The State of Rail and Road Route Transport Networks Integratedness in the City of Johannesburg: An expose

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Abstract

This paper unpacks the extent to which rail-network and road-based public transport networks integration exists between *Gautrain*, *Rea Vaya, Metrorail and Metrobus* within the City of Johannesburg public transport system. A case study research design approach that involved an empirical enquiry using spatial and qualitative methods of data collection and analysis was used. The case study research approach was used to formulate the study problem for detailed investigation, and to gather relevant and accurate information. The key informant interviews and community social mapping were used to supplement data collection methods. Data analysis and interpretations were conducted using techniques such as main content analysis, focal statistics analysis, and Geographic Information Applications. The results reveal that there are some areas where the route networks between the public transport systems are integrated. The results indicate that there are limited spaces where networks of urban public transport systems are integrated, and large sections of the networks are disconnected with no partnerships and sharing on infrastructure. The paper advocates that integrated public transport planning improves a city's connectivity, providing a better mobility service, shorter journeys for the commuters, and brings people and places closer together. The network integration of the public transport modes will lead to better-quality service delivery, inter-connectivity of places of economic activity and advance quality of life.

Keywords
Public transport, networks, integration, disconnected and City of Johannesburg.

1. Introduction

Over the past decades, the City of Johannesburg (CoJ) together with Gauteng Provincial Government and South African National Department of Transport has focused its investments on development of integrated and efficient urban public transport systems. The public transport network efficiency discourse has been towards increasing the integration and efficiency of urban public transport modes. This was seen by the formulation of pertinent policies, strategies and frameworks that are pursued in the development and operation of integrated and efficient urban public transport systems aimed at facilitating the attainment of the so-called smart cities and smart mobility status within the city (Risimati and Gumbo 2019; Chakwizira et al 2019; Walters 2013). This status is perceived as the solution towards

all the public transport problems that among others include unreliability and traffic congestion. The smart mobility shift is aimed towards encouraging communities to utilise public transport and multi-mobility modes in daily commuting activities (Ranchordás 2020). Such a shift would lead to a reduction in the negative impacts of automobile travel, for instance congestion which has become a norm in major roads in urban spaces (Musakwa and Gumbo 2017). Typically, smart mobility describes city transport networks and movement patterns which are utilising active travel modes, energy efficient renewable forms of energy, or shared vehicles wherever possible, resulting in low carbon output per commuter journey (Moyo et al 2020). At same time, integrated multimodal networked public transportation have arisen as a mobility paradigm using 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 spaces (Mbatha and Gumbo 2019). Network integrations provide the public with the ability to efficiently travel from origin to destination using various modes of transport. The analysis of network integration can help decision makers in identifying the weak components, detecting, and preventing failures, and improving integration in terms of decreased travel time, reduced costs, increased accessibility, reliability, etc.

Johannesburg has perceived massive transport infrastructure investments, particularly networks infrastructure. These investments include the implementation and extension of rail and road infrastructures, thus transforming the urban mobility systems, structures and patterns within the city. They embrace newly built *Gautrain*, the fast-innovative train system which connects the outermost regions of the city as well as the broader Gauteng region. In support of the *Gautrain*, the CoJ has also invested in the Rea Vaya, a Bus Rapid Transport system which connects the Johannesburg Inner City to major regional, district and local nodes. It creates connectivity between the historic township localities and the primary economic nodes of the city. The Corridors of Freedom and Integrated Transport Plan are amongst some of the strategic objectives of the City, where *Metrobus* has a pivotal role to play as a provider of public transport. Passenger Rail Agency of South Africa (PRASA) has completed a National and Gauteng Rail Strategic Plan in 2012 that aims to guide infrastructure investment into specific identified corridors. In terms of rail in Gauteng, the goal is to upgrade and transform the existing rail network into high-volume corridors more suitable for Transit-Oriented Development. Rail is also proposed by the newly adopted Gauteng Integrated 25 Year Transport Master Plan as the future backbone of urban development in Gauteng. In short, the intervention will consist of New upgraded rolling stock (more seating and standing capacity); New facilities at stations that include platforms, upgraded ticketing and security systems and additional tracks on certain sections to alleviate bottlenecks in the wider network.

Thus, the question remains as to whether these innovations and investments in urban public transport infrastructure are contributing enough towards spatial integration of the CoJ. There has been rising concerns of the state of urban public transport systems in the city. One of the main among the rising concerns have been lack of well-integrated, reliable and efficient public transport systems. The motivation for this paper is to investigate the efficiency and integration of the rail and road based public transport networks within Johannesburg public transport system. Specifically, the paper unpacks spatial patterns and the extent of network integration of Gautrian, Rea-Vaya, *Metrorail* and *Metrobus*.

2. Approach & Methodology

This study adopted a mixed-method approach which consisted of a case study research design that involved an empirical enquiry using spatial and qualitative methods of data collection and analysis. The case study research approach was used to formulate the study problem for detailed investigation, and to gather complete relevant and accurate information. It was based on an empirical enquiry and analysis of existing transport infrastructure, policy directives, and mobility innovations envisioned. For instance, the planning and development practices within the transport systems are analysed. The case study further explored the theoretical framework of the study while providing an overview of transport planning and designs as well as highlighting spatial integration of transport systems. It also synthesized transport infrastructure integration and systems for the developed world, transitional market countries and the developing world as well as South Africa. This approach of the study required spatial data covering urban public transport infrastructures (i.e. *Gautrain*, Rea Vaya, *Metrorail* and *Metrobus*) from the respective service providers (i.e. *Gautrain* Management Agency; PRASA; and City of Johannesburg).

2.1. Sampling Research Design

Purposeful sampling was useful in selection of key participants for interviews from the Metropolitan Municipality, Johannesburg Roads Agency, Gauteng Department of Roads and Transport, the *Gautrain* Management Agency, the

Passenger Rail Agency of South Africa (PRASA) and Johannesburg Metropolitan Bus Service. Key informant participants were selected purposefully that were especially knowledgeable and experienced in their areas of specialisation about transport planning, development and management in the City of Johannesburg. Accordingly, this sampling design was a useful way of ensuring that interviews provided distinctive, accurate and relevant empirical data for the study.

Snowball sampling technique was central in the sampling of participants during the community social mapping to recruit urban public transport commuters in Johannesburg. The researcher asked the first few participants who were selected via convenience sampling; and these first participants recruited other participants with similar views or situations. It allowed for the collection of qualitative information, whilst engaging a number of participants in an informal group discussion. Participants were able to interact as a group, discuss and debate key elements and issues of various modes of transport. Participants were made aware that informal group discussions were kept anonymous and would be used for the research process only.

2.2. Data Collection

Data for the study was collected through key informant interviews and community social mapping. Urban public transport infrastructure data was collected from urban public transportation service providers during the interviews in shapefile format.

2.2.1. Key informant Interviews

The key informant interviews were used to collect information for this study. The interviews were semi-structured, using open-ended questions to guide the conversations. The interviews were used to unpack the polices that guide transport infrastructure planning and development targets in line with realities, needs, expectations and presences of current and potential users of urban public transport systems. The interviews were held with officials from the CoJ, JRA, Gautrans, PRASA, Johannesburg Metropolitan Bus Services (JMBS) and Gauteng Management Authority (GMA). These interviews enabled accurate information to be obtained about the extent of spatial integration of transport infrastructure and trace the envisioned mobility innovations within the City.

2.2.2. Community Social Mapping

Community social mapping as the interaction of social process, landmarks and interactions within the communities was used to obtain the cognitive understanding of citizens about the spatial design of the city's public transportation. This methodology allowed for the collection of qualitative data, whilst engaging a limited number of participants in an informal group discussion. This was designed as a flexible and fluid process and assisted in highlighting issues not previously considered by the researcher in the methodology design process. Participants were able to interact as a group, discuss and debate key elements and issues of their modes of transport.

2.2.3. Urban Public Transport Infrastructural Data

Spatial data of urban public transport infrastructures (*Gautrain*, *Rea Vaya*, *Metrorail* and *Metrobus*) were collected in shapefile format from their service providers (*Gautrain* Management Agency; Passenger Rail Agency of South Africa (PRASA); Johannesburg Metropolitan Bus Service (JMBS) and City of Johannesburg). The spatial data gathered were used to visualise the spatial trend maps using Geographic Information Application (ArcGIS 10.3 software) to inform analysis and discussion on spatial patterns and infrastructure connectivity of the urban public transport systems. Table 1 below illustrates the summary of spatial datasets gathered whilst table 2 illustrates the geolocation of the spatial datasets gathered.

Table 1. Summary of spatial datasets collected

Datasets		Quantity
Gautrain stations		5 train stations
Gaubus stations		245 bus stations
Rea Vaya stations	Phase 1A	31 bus stations
	Phase 1B	46 bus stations
	Phase 1C	13 bus stations
Metrorail stations		42 Train stations
Metrobus stations		1921 Bus stations

Table 2: Geolocation of spatial datasets collected

Column ID	Column Name	Unit	Interpretation
1	Latitude	Degree	Latitude reference of Infrastructural data
2	Longitude	Degree	Longitude reference of Infrastructural data
3	Format	Point/Polyline	Transportations routes or stations
4	Source	R1/M1/M2/G1/G2	R1=Rea Vaya; M1=Metrorail; M2=Metrobus; G1=Gautrain; G2=Gaubus
5	Location	Point	Suburb or township
6	Date	YYYYMMDD	The day of the month or year which infrastructural data was last updated
7	Time	HMS	The time which infrastructural data was last updated

2.3. Data Analysis

The study followed an inductive approach to data analysis by way of identifying the extent 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. Accordingly, content analysis and statistical analysis as techniques were used to assess all the spatial, qualitative, and quantitative primary and secondary data collected during the study. These analysis techniques were purposefully chosen to define the extent of the spatial integration of non-motorised transport and urban public transport infrastructures consistent with the inductive approach to data analysis.

2.3.1 Content analysis

Content analysis informed by the Systematic Review methodology was used to analyse qualitative data in the form of literature on the spatial distribution of urban transportation systems. Key themes shown in Figure 1 such as the 'Compact city' and 'Transport Oriented development' case studies on the state of the art in urban mobility planning were identified and evaluated. Content analysis on infrastructure projects conducted by the were evaluated. Likewise inferences for future urban public transportation development were evaluated.

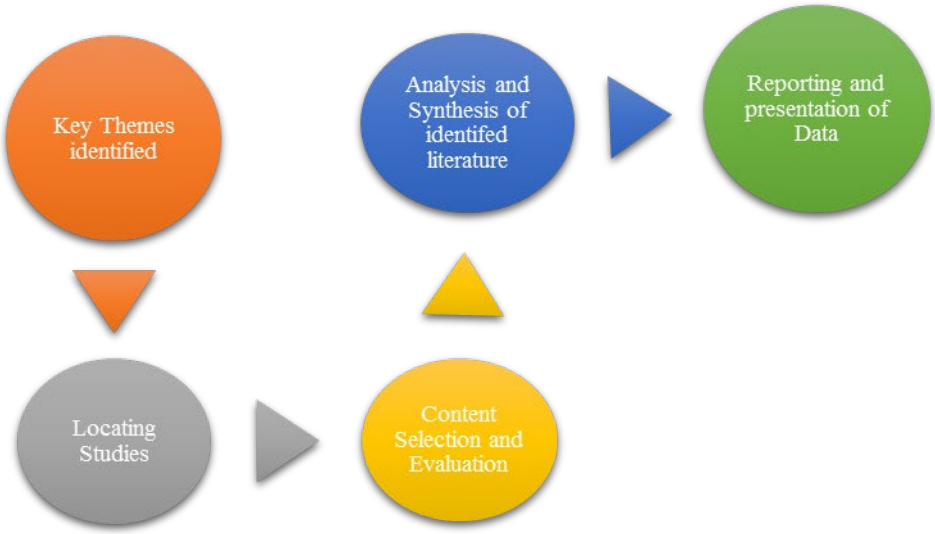

Figure 1. Roadmap of Content Analysis

2.3.2 Focal Statistics Analysis

Focal Statistics is used to perform a neighbourhood analysis operation that computes an output where the value of each output cell is a function of all the input values that are in a specific neighbourhood around the location. Focal statistics was very crucial in the study, as it was used to visualise and identify the distribution of hot spots along the

public transportation networks and rank these hot spots. Likewise, ArcGIS 10.3 was chosen as it provided a myriad of spatial statistical analysis tools for mapping clusters.

Given a polygon, *E* representing the Johannesburg municipality regional boundary, the researcher used this as the processing extent. The set of station points is denoted as *S*, with each point $s \in S$ representing the stations of a public transportation mode. The set of events points, *T* denotes the geographic location of each station point, with each point $t \in T$ having a numeric value *v(t).*

Each public transportation network is denoted as $G = \{V, A\}$ where V is a set of stations and A is a set of public transportation routes. Each route, $a \in A$ is a path between two stations $v_1\ v_2\ \in V$ has a length $l(a)$. Lastly $e(a, b)$ represents the straight-line distance between station *a* and station *b.*

To conduct the Focal Statistics Analysis, the following steps were used:

Step 1: Create a fishnet with grid size 500metres x 500metres within the spatial extent of polygon *E.* 500metres was chosen as a suitable walking distance to a station.
Step 2: Calculate the Frequency = Number of stations in each fishnet grid
Step 3: Calculate Focal Sum = $\Sigma_{t \in N(s)}^{v(t)}$

3. Research Findings and Analysis

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, affordability, and reliability serve as key indicators of their efficiency in any given city (Ndwandwe and Gumbo 2018). This section presents the extent of urban public transport networks integration in the City of Johannesburg. Figure 2., illustrates that there are restricted areas where the rail and route networks of urban public transport systems operational in Johannesburg are spatial integrated.

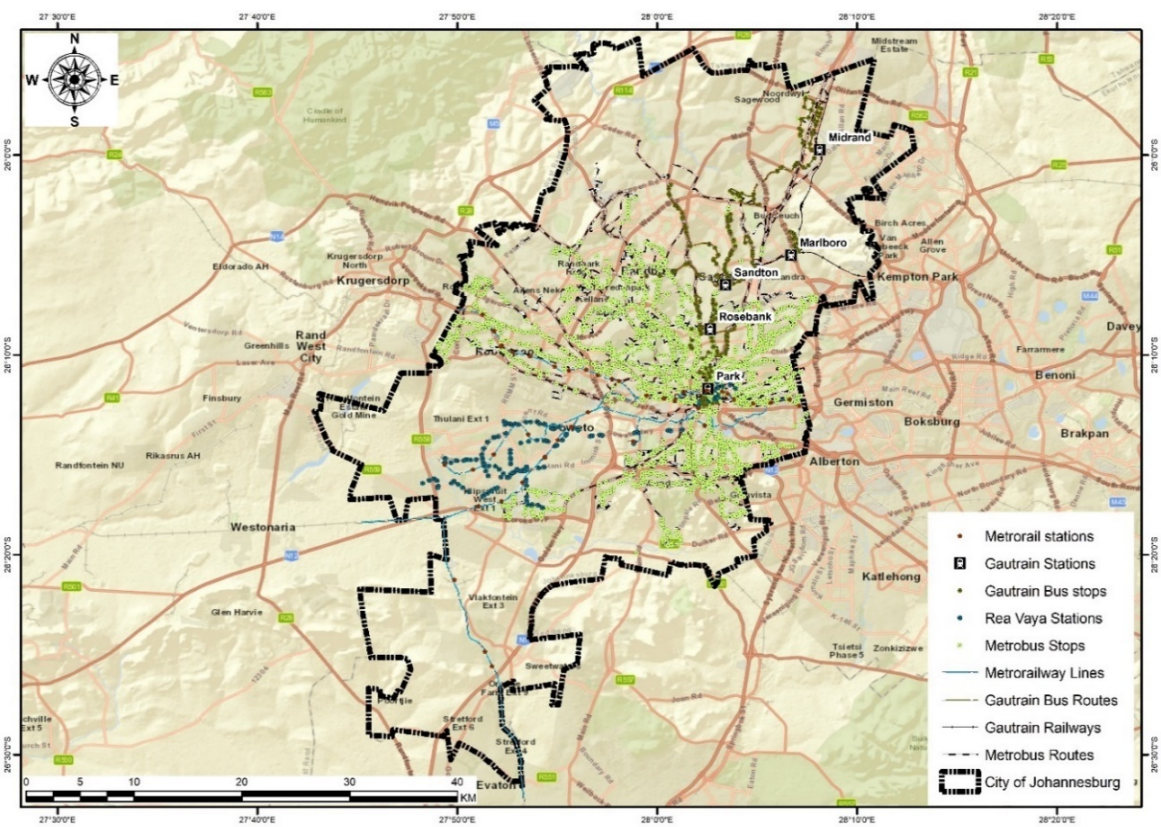

Figure 2. Urban Public Transport Network Integration

At present, the *Metrobus* divides its city's coverage into concentric zones radiating out from the CBD. The Greater part of the *Metrobus* routes begin from the inner-city transport terminals in Zone one, with longer trips crossings various zones. *Metrorail* serves central Johannesburg, Roodepoort, Soweto and Orange Farm, but the service is blighted by poor quality service. The *Gautrain* services the Johannesburg CBD towards upper areas of the city, such as Sandton, Rosebank, Midrand, Fourways and Randburg. While the *Rea Vaya* BRT does not have networks servicing these areas, its Phase 1A has a trunk course working between Ellis Park in Doornfontein and Thokoza Park in Soweto, connecting with various feeder routes in Soweto. The *Rea Vaya* Feeder buses run from Protea Glen to Thokoza Park and from Eldorado park to Lake view. The *Rea Vaya* has enhanced availability to open economic doors for spaces which were once spatially segregated in the city of Johannesburg. As can be perceived, with the route network spilling out towards Soweto, and moving upwards towards the CBD of Johannesburg, the greater part of the *Rea Vaya* stations appears to be very much situated within the high commuter concentration zones.

There is little to no collaboration between *Gautrain*, *Rea Vaya*, *Metrorail* and *Metrobus* since they are developed and offer their service separately. Thus, the current Johannesburg public transport network is spatially disintegrated, and this introduces a knowledge gap of how to interface commuters with areas of economic activities. It is apparent from modern-day scholars (Risimati and Gumbo 2019; Chakwizira et al 2014) that the network connectivity of the urban public transport modes should prompt enhanced inter-connectivity of economic nodes, service delivery and improve quality of life. Thus, to promote smart mobility, there is a requirement for the development of planning supportive networks which direct the development and connectivity of current and future urban public transport modes.

To ensure accuracy in spatial connectivity of urban public transport, stations for various modes were merged into one shapefile. Using focal statistics analysis, a heat map was created to visualise the hot spots of urban public transport services in the city (see figure 3). A clear distribution of hot and cold spots of transportation stations within the study area becomes evident.

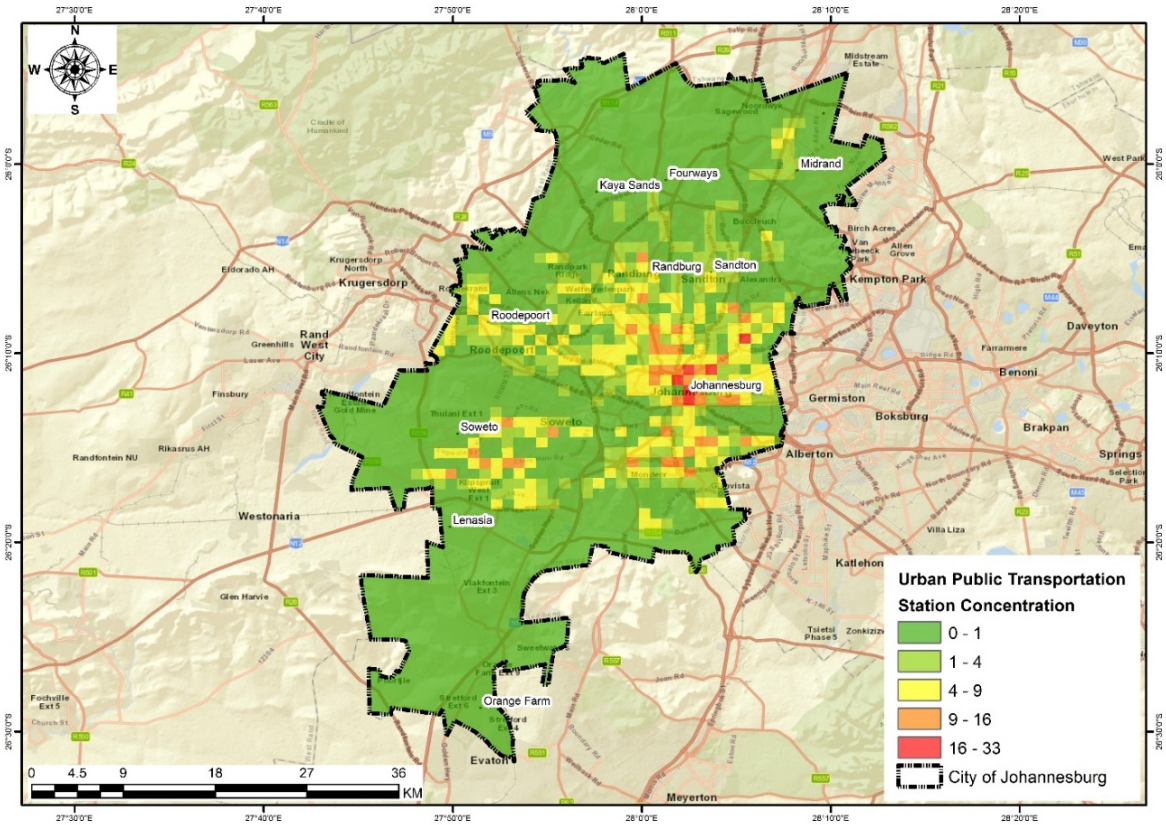

Figure 3. Urban Public Transport station concentration heat map in Johannesburg

A concentration belt can be seen stretching from the CBD, growing outwards as noted in the previous chapter these locations are along the transportation corridors. Another noticeable hot spot is in Soweto. These hot spot sites can be

used to justify the introduction of new economic investments in and around these sites, as there is a high level of commuters in these areas. Likewise, due to the pattern of economic developments along these major transportation routes, nodes can be created around the hot spots, as these have grown to become key points of interest of commuters in the city. However, there is also a need to conduct a neighbour analysis to visualise the infrastructural integration at these hot spot sites of commuters as shown in the subsections below.

3.1. Analysis of Urban Public Transport Networks Integration in the Inner City

There are three possible route networks integration points in the Inner (Inner City Integration Point A, B and C). Inner City Integration Point A is located near Parktown and Hillbrow. It has the potential to serve as an interconnection of Public transportation for the educational and health institutes such as the University of Witwatersrand and Parktown Hospitals. The *Gaubus* routes, *Metrobus* as well as the *Rea Vaya* routes are essential feeders in this area. Parktown is historically known as the first suburb in northern Johannesburg, within close proximity to employment opportunities whilst still maintaining a quiet residential area. Inner City Integration Point B is located in Braamfontein, within close proximity to the University of the Witwatersrand, several tertiary colleges and the Park Station transportation hub. Given Braamfontein's history of being a trendy suburb with a big student community, the promotion of multi-modal transportation is in this Integration point. Inner City Integration Point C is located near Marshalltown, Doornfontein and Ferrierasdorp. It functions as a centre for the administration hub of the inner city. Integration Point C also has the potential to connect the financial and business centres with the high-density residential areas of the inner city. Figure 4 below illustrates the spatial settings of the three possible Inner-City Integration Points.

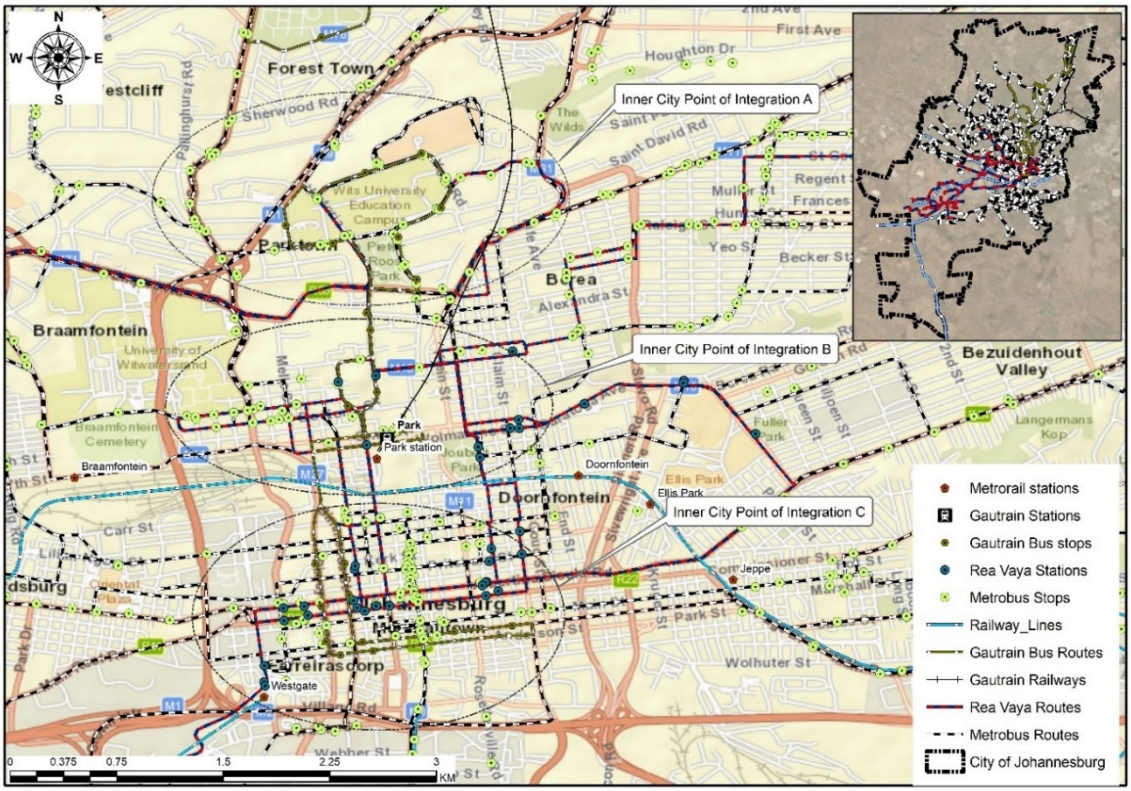

Figure 4. Inner City Urban Public Transport Network Integration

3.1.1. The function of the Inner-City Integration Point A

Inner City Integration Point A provides interconnection of public transport for educational and health institutions such as the University of Witwatersrand, Nelson Mandela Children's Hospital, Park Lane Hospital and Charlotte Maxeke Academic Hospital. The area is neighbour to the high-density residential areas of Hillbrow, Yeoville and Berea. The

Gaubus routes, *Metrobus* as well as the *Rea Vaya* routes are essential feeders and distributor routes in this area. Figure 5 below illustrate interconnection between *Gaubus*, *Rea Vaya* and *Metrobus* (Inner City Integration Point A).

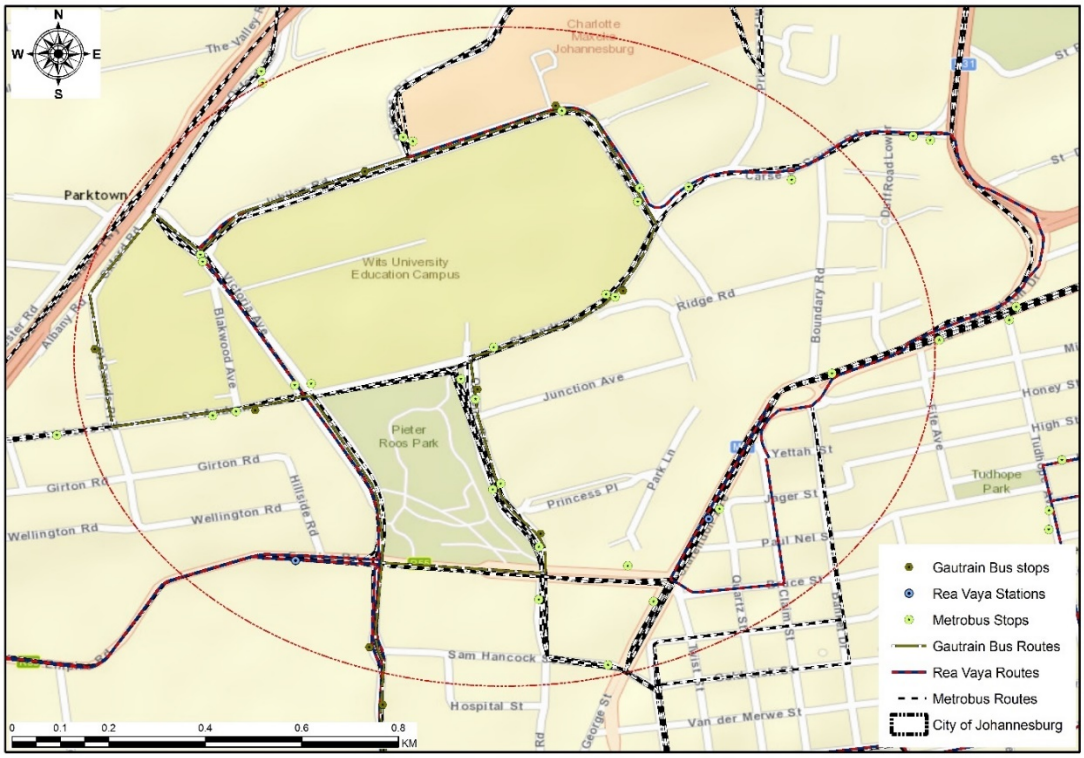

Figure 5. Inner City urban public transport routes Integration Point A

As depicted in the above figure 5, *Gaubus*, *Rea Vaya* and *Metrobus* in this area provide mobility for students, workers and patients from various locations (mostly from Park Station) to educational or health institutions. Indeed, the existing urban public transport networks are spatially integrated. However, there is no sharing of infrastructure amongst these three modes of urban public transport, as they operate independently in this area. It would thus be of benefit for the three modes to partner towards promoting multi-mobility and sharing of infrastructures in this area. This would integrate transport towards areas of education and healthy institutions.

3.1.2. The function of the Inner-City Integration Point B

Inner City networks 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 from all over Johannesburg, South Africa, Africa, or transfer from trains and buses to minibuses. Given that Johannesburg Park Station is a prominent transport terminal, distribution terminals in the form of bus stations, rail stations and taxi ranks are situated in close proximity to the Park Station precinct. The station provides access to the Johannesburg inner city and well-established high-density residential land uses that have undergone significant regeneration in recent years. The *Gautrain*, *Gaubus*, *Rea Vaya*, *Metrobus* and *Metrorail* routes are essential feeders and distributor routes in the area (see figure 6).

Figure 6. Inner City urban public transport routes Integration Point B (Johannesburg Park Station)

As depicted in the above Figure 6, the Johannesburg Park Station provides for an integrated and effective routing and circulation system which reduces the number of transfers required by commuters. It ensures safety for higher numbers of commuters; it promotes the use of public transport and non-motorised transport and encourages the integrated development of surrounding land uses. Each transport mode at the station supports the others by helping to redistribute commuters who overlap among them and caters for commuters' requirements and demand. The station draws large commuter flows in a short time, generally during the peak hours, when numbers of trains, buses and long-distance commuter transport arrive. These commuters are distributed to their destinations by various modes of transport such as *Gaubus*, *Rea Vaya*, *Metrobus* or walking, which is also supported by the surrounding road networks. Findings from key informant personnel from the municipality revealed that the station was planned to take into consideration the demand for gathering and distributing commuters. The 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.

Currently, plenty of middle-income residents in Johannesburg have abandoned private automobiles in favour of public transport. 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. Furthermore, if the *Rea Vaya* bus can improve the time intervals between buses and the reliability of the 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.

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 considered when calculating 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.

3.1.3. The function of the Inner-City Integration Point C

Inner City Integration Point C includes areas such as Marshalltown, Gandhi Square, Carlton Centre and Ferrierasdorp. It is both a popular tourist attraction, and a busy urban hub of administration, commercial, retail activities and high-density residential areas of the inner city. 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 Jeppestown. Figure 7 below depicts *Gaubus*, *Rea Vaya*, *Metrobus* and *Metrorail* network integration point C in the inner city.

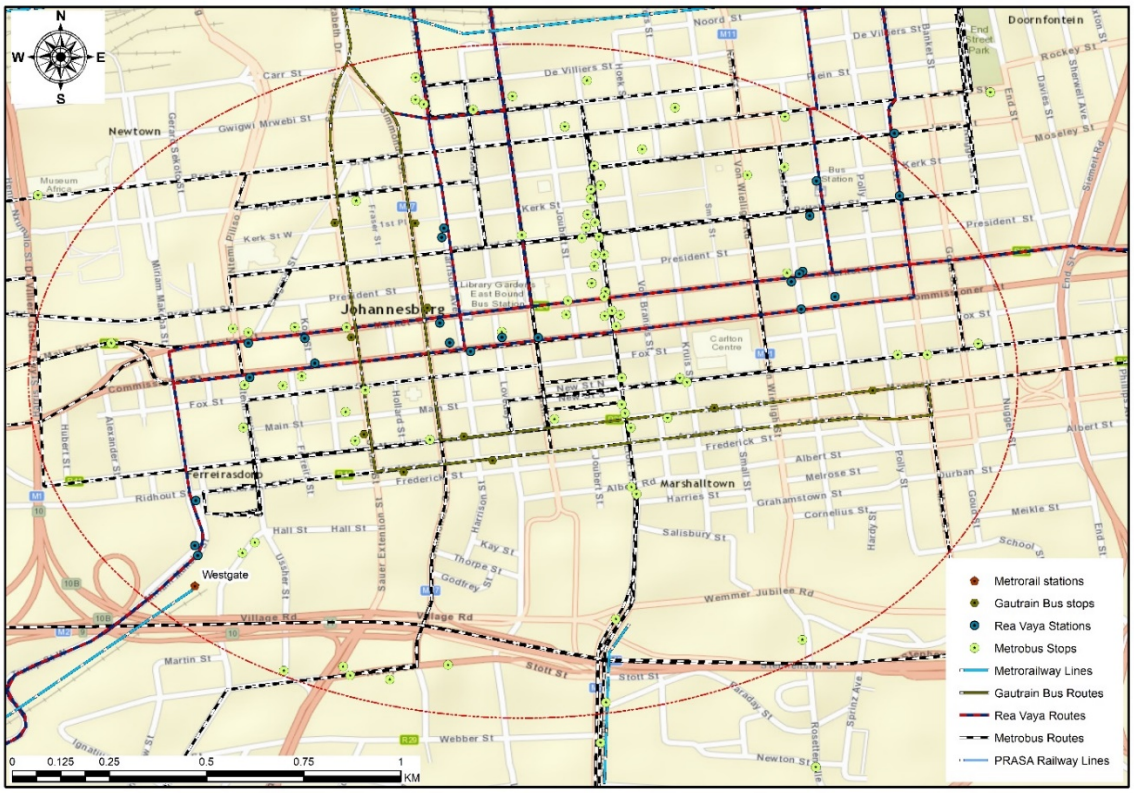

Figure 7. Inner City urban public transport routes Integration Point C

The *Gaubus*, *Rea Vaya*, *Metrobus* and *Metrorail* routes, as illustrated in Figure 7 should also be noted as essential feeders and distributor routes in the area. The inner-city integration point C acts as the main central bus terminus for *Metrobus*. Additionally, the *Gaubus* and *Rea Vaya* routes networks are integrated in this area, allowing public transport commuters to switch between modes smoothly at a short walking distance. Again, there is still no sharing of infrastructure amongst the urban public transport modes. The public transport morning peak-hour demand in this integration point is predicted to reach about 617 000 commuters by 2040, from 298 000 in 2010 (Risimati and Gumbo 2019). With public transport demand expected to be higher by 2040, there is an increasing need for prioritising investment in public transport infrastructure and services across metropolis. The City has realised that enhancing mobility through the provision of reliable public transport will play a key role in improving its economic viability. The Johannesburg Transport Department is thus further developing and promoting the use of urban public transport and non-motorised transport as an increasingly attractive and viable option through strategic public transport infrastructure development and investment initiatives.

3.2. Analysis of Urban Public Transport Networks Integration in the Soweto

Soweto is one of the more densely populated areas in Johannesburg, already housing more than a third of the City's current population (Mokoena et al 2019). There is also evidence of a growing middle class. The low density-built form leaves pockets of spaces for densification strategies especially around defined nodes, both appropriate for mixed use and TOD. In terms of public transport, Soweto is serviced by *Rea Vaya*, *Metrobus* and *Metrorail*; and is located in relatively close proximity to the metropolitan core. *Metrorail* operates commuter trains between Soweto and Inner City. Soweto train stations are at Naledi, Merafe, Inhlazane, Ikwezi, Dube, Phefeni, Phomolong, Mzimhlophe, New Canada, Mlamlankunzi, Orlando, Nancefield, Kliptown, Tshiawelo and Midway. Existing *Metrorail* stations and *Rea Vaya* Station open possibilities for mixed use transit-oriented development. Street networks are well connected internally with high levels of walkability. Figure 8., depicts potential areas of *Rea Vaya*, *Metrobus* and *Metrorail* network integration in Soweto.

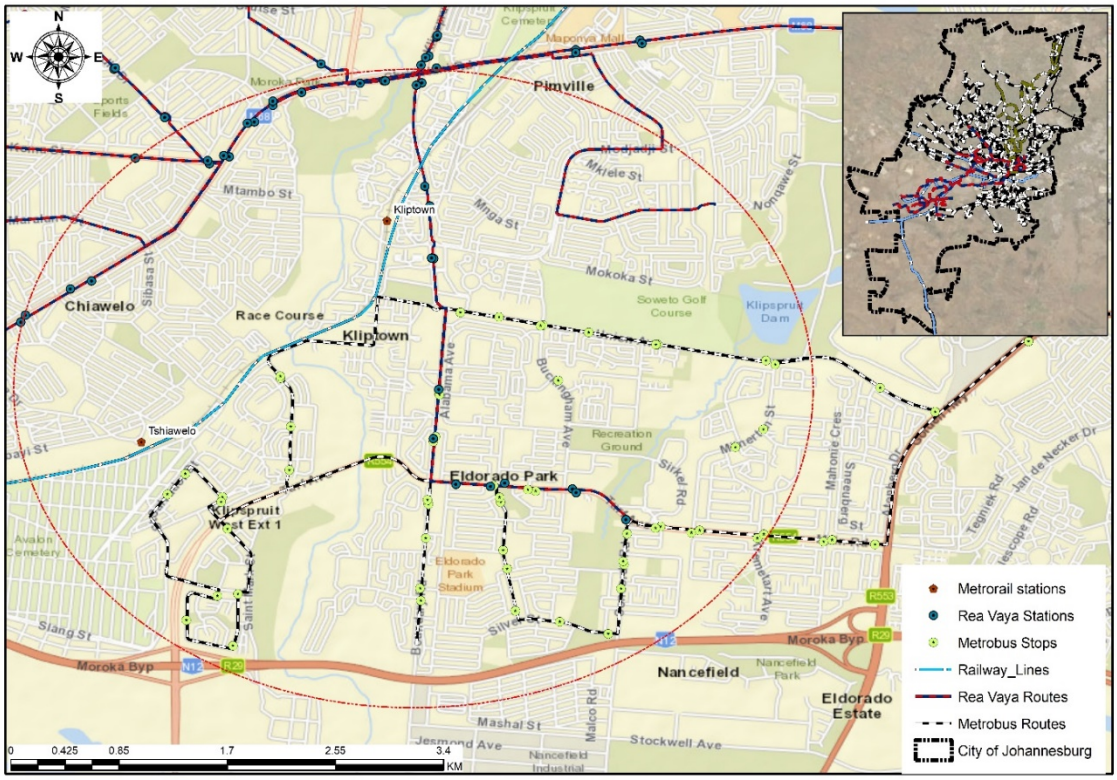

Figure 8. Soweto urban public transport routes Integration Point

With reference to the above, Figure 8., the existing network and station infrastructure *Rea Vaya*, *Metrobus* and *Metrorail* can open possibilities for mixed use transit-oriented development. However, there is currently no sharing of infrastructure, and street networks are well connected internally with high levels of walkability. The *Metrobus* within Soweto covers specific routes to accommodate people with disabilities, offering them a service to and from work. There are six *Metrobus* buses that run along the following routes within Soweto: Soweto to Eldorado Park, Soweto to Johannesburg, Naturena to Johannesburg and Johannesburg to Sandton. The *Rea Vaya* assists with the daily transport of workers from Soweto to Johannesburg and around the City. The *Rea Vaya* route in Soweto starts in Noordgesig and travels through Pimville, New Canada, Highgate, Auckland Park and Braamfontein to Parktown, plus the Metro centre and Rissik Street in the CBD. This route makes it possible for commuters to easily reach key public healthcare centres such as the Rahima Moosa, Helen Joseph and Charlotte Maxeke hospitals. Commuters using the route also gain easily access educational institutions and workplaces. *Rea Vaya* feeder buses run from Protea Glen to Thokoza Park and from Eldorado Park to Lake view. The intermodal hub at Park Station links *Metrorail*, *Metrobus* and *Gautrain* services.

3.3. Analysis of Urban Public Transport Networks Integration in the Rosebank

Rosebank is a vibrant multi-cultural district, business node and tourist attraction. It is a cosmopolitan commercial and residential suburb to the north of central Johannesburg. It is home to many head offices, and also provides an abundance of entertainment to its residents and visitors at a variety of superb shopping malls, pavement cafes, world class restaurants, markets, luxurious hotels, cinemas, art galleries. Due to its compact size, visitors, residents and workers can walk in the area, enjoying the outdoor atmosphere en-route to their destination. One of the latest and undoubtedly most exciting developments to take place in the area, is that of the *Gautrain*, for which Rosebank has been selected to serve as the location for one of the five stations. *Gautrain* operates a train from Park Station to Rosebank every 15 minutes. *Metrobus* operates from the corner of Jan Smuts Avenue and Empire Road in Braamfontein to the corner of Jan Smuts Avenue and Tyrwhitt Road in Rosebank. Figure 9., depicts areas of *Metrobus*, *Gautrain*, and *Gaubus* network in Rosebank.

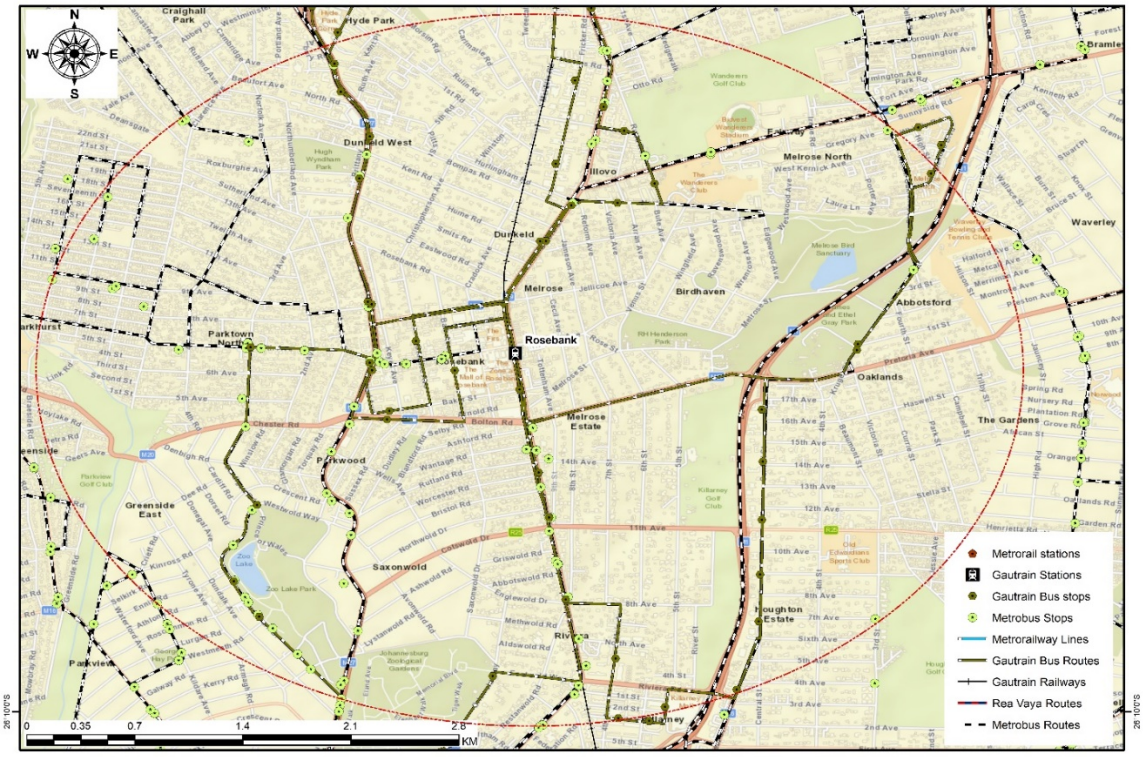

Figure 9. Rosebank urban public transport routes Integration Point

As depicted in Figure 9., existing *Gautrain* and *Metrobus* networks are spatially integrated. However, there is no sharing of infrastructure between the different modes of urban public transport as they operate independently in this area. The greater part of the *Gautrain* and *Metrobus* stations is situated within the high commuter mobility concentration zones. Thus, the partnership between the two modes would be of benefit for promoting multi-mobility, multi-modality and sharing of infrastructure in Rosebank. Within the planned construction of the 20 km cycle lanes linking Rosebank, Melrose Arch and the parks, the area is in line with the City's plan of embracing alternative modes of transport.

3.4. Analysis of Urban Public Transport Networks Integration in the Sandton City

Sandton is a node that continues to be South Africa's premier office location, and it is anticipated to grow slowly and steadily. It has become the largest financial district of South Africa and is Johannesburg's most prominent business centre. Evidence supporting this statement is the presence of banking head office buildings such as Nedbank, Deutsche Bank and the Johannesburg Stock Exchange located on Maude Street. The node attracts daily commuters from all over Gauteng province. People travel not only from the neighbourhood adjacent to Sandton but from places as far

away as Pretoria north, Roodepoort, Benoni, Vanderbijlpark and the East Rand. Figure 10., illustrates areas of the urban public transport network in Sandton.

Figure 10. Sandton City urban public transport routes Integration Point

As illustrated in the above Figure 10., there are areas where urban public transport network is integrated within the Sandton City, although the system does not share infrastructure. The challenge for Sandton is to facilitate continuous development and growth in the context of additional travel demand and a limited transportation network that cannot be expanded easily. Transport infrastructure providing access to these nodes was initially designed to accommodate residential land uses and at most limited commercial land uses. To accommodate increased travel demand, it was possible to widen existing roads and sometimes even to establish one or two new links, creating more capacity on the transport network. However, in time, most of the road upgrade opportunities have been exploited (i.e., the additional through lanes, left slip lanes and right turning lanes have been constructed). The node is prone to traffic congestion during peak times. However, some of this congestion may be alleviated in the future as a result of the continued improvement in infrastructure along with the well-established public transport system which is offered within the Sandton area, inclusive of the *Gautrain* Station and bus feeder routes.

Sandton Central is a key destination in the R3 billion Phase 1C of *Rea Vaya*, which began construction in 2014. This phase comprises 16 km of dedicated trunk route that extends Rea Vaya's route from Parktown to Alexandra and on to Sandton and beyond, with further complementary and feeder routes to and from areas including Sunninghill, Midrand and Ivory Park. The *Rea Vaya* infrastructure also features 30.5 km of walking and cycling paths and a dedicated cycle and walking path from Alexandra to Sandton. The system also creates interchanges that link with other modes of transport, such as *Metrobus*, and minibus and metered taxis as well as walking and cycling. Phase 1 C includes a number of interchanges in Sandton Central, Alexandra and the CBD. The Sandton Central interchange creates a new transport system that also includes the *Gautrain.* The City's official who was interviewed outlined that "*Rea Vaya* will have at least two stations in Sandton Central; making it easier to get around Sandton Central, and commuters will be able to get on and off buses along the public transport loop, with dedicated kerbside bus lanes. There will be several

stops along the route, which begins at the Katherine Drive *Rea Vaya* median station, turns rights into West Street, then right into Rivonia Road, and proceeds left into Fredman Drive, then left into Fifth Street and left to the Rivonia *Rea Vaya* station beside the Sandton *Gautrain Station*". With Rea Vaya, the is adding to the transport modes in Sandton Central and improving those already in place.

4. Recommendations

Integrated public transport planning improves a city's connectivity, providing a better mobility service, shorter journeys for the commuters, and also brings people and places closer together. As part of this, public policy and planning actions should consider integrating infrastructures and operations of urban public transport systems and create easy connections with non-motorised transport (such as walking and cycling). Well integrated public transport modes will increase their usage by commuters. This paper's departure point is that as commuters get more value for money, they will consider public transport as a more convenient mobility option that private motorized transport. 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.

4.1. Contempt of modal integration for spatial connectivity

Because different spheres of government have implemented their projects independently in Johannesburg, spatial connectivity through multimodal urban 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 urban 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 transport most commuters 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 programme did not do justice to the transformation of the mini-bus taxi industry. Instead, public funds were spent without even redressing the alarming safety and crime concerns. This was also done without regard for modal integration. 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 the purpose it serves was found to be also 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 significantly excludes the urban poor and previously disadvantaged communities, thus making its significance limited to connecting major economic nodes for business related trips through serving the middle-upper income transport commuting market (Chakwizira 2007). Thus, the need to integrate all (innovative and traditional) 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 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 transport commuters between residential and economic or other urban opportunities. A multimodal public transport network will enhance spatial connectivity, densification, reduce travel ties and costs and thus enhance efficiency of public transport systems. Through modal integration, infrastructure investments will be utilised more effectively to enable comprehensive public transport throughout municipal areas instead of unnecessarily duplicating services.

5. Conclusion

This paper has deliberated on the spatial patterns of urban public transport systems within the City of Johannesburg. Spatial analysis of both forms of innovative urban transport systems (Rea Vaya and Gautrain) and traditional urban public transport systems (*Metrobus* and *Metrorail*) were conducted. Urban public transport systems spatial connectivity was discussed with reference to the effects of urban public transport mobility. this chapter explored the extent of routes network integration of *Gautrain*, Rea Vaya, *Metrobus* and *Metrorail* within the Johannesburg urban

public transport system. The results indicate that there are limited spaces where networks of urban public transport systems are integrated, and large sections of the networks are disconnected. In particular, the existing transport networks are spatially segregated and there is no partnership between the four 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 purposes.

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