Using Accessibility to Investigate the Level of Integration of the Various Public Transport Systems within the City of Johannesburg

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Abstract

The main focus of this study was to investigate the level of integration between various public transport systems operating within the City of Johannesburg. Accessibility was used to evaluate integration, since integration influences accessibility. Easy access to available public transport from departure points, enables movement between locations and easy reach to goods and services. Two methods were used: the first created 400-metre buffers around the public transport stops, stations and ranks to estimate the service areas for each system and the area served by an integrated public transport system. The population within the buffers was calculated to estimate how many people have access to public transport. The second method used a commuter survey to examine travelling experiences. The results obtained show accessibility varying between transport types: the Metrobus and taxis serve larger areas than the Gautrain, Metrorail and Rea Vaya. However, taxis served the largest population in comparison to all other public transport systems. The results also indicated that the primary public transport systems operated on a fragmented level spatially, with only 0,1% of the spatial area served by an integrated public transport system. The significance of the study was to aid in transport planning. Public transport should be easily available and accessible, so that basic services, jobs and education can be accessed with ease.

Keywords: Public transport integration, Accessibility, Commuter survey, Service area

1. Introduction

The City of Johannesburg's public transport system is crucial for supporting commuting and access to places where goods, services and job opportunities are. However, to reap the benefits of using this public transport system, the various public transport modes need to be integrated to facilitate easy mobility around the city.

Integration is defined as the connection of various variables to form one whole primary system. Dill (2004) defines connectivity as the act of bringing together or coming into contact to establish an existing or supposed link in order to provide access and contact. Connectivity allows links between locations to which people travel and is therefore considered an important concept in transport networking (Dill, 2004).

Public transport is any form of transport available and accessible to the public, that charges a set price and operates on fixed routes (Concise Oxford, 2000). The City of Johannesburg's public transport system is composed of various road and rail modes, namely: the Gautrain Rapid Link and its bus service, the Rea Vaya Bus Rapid Transit system, the Metrorail train, the Metrobus, Putco and other privatised bus operators, mini bus taxis and metered taxis.

Public transport is necessary to transport the majority of the people who live in Johannesburg, which had a population of 4 434 828 in 2011 (Harrison, et al., 2014). This is because the majority of the people who reside in and around the city cannot afford private vehicles and therefore depend on public transport. Public transport services are also a way to decrease traffic congestion on roads.

This study reviewed the spatial distribution of the public transport network system in Johannesburg and the level to which this network system is integrated, based on the ease of access to public transport within a 400m radius from the initial point of departure.

2. Study area

The Gauteng City Region is approximately 200 km north to south and 190 km east to west with an area of approximately 18 179km^2 in which 1 645km^2 encompass the City of Johannesburg (Gotz, et al., 2014). The City of Johannesburg is spatially segmented into the richer north – where suburbs like Sandton, Rosebank and Northgate are located – and the poorer south – in which townships like Soweto and Orange Farm are located (Gotz, et al., 2014). The city is subdivided into seven administrative regions, A to G, as shown in Figure 1.

Johannesburg fast became the economic, business, corporate and logistic heart of the country (Todes, 2011). It connects with other parts of the country and the globe at large through a public transport system composed of road, rail and air transport network systems (City of Johannesburg, 2015). The city's population was recorded to be around 4.4 million in the year 2011 with a density of 2 675 people per km^2 (City of Johannesburg, 2013c).

3. Literature review

3.1 Public Transport System in the City of Johannesburg

The City of Johannesburg's main transport system consists of road and rail networks. The Metrobus and Rea Vaya Bus Rapid Transit systems are the municipal bus services (Adewumi & Allopi, 2013). The Putco, Soweto, Eldorado Park, South Western Areas and Katorus bus services are also provided through the Metrobus Company (City of Johannesburg, 2013c).

The rail system operated by Metrorail is run under the Passenger Rail Authority of South Africa (PRASA) (City of Johannesburg, 2013c). The Gautrain, operated by the Gautrain Management Agency (Walters, 2014), was implemented less than a decade ago. This high speed-train has been designed to connect the three municipalities of Gauteng, the Cities of Johannesburg, Tshwane and

Ekurhuleni (Moyo & Musakwa, 2016). The Gautrain Bus Service offers transport to Gautrain passengers and other commuters around the stations (Moyo & Musakwa, 2016).

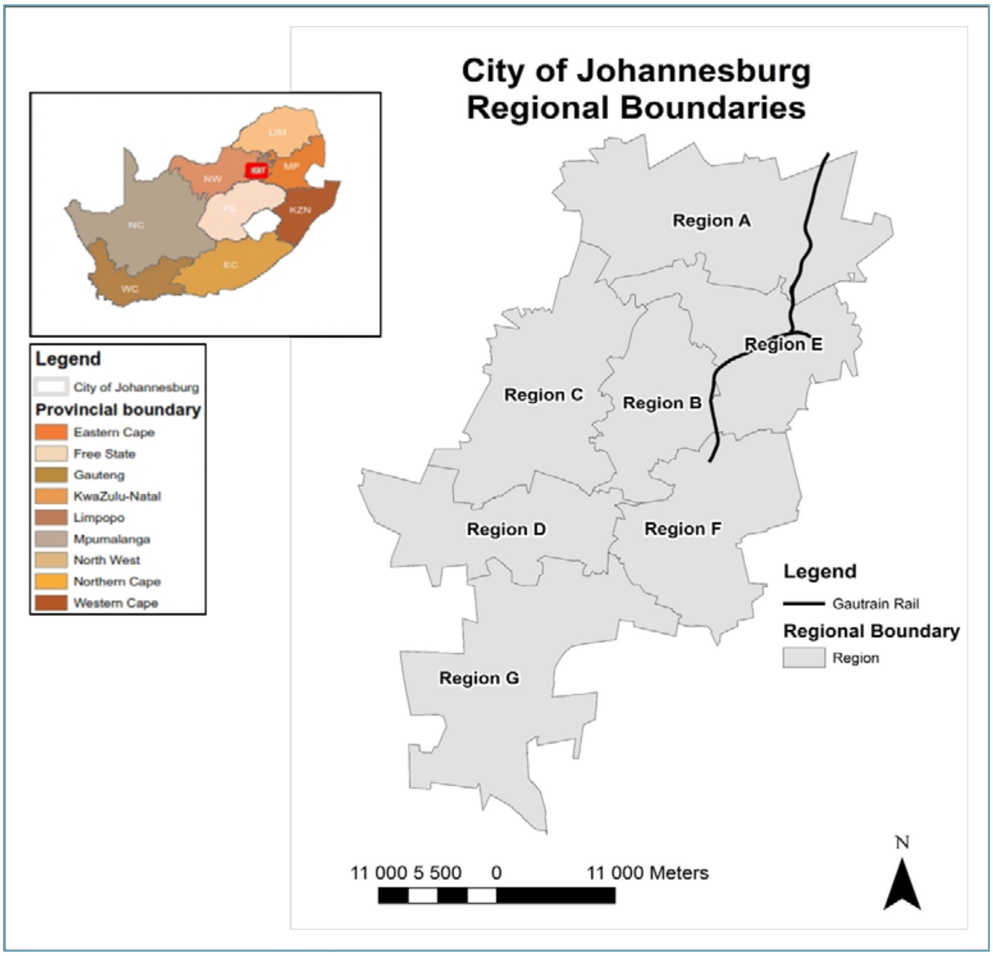

Figure 1. City of Johannesburg Locality Map

A less formal public transport system is the minibus taxi system run by at least 32 Taxi Associations with limited influence from the government (City of Johannesburg, 2013c). Walters (2008) evaluated the public transport policy development of the three main types of public transport: minibus taxi, railway train and bus. The White Paper on National Transport Policy of 1996, the Moving South Africa Strategy (MSA), the South African Government's Public Transport Policy and The National Land Transport Transition Act of 2000 (Walters, 2014) are some of the policies that have been implemented to enhance the public transport network system, to correct inequalities from the past, and to address the issues of efficiency, accessibility and integration of the public transport system in the city (Walters, 2008).

3.2 Integration, Connectivity and Accessibility

Although public transport is not considered a right, Mokonyama & Mubiwa (2014) mentioned that it is a necessary service to access basic rights like healthcare, education, food and water, and to allow freedom of movement. To ensure access to these basic human rights, public transport needs to be efficient, in terms of both cost and ease of travel (Mokonyama & Mubiwa, 2014). Intergrating public transport will therefore enhance the ease of movement from one place to another. Such integration is the combination and connection of various individual public transport modes into one whole network system that works on an integrated front.

The literature provides various methods of measuring connectivity, namely the block length, block size, block density, intersection density, street density, connected node ratio, link-node ratio, grid pattern and pedestrian route directness methods (Dill, 2004). However, these methods work well for street networks rather than public transport network systems.

According to Litman (2015), integration and connectivity impact accessibility; accessibility will therefore be evaluated in this study and the results will be used to evaluate the level of integration of various public transport systems. Litman (2015) evaluated accessibility for transportation planning by observing factors that influence accessibility, which is related to the people's ability to access goods, services and activities. In his study, Litman (2015) states that there are several factors that affect accessibility, mainly the condition of the vehicle used during travel, the quality of other modes, the connectivity of the transport network and the nearness of land use looking at distances between activities. Accessibility in public transport analyses factors such as the availability of public transport within a certain distance from home or work, the number of transfers between travels, the distance of travel between home and service facilities and the time spend accessing public transport.

The shorter the time of travel and waiting between transfers and the lower the costs given the distance travelled, the greater the accessibility of public transport and therefore the higher the level of network connectivity between various public transport systems. Litman (2015) relates accessibility to integration by the extent of integration between transport system links and modes. He links accessibility to network connectivity through the concentration of road and trail connections, and thus the directness of travel between destinations (Litman, 2015).

3.3 The use of GIS to Investigate Accessibility

Topological, logical and structural relationships are used in GIS to analyse the network connectivity of the spatial entities under study. In the case of transportation, the connectivity of a street network is analysed by investigating the extent to which streets connect at nodes (Jiang & Clatamunt, 2004). However, in the case of public transport, especially within the City of Johannesburg, where public transport is composed of formal and semi-formal road and rail modes, analysing connectivity using the city's street network might not bring feasible results.

Common network analysis tools which used to navigate and route through network data of similar type, cannot simply be adapted to route through a public transport network. ArcGIS, for example, automatically assumes that all junctions computed by the network analysis dataset are points at which public transport can be accessed, while in reality only the stops, stations and ranks are entry points to public transport modes.

O'Sullivan *et al* (2000) used traffic and time data to investigate accessibility of public transport by implementing space-time accessibility measures (STAMs), taking into account the locations, travel velocities and the commuters' every day schedules (Miller & Wu, 2000).

Litman (2015) observed that there are several factors that influence accessibility and therefore several methods need to be incorporated to measure accessibility. The walkability, namely the quality, time and distance to walk to first entry points of public transport should be analysed. This analysis is measured by observing the generalized costs relating to time and money. This is done by assessing the commuter's perception as well as total costs by assessing the society's perception (Litman, 2015).

Geertman & van Eck (1995) used composite measurement methods using the distance between the commuter and his destination and the convenience of the different destinations. These methods observe the number of destinations that can be accessed from the point of departure. A single index location profile is then produced that shows the number of destinations, like basic services, work and educational facilities that can be accessed as the distance covered increases (Geertman & van Eck, 1995). More destinations given the distance covered indicate easy access to opportunities.

3.4 Human Walking Distance to Access Public Transport

The current study focuses on accessibility to public transport by walking. Various studies have been conducted to investigate how far a normal person can walk. Morris *et al*. (1978) determined that the acceptable walking distance for a person to access public transport is 400 metres. This 400-metre acceptable walking distance to public transport is also documented by Daniels & Mulley (2013), where they investigated the influence in the walking distance from initial places of departure to points at which they could access public transport. Daniel & Mulley (2013) state that service planners set a guideline of 400 metres as the main distance in network and service planning. Phaphana (2014) also used a 400m acceptable walking distance in her study of food environments in Pretoria, South Africa.

Although this guideline is adopted by other authors researching public transport, the acceptable walking distance a person can take is dependent on factors like the person's age, gender, physical condition, what they are carrying, working status, their journey purpose and time. Walking distance to public transport is vital because it influences the rate at which public transport is accessed and used while ensuring the safety of the commuters. Transport planners and land use planners should therefore ensure that public transport can easily be accessed from initial points of departure to increase in public transport usage.

4. Methodology

The following are the objectives that the study aimed to achieve:

- For each public transport system, investigate the area served within Johannesburg.
- Investigate how many people have access to each public transport system.

- Investigate the area served by an integrated public transport system.
- Investigate how many people have access to an integrated public transport system.
- Using a commuter survey, assess the commuter's perception of public transport in Johannesburg.

4.1 Data sourcing

The City of Johannesburg Transport Data was obtained through the City of Johannesburg's Directorate: Corporate Geo-Informatics (CGIS), Development Planning, from various City departments. The data included public transport datasets showing locations of the BRT, Gautrain, and Metrorail, the Metrobus and taxi routes and stops. This data was necessary to compute accessibility with respect to the 400m walking distance to public transport stops. The City of Johannesburg also provided township and regional boundaries. The Demographic Population Neighbourhood Growth Data for the City of Johannesburg was collected from ESRI, which included, but was not limited to, the population data, migration data, demographic data and other statistics data. This was necessary to calculate the spatial distribution of the population within the 400m buffers.

4.2 Data processing

ArcMap 10.3.1 was used for all data processing. A 400m buffer was generated for each individual public transport stop and station. Public transport stops and stations are the only assumed points at which commuters can get on and off public transport modes. The 400m buffer therefore represents service areas within which the various public transport systems are available and can be accessed by a person. The areas of each public transport system service areas were computed, fractioned and compared to the entire area of the City of Johannesburg, which is 1645km^2.

All generated 400m buffers where overlaid to investigate the total spatial area in which the various public transport systems co-operated spatially. The population distribution was computed for all 400m buffers. The larger the population of people who can easily access public transport closer to their initial points of departure, the easier it is for people to get to places of work, school and services.

4.3 Public transport commuter survey

Survey 123 for ArcGIS was used to implement the online survey. The following information was collected and analysed from the survey:

- The public transport systems used mainly by commuters.
- The difference in the travel time which could indicate a difference in accessibility in certain regions and a variation in traffic in different directions.
- The number of transfers that commuters take during their journey.

- The time is takes for commuters to reach public transport stations and stops. The longer it takes a commuter to reach public transport indicates that public transport is not easily accessed or unavailable.

5. Analysis and results

5.1 GIS analysis

The fraction of the area served by each public transport was compared to the total City of Johannesburg boundary area of 1 645km^2 and the recorded total population of 4 716 249 in 2014 is derived from the Demographic Population Neighbourhood Growth Data. Table 1 below shows the spatial areas computed in ArcMap that each public transport served in metres squared, the percentage area and population served relative to the total boundary area and population of the City of Johannesburg.

Table 1: Spatial Areas and Population Count for each Public Transport Service Area

Public Transport Mode	Spatial Area Served (km^2)	Percentage of Area of City of Johannesburg	Total Population Served	Percentage of Population Served
Gautrain	2.5	0.15 %	21 606	0.46%
Metrorail Train	27.3	1.66 %	332 303	7.05%
BRT Rea Vaya	59.1	3.89 %	830 990	17.62%
Taxi	165.8	10.08 %	2 282 820	48.40%
Metrobus	300.3	18.24 %	1 359 897	28.83%

Figure 2 below shows the spatial distribution of each public transport stop within the 400m buffer as well as the population distribution within each buffer, as summarized in Table 1. Integration evaluates connectivity between various variables. These variables are the various types of Public Transport Systems that operate within the City of Johannesburg.

Unsurprisingly, only 0.02% of the total area was served by all five public transport systems individually. This is where 0.21% of the population had access to all five public transport systems within a 400m walking distance. 0.12% of the total area was served by all four public transport systems in Johannesburg excluding the Gautrain, with only 1.06% of the population in the city. The Gautrain is a recent infrastructure with only 4 stations that exist in Johannesburg and was thus excluded to evaluate the difference it constitutes to an integrated system.

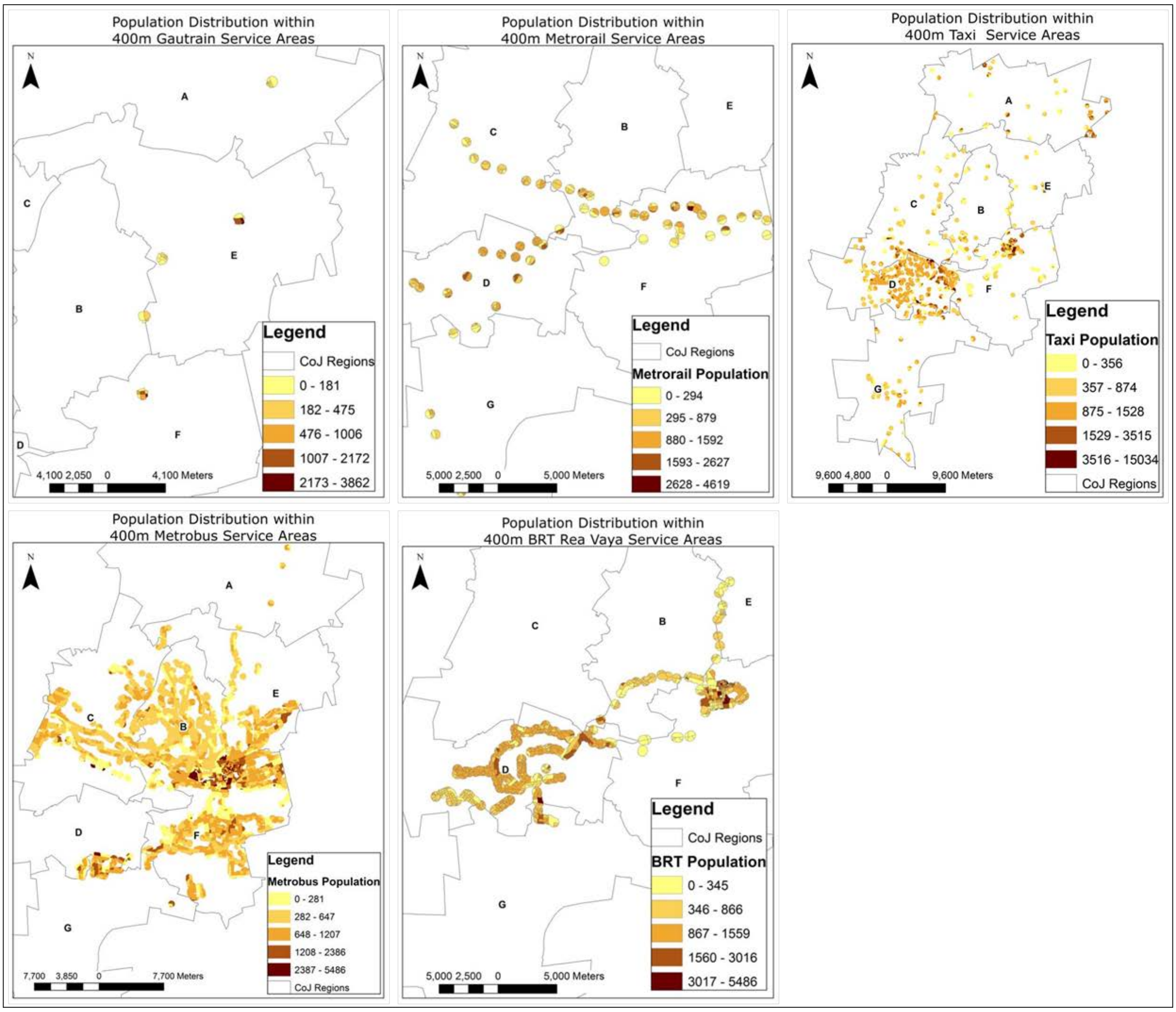

Figure 2: 400m Service Areas and Population Distribution

5.2 Commuter survey

A commuter survey was conducted from June to September 2017 using Survey 123. A sample of 44 commuters was used for the analysis and reporting. The participants are predominantly public transport commuters who work and study in the City of Johannesburg's CBD and surrounding area.

The following information was collected and analysed from the survey:

a. The public transport systems most used by commuters.

The results show that 38 – 40% of the participants use taxis as a mode of commuting. The Rea Vaya BRT is the second most used mode of public transport, followed by the Gautrain. This can indicate that the majority of participants live in and around regions where these three modes are available. Although shown to serve a larger population after the taxis in Section 5.1, only 2 – 4% of the participants use the Metrobus. This could be because the participants do not live in areas where the Metrobus is available.

b. Accessibility to Public Transport

Over 80% of the participants walk to access public transport at their designated stops, stations and ranks. This might indicate that the nearest point to accessing public transport can be reached by walking from their homes, work or educational facilities. However, some participants drive to access public transport, most especially to the Gautrain and Rea Vaya BRT where parking facilities are available for commuters who are mobile.

c. The time is takes for commuters to reach public transport stations and stops.

At least 70% of the participants travel less than 15 minutes to points at which public transport can be accessed at Point A, while 45% of the participants travel less than 15 minutes to access public transport at Point B. This can be an average distance of 1 500 metres for an average person walking on average speed. Time taken to access public transport is vital. To promote an increasing use of public transport, commuters need to access public transport closer to where they live. This means that commuters will use public transport if they travel shorter distances to the initial points of access.

d. Average time taken during transfers

Observing the average time taken during transfers, 57% of the participants take 15 minutes and less transferring from one mode to another during a single trip, while 19% of the participants take longer than 15 minutes to transfer. The longer time during transfers indicates that commuters need to add extra time to their travel journey, while some participants have to wake up earlier than usual in order to get to work or school on time. This therefore implies that transfers are time consuming and are best minimized during trips.

The sample size is relatively small to the total population of Johannesburg. Therefore the response to this perception is dependent on where the participants travel from as well as the availability and access to public transport from their point of departure.

6. Discussion and conclusions

The study evaluated the level of integration of the various public transport systems that operate within the City of Johannesburg. Accessibility was the factor used to evaluate integration. Integration allows connectivity between various public transport systems. A highly integrated system therefore enables people to have access to public transport points and promote movement from one place to another. 400-metre buffers around the five public transport stops, stations and ranks comprising of the Metrobus, Metrotrail, Gautrain, BRT Rea Vaya and taxis where computed using ArcGIS to calculate the service areas served by each transport mode.

The Metrobus served a larger area in the City of Johannesburg, followed by taxis, BRT Rea Vaya, Metrorail and lastly the Gautrain. However, the taxis served a larger population amounting to 48% of the total population of Johannesburg, followed by the Metrobus, the BRT Rea Vaya, Metrorail and lastly the Gautrain.

Observing the spatial area at which all public transport systems served on an integrated space, a small area namely 0.02% of the entire area of Johannesburg was served by all five public transports. This indicated that accessibility to a highly integrated public transport was not probable to over 99% of the spatial area in Johannesburg.

Observing the geospatial data, accessibility varies throughout the city. The Regions B, C, D, E and F have a rich supply of public transport stops and stations, while Regions A and G which constitute the northern and southern regions in the city respectively lack in the choice of public transport commuters can use. A rich supply of public transport allows better access to a large available public transport system and therefore allows a better and easy movement between locations given time and cost of travel. The lack in access to public transport indicates that the public transport system in Johannesburg is not integrated.

From the results and analysis, it can be deduced that public transport is neither easily accessed nor available to the larger population living in the City of Johannesburg. Furthermore, a very small population can access and have a choice of using any of the five public transport systems from their point of departure.

Assuming the accuracy of the data used during the analysis, the conclusion is that the various public transport systems within the City of Johannesburg operate on a fragmented spatial area, and therefore are not integrated.

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