of government and align transport to sustainable development (Department of Transport, 2014). The overall vision of the NLTSF is to create an integrated and efficient transport system supporting a thriving economy that promotes sustainable economic growth, provides safe and accessible mobility options, socially includes all communities and preserves the environment.

5.2.6. National rail policy green paper was launched in 2015

The 2015 National Rail Policy Green paper provides guidelines that are meant to move development. The main emphasis of this is renewal of the current rail sector to perform optimally, satisfy stakeholders’ needs effectively and contribute definitely towards socio-economic development in South Africa. The apartheid administration in South Africa
significantly impacted on rail sector development, and together with a variety of factors led to a railway sector which currently experiences major challenges (Letaifa, 2015). According to the Ministry of Transport (2014:26), “Recent challenges comprise of aging, obsolete or deteriorating government of much of the rail infrastructure and rolling stock, a capital investment backlog and a need for investment funds, and a preference by logistic transport service providers to transport freight by road rather than rail. There also exists the preference by long distance passengers to travel by road rather by rail, poor rail security for both passenger and freight, inefficient rail operations and shortage of technical skills and experience within the rail sector”. Over the past 2 decades of under-maintaining and overloading rail infrastructure, the situation of the traditional commuter rolling stock has worsened to crisis levels, and is incapable to satisfy commuter demands. At the same time, the rail network infrastructure was unable to meet the demands of a fast transforming society. The Passenger Rail Agency of South Africa was introduced in 2009 to consolidate the rail commuters of Shosholoza and Metrorail.

Lack of regulations on road freight during 1988 led to substantial amounts of high-value density freight on the main network moving from rail to road in the 1990s. In the 2000s, lack of investment and competitiveness by Transnet Freight Rail led to road haulers organising side tipper interlinks to intrude on the last mainstay of freight rail, hauling of heavy loads commodities for long distance such as grain, ore and coal (Hanson et al., 2017). Generally, railways use in South Africa had declined to a level where the necessity to adjust to rail’s global revitalisation had become obvious to the majority of stakeholders (National Rail Policy, 2015). From 2012, Transnet has however been investing in new locomotives and rail infrastructure. Two optimistic steps were the setting up of the Railway Safety Regulatory and the establishment of the Gautrain Rapid Rail Links as a public private partnership with a concession agreement between the Bombela Concession Company and the Gauteng Provincial Government. Gautrain launched for service in May 2010, in time for the anticipated large volumes of commuters expected at the FIFA soccer World cup.
5.2.7. The 2017 Revised White Paper on National Transport Policy

Transportation plays a critical function in the social and economic development on any country, and the National Government of the Republic of South Africa has recognised transport as one of its priority areas for socio-economic development. The efficiency of the role played by transport is to a great extent dictated by the soundness of the transport policy and the strategies utilised in implementing the policy. The policies expressed in the revised White Paper on National Transport Policy are thus the result of a broad public policy making process. The revised White Paper strove to address the challenges of poverty, unemployment and inequality through a more effective and efficient transport systems.

The white paper identified the need for a pro-active approach to support the goals of the prevailing National Development Plan 2030, National Infrastructure Plan and Government’s Programme of Action; improve the safety, security, reliability, quality, and speed of transporting goods and people; improve South Africa’s competitiveness and that of its transport infrastructure and operations by reducing the cost of doing business; invest in infrastructure or transport systems in ways that satisfy social, economic or strategic investment criteria; achieve the above objectives in a manner that is economically and environmentally sustainable, and minimises negative side effects; and develop strategies to attain these policy goals.

5.2.8. National Spatial Development Framework (NSDF), 2018

The National Spatial Development Framework (NSDF) seeks to make a bold and decisive contribution to bringing about the peaceful, prosperous and truly transformed South Africa, as articulated in the Freedom Charter, the Reconstruction and Development Programme and the National Development Plan. It does so in full recognition of the stranglehold that the unjust national spatial development paradigms, logics and patterns of the past have placed on many attempts at breaking the back of poverty, unemployment and inequality; The valuable, and often hard lessons South Africa have learnt over the last twenty-four years in the pursuit of national reconstruction, inclusive economic growth and spatial transformation; and the necessity for decisive, collaborative and targeted state action in national space, to drive our country towards the shared, inclusive and sustainable future we desire and require (Gauteng Government, 2018).
The National Spatial Development Frame and ‘set of NSDF Sub-frames’ set out and provide a guiding framework to achieve the desired future National Spatial Development Pattern for South Africa in 2050. In line with the purpose and role of the NSDF, as outlined in Part One, these frames provide a national spatial schema to inform, direct and guide all future infrastructure investment and development spending decisions by government and the private sector, to (1) optimise place based potentials and spatial interdependencies, and (2) realise the 2050-National Spatial Development Vision and our core national development objectives; A carefully chosen, distinct set of nationally-significant places, connectors and areas in and around which to align, integrate and coordinate investment by the private sector and all three spheres of government when preparing and reviewing (1) area/place-based provincial, regional and municipal SDFs, and (2) sector-specific and macro-infrastructure national and SADC focused investment plans; and The framework promote the integration of transport and land use planning, which is essential to the achievement of sustainable development (Gauteng Government, 2018).

5.2.9. National Transport Master Plan 2050

The National Transport Master Plan 2050 (NATMAP 2050) was commissioned in 2005, developed from 2007 and finalised in 2010/11 (Dawood & Mokonyama, 2014). The NATMAP 2050 Vision reinforces that transport is the heartbeat of the economy and the fabric of the country’s socio-economic development as well as its alignment with key policy, legislation and planning frameworks recently developed. The primary goal of the NATMAP 2050 is the development of an integrated, dynamic, sustainable framework for transport infrastructure and services provision in South Africa. The aim of this NATMAP 2050 synopsis update is to update data contained in the NATMAP 2050 and to align the plan with the NDP 2030, the government’s Medium Term Expenditure Framework (MTEF) and Medium Term Strategic Framework (MTSF 2014–2019) as well as other government strategies and initiatives that have emerged since 2007 (Walters, 2012).

“The NATMAP 2050, therefore, aims to achieve well planned, integrated and aligned across sectors; responsive to growing passenger and freight customer needs; supports an inclusive spatial vision; well maintained and preserved and further developed to address or overcome developmental challenges; Supports economic competitiveness through seamless multimodal trade corridors; offers safe, affordable and accessible modal options for commuters; Preserves
Transportation and related cost-effective infrastructure facilities are prerequisites for the socio-economic development of South Africa. Transport is considered the heartbeat of the nation economy; stimulating socio-economic development and poverty alleviation through wealth creation provides access to regional and global economies. The NATMAP 2050 is the result of a thorough process involving technical appraisals made on the back of detailed economic, socio-economic, political, institutional, and transportation data analyses, supported by a comprehensive consultative process with broad spectrum stakeholders (Walters, 2012). The NATMAP 2050 is fully aligned with the current administration’s MTSF and other strategic plans and the NDP 2030’s principles, which will ensure that a collaborative vision is achieved that will improve the daily lives of all South Africans. Achieving the NATMAP 2050 vision will ensure continued and sustainable development of spatial planning and growth matched to developmental, transformative and demand driven capacity supply.

5.2.10. Urban public transport transformation policy interventions Post 1994

Despite various initiatives to improve South Africa’s urban public transport system, not much progress has been recorded, even after the promulgation of the National Land Transport Act (Dawood & Mokonyama, 2014). This was soon followed by attempts to recapitalise minibus taxis and the restructuring of bus operations contracts under the accelerated modal upgrade programme (Pérez et al., 2012). Dawood and Mokonyama (2015) observe that the South African public transport challenges have been persistent despite various transformation and formalisation initiatives since 1996. The table below depicts public transport planning, complex issues, policy interventions and outcomes since 1994 as observed by Ahmed (2004); van Ryneveld (2008); Dawood & Mokonyama (2015). Table 6 provides synopsis of urban public transport transformation interventions Post 1994.
Problems associated with public transport systems and infrastructure

- Spatial fragmentation due to past land use planning patterns.
- Rapid population growth and densely populated previously disadvantaged communities.
- High costs and long travel hours affecting mostly the urban poor.
- Lack of cooperation from transport operators.
- Poor ticketing system, where commuters had to pay for every mode of transport they use.
- Increased number of private transport users.
- Informal and non-regulated public transport operations.
- Poor subsidy targeting

Interventions to transform urban public transport systems and operations

- Public transport subsidy scheme to target low income earners.
- The National Land Transport Transition Act (Act 22 of 2000)
- Accelerated Modal Upgrading.
- Integrated Rapid Public Transport Networks (IRFTNs).
- Gautrain (Rapid Rail) and Bus Rapid Transit (BRT) systems.

Outcomes of interventions or transformation strategies and prevailing circumstances

- Introduction of innovative urban public transport systems in the form of Bus Rapid Transit in major cities.
- Gautrain connecting mainly the three Gauteng Metropolitan Cities major transport nodes.
- Increased public transport subsidy expenditure without balanced benefits by the previously disadvantaged and the general public.
- Mini-buses or taxis still not covered by the public subsidy.
- BRT and Gautrain having own subsidy requirements.
- Innovative urban public transport systems though not prioritising the urban previously disadvantaged.

Table 6: Synopsis of Urban Public Transport Transformation Interventions Post 1994
[Source: Author, 2018]

As depicted in the table 6 above, there has been slow progress in terms of the impact of public transport infrastructure investments despite major policy interventions. There is a need consequently for more innovative approaches to collective strategy formulation by stakeholders. Such interdependent sector departments need to carefully analyse the nature of their core functions in relation to public transport market trends. This will help them attain holistic policy interventions characterised by qualities of integrated spatial form and socio-economic transformation. Stakeholder cooperation has long been identified as lacking in its support of massive public transport infrastructure investments (Pretorius & Schurink, 2007). To date therefore, effectiveness of intergovernmental collaboration in implementation process leaves much to be desired.
Todes (2012) observes that transit-orientated infrastructure development consistent with the concepts of smart growth plays an integral role in shaping urban form. Since 2005, Innovative Urban Public Transport Systems have been commissioned as a revised strategy to accelerate socio-economic transformation. This has been part of the national government led initiative known as Integrated Rapid Public Transport Networks which saw the introduction of the Gautrain and Bus Rapid Transit (Van Ryneveld, 2008). Despite the various investments in public transport infrastructure however, Mashiri et al. (2014) argue that poor planning has resulted in no significant changes in road traffic congestion, conflicting vehicle-pedestrian movements, an increased number of uncoordinated small-scale freight vehicles and severe parking shortages.

Evidently, post 1994 South Africa has emphasised spatial and socio-economic transformation through policy pronouncements to deal with past spatial injustices to alleviate poverty and unemployment. With the promulgation of the Infrastructure Act, (Act 23 of 2014) and the Spatial Planning and Land Use Management Act, (SPLUMA) (Act 16 of 2013), South Africa has recognised the need to carefully manage infrastructure investments to attain spatial and socio-economic transformation. Many discussions are taking place around spatial restructuring of public transport to support the economy, but implementation of these legislative frameworks remains to be seen. If the implementation of previous policy interventions is anything to go by, these legislations might also end up being good pronouncements with no substantial transformation to the benefit of the urban poor and previously disadvantaged
5.3. GAUTENG PUBLIC TRANSPORT INFRASTRUCTURE POLICY DIRECTIVES 25 YEAR-INTEGRATED TRANSPORT MASTER PLAN (ITMP), 2013

National, provincial and local government in South Africa all fund public transport infrastructure projects in line with their competency areas and core mandates. For Gauteng Province, central to the public transport infrastructure is the 2013 Gauteng 25 year ITMP. This aims to provide policy directives and maps out the desired future of the Gauteng public transport network that will respond to the challenges of spatial segregation and socio-economic disparities (Gauteng Government, 2013). The Gauteng ITMP 25 was derived from all existing transport plans across the Gauteng Metropolitan Region, with the Department of Roads and Transport being tasked with the responsibility of managing and coordinating the implementation processes of the said plan.

The Gauteng Metropolitan Region as the economic hub of South Africa, is facing an ever-growing demand for well integrated public transport systems. The transportation challenge that the region is experiencing can be attributed to the absence of cross municipal boundary integration of public transport amenities. Public transport affordability, accessibility, consistency, safety and efficiency is needed to remedy apartheid spatial planning; reducing socio-economic opportunity costs for communities to access economic opportunities and allowing economic growth (Kourtit & Nijkamp, 2012). As a result, the Gauteng province developed a 25 year-Integrated Transport Master Plan in 2013 which aims to enhance urban public transport systems in the province. The Integrated Master Plan pursues numerous objectives through the implementation of many approaches. Amongst these are the efficient urban public transport systems which are thriving and are integrated to promote their ridership and with reduced reliance on private transport modes (Letaifa, 2015). This has led to a rise in BRT systems such as Rea Vaya in the City of Johannesburg, Are Yeng in the City of Tshwane, and the High-speed railway (Gautrain).

The main objective of the year ITMP is to provide a world class holistic mobility system which will be the mainstay of the social, economic, environmental and cultural objectives of Gauteng province. Furthermore, the objective of the Master plan is to establish a mobility system for Gauteng Province in the next 25 years that will be viable and also lead to skills development, better quality of life and sustainable job creation. The Integrated Transport Master Plan has to enable the Gauteng Province Department of Roads and Transport to plan, develop and regulate
a well-integrated and efficient mobility system which will improve mobility and be secure, safe and environmentally viable.

The Gauteng Integrated Transport Master Plan has to support the full implementation of the policy for amendment of the mobility system in the province within the next 25 years. Urgent initiatives are needed, considering the critical challenges to mobility in the metropolitan region. The Master plan must be pro-active in redressing these, and also accelerating the mobility system development that reinforces Gauteng City Region development. Therefore, it has several fundamental initiatives and projects which have to be realised in the near future (Kourtit & Nijkamp, 2012). “It comprises of three categories of key initiatives and projects which include Main short-term initiatives that will lessen “bottle-necks” in the short term to medium-term; key transport capital projects to be supported in the short to medium term; and lists of all approved transport capital projects on budget of government departments, agencies and entities” (Gauteng Government, 2013: 15).

Cooperatively, these crucial initiatives constitute the five Year Gauteng Transport Implementation Plan that is being considered by the Gauteng Department of Roads and Transport. Also these key initiatives of ITMP 25 were recognised, based on a survey and assessment of all approved mobility plans appropriate to the Gauteng City Region and present inputs of stakeholders in workshops on mobility matters. Altogether these initiatives fall within the provincial government’s fundamental functions, and where it can impact the implementation of an integrated transport network as part of its mobility coordination role.

5.4. STRATEGIC INTEGRATED TRANSPORT PLAN FRAMEWORK FOR THE CITY OF JOHANNESBURG

The City of Johannesburg developed its first Integrated Transport Plan (ITP) in August 2013. This was updated three times by the Johannesburg metropolitan city council, in 2004, 2006 and 2007, as the plan was operational from 2003 to 2008. Currently, the City of Johannesburg’s Integrated Transport Plan which started in 2012 is in place for 2013-2018. This Integrated Transport Plan aims to inform how the public transportation infrastructure and services will develop within the City of Johannesburg (Letaifa, 2015). There are components that have been developed to support the current operational City of Johannesburg Integrated Transport Plan. However, the Strategic Integrated Transport Framework is the first component, which aims to
unpack the status quo and provide an overview of some of the significant developments and deficiencies over the past ten years. It draws out the City’s goals and visions for its mobility system framework, and the approaches through which it aims to achieve them. Outcomes and indicators which will be utilised to assess the City of Johannesburg’s performance are set out, as well as the measures for mobility infrastructure and public transport benefits that can be anticipated by the public. A high level spatial network has been established which demonstrates the fundamental routes and corridors for public transport, cycling, walking and freight.

The second component is the Database, obtained through a Johannesburg Household Travel Survey done in the first half of 2013 and a Mobility information register, for which information gathering occurred in 2012 and 2013. Following these components, and guided by the framework and information, the Department of Transport will organise and integrate transport showing the public transport routes and corridors that the city will be investing in. This includes a ten years integrated transport plan for its principle initiatives to extend the public transport network. The fourth components are operational Plans that will be developed as and when they need to be done, for example in connection with the specific projects or programmes. These four components are illustrated in figure 6.
5.5. CITY OF JOHANNESBURG STRATEGIC PUBLIC TRANSPORT NETWORKS

The major thrust of the 2003-2008 City of Johannesburg’s Integrated Transport Plan was to move from the historic accent on enhancing mobility for private automobiles, towards enhancing accessibility and mobility for people through enhancement to the urban public mobility system (Letaifa, 2015). As strongly recommended by the Integrated Transport Plan, the City of Johannesburg developed the Strategic Public Transport Network (SPTN) for both concepts of operation and network. The SPTN aimed to recognise the main public transport integrations that were required to be prepared. This was planned with the intention of promoting a multi-nodal city form and compact city concept. It was achieved by giving a clear public mobility ‘grid’ of intensive, high-recurrence public mobility routes integrating main high-density hubs and also highly populated residential spaces. On the grid form, every important destination can be accessed through the public mobility system. This is achieved through the inclusive continuity of integrations it structures as a framework of public mobility.
routes. These extend to about 325 km total length, and interfacing 45 or so improvement hubs in the City of Johannesburg with each other, along major mobility spines.

Operationally, dedicated lanes were anticipated on public transport intersections for the specific use of minibus-taxis and other transport. At the routes starts and adequately smaller commuters’ amenities along the routes, only a few terminals were proposed mainly at the points where the routes are integrated, and where commuters’ could change from one mode to another (Walters, 2012). Ride facilities and stations were also proposed which were, focused at nodes on the SPTN in places of high private automobile ownership. The rationale was that Johannesburg had evolved throughout the years towards a multi-modal structure. While the Central Business District (CBD) continued as the most important single hub, it was by all accounts not the only hub. Actual 26% of commuter journeys in Johannesburg have the City centre as their final end point. Generally though, transport, rail and minibus-taxi routes all converge on the City centre. There were likewise a large number of routes, scattered over the system, functioning at moderately low frequencies. The essential network of 325 km was expected to be bolstered by an auxiliary system of feeder and dispersion routes around the greater part of the 45 hubs on the framework. These were proposed to give further inclusion (Kourtit & Nijkamp, 2012).

The recapitalised 18-seater minibus taxi was viewed as the most cost-effective mode for this assignment by and large, and an expected 1 500 minibuses would to benefit the hubs once the system was completely operational (Walters, 2012). Having a vibrant public mobility network would empower Johannesburg with a more compelling approach to deal with delivery of public mobility, measures. This would make public transport services and infrastructure more accessible for people with disabilities. It would increase security measures focused at the hubs, such as 24-hour retail activity, excellent lighting, and closed circuit television surveillance and law enforcement measures. Commuters’ data shows, street furniture, shelters devoted stops and landscaping would provide the corridors with a perceptible and visible identity. Measures should be taken to create public mobility infrastructure and facilities more suitable for people with handicaps. Wellbeing and safety efforts should be centred at the nodes, such an excellent lighting, 24-hour retail activity and short circuit TV reconnaissance. Routing of subsidised services can be to the benefit of the Strategic Public Transport Network. Benefits can include all-day services and integrating services such as fare systems (Letaifa, 2015).
5.6. EFFICACY OF POST-APARTHEID POLICY INTERVENTIONS

Lastly all development initiatives and investments in post-apartheid South Africa are centred on spatial and socio-economic transformation. Hence there is a need for an integrated approach to innovative urban public transport systems for creation of vibrant economic nodes. However, regardless of the complex development challenges facing communities, there are substantial investments being made. These should make meaningful contributions to spatial integration of public transport systems. However, coordination and collaboration amongst stakeholders is a concern, because of the absence of a collective strategy and an implementation plan. Government expenditures seem to be a ‘tick-the box’ exercise, where more often than not, practice will precede research, resulting in the development programmes being implemented without even understanding the local context. Because of political pressure, government officials are driven by how much they spend from the allocated budget without any measure being put in place to ensure holistic sustainability of government’s investment program.

Concerns were raised by the National Transport Minister during the 36th Annual Southern African Transport Conference (2017) held under the theme ‘Southern African Solutions to Public Transport Challenges’ about the need for innovative urban public transport systems implementation in the City of Johannesburg. Here he questioned prioritisation criteria on public transport investment, since most BRT buses travel with few or no passengers. It seems that many policies and programmes have been put in place by the South African government towards social and economic transformation for sustainable livelihoods, but the prevailing circumstances leave much to be desired (Gumede, 2013). Statistics suggest that there has been little if any progress in bridging the inequality gap and poverty alleviation. Central to this are the increasing problems of unemployment, labour market polarisation, informal settlements, low literacy skills and lack of access to basic amenities in most rural communities. Meanwhile, the state continues to produce policies and plans that look good on paper but which have limited or no significant impact in improving people’s lives (Cilliers & Camp, 2013).

5.7. CONCLUSION

This chapter has discussed public transport infrastructure investments and policy interventions across the three spheres of government that is the National government, Gauteng Province and City of City of Johannesburg. The chapter reviewed the developments in policies and
legislative governing public transport, since the advent of democracy in 1994 with an emphasis on metropolitan and city public transport. The chapter has shown, from the White Paper on National Transport Policy, South Africa has been adopting several enabling policies and legislative instruments to promote innovative urban public transport systems and these commenced with the National Constitution of 1996; The Green Paper on National Transport Policy White Paper; the National Rail Policy Green paper was; and the Gauteng’s 25-year Integrated Master Plan to solicit views and ways of facilitating the planning and development of improved railway transport systems within the Gauteng province and the country. The Chapter also discussed the effectiveness of post-apartheid legislative frameworks and policy interventions on public transport infrastructure. This chapter also emphasizes the need for interdependent stakeholders or public institutions entrusted with different mandates of community development to work together in attempt to address the needs of the complex community challenges by ensuring synergies in their policy development and implementation through a collective strategy.
CHAPTER 6: SPATIAL PATTERNS AND ROUTES NETWORK INTEGRATION BETWEEN GAUTRAIN AND REA VAYA

6.1. INTRODUCTION

This chapter focuses on data representation and key findings, given the City of Johannesburg’s innovative urban public transport systems and the impact of these systems on urban mobility and spatial integration. The pattern of innovative urban public transport systems have been developed consistent with the Integrated Rapid Public Transport Network (IRPTN) national strategy for spatial integration and the modal upgrade of urban public transport systems. Accordingly, vigilant consideration was given as to how implementation of innovative urban public transport systems has contributed to improved urban mobility. Specific reference has been made to its efficiency and the inclusion of previously disadvantaged communities through a spatially integrated urban form. The urban mobility principles used to assess the extent of spatial integration and efficacy of innovative urban public transport systems are accessibility, efficiency, reliability and convenience.

The study findings are represented, interpreted, analysed and discussed consistent with objective two (2). This is to explore the status quo of spatial patterns and routes network integration between the Gautrain and Rea Vaya and determine the network connectivity of these innovative urban public transport systems. The qualitative data obtained through conducting key informant interviews were also central to the discussions in this chapter. It was crucial to recognise the City of Johannesburg population dynamics, labour market activities and business operations to enable the study to contribute meaningful knowledge of city conditions. Spatial data gathered were used to create maps to inform analysis and discussion on spatial connectivity. Thus, discussions throughout this chapter focus on how the spatial pattern of public transport systems responds to prevailing spatial disparities through easy accessibility and convenience of public transport systems. Spatial connectivity through public transport networks routes and the use of stations as connector points for multi-modal operational integration were used as the perspectives to assess the integration of urban mobility.
6.2. GAUTRIAN SPATIAL PATTERN WITHIN THE CITY OF JOHANNESBURG

Gautrain is one of the strategically integrated Gauteng Provincial Projects designed to meet future transport demands because of anticipated economic and population growth. This project is still at its inception as it was only implemented in 2010, and how 7 years down the line it is still not near completion. There are only 10 fully functional train stations, namely: Park; Rosebank; Sandton, Marlboro; Midrand; Centurion; Pretoria; Hatfield; OR Tambo; and Rhodesfield. It is a state-of-the-art rapid rail connection between Johannesburg (Africa’s business capital) and Pretoria. The Gautrain has been identified as the backbone for public transit provision in the province (Du Plessis, 2010). Consequently, a need has arisen for more research on how this can become a reality. The Gauteng City Region (GCR) can be best be described as a cohesive cluster of cities, towns and urban nodes which collectively make up the economic hub of South Africa, generating more than 36% of the country’s Gross Domestic Product (GDP) whilst covering less than 2% of the country’s total surface area.

In terms of routes network, the Gautrain alone operates in three metropolitan cities in Gauteng province namely City of Johannesburg, City of Pretoria and Ekurhuleni Metro. However, a need for its expansion and integration to other parts of the province still exists. The Gauteng Provincial Government has identified the Pretoria CBD, Johannesburg CBD, Sandton City and OR Tambo airport in East Rand as the most important nodes to be linked by the Gautrain. Over time, this has led to the growth of activities on the other nodes namely Rosebank and Hatfield (Ruwanspathiran & Perera, 2015). However, the Gautrain within the jurisdiction of the City of Johannesburg operates in the upper spaces such as Rosebank, Sandton, Marlboro and Midrand. The Gautrain currently does not operate in the southern areas of Johannesburg, which has potential commuters. An expansion and integration with Rea Vaya will therefore improve mobility patterns in Johannesburg. Figure 7 depicts the Gautrain routes and stations map.
The Gautrain has four stations within the City of Johannesburg, and the Gaubus, with numerous stations, as depicted in figure 6 which feeds into the Gautrain stations. This suggests that Gautrain commuters have the potential of accessing economic opportunities within the City of Johannesburg. However, the affordability of Gautrain fares by the urban poor compared to other modes of public transport remains questionable. The Gaubus seems to cover a huge geographical area compared to the Gautrain. Its main role is to convey commuters towards and from the Gautrain stations. Figure 8 below illustrates the Gautrain routes network in the central city.
The City of Johannesburg, being the country’s economic hub currently experiences traffic congestion on its major routes, especially in its hubs, because the current transport facilities and services between these two cities are mainly road based. Accordingly, the Gautrain was supposed to ease this traffic congestion in an attempt to create a smart city based on mixed land use and development corridors. The Gautrain project is also meant to rejuvenate central Johannesburg and Pretoria. Construction of the Gautrain was informed by spatial planning embedded in two parallel strategies that were initiated by the Gauteng Provincial Government; namely the Gauteng Spatial Development Framework (GSDF) 2000 and the Gauteng Spatial Development Initiatives (SDI’s). Consequently, the Gautrain will promote mobility and accessibility and redirect urban growth and resource based economic and rural development beyond the urban edge.

During the site visit, it was observed that Gaubuses are used by a small number of commuters, while masses of people are in need of public transport. The disintegration of the Gautrain and Rea Vaya infrastructure investments contributes significantly towards mismanagement of
government funds, in contradiction to being a strategic investment in public transport infrastructure. The independent existence of the Gaubus and the Rea Vaya network appears to be a waste of government resources. Conversely, the integration of the two modes will lead to multimodal public transport network integration, where commuters can easily switch from one mode of public transport to another. Through multimodal network integration, efficient utilisation of the public transport infrastructure and reduction of automobile travel can be attained. More areas could be covered by the network instead of duplicating similar services in one geographic space.

The City of Johannesburg public transport system has been appointed in terms of the Service Delivery Agreement by the City of Johannesburg to deliver integrated, efficient and reliable public transport to the residents of the city. As such, the Johannesburg public transport system operates in commitment to the City of Johannesburg legislative mandate regarding urban public transport and the systems. It is guided by the strategic direction of the City of Johannesburg as derived from the Integrated Development Plan and the Province Growth Development Strategy. The Corridor of Freedom and Integrated Transport Plan are amongst some key strategic objectives of the Johannesburg public transport system, where the Gautrain and Rea Vaya have a fundamental role to play in provision of public transportation. During the key informant interviews, it was highlighted that intentions to operationally integrate the Gautrain and Rea Vaya exist, but there is no clear collaboration between the two modes of public transport.

Affordability of Gautrain by the urban poor is already questionable, which means the Gautrain has become the public transportation for middle and high-income groups as well as business people. The Gautrain is the costliest to implement compared to the Rea Vaya. Government funds’ investments prioritisation thus leaves much to be desired related to its responsiveness to prevailing spatial and socio-economic disparities. The Gautrain infrastructure is very costly and should not be a priority granting the current spatial and socio-economic inequalities. The status quo, spatial segregation and socio-economic inequalities are systematically perpetuated through exclusion of the previously disadvantaged or urban poor. Thus, state policies on spatial and socio-economic transformation seem not to be in harmony with the practical government investments direction which neglects the urban poor.
6.2.1. Gautrain Commuters experiences on the service provision

The principles of affordability, accessibility, efficiency and reliability were used as pointers to assess commuters’ experiences of the innovative public transport systems. This was in harmony with the assessment of the efficacy of innovative urban public transport systems, as illustrated in figure 8. Evidently, the Gautrain provides services of high quality and standards, but it’s affordability by all economic classes, particularly the urban poor leaves much to be desired. Figure 9 illustrate Gautrain commuters’ experiences on service provision.

![Evaluation of the Gautrain service](image)

Figure 9: Gautrain commuters’ experiences on service provision [Source: Author, 2018]

As depicted in figure 9, the Gautrain is perceived to be providing efficient and reliable service and is thus highly commended by most commuters, with 75% of the people evaluating it as either good or very good. This may be closely linked to the punctuality and reduced travel times when using the service to commute between Midrand, Sandton, Rosebank and Park station. To a certain extent, the very good efficiency and reliability may attract business people to use the service for their daily business trips. However, affordability remains a major concern by most commuters who perceive Gautrain fares as systematically excluding the urban poor and previously disadvantaged.
6.3. SPATIAL PATTERN OF REA VAYA BUS RAPID TRANSIT NETWORK

The Rea Vaya Bus Rapid Transit (BRT) is a fairly new bus system implemented and operational in the City of Johannesburg. Its launch in 2009 was met with much uncertainty, but also with positivity as a new public transport initiative for the city. Johannesburg is one the twelve municipalities which were identified by the National Department of Transport to implement Innovative Urban Public transport Systems under the IRPTN initiative. It is therefore essential that the spatial pattern of IRPTN aligned public transport infrastructure investments responds to the spatial and socio-economic inequalities. Figure 10 below depicts the spatial pattern of the Rea Vaya network.

![Figure 10: Rea Vaya Bus Stations and Bus Routes map](source: Author, 2018)

Figure 10 above depicts that the system is found across the greater urban fabric of Johannesburg, connecting the south to the north and the east to the west. It covers a route of 325 km to date and continues to expand (Department of Roads and Transport, 2012). Rea Vaya operates in Region B, D and F of the City of Johannesburg. It operates in different phases and has systematic hierarchical routes which connect micro city centres in the metropolitan city of
Johannesburg. It has completed the construction of Phase 1A and 1B and is currently developing Phase 1C. Rea Vaya’s Phase 1A has a trunk route operating between Ellis Park in Doornfontein and Thokoza Park in Soweto, linking with several feeder routes to Soweto (Gauteng Government, 2013). Feeder buses run from Protea Glen to Thokoza Park and from Eldorado Park to Lakeview. The route covers 325 km of special lanes and intersections, while feeder and complementary buses carry passengers to the trunk route stations. Figure 11 below illustrates the Rea Vaya Inner city route map.

Figure 11: Rea Vaya Inner city route map [Source: Author, 2018]

The inner city circular route travels around the Central Business District from Hillbrow and Braamfontein, to Ellis Park in the east and Chancellor House on the western edge of the city (Gauteng Government, 2013). The Phase 1B has routes that operate through Cresta, Windsor West, Parktown and Yeoville. In addition, routes that operate to and from the University of Johannesburg Soweto Campus are being added. The route starts in Noordgesig in Soweto and travels through Pennyville, New Canada, Highgate, Auckland Park and Braamfontein to Parktown, Metro centre and Rissik Street in the CBD. This has made it possible for commuters to easily reach key public healthcare centres such as the Rahima Moosa, Helen Joseph and
Charlotte Maxeke hospitals. Commuters can also access educational institutions such as the University of Johannesburg, Wits University, Milpark College, Parktown Boy’s High School and Barnato Park High School. Feeders run to and from Leaglen, Stormhill, Florida, Cresta, Yeoville and Parktown.

There are also additional feeders in Soweto from Pimville and Mapetle. These are linked to the Metro Centre Rea Vaya loop which travels to the inner city through Braamfontein. The system is made up of trunk routes that keep to the designated lanes and are connected by the stations. For example, the T1 route runs from Thokoza Park in Rockville, Soweto and ends in Ellis Park. There are more than 15 bus stations across this route which facilitates access to the buses. The main trunk routes are supported by complimentary and feeder routes that navigate other parts of the city. These feeder buses use the main road network like other vehicles and public transport systems. Figure 12 illustrates the Rea Vaya Soweto route map.

![Rea Vaya Soweto route map](image)
Rea Vaya’s current focus is the development of Phase 1C following the completion of Phase 1B. Phase 1C will run from Parktown to Alexandra, then Alexandra to Sandton, with complementary services between the CBD and Ivory Park and from the CBD to Sunninghill on Oxford Road and Rivonia. Future plans also include extending the Phase 1C route from Sandton to Randburg by 2018, and possibly extending the trunk route from the Soweto Highway to Dobsonville, enabling feeders to services areas such as Braamfisherville. Construction for the routes and stations has already started in the Sandton area. The Rea Vaya trunk routes from the CBD to Sunninghill through Oxford Road and Ivory Park to Sunninghill will be prioritised after 2018. The three interchanges will be at Sandton, Alexandra and Westgate, where a number of station modules will be clustered and there will be integration with other modes of transport, including walking and cycling. With its intention to be one of the most sustainable forms of public transport in the city, the Rea Vaya is noted as cost effective, safe and relatively reliable. It is considered as an inherent component of the city’s future urban form, as it is one of the main elements of the Corridors of Freedom initiative.

Rea Vaya is referred to as one of the most determined initiatives by the city, being spear headed by a woman and having a completion goal of three years from ground breaking to operation (Moosajee, 2015). As illustrated in figure 12, there is a commendable effort by the BRT network on spatial connectivity, as it links residential and economic activities. It is evident that some of the people find difficulty accessing their work places directly from the BRT stations. The Lanzhou Bike Sharing system in Chai can be used as an option to strengthen connectivity for direct access from stations to work places. The BRT network should be integrated to other modes of public transport to create multi-modal public transport networks. Such interventions should promote spatial integration by facilitating easy access to economic opportunities and other urban amenities. Land use patterns of a city or town also influence the travel pattern, transport network and public transport demands (Cervero, 2001).
6.3.1. Commuter experience of the Rea Vaya service

Rea Vaya has been effective in improving accessibility to economic opportunities for formerly marginalised places such as Soweto since the network flows from Soweto moving towards the Central Business District and the Northern places of the city. Rea Vaya appears to be more accommodating to the low-income groups in terms of affordability. Figure 13 below depicts commuters’ experiences, given the principles of affordability, accessibility, efficiency and reliability.

![Evaluation of Rea Vaya service](image)

**Figure 13:** Rea Vaya commuters’ Experience [Source: Author, 2018]

As depicted in figure 13, Rea Vaya is arguably doing commendable work in improving urban mobility. The BRT is affordable across all income groups, with government subsidy said to be the main reason behind the affordability. The socio-economic challenges continue to be manifest spatially and racially in the City of Johannesburg, consistent with Apartheid racial divides (Moosajee, 2015). The Rea Vaya thus appears to be the most appropriate mode of transport for investment prioritisation. This will result in the reduction of travel costs, which will make a meaningful impact on the strained income of the previously disadvantaged. The continued use of taxis as reliable modes of public transport suggests that improvement of the public transport systems should include upgrading of the taxi industry.
6.4. SPATIAL CONNECTIVITY OF PUBLIC TRANSPORT SYSTEMS

The need for improved urban mobility which goes beyond providing transportation is evident, as public transport systems are essential providing access to economic activities and linking people with various other urban amenities and opportunities available (Cervero, 2013). The results of this study and lessons learnt from international experiences reveal that innovative urban public transport systems are at the centre of improving the state of urban mobility through multimodal integration for spatial connectivity. The principles of accessibility, efficiency, affordability and reliability serve as key indicators of the efficacy of the urban public transport system in any given city (Litman, 2017; Roux et al., 2012). This section of the research report presents the research results related to the extent of networks integration between the Gautrain and Rea Vaya within the City of Johannesburg Urban Public Transport System. Figure 14 below depicts the overlay routes network of Gautrain and Rea Vaya.

Figure 14: Gautrain and Rea Vaya Networks Integration [Source: Author, 2018]

As depicted in figure 14; the findings indicate that there are limited areas where the networks between the two public transport systems are connected. Presently, the Gautrain operates in the
northern areas of the city, such as Rosebank, Midrand, Sandton, Randburg and Fourways. The Rea Vaya does not have existing routes in these locations. Rea Vaya’s Phase 1A has a trunk route operating between Ellis Park in New Doornfontein and Thokoza Park in Soweto, linking with several feeder routes from Soweto. Feeder buses run from Protea Glen to Thokoza Park and from Eldorado Park to Lakeview. The Rea Vaya has proven successful in improving accessibility to economic opportunities for locations which were once spatially segregated. This can be seen with the network flowing from Soweto moving towards the Johannesburg CBD.

Evident from the key informant interviews is that the fundamental principle of any innovative public transport system is facilitation of an efficient, affordable urban public transport network connectivity. The opposite would be duplication of the urban public transport network for spatial connectivity. As depicted in figure 13, there has been a commendable effort to provide for spatial connectivity. However, duplication of Rea Vaya and Gaubus indicates that there is minimal cooperation between the provincial government, responsible for the Gautrain and the municipality, responsible for the Rea Vaya. Transport planning has evolved from a more traditional approach to a rational, comprehensive approach that considers all modes of transport (Litman, 2013). It should foster investment returns in the form of socio-economic benefits. Mechanisms must hence be developed to ensure that investment decisions do not compromise the value of social, economic and environmental aspects of development focusing on realistic solutions to community problems.

6.4.1. Analysis of Gautrain and Rea Vaya Networks Integration
The existing urban public transport network is spatially segregated, and there is little to no clear collaboration between the two modes of public transport. They were developed and currently operate separately. Initially the two modes were developed in preparation for the 2010 FIFA World Cup. However over the years there have been advancements with a variety of goals as the Gautrain seeks to service the high to medium income group, and the Rea Vaya seeks to provide service for the medium to lower income groups. This illustrates a knowledge gap of how to connect commuters to places of economic and business activities. As is apparent from the works of modern scholars (Risimati & Gumbo, 2018; Moyo & Musakwa, 2016; Nune et al., 2014), the network integration of public transport systems will lead to improved service delivery, inter-connectivity of places of economic activity and improve quality of life. Thus,
for the City of Johannesburg to encourage smart mobility, there is a need for the development of planning support systems which will guide the integration of the existing and future public transport systems. Figure 15 illustrates three possible Gautrain and Rea Vaya network integrations.

Notably, as depicted in Figure 15, there are three possible route network integration points A, B and C. Integration Point A is located near Marshalltown and Ferrieraardorp. It functions as a centre for the administration hub, high density residential areas and commercial centres of the inner city. Integration point C, located in Parktown provides an interconnection of Public transportation for the educational and health institutes such as the University of Witwatersrand and Parktown Hospitals. The Gautrain Park Station bus routes as well as the Rea Vaya Bus Rapid Transit routes should also be noted as essential feeders in the area.
6.4.2. **The function of Urban Public Transport Integration point A**

The Integration point A includes areas such as Marshalltown, Gandhi Square, Carlton Centre and Ferrieraasdorp. It is a busy urban hub of commercial, retail activity, administration and high density residential areas of the inner city (see figure 16). It is situated in the Johannesburg inner city, recapturing its position as the financial and business centre of the major city. The area is neighbour to the cultural centres of Newtown, Westgate and Jeppesetown. The integration point is part of the city’s history and is reclaiming its strategic relevance in the social and economic development of the city. It is fast assuming its rightful position as the continent’s powerhouse. The area is both a popular tourist attraction and a busy urban hub of commercial and retail activity. It is about 25 minutes from both Sandton (a commercial epicentre) and the OR Tambo International Airport, which welcomes millions of international visitors every year. Figure 16 below depicts Gautrain and Rea Vaya network integration point A in the inner city.

![Gautrain and Rea Vaya network integration point A in the Inner City](image)

**Figure 16:** Gautrain and Rea Vaya network integration point A in the Inner City [Source: Author, 2018]
The integration point A acts as the main central bus terminus for Metrobus. However, the Gautrain and Rea Vaya routes networks are integrated in this area, allowing public transport commuters to switch between modes of public transport smoothly at a short walking distance. There is still no sharing of infrastructure between both the Gautrain, Rea Vaya and Metrobus. The public transport morning peak-hour demand in this integration point is predicted to total 617 000 commuters by 2040, from 298 000 in 2010, according to the City’s 2017-2018 Integrated Development Plan (IDP). With public transport demand expected to almost double by 2040, the City of Johannesburg is increasingly prioritising investment in public transport infrastructure and services across the metropolis. The city of Johannesburg has recognised that enhancing mobility through the provision of reliable public transport will play a key role in improving Johannesburg’s economic viability. The Johannesburg Transport Department is thus making the use of public and non-motorised transport an increasingly attractive and viable option through strategic public transport infrastructure development and investment initiatives.

6.4.3. The protagonist of Johannesburg Park Station (Integration Point B)

Routes network Integration Point B, the Johannesburg Park Station which is situated at the Johannesburg CBD functions as a vibrant intermodal transport node. It is a major public transport interchange, where public transport routes integrate, and commuters come all from all over Johannesburg, South Africa, Africa, or transfer from trains and buses to minibuses. Gautrain, Rea Vaya and other modes of public transport at the Park station provide for intracity, inter-city as well as regional transport services. Given that Johannesburg Park Station is a prominent transport terminal, distribution terminals in the form of bus stations, rail stations and taxi ranks are located in close proximity to the Park Station precinct.

The station provides access to the Johannesburg inner city and well-established high-density precincts that have undergone significant regeneration in recent years. The Park station is characterised by a mixture of high intensity land uses. These range from clustering of mostly commercial land use to the south of the station to a concentration of educational and government institutions, commercial, parking and other mixed land uses to the north. Due to the high intensity of land uses in the area as well as the high volumes of people working or visiting government, educational or commercial facilities, public parking is a necessary requirement. Park Station is a prominent transport terminal in City of Johannesburg, Gauteng province and Southern Africa. Therefore, Metro rail stations and platforms, and taxi ranks are
located within close proximity to the Park Station precinct. The Gautrain, bus routes as well as the Rea Vaya routes should also be noted as essential feeders and distributor routes in the area.

The Johannesburg Park Station provides for an integrated and effective routing and circulation which reduces the number of transfer required. It ensures safety for higher levels of commuters; promotes the use of public transport and non-motorised modes of transport and also encourages the integrated development of surrounding land uses. Each transport mode at the park station supports the others by helping to redistribute commuters overlapped among them and caters to commuters’ requirements and demand. Thus, the diverse needs and features of each transport mode should develop a sustainable and viable design, particularly with regards to construction and operation to achieve integrated mobility.

6.4.3.1. Potential of connectivity at transportation hub

The Johannesburg Park Station draws in large commuter flows in a short time, generally during the rush hours, when a large number of trains, buses and long-distances commuter transport coaches arrive. During this period after trains or coaches such as Gautrain and Metrorail have arrived, commuters need to be distributed to their destinations by various modes of transport such as the Gaubus, Rea Vaya, Metrobus or walking, a process which is supported by the surrounding road networks. The surrounding road networks however, need to accommodate the large flow of commuters and vehicles from Park station so as to minimise congestion that can hamper the normal operation of the traffic network. Findings from key informant personnel from the municipality reveal that the station was planned to take into consideration the demand for gathering and distributing commuters. Figure 17 illustrates that Park Station is surrounded by an existing ring road network which integrates surrounding roads with interchanges and the South and North Johannesburg roads. The ring has three access points, which help reduce traffic congestion because of the large commuter flows on the surrounding road network.
6.4.3.2 Transit Mode share targets

Transit mode share is the percentage of commuters using a precise type of transportation, for instance bus, taxi, car and non-motorised transport. Moreover, it refers to the number of trips that commuters take in relation to their preferred mode of transport. Gauging transit mode share enables node operates and planners to get an overview of commuter demand. It assists them to develop strategies (in terms of policies, structure and layout and marketing) to create a more balanced mode share, and identify the best way to integrate different transportation modes. In the case of Park Station, initial estimates predicted that the Metrorail would accommodate 40% of the total number of commuters, whereas the remaining 60% would use buses, taxis and private vehicles. It was however found that surrounding roads did not have sufficient capacity to deal with such huge volumes of commuters. Hence, another subway line, the Gautrain was built during the preparation for the 2010 FIFA world Cup to pass through the Park Station. This accommodated and shifted the 60% of the total number of commuters towards the use of the line. Thus resulted in a corresponding decrease in road traffic.
Analysing transit mode share within the range of influence of the interchange hub enables planners to manage traffic demand as well as passenger behaviour. It should be noted that non-motorised transport, such as walking, cycling and other variants has not been taken into account when discerning the transit mode share for public transport interchange stations in South Africa. Almost all public transport in Johannesburg does not contain parking spaces for bicycles. These bicycle parking areas were subsequently reduced for the following reasons: (i) cycling has gradually been replaced by perceived ‘convenient’ methods of transport, such trains, buses and private cars; (ii) the volume of private vehicles is rapidly increasing, and private vehicles have proven to be more popular than bicycles; (iii) cycle parking provision should be improved, but there is a high risk of bicycles getting stolen when commuters leave them in station overnight.

6.4.3.3. Potential benefits of Johannesburg park Station

There are number of city-wide benefits that resulted from the establishment of the Johannesburg Multimodal hub, the Park station. As supported by local residents, jurisdiction and operators, the station provides for an effective and integrated system of routing and circulation which reduces the number of transfers required. It ensures safety for higher level of commuters; promotes the use of public transport and non-motorised modes; and encourages the integrated development of surrounding land uses. In addition, Park Station enriches service integration and reduces the time and distance penalties of rail to rail and rail to bus interchanges.

Currently, plenty of middle-income residents in Johannesburg have abandoned private automobiles in favour of public transport. The economic boom of the democratic era in South Africa has brought a dramatic rise in the number of auto-oriented trips. Further, the prospect of an integrated system of the Park Station and accompanying land use persuades many of the residents to rely on public transport for most trips. This is effectively lessening the negative impacts of automobile use, for instance urban congestion, inefficient use of resources and poor air quality. The location of business nodes and commercial activities near the Park Station also assists the growing trend towards ‘trip chaining’ between work and home. Moreover, another potential benefit of Park Station is the improvement in the quality of public transport services feeding into the city. Park Station plays an essential role in safer, more efficient, off-street boarding and alighting and better travel times, particularly during rush periods. Conversely, if
the Rea Vaya bus can improve the time intervals between buses and reliability of bus service, it will offer opportunities to extend the catchment areas of Gautrain and Rea Vaya stations and increase the importance of bus feeder systems.

6.4.4. The function of Urban Public Transport Integration Point C
Integration point C is situated in Parktown and provides connections to educational and health institutions such as the University of Witwatersrand, Nelson Mandela Children’s’ Hospital, Park Lane Hospital and Charlotte Maxeke Academic Hospital (See figure 18). The area neighbours the high density residential areas of Hillbrow, Yeoville and Berea. Public transport systems in this area provide mobility for students, workers and patients from various origins to educational or health institutions. The Gautrain Park Station, bus routes as well as the Rea Vaya Bus Rapid Transit routes should also be noted as essential feeders and distributor routes in the area. Figure 18 illustrates Gautrain and Rea Vaya network integration point C in Parktown.

Figure 18: Gautrain and Rea Vaya network integration point C in Parktown [Source: Author, 2018]
As depicted in the above figure 18, the existing Gautrain and Rea Vaya networks are spatially integrated, however there is no sharing of infrastructure between the two modes of public transport, as they operate independently in this area. It would be of benefit for the two modes to partner towards promoting multi-mobility and sharing of infrastructure in this area. This would integrate transport towards areas of educational and healthy institutions.

6.5. CONCLUSION

This chapter has deliberated on the spatial patterns of urban public transport systems within the City of Johannesburg. Spatial analyses of both forms of innovative urban public transport systems (Rea Vaya and Gautrain) were conducted. Urban public transport systems’ spatial connectivity was discussed with reference to the effects of innovative urban public transport mobility. Commendable work has been done through innovative urban public transport systems. Nevertheless, the criteria for policy interventions for those who most need public transport appears to be far from being a top priority. Lack of cooperation and coordination between three spheres of government was found to be a hindrance to the effectiveness of public transport infrastructure investments. This chapter further explored the extent of routes network integration between the Gautrain and Rea Vaya within the Johannesburg urban public transport system. The results indicate that there are limited areas where the route networks between the public transport systems are connected, and large sections of the networks are disintegrated. Actually, the existing transit networks are spatially segregated and there is no partnership between the two modes of public transport, since they operate independently. The results can further be used as a reference to spot underserved areas by transport and estimate the transit demand for planning purpose.
CHAPTER 7: URBAN PUBLIC TRANSPORT SYSTEMS COMMUTERS PATTERNS THROUGH GEOLOCATION SOCIAL MEDIA DATA

7.1. INTRODUCTION

This chapter presents the applicability of location based services to visualise public transport commuters’ concentrations and movement patterns within the City of Johannesburg. Crowd sourced data from social media posts (Twitter and Facebook) were collected from Echo-Echo, a private company that collects and analyses social media information from a variety of web 2.0 platforms. A total of 39391 Gautrain and Rea Vaya geolocation social media datasets were received in an Excel format from the Echo-Echo. Crowd-source data is still a novel research activity, and this chapter shows the potential for this real-time data to be valuable in understanding system integration. Crowd sourced data is able to measure transit coverage areas, visualise high and low commuter concentration zones, and also track the movement patterns of commuters.

In the chapter, the analysis and creation of maps to reveal the commuters’ travel concentrations was prepared through the use of the kriging interpolation method. Maps were used to visualise high and low commuters’ concentration zones and movement patterns when using the Gautrain and Rea Vaya. The use of geolocation based data has been identified as a possible solution to defining the spatial integration of public transport systems. Geolocation data can take the form of geo-tagged data from social media and crowd-sourced geolocation based information.

7.2. GAUTRAIN COMMUTERS SOCIAL MEDIA CONCENTRATION ANALYSIS

The study initially focused on the social media concentration zones of the posts by Gautrain commuters through the kriging interpolation method (see figure 18). The findings indicate that the Gautrain highest commuters’ social media concentrations were located at the Johannesburg Park station and the adjacent spaces. Areas such as Rosebank, Sandton and Midrand were seen to have equal commuter concentrations (figure 19). This is because these areas are located within economic activities and business hubs, thus commuters traverse between these three locations. From the analysis it appears that the kriging interpolation is relatively sensitive to the presence of outliers’ values, since some clear indications of lowest commuter social media concentrations can be seen in the northern spaces of Johannesburg.
Figure 19 above depicts that most of the Gautrain stations are well located within the high commuter concentration zones based on the kriging interpolation. Table 7 below gives the statistical analysis of the integrated social media commuter concentrations.

<table>
<thead>
<tr>
<th>Integrated Social Media Concentration</th>
<th>Number of Social Media Posts</th>
<th>Commuter Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1034</td>
<td>Low Concentration</td>
</tr>
<tr>
<td>2</td>
<td>2430</td>
<td>Medium Concentration</td>
</tr>
<tr>
<td>3</td>
<td>3780</td>
<td>Moderate Concentration</td>
</tr>
<tr>
<td>4</td>
<td>7534</td>
<td>High Concentration</td>
</tr>
<tr>
<td>5</td>
<td>13188</td>
<td>Extremely High Concentration</td>
</tr>
</tbody>
</table>

Table 7: Analysis of integrated Gautrain commuter concentration [Source: Author, 2018]

Figure 19 and Table 7 also illustrate that the Midrand station has high commuters’ concentration. This is influenced by Gautrain commuters requiring access to the important business nodes from the residential areas of Midrand. Surprisingly, the results also reveal that areas not directly serviced by the Gautrain, for example Roodepoort and Soweto also have a
high social media concentration. Commuters who reside in Soweto use Rea Vaya before they can access the Gautrain. Thus a partnership seems worthwhile between the Gautrain and Rea Vaya, as the Rea Vaya has an existing route that runs from Soweto to Johannesburg Park Station.

7.3. REA VAYA COMMUTER SOCIAL MEDIA CONCENTRATION ANALYSIS

The Rea Vaya has proven successful in improving accessibility to economic opportunities for locations which were once spatially segregated in Johannesburg. A total of 70% of the social media posts reflect positive views regarding routes and timetables of the Rea Vaya. This is because of route networks flowing from Soweto moving upwards towards the city centre, and the recent infrastructural upgrades to the network flow from Soweto to the inner CBD. The findings from the kriging interpolation method indicate that the highest commuter social media concentrations emerged from the Johannesburg CBD, particularly from Park Station stretching towards the western areas of the City (see figure 20 and table 8). Furthermore, the findings reveal that most of the Rea Vaya stations are well located, as they are situated within the high commuter social media concentration spots.
Figure 20: Rea Vaya Commuter Social Media Concentration [Source: Author, 2018]

Figure 20 above depicts that most of the Rea Vaya stations are well located, as they are within the high commuter concentration zones. Table 8 below presents the statistical analysis of the Rea Vaya social media commuter concentrations.

<table>
<thead>
<tr>
<th>Integrated Social Media Concentration</th>
<th>Number of Social Media Posts</th>
<th>Commuter Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>686</td>
<td>Low Concentration</td>
</tr>
<tr>
<td>2</td>
<td>1680</td>
<td>Medium Concentration</td>
</tr>
<tr>
<td>3</td>
<td>2058</td>
<td>Moderate Concentration</td>
</tr>
<tr>
<td>4</td>
<td>2430</td>
<td>High Concentration</td>
</tr>
<tr>
<td>5</td>
<td>4570</td>
<td>Extremely High Concentration</td>
</tr>
</tbody>
</table>

Table 8: Analysis of Rea Vaya commuter concentration [Source: Author, 2018]

Figure 20 illustrates that at present the Rea Vaya does not have existing stations in the upper spaces of the city. These include Roodepoort, Sandton, Randburg and Fourways. Remarkably Roodepoort, Sandton, Randburg and Fourways have a medium commuter concentration. Certainly, these locations could be areas worth investing in by either expanding bus routes,
since they are clearly a ready market for the Rea Vaya. This is another lacuna identified that justifies this present study. It would entail improving access to areas of economic nodes, since the Rea Vaya has been successfully in improving commuter access to the economic nodes of Johannesburg.

7.4. GAUTRAIN AND REA VAYA COMMUTERS SOCIAL MEDIA CONCENTRATION ANALYSIS

Using earlier results, the commuter concentration zones of the Gautrain and Rea Vaya were overlaid on a ratio of 50:50, to visualise the integrated commuters’ social media concentrations. The findings indicate that highest commuter concentrations emerge from the Johannesburg CBD, particularly Park Station stretching towards the western areas of the city (Figure 20). This means that the majority of the commuters are located near the stations because these are located in the melting points of commuters. For instance the Park Station, which acts as the main entry point for most regional and local commuters. It is also situated at the close proximity to the MTN and Bree Taxi Ranks within a distance of about 10 minutes away. This node has a high connectivity level of public transportation; the Gautrain and Rea Vaya routes network are integrated in this area allowing public transport commuters to switch public transport modes smoothly with only a short walking distance. Notable spaces which are currently not serviced by the Gautrain and Rea Vaya are Roodepoort, Randburg, Honeydew, Lenasia and Lawley.
Figure 21: Integrated Gautrain and Rea Vaya Social Media Commuter Concentration [Source: Author, 2018]

Figure 21 above depicts that most of the Gautrain and Rea Vaya stations seem to be well located, as they are within the high commuter concentration zone. Table 9 summarises the analysis of the integrated social media commuter concentrations.

<table>
<thead>
<tr>
<th>Integrated Social Media Concentration</th>
<th>Number of Social Media Posts</th>
<th>Commuter Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1315</td>
<td>Low Concentration</td>
</tr>
<tr>
<td>2</td>
<td>3239</td>
<td>Medium Concentration</td>
</tr>
<tr>
<td>3</td>
<td>5349</td>
<td>Moderate Concentration</td>
</tr>
<tr>
<td>4</td>
<td>13412</td>
<td>High Concentration</td>
</tr>
<tr>
<td>5</td>
<td>19315</td>
<td>Extremely High Concentration</td>
</tr>
</tbody>
</table>

Table 9: Analysis of integrated Gautrain and Rea Vaya Social Media Commuter Concentration [Source: Author, 2018]

With the extremely high commuter concentrations (see Table 9), improving commuter transfer in the geolocation would be a good starting point, since the infrastructure and commuter numbers are already pre-existing. While variations in income levels may be preventing inter-
transfer between the two modes, commuters should be given an incentive for using both modes of transit in one trip, such as a discount in commuter fares, or points which can be later redeemed for a discount. This would build on the existing commuter concentration, and further attract other commuters to join the system. Moreover, it would be cost effective for the two public transit providers to partner towards promoting multi-mobility within City of Johannesburg. Building separate infrastructure, as the Gautrain would therefore link commuters to economic and business hubs in the northern zones of Johannesburg, Namely: Sandton, Rosebank, Marlboro and Midrand. The Rea Vaya would also integrate commuters to areas of economic and business nodes in the southern zones of the city such as Soweto.

7.5. COMMUTERS MOVEMENT PATTERNS OF PUBLIC TRANSPORT SYSTEMS

In this study, social media comments and their geographic location co-ordinates were used to track the movement patterns of Gautrain and Rea Vaya commuters. Although commuter origins and destinations varied, they were mainly economic hubs such as Park station, Rosebank and Sandton. Their origins were mainly the residential areas of the city such as Soweto, Roodepoort and Midrand. The location origins of the commuters’ social media posts and the comments on their destinations were used to digitize the maps (see Figure 22a and b).

Surprisingly, social media posts have been made in areas which are currently not serviced by either Gautrain or Rea Vaya such as areas of Region C and G; this shows that there is a need for expansion of public transport in these catchment areas. The movement of commuters within the city changes with time as a result of developing transportation in addition to innovations within the ICT Sector (Risimati & Gumbo, 2018). While exploring the state of public transport spatial connectivity within the City of Johannesburg in this endeavour, it was essential to understand the commuters’ movements within various areas of the city. Figure 22a and b illustrate Gautrain and Rea Vaya Movement of commuters [Source: Author, 2018]
Figure 22a: Gautrain Movement of commuters [Source: Author, 2018]

Figure 23b: Rea Vaya Movement of commuters [Source: Author, 2018]
It can be deduced from the results that commuters have two or three possible routes that they can take when travelling from their origins to destinations. For instance a commuter has two or three possible routes that he/she can take when travelling between Johannesburg Park Station and Sandton. These routes may be direct links from their origin to their destinations, or may be interconnected through other stations as alternative routes to reach their destinations of choice. The two modes of public transport in Johannesburg metropolitan city should constantly track the movement of their commuters because of changes in their origin and destinations over time.

Thus the idea of location based services is applicable in tracking commuter movement through geolocation patterns that display commuter concentration zones. The idea is for the service provider to reach out to commuters in the form of expanding services or contracting emergency and temporary urban public transport in times when required most. This includes situations such as traffic congestion and tracking social media feeds using location based services analysis software such as Echo-Echo to manage their social media platforms effectively. This in turn will render real-time and effective service to many of its commuters.

7.6. CONCLUSION

This chapter has discussed the applicability of location based services to visualise public transport commuters’ concentrations and movement patterns within the City of Johannesburg. Crowd-sourced data is still a novel research activity, and the chapter showed the potential for these real-time data to be valuable in understanding systems integration. A total of 39391 Gautrain and Rea Vaya Crowd sourced datasets were collected from Echo-Echo measured transit coverage areas. They allowed visualisation of high and low commuters’ concentrations zones and also tracked their movement patterns. Based on the data analyses, the majority of the commuters are located near stations located in melting points of commuters. This includes the Park Station in the Johannesburg CBD and which acts as a main interchange hub of Johannesburg. It is an entry point for most regional and local commuters and is in close proximity to the MTN and Bree Taxi Ranks located only 10 minutes away.
CHAPTER 8: SUMMARY OF RESULTS AND CONCLUSIONS
RECOMMENDATIONS

8.1. INTRODUCTION

The integration of urban public transport systems has the potential benefits of creating sustainable urban mobility and enhancing social inclusion. Conversely, the disintegrated public transport concomitant with an imbalanced distribution of public transport services across the population results in adverse effects for some social groups and the quality of transit ridership. Within this context, this chapter presents the study recommendations for promoting the provision of well integrated and efficient public transport, as this can help in reduction of energy consumption and carbon footprints and mitigate traffic congestion and accidents. Integrated public transport can improve quality of life, enhance social inclusion and also provide a more environmentally-friendly and healthier activity pattern (Lopez-Iglesias et., 2018). This chapter also suggests possible future research and brings the study into conclusion.

8.2. SUMMARY OF RESULTS

The context of spatial integrated public transport and transit-oriented developing planning is continuously adapting to a daily variety of challenges in line with the global shift towards the concept of smart city planning. The move towards encouraging societies to using multi-mobility transport modes in their daily commute and lessen the negative impacts of automobile dependence is the anticipated shift of the City of Johannesburg. Integrating and improving public transport modes is a desirable method for enhancing multi-mobility and promoting transit ridership.

8.2.1. Legislatives frameworks and policy interventions

The provision and management of well-integrated, affordable and reliable modern public transportation systems in South African cities is critical in ensuring both smart cities and mobility within them. Notwithstanding the evident benefits of modern urban public transport systems, governments of the developing world at all levels, have been struggling to plan for, develop and manage public transport systems of acceptable standards (Musakwa & Gumbo, 2017). African governments in particular, have been struggling to provide well-coordinated, efficient, reliable and affordable public transport systems in their ever-growing cities spatially and demographically (Risimati & Gumbo, 2018).
Consequently, there have been spirited efforts in South Africa to not only enact relevant urban transport legislative frameworks and policies but also their implementation to facilitate the development of efficient modern public transport systems. Colonial and apartheid spatial planning mechanisms contributed to the current disintegrated land use pattern. This perpetuated increased travel times and costs from isolated townships to economic nodes for employment and other urban amenities. The apartheid spatial planning was characterised by a mass public transport rail network. This also influenced the rise of the mini-bus taxi industry as an alternative form of public transport to take people from isolated residential areas to places of employment. Notably, South Africa has adopted several enabling policies and legislative instruments to promote innovative urban public transport systems since the realisation of the democratic dispensation in 1994. These commenced with the National Constitution of 1996 which led to the adoption of the National Transport Policy White Paper later in the same year. Recently, the National Rail Policy Green Paper was launched in 2015 to solicit views and ways of facilitating the planning and development of improved railway transport systems.

In particular, the Gauteng province as the economic hub of South Africa, is experiencing a growing demand for public transport, hence the innovations in transport systems. Consequently, the province has adopted the Gauteng’s 25 year Integrated Transport Master Plan which seeks to improve urban public transport systems within the province. Thus, the policies that sought to promote public transport in Johannesburg include the National Rail Policy Green Paper of 2015, National Transport Policy Green and White Papers of 1996 and the Gauteng’s 25 year integrated Transport Master Plan of 2013 (ITMP 25) (Gauteng government, 2013). The ITMP 25 plan seeks to achieve its objectives through the implementation of several strategies. They include the provision of efficient urban public transport systems well linked to promote its use and reduce reliance on private transport. Consequently, this has given rise to BRT systems such as the Are Yeng in Tshwane, and Rea Vaya in Johannesburg and the high-speed railway (Gautrain).

8.2.2. Spatial patterns and routes network integration of innovative urban public transport systems

Implementation of innovative urban public transport systems in Johannesburg are currently far from being responsive due to spatial fragmentation. There is a continuation of various modes of public transport that are operationally disintegrated. Further, there are no clear indications
of how the Municipality intends ensuring that all areas are covered with efficient modes of public transport through modal integration. Instead, both the Gautrain and Rea Vaya appear to set themselves apart from other modes of public transport. The two modes of public transport are not even operationally integrated with each other.

Accordingly, the study revealed that the existing urban public transport network is spatially segregated, and there is little to no collaboration between the Gautrain and Rea Vaya. The Gautrain services the northern spaces of Johannesburg, whilst the Rea Vaya does not have existing networks in these spaces. The Rea Vaya BRT system, services the southern spaces of the city, which were spatially segregated during the Apartheid administration.

This illustrates a knowledge gap of how to connect commuters to places of economic activities. With this status quo, improving commuter transfer at points of interest (such as places of economic activities) would be a good starting point, as the infrastructure and commuter numbers already pre-exist. It would also be cost effective for the two public transit providers to partnership in promoting multi-mobility within the City of Johannesburg. The Gautrain would then link commuters to economic and business nodes in the northern spaces of Johannesburg (Rosebank, Sandton, Marlboro and Midrand), while the Rea Vaya would link commuters to areas of economic and business nodes in the south. In addition, the network integration of the public transport systems would lead to improved service delivery, inter-connectivity of places of economic activities and improved public transport ridership.

Though the Gautrain provides an efficient service, its unaffordability by the urban poor leaves much to be desired. Hence it is identified as viable for business trips by middle and high-income earners. The light rail that has been successfully implemented in Addis Ababa and their model could be used to inform how the Gautrain can become more affordable and innovative. This could also inform South African Cities going forward for improving, affordable urban mobility for all income groups. With each mode of urban public transport, it is important to identify which role they can contribute towards. This will lead to a strengthening of that mode in a specific segment and establish a multimodal public transport network. This will ensure that no form or mode of public transport unnecessarily duplicates the service already provided. Rea Vaya has proven effectively in improving accessibility to economic opportunities for formerly marginalised locations such as Soweto, since its network flows from Soweto moving towards
the Central Business District and the Northern spaces of the city. In addition, the majority of Rea Vaya stations are well located within the commuter concentration spaces, as revealed by the analyses of co-ordinates of the social media posts through the kriging exercise.

The study further reveals that Johannesburg park station is essential in promoting support for public transport integration within the city of Johannesburg. The kriging interpolation analysis reflects that the majority of the social media commuters’ concentrations are located at the Johannesburg park station. This is because the station functions as a vibrant intermodal transport hub and is situated in the melting areas of commuters such as the Central Business District. It is an entry point for most regional and local commuters and is located adjacent to the Bree and MTN Taxi ranks. The station represents a gateway for many commuters, not only from other South African cities, however also from Africa.

Gautrain, Metrorail and bus services at the station provide inter-city as well as intra-city and regional transport services. The Park station hub provides access to the inner-city and provides integrated and effective routing and circulation which reduces the number of transfers required. It ensures safety for high level commuters and promotes the use of public transport and non-motorised modes of transport. It also encourages the integrated development and use of surrounding land uses and other resources, and links various modes of transport in one location. Each transport mode at the station supports the others redistributing commuter overloads between them and caters to commuting requirements and demand. Thus, the diverse needs and features of each transport mode should be considered during the planning and design state. This will help to develop a sustainable design, particularly in terms of construction and operation in order to achieve effective and integrated mobility.

8.2.3. Determining urban public transport systems commuters’ concentrations through Social media data

The use of geolocation based data in this study has been identified as a possible solution to defining the integration of public transport systems. It can take the form of geo-tagged data from crowd-sourced social media location information. Accordingly, in this study, crowd-sourced data analysed through kriging interpolation method were used to visualise high and low commuters’ concentration zones, and also track the movement patterns of commuters using the Gautrain and Rea Vaya.
Gautrain commuters’ social media posts reflected high concentrations at areas such as Rosebank, Sandton and Midrand. This is because these areas are located within business hubs, thus commuters traverse between these three locations. Gautrain commuters required access to the business nodes from the residential areas of Midrand. Surprisingly, the results also reveal areas which are not directly serviced by the Gautrain, for example Roodepoort and Soweto have a high social media concentration. Commuters who reside in Soweto use Rea Vaya before they can access the Gautrain. Thus, a partnership seems worthwhile for the Gautrain and the Rea Vaya, which has an existing route that runs from Soweto to Johannesburg Park Station. A total of 70% of the social media posts reflected positive views regarding routes and timetables of the Rea Vaya. This was seen with the route network which flowed from Soweto towards the city centre and the recent infrastructural upgrade which has improved the network flow from Soweto to the inner city.

According to the findings of crowd sourced data, the majority of the commuters are located near the stations. This is due to the current stations being located in melting points of commuters such as Park Station in the Johannesburg CBD. This acts as a main interchange hub of Johannesburg, and is an entry point for most regional and local commuters. It also has close proximity to the MTN and Bree Taxi Ranks. It is a major public transport interchange, where public transport networks merge and commuters come from all over Johannesburg, South Africa, African countries. Gautrain and Rea Vaya services at Park Station provide for intercity as well as intra-city and regional transport services. Given that Johannesburg Park Station is a prominent transport terminus, transport modes in the form of bus stations, rail stations and taxi ranks draws high commuters’ concentration levels. This enables commuters to switch between modes of public transport smoothly within a short walking distance.

Notably, the study results revealed areas such as Soweto which are currently not directly serviced by the Gautrain but which have a high Gautrain commuter concentration. This is because commuters who reside in Soweto use Rea Vaya before they can access the Gautrain system. Accordingly, a partnership seems worthwhile for the Gautrain and Rea Vaya, since the Rea Vaya has an existing road network that flows from Soweto towards the Johannesburg Park Station. The Gautrain routes network also flows from Park station towards the northern spaces of the city. The results also indicate that social media communications have been made in areas such as Roodepoort and Lenasia in Region C and G which are currently not serviced by both
the two public transport modes. This means that commuters who reside in these areas use another form of mobility before they can access either Gautrain or Rea Vaya. Thus, these are potential areas for route network expansion of both Gautrain and Rea Vaya.

8.3. CONCLUSIONS

To conclude, mobility is continuously adapting and transforming to challenges, and can be perceived as the global shift towards smart city planning. The shift is towards encouraging communities to utilise multi-mobility modes and public transport in their everyday commute and reduce the negative impacts of private-car-dependence. Consistent with the summary of the findings, which were cross-referenced with international experiences, three conclusions were reached in harmony with the first three study objectives. These conclusions depict critical issues on policy formulation and implementation. They embrace spatial patterns of innovative urban public transport systems in a manner which anchors spatial connectivity through multi-modal integrated public transport planning. They include the design of interchange hubs as hotbeds for innovation through creation of vibrant urban spaces for social and economic interaction. Crowd-sourced data is still a novel research activity, but the conclusions of the study show the potential for these real-time data to be valuable in understanding system integration. Crowd sourced data is able to measure transit coverage areas, reveal high and low commuter concentration zones, and track the movement patterns of commuters.

8.3.1. Absence of practical collaboration on policy implementation

Post 1994, South Africa has emphasised spatial and socio-economic transformation through policy creation to deal with past spatial injustices, to reduce poverty, unemployment and the inequality gap. Interventions have been centred on spatial restructuring through a public transport framework. However, other than visible physical infrastructures, spatial integration and socio-economic transformation as realistic indictors of transformative policy and legislative interventions have lacked effectiveness.

Though commendable work has been done, the criteria for prioritisation on policy interventions must therefore be reviewed, as those who need public transport the most appear to be far from being a top priority. It is evident that all spheres of government and some sector departments are interdependent in their core functions despite each having its own constitutional responsibility and legislative autonomy. This autonomous approach to implementation by each
sphere of government or even sector departments have meant that all public transport infrastructure investments consistent with policy and legislative frameworks have perpetuated spatial and socio-economic disparities. Thus, a collective implementation strategy is central to attaining redressing spatial disparities.

8.3.2. Disregard of modal integration for spatial connectivity

Because the different spheres of government have implemented their projects independently, spatial connectivity through multimodal public transport networks is still not effectively pursued. This has led to creation of modes of public transport which are operationally disintegrated. Even different types of innovative urban public transport systems (Gautrain and Rea Vaya) operate independently of other existing forms or modes of public transport. Thus, duplication of multiple modes of public transport in the same geographical area without making any difference is inevitable.

It should be acknowledged that mini-bus taxis and Metrorail transport most people from previously disadvantaged communities and therefore should form an integral part of the public transport modal integration. The mini-bus taxi industry is still completely disregarded in the current transport innovations despite them being responsible for transporting sizeable numbers of commuters from disadvantaged communities. The previous recapitalisation program did not do justice to the transformation of the mini-bus taxi industry. Instead, public funds were spent without even redressing the alarming safety concerns. This was also done without regard for modal integration, and this continues to be case even with implementation of innovative urban public transport systems consistent with the IRPTN national government strategy.

It is evident from the study findings that without an integrated (multi-modal) urban public transport network, spatial integration will be hard to attain, regardless of how many technologically advanced modes of public transport are introduced. The appropriateness of a mode of public transport for the people and purpose it serves was found to also be essential when devising strategies for modal integration. In this regard, the Gautrain was found to be costly to implement while also having high travel costs. It excludes the urban poor and previously disadvantaged communities, thus making its significance limited to connecting major economic nodes for business related trips.
8.3.3. The impact of public transport systems integration on commuters’ concentrations and commuters movement patterns

The integration of public transport systems has a huge impact on city mobility, since public transport commuters can easily switch between modes of transport with only short walking distances. The study results indicate that most of Gautrain and Rea Vaya networks are not integrated which affects the ability of commuters to conveniently switch between the Gautrain and Rea Vaya. This existing spatial segregation illustrates a knowledge gap of how to connect commuters to places of economic and business activities. As the infrastructure and commuter numbers are already pre-existing, this information could be used to improve commuter transfer in the geolocation.

Also, it would be more cost effective for the two public transit providers to partner in promoting multi-mobility within Johannesburg rather than building separate infrastructures. The Gautrain could link commuters to economic and business nodes in the northern parts of Johannesburg (namely Rosebank, Sandton, Marlboro and Midrand), while Rea Vaya would link commuters to areas of economic and business nodes in the southern part of the city. The kriging interpolation analysis revealed areas such as Soweto which are not directly serviced by the Gautrain, but which have a high commuter concentration. Thus, commuters who reside in Soweto must use Rea Vaya before they can access the Gautrain system.

The partnership would also be worthwhile, because Rea Vaya has an existing road network that flows from Soweto towards the Johannesburg Park Station, and Gautrain flows from the Johannesburg park station towards the northern spaces of the city. In addition, social media posts have been made in areas such as Roodepoort and Lenasia in Region C and G, which are currently not serviced by both the two public transport modes. Commuters who reside in these areas must therefore use another form of mobility before they can access either the Gautrain or Rea Vaya. Therefore, these are potential areas for routes network expansion of both Gautrain and Rea Vaya.
8.4. TOWARDS A COMPREHENSIVE INTEGRATED TRANSPORT PLANNING FRAMEWORK

It is therefore evident that stakeholders’ integration on policy intervention, collaboration by public transport service for multimodal public transport network, and creation of non-motorised transport should always be the obligatory principles of public transport infrastructure investments. Implementation of innovative urban public transport systems with a strong focus on integration will enable cities to become centres for innovation, where trade, tourism, commerce, services and education will be improved. Fostering such investment returns and positive spinoffs through socio-economic benefits will lead to economic growth. This will be achieved through easy access to economic opportunities, improved business opportunities, affordable transport options and a fully functional, integrated urban public transport network. Such a network should help reduce travel time and costs thereby improving productivity in work places. It will eliminate the element of discouraged, unemployed residents resulting from high travel costs for low income groups (mostly from isolated townships) who end up spending more than 50% of their wages on transport.

8.4.1. A Framework for Comprehensive Integrated Transport Planning

Public transport plays a vibrant role in maintaining quality of life and enhancing attractiveness for industry development in a city. Thus, the public transport system should be maintained effectively and enhanced through comprehensive integrated planning. A suitable framework for such an approach should combine long-term planning for land use, all modes of transport and the environment. It should consist of three key components, namely: outcomes which determine the desired transport system; principles to guide the development of transport system options, and a process which provides a systematic and consistent approach to transport planning.

The Collaborative Planning Process forms the core of multi-disciplinary strategy development by interdependent institutions. Dehghan and Shakeri (2008) states that communicative platforms created for deliberation and engagement amongst stakeholders are instrumental in ensuring that all contribute to devising a collective strategy. Therefore, the Collaborative Planning Process must be robust, and have well facilitated, trained planners to ensure that the final outcomes yield positive socio-economic benefits. Thus, figure 22 below represents a Comprehensive Integrated public transport planning framework.
Figure 24: Comprehensive Integrated Planning framework for Innovative Urban Public Transport Systems [Source: Author, 2018]
<table>
<thead>
<tr>
<th>Principal Factors</th>
<th>Policy and Legislative Frameworks</th>
<th>Improved Urban Mobility</th>
<th>Socio-economic Development</th>
<th>Key Performance Indicators (KPIs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Status Quo Analysis</td>
<td>✓ Rigorous research on pre-existing conditions on local development needs and challenges</td>
<td>✓ Determining public transport infrastructure needs and challenges, types of operations, condition of different modes of public transport</td>
<td>✓ Socio-economic profiling of the local community, public transport affordability and socio-economic challenges</td>
<td>✓ Identification of priority areas for policy intervention ✓ Identification of relevant stakeholders</td>
</tr>
<tr>
<td>Integration</td>
<td>✓ Integrating stakeholders with interdependent functional areas associated with identified development needs.</td>
<td>✓ Forging a working relationship for collaboration amongst public transport service providers ✓ Design for a single Integration public transport network</td>
<td>✓ Integrated billing system charging fares per single trip regardless of interchanges ✓ Easy access to economic opportunities</td>
<td>✓ Integrated public transport network covering every area. ✓ Integrated billing system ✓ Integration of residential and economic opportunities</td>
</tr>
<tr>
<td>Urban Growth Management</td>
<td>✓ Government responsive to development needs by creating an enabling environment for public-private partnership without state bureaucracy</td>
<td>✓ Housing opportunities for all income along public transport corridors, i.e. densification. ✓ Public transport to help reduce traffic congestion and travel times</td>
<td>✓ Creation of Activity Nodes mixed-use development around stations and connector points social and economic opportunities</td>
<td>✓ Housing opportunities for all income groups along densification corridors ✓ Skilled professionals and entrepreneurs</td>
</tr>
<tr>
<td>Collective Strategy formulation</td>
<td>✓ Planners as facilitators of the process responsible for conflict management and ensuring synergies amongst stakeholders</td>
<td>✓ Provision of affordable, efficient, reliable public transport that enhances access to opportunities by redressing spatial imbalances.</td>
<td>✓ Development that encourage the use of public transport and enhances access to economic opportunities</td>
<td>✓ Efficient, reliable public transport systems ✓ Business growth ✓ Employment creation</td>
</tr>
<tr>
<td>Decision Making</td>
<td>✓ Development proposals formulated into two or more policy options for final decision making</td>
<td>✓ Types and modes of public transport suitable for each segment of the community given their socio-economic profile and needs.</td>
<td>✓ Investments on social and local economy development. ✓ Availability of funding for upcoming entrepreneurs</td>
<td>✓ Implementation Plan, ✓ Investment Framework and Monitoring and Evaluation Framework.</td>
</tr>
</tbody>
</table>

8.4.2. Fundamental features for a comprehensive integrated approach in urban public transport Planning

The study advocates a comprehensive integrated planning approach for innovative urban public transport systems anchored through a Collaborative Planning Process. This originates from the interdependent nature of the policy mediations, spatial connectivity and commuters movement patterns. The Collaborative Planning Process requires commitment and patient deliberation, as it brings together stakeholders with a variety of interests though they are interdependent due to cross-cutting issues they deal with. Prominent issues identified through findings on efficacy on policy and legislatives frameworks, spatial patterns of innovative urban public transport systems, commuters’ concentrations zones and their movement patterns can be summarised in the following fundamental features:

i. Status quo analysis

The cross cutting issues reflected through the summary of results affirms the need for understanding pre-existing conditions prior to development planning and implementation. A clear understanding of local knowledge will provide a concrete base for stakeholders to identify areas of prioritisation.

ii. Integration

The principles of integration of urban public transport planning are categorised under ‘balance’, ‘integration’ and ‘partnerships.’ Thus, integrated transport planning is about finding the right balance across a wide range of economic, environmental and social factors to achieve the best overall outcomes. To consider the benefits, costs, risks and opportunities in a balanced way requires an understanding of how these factors interact and influence each other. There are four key aspects to integration, namely: integrating the transport system; integrating transport and land use; integrating transport and other planning; and as well integrating across levels of planning and jurisdictions. Strong partnerships across governments, industry and the community are essential in integrated transport planning. This allows planners to draw on a wide range of views, expertise and experience to ensure the needs, priorities and values of stakeholders are met.
The necessity for integration in this study encompasses the three conclusions arrived at, but under different settings. The policy and legislative framework relates to the need for stakeholders collaboration for innovative public transport systems. Spatial patterns relates to modal integration; while commuter concentrations zones and their movement patterns relate to integrating public transport infrastructure with land use and local economic development investments.

iii. Urban growth management
For urban growth management, densification and a mixed-use approach to create self-sustainable communities were identified as essential. Creation of activity nodes on major intersections along densification corridors was identified as central to decentralisation of economic opportunities and promotion of small-scale entrepreneurship. Thus, vibrant urban nodes for social and economic interaction would be created, where people could live closer to or have easy access to economic opportunities.

iv. Collective approach formulation
For an integrated approach to innovative urban public transport systems and socio-economic transformation, policies and implementation plans must be formulated collectively and agreed upon by all interdependent stakeholders. Such development programs must ensure that urban mobility principles of accessibility, affordability, efficiency and reliability are attained through innovative urban public transport systems investments. An enabling environment for business growth should be created to ensure that policy interventions and investments are responsive to spatial connectivity and socio-economic transformation development challenges.

v. Decision making
The nature of decision making for public transport infrastructure and socio-economic transformation administered by various stakeholders is complex and interdependent. It is important therefore that an investment decision by one stakeholder complements a decision by another. Designing an investment framework aligned to a collective strategy will assist in determining who will be responsible for funding which aspect of the holistic development program. This will guide stakeholders towards a common goal while eliminating the possibility
of creation of ‘white elephant’ developments, where public funds are spent on development programs that are not responsive to spatial and socio-economic disparities.

8.5. RECOMMENDATIONS

Integrated public transport planning improves a city’s connectivity, providing a better mobility service, shorter journeys for the commuters, and also bringing people and places closer together. As part of this, the City of Johannesburg should consider integrating infrastructures and operations for public transport planning and create easy connections with non-motorised transport (such as walking and cycling). Properly integrated public transport modes will increase their usage by commuters; since commuters get more value for money, and they will consider public transport as a more convenient mobility option. One of the main benefits is that integrated transport systems foster social equality, providing access to services, jobs, education and entertainment and access to the whole city. Peoples’ use of more sustainable modes of transport can reduce congestion, emissions, travel times and, if managed properly, even road accidents.

8.5.1. Implications to planning

It is recommended that conscious efforts be made in planning and developing both rail and route networks that are integrated to promote efficiency of public transport systems. The integration of the public transport systems will lead towards improvements of service delivery, inter-connectivity of places of economic activity and improved quality of life. Thus, there is need for development of planning support systems that will guide the growth of the existing and future public transport modes within Johannesburg city. Typically, sustainable urban mobility or smart mobility describes movement patterns or city transport networks. These utilise active travel modes, efficient renewable forms of energy, or shared vehicles wherever possible, resulting in low carbon output per commuter journey.

8.5.2. Implication to Policy and Legislative frameworks

Mobility is a fundamental element in the functionality of the City of Johannesburg, which influences all sectors. Therefore integrated transport planning should be a part of every urban development plan, programme and project. This will ensure that the city can expand its public transport networks without worrying about administrative changes at any government level. Sustainable urban mobility plans could be an ideal way to provide the backbone for specific
plans with short medium timescales, such as plans for traffic, public transport, parking, freight or cycling.

The findings further reveal the complexity of spatial and communicative platforms with a multiplicity of urban public transport modes resulting in complex models of urban public transport operations. It is therefore recommended that there should be conscious efforts in planning and developing transport interchange hubs which are integrated to promote the efficiency of public transport systems. In addition, the diverse needs and features of each transport mode should be considered during the planning and design state to develop a sustainable and viable design, particularly in terms of construction and operation in order to achieve effective mobility.

The City of Johannesburg does not currently have an effective and capable integrated public transport system to diminish automobile dominance and the many congestion-related problems. Much still must be done to steer the city’s mobility towards more sustainable transport, therefore, an attractive alternative embodied in public transport modes must be implemented. One of the challenges of the public transport modes lies in presenting a simple face to commuters in terms of connectivity and intermodal connectivity.

Integrated multimodal networked public transport has emerged as a mobility paradigm, utilising transfer potential to provide maximal service for an efficient operating budget. It must therefore provide a genuinely feasible alternative to automobile travel for many journeys within urban areas. Beyond providing improved urban mobility, the multimodal hubs function as a major element of urban development and renewal. The huge potential of multi-mobility is that it provides a guide that can be used by planners, government agencies, and other experts to learn from the good practice that is being developed. The results from the study indicate the complexity of spatial and communicative platforms and the multiplicity of urban public transport modes which result in complex models of urban public transport. Thus, it is recommended that there should be great initiatives in planning and development of public transport interchange hubs which encourage integration of multi-mobility and promote efficiency of public transport modes. In addition, the diverse features of each transport mode should be considered during the planning state to develop a sustainable design in terms of construction and operation.
8.5.3. Multi-modal (integrated) urban public transport network

The need to integrate all (innovative and other) modes of public transport is encouraged as the backbone of effective functioning of economic communities. When integrating varied modes of public transport, it is important to define the purpose of each mode or type of public transport in the overall public transport network to ensure improve urban mobility. For example, the Gautrain may be designated to connect major economic nodes, while other modes of public transport focus on commuting passengers between residential and economic or other urban opportunities. An integrated (multimodal) public transport network will enhance spatial connectivity, densification, reduce travel times and costs and thus enhance efficiency of public transport systems.

Through modal integration, public transport infrastructure investments will be utilised more effectively to enable comprehensive public transport throughout municipal areas of jurisdiction instead of unnecessarily duplicating public transport services. A Public Transport Corporation should be created, where all public and private public transport service providers collectively manage operations of an integrated (multi-modal) transport network. This will enable centralisation of operations and creation of integrated billing systems, with different stakeholders owning modes of public transport they originally operated prior to modal integration.

Government must take the lead in creating an enabling environment through legislative frameworks to allow for public private partnerships. Policy formulation roles should be separated from operational matters to eliminate state bureaucracy. Government should also not seek to replace the taxi industry or compete with it. Instead it must be incorporated into the public transport corporation as an important stakeholder in a multimodal integration. The state should refrain from autonomously imposing itself on the taxi industry by dictating terms through introduction of other modes of public transport in areas where taxis operate. Unlike government, the taxi industry has many cultural and organisational complexities and thus, negotiation with all taxi owners will get full buy-in and cooperation instead of limiting discussions to taxi associations’ leadership.
8.5.4. Technical and financial considerations
Most technical challenges relate to the ability to design an integrated public transport network that provides highly reliable and comfortable transport with a good information system and a minimum number of transfers. The challenge is greater when creating such a network with limited financial resources, with no subsidies and where only income generated by commuters’ fares covers the costs of the operation. It is recommended that government agencies should provide public transport subsidies, because the development of an integrated public transport network can be costly. The subsidies for integrated public transport planning will result in better services, more commuters, and contribute to modal shifts and intermodal integration (such as from the use of private cars to public transport). In addition, forming partnerships between all levels of government is the best way to address integrated transport network planning.

8.5.5. Corridors of freedom for a people-centred city
The city of Johannesburg is embarking on new spatial plans in line with the Johannesburg Growth Development Strategy, 2040 based on transport-oriented development. This study recommends embracing these new spatial plans, more particularly the Corridors of Freedom. Since the shape of the city will consist of well-planned transport arteries; the Corridors of Freedom will be linked to interchanges, where the focus will be on mixed-use development. Therefore, the Johannesburg public will not have to use private transport but can opt for alternative means including cycling, transit lanes and pedestrian walkways. The corridors of Freedom will transform entrenched settlement patterns which have shunted the majority of residents to the city’s outskirts, away from economic opportunities and access to jobs and growth. Gone will be the days of being forced to rise at dawn to catch a train, bus or taxi to a place of work. Families will be able to have quality time, with spouses and children sharing meals together in the evening.

The Corridors of Freedom will usher a new era of access to opportunity and a choice for residents to work, stay and play within the same space, without the inconvenience and high costs of travelling long distances. The transit-orientated development includes the Bus Rapid Transit system, Rea Vaya, which will have fast, safe and affordable mobility along corridors. Thus, these corridors of freedom will give residents increased movement and economic freedom; liberating them from the apartheid spatial legacy characterised by informal
settlements, poor schooling and limited recreational spaces. Johannesburg’s transport system will comprise well-planned transport arteries. The Corridors of Freedom will link to mixed-use development nodes with high density accommodation supported by office buildings, retail development and opportunities for education and recreation. This will give rise to a people-centred city, where communities’ needs, their safety, comfort and economic well-being are placed at the core of planning and delivery processes. The corridors of Freedom will also result in reduced poverty for the majority of the City’s residents, who are currently spending a large percentage of their income on transport.

8.5.6. Targeted Areas for Johannesburg integrated public transport system
The apartheid spatial planning has left the City of Johannesburg with sprawling low-density spaces feasible for use as public mobility systems. The larger part of workers and poor residents are still residing on the edges of the City centre and need to commute long distances to get to work. Private automobile usage is a noteworthy source of energy utilisation and ozone depleting substances in the city. A 10% move of private vehicle clients to public transport will result in an 8% decrease in energy consumption. It is suggested that future planning must therefore readdress this sustainability imbalance. The most productive urban shape is compact and energy efficient. It gives residents more noteworthy access to amenities and supports mixed use intensification and social cohesion. It provides an extensive public mobility network that comprises high intensity movement corridors and with an attractive urban environment for cycling and walking.

The Corridors of Freedom program is the main edge of the compact polycentricism approach that must adjust the spatial shape and supportability of the City on a very basic level. Public transport is the spine on which the new city will be developed. It fills a double need of moving individuals and is an organising component for mixed use strengthening. The development corridors or public transport backbone will act as channels for economic activity and will develop anchor points for economic development, where main roads interconnect them. The outcome of the strategy is to increase the job density around these highly accessible points and to attract development in economically underdeveloped areas such as Soweto and Alexandra.
8.6. SUGGESTIONS FOR FUTURE RESEARCH

Developments which have currently tailored the improvement of transport integration, particularly public transport systems have been taking place in most cities of the developing world. For example, improvement of public transport integration begins with evolving an all-inclusive transportation chain instead of only focusing on one part of the journey. This is accomplished by facilitating spatial integration between diverse transport modalities (for instance the bus, walking and cycling) to allow for a multiplicity in travel opportunities. Consequently, it is suggested that the future research will mainly focus on interrogating the extent of spatial integration of motorised and non-motorised innovative public transport infrastructures. This will assist to develop policy frameworks in integrating commuting, cycling and walking in cities of the developing world, learning from the City of Johannesburg.

8.7. CONCLUSION REMARKS

To conclude, the setting of transit-oriented and urban public transport development planning is constantly transforming and adapting to daily challenges, and can be seen with the worldwide move towards planning for smart cities. The move is towards urging commuters to use public transport and multi-mobility modes in their daily commute. This will lessen the negative effects of private automobile reliance in urban settings. Improving and integrating urban public transport modes is an alluring strategy for promoting the usage of transit ridership and multi-mobility. This study explored the state of the spatial integration among Rea Vaya and Gautrain in the Johannesburg urban public transport environment. Crowd-sourced data is as yet a novel research activity, and this study demonstrated the potential for these real-time data to be used in understanding integration of a system. Crowd-sourced data was managed to visualise high and low commuter concentration zones, measure transit coverage areas, and track the commuters’ movement patterns.

The results of the study revealed that there are restricted spaces, where the route networks between the two urban public transport systems are integrated and huge sections of the network are disconnected. Essentially, the existing transit networks are spatially segregated and there is no partnership between the two modes of public transport. The results can further be used as a reference to spot underserved areas by transport and estimate the transit demand for planning purposes. However, the network integration of the public transport systems will lead to
improved service delivery, inter-connectivity of places of economic activities and improved public transit ridership.

The Gautrain services the northern spaces of the City, whilst the BRT Rea Vaya services the southern spaces of the city, which were previously disadvantaged. Spatially, the Rea Vaya has proven effective in improving accessibility to economic opportunities for formerly marginalised locations, such as Soweto. This is because the network flows from Soweto moving towards the Central Business District and the Northern Spaces of the City. In addition, the majority of the Rea Vaya stations are well located within the commuter concentration spaces, as revealed by the analysis of co-ordinates of social media posts through the kriging exercise. The existing urban public transport network is spatially segregated, and there is little to no collaboration between the Gautrain and Rea Vaya, since they are developed and operate separately.

The study therefore recommends that conscious efforts in planning and developing both rail and routes networks are integrated to promote efficiency of public transport. The network integration of the public transport will lead to improved service delivery, inter-connectivity of places of economic activity and improved quality of life. For the City of Johannesburg to promote smart mobility, there is thus a need for development of plans which will guide the integration of the existing and future public transport systems. Typically, sustainable urban mobility describes movement patterns or city transport networks which utilise active travel modes, efficient renewable forms of energy, or shared vehicles wherever possible, resulting in a low carbon output per commuter. Integrated multimodal networked public transport has emerged as a mobility paradigm, utilising transfer potential to provide maximal service for an efficient operating budget, providing a genuinely feasible alternative to the automobile travel for many trips within urban areas.
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LIST OF ANNEXURES

ANNEXURE A: CONFIRMATION LETTER OF PAPERS PUBLICATIONS AND PUBLISHED PAPERS

ANNEXURE B: KEY INFORMANT (SEMI-STRUCTURED) INTERVIEW QUESTIONNAIRE

ANNEXURE C: SAMPLE OF COLLECTED CROWD SOURCED DATA FROM ECHO ECHO
ANNEXURE A

CONFIRMATION LETTER OF PAPERS PUBLICATIONS AND PAPERS
Dear Examiners,

RE: CONFIRMATION LETTER OF PAPERS PUBLICATIONS OF THE SUBJECT DISSERTATION

I am pleased to inform you that some work of the subject dissertation have been officially published by the authors. Following are the officially published papers of the subject dissertation:

   - *Journal of Infrastructure*: Exploring the Applicability of Location-Based Services to Delineate the State Public Transport Routes Integratedness within the City of Johannesburg.

b) 23rd international Conference on Urban Planning and Regional Development in the information Society 2018: TU Wien, Vienna, Austria.
   - *Conference paper*: Examining the role of Public transport interchange hubs in supportive public transport integration in City of Johannesburg.
   - *Conference paper*: Exploring the applicability of location based services to delineate the state public transport routes integratedness within the City of Johannesburg.

Please review the attached below papers for additional details regarding the published work of the subject dissertation. Thank you for your time and consideration.

Yours Sincerely,

Mr. BRIGHTNES RISIMATI
Student (Reg No. 201308075)
Department of Quality and Operations Management
Cell: 078 3326 246 | Email: brightnesrisimati@gmail.com
Abstract: In the past decade, Johannesburg has actively participated in the investment and development of the Gautrain and Rea Vaya public transportation modes. However, the state of route networks connectedness amongst the two public transport modes has not been well documented. Thus, this study aimed to delineate the extent of routes network integration among the two modes. The study adopted a phenomenological case study survey design which applied a mixed-method approach to gather spatial, qualitative and quantitative data. Crowd sourced datasets from Facebook and Twitter were collected, and analyzed using the kriging interpolation method and descriptive statistics. Key informant interviews were also used to unpack the status quo of the two modes. Results indicate that there are limited areas where the route networks between the two modes are currently integrated. Variations in income levels may be a factor currently preventing inter-transfer between the two modes. The Rea Vaya has proven successful in improving accessibility to economic opportunities, with 70% of the social media posts reflecting positive views regarding route and travel timetables. The study recommends conscious efforts in planning and developing integrated rail and road route networks to promote efficiency of public transport systems.

Keywords: integration; route networks; urban public transport; multimodal integrated system; rail-networks; City of Johannesburg

1. Introduction

In cities of developing countries, particularly in African, Asian and Latin American continents, there have been growing concerns regarding the state of public transportation systems. One of the main concerns has been a lack of well-integrated, reliable and efficient public transport systems. This is particularly so in urban centers due to rapid growth of the urban population coinciding with the end of colonialism and giving rise to large scale economic, spatial and structural transformations of urban landscapes. The consciousness of the need for well-functioning innovative public transport systems in all spheres of governments and private sector institutions has thus prompted precipitate action in the past decades to invest in innovative transport systems.

On the other hand, mobility in the urban context is continuously adapting and transforming to quotidian challenges, as seen with the global shift towards smart city planning. This shift which encourages communities to utilize multi-mobility modes and public transport in their everyday commute has led to a lessening of the negative impacts of private-car-dependence in the developed
cities (such as congestion which has become a norm in major roads in urban areas) [1]. Typically, sustainable urban mobility describes movement patterns or city transport networks which are utilizing active travel modes, energy efficient renewable forms of energy or shared vehicles wherever possible, resulting in a low carbon output per commuter journey [2]. Integrated multimodal networked public transport has emerged as a mobility paradigm, utilizing transfer potential to provide maximal service for a reasonable and efficient operating budget, providing a genuinely feasible alternative to automobile travel for many trips within urban areas [3].

However, just like any other rapid growing metropolitan municipality in developing and emerging economies, Johannesburg has not been released from continuous public transport challenges. In the past decade, Johannesburg has therefore actively participated in the development of the Gautrain first fast train system within the Gauteng province in conjunction with two other metropolitan cities (City of Tshwane and Ekurhuleni Metropolitan Municipality). To support this innovative train system, Johannesburg also invested in and developed the Rea Vaya rapid Bus Transit System (BRT). However, the state of connectedness between the rail and road route networks within the city has not been well documented. The aim of the current study was therefore to delineate the extent of network integration between the Gautrain and Rea Vaya within the Johannesburg urban public transport system. The cognizant planning efforts on improving the operational relationship among the two modes of urban public transport are also highlighted to achieve well-functioning, convenient and integrated public transport commuting.


Literature on commuters’ need for integrated urban public transport has been well documented [4–7], as there has been a global growth in research on how to achieve integrated public transport operations in cities around the world. Some researchers suggest that “the term transport integration denominates concepts such as technical, economic, organizational, information and policy-based concepts; and solutions that pledge the continuity of travels from door to door” [8]. Nevertheless, transport integration is mainly focused on connecting various transportation modes operating in certain transport systems, providing solutions to facilitate commuters between the modes, and assuring an efficient, smooth flow of commuters from their origins to their destinations [9].

Integration of an urban public transportation is defined as an organizational process by which components of the commuter public transportation system (Network and infrastructure, information and marketing components, fares and ticketing systems) and a variety of carriers [10], who serve different transportation modes interact more closely and efficiently. This generates an overall improvement in service quality level and enhanced performance of the combined public and individual transportation. In particular, the implementation of various transport integration solutions may result in benefits such as reduction of travel times, transportation costs, environmental pollution and traffic congestion [8]. Transport integrating solutions may additionally improve the urban public transport system accessibility and overall competitiveness as well as assuring better utilization of different transportation means and infrastructure.

Moreover, integration of urban public transportation is mostly determined by the pattern of land use, the nature of the transportation systems, and the characteristics of the commuters [4]. Travel cost, time, distance, and the choice of travel mode are also important factors. The closer the origin and destination to the main transportation system the higher the level of connectivity [10]. Furthermore, a wider variety of modes for travelling between a given origin and a particular destination will promote greater connectivity. In addition, less time and money spent in travel enables greater connectivity through enabling more places to be reached within a certain budget [11]. For the concept of connectivity to be useful for evaluation of the need for and effectiveness of transportation and land use planning policies, it needs to be translated into measures of connectivity. These determine the degree of connectivity within a transportation network.
There are different types and forms of transport integration in the urban areas. These include integration of different modes of public transportation and integration of public and individual transportation. They incorporate integration of transportation policy with other policies concerning spatial planning and city management; spatial integration based on the application of efficient land use strategies (such as multimodal terminals and interchange platforms and shared lanes for means of public transportation) [12]. They further comprise of infrastructural integration based on development of various technical solutions in transportation infrastructure (for instance passageways connecting public transportation stops, overpasses, underpasses, shared stops for public transportation); organizational integration (for instance metropolitan tickets various transportation modes and coordinated timetables); economic integration focused on introduction of various measures supporting sustainability and efficiency of the public transportation systems (for example integrated tariffs). Informational integration (passengers’ information systems; web pages; electronic travel planners [13].

3. Study Area

Johannesburg Metropolitan City is a well-developed economic hub and the fastest growing city in terms of the population, economy and development in South Africa. The city is located in the Gauteng Province, and covers an area of approximately 1645 km² [14]. It is divided into seven regions, namely Region A, B, C, D, E, F and G (illustrated in Figure 1). Johannesburg is over populated, but is the economic hub of South Africa. The Johannesburg metropolitan City, and its neighboring metropolitan cities (City of Tshwane and City of Ekurhuleni) share the most innovative transportation mode, the Gautrain in Gauteng, connecting these three functional cities into one capital and economic region (see Figure 1). Thus perpetuated by demand, routes of urban public transport systems, commuters’ movement patterns and accessibility have become central issues within the Johannesburg Metropolitan City.
Johannesburg has been defined as a world-class African city. This definition entails that the city will strive to become a smarter city; however, what is it to be ‘smart’. Does this only involve decision-making or the use of advanced technology? Scholars have over the years articulated that at the core of the development of smart cities is the need for developments which improve the quality of life of the citizens [15]. Currently, Johannesburg is promoting transit-oriented developments (TODs) in previously marginalized areas by focusing on development of economic and business nodes located within Regions F, B and E (Figure 1). Regions G and D are characterized by medium to low income residential spaces. Regions A and C are characterized by medium to high income residential spaces with some commercial activities. However, the existing urban public transportation network is spatially segregated, and there is little to no clear collaboration between the various public transit providers (namely the Rea Vaya; Gautrain/bus; Metro Bus/rail; Meter-taxis; Mini-bus taxi; and Uber), as they are developed and operated separately. Hence a knowledge gap exists of how to connect commuters and these places of economic and business activities.

Urban public transport is at the heart of Johannesburg’s development agenda. There have been efforts made to create a Transit Oriented Development Urban renewal as a way of building a corridor of freedom [16]. The Johannesburg Metropolitan Municipality caters for both non-motorized and motorized urban public transportation. These include Gautrain, Rea Vaya BRT, Metrobus, Metrorail, Putco, Minibus Taxis, Uber and dedicated lanes for private bicycle cyclists. Public transportation in the Johannesburg Metropolitan City is used by youth to commute to school, to get to service hubs and recreational areas, while adults use these to commute to work and recreational areas. Old aged citizens use them to commute for leisure and to get to basic services. However, for the purpose of this study two urban public transport modes are explored on the state of routes connectivity.

The Rea Vaya BRT and Gautrain are located in the City of Johannesburg within the Gauteng province, Republic of South Africa. The Rea Vaya operates only under the jurisdiction of Johannesburg in the southern region. The Gautrain operates within the three metropolitan cities in Gauteng province, including the City of Tshwane, City of Johannesburg and City of Ekurhuleni in the East Rand of Gauteng Province. The three metros, as mentioned earlier, form the region which is the economic hub of the Republic of South Africa, and are the only cities in the entire country that have a rapid transit train. These two public transport modes started operating during the 2010 FIFA World Cup which was hosted by South Africa. They also operate along mixed land used as well as in major economic, institutional and social nodes, such as the Johannesburg Park Station, OR Tambo International Airport, FNB Stadium, Emirates Airline Park Stadium and Sandton and so on.

4. Materials and Methods

The study adopted a phenomenological case study survey design which applied a mixed-method approach to gather spatial, qualitative and quantitative data. The study examined the applicability of location based services to define the state of public transport routes connectivity and movement patterns of commuters within the Johannesburg Metropolitan City. The exploratory approach was used to formulate the research problem for precise investigation, while the descriptive approach was used to gather complete and accurate information. Key informant interviews were held with a variety of key informant personnel from the Johannesburg Roads Agency (JRA), Gautrain Management Agency (GMA) and Gauteng Department of Roads and Transport. This gave complete and accurate information on the Gautrain and Rea Vaya routes connectivity in Johannesburg Metropolitan City; and the attained information was analyzed using content analysis.

The study period was from January to August 2017, and the spatial, qualitative and quantitative analyses were triangulated to yield viable results. Crowd sourced data from social media posts (Twitter and Facebook) were collected and analyzed through Echo-Echo. A total of 42630 Rea-Vaya and Gautrain geo-location social media datasets were received in Excel format from Echo-Echo. Nevertheless, Echo-Echo is an independent private company that collects and analyzes social media information from a variety of web 2.0 platforms. Using sentiment analysis and semantics analysis,
Echo-Echo untangles the big social media data to derive meaning from these large quantities of text [6]. The results are captured live and analyzed through Echo-Echo. In this study, co-ordinates of geographic locations of the social media posts were converted into shapefiles and spatially interpreted using the Geographic Information Application (ArcGIS 10.3). The aim of this conversion of geographic social media co-ordinates into shapefiles was to create maps through the kriging interpolation method. Maps were also used to visualize high commuter concentration zones and low commuter concentration zones and to help to track the movement patterns of commuters using Rea Vaya and the Gautrain. Table 1 below illustrates the summary of information gathered during the study.

Table 1. Summary of the information collected during the study.

<table>
<thead>
<tr>
<th>Datasets</th>
<th>Quantity</th>
<th>Formats</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gautrain Stations</td>
<td>5 train stations</td>
<td>Esri shapefile</td>
</tr>
<tr>
<td>Gautrain bus stops</td>
<td>245 bus stops</td>
<td>Esri shapefile</td>
</tr>
<tr>
<td>Rea Vaya bus stops</td>
<td>209 bus stops</td>
<td>Esri shapefile</td>
</tr>
<tr>
<td>Gautrain commuters</td>
<td>8264 commuters</td>
<td>Microsoft Excel</td>
</tr>
<tr>
<td>Rea Vaya commuters</td>
<td>11,424 commuters</td>
<td>Microsoft Excel</td>
</tr>
<tr>
<td>Gautrain and Rea Vaya Social Media posts</td>
<td>42,630 posts with geolocation co-ordinates</td>
<td>Microsoft Excel</td>
</tr>
</tbody>
</table>

5. Results of the Study: Modes of Public Transport and Their Routes’ Integratedness within the Johannesburg Metropolitan City

This section of the manuscript presents the research results related to the extent of the networks integration among the Gautrain and Rea Vaya within the City of Johannesburg urban public transport system. The section further connects the study results with the aim and objectives of the study and affirms the study results to come up with conclusions and recommendations. A starting point for this section was that the Johannesburg Urban Public Transport has been appointed in terms of a Service Delivery Agreement by the City of Johannesburg to provide integrated, reliable and efficient urban public transportation to the residents of the city, including the previously marginalized areas of the city. Therefore, the Johannesburg public transport system functions in the purpose of the City of Johannesburg legislative mandate regarding urban public transport and the systems. It is guided by the strategic direction of the City, as derived from the Province Growth Development Strategy and Integrated Development Plan. The Corridor of Freedom and Integrated Transport Plan are amongst some key strategic objectives of the Johannesburg public transport system, where Gautrain and Rea Vaya play the main roles in the provision of public transportation.

5.1. Moving with Gautrain

The Gautrain is one of several strategically integrated Gauteng Provincial Government projects designed to meet future transport demands anticipated because of economic and population growth [6]. It is also referred to as a mega-engineering project. It is a state-of-the-art rapid rail connection between the City of Johannesburg (Africa’s business capital), the City of Tshwane, and the City of Ekurhuleni [13]. The Gautrain has been identified as the backbone for public transit provision in the Gauteng province. The Gauteng City Region (GCR) can best be described as a cohesive cluster of cities, towns and urban nodes. These collectively make up the economic hub of South Africa, generating more than 36% of the country’s Gross Domestic Product (GDP), whilst covering less than 2% of the South Africa’s total surface area. Figure 2 illustrates the Gautrain routes and stations map.

In terms of routes networks, the Gautrain alone operates in three metropolitan cities in Gauteng province namely the City of Johannesburg, City of Pretoria and Ekurhuleni Metropolitan municipality. It has only 10 functional train stations, namely Park, Rosebank, Sandton, Marlboro, Midrand, Centurion, Pretoria, Hatfield, OR Tambo and Rhodesfield. However, the Gautrain within jurisdiction of City of Johannesburg operates in the up market areas such as Rosebank, Sandton, Randburg and Fourways. Gautrain does not operate in the southern areas of Johannesburg, and conversely there are
potential clients and a need for expansion and integration with Rea Vaya that is currently operating in that area (See Figure 2).

Figure 2. Gautrain routes and stations map.

5.2. Relying on Rea Vaya

The Rea Vaya Bus Rapid Transit (BRT) is a fairly new bus system in Johannesburg. Its launch in 2009 was met with much uncertainty, but also with positivity, as a new public transport initiative for the city. The system can be found in many different areas across the greater urban fabric of Johannesburg, connecting the south to the north and the east to the west. It covers a route of 325 km to date and continues to expand [4]. The system is made up of trunk routes that keep to designated lanes and are connected by stations along the route. The T1 route runs from Thokoza Park in Rockville, Soweto and ends in Ellis Park. There are more than 15 bus stations across this route, which facilitate access to the buses. The main trunk routes are supported by complimentary and feeder routes which navigate other parts of the city. These feeder buses use the main routes of the road network like other vehicles and public transport systems. Figure 3 illustrates the Rea Vaya Bus Stations and Bus Routes.

In terms of the routes network, Rea Vaya operates in Regions B, D and F within the Johannesburg Metropolitan City. It operates in different phases and has systematic hierarchical routes which connect micro city hubs in the metropolitan city of Johannesburg. It has completed the construction of Phases 1A and 1B and is currently developing Phase 1C. Rea Vaya’s Phase 1A has a trunk route operating between Ellis Park in Doornfontein and Thokoza Park in Soweto, linking with several feeder routes to Soweto. Feeder buses run from Protea Glen to Thokoza Park and from Eldorado Park to Lakeview. The route covers 325 km of special lanes and intersections, while feeder and complementary buses carry passengers to the trunk route stations.

The inner city circular route travels around the Central Business District from Hillbrow and Braamfontein to Ellis Park in the east and Chancellor House on the western edge of the city. The Phase 1B has routes which operate through Cresta, Windsor West, Parktown and Yeoville. In addition, routes operating to and from the University of Johannesburg Soweto Campus are being added. The route
starts in Noordgesig in Soweto and travels through Pennyville, New Canada, Highgate, Auckland Park and Braamfontein to Parktown, Metro center and Rissik Street in the Johannesburg Central Business District.

Figure 3. Rea Vaya routes and stations map.

The route has made it possible for commuters to easily reach key public healthcare centers such as the Rahima Moosa, Helen Joseph and Charlotte Maxeke hospitals. It has also enabled easy reach of educational institutions such as the University of Johannesburg, Wits University, Milpark College, Parktown Boy’s High School and Barnato Park High School. Feeders run to and from Leaglen, Stormhill, Florida, Cresta, Yeoville and Parktown. There are also additional feeders in Soweto from Pimville and Mapetle. These routes are now linked to the Metro Centre Rea Vaya loop which travels to the inner city through Braamfontein.

Rea Vaya’s current focus is the development of Phase 1C following the completion of Phase 1B. Phase 1C will run from: Parktown to Alexandra; then Alexandra to Sandton, with complementary services between the CBD and Ivory Park; and from the CBD to Sunninghill on Oxford and Rivonia Roads. Future plans also include extending the Phase 1C route from Sandton to Randburg by 2018, and possibly extending the Phase to the trunk route from Soweto Highway to Dobsonville, enabling feeders to services areas such as Braamfisherville. Construction for the routes and stations has already started in the Sandton area. The Rea Vaya trunk routes from the CBD to Sunninghill through Oxford Road and Ivory Park to Sunninghill will be prioritized after 2018. The three interchanges will be at Sandton, Alexandra and Westgate, where a number of station modules will be clustered, and there will be integration with other modes of transport, including walking and cycling.

With an intention to be one of the most sustainable forms of public transport in the city, the Rea Vaya is noted as cost effective, safe and relatively reliable. It is considered as an inherent component of the city’s future urban form, as it is one of the main elements of the corridors of freedom initiative. Finally, the Rea-Vaya is referred to as one of the most determined initiatives by the city, being
spear headed by a woman and having a completion goal of three years from ground breaking to implementation and operation [5].

5.3. Analysis of Gautrain and Rea Vaya Networks Integration

The findings of this study indicate that there are limited areas where the routes networks between the two public transport systems are connected (see Figure 4). Currently, the Gautrain operates in the upper market areas of Johannesburg, such as Rosebank, Midrand, Sandton, Randburg and Fourways. Whilst the Rea Vaya does not have existing networks in these locations. Rea Vaya’s Phase 1A has a trunk route operating between Ellis Park in Doornfontein and Thokoza Park in Soweto, linking with several feeder routes from Soweto. Feeder buses run from Protea Glen to Thokoza Park and from Eldorado Park to Lakeview. The Rea Vaya has proven successful in improving accessibility to economic opportunities for locations which were once spatially segregated in Johannesburg. A total of 70% of the social media posts reflect positive views regarding route and timetables of the Rea Vaya. This can be seen through the recent infrastructural upgrades which have improved the network flow from Soweto to the inner CBD in Braamfontein.

The existing urban public transport network is spatially segregated, and there is little to no clear collaboration between the Gautrain and Rea Vaya. They were developed and currently operate separately (initially the two modes were developed in preparation for the 2010 FIFA World Cup; however over the years there have been advances with different goals, since the Gautrain seeks to service the high to medium income group and the Rea Vaya the medium to low income group). This presents a knowledge gap of how to connect commuters to places of economic and business activities. However, from the works of modern day scholars [10,13,15], the network integration of the public transport systems will lead to improved service delivery, inter-connectivity of places of economic activity and improve quality of life. Therefore, for the City of Johannesburg to promote smart mobility there is a need for the development of planning support systems which will guide the growth and integration of the existing and future public transport systems.

![Figure 4. Gautrain and Rea Vaya Networks Integration.](image-url)
Notably, as illustrated in Figure 4, there are three possible connections: Integration points A, B, and C. Integration Point A is located near Marshalltown and Ferreirasdorp, and will function as a center for Administration hub, high density residential areas and commercial center of the inner city. At Integration Point B, the Johannesburg Park Station which is situated at the CBD of the city functions as a vibrant intermodal transport node. It is a major public transport interchange, where public transport networks integrate, and commuters come from all over Johannesburg, South Africa, Africa, or transfer from trains and buses to minibuses and more. The Gautrain and Rea Vaya services at Park station provide inter-city transport as well as intra-city and regional transport services. Given that Johannesburg Park Station is a prominent transport terminal in Johannesburg, Gauteng, South Africa, and Africa, distribution terminals in the form of bus stations, rail stations and taxi ranks are located in close proximity to the Park Station precinct. Integration point C, located in Parktown provides an interconnection of Public transportation for Educational and health institutes such as the University of Witwatersrand and Parktown Hospitals. The Gautrain Park Station, bus routes as well as the Rea Vaya Bus Rapid Transit routes should also be noted as essential feeders and distributor routes in the area.

5.4. Gautrain and Rea Vaya Social Media Commuter Concentration

The analysis and creation of maps to visualize the social media commuter concentration was prepared through the use of the kriging interpolation method. Based on the kriging interpolation of the locations of posts on social media, the majority of the commuters are located near the stations. This is due to the current stations being located in merging points of commuters such as the Park Station. This is located in the Johannesburg CBD and acts as the main interchange hub of Johannesburg and an entry point for most regional and local commuters. Also it is within close proximity to the MTN Taxi rank and Bree St Taxi Rank located only 10 min away. This hub has a high connectivity with public transportation levels. Notable areas, which are currently not serviced by the Gautrain and Rea Vaya, include Roodepoort; Randburg; Woodmead; Magaliessig; Honeydew; Fourways; Lenasia; Glenvista; and Lawley (see Figure 5). Park Station has the highest integrated commuter concentration as shown in Figure 5 and Table 2.
Table 2. Analysis of integrated Gautrain and Rea Vaya Social Media Commuter Concentration.

<table>
<thead>
<tr>
<th>Integrated Social Media Concentration</th>
<th>Number of Social Media Posts</th>
<th>Commuter Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1315</td>
<td>Low Concentration</td>
</tr>
<tr>
<td>2</td>
<td>3239</td>
<td>Medium Concentration</td>
</tr>
<tr>
<td>3</td>
<td>5349</td>
<td>Moderate Concentration</td>
</tr>
<tr>
<td>4</td>
<td>13,412</td>
<td>High Concentration</td>
</tr>
<tr>
<td>5</td>
<td>19,315</td>
<td>Extremely High Concentration</td>
</tr>
</tbody>
</table>

Figure 5 above depicts that most of the Rea Vaya stations seem to be well located, as they are within the high commuter concentration zone based on the kriging interpolation of the locations of posts on social media. Table 2 summarizes the analysis of the integrated social media commuter concentrations.

With the extremely high commuter concentration (see Table 2), improving commuter transfer in the geolocation would be a virtuous starting point, since the infrastructure and commuter numbers are already pre-existing. While variations in income levels may be a factor to prevent inter-transfer between the two modes, commuters should be given an incentive for using both modes of transit in one trip. This could be a discount in commuter fares or points which can later be redeemed for a discount. This would build on the existing commuter concentration, and further attract other commuters to join the system. Moreover, as it would be cost effective for the two public transit providers to partner towards promoting multi-mobility within City of Johannesburg, rather than building separate infrastructures. The Gautrain would link commuters to economic and business hubs in the northern zones of Johannesburg, namely: Sandton, Rosebank, Marlboro and Midrand. The Rea Vaya would bring commuters to areas of economic and business nodes in the southern zones of the city.

5.5. Gautrain and Rea Vaya Commuters Movement within the City of Johannesburg

In this study, social media comments and their geographic location co-ordinates were used to track the movement patterns of commuters using Gautrain and Rea Vaya. Although their origins and destinations varied, their destinations were mainly economic hubs and places of economic activities such as Park station, Rosebank and Sandton. Their origins were mainly the residential areas of the city such as Soweto, Roodeport and Midrand. The location origins of the commuters’ social media posts and the comments on their destinations were used to digitize the maps (see Figure 6a,b). Surprisingly, social media posts have been made in areas which are currently not serviced by either Gautrain or Rea Vaya such as areas of Region C and G; this shows that there is a need for expansion of public transportation in the catchment areas. The movement of commuters within the city changes with time [9] as a result of developing transportation systems in addition to innovations within the Information and Communication Technologies Sector. While exploring the state of public transport networks integratedness within the City of Johannesburg in this endeavor, it is essential to understand the commuters’ movements within various areas of the city [15].

It can be deduced from the results that from each location, commuters have two or three possible routes that they can take when travelling from their origins to destinations. For instance a commuter has two or three possible routes that he/she can take when travelling between Johannesburg Park Station and Sandton. These routes may be direct links from their origin to their destinations, or may be interconnected through other stations as alternative routes to reach their destinations of choice conveniently. The two modes of public transport in Johannesburg metropolitan city constantly need to track the movement of their commuters because of changes in their origin and destinations over time. Thus the idea of location based services is applicable in tracking commuter movement patterns through geo-locational patterns that display commuter concentration zones. Therefore, the idea is for the service provider to reach out to commuters in the form of expanding services or contracting emergency and temporary urban public transport in times when required most. This includes situations such as traffic congestion and tracking social media feeds using location based services analysis software such as...
Echo-Echo to manage their social media platforms effectively. This in turn will render real-time and effective service to many of its commuters and the public at large.

Figure 6. Gautrain and Rea Vaya Commuters Movement. (a) Gautrain Movement of commuters; (b) Rea Vaya Movement of commuters.
6. Discussion of Study Results

The context of public transport and transit-oriented development planning is continuously adapting and changing according to a number of challenges, as can be seen with the global shift towards smart city planning. The move towards encouraging societies to use transport multi-mobility modes in their daily commute, and to endorse the lessening in the negative impacts of automobile dependence is the anticipated shift in Johannesburg. Integrating and improving public transport modes is a desirable method for enhancing the use of multi-mobility and promoting transit ridership. However, the results of the study revealed that there are limited spaces where the route networks between the urban public transport systems are connected. However, the network integration of the public transport systems will lead to improved service delivery, inter-connectivity of places of economic activities and improved public transit ridership (Refer to Figure 4). For example, the Gautrain services the northern areas of the City, whilst the Rea Vaya does not have existing networks in these areas. The Johannesburg BRT system and Rea Vaya service the southern spaces of the city, which were previously disadvantaged and spatially segregated during the Apartheid administration.

As made clear by the study findings, Rea Vaya has proven effectively in improving accessibility to economic opportunities for formerly marginalized locations such as Soweto. This is because the network flows from Soweto moving towards the Central Business District and the Northern parts of the City. In addition, the majority of the Rea Vaya stations are well located within the commuter concentration zones as revealed by the analysis co-ordinates of social media posts through the kriging exercise. The existing urban public transport network is spatially segregated, and there is little or no collaboration between the Gautrain and Rea Vaya, since they have been developed and operated separately. This illustrates a knowledge gap of how to connect commuters to places of economic and business activities. With this situation, improving commuter transfers in the geolocation would be a good starting point, as the infrastructure and commuter numbers are already pre-existing. Also, it would be cost effective for the two public transit providers to partner towards promoting multi-mobility within Johannesburg rather than building separate infrastructure. The Gautrain would link commuters to economic and business nodes in the northern parts of Johannesburg (namely Rosebank, Sandton, Marlboro and Midrand), and the Rea Vaya would link commuters to areas of economic and business nodes in the southern part of the city.

Notably, the kriging interpolation maps reveal areas which are currently not directly serviced by the Gautrain such as Soweto which has a high commuter concentration. With this in mind, commuters who reside in Soweto use Rea Vaya before they can access the Gautrain system. Accordingly, a partnership seems worthwhile for the Gautrain and Rea Vaya, since the Rea Vaya has an existing road network that flows from Soweto towards Johannesburg Park Station, and the Gautrain routes network flows from the Johannesburg Park station towards the northern areas of the city. In addition, the results also indicate that social media posts have been made in areas such as Roodeport and Lenasia in Regions C and G, which are currently not serviced by both the two public transport modes. This means that commuters who reside in these areas use another form of mobility before they can access either the Gautrain or Rea Vaya. Therefore, these are potential areas for routes network expansion of both Gautrain and Rea Vaya.

7. Conclusions

To conclude, mobility is continuously adapting and transforming to daily challenges, and should be perceived as a response to the global shift towards smart city planning. The shift is towards encouraging communities to utilizing multi-mobility modes and public transport in their everyday commutes. This will reduce the negative impacts of private-car-dependence in the urban contexts. This study delineated the extent of routes network integration of Gautrain and Rea Vaya within the Johannesburg urban public transport system. Crowd-source data is still a novel research activity, and this work shows the potential for these real-time data to be valuable in understanding system integration. Crowd sourced data is able to measure transit coverage area, visualize high and low
commuter concentration zones, and also tracks the movement patterns of commuters. The study indicates that there are limited areas where the route networks between the public transport systems are connected. The large sections of the networks are fragmented. Actually, the existing transit networks are spatially segregated, and there is no partnership between the two modes of public transport, since they operate independently. The results can further be used as a reference to spot areas underserved by transport, and estimate the transit demand for planning purposes.

However, it is recommended that conscious efforts in planning and developing both rail and routes networks are integrated to promote efficiency of public transport systems. The network integration of the public transport systems will lead to improved service delivery, inter-connectivity of places of economic activity and improve quality of life. Therefore, for the City of Johannesburg to promote smart mobility, there is a need for development of planning support systems which will guide the growth and integration of the existing and future public transport systems. Typically, sustainable urban mobility describes movement patterns or city transport networks. These utilize active travel modes, energy efficient renewable forms of energy, or shared vehicles wherever possible, resulting in low carbon output per commuter journey. Integrated multimodal networked public transport has thus emerged as a mobility paradigm, utilizing transfer potential to provide maximal service for a reasonable and efficient operating budget, providing a genuinely feasible alternative to the automobile travel for many trips within urban areas.

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Examining the Role of Public Transport Interchange Hubs in Supportive Public Transport Integration in City of Johannesburg

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1 ABSTRACT

The focus on developing integrated urban public transport systems have become major priorities globally, particularly in developed and transitional economies in order to achieve effective mobility. Similarly, increasing the connectedness and efficiency of urban public transport modes has become a necessity within cities of developing countries. Subsequently, the City of Johannesburg formulated relevant policies, strategies and frameworks that seek to inform the development and operation of efficient and integrated urban public transport systems. Thus, interchange hubs are starting points of public transportation ride and the first points of interaction commuters have with the available service. Subsequently, this study aims to examine the role of public transport interchange hubs in supportive of integration between Gautrain and Rea Vaya BRT operations in Johannesburg metropolitan city, using a phenomenological case study survey design and mixed methods approaches consisting of spatial, quantitative and qualitative data. The exploratory approach was used to formulate the research problem for comprehensive investigation, whereas descriptive approach was used to gather broad and accurate information. Research techniques such as social media, crowd-sourcing, and interviews were used to collected data.Whilst data analysis and interpretations were conducted with techniques such as Echo-Echo, main content analysis, Geographic Information Technologies. This study presents novel data analysed into empirical results suggesting that public transport interchange hubs plays a pivotal influence in supportive the integration of Gautrain and Rea Vaya operations in city of Johannesburg. The findings further reveal the complexity of spatial and communicative platforms in multiplicity of urban public transport modes resulting in complex models of urban public transport operations.

Keywords: public transport, efficiency, interchange hubs, commuters, Gautrain, Rea Vaya BRT, integration.

2 INTRODUCTION

In contemporary years, increasing emphasis has been placed on the development of intermodal transport hubs as tools with which to improve urban mobility. Mobility appears as a fundamental component of the daily lives of people. However, mobility patterns are clearly linked to urban density and the relative location of activities. Hence, Integration of multimodal transport systems has received particular interest in recent years to promote mode switch. In developed and transitional economies, where transit is widely spread, commuters are served by an intermodal transport system, integrating a number of bus routes and a rail line connected at different transfer stations (Paulley and Webster, 2017). In such a system, commuters may need one or more transfers to complete their journey. Hull (2008) emphasized the importance of maintaining interoperating and interconnectivity across service providers to optimize intermodal public transport systems. Long transfer times significantly deteriorate the service quality when the system is operated without coordination. Effective intermodal integration significantly enhances the attractiveness and productivity of a combined bus and rail transit system (Hickey, 1992). Indeed, maintaining a stable headway along a bus route is difficult due to traffic congestion, vehicle breakdown, incidents and the variation of demand over time and space (Filippi et al., 2013). Pure schedule synchronization for connecting routes at transfer stations may not reduce the transfer time effectively (Datta, 2015). Conversely, holdings times added into the schedules of coordinated routes required to increase the probability of successful connection.

Conversely, integration of multimodal urban public transport system has remained on of the major policy agenda for a relatively long time in the City of Johannesburg. Increasing the connectedness and efficiency of urban public transport systems has become a major issue for the City of Johannesburg, owing its culpabilities to the historic segregation and rapid urban population growth (Moswane and Gumbo, 2016). The City of Johannesburg formulated relevant policies, strategies and frameworks that seek to inform the development and operation of efficient and integrated urban public transport systems. Thus, interchange hubs are starting
points of public transportation ride and the first points of interaction commuters have with the available service. Subsequently, this study aims to examine the role of public transport interchange hubs in supportive of integration between Gautrain and Rea Vaya BRT operations in Johannesburg metropolitan city, using a phenomenological case study survey design and mixed methods approaches consisting of spatial, quantitative and qualitative data.

3 STUDY AREA: LOCALIZING THE CONTEXT
The greater Johannesburg metropolitan city is the political capital and the largest economic hub of the Republic of South Africa, yet it is the smallest in terms of physical size in its located province of Gauteng, as depicted by figure 1. The City of Johannesburg covers an area of 1,645 square kilometers, starting from Orange Farm in the South to Midrand in the North (Smith, 2013). The City of Johannesburg is the driving economy or an economic engine of the country and a place of opportunity to many. It is the most densely urbanized area of the Republic and it is home to 11.3 million publics.

The Rea Vaya BRT and Gautrain are located in City of Johannesburg of Gauteng province, Republic of South Africa. The Rea Vaya operates only under the jurisdiction of the City of Johannesburg in southern part. Whilst Gautrain operates within the three metropolitan cities in Gauteng province which include City of Tshwane, City of Johannesburg and City of Ekuruleni in the East Rand of Gauteng Province. The three metros, as mentioned earlier they form the region which is the economic hub of the Republic of South Africa and are only cities in the entire African continent that has a rapid transit train. These two public transport modes started operating during the 2010 FIFA World Cup which was hosted by South Africa.

4 METHODOLOGY
The study adopted a phenomenological case study survey research design. A mixed-methods research approach was used, where spatial qualitative and quantitative data was collected and analysed. The study examined the role of public transport interchange hubs in supportive public transport integration in City of Johannesburg, thus the exploratory approach was used to formulate the research problem for comprehensive investigation, whereas descriptive approach was used to gather broad and accurate information. Key

![Figure 1: City of Johannesburg Map (Source: Author, 2017)](image-url)
onformat interviews were used conducted with key informant officials from Johannesburg Roads Agency (JRA), Gautrain Management Agency (GMA) and Gauteng Department of Roads and Transport to give more accurate information on the role of Johannesburg Park Station in supportive of the urban public transport integration in City of Johannesburg. In addition, social media data and crowd-sourced data were collected from echoecho. Whilst data analysis and interpretations were conducted using techniques such main content analysis, Geographic Information Technologies.

5 THE JOHANNESBURG PARK STATION, THE CITY OF JOHANNESBURG INTERCHANGE HUB AND ITS ROLE IN SUPPORTIVE PUBLIC TRANSPORT INTEGRATION

The approach to the Concept interchange, the Johannesburg Park Station taken in the City of Johannesburg is a wide one, as it is stated in the document Towards Commuter Intermodality in the EU (2004), “intermodality is a policy and planning principle that aims to provide a commuter using different modes of transport in a combined trip chain with seamless journey”. Henceforth, the intermodality is crucial for the integration of various modes of public transport into one efficiency system. Conversely, the co-presence of multiple modes of public transport, even at the same building is not enough for an interchange, an interchange approach should focus on transfers’ easiness and should aim at a seamless trip. This further yields a sharp distinction between station and interchange. Whereas stations are mainly about access and dispersal to a transport system, interchange involve interconnection of various transport systems. The Johannesburg Park Station, an interchange hub of the City of Johannesburg is one of the most important components of urban transport. It is created and evolves with socio-economic and transport development in Johannesburg Metropolitan City, whereas simultaneously having aggregation and scale effects on the City. However, factors that have an impact include socio-economic development, urban structure regional transport conditions, and the need for sustainable development. Figure 2 illustrate the location of Johannesburg Park Station within the City of Johannesburg.

![Figure 2: Johannesburg Park Station Location (Source: Author, 2017)](image)

The Park Station hub functions as a vibrant intermodal transport node (see figure 2). However, it represents the gateway to City of Johannesburg for many commuters, not only from other cities, conversely also from other African countries. Gautrain and Metro Rail and bus services at park station provide for inter-city
transport as well as intra-city and regional transport services. The Park Station hub provides access to the inner city, and it also provide access to Braamfontein, a well-established high-density precinct that has undergone significant regeneration in contemporary years. Also Braamfontein hosts a diversity of government departments, education facilities (of which Wits University is the most prominent), student accommodation, local retail businesses, and financial and municipal institutions. Due to Braamfontein’s urban function, plenty of people commute on a daily basis through the area, resulting in pressure on the levels and standards of service delivery.

The Interchange is characterised by a mixture of high intensity land uses ranging from clustering of mostly commercial land use to the south of the interchange to a concentration educational and other government, commercial, parking and other mixed land uses to the north. Because of the high intensity of land uses in the area as well as the high volumes of people working or visiting government, educational or commercial facilities, public parking is a necessary requirement. Given that Park Station is a prominent transport terminal in Johannesburg, Gauteng, and South and southern Africa, distribution terminals in the form of bus stations, metro rail stations and platforms, and taxi ranks are located in the close proximity to the Park Station precinct. The Gautrain Park Station, bus routes as well as the Bus Rapid Transit routes should also be noted as an essential feeder and distributor routes in the area.

The Johannesburg Park Station provides for an integrated and effective of routing and circulation that reduces the number of transfer required; ensure safety for higher level of commuter; promotes the use of public transport and non-motorised modes of transport; and also encourages the integrated development of surrounding land uses. The Park Station links various modes of transport in one location, while also improving the efficiency of land uses and other resources. Each transport mode at the Johannesburg Park station supports the other by helping to redistribute commuter overloads among them and caters to commuters commuting requirements and demand. Thus, the diverse needs and features of each transport mode should be considered during the planning and design state to develop a sustainable and viable design, particularly in terms of construction and operation in order to achieve effective mobility.
Figure 4: Johannesburg Park Station and Integrated Social Media Concentration Analysis

Figure 5. Park Station and Integrated Social Media Concentration
Given that the commuter concentration zones of the Gautrain and Rea Vaya were overlapped on a ratio of 50:50, to ascertain which stations should be used as the initial geolocations to promote multi-mobility. The Johannesburg Park Station had the highest integrated commuter concentration as displayed in figure 4. With this high commuter integration, improving commuter transfer in the geolocation would be a good idea, as the infrastructure and commuter numbers are already pre-existing. Moreover, it will be cost effective for the Johannesburg Park Station operators to partner with various Rea Vaya and Gautrain agencies towards promoting multi-mobility within the Johannesburg Metropolitan region, then building separate infrastructure, as the Gautrain links commuters to economic and business nodes in the Northern parts of the city, namely: Rosebank, Sandton, Marlboro and Midrand; and Rea Vaya links commuters to the Southern part of the City, as presented in figure 5.

5.1 Integration of Existing Transport Systems around the Hub

5.1.1 Influence of Johannesburg Park Station on the Nearby Road Network

The Johannesburg Park Station draws in large commuter flows in a short time, generally during the rush hours when a large number of trains, buses, and long-distance commuter transport coaches arrive. During the period of immediately after trains or coaches such as Gautrain and Metrorail have arrived, commuters need to be distributed to their various destinations by various modes of transport such as Gautbus, Rea Vaya, Metrobus or walking, a process which will be supported by the surrounding road network. However, the surrounding road networks need to accommodate the large flow of commuters and vehicles from the Park station to minimize congestion that can hamper the normal operation of the Johannesburg traffic network. Thus, Johannesburg Station was planned to take into consideration the demand for gathering and distributing commuters.

Figure 6 shows the Johannesburg Park Station surrounded by an existing road network which forms a ring road network by connecting surrounding roads with interchanges and the South and North Johannesburg roads. The ring road has three access points, which help reduce traffic congestion due to large commuter flows on the surrounding road network.
5.1.2 Transit Mode share targets

Transit mode share is the percentage of commuters using a precise type of transportation, for instance bus, train, taxi, car or non-motorized transport. Moreover, it way refer to the number of trips that commuters take in relation to their preferred mode of transport. Conversely, gauging transit mode share enables hub operators and planners to get an overview of commuter demand, develop strategies (in terms of policies, structure and layout, and marketing) to create a more balanced mode share, and identify the best way to integrate different transportation modes. In the case of Johannesburg Park Station, initial estimates predicted that the Metrorail would accommodate 40% of the total number of commuters, whereas the remaining 60% would use buses, taxis and private vehicles. Nevertheless, according to this comparative ratio, it was found that surrounding roads did not have sufficient capacity to deal with such a huge volume of commuters, henceforth, another subway line, the Gautrain was built during the preparation 2010 FIFA World Cup to pass through the Johannesburg Park Station, to accommodate and shift the 60% of the total number of commuters towards the use of the line. This resulted to a corresponding decrease in road traffic.

Analysing transit mode share within the range of influence of the interchange hub enables planners to manage traffic demand as well as passenger behaviour. Therefore, it should be noted that non-motorized transport, such as walking, cycling and other variants has not been taken into account when shrewd the transit mode share for public transport interchange stations in South Africa. In fact almost all public transport stations in Johannesburg do not contain parking areas for bicycles. However, these bicycle parking areas were consequently reduced for the following reasons: (i) cycling has gradually been replaced by perceived “convenient” methods of transport, such trains, buses and private cars; (ii) the volume of private vehicles is rapidly increasing and private vehicles have proven to be more popular than bicycles; (iii) cycle parking provision should be improved, ta there is a high risk of bicycles getting stolen when commuters leave the in station overnight.

5.2 Potential Benefits of Johannesburg Park Station

There are number of city-wide benefits that resulted from the establishment of the Johannesburg Interchange hub, the Park Station. As supported by local residents, jurisdiction and operators, the Park Station provides for an effective system of routing and circulation that reduces the number of transfer required; ensures safety for higher level of commuters; promotes the use of public transport and non-motorised modes; and encourages the coordinated development of surrounding land uses. In addition, Park Station enhance service integration, reduces the time and distance penalties of rail to rail and rail to bus interchanges.

Currently, plenty of middle-income residents in Johannesburg have abandoned private automobile in favour of public transport. Whereas auto ownership has been on the rise in past 2 decades, the economic boom of the democratic era in South Africa has brought a dramatic rise in the number of auto-oriented trips. However, the prospect of an integrated system of the Park Station and accompanying land uses persuade many of the residents to rely on public transport for most trips., effectively lessening the negative impacts of auto mobile use, for instance urban congestion, inefficient use of resources and poor air quality. For example, the location of business nodes and commercial activities near the park station to address the growing trend towards ‘trip chaining’ between work and home.

Moreover, another potential benefit of the Park Station is the improvement in the quality of public transport services feeding into the city. Subsequently, park station plays an essential role in safer, more efficient, off-street boarding and alighting; and in better travel times, particularly during rush periods. Conversely, if the Rea Vaya bus priority can improve the speed and reliability of bus services, it will offer opportunities to extend the catchment area Gautrain stations and increase the importance of bus feeder systems.

6 CONCLUSION

To conclude, study examined the role of public transport interchange hubs in supportive of integration between Gautrain and Rea Vaya BRT operations in Johannesburg metropolitan city. Moreover, study presented novel data analysed into empirical results suggesting that public transport interchange hubs plays a pivotal influence in supportive the integration of Gautrain and Rea Vaya operations in city of Johannesburg. The Johannesburg Park Station, an interchange hub of Johannesburg metropolitan City facilitate urban mobility by integrating existing urban public transport network. It also enhances the journey experience through people-oriented facilities and feature. Beyond improving urban mobility, the interchange hub also
function as a major element of urban development and renewal. The huge potential of interchange hub is that it highlights the need for a guide that can be used by planners, government agencies, and other experts to learn from the good practice that is being developed. The findings further reveal the complexity of spatial and communicative platforms in multiplicity of urban public transport modes resulting in complex models of urban public transport operations. Conversely, it is recommended that there should conscious efforts in planning and developing public transport interchange hubs that are integrated to promote efficiency of public transport systems. In addition, the diverse needs and features of each transport mode should be considered during the planning and design state to develop a sustainable and viable design, particularly in terms of construction and operation in order to achieve effective mobility.

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Exploring the Applicability of Location Based Services to Determine the State Routes Transport Networks Integratedness in the City of Johannesburg

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1 ABSTRACT

In cities of the developing countries, particularly in African, Asian and Latin American continents; there have been growing concerns in terms of the state of public transportation systems. One of the main among the concerns have been lack of well-integrated, reliable and efficient public transport systems. This is particularly so in urban centres, due to rapid growth of the urban population coincided with the end of colonialism, giving rise to large scale economic, spatial and structural transformation of urban landscapes. The consciousness of the need for well-functioning innovative public transport systems by all spheres of governments and the private sector institutions has prompted precipitate action in the past decades to invest in innovative transport systems. Conversely, just like any other rapid growing metropolitan municipalities in developing and emerging economies, the city of Johannesburg has not been released with regards continuous public transport challenges. In the past decade, the City of Johannesburg has actively participated in the development of the first fast train system; the Gautrain in conjunction with two other metropolitan cities within the province. To support the innovative train system, the city also invested in and developed the Rea Vaya; a rapid bus system. However, the state of connectedness of the rail and road route networks within the city have not been well documented. Therefore, this study aims to delineate the extent routes network integration among Gautrain and Rea Vaya within the Johannesburg urban public transport system and how working relationships could be improved. The study adopted a phenomenological case study survey design that applied mixed-method approaches to gather spatial, qualitative and quantitative data. The exploratory approach was used to formulate the research problem for precise investigation whilst the descriptive approach was used to gather complete and accurate information. Research techniques such as crowdsourcing, interviews, social media was used to collected data. Whilst data analysis and interpretations were conducted with techniques such as main content analysis, Geographic Information Technologies and Echo-Echo. Research findings; indicate that there are limited areas where the route networks between the public transport systems are connected. The large sections of the networks are disintegrated. The work recommends conscious efforts in planning and developing both rail and road route networks that are integrated to promote efficiency of public transport systems.

Keywords: integration, route networks, urban public transport, multimodal integrated system, rail-networks, City of Johannesburg.

2 INTRODUCTION

In cities of the developing countries, particularly in African, Asian and Latin American continents; there have been growing concerns in terms of the state of public transportation systems. One of the main among the concerns have been lack of well-integrated, reliable and efficient public transport systems. This is particularly so in urban centres, due to rapid growth of the urban population coincided with the end of colonialism, giving rise to large scale economic, spatial and structural transformation of urban landscapes. The consciousness of the need for well-functioning innovative public transport systems by all spheres of governments and the private sector institutions has prompted precipitate action in the past decades to invest in innovative transport systems.

On the other hand, mobility in urban context is continuously adapting and transforming to quotidian challenges, as can be perceived with the global shift towards smart city planning. This shift towards encourage communities to utilising multi-mobility modes and public transport in their everyday commute has led to a lessening in the negative impacts of private-car–dependence (such as congestion which has become a norm in major roads in urban areas) in the developed cities (Miranda and Rodrigues da Silva, 2012). Typically, sustainable urban mobility describe movement patterns or city transport networks, which are utilizing active travel modes, energy efficient renewable forms of energy, or shared vehicles wherever
Exploring the Applicability of Location Based Services to Determine the State Routes Transport Networks Integratedness in the City of Johannesburg

possible, resulting in low carbon output per commuter journey (Banister, 2005). Integrated multimodal networked public transport have emerged as a mobility paradigm, utilizing transfer potential to provide maximal service for a reasonable and efficient operating budget, providing a genuinely feasible alternative to the automobile travel for many trips within urban areas (Goodwin et al., 1991).

Conversely, just like any other rapid growing metropolitan municipalities in developing and emerging economies, the city of Johannesburg has not been released with regards continuous public transport challenges. In the past decade, the City of Johannesburg has actively participated in the development of the first fast train system; the Gautrain in conjunction with two other metropolitan cities within the province. To support the innovative train system, the city also invested in and developed the Rea Vaya; a rapid bus system. Conversely, the state of connectedness of the rail and road route networks within the city have not been well documented. Therefore, the aim of this paper is to delineate the extent network integration among Gautrain and Rea Vaya within the Johannesburg urban public transport system and how working relationships could be improved.

3 CONCEPTUAL FRAMEWORK: INTEGRATION IN URBAN PUBLIC TRANSPORT Provision

Literature on commuters need for integrated urban public transport has been well documented (Jackiva et al., 2015; Nunes et al, 2014, Musakwa and Moyo, 2016; Filippi et al., 2013), henceforth contemporary there has been a global growth in research on how to achieve integrated public transport operations in cities around the world. According to Reggiani (2001), “the term transport integration denominates concepts such as technical, economic, organizational, information and policy-based concepts; and solutions that pledge the continuity of travels from door to door. Nevertheless, transport integration is mainly focused on connecting various transportation modes operating in certain transport system, providing solutions to facilitate commuters between the modes and assuring efficient, smooth and safe flow of commuters from their origins to their destinations (Ibrahim, 2003).

Integration of an urban public transportation is defined as an organizational process by which components of the commuter public transportation system (Network and infrastructure, information and marketing components, fares and ticketing systems) and a variety of carriers, (Kourtit and Nijkamp, 2012) who serve different transportation modes, interact more closely and efficiently, to generate an overall improvement in service quality level and enhanced performance of the combined public and individual transportation. In particular, the implementation of various transport integration solutions may results in the benefits such as reduction of travel times, transportation costs; environmental pollution and traffic congestion (Paulley and Webster, 2017). Transport integrating solutions may improve the urban public transport system accessibility and overall competitiveness as well as assure better utilization of different transportation means and infrastructure.

Moreover, integration of urban public transportation is mostly determined by the pattern of land use, the nature of the transportation systems, and the characteristics of the traveller (Hidalgo and King, 2014). Travel cost, time, distance, and the choice of travel mode are all important. The closer the origin and destination to the main transportation system the higher the level of connectivity (De Abreu Freire & Painho, 2014). The wider the variety of modes for travelling between a given origin and a particular destination the greater the connectivity. In addition, the less time and money spent in travel the more places that can be reached within a certain budget and the greater the connectivity (Datta, 2015). In order for the concept of connectivity to be useful for evaluation of the need for and effectiveness of transportation and land use planning policies it needs to be translated into measures of connectivity.

There are different types and forms of transport integration in the urban areas. These include integration of different modes of public transportation; integration of public and individual transportation; integration of transportation policy with other policies concerning spatial planning and city management; spatial integration based on the application of efficient land use strategies (such as multimodal terminals and interchange platforms, shared lanes for means of public transportation) (Paulley and Webster, 2017). Moreover, infrastructural integration based on development of various technical solutions in transportation infrastructure (for instance passageways connecting public transportation stops, overpasses, underpasses, shared stops for public transportation); organizational integration (for instance metropolitan tickets various
transportation modes and coordinated timetables); economic integration focused on introduction of various measures supporting sustainability and efficiency of the public transportation systems (for example integrated tariffs). Informational integration (passengers’ information systems; web pages; electronic travel planners) (Kourtit and Nijkamp, 2012).

4 STUDY AREA

The Johannesburg Metropolitan City is well-developed economic hub and the ever fast growing city in terms of the population, economy and development in South Africa. The city is located in the Gauteng Province, and covers an area of approximately 1,645 km² (City of Johannesburg, 2013). It is divided into seven regions, namely Region A, B, C, D, E, F and G. Besides, Johannesburg being the over populated and economic hub of South Africa, the Johannesburg metropolitan City as well as its neighbouring metropolitan cities (City of Tshwane and City of Ekurhuleni) share the most innovative transportation mode, the Gautrain in Gauteng connecting these three functional cities into one capital and economic region (see figure 1). Subsequently, routes of urban public transport systems, commuters movement patterns and accessibility become central issues within the Johannesburg Metropolitan City perpetuated by demand.

The city of Johannesburg has been defined as a world class African city. This definition entails that the city will strive to become a smarter city, but what is it to be ‘smart’, does it only involve decision-making or the use of advanced technology? Scholars have over the years articulated that at the core of development of smart cities is the need for developments which improves the quality of life of the citizens (Kummitha & Crutzen, 2017; Bakici et al., 2013; Ferreira et al., 2017). Currently the city of Johannesburg is promoting transit oriented developments (TOD) in previously marginalised areas by focusing on development on economic and business nodes (see figure 1). However the existing urban public transportation network is spatial segregated and there is little to no clear collaboration between the various public transit providers (namely the Reya Vaya; Gautrain/bus; Metro Bus/rail; Meter-taxis; Mini-bus taxi; and Uber), as they are developed and operated separately. Hence this presents a knowledge gap of how to connect commuters and these places of economic and business activities.
Exploring the Applicability of Location Based Services to Determine the State Routes Transport Networks Integratedness in the City of Johannesburg

Urban public transport is at the heart of the City of Johannesburg’s development agenda. The has been making efforts in the city to create Transit Oriented Development (TOD) Urban renewal as a way of building ‘corridor of freedom’ (Gauteng Department of Roads and Transport, 2013; Steer, 2012). Johannesburg Metropolitan Municipality caters for both non-motorized and motorized urban public transportation. These include Gautrain, Rea Vaya BRT, Metrorail, Putco, Minibus Taxis, Uber and dedicated bicycles lanes for private cycle lanes for private bicycle cyclists. Public transportation in Johannesburg Metropolitan City is used by the youth to commute to school, to get to service centres and recreational areas; adults to commute to work and recreational areas and by old aged citizens to commute for leisure and to get to basic services. Conversely, for the purpose of this study two urban public transport modes are explored on state of routes integratedness.

The Rea Vaya BRT and Gautrain are located in City of Johannesburg of Gauteng province, Republic of South Africa. The Rea Vaya operates only under the jurisdiction of the City of Johannesburg in southern part. Whilst Gautrain operates within the three metropolitan cities in Gauteng province which include City of Tshwane, City of Johannesburg and City of Ekurhuleni in the East Rand of Gauteng Province. The three metros, as mentioned earlier they form the region which is the economic hub of the Republic of South Africa and are only cities in the entire African continent that has a rapid transit train. These two public transport modes started operating during the 2010 FIFA World Cup which was hosted by South Africa. They also operate along mixed land used as well as major economic, institutional and social nodes such as the Johannesburg Park Station, OR Tambo International Airport, FNB Stadium, Emirates Airline Park Stadium, Sandton and so on.

5 METHODOLOGY

The study adopted a phenomenological case study survey design that applied mixed-method approaches to gather spatial, qualitative and quantitative data. The study examined the applicability of location based services to define the state of public transport routes integratedness and movement patterns of commuters within Johannesburg Metropolitan City. The exploratory approach was used to formulate the research problem for precise investigation whilst the descriptive approach was used to gather complete and accurate information. Key informant interviews were also conducted with key informant personnel from Johannesburg Roads Agency (JRA), Gautrain Management Agency (GMA) and Gauteng Department of Roads and Transport to give complete and accurate information on Gautrain and Rea Vaya Routes Integratedness in Johannesburg Metropolitan City.

Data from Echo-Echo was used to gather social media comments on the urban public transport modes and locations co-ordinates of where the comments were made. The co-ordinates were converted into shape files, which in turn were used to create the krigging maps. Conversely, these maps display High Commuter Concentrations zones and Low Commuter Concentrations Zones and help to track the movement patterns of commuters using urban public transport and survey questions about origin and destination were included to validate locations and create maps with possible routes emanating from various locations to major nodes of the City of Johannesburg. The data in this study were analysed and interpreted thematically, semantically and spatially through techniques such as content analysis and Geographic Information Technologies. The study period is from January to August 2017, and the spatial, qualitative and quantitative analysis were triangulated to yield viable results.

6 Modes of Public Transport and Their Routes Integratedness Within the Johannesburg Metropolitan City

6.1 Moving with Gautrain

Gautrain in one of several strategically integrated Gauteng Provincial Government projects to meet future transport demands anticipated because of economic and population growth (Ruwanarupathirana and Perera, 2015). It is also referred to as a mega-engineering project. It is a state-of-art rapid rail connection between City of Johannesburg (Africa’s business capital), City of Tshwane, and City of Ekurhuleni (Moosa, 2015). The gautain has been identified as the backbone for public transit provision in the Gauteng province, since according to Gauteng City Region (GCR) can best described as a cohesive cluster of cites, towns and urban nodes which collectively make up the economic hub of South Africa, generating more than 36% of the
country’s Gross Domestic Product (GDP), whilst covering less than 2% of the South Africa’s total surface area. Figure 2 illustrate Gautrain routes and stations map.

![Gautrain routes and stations map](image)

In terms of routes network, the Gautrain alone operates in three metropolitan cities in Gauteng province namely City of Johannesburg, City of Pretoria and Ekurhuleni Metropolitan municipality. It has only 10 functional train stations, namely Park, Rosebank, Sandton, Marlboro, Midrand, Centurion, Pretoria, Hatfied, OR Tambo and Rhodesfield. However, the Gautrain within jurisdiction of City of Johannesburg operates in the upper spaces such as Rosebank, Sandton, Randburg and Fourways. Gautrain does operate on the southern spaces of the Johannesburg, and conversly there are potential clients and need for expansion and integration with Rea Vaya that is currently operating in that area (See figure 2).

### 6.2 Relying on Rea-Vaya

The Rea Vaya Bus Rapid Transit (BRT) is a fairly new bus system in the city of Johannesburg. Its launch in 2009 was met with much uncertainty, but great hope as a new public transport initiative for the city. The system can be found in many different areas across the greater urban fabric of Johannesburg, connecting the south to the north and the east to the west. It covers a route of 325 km to date and continues to be in the process of expanding (COJ, 2015). The system is made up of trunk routes that keep to the designated lanes and are connected by the stations along the route. The T1 route runs from Thokoza Park in Rockville, Soweto and ends in Ellis Park. There are more than 15 bus stations across this route that facilitates access onto the buses. The main trunk routes are supported by complimentary and feeder routes that navigate other parts of the city. These feeder buses use the main routes of the road network like other vehicles and public transport systems. Figure illustrate Rea Vaya Bus Stations and Bus Route. Figure 3 illustrate Rea Vaya Bus Stations and Bus Routes.

In terms of routes network, Rea Vaya Operates in Region A to F within the Johannesburg Metropolitan City. It operates in different phases and has systematic hierarchical routes that connect micro city centers in the metropolitan city of Johannesburg. It has completed the construction of Phase 1A and 1B and currently developing Phase 1C. Rea Vaya’s Phase 1A has a trunk route operating between Ellis Park in Doornfontein and Thokoza Park in Soweto, linking with several feeder routes Soweto (Rea Vaya, 2016). Feeder buses run from Protea Glen to Thokoza Park and from Eldorado Park to Lakeview (Rea Vaya, 2016). The route covers
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325 km of special lanes and intersections while feeder and complementary buses carry passengers to the trunk route stations.

The inner city circular route travels around the Central Business District from Hillbrow and Braamfontein, to Ellis Park in the east and Chancellor House on the western edge of the city (Rea Vaya, 2015). The Phase 1B has routes that operate through Cresta, Windsor West, Parktown, Yeoville. In addition, routes that operate to and from University of Johannesburg Soweto Campus are being added. The route starts in Noordgesig in Soweto and travels through Pennyville, New Canada, Highgate, Auckland Park and Braamfontein to Parktown, Metro centre and Rissik Street in the CBD.

The route has made it possible for commuters to easily reach key public healthcare centres such as the Rahima Moosa, Helen Joseph and Charlotte Maxeke hospitals as well as educational institutions such as University of Johannesburg, Wits University, Milpark College, Parktown Boy’s High School and Barnato Park High School. Feeders run to and from Leaglen, Stormhill, Florida, Cresta, Yeoville and Parktown. There are also additional feeders in Soweto from Pemville and Mapetle. These routes are now linked to the Metro Centre Rea Vaya loop, which travels to the inner city through Braamfontein.

Rea Vaya’s current focus is the development of Phase 1C following the completion of Phase 1B. Phase 1C will run from: Parktown to Alexandra; then Alexandra to Sandton, with complementary services between the CBD and Ivory Park; and from the CBD to Sunninghill on Oxfords and Revonia. Future plans also include extending the Phase 1C route from Sandton to Ranburg by 2018, and possibly extending the Phase the trunk route from Soweto Highway to Dobsonville, enabling feeders to services areas such as Braamfisherville. Construction for the routes and stations has already started in the Sandton area. The Rea Vaya trunk routes from the CBD to Sunninghill through Oxford Road and Ivory Park to Sunninghill will be prioritized after 2018. The three interchanges will be at Sandton, Alexandra and Westgate, where a number of station modules will be clustered and there will be integration with other modes of transport, including walking and cycling.

With its intention to be one of the most sustainable forms of public transport in the city, the Rea-Vaya is noted as cost effective, safe and relatively reliable. It is considered as an inherent component of the city’s future urban form as it is one of the main elements of the corridors of freedom initiative. Finally, the Rea-Vaya is referred to as one of the most determined initiatives by the city, being spread headed by a woman and having a completion goal of three years from ground breaking to implementation and operation (Moosajee, 2015).
6.3 Analysis of Gautrain and Rea Vaya Routes Integratedness

The findings of this study indicate that there are limited areas where the route networks between the public transport systems are connected (see figure 4). Currently, the Gautrain operates in the upper spaces of Johannesburg, such as Rosebank, Midrand, Sandton, Randburg and Fourways. Whilst the Rea Vaya does not have existing networks in these locations. Rea Vaya’s Phase 1A has a trunk route operating between Ellis Park in Doornfontein and Thokoza Park in Soweto, linking with several feeder routes Soweto. Feeder buses run from Protea Glen to Thokoza Park and from Eldorado Park to Lakeview. The Rea Vaya has proven successfully in improving accessibility to economic opportunities for locations which were once spatially segregated in Johannesburg. As can be seen with the network flowing from Soweto moving upwards to the inner CBD in Braamfontein. Most of the Rea Vaya stations seem to be well located as they are within the high commuter concentration zone (see figure 4).

The existing urban public transport network is spatial segregated, and there is little to no clear collaboration between the Gautrain and Rea Vaya, as they are developed and operate separately. Hence this presents a knowledge gap of how to connect commuters to places of economic and business activities. Conversely, from the works of modern day scholars (Filippi et al., 2013; Nune et al., 2014), the network integration of the public transport systems will lead to improved service delivery, inter-connectivity of places of economic activity and improve quality of life. Therefore, for City of Johannesburg to promote smart mobility, there is need for development of planning support systems which will guide the growth and integration of the existing and future public transport systems.

On the other hand, the Johannesburg Park Station hub function as vibrant intermodal transport node (see figure 4). It is a major public transport interchange where public transport network integrate, and commuters from all over Johannesburg, South Africa, Africa transfer from trains and buses to minibus and more. Gautrain and Rea Vaya services at Park station provide for inter-city transport as well as intra-city and regional transport service. Given that Johannesburg Park Station is a prominent transport terminal in Johannesburg, Gauteng, South Africa, and Africa, distribution terminals in the form of bus stations, rail stations and taxi ranks are located in the close proximity to the Park Station precinct. The Gautrain Park Station, bus routes as well as the Rea Vaya Bus Rapid Transit routes should also be noted as an essential feeder and distributor routes in the area.
6.4 Gautrain and Rea Vaya Social Media Commuter Concentration

Accordingly, from the findings, the majority of the commuters are located near the stations, this is due to the current stations are located in melting points of commuters, such as the Park Station, which is located in the Johannesburg CBD and acts as main interchange hubs of Johannesburg and an entry point for most regional and local commuters, also it is at the close proximity to MTN Taxi rank and Bree Taxi Rank located only 10 minutes away. This hub has a high connectivity of public transportation level. Notable areas which are currently not serviced by the Gautrain and Rea Vaya, include Roodepoort; Randburg; Woodmead; Magaliessig; Honeydew; Fourways; Lenasia; Glenvist; and Lawley. The commuter concentration zones of the Gautrain and Rea Vaya were then overlaid on a ratio of 50:50, to ascertain which stations should as the initial geolocations to promote multi-mobility. Park Station had the highest integrated commuter concentration as shown in figure 5.

![Figure 5: Routes Network Integratedness (Source: Author, 2017)](image)

With this high commuter integrated, improving commuter transfer in the geolocation would be a virtuous starting point, since the infrastructure and commuter number are already pre-existing. While variations in income levels may be a factor to prevent inter-transfer between the two modes commuters should be given an incentive for using both modes of transit in one trip, such as a discount in commuter fares or points which can be later redeemed for a discount. This would build on the existing commuter concentration, and further attract other commuters to join the system. Moreover, as it would be cost effective for the two public transit provides to partner towards promoting multi-mobility within City of Johannesburg, then building separate infrastructure, as the Gautrain would link commuters to economic and business hubs in the northern zones of Johannesburg, Namely: Sandton, Rosebank, Marlboro and Midrand; and the Rea Vaya would integrate commuters to areas of economic and business nodes in the southern zones of the city.

6.5 Gautrain and Rea Vaya Commuters Movement within the City of Johannesburg

The movement of commuters within the city changes with time (Mitchell and Casalogno, 2005), as a result of developing transportation systems in addition to innovations within the Information and Communication Technologies Sector. While exploring the state of public transport networks integratedness within City of Johannesburg in this endeavour, it is essentially to understand the commuters movement within various areas of the city (Ambrosino et al., 2014).
Conversely, figure 6 and 7 illustrate the possible origin and destination areas of Gautrain and Rea Vaya commuters who form part of the study. From the results it can be deduced that from each location, commuters has two or three possible routes that they can take when travelling from their origin to destinations. For instance a commuter has two or three possible routes that he/she can take when travelling between Johannesburg Park Station and Sandton.

These routes may be direct links from their origin to their destinations on or may be interconnected through other stations as alternative routes to reach their destinations of choice conveniently. The two modes of public transport in Johannesburg metropolitan city constantly need to track the movement of their commuters because of change in origin and destinations over time, thus the idea of location based services is applicable in tracking commuter movement patterns through geo-locational patterns that display commuter concentration zones. Therefore, the idea is for the service provider to reach out to commuters in the form of expanding services or contracting emergency and temporary urban public transport in times when required most, such as traffic congestions and tracking social media feeds using location based services analysis software such as Echo-Echo to manage their social media platforms effectively which in turn renders real-time and effective service to many of its commuters and the public at large.

7 CONCLUSION

To conclude mobility is continuously adapting and transforming to quasidian challenges, and be perceived with the global shift towards smart city planning. The shift towards encourage communities to utilizing multimobility modes and public transport in their everyday commute, to promote the reduction in the negative impacts of private-car-dependence in the urban contexts. This study delineated the extent routes network integration among Gautrain and Rea Vaya within the Johannesburg urban public transport system. The study findings; indicated that there are limited areas where the route networks between the public transport systems are connected. The large sections of the networks are disintegrated.

However, it is recommended that conscious efforts in planning and developing both rail and routes networks that are integrated to promote efficiency of public transport systems. The network integration of the public transport systems will lead to improved service delivery, inter-connectivity of places of economic activity and improve quality of life. Therefore, for City of Johannesburg to promote smart mobility, there is need for development of planning support systems which will guide the growth and integration of the existing and
Exploring the Applicability of Location Based Services to Determine the State Routes Transport Networks Integratedness in the City of Johannesburg

future public transport systems. Typically, sustainable urban mobility describe movement patterns or city transport networks, which are utilizing active travel modes, energy efficient renewable forms of energy, or shared vehicles wherever possible, resulting in low carbon output per commuter journey. Integrated multimodal networked public transport have emerged as a mobility paradigm, utilizing transfer potentital to provide maximal service for a reasonable and efficient operating budget, providing a genuinely feasible alternative to the automobile travel for many trips within urban areas.

8 REFERENCE


Moyo, T. and Musakwa, W., 2016. Using crowdsourced data (Twitter & Facebook) to delineate the origin and destination of commuters of the Gautrain public transit system in South Africa.


ANNEXURE B

KEY INFORMANT (SEMI-STRUCTURED) INTERVIEW QUESTIONNAIRE
Dear Participant,

My name is Brightnes Risimati, a registered Masters student with the Department of Quality and Operations Management, University of Johannesburg. My Master’s degree aims to explore the extent of spatial integration of innovative urban public transport systems in the City of Johannesburg and create a comprehensive integrated transport planning framework that can inform the spatial integration of the existing public transport systems. Thus, I hereby request your assistance in participating to the key informant interview questionnaire of the study on the above-mentioned at the City of Johannesburg. These questionnaire has been designed to capture the required information. The Information collected is only for academic purposes. Besides serving to fulfil Master’s requirements, the information gathered will be used in formulating future strategies for planning and management of well-spatial integrated innovative urban public transport systems in South African cities. All the information you provide in this key interview questionnaire will be treated as STRICTLY CONFIDENTIAL, will only be used for academic purposes and no mention will be made of executive directors, managers or providers of information.

For more information please do not hesitate to contact Prof Trynos Gumbo (0115596062/tgumbo@uj.ac.za).

Your assistance in this regard will be highly appreciated!

Participant Name: _____________________________________________________________

Institution/Agency:  ____________________________________________________________

Position held:  __________________________________________________________________

Date:  _______________________________________________________________________

Interviewer: Risimati Brightnes (Student at the University of Johannesburg)
1. Are innovative urban public transport systems phase in the right direction to transform the apartheid inherited spatial form to promote public transport ridership and enhance economic growth?
   a) Gautrain (Yes or No): __________________________
   b) Rea Vaya (Yes or No): __________________________

2. In your professional opinion, are the policy and legislative instruments in place effective enough to facilitate the provision and management of well-integrated, affordable and reliable modern public transportation systems in South African cities?
   __________________________________________________________________________
   __________________________________________________________________________
   __________________________________________________________________________
   __________________________________________________________________________
   __________________________________________________________________________

3. What are the initiatives and ingenuities in place to ensure that Gauteng province and City of Johannesburg transport policy, strategies and legislative frameworks governing public transport infrastructure are adequate to inform the development and operation of efficient and integrated urban public transport systems in the City of Johannesburg?
   __________________________________________________________________________
   __________________________________________________________________________
   __________________________________________________________________________
   __________________________________________________________________________
   __________________________________________________________________________

4. Does the Gautrain and Rea Vaya services contribute to integration of residential and economic opportunities in Johannesburg?
   a) Gautrain (Yes or No): __________________________
   b) Rea Vaya (Yes or No): __________________________

5. Given your response in the above question 3, what is your professional opinion on the local economic transformation and improved accessibility to economic opportunities for formerly marginalised places of Johannesburg?
   __________________________________________________________________________
   __________________________________________________________________________
   __________________________________________________________________________
   __________________________________________________________________________
   __________________________________________________________________________
6. To what extent are the spatial patterns and routes networks integrated between the Gautrain and Rea Vaya?

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

7. Does the state of spatial patterns and spatial integration of Gautrain and Rea Vaya have an impact on commuters’ experiences?

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

8. In your professional opinion, is there any possibility of developing a comprehensive integrated public transport framework that can be used to integrate the existing urban public transport systems?

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

9. In general, any possible improvements you would like to see in terms of service provisions by Gautrain and Rea Vaya in the Johannesburg Region:

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________

Thank you for your time and participation in the survey!!!
ANNEXURE C

SAMPLE OF COLLECTED CROWD SOURCED DATA FROM ECHO ECHO
<table>
<thead>
<tr>
<th>Message</th>
<th>Social User</th>
<th>Latitude</th>
<th>Longitude</th>
<th>City</th>
<th>Source</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>The fees they pay, the Res they stay in - the Gautrain and BRT buses</td>
<td>EsethuHasane</td>
<td>-25.73134</td>
<td>28.21837</td>
<td>Pretoria, South Africa</td>
<td>Twitter</td>
<td>2017-06-15 12:12:10.000</td>
</tr>
<tr>
<td>they use to get there.. The list is endless <a href="https://t.co/sCFwAO7YKu">https://t.co/sCFwAO7YKu</a></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>When media talks of how good DA is dey always have a park station at Cape</td>
<td>Rorisang112</td>
<td>-26.2041028</td>
<td>28.0473051</td>
<td>Johannesburg</td>
<td>Twitter</td>
<td>2017-06-15 11:18:25.000</td>
</tr>
<tr>
<td>Town, I wish I could say I wanda why not broad Western Cape</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RT @lion_queeen: @CityofJoburgZA the meter cab drivers are not attacking</td>
<td>walker8701</td>
<td>-30.559482</td>
<td>22.937506</td>
<td>South Africa</td>
<td>Twitter</td>
<td>2017-06-15 10:07:50.000</td>
</tr>
<tr>
<td>citizens inside the Gautrain station, they're harassing outside on...</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>#gautrain #Noo @ Kempton Park, Gauteng <a href="https://t.co/0QcJP6vqWk">https://t.co/0QcJP6vqWk</a></td>
<td>jolenecmom</td>
<td>-26.1000038</td>
<td>28.25</td>
<td>Kempton Park</td>
<td>Twitter</td>
<td>2017-06-15 10:02:35.000</td>
</tr>
<tr>
<td>You have the video already. What are you @TheGautrain doing about it?</td>
<td>khozaTT</td>
<td>-26.2041028</td>
<td>28.0473051</td>
<td>Johannesburg, South Africa</td>
<td>Twitter</td>
<td>2017-06-15 09:56:47.000</td>
</tr>
<tr>
<td>Why are you putting the burden on us? <a href="https://t.co/uIRcjXck1O">https://t.co/uIRcjXck1O</a></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>@TheGautrain <a href="https://t.co/RwfgRyA15L">https://t.co/RwfgRyA15L</a></td>
<td>khozaTT</td>
<td>-26.2041028</td>
<td>28.0473051</td>
<td>Johannesburg, South Africa</td>
<td>Twitter</td>
<td>2017-06-15 09:54:07.000</td>
</tr>
<tr>
<td>Username</td>
<td>Message</td>
<td>Coordinates</td>
<td>Location</td>
<td>Platform</td>
<td>Time</td>
<td></td>
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<td>----------</td>
<td>----------</td>
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<td></td>
</tr>
<tr>
<td>@unobus</td>
<td>The 607 from Business park to Hatfield Station will not service Lemsford Road due to parked cars blocking the access</td>
<td>51.8097823</td>
<td>-0.2376744</td>
<td>Hertfordshire</td>
<td>Twitter</td>
<td>2017-06-15 09:25:14.000</td>
</tr>
<tr>
<td>@CityofCT</td>
<td>What would the feedback be for a &quot;Gautrain&quot;, fit for the Cape, linking the airport to the CBD?</td>
<td>-26.2041028</td>
<td>28.0473051</td>
<td>Johannesburg, South Africa</td>
<td>Twitter</td>
<td>2017-06-15 09:33:26.000</td>
</tr>
<tr>
<td>@SuperSportTV</td>
<td>go with the gautrain into the bus CR7</td>
<td>-30.264216</td>
<td>29.9191194</td>
<td>Emzimkhulu,kzn</td>
<td>Twitter</td>
<td>2017-06-15 09:32:10.000</td>
</tr>
<tr>
<td>Shhhhhhh</td>
<td>@ Gautrain Park Station</td>
<td>-26.1956749</td>
<td>28.04177094</td>
<td>Johannesburg</td>
<td>Twitter</td>
<td>2017-06-15 09:25:30.000</td>
</tr>
<tr>
<td>The 607 from Business park to Hatfield Station will not service Lemsford Road due to parked cars blocking the access</td>
<td>51.8097823</td>
<td>-0.2376744</td>
<td>Hertfordshire</td>
<td>Twitter</td>
<td>2017-06-15 09:25:14.000</td>
<td></td>
</tr>
<tr>
<td>@ILuvDBN</td>
<td>What would your followers say to a &quot;Gautrain&quot; network connecting the North and South of Durban?</td>
<td>-26.2041028</td>
<td>28.0473051</td>
<td>Johannesburg, South Africa</td>
<td>Twitter</td>
<td>2017-06-15 09:14:41.000</td>
</tr>
<tr>
<td>Is it time for the Cape Town to receive its own &quot;Gautrain&quot;?</td>
<td>-26.2041028</td>
<td>28.0473051</td>
<td>Johannesburg, South Africa</td>
<td>Twitter</td>
<td>2017-06-15 08:59:35.000</td>
<td></td>
</tr>
<tr>
<td>First trip on #gautrain to fetch #Noo from school. My nerves are…</td>
<td>-26.10769081</td>
<td>28.05743408</td>
<td>Sandton</td>
<td>Twitter</td>
<td>2017-06-15 08:34:31.000</td>
<td></td>
</tr>
</tbody>
</table>
## SAMPLE REA VAYA CROWD SOURCED DATA FROM ECHO ECHO

<table>
<thead>
<tr>
<th>Message</th>
<th>Latitude</th>
<th>Longitude</th>
<th>City</th>
<th>Source</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rea Vaya will be operating tomorrow, 16 June 2016 from 06H00 - 19H00 with a bus frequency of 30 minutes throughout the day.</td>
<td>-26.20410347</td>
<td>28.04730415</td>
<td>johannesburg</td>
<td>Twitter</td>
<td>2017-06-15 12:57:08.000</td>
</tr>
<tr>
<td>@ReaVayaBus could @JMPDSafety @CityofJoburgZA Please look into matter urgently, school kids cross da highway daily. robots are functional, yet</td>
<td>-26.277559</td>
<td>27.84824</td>
<td>Soweto, Johannesburg</td>
<td>Twitter</td>
<td>2017-06-15 10:59:59.000</td>
</tr>
<tr>
<td>@ReaVayaBus How close can the buses get me to it? in terms of walking distance.</td>
<td>-26.1749328</td>
<td>28.0083618</td>
<td>Melville</td>
<td>Twitter</td>
<td>2017-06-15 10:39:59.000</td>
</tr>
<tr>
<td>RT @takatso_moloi: @ReaVayaBus @CityofJoburgZA @MovingGauteng JMPD responded quickly to the protests... However buses are still delayed</td>
<td>-26.2707593</td>
<td>28.1122679</td>
<td>Gauteng</td>
<td>Twitter</td>
<td>2017-06-15 10:22:39.000</td>
</tr>
<tr>
<td>RT @takatso_moloi: There's a community protest at Pimville @ReaVayaBus F10 route affected @CityofJoburgZA @MovingGauteng</td>
<td>-26.2707593</td>
<td>28.1122679</td>
<td>Gauteng</td>
<td>Twitter</td>
<td>2017-06-15 10:22:36.000</td>
</tr>
<tr>
<td>@ReaVayaBus @CityofJoburgZA @MovingGauteng JMPD responded quickly to the protests... However buses are still delayed</td>
<td>-26.2574817</td>
<td>27.8282121</td>
<td>Soweto, Naledi</td>
<td>Twitter</td>
<td>2017-06-15 10:17:33.000</td>
</tr>
<tr>
<td>There's a community protest at Pimville @ReaVayaBus F10 route affected @CityofJoburgZA @MovingGauteng</td>
<td>-26.2574817</td>
<td>27.8282121</td>
<td>Soweto, Naledi</td>
<td>Twitter</td>
<td>2017-06-15 10:06:19.000</td>
</tr>
<tr>
<td>@CityofJoburgZA @Paleesa_Mav @ReaVayaBus #hahahaha #tantrums</td>
<td>56.4906712</td>
<td>-4.2026458</td>
<td>scottland</td>
<td>Twitter</td>
<td>2017-06-15 09:57:23.000</td>
</tr>
<tr>
<td>Username</td>
<td>Location</td>
<td>Coordinates</td>
<td>Tweet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------</td>
<td>-------------------</td>
<td>-------------------</td>
<td>----------------------------------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>@CityofJoburgZA</td>
<td>Sandton</td>
<td>-26.2041028</td>
<td>Scheduled for Sandton, Rosebank. As you may know, implementing Reavaya is not as quick as a tweet, it takes yrs^TK...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>@CityofJoburgZA</td>
<td>Randburg, South Africa</td>
<td>28.0063889</td>
<td>@Paleesa_Mav @ReaVayaBus yep stealing lanes is hard work...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>@lebzanediddi:</td>
<td>Melville</td>
<td>-26.1749328</td>
<td>@ReaVayaBus @iamthebe_m all the time I have forgotten what peak and off peak mean, and when they come they are follow...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>@CityofJoburgZA</td>
<td>South Africa</td>
<td>22.937506</td>
<td>Scheduled for Sandton, Rosebank. As you may know, implementing Reavaya is not as quick as a tweet, it takes yrs^TK...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>@ReaVayaBus</td>
<td>Johannesburg</td>
<td>28.0083618</td>
<td>when travelling to ClearWater mall from park station, which bus do I take?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>@CityofJoburgZA</td>
<td>International</td>
<td>35.010009</td>
<td>Scheduled for Sandton, Rosebank. As you may know, implementing Reavaya is not as quick as a tweet, it takes yrs^TK...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>@CityofJoburgZA</td>
<td>Jobburg</td>
<td>28.0473051</td>
<td>Scheduled for Sandton, Rosebank. As you may know, implementing Reavaya is not as quick as a tweet, it takes yrs^TK...</td>
<td></td>
<td></td>
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<td>@CityofJoburgZA</td>
<td>Johannesburg</td>
<td>28.0473051</td>
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