SOCIAL FACILITY PLANNING: COMPARING ACCESSIBILITY IN TSHWANE BASED ON DIFFERENT TRANSPORT NETWORKS

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ABSTRACT

Detailed transport networks providing distance or time measurements are a common way to measure levels of spatial accessibility. An often-overlooked matter is that using a single transport network does not consider how different portions of the population may depend on different modes of transportation. This means the actual accessibility of facilities would be overestimated since one would assume commuters travelling with a private vehicle in cities within developing countries like South Africa would take less time and have greater access to facilities than those using public transportation. A matter to consider is that most accessibility analyses have not focused on classifying the population based on the mode of transport that they would mostly depend on. A tool developed by the CSIR to determine spatial accessibility was used to illustrate this. This research thesis compares the spatial accessibility of social facilities based on different modes of transportation (private vehicle; bus; rail and taxi). An impedance unit was applied to each of the modes of transport reflecting how far one may have to travel from their origin to reach the nearest node or stop. It was found that there is a significant disparity in terms of the spatial accessibility of certain social facilities for the estimated population in the City of Tshwane. A much larger proportion of Tshwane's population has access to the facilities included in the research if they have access to private transportation as compared to public transport services. Subsequently, suggestions were made to address the matter at hand, including the extension of the public transport networks, the establishment of more social facilities or the relaxation of the standards used to determine how far is reasonable for residents to travel to reach their nearest facility.

Keywords: Accessibility, service delivery, social facility, spatial justice, spatial transformation.

1. INTRODUCTION

Spatial analysis is often conducted to determine the geographic accessibility of certain sites such as social facilities to the public. This is, in turn, used for facility planning to ascertain whether an acceptable proportion of the public has access to these social facilities based on pre-determined standards and rules (Green, 2012).

Detailed transport networks providing distance or time measurements are a common way to measure levels of accessibility (Mokgalaka, 2015). An often-overlooked matter is that assessing the geospatial accessibility of private transport modes only does not consider how different portions of the population may depend on different modes of transportation.

This would mean that the actual accessibility of facilities would be overestimated since one would reasonably believe people travelling from point A to B with a private vehicle in the cities within developing countries like South Africa would take less time and have greater access to facilities than those using public transportation.

The Council for Scientific and Industrial Research has published related work on education, emergency services, health services and recreational service facilities amongst others (Baloyi et al., 2017). The focus was on determining the geospatial accessibility of social facilities based on a single detailed road network (be it from a travel time or travel distance basis). This study compares the spatial accessibility of social facilities based on different modes of transportation (standard road, taxi, Tshwane Bus Service, and rail in terms of travel distance from origin to destination). This comparison can then be used as decision support for not only social facility planning but spatial and transport planning as well.

The use of a single transport dataset in accessibility analysis with the goal of social facility planning may lead to over-estimations since different socio-economic groups depend on different forms of transport. The implications are that the people who depend on public transport would not be sufficiently accounted for when the capacities and locations of social facilities are introduced in future development plans (e.g., Integrated Development Plans). This also has implications for resource allocation planning as priority areas in greater need of intervention may not be optimally identified. Therefore, there is a need for an approach that considers different modes of transport which would then provide more comparative evidence for informed decision making in spatial planning in support of spatial transformation.

To achieve the research aims, objectives were set to determine the spatial accessibility of primary and secondary schools as well as primary health care centres and police stations using a detailed road network; the Tshwane Bus Service network; a taxi route network and the railway network. Comparisons of the results are made followed by a discussion regarding their implications.

Following the introductory chapter, a variety of concepts are discussed in a literature review to form the core of this study, such as, accessibility and service delivery, mode of transportation and finally, spatial justice. The methods chapter begins with the overall research approach and is followed by the research methodology, providing clarity on the various steps taken throughout the research. The study area is also conferred before the data and software used is elucidated.

The results chapter provides the analysis results based on a standard road network; the Tshwane Bus Service; minibus-taxi network and railway line. These different networks were used to obtain geo-spatial accessibility results for the South African Police Services, Primary Health Care Centres and Basic Education facilities. Finally, the impact and implications of these results from an urban planning perspective are presented.

The concluding chapter provides a summary of the key results of each of the stated research objectives. The conclusion is followed by discussion of the implications of the findings, the research limitations and finally recommendations for potential further future research.

2. LITERATURE REVIEW

2.1 Accessibility Approaches

2.1.1 Accessibility and Transportation

As a concept, accessibility has origins from the 1920s when it was used in location theory and regional economic planning. Accessibility has been used to refer to the measure of the relative proximity of a single person and place to all other people and places. For this reason, the concept has been said to be associated with Newton's law of gravity. Accessibility has also been defined as the potential of opportunities for interaction and in modern-day accessibility analyses, the concept has addressed the issue of spatial interaction (Geurs, De Montis & Reggiani, 2015).

One can strongly relate accessibility to transportation. In fact, Levine, Merlin and Grengs (2017) have said accessibility is the suitable rubric for planning as well as assessing investment in transportation and all the aspects involving transportation when witnessing developments in land-use. This is an important point for the research at hand as it involves the accessibility of social facilities based on several transport networks. The spatial accessibility of these facilities will be used to make comments on possible investment in transportation networks for future planning.

2.1.2 Methods of Determining Geospatial Accessibility

Euclidean distance, distance along a transport network and travel time are metrics that are types of distance and time measures that are used to measure spatial accessibility. The mentioned metrics are both identified and elucidated in Table 1 below.

Table 1: Distance/Time Measure Metrics

Metric	Explanation
Euclidean distance	This involves the use of a straight line between origin and destination to determine accessibility. It does not consider physical barriers such as water bodies (rivers, lakes etc.), forests and mountains as well as the conditions of the road or transport network and mode of transport used (thus, it is found less desirable for measuring accessibility in comparison to other metrics).
Travel time	This uses a measure of the time it may take individuals to travel from their origin(s) to their destination(s). In some cases, it may account for the mode of transport used. It may also account for the conditions of the road or transport network (however, it will require the slope and road condition information as well as the information regarding the typical vehicle used).
Distance along transport network	This uses the physical distance along the transport network travelled between the origins and the destinations to determine the spatial accessibility. Constraints may also be placed such as roads which only allow travel in one direction (one-ways) as well as capacities of facilities. However, it does not consider the effect of slope or road conditions.

Source: Yao et al., 2013

For the purposes of this research, the distance along the transport network is used as a metric since travel times are often difficult datasets to find or calculate and it may involve assumptions such as the speed that would be travelled on the network. The distance along a transport network metric is also a more practical and real-world measure of access than a Euclidean distance. Additionally, an impedance distance unit is applied to each transport network to explain how far people could be expected to reach the nearest node or stop. This is lower in standard road networks (50m); then higher in minibus-taxi networks (100m) and in bus routes (500m) and finally, the railway (1km). These impedance distances were based on discussions with the developer of the CSIR Social Facility Accessibility tool as well as other seasoned professionals who have worked in accessibility analysis and transport modelling.

2.2 Public and Private Transport Networks in Accessibility

In a paper by van Heerden et al. (2022), the focus was on the provision of accessibility to amenities, jobs, and services for previously disadvantaged groups. It noted that households may be constrained in their choices in terms of mode of transport as disadvantaged groups may not be able to afford certain modes of transport. Such a situation is exacerbated by the spatial fragmentation found in South African cities stemming from the apartheid regime and its planning methods. An important statement made in the paper is that there is probably no ideal measure for spatial accessibility; however, it is essential to find a balance among compatibility, interpretability and relevance when considering spatial accessibility to resources. The authors found that the provision of more facilities to increase service capacities in particular areas without sufficient public transport networks would not efficiently aid the spatial accessibility of social facilities and may even worsen the accessibility of said facilities for residents if the facilities are not placed in the most optimal locations. Another important point which can be taken from the study is that government subsidies may lower fares for public transport use, such as for the minibus taxi mode which many commuters depend on.

It was noted by Van Heerden et al. (2022) that in cities (especially those in Europe) with better access to public transport services and higher densities, people's distance to work and their commuting time often becomes a critical factor in the decisions made in households. Cities that are in developing countries often have much more unemployment and this leads residents to travel far for work and even walk. Waldeck and Van Heerden (2017) noted that 80% of city residents in Tshwane depend on public transport whilst 15% use private transport and the remaining 5% walk. In relation to this research project, it was observed that there is a significant dependence on public transportation. This adds to the essentiality of an accessibility approach that considers various forms of public transportation.

In terms of accessibility studies conducted in the past, Kawabata (2003) noted that the mode of travel may be of greater significance in accessibility (to jobs in this case) than location. This argument was based on the belief that the disparity between private and public transportation is more substantial than the disparity in geography. That approach arose from the context of certain areas in the United States of America. In South Africa, significant disparities in income, as well as geographical disparity due to the influence of apartheid spatial planning and policies, makes the argument much more complex so several factors need to be considered rather than simply focusing on modes of transportation (Van Heerden et al., 2022). For this research, factors such as the age of the population for the spatial accessibility analyses for schools; geographic disparities; capacities of social facilities; and modes of transportation were considered. All the facilities

covered in this research are public facilities as these are meant to be open to everyone in the public. This aids in ensuring the equitable allotment of services (as opposed to private facilities which may be costly to use, hence excluding the poor).

3. DATA AND METHODOLOGY

3.1 Research Methodology

The research began with obtaining resources such as the necessary data and access to the relevant software. The resources collected in this study include the facility locations and capacities of public education, health, and police social facilities in the City of Tshwane. The different departments were contacted through assistance from Tshwane's Knowledge Management directorate to obtain the necessary data and confirm it in 2020. This data was superimposed on the standard road network (assuming the use of private transport on it) that the CSIR has previously obtained from TomTom and separately compared to public transport networks such as bus (Tshwane Bus Service), taxi (minibuses) and rail networks (Metrorail) (collected from data custodians through related projects the CSIR was involved with from 2015-2020). Subsequently, catchment area analyses operations were run using GIS (an online Social Facility Accessibility tool developed by the CSIR in 2022) that provided statistical results (the number of people in different tessellated cells that are a certain distance away from their nearest facility) that were used in maps (drawn up on ArcGIS and Excel classifications to depict the areas that are within the current distance standards (served) as dictated by their guidelines or beyond the current standards (unserved)) (Green, 2012). The guidelines include that primary and secondary schools should be accessible in 5km; primary health care centres should also be accessible in 5km, and police stations should be accessible in 8km for high density areas and 24km for low density areas. The results (number of residents in Tshwane travelling certain distances to reach their nearest facilities) from the geo-accessibility analyses were then compared and the implications documented. The comparisons are based on the different mode of travel scenarios included in this research.

3.2 Study Area

The City of Tshwane is the administrative capital of South Africa and is an important point of study. The researcher is well accustomed to both private and public transport within the City and this adds to the incentive to study the entirety of the municipal area's status quo in terms of social facility provision and transportation within the City. Additionally, the CSIR has conducted a comprehensive accessibility study of the social facilities in the City; however, that study did not focus on public transport. This adds to the importance of this project in furthering research into a pertinent issue regarding social facility planning and transport.

4. RESULTS AND DISCUSSION

4.1 Population Distribution and Transport Network Coverage

The distribution of the population within the City of Tshwane is an important point of departure to quantify the demand for various types of facilities in the city. The total estimated population for the City of Tshwane for the year 2021 was 3 583 679.

The distribution and size of the population are depicted in Figure 1 below. All the information provided from Figure 1 to Figure 2 was obtained with permission from all the parties concerned, including the CSIR and the City of Tshwane. From the map, the high-density core of the City of Tshwane hosts the highest population as compared to the rest of the city. This forms part of the high-density core of the city with the lowest population figures located in the low-density outlying areas. There is a considerable concentration of population in the Mamelodi, Ga-Rankuwa and Saulsville areas which also contains several informal settlements in these locations. Informal settlements are known for high population densities with fast-growing settlements expanding incessantly. These informal settlements are also synonymous with residents of a lower socio-economic status. One would thus reasonably expect a greater dependence on public transportation than private transportation (i.e., residents having their own vehicles to travel from point A to point B) in these areas.

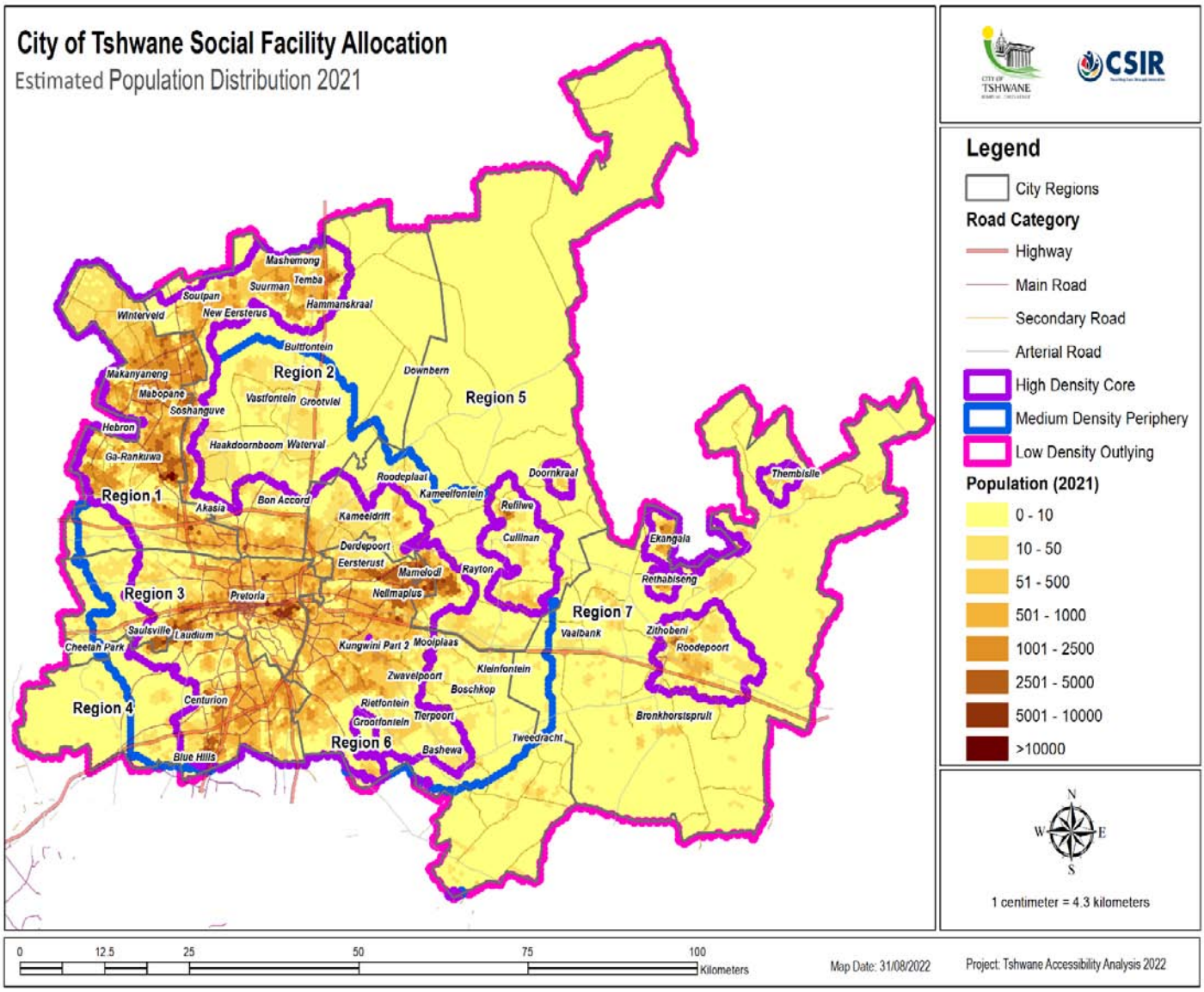

Figure 1: City of Tshwane estimated population (2021)

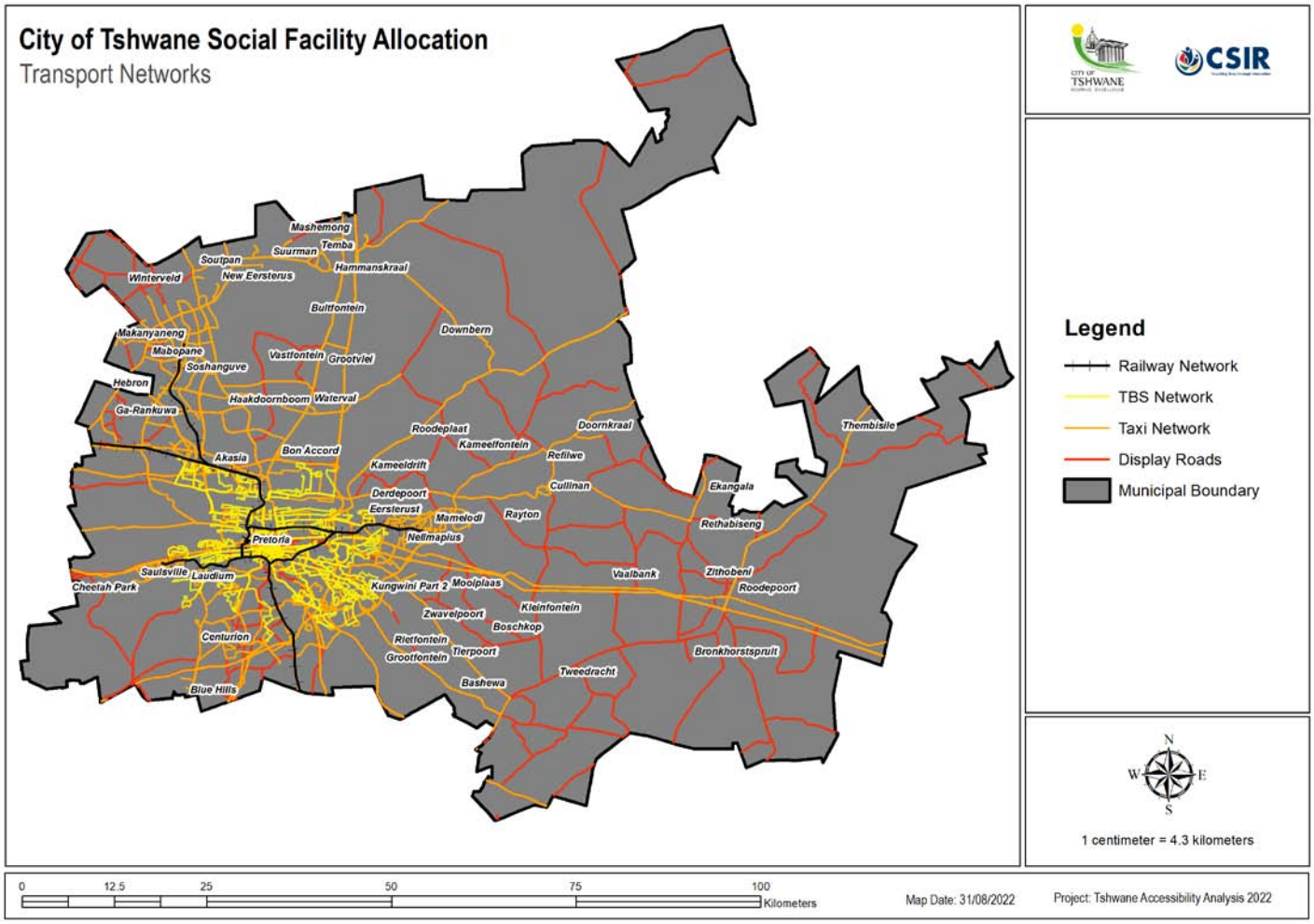

Figure 2: Transport networks used in the research (for display purposes)

It was observed via maps that the Tshwane Bus Service (TBS) network only extends around the Central Business District (CBD) of the city. The taxi network reaches beyond the boundaries of Tshwane; however, it is not as extensive as the detailed road network used in this research. The railway network mostly spans through the most populous areas of the Municipality but does not have as many routes or links as the other forms of transportation considered in this research. This logically leads to the areas closest to the CBD being the most served by each transport network. Areas further away would then not be accessible if one were to use the TBS, minibus taxi or rail networks since those are limited in terms of the various routes one could use to reach social facilities using them. The standard road network obtained from TomTom, however, extends even beyond the boundaries of the City of Tshwane (CoT). This provides a rationale for the disparities in terms of the spatial accessibility results.

4.2 Results Comparison

This subsection compares the spatial accessibility results of facilities when the road network (standard road links) and the public transport networks (Tshwane Bus Service, taxi routes and railway) included in this study are considered. The geo-accessibility results are then put into context as to what their implications would be. These geo-accessibility results show how many people live within the guideline distance of the different facilities if they were to depend on the different modes of transport. Table 2 below displays how the different transport networks compare for the same social facilities when the standards

(including each facility's capacity) of spatial access to those facilities are considered with the inclusion of an impedance distance. These results are presented in terms of the percentage of Tshwane's population which have spatial access to their nearest facility.

Table 2: Comparison of spatial access to facilities in Tshwane (percentage of population served) using different networks

City of Tshwane Facility Accessibility Results	Standard Road Network	Tshwane Bus Service	Taxi Network	Rail Network
Primary School	73.21%	14.99%	37.81%	54.38%
Secondary School	62.92%	8.93%	29.26%	46.47%
Primary Health Care facility	69.23%	8.86%	17.58%	46.51%
South African Police Service	87.72%	8.63%	11.24%	61.80%

For education facilities, primary schools are spatially accessible to 73.21% of the primary school-going population in the City of Tshwane (CoT) using the standard road network. However, this figure is only 54.38% for the rail network, 37.8% for the taxi network and 14.99% for the Tshwane Bus Service (TBS) network. The same trend occurs for the secondary school-going population as 62.92% of the population is served using the standard road network, but this figure is only 46.47% for the population closest to the rail network, 8.93% for those using the TBS network and 29.26% for the taxi network. The results present a significant disparity, illustrating that only those near the centre of the high-density core of Tshwane have the benefit of using the various transport networks if they desire to access education facilities in the context of this study. The implication of this is that students would have to find alternative methods of travel if they do not have a private vehicle in their household and reside far from the centre of the high-density core yet attend school near the centre of the high-density core (if they believe they can obtain a better quality of education at schools in the high-density core than at their nearest school). This will increase the time residents spend travelling as well as the personal cost to commute to school daily if they need to combine different forms of transport to get to school. The department would then need to consider which of the following is more feasible: extending public transport networks; investing in the establishment of more significant educational facilities away from the centre of the high-density core (decentralisation); or easing the standards of spatial access to facilities (Green, 2012).

When primary health care facilities are considered, 69.23% of the population may find the facilities spatially accessible using the standard road network, however, this figure is 46.51% for the railway network; 17.58% for the taxi network and 8.86% for those closest to the TBS network. The results indicate that people may have to find alternative methods of travel to access public health care facilities if they do not have a private vehicle in their household and reside far from the centre of the high-density core. Time is often a matter of importance when needing to access a health facility; therefore, other forms of transportation (the closest and quickest) may need to be used to avoid wait times and long walks to access health facilities.

Lastly, when police stations are the focus, 87.72% of the population may find the facilities spatially accessible using the standard road network; however, this figure is 61.8% for the rail network; 11.24% for the taxi network and 8.63% for those closest to the TBS network. The results show that people may either have to walk considerable distances or find alternative methods of travel if they do not have a private vehicle in their household and reside far from the centre of the high-density core to access a police station. Reporting a crime, certifying documents, or applying for police clearance are unfortunately issues people may need to address from time-to-time in Tshwane. This makes their access to a police station vital as it speaks to their safety and security. The stated figures in the CoT unfortunately imply that a majority of the population is not able to use public transport networks to access safety and security facilities in times of an emergency. This speaks to people who have a private vehicle available to them having better spatial access to safety and security services.

The comparisons between the standard road network (i.e., using private transportation) and the public transport networks (i.e., municipal bus services, mini-bus taxis, or rail) illustrate significant disparities in terms of the spatial accessibility of certain social facilities for the population in the City of Tshwane. A much larger proportion of Tshwane's population has access to the facilities included in the research if they have access to private transportation as compared to public transport services. One may then suggest either the extension of the public transport networks, the establishment of more social facilities or the relaxation of the standards used to determine how far is reasonable enough for residents to travel to reach their nearest facility.

5. CONCLUSION AND RECOMMENDATIONS

A discernible trend evident from the results in the fourth chapter is that social facility provision may have been overlooked for the population which may depend on public transportation as compared to the population using private transportation. Access to primary health care centres and South African Police Service stations were included to speak the City of Tshwane's Integrated Development Plan for 2022-2026 which addresses "Enhancing city safety, security and emergency services." The City of Tshwane's IDP states that the safety and emergency services environments need to be strengthened continuously and, for this to happen, the facilities providing these services need to be observed in terms of the service they provide to the public. In terms of the specifics of this research, the provision of safety, security and emergency services was observed from the perspectives of residents who may depend on various forms of transport to spatially access the before mentioned services. It became clear that intervention may be necessary, either through the establishment of more facilities, extension of public transport networks or easing of the spatial accessibility standards imposed on the facilities. Each of these interventions would require a feasibility study. However, a feasibility study is beyond the scope of this research. It is essential to remember that an impedance distance is applied to each transport network to explain how far people could be expected to walk to reach the nearest node/ stop. This is lower in standard road networks (50m); then higher in minibus-taxi networks (100m) and in bus routes (500m) and finally, the railway (1km). The impedance distances had a significant impact on the results obtained as it was found that they may not be the most appropriate in comparing accessibility rates between different modes – especially in the case of minibus-taxis and this would need to be adjusted.

Additionally, the City of Tshwane's IDP speaks on the maintenance and expansion of road infrastructure and public transportation. The IDP of Tshwane notes the essentiality of the

road network in facilitating the mobility of residents across the municipality. Most relevantly, it mentions that the provision of public transport services would make the city accessible, and this increased mobility would help grow the local economy. In this research, areas that may be seen as priorities for intervention in terms of education, health, as well as safety and security facilities were identified. These areas include Mamelodi, Roodepoort, Hammanskraal, Mabopane, Soshanguve, Ga-Rankuwa, Saulsville, Blue Hills and the centre of the high-density core of the municipality.

These areas are also located where the highest concentrations of the population were identified. This may be attributed to the presence of informal settlements that tend to grow exponentially in area and population. Decentralisation is often brought up as a solution to addressing areas of high concentrations of population; however, it would need a feasibility study which is not in the scope of this research. An additional suggestion can be made for the subsidisation of service providers which would aim to decrease the gap in spatial accessibility of social facilities for residents who do not have access to private transportation as compared to those who have access to private vehicles. This will require a feasibility study from the local government.

Four potential responses to issues identified by the analysis have been suggested. These include easing the spatial access standards of facilities; increasing subsidies for transport providers; extending public transport networks and finally, establishing more social facilities to meet the ever-increasing demand for services. These suggestions may present their own advantages and disadvantages and would need further study to ascertain their implications.

Firstly, it is important to note that the spatial access standards of facilities were established after extensive research by seasoned professionals (Green, 2012). These access standards considered both the needs of residents as well as the limitations of service providers. However, the research paper at hand observes the matter from a strictly analytical view. The results from the spatial accessibility analysis using the standard road network are the best way to tell whether easing the access standard is worth consideration due to its level of detail. It was noted that only close to two-thirds of the secondary school going population is served. One could then mention that this is a facility of concern as the access distance standard seems too restricted for the type of facility. Not many households have the financial resources to send children to private schools and this needs to be considered if building more schools is not feasible, the construction of more roads is too costly, or the establishment of more public transport networks takes too long. Easing access standards may have the advantage of simply making the statistics look better, however, it has the disadvantage of assuming the public would be able to travel further to reach their nearest facility.

Secondly, increasing subsidies for transport providers is a matter that is raised due to the dependence of socio-economic groups that may not have the financial resources to purchase a private vehicle. Having more subsidised bus companies (service providers) would increase the competition in the field and could lessen the cost to customers. This could possibly also increase the number of pick-up points and bus routes that the Tshwane Bus Service could not reach. The main disadvantage of such an action is that it would be a costly expense for the government to bear. The taxi industry has also brought up the matter of their services being subsidised; however, the implementation of this action would require immense administration and effort which the government may not have the full resources for.

Furthermore, a suggestion has been made regarding the extension of public transport networks. With regards to the research thesis at hand, this would speak directly to the Tshwane Bus Service (TBS), taxi routes and the rail network. This action is the most advised in terms of this research thesis. Extending public transport networks would ensure that lower income groups have a greater spatial access to necessary social service facilities. Limitations in the routes for the Tshwane Bus Service (TBS), rail network and the taxi network were brought up during this study and it would be beneficial to address these limitations. The Tshwane Municipal Spatial Development Framework (MSDF) (2021b) documents extensions of the railway network as well as the Bus Rapid Transport (BRT). This research thesis supports the extension of the railway network; however, the BRT is not in the scope of this research. The major concern for extensions in transport networks is whether there is land available for infrastructure developments or upgrades (which may often be costly) and the influence this would have on traffic. One must note that increasing incentives for people to use public transport may assist in having fewer private vehicles on the road if the convenience of the public transport exceeds the cost of the private transport.

Lastly, a suggestion is made to simply establish more facilities in areas with a considerably high concentration of demand. This is a practical solution to the problem of having several areas with an immense demand for social service facilities such as Mamelodi, the centre of the high-density core, Saulsville, Ga-Rankuwa, Hammanskraal and Centurion which were noted in chapter 4. The impact of informal settlements is also noted in section 4.1 as these settlements tend to expand considerably and need to be considered in planning decisions. The benefit of establishing more social facilities is that their spatial accessibility improves, which aids in improving the quality of life of the public. However, this is a costly action for the different social service departments to make. Different departments have unequal budgets; thus, it may not always be financially feasible to simply build new facilities. Optimisation modelling may be used to identify the best locations to establish new facilities (or an amalgamation of facilities where possible) to address the remaining demand noted in chapter 4.

In conclusion, there are actions that can aid in improving the spatial accessibility of social service facilities. The main impediment with these actions is often the cost associated with performing them, however, if improving the quality of life and productivity of the public as well as the impact of social service facilities is to be prioritised, these actions may be necessary. Additionally, these actions can be used in unison if feasible and further research is made to ensure the public is served more equitably.

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