The Potential of Using Volunteered Locational Data in Planning for Smart Multi-Mobility Systems

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1 ABSTRACT

Development of smart mobility systems in recent literature has received great interest, as many cities thrive to become smarter. As mobility plays an integral part in shaping citizens' lived experiences, improvement of mobility modes would lead to better quality of life in the city. Also given the correlation with economic activities within the city, investment into smart mobility systems promises many capabilities for city planners. To achieve this aim, the paper proposes the examination of factors which determine demand and supply capability of public transport systems (namely the Gaubus, a form of Bus Rapid Transit in Johannesburg, South Africa). Using an empirical research design, and quantitative data in the form of questionnaires and spatial data we determined the factors which influence demand and supply. A set of indicators were consequently developed to score these factors. The results reveal that commuter mobility choice is dependent upon distance travelled to bus/train station and also availability of alternative connecting points to other forms of mobility. Hence to promote the use of public transportation in the city, there is a need to improve connectivity between the various modes of mobility.

Keywords: Demand and supply; mobility; quality of life; public transport

2 INTRODUCTION

Development of smart mobility systems in recent literature has received great interest, as many cities thrive to become smarter. As mobility plays an integral part in the shaping of citizens' lived experiences, improvement of mobility modes would lead to better quality of life in the city. Given how public transport is a key feature in sustainable growth, it should be designed to become flexible and meet the continuously changing demands in modern cities (Gheorghiu and Surugiu, 2015); notwithsatnding the importance of understanding the needs of passengers, as they play a vital role in ensuring the success of the mobility system. Hence commuter satisfaction has become an area which public transportation providers seek to understand and manage (Mouwen, 2015). Effective collaboration from various organisations should be a shared priority by all key stakeholders to reach an efficient and smart public transport system.

The City of Johannesburg has an objective to identify the movement patterns at the major taxi ranks, Metrorail, Rea Vaya and Gautrain stations with the aim to upgrade road facilities such as pavements, signage and lighting (Chakwizira, 2007). The provision of infrastructure for public transportation has been perceived as an interesting and acceptable solution to traffic congestion that needs to be seriously considered (Mbara & Celliers, 2013). Theoretically, such investment into the public transportation sector was supposed to encourage the use of public transportation within the city. Unfortunately, due to the lack of co-operation from the various public transportation providers, the shift by citizens to move to public transportation has been slow. There have been incidences where commuter mini-bus taxis use the green lanes for parking (Musakwa and Selala, 2016) and the Bus rapid transportation (BRT) lanes to overtake, offload or pick up passengers (City of Johannesburg, 2013). Given the correlation with economic activities within the city, investment into smart mobility systems promises many capabilities for city planners as the public would be involved in the co-creation of the public transporation system. To achieve this aim, the paper proposes the examination of factors which determine demand and supply capability of public transport systems, namely the Gaubus, a form of BRT in the City of Johannesburg, South Africa.

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3 CONCEPTUAL FRAMEWORK

While the word innovation is derived from the Latin noun innovates, the modern interpretation of innovation relates to new combinations of existing or new data, services, tools, and other factors. With regard to transport planning it is about the changes that occur in the management of challenges of maintaining the relationship between supply and demand. The transportation industry has remarkably grown robust and has adapted to the various situations that have emerged over the years (Banister, 2008). Bretzke and Barkawi (2013) have given an example of a crisis of congestion at intersections. Through the use of technology, traffic is now being controlled at intersections, however it remains unclear how the traffic situation would have adapted if these systems had not been put in place.

According to Dziekan and Kottenhof (2007, p 490), “experts in the public transport information provision do not directly attribute travel mode choice to new technologies. However, travel behaviour and attitudes are contributing factors towards the choice of transport.” The Science International Cooperation (2003) found that at bus stops, real time displays were consulted more often than other printed information such as time tables. It is therefore important to understand the ‘effects’ or categories of real-time public information displays. Seven categories have been identified: reduced waiting time, positive psychological effects, adjusted travel behaviour, modal choice, higher customer satisfaction and better image (Dziekan and Kottenhof, 2007). Rakabe et al (2017) have shown that providing good quality, dependable, up to date information may be an effective way to achieve sustainable mobility.

Modern cities have managed to balance the relationship between supply and demand of services through clear planning strategies which advocate smart solutions to the ever increasing demand for public tranportation services. The end goal is not to prohibit citizens to use their private cars, but to create an enabling smart system at a suitable scale which would lead to citizens not needing to own or drive a car (Banister, 2008). To go one step further local authorities in cities like Beijing in China have also adopted regulations to control the vehicle market, were they have monthly auctions to get license plates, hence they can control the number of newly registered cars (Attias and Mira-Bonnardel, 2017). Other cities such as Amterdam in the Netherlands have introduced car-free neigbourhoods with the aim to limit the space dedicated to vehicles in public spaces.

Moyo et al., (2018) have expressed how commuters in the global south rely to a great exent on historical experiences when deciding when and how to plan for their trips. Through empirical research, scholars such as Poslad et al (2015) have articulated how urban transportation should not only be viewed as an efficient and manageable system for the city authorities, but that it should meet the needs and wants of the end user, that is the commuter through research into factors that influence mobility and co-creation to plan how and where to supply mobility services. Co-creation is referring to the joint effort by commuters, service providers, city authorities and scholars at large in developing a smart sustainable mobility system.

Other scholars have suggested the use of support systems. Support systems are an innovative approach combining data and the smart city concept, such as decision support systems. Klosterman (1997, p.50) defines decision support systems as systems that “allow decision makers to systematically generate and evaluate a number of alternative solutions.” This approach turns quality of life into a main priority of system development. Given that one of the indicators of quality of life is efficient and reliable mobility, Guo and Schneider (2010) advocate for authorities to merge bottom-up and top-down approaches to planning, to ensure commuters and service provides are both involved the co-creation of the city transportation system.

In understanding how commuters perceive mobility scholars have analysed the factors which influence demand for mobility. Banister (2008) explored how commuter interpretate travel cost and travel time to evaluate transportation as a demand or a valued activity. For most commuters a mobility mode will be favourable if the trip cost is reasonable for a given distance, with most commuters preferring the cheaper option. However with the introduction of new technology, trip travel times have been reduced, hence commuters are now more flexible with this factor. A local example in South Africa shows that previous commuters would only be willing to pay the lowest trip fare; however with the introduction of the Gautrain, commuters are now willing to pay a little extra as the Gautrain will get them to their destination faster than other modes of mobility.

Salonen et al (2014) utilised a combination of mapping travel behaviour responses from a survey of advanced travel models. Their results show that trip distance and travel time play a vital role in daily trips, and, based upon the respondents, that commuters have a skewed estimation of these when they use various modes of mobility. Using GIS software they were able to map the actual distances travelled by commuters. With the addition of data from more than one mobility mode, the GIS algorithms were able to route for each respective mode, saving on time to analyse and interpret the data.

Another mapping tool for spatial analysis is focal statistics. The neighbourhood statistics tool in Arc GIS is used to obtain the relative values of cells with respect to the subject within a particular neighbourhood. The geolocation of commuters can be used as an input for this analysis. This technique has proven usefully in solving real world situations, such as by investigating the correlation connecting an object and similar adjacent similar objects within the GIS environment (Cressie, 1993; Yuan, et al., 2012; Moyo and Musakwa, 2016). Examples include when deciding which service should be made available for a particular location based on surrounding existing services.

Given how the variables which govern demand and supply are ever changing for the development of a smart sustainable transport system in the city there is a need for active citizen engagement which would lead to co-creation. The growth of social media platforms presents a unique data source, as they have become entangled into most citizen‘s lives, as people now post their daily experiences ranging from shopping habits to likes/dislikes, eating preferences and, most importantly, travelling habits. Social media users post which mode of mobility they will use and were they are going. What is most noteworthy about this data is that it can be collected in realtime and it has locational data, hence the service provider can increase supply on a particular route based on anticipated demand. From a researcher pespective one can visualise commuter points of intereset (POI) in the city, and this can be used for route planning (Waze W10, 2014), infrastructure development (Moyo and Musakwa, 2016) and supply and demand management (Bretzke and Barkawi, 2013).

Over the years the development of a transporation model has grown rapidly and the way it visualises the movement of citizens along the transportation network in a specific location. Other scholars have highlighted how this tool facilitates the simulation of the behaviour of the city’s mobility system (Rakabe et al, 2017; Okrazewska et al, 2018; Risimati and Gumbo, 2018). However the question of type and level of citizen engagement is still open, as different designs are being implemented between constraints and incentives (Attias and Mira-Bonnardel, 2017). In responding to the need for mobility management cities globally need to couple offers from local and international players to meet the needs of both the commuter and service provider, whilst relying on technology and tools to develop a smart sustainable system.

4 STUDY AREA

Having an efficiently and effectively run public transportation system is a crucial and indispensable factor for any developing city region. However as the provision of public transportation is a multifaceted process, with intertwining elements such as culture, politics, finance and shareholder interests. Smart means of monitoring and mitigating the challenges faced in the provision of public transportation need to be developed continuously. The Gauteng city region is likewise faced with this challenge. With this region being the economic hub of South Africa, this has greatly affected the operation of the Gautrain system and the BRT systems within the region, as more and more people require a fast and reliable transportation means to move in and out the metropolitan cities.

Currently the city of Johannesburg is grappling with the pressure of growing demand for access and mobility due to a growing population. The increase in demand is not being met by the current investment in transport, especially in public transport. This has resulted in worsening traffic congestion and the deterioration of the public transport service. The Gautrain system has extended the service not only to offer public rail transportation but also a BRT system called the Gaubus (Gautrain Management Agency, 2014). The Gaubus route network covers the northern and central parts of the city of Johannesburg (figure 1). Although the Gaubus was recently introduced, there has been a growing demand for their service, as is evident from the numerous social media posts concerning the Gaubus on Twitter.

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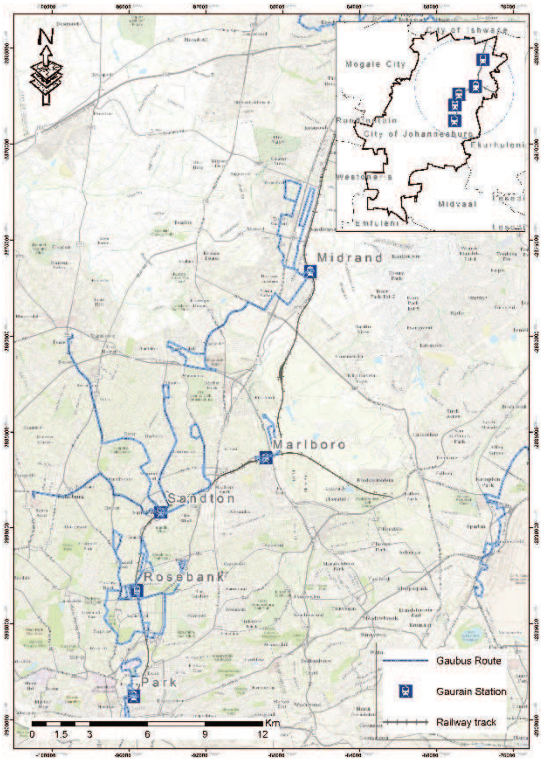

Figure 1: Gaubus Bus Rapid Transportation Route in the City of Johannesburg (Source: Author, 2019)

5 METHODOLODY

The study relied on a questionnaire-based survey that was administered to 60 respondents. The questionnaire had both closed and open-ended questions which were administered online through Google forms so as to obtain a good response rate from commuters who reside within the study area. The questions centred on identifying factors influencing the commuter's travelling patterns (Table 1). Gautrain Management Agency reports and literature were also utilised to supplement infomation gleaned from the questionnaire.

Theme	Criteria	Description
Spatial space	Landuse along the BRT route Infrastructure Accessibility of Bus stop locations	How much are commuters aware about the space around them when they travel using the BRT
Time	Access to BRT timetable Trip duration Trip updates	How much are commuters concerned with the time they take to traversebetween the origin and destinations
Mobility and connectivity	Connetivity to other mobility modes Connectivity to commuter POI	How perceptive are commuters with regards to connectivity at the various bus stops or along the BRT route
Financial Cost	Affordability of BRT	How perceptive are commuters with regards to cost

Table 1: Questionnaire Themes(Source: Author, 2019)

Besides the questionnaire, secondary data was collected from Twitter (tweets) concerning the Gaubus and Gautrain (between the period of August to November 2018). Figure 2 shows the technical architecture of how the tweets were collected and analysed (Moyo and Musakwa, 2016). Posts from 380 users were analysed. This data was used to spatially identify POI of Gaubus users and also to identify the spatial relationship between land use activities, Gaubus routes, Gaubus stops, Gautrain stations and Guatrain routes. A neighboorhood analysis was run using a focal statistics based tool to map the spatial distribution of commuters of the Gaubus.

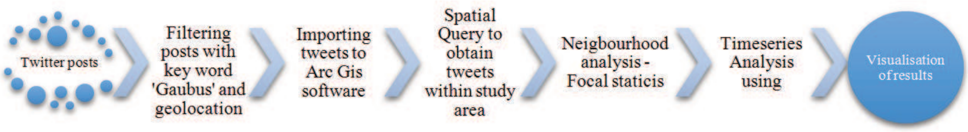

Figure 2: Framework to extract and analyse geolocational Tweets (Source: Author, 2019)

6 FINDINGS

The first section of questions from the survey requested the commuter's comments on accessibility of the bus stops from their POI within the study area. Each respondent had various opinions about how accessibility can be improved. From the figure 3 one can observe the approximate time each respondent takes to access the bus stops. It seems that most of the bus stops are within reasonable travel time as most of the respondents take between 1 minute to 6 minutes. Comments received concerning accessibility highlight how the respondents would only use the Gaubus if the Gaubus stops or route are within close proximity to key POI such as work, home or leisure such as malls and parks.

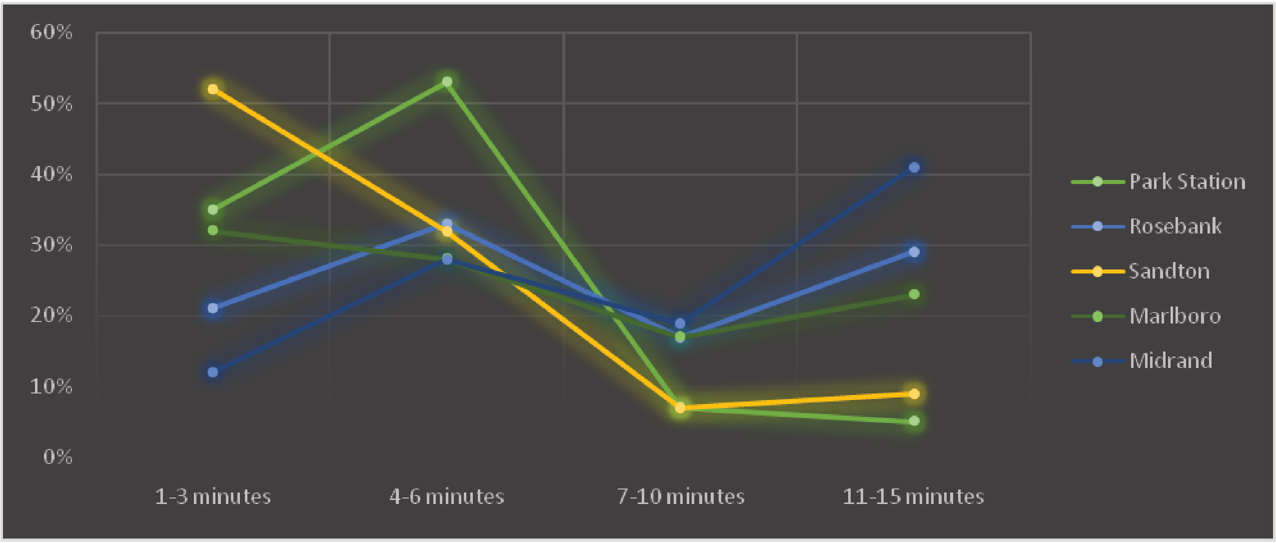

Figure 3: Approximate time to access bus stop (Source: Author, 2019)

The Gaubus seems quite affordable as most of the respondents use the Gaubus frequently with the majority using it at least once a week. Given how the Gaubus and Gautrain are interlinked, most of the Gaubus commuters, utilise the Gautrain to traverse to other parts of the city. Moreover, the respondents wanted an intergrated system that will enable them to book and pay for trips in advance. On a social front, allowing public interactive systems should be multilingual using other local languages such as Tshwana, Venda and IsiZulu. The overall commentary from users was veered towards an efficient and sustainable transport system, reaching user satisfaction and attracting potential audiences. With regards to payment of trips, most respondents favoured using other modes of mobility such as mini-taxis, but some noted that the Gaubus was more affordable when used in conjunction with the Gautrain as they received a discount on the total trip fare. Figure 4 summarises the respondents' views with regards to affordability at the various locations within the study area. When commuters travel in areas around Midrand and Sandton the trip fare is a high priority. Whilst areas around Marlboro and Park had the lowest fare priority. This relationship of trip fare and location maybe influenced by the surrounding land uses within these areas (see figure 8).

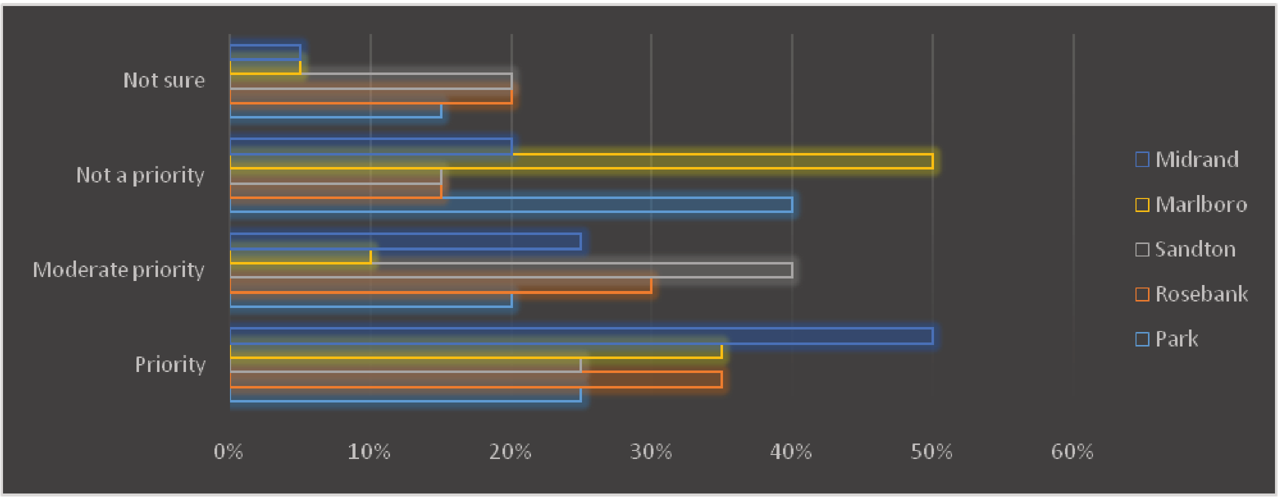

Figure 4: Affodability of Gaubus and Gautrain Services (Source: Author, 2019)

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The factors in figure 5 highlight the comments from the respondents taken from the survey regarding factors influencing trip mode choice. The purpose of the questions was not only to identify respondents' opinions but also to explore the experiences, needs and expectations of commuters. It should be taken into account that travellers have different needs and priorities and therefore there is a need to understand the expectations and satisfaction with the quality of service attributes and the importance attached to them. From figure 5, travel time, routing and trip cost seem to be the most important factors that the respondents prioritise, whilst connectivity and accesibility to bus stops had the lowest score. There is a need for service providers to invest more in improving travel time and reducing travel costs, as the Gaubus and Gautrain are currently aimed at medium income groups, i.e. mostly the under 26 to 40 years of age group who are mostly recently employeed. Such improvements would increase the number of commuting trips made using the Gaubus and Gautrain whilst also improving the commuting experiences.

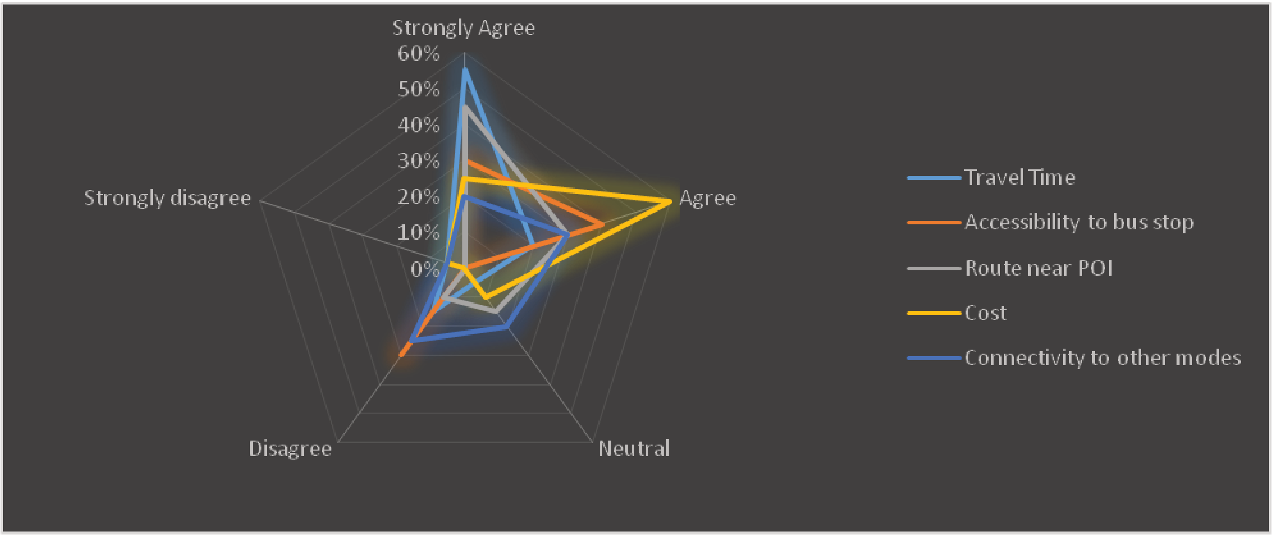

Figure 5: Factors determining commuting using Gaubus (Source: Author, 2019)

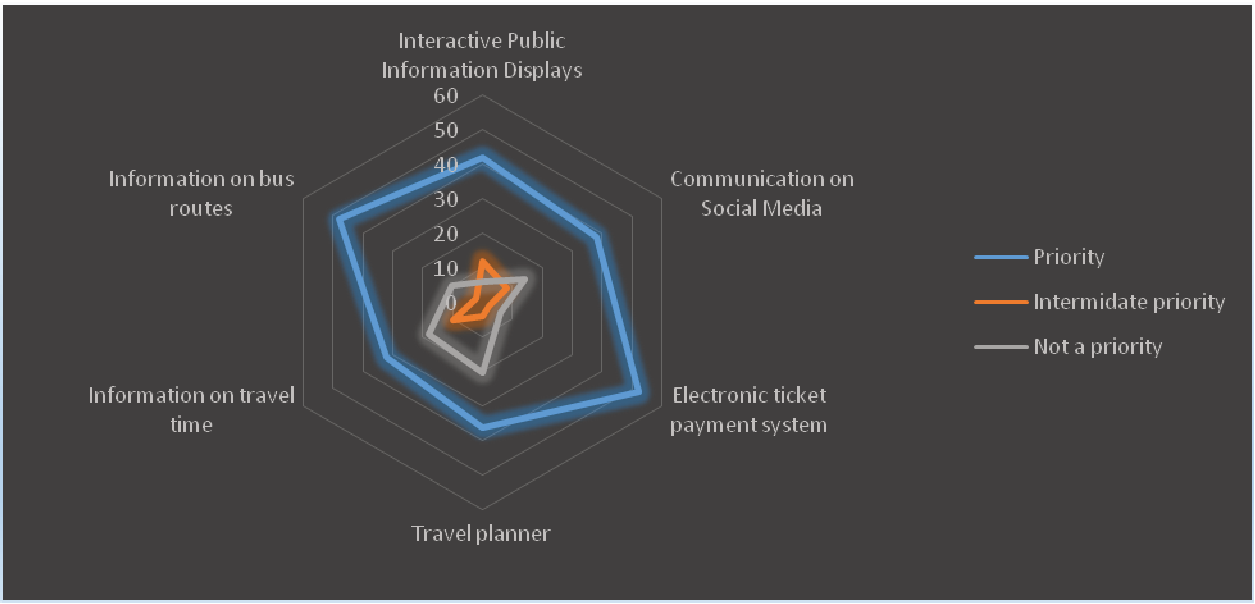

Figure 6: Indicators for a desirable mobility system (Source: Author, 2019)

In an increasingly competitive and highly dynamic multi-modal transportation market the factors in figure 6 have become vital in connecting service providers and commuters. The need for accessibility of information seems very important to the respondents, as most respondents highlighted that they need demand-responsive and user-friendly systems. Also their comments identify continuing challenges of public transport in various sectors, such as safety and security, population growth and the inability of cities and transport systems to cater for such demand. The continued rise of expanding transportation infrastructure is limited by fiscal, political and environmental constraints as well as basic physical limitations. Given the complicated nature of demand-supply interactions on temporal, spatial dimensions and the inherent difficulties in large-scale optimisation, there is a need for a system which sends feedback to service providers to be able to respond to sudden flaxtuations in demand. A simple source of obtaining feedback could be social media data as most commuters frequently post online.

Certain seasonal and monthly variations become evident from the geolocation social media posts when viewed over a time series analysis (as shown in figure 7). Using focal statistics to conduct a neighbourhood analysis, the time series reveals an estimate of location concentration points or hot spots, which are commuter POI across the study area. The month of September had a high concentration of 120 along the Gaubus routes in Sandton and of 131 around Midrand area, whilst in the month of October there was a decline to 68 in Sandton and a spike around Midrand of 88. Lastly in November only the Midrand area had a high concentration of 161. The results for the three month period (see figure 7) reveal that the majority of the commuters are located near Midrand and Sandton having a concentration level averaging from 260 to 380. Whilst the Rosebank area has a moderate concentration level of around 180 to 250. This could be due to the existing land uses around these locations which have created a melting point for commuters.

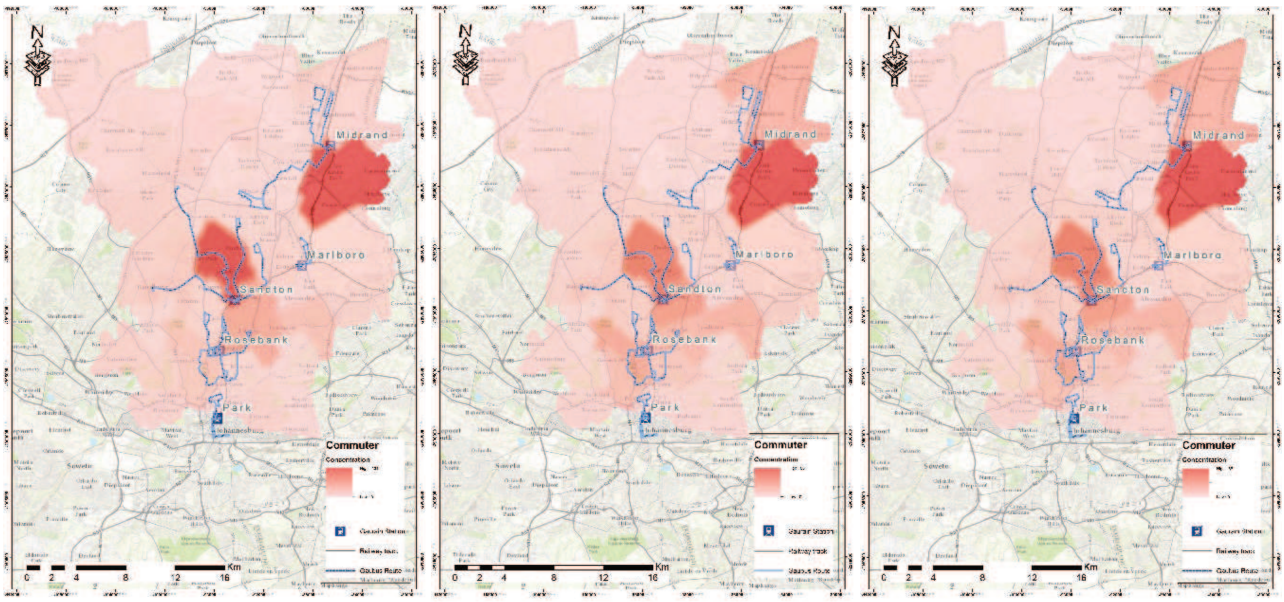

Figure 7: Time series analysis of commuter concentration (Source: Author, 2019)

From figure 8, the Midrand, Sandton and Rosebank areas have a high volume of commercial and industrial land uses. From gleaning through the tweets posted by commuters it is evident that due to the urban functions located in these areas most commuters use the Gaubus to traverse from home to the Gautrain station, then from the Gautrain station utilise the Gaubus again to access their work place on a daily basis. Areas around Park have also a high number of commercial and industrial land uses, however areas around Park have the lowest volume of commuter concentration. This could be due to the high presence of mobility modes around the Park node. The Park node located in Braamfontein services the Central Business District in Johannesburg and also acts as an entry point for most regional and local commuters. Hence commuters have a wide range of BRT modes to choose from, such as the Rea Vaya (another form of BRT which services the Southern part of the city) and Metro Bus (which services the inner and southern part of the city). Also within close proximity are the Bree Taxi rank and the MTN Taxi Rank in an area located only 10 mins away (Mini-bus taxis located at these taxi ranks service most residential and commercial areas in the city).

Given the prominent economic activities located around existing Gautrain stations (namely Park; Rosebank; Sandton; Malboro and Midrand), continued investment in BRT to service as essential feeders in and around these areas will lead to reduced congestion at these locations. Also, given how the Gautrain system already offers the main mode of mobility for their commuters that is rail and road (Gautrain and Gaubus), perhaps it would be cost effective for the Gautrain to expand the existing network, by providing other additional services to assist commuters to cover the last mile of their trip, such as bike sharing services. The bike sharing services can be linked to the existing Gautrain system, hence commuters only need the Gautrain card to collect and return the bikes. As this service will not be needed by all commuters of the Gaubus, it would be cheaper than adding new buses and routes, notwithstanding how it would be cheaper to set-up and

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maintain as an additional service. These bike sharing services could also be used to connect the existing Gaubus network, as currently the Gaubus routes only connect to one Gautrain station and there is no link besides the Gautrain to the next Gautrain station. An example is the Gaubus network in Sandton and Rosebank where, if the Gautrain network has a break, commuters are no-longer able to traverse between these two locations.

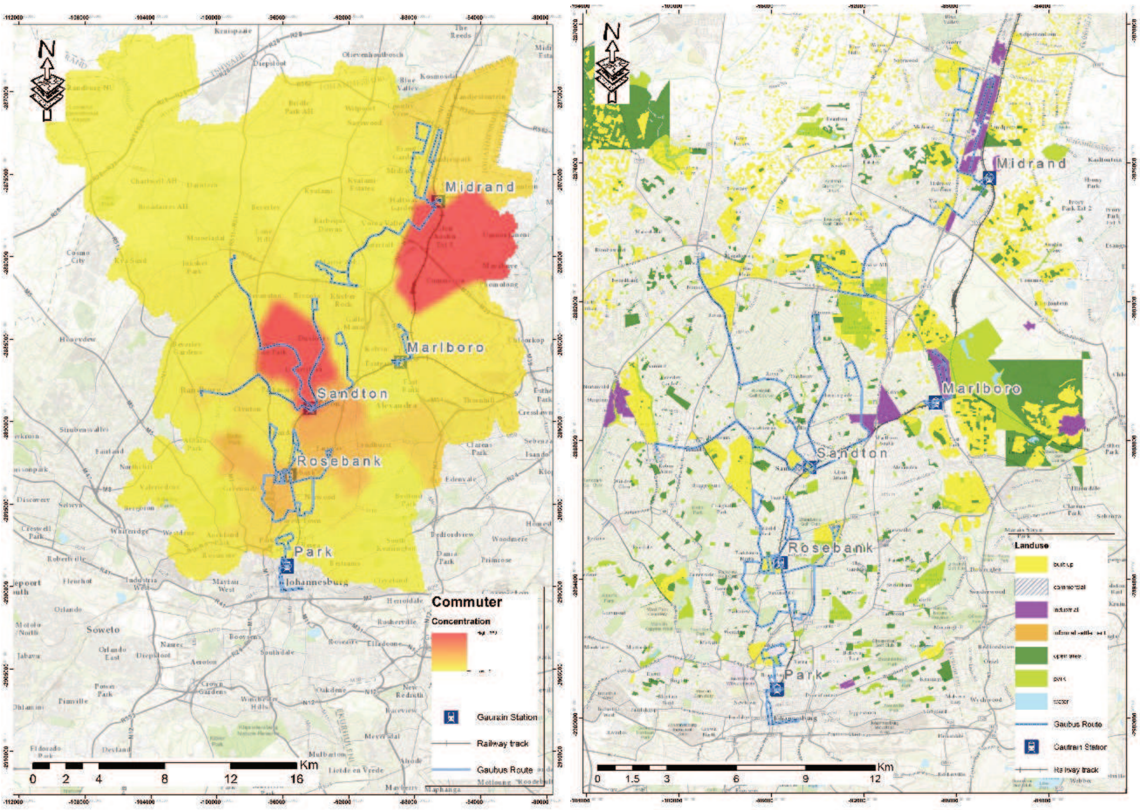

Figure 8: Commuter concentration and Land use distribution (Source: Author, 2019)

7 CONCLUSION

The paper sought to identify how commuter movement can be understood by assessing the factors influencing demand and supply within the Gaubus BRT network. The factors affecting demand and supply were highlighted whilst also exploring possible indicators for a desirable urban mobility system. The various information needs of commuters created a discussion around the smart city theories such as co-creation, and sustainable planning for the future. The results from the social media posts revealed locations with high and low demand for the BRT service, whilst results from the questionnaire revealed which factors influence demand and supply. Moreover, the comments from the respondents and results from neighbourhood analysis show that there is potential for investment into multi-modes of mobility through the use of bike sharing services. This method would assist in spatially targeting areas where the Bus Rapid Transport and cyclist movement patterns intersect, linking the community to places of economic opportunities.

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