Provisioning Segregation:

Investigating mobility induced social exclusion in Pretoria-Tshwane, South Africa

Bachelor's In Development Studies

SGED10

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Abstract

Apartheid ended in 1994, yet the effects of this system of institutionalised segregation is still felt today throughout South Africa. In contemporary Pretoria-Tshwane segregation is maintained on race-class basis, with large portions of the population rendered immobile beyond their home township. This stems from the transport poverty phenomenon wherein lack of accessible and affordable means of transportation renders a group of individuals unable to reach key activities. So as to understand how transport poverty impacts the reach of Pretoria-Tshwane's highly segregated residential areas, Roberto's (2018) Spatial Proximity and Connectivity method, together with the Dissimilarity Index by Duncan & Duncan (1955), is employed. Foundational for the analyses where 2011 Census data from StatSA (2012) which served as the analytical base. This study finds that most of the study areas function as residential islands, which signifies areas with monocultural land-use, separate either completely or from specific parts of the metropolitan municipality. Often this separation entails a disconnect from Pretoria and Centurion, the city's primary metropolitan areas. These are become problems because of the transport poverty phenomenon as that serves to sever connectivity and proximity through the municipality. Interconnection between all areas of Pretoria-Tshwane, and a more equitable distribution of industries would undoubtedly contribute to desegregation and integration.

Acknowledgment

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In solidarity, forever.

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List of abbreviations

CTMM	City of Tshwane Metropolitan Municipality
GAA	Group Areas Act(s)
SA	South Africa
SSA	Sub-Saharan Africa
StatSA	Statistics South Africa

Figures and Tables

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Introduction

Central to both Development Studies and Human Geography is the phenomenon of uneven geographic development. Harvey (2019) elaborates by stating how different social groups have different ways in which modes of sociality are embedded in their web of life. This entails the disparate uneven development between areas at varying scales. It also highlights the way that varying social groups (defined by class or ethnicity) shape society (materially and ideologically). These two factors illustrate the dialectical relationship between of people and their environment.

In the case of South Africa, which has undergone radical changes in its spatial organisation in recent decades, starting with the institutionalisation of apartheid in 1948, and its abolition in 1994 (Lemon, 2021). The fall of apartheid came with high hopes for what would come after, but would fall short as a result of the implementation of neoliberal economic policy, which stopped cities from pursing spatial and social integration (Maharaj & Narsiah, 2002). As such, contemporary segregation in South Africa forms the foundation for this study. This phenomenon is coupled with the notion of transport poverty. A large subset of South Africa's low-income population lacks adequate access to affordable transportation, irrespective of it being private or public. Hence, a large number relay on walking as their primary means of transportation. With the city suspending its integrative mission, having access to transportation becomes a key factor for people to better their lives. Yet, motorised transportation is a variable primarily confined to society's more affluent groups. Investigating the proximity, and the extent to which low-income groups in highly segregated areas have connectivity, between areas of a city is foundational in understanding magnitude of mobility induced social exclusion.

To answer this problem, the study will employ measurements of segregation at varying scales, as well as investigate reach, both euclidean and physical/corporeal, of various areal units within the highly segregated areas of study.

1.1 Aims and research question(s)

This study aims to develop an understanding of the linkage between spatial race-class segregation and the connectivity/proximity of non-car owners in post-apartheid Pretoria-Tshwane. This is done to bring academic perspectives on mobility induced social exclusion

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(primarily confined to the, so called, Global North) together with the lively debate around post-apartheid segregation in South Africa. Investigating the connectivity/proximity of various areas of a larger metropolitan municipality helps to illustrate how segregation is perpetuated to this day. To do this, the study employs a guiding research puzzle: why does social exclusion persist in Pretoria-Tshwane, despite change in the racial composition of the city's metropolitan core? This puzzle is operationalised in accordance with previous literature – on transport poverty, segregation indices (particularly a mobility based one) and historical investigations on apartheid planning – which come together to formulate the following research question:

> How does the prevalence of transport poverty impact connectivity and proximity of local neighbourhoods with regards to segregation in post-apartheid Pretoria-Tshwane?

1.2 Delimitations

This study confines itself it to former group- and homeland areas of the City of Tshwane Metropolitan Municipality: Atteridgeville, Ga-Rankuwa, Mabopane, Mamelodi, Soshanguve, Temba, Winterveld. The choice of these areas come down to the large concentration of Black-Africans of low-income who experience high levels of segregation. This is more or less in line with the areas function under apartheid, studying why this is still the case and how it is perpetuated contemporarily becomes of essence.

The study is further delimited by investigating the effects of post-apartheid segregation on the large subset of the population in the study areas who do not have access to a private or public motor vehicle for transport. This is justified, from what is argued in the theoretical section, through how the needs of low-income groups are neglected in contrast to more affluent groups. Hence, accessibility of roads, for those whose primary means of transportation is walking, is of further value.

1.2.1 Key concepts

Transport poverty: This concept denotes two primary meanings. One being that related to availability and accessibility, and the other related to affordability. Together they can be summarised as hindering the individual from fulfilling the needs of their everyday life in safe, affordable and reliable way.

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CTMM/Pretoria-Tshwane/Pretoria: The official name of the city at its smallest extent is the City of Tshwane Metropolitan Municipality. Throughout the text this may be abbreviated as *CTMM*. Pretoria-Tshwane is an alternative, less formal, way of referring to the city at the same extent as CTMM. When Pretoria alone is used, this refers to the local municipality that exists within the CTMM.

Racial-Residential/Race-Class segregation: The former refers to spatial separation on ethnic grounds, that relates to conditions of isolation, exclusion, and deprivation. While racial-residential segregation has been defined to incorporate spatial separation between income groups (Hamann & Horn, 2015), for this study the latter term of race-class segregation is utilised to emphasis the shift to a more class-based segregation that occurred after apartheid.

1.3   Organisation of the paper

The paper is organised through a background section giving a historical overview of segregation and case city of Pretoria-Tshwane, followed by a short overview of the contemporary situation of the city. This section is followed by a closely linked literature review section which elaborates on how studies on segregation has been conducted before, as well as what the debate around segregation is contemporality in South Africa. After this is when the phenomenon of car dependence is introduced. Understanding this phenomenon is foundational for understanding the concept of transport poverty. The provisioning of car dependence results in transport poverty, they are interlinked phenomena who cannot exist without each other. That is why car dependence and transport poverty are both included in theoretical section of the paper. The theoretical section also includes theories on the spatial formation of South African cities (historically and contemporarily), as well as a continuum on the question of segregation's continuity. Together all of these perspectives provide the appropriate lenses to understand mobility induced social exclusion in Pretoria-Tshwane.

The section on methodology follows an introduction of the primary method Spatial Proximity and Connectivity (SPC), as well as how it will be conducted for the analyses as it will diverge a bit from it has been outlined by the original author. This has to with that this research utilise ArcGIS pro instead of the R software. After the section on methodology, the analyses follow continued by a discussion segment reviewing the findings from the analyses in connection with previous research and the chosen theoretical frameworks.

Background

2.1 Historical overview

2.1.1 Origins of Segregation

To understand why segregation maintains itself in Pretoria-Tshwane (both socio-spatially and socio-economically), an overview of the development of, and planning behind, both segregation cities and apartheid cities is necessary.

Pretoria-Tshwane was founded as a mining settlement in 1855 (Horn, 2021, p.81). It was around this time that racialised thinking had become commonplace within the British imperial rulership, which would influence segregationist policies and planning throughout its numerous colonies (Christopher, 1983). Horn (2021, p.81) explains how the city would take shape throughout its early years. With White settlers arriving in what today is the central part of the city, the city population would remain comparatively small (compared to other settlements), until numerous factors (like environmental disasters, social upheaval, and colonial displacement) forced a sizable Black-African population to move near the city. Black-Africans often came to fulfil the function of a reserve army of labour as the White population could not meet the needs of the mines (Maharaj, 2020, p.41). Around the time of apartheid's institutionalisation in the 1950s, the Black-African population constituted upwards of 90'000 people (Horn, 2021, p.81). Uniquely for the city, its Asian and Coloured population groups would remain comparatively small contrasted with other South African cities. The areas originally settled by Black-African population throughout the decades would become more permanent with the proclamation of the Native Land Acts of 1913 and 1923. These resulted in land confiscation from the Black-African population to the favour of the White population (Horn, 2021, p.81; Maharaj, 2020, p.40)[1].

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[1] This can in-part be compared to the enclosures of the commons and original/primitive accumulation back on the home islands, which spurred the nascent capitalism and accelerated establishment and growth of manufactories, industries and resources extractive operations (Davies, 1981; Marx, 1990, pp.874–875). As have been established, colonialisation and apartheid led to displacement and separation from the historically settled lands of Black-African population. With original/primitive accumulation in mind, one can hence see how this is done to subordinate the non-capitalist producers (like with the example of the De Beers compound), as this is not something that can be achieved through, as Post (2023, p.91) puts it "fair and equal exchange" or "out-producing backward producers", as these non-capitalist producers control both their means of production and subsistence (often the land itself). Race comes into the picture as it becomes a key part in the justification of the expropriating colonised peoples.

2.1.2   Pretoria-Tshwane – Segregation, Apartheid, and the Question of Desegregation

These Land Acts would rapidly deteriorate the living conditions of those confined to the specific areas, which promoted further urbanisation of the subjected populations. This in turn provoked a class harmonious response from the White population, wherein both worker and capitalist alike pushed for control, management, and segregation of the Black-African population (Lemon, 2021, p.3; Maharaj, 2020, p.41). We see here the beginnings of the racist ideology's notions of, as written by Post (2023, p.92), the "inherent and unchangeable relations of inequality" which serves to explain and justify capitalist social-property relations in the eyes of both capitalist and worker alike. This ideology has then manifested itself differently throughout the world in accordance with the variations in the historical forms of capitalist social relations (and the geographic expansion), which dictated who and in what ways certain groups were and are superior/inferior (Post, 2023).

In 1948 the Nationalist Party was elected, and swiftly introduced and institutionalised apartheid throughout the country (Maharaj, 2020, p.42). Their election, and subsequent policy institutionalisation, had been generally accepted among the society's White population based on the "fears" regarding Black-African urban encroachment. With the Group Areas Acts (GAA) of 1950 and 1966 creating artificial ethnic lines of separation. This changed the *de jure* composition of the cities (particularly to strengthen the position of Whites and Weaken the position of Black-Africans) by grouping the varying European coloniser ethnicities together under the White category, artificially strengthening their position in contrast to the native population which was divided into various smaller groups on ethnic and cultural lines. These GAAs would materially manifest themselves in the urban planning and urban form (Lemon, 2021, pp.5–6). Figure 2.1-2 visualises how a generic city could look like under the apartheid system, contrast that with Figure 2.1-1 which shows the segregationist city from the colonial era and the differences are quite stark (even if they both seek to separate groups of people from one another)[2]. Primarily in how White populations in the apartheid city are kept physically separated (barriers and buffers) from the other population groups, as well as being permitted good opportunities for expansion – contrast that with the segregation city where the White population was almost encircled by non-White groups (Maharaj, 2020, p.43). The GAAs also resulted in further displacement, as non-White groups were forcefully displaced to make room for the allocated growth directions of White areas (Maharaj, 2020, p.44).

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[2] See Davies (1981) for more detailed explanations of how these respective cities were structured.

Figure 2.1-1: The Segregation City (Lemon, 2021, p.5 (Davies, 1981))

Figure 2.1-2: The Apartheid City (Lemon, 2021, p.8 (Davies, 1981))

There was a particular strong emphasis on separating Black-Africans, either through environmental barriers or through man-made ones, and if neither was possible then through buffer zones (Maharaj, 2020, p.43).

As time passed the apartheid system would start to crack in the seams. Maharaj (2020, pp.46 & 49) explain how as had occurred with the Land Acts in the early 20th century, the GAAs had resulted in abject poverty, lack of opportunities, inadequate housing situations etc. which prompted affected demographics to relocate closer to the urban centre (in a process referred to as 'land invasions'). Grey areas (similar to 20th century 'mixing zones', see figure 2.1-1) would spring up organically, or in some cases officially through so called free settlements (where mixing was legally permitted). The "land invasions" would prompt White people particularly in the central city districts, to suburbanise (referred to as 'White flight'). Both 'White flight'

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and 'land invasions' would cause the inner cities to deteriorate[3]. Often this is said to stem from the economic policies (i.e. GEAR, see Maharaj & Narsiah, 2002 for an explanation of these early post-apartheid policies). These factors together form the basis for the perpetuation of segregation in post-apartheid South Africa. While it still predominantly affects Black-Africans, it is founded on a race-class basis now, this is shown through how most of South Africa's urban inhabitants reside in former townships, while the more affluent and socio-economically mobile Black-African elite leave these areas, to move to former White only areas. Low income Black-Africans remain in large parts confined to former group- and homeland areas (Maharaj, 2020, pp.50–51).

Hence it is clear that continued segregation through the urban form is heavily influenced by the historical development of the South African city through its colonial and subsequent apartheid eras.

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[3] What happened in many South African cities has many parallels to the institutionalised policy knowns as 'red lining' in the United States. Wherein African-American households would be systematically denied housing as a result of a two-tiered residential lending system which favoured US-born white suburbanites, who were provided with federally backed mortgages contrast with African-Americans being denied access. In the South African context, this phenomenon manifested itself through financial institutions prioritising loans to suburbs over inner city areas (Maharaj, 2020, p.49).

2.2   Contemporary Pretoria-Tshwane

Pertaining to the studies time frame (and the latest completely available census), as of 2011 the City of Tshwane Metropolitan Municipality (CTMM, otherwise referred to throughout the text as Pretoria-Tshwane), is a city experiencing continuous growth (economically and spatially), constituting one out of the two central metropolitan municipalities[4] in the Gauteng province together with the City of Johannesburg. Since the end of apartheid to the present day, the city's administrative extent has seen rapid expansion. Right after the apartheid's demise, the city (known then as the Greater Pretoria Metropolitan Municipality) constituted approximately 1,300km^2, skip ahead to May of 2011 and the city (now known as CTMM) has expanded in every direction, primarily towards the east with the absorption of Metsweding District (Horn, 2021, pp.83–86; StatSA, 2012). With all the incorporations the CTMM now constituted almost 6,300 km^2 (StatSA, 2012). Pretoria-Tshwane became the spatially largest municipality within the Gauteng province, expansions like these rarely come without complications which has become the case for the CTMM (Horn, 2021, p.86).

As per Hamann & Horn (2015) comprehensive overview of the continuity of segregation within Pretoria-Tshwane presently, this study will primarily focus on areas marked by them as *Continued segregation*. These areas include the former Group Areas of Soshanguve, Ga-Rankuwa, Atteridgeville, and Mamelodi. These four areas all have a population constituting of 99 percent Black-African (StatSA, 2012). Emphasising the point of continued segregation in the former townships and Group Areas (Maharaj, 2020, p.48), especially as de-segregation only occurred in White low-median income areas (Hamann & Horn, 2015). Segregation today, at larger scales (e.g. neighbourhoods), is primarily influenced through various property market forces. These forces result in people being segregated from one another because of their financial capabilities or socio-economic status. "Prospective home buyers' preference of neighbourhood comes second to their ability to afford a home in that particular neighbourhood." (Hamann & Horn, 2015, p.2). According to Hamann & Horn (2015), other factors that appear to similarly contribute to racial residential segregation in Pretoria include for example "red lining" (see Locke et al., 2021), "gentrification" (see Pacione, 2009, pp.211–212), and "blockbusting" (see Rubenstein, 2011, p.215). While some of these are specifically United Statesian phenomena, the process looks similar in Pretoria-Tshwane nonetheless. Herein the race-class nature of segregation in the contemporary city becomes noticeable.

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[4] And one out of five districts within the Gauteng province.

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Historically during the apartheid era, planning often involved demarcation and construction of various forms of physical barriers to separate the non-White townships and Group Areas (particularly the Black-African ones) from the White neighbourhoods and suburbs (Maharaj, 2020, p.46). In the case of Pretoria this also came to include the natural environment which separated the northern half of the city from the southern half (Hamann & Horn, 2015). There are also railroad tracks and highways running through the municipality, their impact needs to explored. (Roberto, 2018). The city has attempted to mend this isolation with targeted development initiatives. Initiatives which have either largely proved unsuccessful because they were too decentralised, or they ignored or did not facilitated development for the low-income areas in the northern half (Hamann & Horn, 2015).

Pretoria-Tshwane also stands out in several ways compared to other countries in SSA and compared to its direct neighbours. Primarily through its comparatively advanced economy and the factors related to that, like motor vehicle ownership and socio-economic status. While motor vehicle ownership is comparatively high, it is disproportionately distributed among the country's population groups. Only 10% of the Black-African population even has a drivers' licences, compared to the 83% of the White population – this, coupled with the lack of accessible and affordable alternative means of transportation means that 40% of low-income workers walk to their place of employment (Lucas, 2011). Furthermore, only 20% of low-income households have access to a car, with an additional 40% and 75% lacking adequate access to buses and trains respectively (Lucas, 2011).

The middle-class compromise between 20.4% and 31.6% of the population (the former referring to affluence, and the latter referring to middle income strata). Around ~80% of those belong to the Black-African population group (Black-Africans constitute 94.3% of the lower class, and 51.3% of the upper class), with Whites constituting a meagre 2.8% of the middle-class (compared the 0.4% of the lower class, and 29.2% of the upper class belonging to the White group). This highlights in part the socio-economic shift that occurred post-apartheid (Visagie & Posel, 2013, pp. 158-159), as well as the entrenched nature of legacies of apartheid (Maharaj, 2020, pp.49 & 51) with the continued strong position of the White population in the most affluent segments of society.

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CTMM has a high rate of poverty (27.9%), majority of those in this category are concentrated it the Metropolitan Municipality's peripheral districts (Theodore et al., 2017, p. 146). With an unemployment rate of 24.2%, most of whom are also concentrated in the periphery districts, it is not unsurprising that a large number choose to work as a day labourers in the urban economic centres of Pretoria and Centurion (Theodore et al., 2017, p. 146-147).

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Literature review

3.1 Segregation

3.1.1 Segregation Measurements

Segregation was principal feature of the South African urban form for centuries, and to some regards still is today. Measuring it however is a tricky process. Something that has evolved over the decades. The most common method (that most other methods are also based upon), is the Dissimilarity Index developed by Duncan & Duncan (1955). An easy to use, and easy to interpret method that has found wide appeal (Candipan et al., 2021). Particularly in how it explains the distributional characteristics of residential segregation (Roberto, 2018). However, these explanations have been critiqued by Hamann & Horn (2015) as a failure to account for spatial proximity (location of areas in relation to one another), and the spatial representativeness (of only accounting for two population groups (White and Black-African)). This is not applicable to the contemporary multi-ethnic South Africa, especially as the cities' populations are less confined geographically.

There is little consensus for a uniform segregation index, hence there is such a large quantity from study to study. Roberto (2018) highlights some biases, solutions, and potential problems regarding that. The scale at which segregation is measured can vary, often it is done at a large scale. Either way, looking at just one specific scale means that comparisons between scales are left out. When comparing different scales with each other it becomes important to account for the varied spatial arrangement of areal units at each scale. This can be done through measuring proximity of units (or neighbourhoods, as it is called a large scales) within at a given scale. Roberto makes it clear that this can lead to problems, as there often stark variations in composition (demographically and spatially) between units. Hence it becomes necessary for segregation indices to account for interaction (and movement which facilitates interaction) effects between population groups (Candipan et al., 2021). Particularly as there can be disparities between residential environment and other spheres (e.g. place of employment). Hence meso-micro level studies can be quite common to understand the segregation of individual's "everyday activity spaces" (Candipan et al., 2021).

3.1.2 Debate on South African (de-)segregation

Segregation in South Africa has evolved a lot throughout history. Generally, consensus is that segregation remains a fact of many South African cities like Cape Town (Visser & Horn, 2021, p.30), Johannesburg (Ballard et al., 2021, pp.50–51), Durban (Maharaj, 2021, p.76), Buffalo City (Seethal et al., 2021, p.114), Pietermaritzburg (Nel et al., 2021, p.144), and Pretoria (Horn, 2021, p.98) are some examples of major cities that suffer from continued segregation. With the authors also stressing the shift from racial classification to socio-economic status and class being the main denominator of their respective cases. This further reinforces the arguments made by the likes of Hamann & Horn (2015), Maharaj (2020, 2021, p.50) and Pieterse (2007). In contrast to the more optimistic arguments laid forth by Christopher (2001) and Marais (2021, pp.125–126), who argue that segregation has observably decreased in part because of population shifts within certain areas of the cities' districts. But even they highlight socio-economic concerns facing the Group Areas and townships. Even as there are clear variations in the magnitude and severity of the continued segregation, it undeniable that apartheid has entrenched itself, and continues to reproduce itself throughout the urban areas of much of South Africa (Hamann & Horn, 2015).

Through their case study on Pretoria-Tshwane, Hamann & Horn (2015) explain how continued segregation is the most prevalent in former Group Areas (primarily in Eastern, and Central-Western, and in part in the North-Western (Soshanguve and Ga-Rankuwa) areas). New segregation has primarily taken place areas affected by land invasions (peripheries of home areas, buffer zones etc.). They conclude based on this, that the Black-African population continues to be confined in large extents to the city's periphery (Hamann & Horn, 2015). And that the high levels of continued racial residential segregation stems from socio-economic factors, and socio-spatial distances are reinforced through physical barriers. All-all-all it is the spatial patterns of the city that has changed, racial-residential segregation continues. The ultimate hindrance to desegregation is socio-economic factors. As such they characterise Pretoria-Tshwane with disconnected-continuity.

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3.2   Car dependence

The phenomenon is generally associated with excessive use of private motor vehicles (Kenworthy et al., 1999, p.1) following the post WWII economic boom in the United Sates (Newman & Kenworthy, 2015). Some scholars have however questioned the norm of car use as the sole determinant of the dependence (Handy et al., 2005; Mattioli et al., 2016, 2020; Saeidizand et al., 2022). They argue that studies on car dependence need to take into consideration forced contra willing car use; the different levels at which car dependence occurs, as well as the cultures and systems that reinforce and maintain it; availability and access to other means of transportation. It hence becomes clear that there is a lack of consensus of what even constitutes car dependence (Mattioli et al., 2016). This lack has spurred authors like Mattioli et al. (2020) incorporate elements from commodity studies and sociology ("provisioning", "structures", "agency" etc.).

Culture around car dependence has become a central part of the capitalist cultural hegemony, particularly in how it symbolises consumerist freedoms (Haines-Doran, 2023). Car dependence generally confined itself to the more advanced capitalist regions (North America and Europe) up until the collapse of the Soviet bloc around the 1990s. This collapse led to a rapid spread of the material culture around automobiles. Cavoli (2021) points out that where extensive public transport networks had dominated throughout the Soviet bloc, after reintegration into the capitalist world system, expenditures would be slashed, and planning would be halted. As a replacement, came individualised and commodified solutions. The material culture around had become the symbol of capitalist freedom and luxury. Heavy investments into car infrastructure, and large imports of cheap and polluting cars followed. Here too would density and compactness in urban planning be replaced with sprawl and low-density.

Previous studies on the car dependence phenomenon has been confined to primarily to North America, Europe, and (to a lesser extent) Asia (Mattioli et al., 2020; Saeidizand et al., 2022). Not surprising, as motor vehicle ownership remains low throughout much of Sub-Saharan Africa (SSA), (see figure 3.2-1) South Africa (214) stands out in the region with an ownership ratio comparable to China (210). Following the trends of other countries in the Global South, this ownership factor stems from South Africa's more advanced economy and large middle class (in SSA only about 128 million people out of 900 can be said to belong to a middle-income group (AfDB, 2011)).

In the context of more advanced economies, transport poverty specifically concerns the minority of households that need to spend a disproportionate share of their income on car-related costs in order to access essential services and opportunities (Mattioli et al., 2017). In contrast with advanced economies like South Africa, this phenomenon affects a stark majority of people (Lucas, 2011). It is harder to generalise across the whole country as urban-rural divides present far more radical inequalities for the two subsets of the population in regards to accessibility, affordability, availability of varying means of transportation (Lucas, 2011). In the urban context (also less explored compared to rural one), it is not a question of a lack in appropriate infrastructure or a lack of motorised public transport (the paratransit alternative, minibus taxis is a huge phenomenon), but rather it is an issue of cost, reliability, suitability, and safety (Lucas, 2011). As highlighted by Mattioli et al. (2017), monofunctional land-use patterns correlate with increased car travel, hence then transport poverty goes together with the relationship between land-use, built environment, and travel behaviour.

The case study conducted by Lucas (2011) identified access to transportation as a popularly understood basic need, as low-income individuals seeking employment often times need to travel further than they can feasibly walk – which hence necessitates access to motorised transport. Furthermore, it shows the fortitude of the material culture around car dependence, that even those excluded from participating with cars and related infrastructure, still see it as the only alternative.
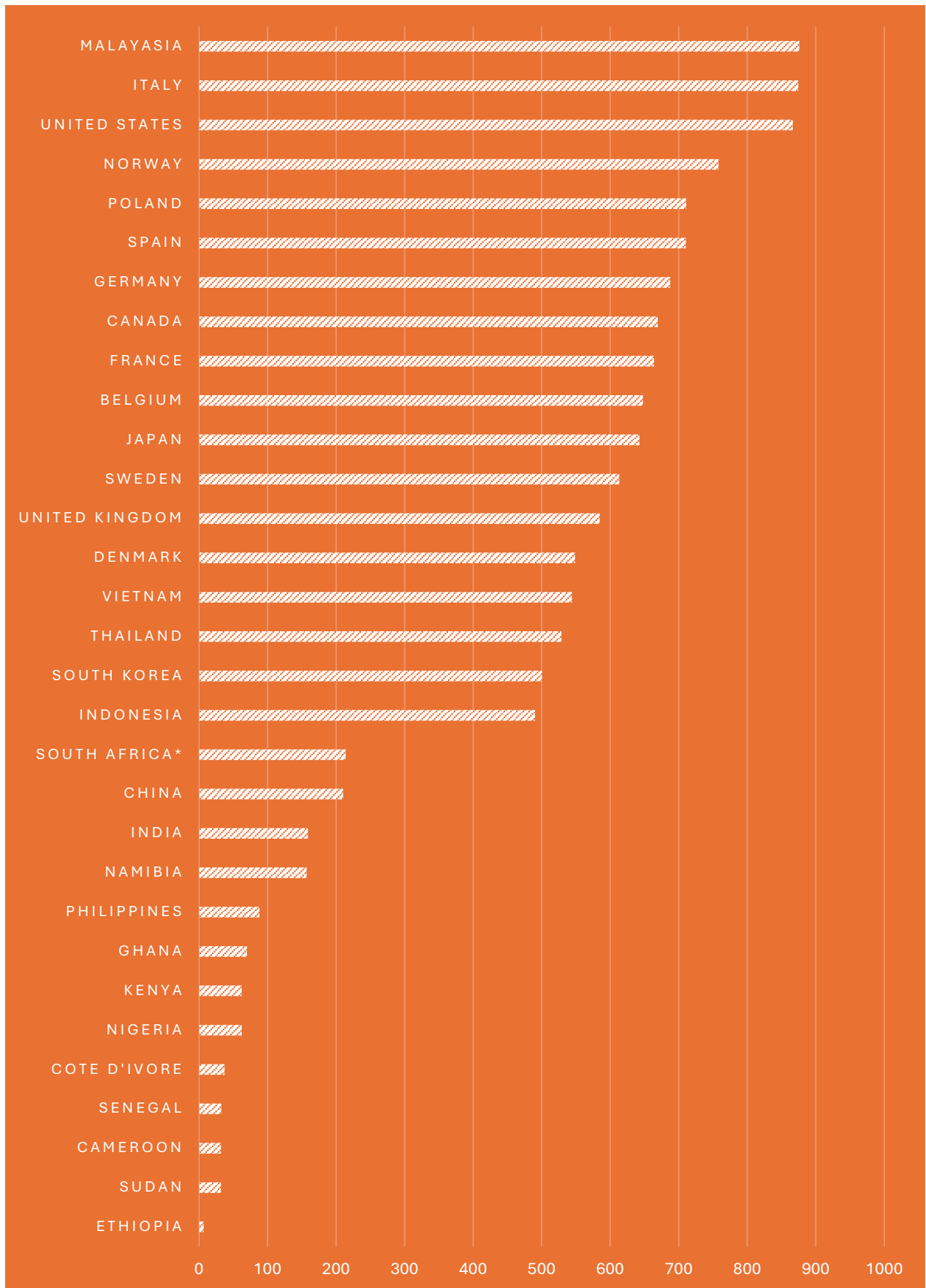
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*Figure 3.2-1: Vehicle Ownership per 1000 inhabitants. Sources: WHO, Global Health Observatory (2022); United Nations - Population Division (2022); *Knoema (n.d.)*

Theoretical Frameworks

4.1 Car dependence inducing transport poverty

4.1.1 Provisioning of Car Dependence in the Global South

Mattioli et al. (2020) have analysed the political economy of car dependence based on the Systems of Provision approach (SoP)[5] (see Bayliss & Fine, 2020). While their aims and conclusions primarily concern the effects of car dependence from an environmental perspective (they argue that car dependence results in carbon lock-in), their analytical model of the industry and material cultures provide a fundamental perspective for understanding car dependence and subsequent effects of transport poverty in regard to segregation in post-apartheid South Africa.

They (Mattioli et al., 2020) highlight how the provisioning of car infrastructure contribute to dependence, as that is what has led to the dominance of the car in so many aspects of peoples' lives. The privileged position of middle-income groups in society manifests this provisioning as said group grows. In line zowith that, the demands for private motorised vehicles rise, which also result in state initiatives to encourage the demand further (through infrastructure investments, fuel subsidies etc.) (Lucas, 2011; Mattioli et al., 2020). This coincides with the commonly held assumption that automotive industries are a vital for industrialisation and modernisation (Short & Martínez, 2020), a demand that cannot be filled by low-income groups as the costs related to motor vehicles are too high (Lucas, 2011). In South Africa for example, owning a car is a more high status symbol than owning a house (Short & Martínez, 2020).

The large quantities of subsidies and investments for car infrastructure normalises the car dependence to such an extent that any alternative becomes borderline unimaginable (Mattioli et al., 2020). This point can be illustrated with the example of cost distribution from Mattioli et al. (2020), wherein car infrastructure costs are distributed between both the government and individuals. This results in anything politically negative concerning cars turning into a personal issue for individuals as they are directly invested in it. Contrast that with public transport, which

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[5] The Systems of Provision (SoP) approach is a framework for analysing consumption in relation to material cultures. Particularly through the entire chain of provisioning. This differs from orthodox consumption theory which generally employs a horizonal perspective, focusing on consumer and producer/sellers. SoP aims to understand the diverse nature behind the drivers of consumption, as they are often more than just imagined needs from the consumer's side. Understanding consumption necessitates understanding the processes of production, as well as the interlinkage between the public and private – something which orthodox often ignored as it did not fit their ethos of consumption. The SoP approach typically focuses on a specific commodity, in the case of Mattioli et al. (2020), that would be private motor vehicles.

is solely funded through public means, and as such are harder to defend or justify. This inequitable distribution of cost means that low (or non) users pay disproportionately compared to high users.

4.1.2 The provisioning of Transport Poverty

At the junction of segregation and car dependence, there is the phenomenon of transport poverty. The phenomenon of transport poverty denotes two meanings as per Mattioli et al. (2017), one a general, and one specific. Generally, it refers to inequalities connected to accessibility and availability. Specifically, it refers to the inequality aspects stemming from forced car ownership (as a result from a lack of alternative means) or car-related economic stress (numerous costs, from gas to insurances) forced upon the users.

Transport poverty is also strictly an individual phenomenon, it does not pertain to households as a collective *per se* (Lucas et al., 2016). This is an important distinction to make because often it is only specific members of the household that experience it, these experiences are mostly divided around gendered lines. Lucas et al. (2016) identified four broad notions which encompass transport poverty, which partially overlap with the meanings defined by Mattioli et al. (2017). The first notion is that of mobility, wherein a systematic lack of transportation (often connected to a lack in infrastructure) hinders movement; the second notion is that of accessibility, where key activities fall outside what is feasible to reach at reasonable time, cost, and ease; the third notion concerns affordability, where individuals (and through them, the household as a whole) lack the means to afford transportation (public or private); the fourth and final notion is that of exposure to externalities, this refers to the negative effects surrounding the transport system (often car dependency related effects) like traffic fatalities, pollution related diseases, noise, stress etc.

Hence, transport poverty comes down to a lack of suitable options for the target group (often low-income groups) or the whole population. It also pertains to the unfulfillment of existing options in providing access to key activities in the individual's life. Then finally there are the time, cost and safety factors – all of which are often times high for the group experiencing transport poverty, as the means available to them are insufficient.

4.2 Spatial formation of South African cities –Past-present connection

4.2.1 Apartheid City Planning

As cities were never really part of the indigenous populations' tradition in what is today South Africa, unsurprisingly they came to be dominated by the White settlers who founded them in the 17th century (Davies, 1981). This was further reinforced through the enclosures and dispossessions of the indigenous Black-African population, which resulted in them being moved into (or within the near vicinity) of the cities as a reserve labour force. Particularly important for the mining industries. With the allocation of specific race areas throughout South Africa's cities following the implementation of the Group Areas Acts (GAA), forceful relocations became a necessity. And as these GAAs had to allocate space for future expansion and population growth, physical barriers (or buffer zones) where necessitated to stop intermixing of population growth through organic expansion into each other's designated areas (Davies, 1981).

With the case of Pretoria(-Tshwane) (see figure 4.2-1[6]), Whites generally dominated the urban centre, south, east, and partially the north areas of the city. With urban non-White population groups being confined to periphery locations in the east and west. This policies were also reinforced and maintained by separating lines of movement by constructing tracks and roads, which spatially constrained areas from one another (Davies, 1981).

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[6] Pretoria(-Tshwane) was both much smaller geographically in the 1970s and Black-African group areas where not continuously part of the metropolitan municipality, which is why group areas like in the northwest are not shown on the map.
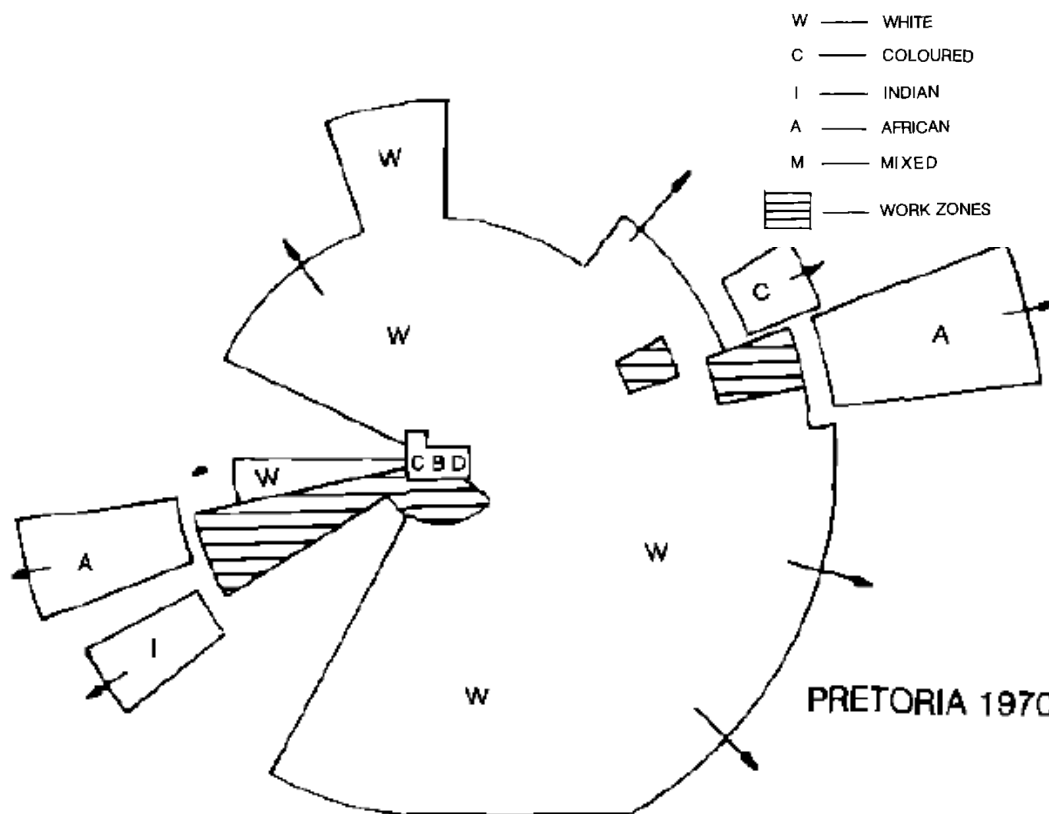
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Figure 4.2-1: Sector map of Pretoria's population group composition in 1970 (Davies, 1981)

4.2.2 Legacies

While urban planning initiatives vary from city to city in contemporary South Africa, the perpetuation of segregation and uneven developments of municipal districts throughout them result in perpetuation of apartheid-era residential-segregation patterns (see the case studies done in Lemon et al. (2021) post-apartheid legacies in major South African cities). Pretoria-Tshwane (see figure 4.2-2) has seen population shifts from White to Black-African in many middle- and high-income areas, with the low-income population is however still confined to the same areas as under apartheid.

The post-apartheid infrastructure investments, while substantial, has failed to affect socio-spatial inequalities in a positive way (Maharaj, 2021, p.49). Adoption of neoliberal policies in South Africa around the turn of the century, resulted in the international trends of spatial decentralisation of businesses (which moved to peripheries along with Whites) coming to South Africa's cities. Cities as a result had to become profitable which meant they could no longer afford to continue their mission of integration as had begun after the end of apartheid (Massey, 2020, p.272). The effects of which are coupled with the indirect expansion of informal

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housing developments in periphery areas – constraining low-income groups physically, while limiting or stopping them from seeking better opportunities. While the city is aware of these issues, remedial solutions have mainly been delegated to local initiatives. Which have not been able to deliver as it requires coordination at a much higher level (provincial or even national) to be effective (Horn, 2021, p.96)
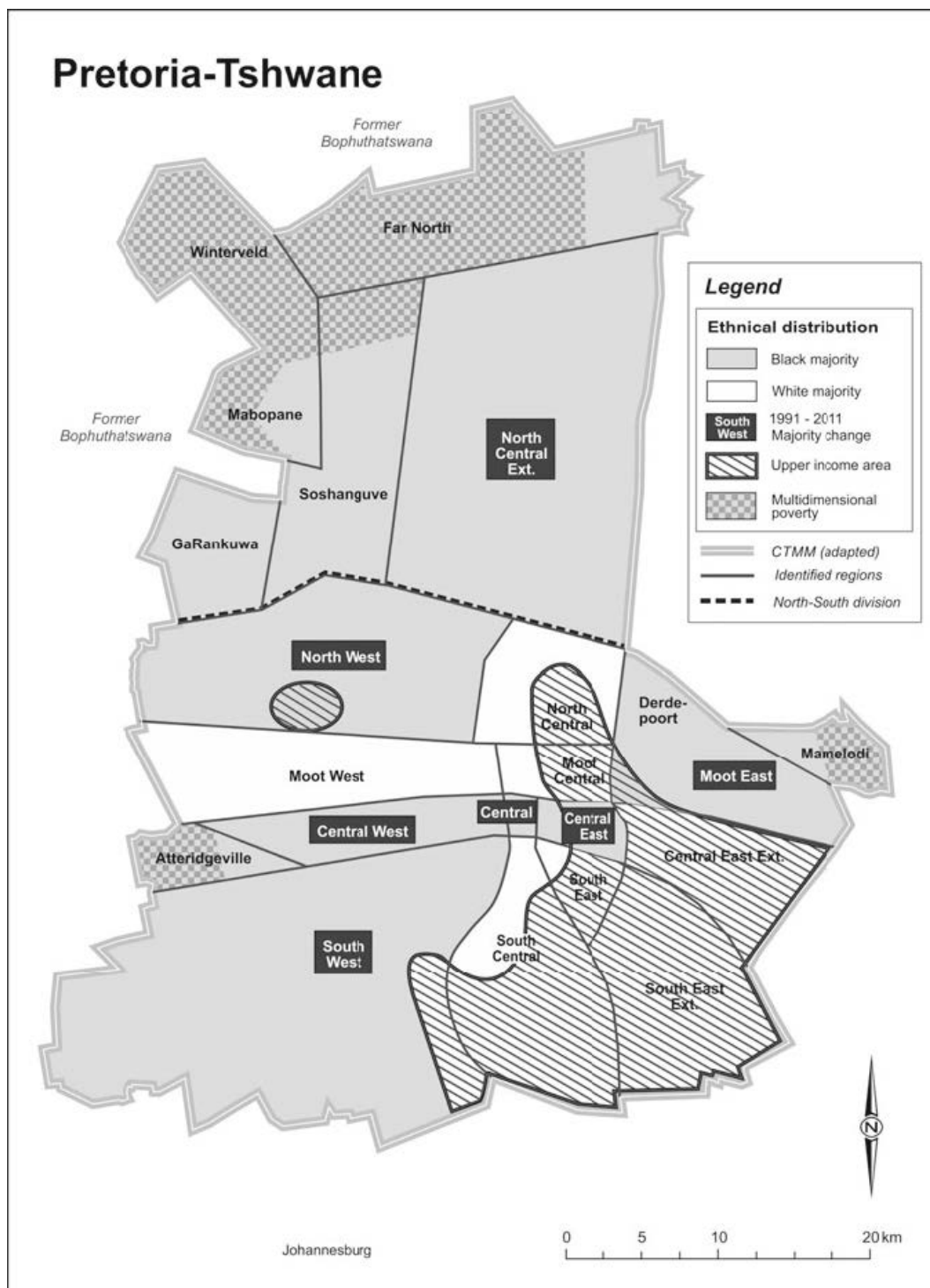

Figure 4.2-2: Pretoria-Tshwane - race and income (Horn, 2021, p.88)

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4.3 Continuity-discontinuity continuum

Segregation studies have been suffering from numerous methodological challenges (as discussed in segregation metrics), which is why there is an abundance of indices (Hamann & Horn, 2015). Numerous studies have drawn comparisons between the colonial and apartheid era cities with that of the contemporary cities (see the literature review for the discussion on this). Because the continuum of segregation varies from location to location (horizontally, between places in the city; vertically, variations at different geographic levels), as such no place has or is experiencing complete desegregation or segregation. Hamann & Horn (2015) employ the *continuity-discontinuity continuum* to cover the three primary positions within the contemporary South African city.

The first one is the *connected-continuity*: Apartheid-era influences still perpetuate themselves throughout the cities, whose urban form also remain relatively unchanged. The second one is *disconnected-continuity*: spatial segregation persists throughout the city, but in new or different forms (i.e. the shift from class over race). The third and final one, *discontinuity*: the economic, institutional, spatial and social conditions of apartheid no longer constrain the city.

These distinctions become important as the lingering effects of apartheid are far more subtle now that is not a government policy anymore, especially when income differences are understood as the genesis of racial residential segregation. Black-Africans generally do not experience residential mobility like affluent White households[7] (Hamann & Horn, 2015). With the land invasions and the White flight towards the end of apartheid, this was first observed as desegregation. But because of the White population's relatively entrenched socio-economic status, and the partial economic decline of the inner cities (Maharaj, 2020, p.49), numerous areas would end up either (see Hamann & Horn, 2015) continuing segregation, experiencing new segregation, re-segregate, falsely desegregate – a minority of areas would continue to actively desegregate.

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[7] Numerous factors, primarily related to property market forces, serve to perpetuate, and reinforce segregation. This means that peoples financial capabilities or socio-economic status is a main driver behind where people can live (hence segregation). Other factors that explain and contribute to this are for example red lining (see Locke et al., 2021), gentrification (see Pacione, 2009, pp.211–212), and block busting (see Rubenstein, 2011, p.215).

Research Design

5.1 Methodology

This study has a three-fold approach to answering the set research question. Essentially these three methods include conducting segregation analyses using two indices at varying geographical levels; a spatial disconnect analysis following euclidean distance measurement to analyse proximity; and a connectivity analysis conducted along the city's road network to measure physical/corporeal reach. These three analyses come together and complement each other in answering the stated research question.

5.2 Methods

5.2.1 Spatial Proximity and Connectivity (SPC) method

To analyse the overlapping effects of segregation and transport poverty in the context of post-apartheid South Africa, a specific type of segregation index is required. To analyse this specific intersection, the SPC method devised by Roberto (2018) is employed. Proximity refers to the relative location of areas to each other (Roberto, 2018). Measuring proximity can be done either through a straight-line (euclidean) distance analysis or through a physical/corporeal network analysis (along e.g. a road network). The lacklustre incorporation of "proximity" into other segregation indices (as outlined in segregation measurements), means that those measures do not take the prevalence of multiple ethnicities into account (which is more understandable in an United Statesian context, or a apartheid era South African context, where primarily two ethnic groups where of interest for researchers ("Black" and "White"), but makes less sense in place with multiple varied population groups) (Hamann & Horn, 2015).

There is however a methodological issue that generally occurs within other proximity studies, and that is how they often fail to capture spatial differences in the organisation of e.g. neighbourhoods (Roberto, 2018). A lack of consideration for presences of the built environment is a common pitfall, another is the overreliance on straight-line distances. To amend these issues, Roberto (2018) has chosen to incorporate connectivity as a vital function of their analysis. Connectivity refers to the physical barriers in the environment (whether it be land or structures like railway tracks) (Roberto, 2018). Segregation is analysed through an incorporation of physical barriers and road networks. Using road networks over straight-line-distances is done to counter the spatial connectivity problems that occur within other types of

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proximity studies. This is important as two neighbourhoods might appear close to another but might be separated by a physical barrier so that their distance on the road network is much further than the straight-line-distance would be. These can also be used in conjunction with one another to highlight specifics that might be missed by one form of analysis.

The inclusion of specifically physical barriers is justified by Roberto (2018) as it has in different places been used as mechanism to either reinforce or exacerbate existing segregation (increasing the spatial distances, furthering separation between groups). In the Pretoria-Tshwane case an example of physical barrier's impact on the spatial distances would be the mountain ranges running through the city, separating north and south. The northern part of the city had been predominantly Black-African (with the exception of North Central Extension which was mostly White owned farmlands) and remains poor after apartheid (Hamann & Horn, 2015; Horn, 2021, p.88).

This proximity analysis will be combined with transport poverty in order to show the interconnected nature of the two variables. Inaccessibility is then understood both theoretically (through provisioning) and methodologically (the effects of the phenomenon). The effects here are two-fold according to Mattioli et al. (2017). Firstly, they refer to the social exclusion and isolation that stems from inaccessibility to transportation. Secondly, affordability related issues like e.g. "forced car ownership" – no other affordable or accessible means of transportation; "car-related economic stress" – the costs related to owning and operating a car.

While Roberto (2018) uses R[8] for their analysis, the author of this study has opted to use ArcGIS to conduct the analysis. The choice of ArcGIS over R is primarily a question of experience on the author's side. With the author having previous experience with ArcGIS but lacking experience with R. Hence, the steps outlined by Roberto (2018) will in part be replicated, but adapted for ArcGIS and the requirements of this study. This primarily comes down to the road network analysis comparative to the straight-line-distance analysis (further ahead there will be a detailed overview of the steps involved in each of the analyses)

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[8] https://www.r-project.org/

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5.3 Methodological Problems

There are two primary methodological problems of concern when working with segregation. These are the checkerboard problem and the Modifiable Areal Unit Problem (MAUP). In essence both occur when studies are conducted aspatially, i.e. without concern for space those studied exist within. A common occurrence is the lack of consideration for the relative relation of studied areas to one another. In an aspatial approach, all areas are each other's neighbour. In reality this might not be the case, as there can be kilometres in-between populated neighbourhoods. With the case of Pretoria-Tshwane this becomes particularly applicable as there still vast remanent buffer land left over from apartheid planning that separate former group- and homeland areas from the city proper.

The importance of conducting spatial segregation analyses at multiple administrative levels is necessitated because of the MAUP. Conducting research at only one geographic scale can give inaccurate image of a specific phenomenon (see figure 5.3-1). To exemplify with the case of Pretoria-Tshwane, racial-residential segregation can manifest itself differently at larger/smaller geographic scales. At the municipal (City of Tshwane Metropolitan Municipality) level there is a 70/25% demographic split between Black-Africans and Whites. This highlights a large disparity in the population but looking at larger scale of the city itself (Pretoria-Tshwane), then there is an even split of 50/40%. Going even larger reveals a divided city (see figure 4.2-2), with the White population being situated in the affluent central and south-eastern parts, and the Black-African population in the remaining parts.
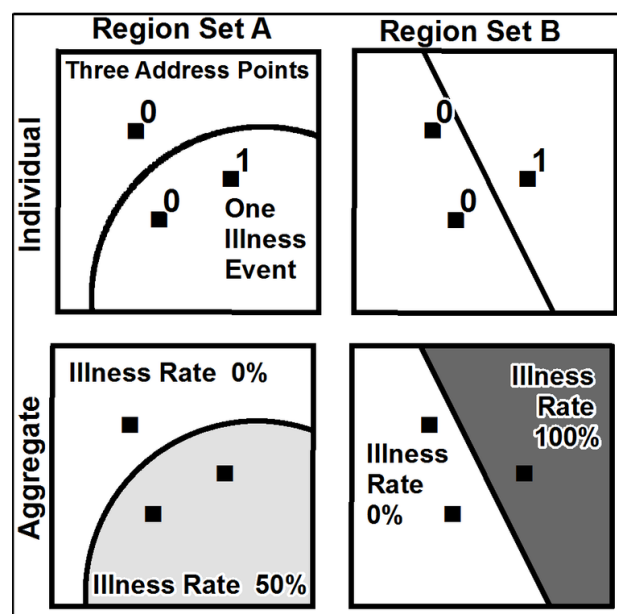

Figure 5.3-1: Simple summary of MAUP issue for illness rate calculation. (Andresswift, 2010). CC BY 3.0

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5.4 Analyses workflows
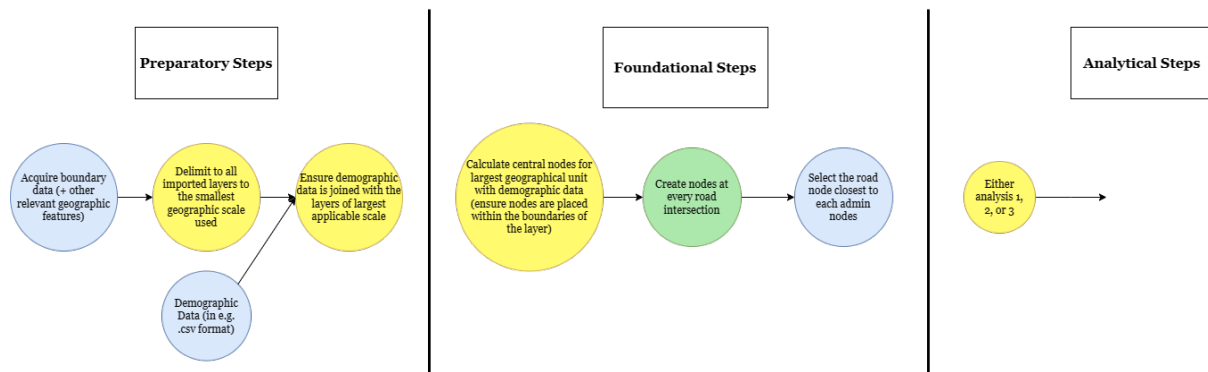
5.4.1 Analytical foundations

Figure 5.4-1: A workflow diagram illustrating the initial steps for conducting the analyses (Author, 2024)

The initial steps of each separate analysis follows the same foundational structure (see figure 5.4-1). This is the case as each respective analysis uses data from the same source (StatSA, 2012), which after importing into the software of use (in this case, ArcGIS pro) is prepared in the same way for each analysis. This entails basic processes like delimitations to the case region, joins between spreadsheets and vector file features (like administrative boundary polygons). It also involves more analytically specific processes like the creation of nodes at road intersection, as well as the selection of focal intersection nodes, closest to the centroid of the largest used administrative boundary layer.
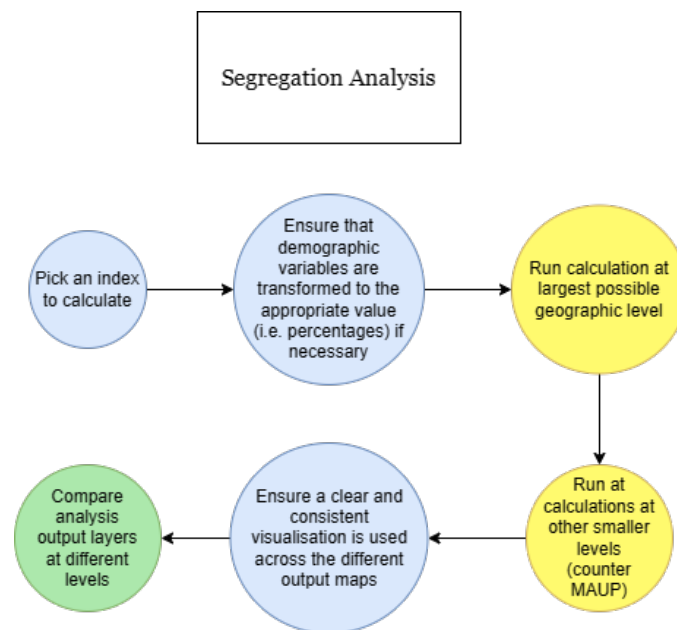
5.4.2 Segregation analysis

Figure 5.4-2: A workflow diagram illustrating the general steps of the segregation analysis (Author, 2024)

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The segregation analyses are specific to the chosen segregation indices to be measured, generally they follow a similar outline (see figure 5.4-2). Here it is important that demographic variables are transformed into appropriate number type, e.g. percentage, as provided data might only present figures in integers or non-integers. With the case of this study being Pretoria-Tshwane and the lack of data availability at the largest geographic levels (census tracts / enumeration areas), the closest level with complete data coverage is chosen to calculate the indices at, which in this case is the Sub Place layer. Analysis is also conducted at the smaller Main Place level, as to be aware of potential disparities in output between the different levels (i.e. MAUP).

The indices to be used are Duncan & Duncan's (1955) Dissimilarity Index (DI). This is measured with the following equation:

$$0.5 \times \sum_i \left| \frac{b_i}{B} - \frac{w_i}{W} \right|$$

DI in this study will be calculated for each population group against every other ethnic group. b_i represents the total (in this case Black-African) population within a given areal unit, i. This is then divided with the total population group count of the entire study area. w_i represent the population group to be compared against (in this case Whites), also divided by the total count. Outputs range from 0-100, where 100 is complete segregation and 0 is no segregation.

The second index used is the Multigroup Dissimilarity Index (DI(m)) by Wong (1998).

$$0.5 \frac{\sum_i \sum_j \left| N_{ij} - E_{ij} \right|}{\sum_j N P_j (1 - P_j)}$$

This is a comparison between all groups, whereas the DI is a comparison between each group and every other group separately. N_{ij} represents the total population of a specific group within a given areal unit, i. N_j is the total population of a specific group, j. N is the total population within the entire study area. P_j is the proportion of population within group j. E_{ij} is an assumption of population size of a given group j within a given areal unit i, if the population is distributed proportionally. The output is also presented from 0-100, increasing numbers indicating increased segregation.

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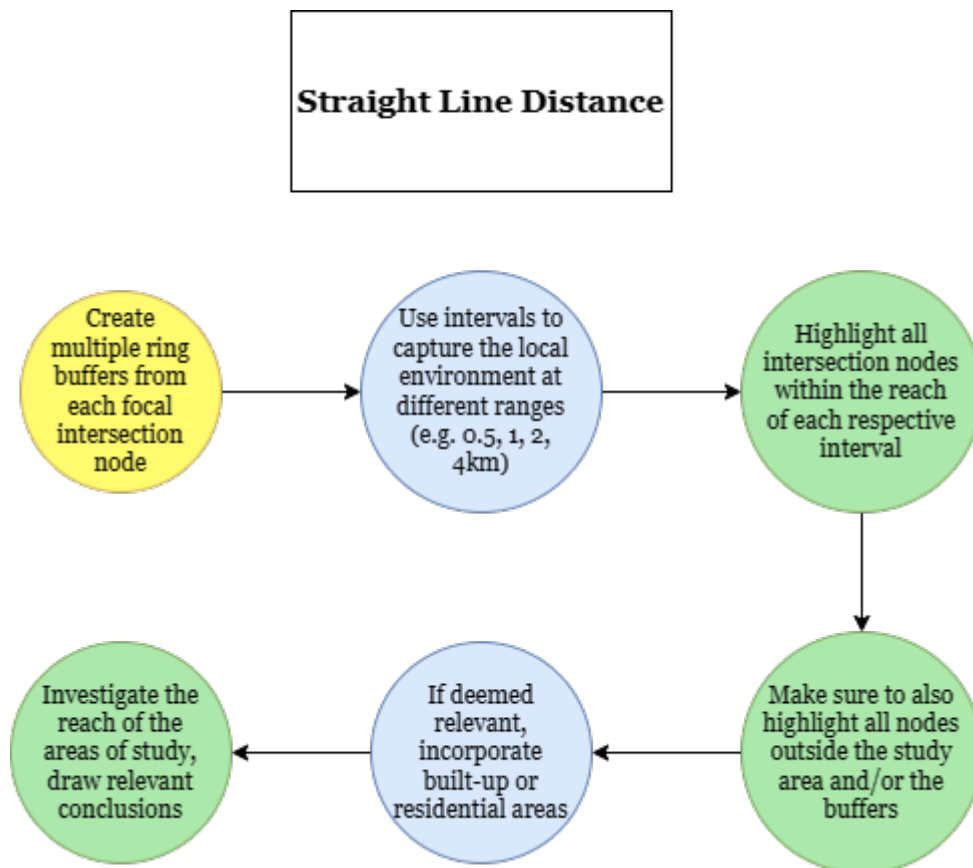
5.4.3   Straight-Line-Distance analysis

Figure 5.4-3: A workflow diagram illustrating the general steps of the Straight-Line-Distance analysis (Author, 2024)

To measure the spatial disconnect within and between the chosen regions of the study (former group- and homeland areas, and city proper (Pretoria and Centurion)) a straight-line-distance[9] analysis is conducted (see figure 5.4-3). The author opted to use multiple-ring buffers instead of lines to measure euclidean distance because of the ease to do so in ArcGIS pro. The outcome becomes the same as it follows the same logic. The added benefit of using buffers is that it becomes clearer to visualise nodes within the different intervals. In the end, doing this analysis will visualise the reach of the case Sub Places. This analysis does not consider the physical environment. However, it is nonetheless useful as it will illustrate the reach of local environments compared to neighbouring places, as well as the reach of the areas of analysis as a group (essentially at the Main Place level). Here it can also be valuable to incorporate residential or built-up areas to visualise the (dis)connection between areas of the municipality.

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[9] Throughout the rest of this study, straight-line-distance will be referred to as *euclidean distance*, this as that is more in line what actually occurs in the analysis. This is slight divergence from how Roberto (2018) formulated it in the SPC method, but the concept remains the same nonetheless.

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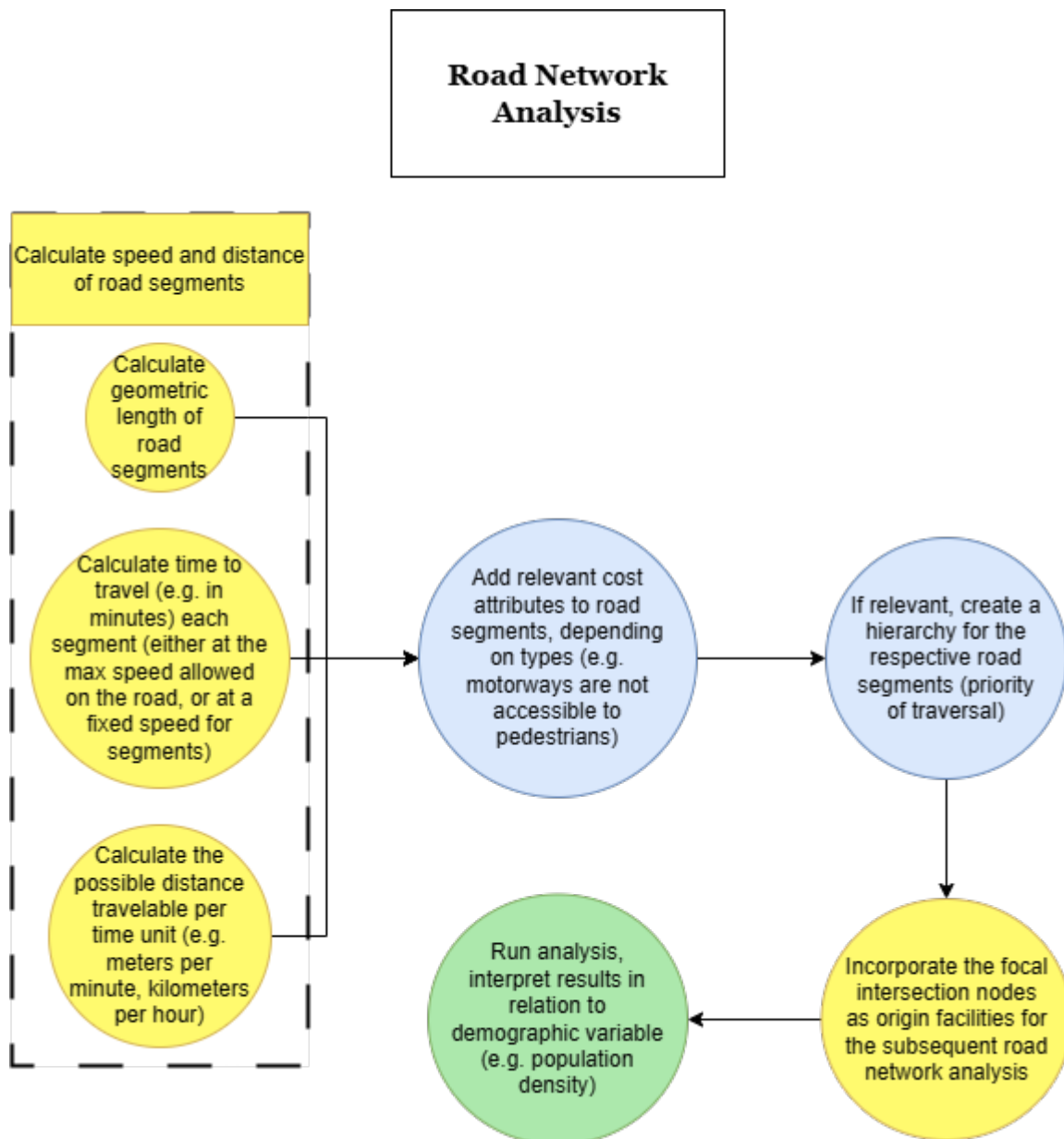
5.4.4 Road Network analysis

Figure 5.4-4: A workflow diagram illustrating the general steps of the Road Network analysis (Author, 2024)

Road network analysis in this study (see figure 5.4-4) is used alongside Straight-Line-Distance to illustrate the changes in connectivity when accounting for the physical environment (Roberto, 2018). For this study that entails certain restrictions when conducting the analysis, like only accounting for pedestrian movement, only being able to move on roads, certain roads (like motorways) being forbidden. Focal intersection nodes represent the centroid of each enumeration area's (EA) road network. It's important to use these over conventional geographical centroids, as the distribution and density of roads vary between EA's. This allows for a more accurate estimation of reach where there the EA population can be assumed to be highest and/or densest (because of the lack in large scale aggregation of census data).

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Together the analyses will serve to provide an accurate picture of reality of segregation at two different geographic instances, while also accounting for proximity and connectivity. Measuring proximity and connectivity both in accordance with euclidean distance and along the road network is beneficial because the former can highlight the general impact of larger physical barriers (like a forest plantation) in relation to the wider area of study. Whereas the road network analyses visualise the impact of the accessibility and connectivity a long a given areas road networks with that of other areas. Two areas might be bordering one another, but the lack of roads connecting them can serve to inhibit interactions between areas.

5.5   Data Sources and Collection

This being a quantitative study entails data collection primarily from the Statistics South Africa (StatSA), the official state statistical authority for the country. Their data is primarily collected through their decennially censuses, wherein for this study the latest and most developed census was the one from 2011 (StatSA, 2012). The accessibility of acquisition of this data varies depending on the required scale and requested materials, as to respect the privacy of the census respondents. The ways in which the data is provided, once StatSA is satisfied with the researchers' justification for the request, can vary. And with the scope of this study being rather limited, getting raw census data in in non-standardised formats can prove to be an unnecessary hassle.

Most research (and all research relevant to South Africa in this study) use up to the 2011 census (or earlier censuses). The reason for using 2011 and not 2022 census data, while the latter is technically available, is that aggregation to larger scales have not been completed as of writing this study. Hence, one is presented with either using up-to-date available demographic data at small scales like the provincial level, or using older data that is available at more desirable larger scales. Still not ideal, as the largest scale – enumeration areas – are deemed to privacy invasive to be made accessible for this research (StatSA pers. comm., 2024). Hence this study becomes confined at the largest level to the Sub Place (GADM classification equals to level 6, the other layer used in analysis is the "Main Place" which equals to level 5). Enumeration areas are include as a visual guide for composition of neighbourhoods, even if they do not contain any data.

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5.6   Limitations

Conducting a census like that which has been done by StatSA is a monumental task, this impacts the analyses especially because of the complexity involved in using raw data directly from StatSA (Bryman & Bell, 2019, pp.122–126), the data is often provided in non IS formats or is locked behind vetting and back-and-fourth email conversations. To get around that, the study employs the usage of Frith (n.d.) who has complied the census in an accessible format suitable for the analysis of this project. As the data is acquired from a second party there could be questions of its validity, but as the analysis only requires demographic data for the country's population groups this can easily be cross referenced with data provided directly from StatSA (2012).

Another concern with the data is that of the fairly large undercount of 14.6%, though this mainly affects cross-census comparative studies (Christopher, 2014) and not this one to the same extent. As this study is focused on cross-regional comparisons (not chronological comparisons), the undercount is less of a concern, as general arguments still hold merit. It is however problematic as the extent of the undercount can be difficult to determine for the specific case(s).

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Analysis

6.1 Segregation geographic scale analysis

The present state of segregation in Pretoria-Tshwane shows variations at both different geographic scales, and between population groups. To give an overview of this, table 6.1-1 shows the values of segregation between each population group (analysed against each other), as well as all non-White population groups against the White group. The output herein, from Duncan & Duncan's (1955) Dissimilarity Index (DI), show how similar the values at the Sub Place level are for the White population compared to the Black-African group (84,98) contrasted with the White population group also compared to all other groups (83,28) of Pretoria-Tshwane. The impact of all non-White groups contrasted with the White group, compared to the Black-African group contrasted with the White group is minimal. This is reflective of small population numbers of these other non-White groups. This becomes important because it highlights the unique composition of Pretoria-Tshwane compared to South Africa's other large cities. Cape Town, Durban, and Johannesburg have Indian/Asian and Coloured population groups of between 10-35%, significantly more than Pretoria-Tshwane's of barely 5% (StatSA, 2012). The inclusion of other minority groups is still important even if the study chooses to primarily focus on the two majority groups.

That said, this does not mean that experiences in segregation of the other non-White groups should be ignored. Rather as the table shows, that these groups also experience high segregation contrasted with the White population group (65,89 for Coloureds, 63,66 for Indians/Asians, 50,81 for Others). Indian/Asian and Coloured populations being concentrated primarily in two small areas of the city (Hamann & Horn, 2015) also explains why there is high segregation between these two groups (81,71 and 71,97 respectively) and the Black-African group.

Table 6.1-1: Comparison of the DI at the Sub Place (SP) and Main Place (MP) levels (compiled by the author (2024), with data from StatSA (2012). Italicised numbers signify a comparison to all other groups.

	Black-African		Coloured		Indian/Asian		Other Race		White	
	SP	MP	SP	MP	SP	MP	SP	MP	SP	MP
Black-African	*81,30*	*75,28*	71,97	67,80	81,71	75,74	55,62	45,98	84,98	77,93
Coloured			*58,30*	*51,36*	63,66	55,88	63,20	41,89	65,89	55,43
Indian/Asian					*69,01*	*59.39*	50,81	52,88	63,66	46,93
Other Race							*40,42*	*29,54*	50,81	39,00
White									*83,28*	*76,00*

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While the differences appear more varied or lower between groups at the Main Place level (see table 6.1-1) this has primarily to do with the changes in composition at smaller levels in many former White only areas after the end of apartheid (Horn, 2021, pp.86–88) (see figure 4.2-1). As a result in major demographic shifts throughout the city, particularly at larger levels. Greater numbers of certain population groups impact the visibility and representability of other small groups in the output. Hence, the output from the analysis manifests itself like this at smaller levels because the DI cannot account for the prevalence of a multitude of population groups within the same areal unit (Hamann & Horn, 2015), or segregation within population groups because of other factors.

Hence calculating the Multigroup Dissimilarity Index (DI(m)) becomes valuable as it shows the structural segregation among all groups, instead of each group compared individually to every other group as per the DI. The DI(m) output at the Sub Place shows as value of 79.68 whereas at the Main Place it shows a value of 72.85. Indicating a high degree of segregation when all groups are compared (Wong, 1998). The DI(m) output is then also correlates fairly well with the values from the DI calculations between Black-Africans and Whites, and all non-White groups and Whites.
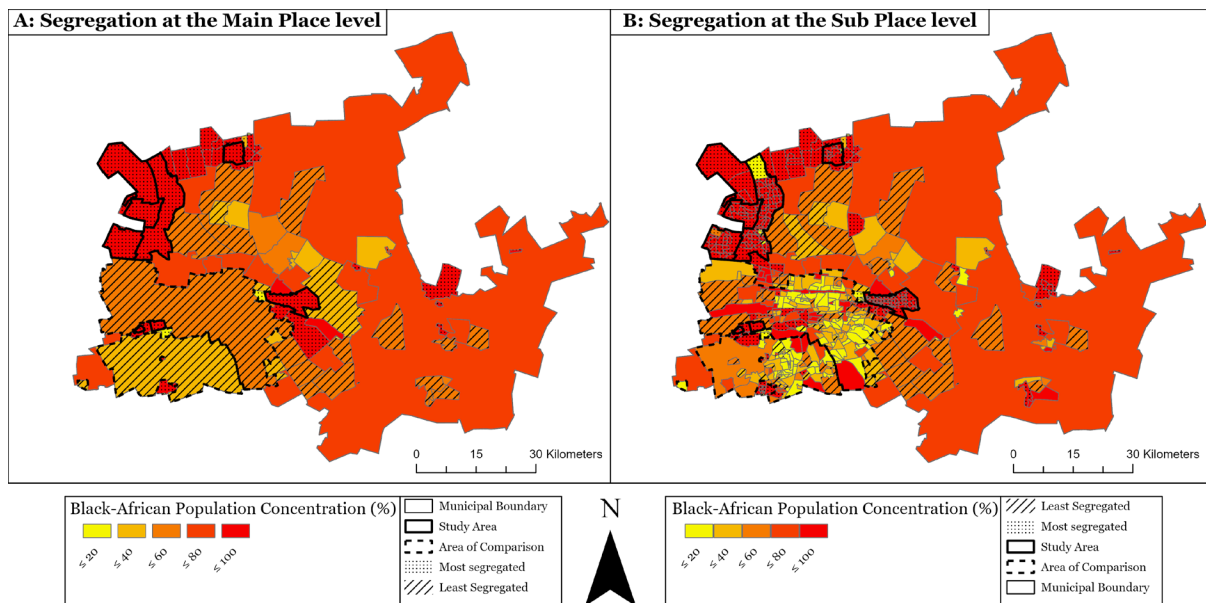
Figure 6.1-1: Segregation and Black-African population concentration at the Sub and Main Place levels (Author, 2024)

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The spatial isolation endured by the majority population in the study area, entails not only isolation from other population groups but also isolation from people of the same population group (see figure 6.1-1). The variations in segregation at different geographic scales (see table 6.1-1), reveals itself more starkly through a cartographic *vis-à-vis* a tabular visualisation. This map then serves to illustrate the differences in table 6.1-1's output between the Sub and Main Place, but through a spatial presentation. E.g. figure 6.1-1:A shows Pretoria and Centurion as the "least segregated" Main Place areas (a DI value of > 11 (the lowest quantile)), but looking at the same area at the Sub Place level (see figure 6.1-1:B) presents a different reality. With numerous Black-African majority areas are classified as "most segregated" (a DI value of < 44 (the highest quantile)), and none of the White dominated areas being marked as "most segregated". This highlights the importance of conducting such analyses at varying geographic levels, as otherwise results may be misleading and give false impressions.

Hence, it becomes clear that Black-Africans are experiencing segregation at an unprecedented scale compared to other population groups (this is confirmed through Hamann & Horn's (2015) study on the continuity of segregation). Moving forward it is also important to keep in mind that the areas of study are to large extents experiencing multidimensional levels of poverty (Horn, 2021, p.93), and that segregation contemporarily is far more complex than just the spatial isolation between groups, it becomes clear that there is isolation within groups too. With population concentration in mind (see figure 6.1-1), the disproportionate spatial distribution gives precedence for focusing the subsequent analytical parts on these former group- and homeland areas. The established separation of these high population areas (Hamann & Horn, 2015) require further investigation, especially because of the aspatial approach of DI and DI(m), it cannot account for distances and barriers hindering or impeding population shifts which would be required to lower segregation (Wong, 1998).

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6.2   Spatial Disconnect

With having established segregation as a material reality for many low-income Black-Africans in former group- and homeland areas (see the background section contemporary Pretoria-Tshwane, and the literature review section on the debate on segregation in South Africa). It's important to put this in the context of the wider city, especially the two largest (Pretoria and Centurion) district municipalities (Main Places) that are not townships like former group- or homeland areas. Because of their important economic functions, with Pretoria housing much industry as well as the historical central business district (Horn, 2021, pp.96–99). Centurion has also experienced expansion and densification of its built-up areas (industrial, economic, and residential), resulting of municipal development initiatives. With that in mind, it becomes important to understand the euclidean distance reach of the neighbourhood local environments within the study areas (see figure 6.2-1). This entails the distance of the local environment from focal nodes and stretching outwards as the crow flies. For this study, the value of that is derived from how it highlights proximity of neighbourhoods within the study area to those within the reach of its local environment (at intervals up to 4km). This helps visualising the impact of monocultural land-use in keeping certain areas spatially separated.
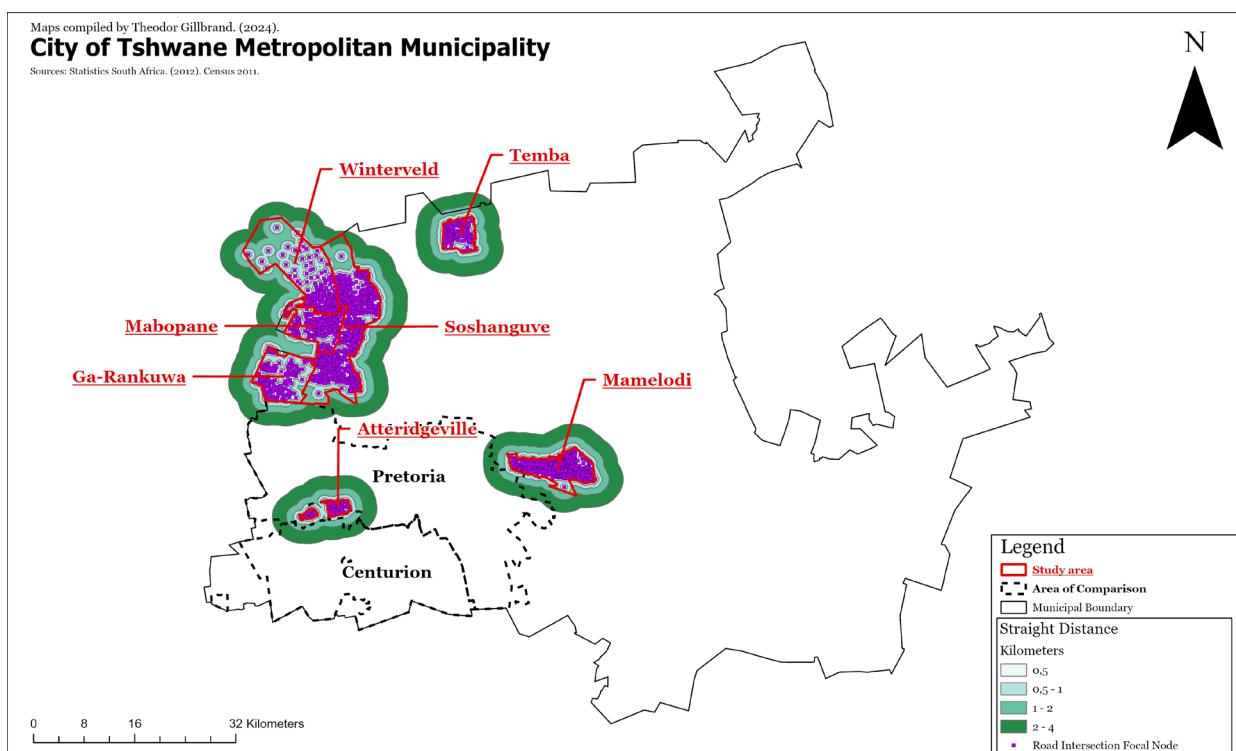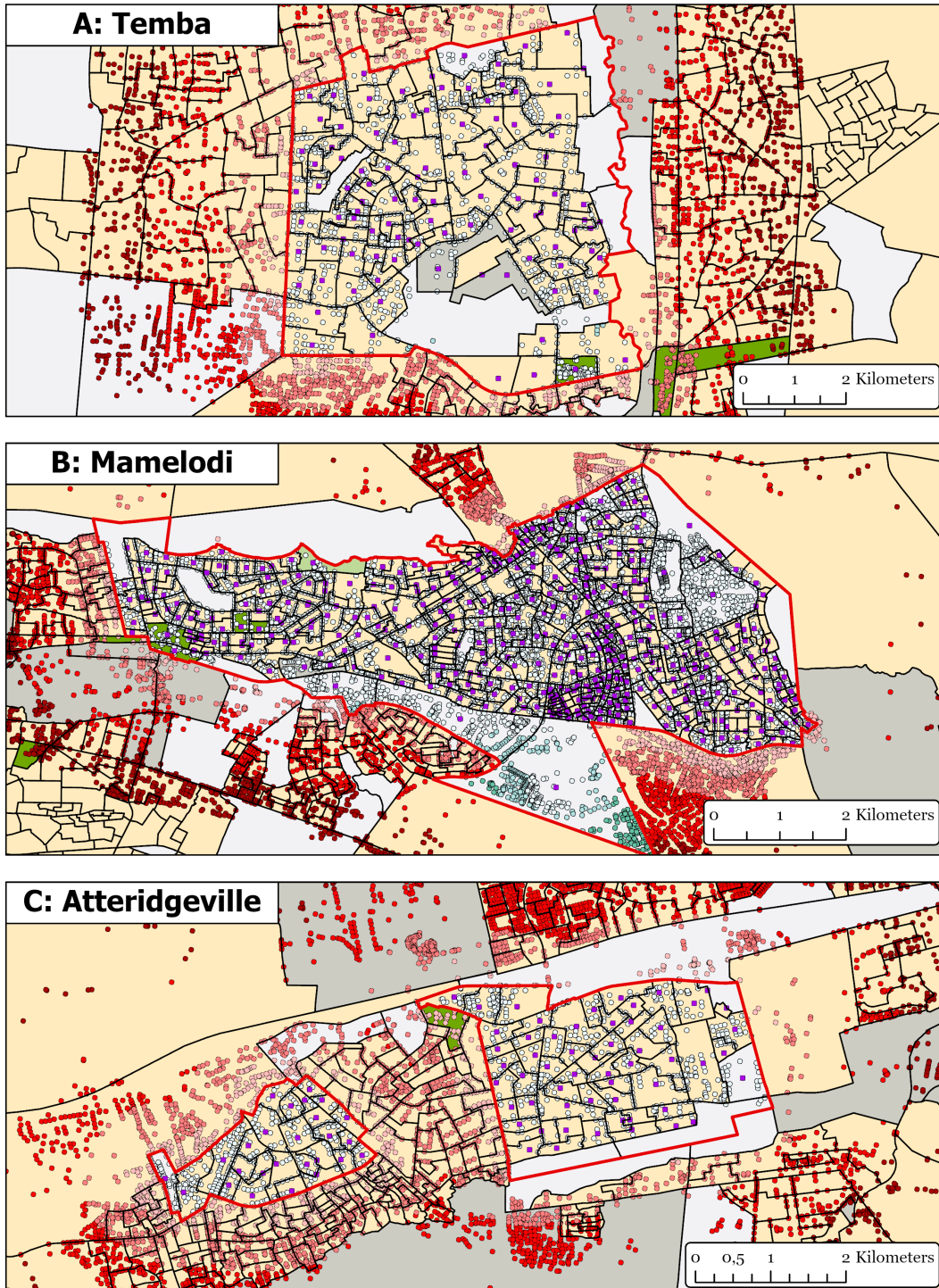

Figure 6.2-1: Straight Distance analysis in former group- and homeland areas in Pretoria-Tshwane (Author, 2024)

In figures 6.2-2 and 6.2-3 this is visualised across the maps in two ways. The first is using shades of green at intervals to denote intersection points on the road network within the areas

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of study that are at varying distances of reach – darker colours symbolise increased distance. The second is the variation in shades of red which signifies the same type of point as before, this time outside the areas of study. The standardised intervals of local environment (0.5-4km), without accounting for the built environment, results in an output of equal proportion of connectivity from each node, while proximity between nodes is more clearly visible, particularly at larger scales as per figures 6.2-2 and 6.3-1:A.

General observations across all of study areas show how there is great density in proximity between neighbourhoods within the specific areal units, but how this density vanes quickly beyond the borders of the township or district studied. The only real exception are areas which have seen development of large informal settlements around its *de jure* boundaries. These are left unadministered by the city municipal government, as is partly shown by the lack of enumeration areas covering these informal districts.

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Maps compiled by Theodor Gillbrand. (2024).

Sources: Statistics South Africa. (2012). Census 2011.
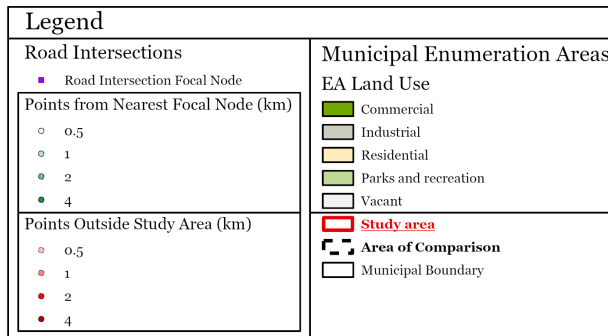
Figure 6.2-2: Straight Distance analysis of the outlying study areas (Author, 2024)
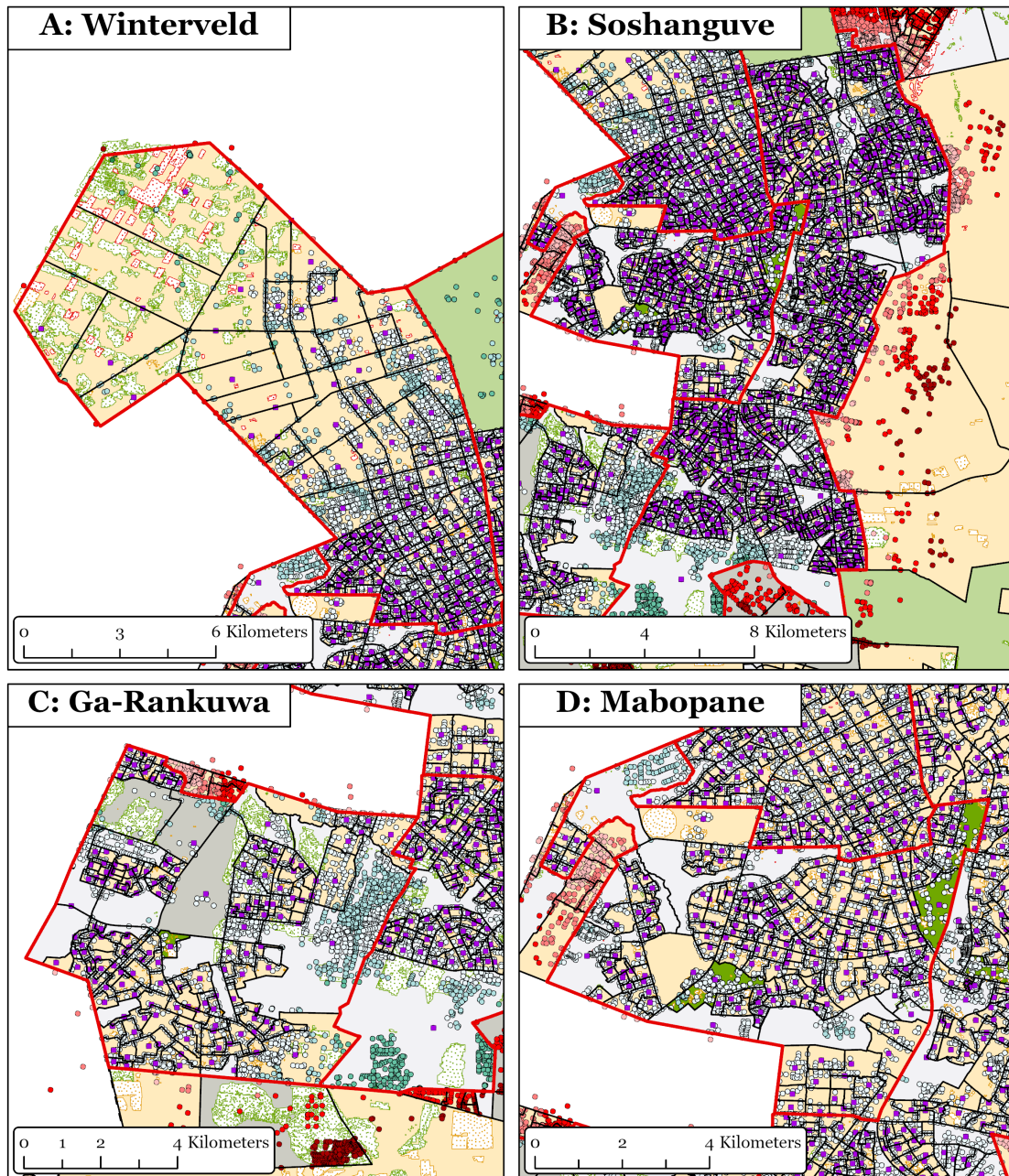
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Maps compiled by Theodor Gillbrand. (2024).

Sources: Statistics South Africa. (2012). Census 2011.; Department of Forestry, Fisheries & The Environment. (2020). Land Cover.
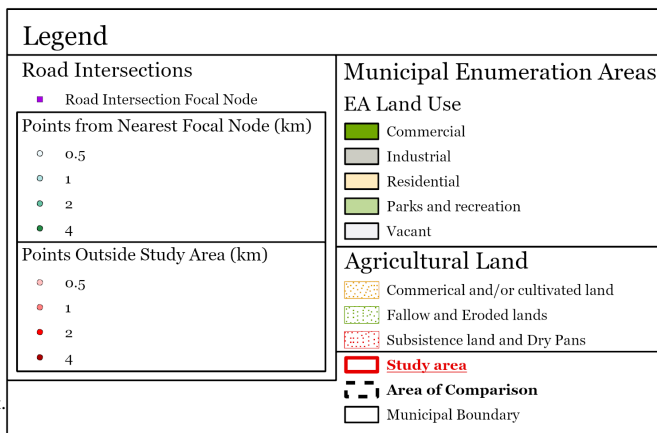
Figure 6.2-3: Straight Distance analysis of the north-west study areas group (Author, 2024)

Ga-Rankuwa (see figure 6.2-3:C) and Mabopane's (see figure 6.2-3:D) cases is shown to be the most disconnected of all the areas of study. With Ga-Rankuwa's only real residential-to-residential connection being to that of Soshanguve in the north-east/east. Elsewhere the township is surrounded by physical barriers in the form of vacant land (land which also often has the secondary usage of being agricultural). The high presence of vacant land also appears within the boundaries of both districts, by cutting them up internally resulting in separated disconnected residential islands.

Figures 6.2-3:B and 6.2-2:C highlight the lasting impact of apartheid-era buffer zones. Here these former group- and homeland areas are spatially cut off from the rest of the city (Pretoria and Centurion). Soshanguve (see figure 6.2-3:B) is of note as there is a combination of buffers types, both vacant land and industrial districts in the south. Expansion of the township is occurring in an easterly direction, to be stopped south of a nature reserve and the industrial area. Atteridgeville (see figure 6.2-2:C) show similar patterns eastward towards Pretoria, with both the north-western and south-western parts being encircled with informal settlements. Hence, the density in connectivity between residents until the industrial and/or vacant lands in the north and south of the municipal district and its extensions (the informal settlements), abruptly hinders expansion towards the east and the city proper (of note here is how there are no demarked enumeration areas, this as the city does not administer informal settlements). Hamann & Horn's (2015) classification of Soshanguve and Atteridgeville as experiencing "new segregation" as per their continuum categories, becomes understandable with their post-apartheid expansion in mind (particularly Soshanguve which did not exist before 1976). The case of Temba (see figure 6.2-2:A) illustrates a similar situation to the previous two. Here however, the scale is more extreme as Temba is *de jure* a relatively small district, the presence of informal settlements around it means that it has dramatically increased the size of its *de facto* boundaries. Stretching outward in every direction. Of note is the remanent buffers which form either strips of unused land or industrial areas. Yet compared to Atteridgeville and Mamelodi the informal expansion has not ceased because of that.

Mamelodi (see figure 6.2-2:B) is the most positive in regards spatial connectivity (compared to the other areas of study that is). Here there is only an industrial park which has resulted in similar situation as with Temba – expansion has taken place despite it presence and former purpose. As argued by Hamann & Horn (2015), the presence of the industrial park has in part

contributed to desegregation of areas around it – as it has facilitated the development of formal residential areas, as well as brought with it employment and increased incomes.

In conclusion, the varied distribution of township and their subsequent proximity and isolation from each other and the other districts is shown clearly through this analysis. Particularly in how certain types of land-use serve the function contemporarily as physical barriers in a similar way as the planned buffer zones did under apartheid. With the conclusions by Hamann & Horn (2015) in how industrial developments function as potential drivers of desegregation, it becomes clear that land-use wise, the possibility of facilitating industrial developments along development corridors to foster desegregation is a potential viable solution. Of course, other factors play a role too, the overstretched and overburdened administration need help from provincial or national governments in other to even start integrating these various separated residential islands.

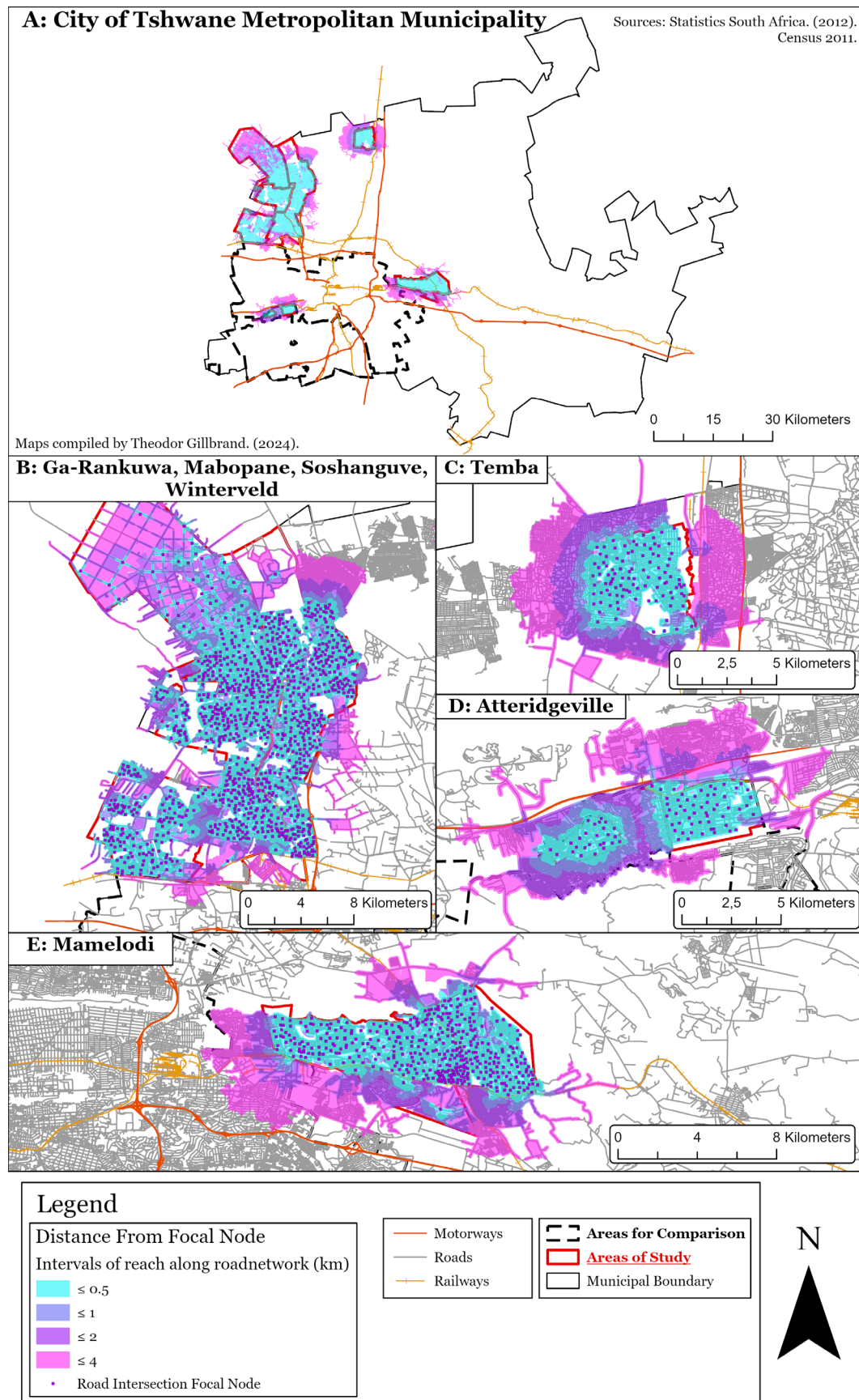Theodor Gillbrand - 010114

6.3 Network Connectivity

Figure 6.3-1: Road Network connectivity from the study areas (Author, 2024)

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The spatial disconnect analysis which utilised euclidean distance for its calculations of local environment reach, has limitations in its relevance to the actual material reality where the availability and accessibility of roads impact reach in substantial ways. Especially as such a large number of the study area's inhabitants do not have access to any private motorised means of transportation, effects of which are amplified with the subpar availability and accessibility of alternative (primarily public) transport, and accommodation for alternative means.

Comparing figures 6.2-1 to figure 6.3-1:A both confirms the analytical output from the spatial disconnect analysis, while also presenting some new revelations. In regard to said output, what ends up being confirmed is primarily how reach (both physical/corporeal alongside the road network and the euclidean distance) follows the patterns of residential expansion. Which means that there is greater connectivity between areas of high residential density. Here the presence of physical barriers in the local environment also makes a noticeable impact as they generally break up patterns of connectivity on the road network. The only real exception being Mamelodi (see figure 6.3-1:E) and its bordering industrial park. Temba's case (see figure 6.3-1:C) shows how connectivity on the road network is far denser in every direction of residential expansion, except for east where the vacant land buffers have left a negligible impact on expansion and connectivity – aside from interconnectivity between Temba and the informal extension where the avenues for road connectivity are limited to just two roads.

Ga-Rankuwa's (see figure 6.3-1:B) case highlights that connectivity within the metropolitan municipality is limited, but that the road segment cutoff extends in a westerly direction (unsurprising as there are informal settlements there connecting themselves with Ga-Rankuwa, even if they fall outside the CTMM boundary). Ga-Rankuwa's internal division with residential islands separated by various land-use types (vacant or industrial, see figure 6.2-3:C) is further highlighted through this analysis as the internal connectivity is quite sporadic.

The presence of motorways and railway tracks is a typical examples of physical barriers as per Roberto (2018) and as such are an important variable to consider. While they inhibit the movements of pedestrians, more interestingly is how it has served to inhibit residential expansion. Soshanguve (see figure 6.3-4:B) is impacted similarly like the case of Temba but with, but with roads and tracks instead of land. This in part explains why informal settlements have expanded in the north and north-east of the district, but not for the parts confined by motor- and railways, which primarily runs alongside the township's eastern boundary. Though

it should be noted that the impact of roads and tracks varies, as Atteridgeville (see figure 6.3-1:D) confirms it as well. The railway has a much greater impact than the motorway, as connectivity in the southern half of the township is worse with the informal settlements east of it, compared to in the northern half of the township where connectivity improves. But this phenomenon is in part counteracted by the cases of Temba and Mamelodi, as expansion beyond these places has not been hindered by the presence of said barriers.

In sum, the road network connectivity analysis concludes that large roads and railways often do impact connectivity between regions. There are exceptions to this with some areas however, this probably comes down to motorways being less limiting on residential expansion compared to railway tracks (as is shown by the Soshanguve railway/motorway barriers).

Discussion

As the aim of this thesis is to understand the persistence of social exclusion, the impact of apartheid era planning and its mixed legacy, wherein racial-residential patterns have shifted and race-class segregation has taken hold (Hamann & Horn, 2015; Horn, 2021, p.98; Maharaj, 2020, p.48) will be discussed through the lens of transport poverty. Throughout the Spatial Disconnect and Network Connectivity analyses, the impacts of apartheid-legacy physical barriers (in the shape of vacant lands and industrial parks) is a factor that recurringly inhibits the connectivity between areas. Couple that with the remnant and/or expanded primary roads and railway tracks that further exacerbated distances between specific districts within CTMM, and especially the periphery former group- and homeland areas from the metropolitan centres. Both of these barrier types serve to inhibit the movement of residents within and beyond specific districts to varying extents.

With a lack of social mobility opportunities for the inhabitants of the study area, combined with a poverty of the available means of transportation in the same areas (Lucas, 2011), it becomes undeniable then that the continuation of segregation persist (even if its racial-residential character is obfuscated towards a race-class basis) in part because of the mobility induced social exclusion. This persistence is reinforced by the disconnects (euclidean or not, spatial or aspatial) between areas at varying scales, highlighting the dialectical nature of segregation in Pretoria-Tshwane. Illustrated most notably through the historical origins of segregation in the colonial and apartheid systems, as the system was not envisioned and designed by the country's native population, rather it was imposed upon them, but it is in part maintained by them (as affluent Black-Africans participate in the reinforcement of isolation of the low-income Black-Africans) contemporarily. Then there are the power dynamics that began with the racial-residential system wherein the White population exerted power over the Black-African population, for it to be replaced in part by different social strata domineering the lives of the less affluent ones. Contemporarily there are more complex dynamics involved in this process. Both socio-economically as shown by the previous literature, but also varying geographic instances (horizontally, with variations between the different areas of the CTMM; vertically, with varying levels of quantifiable segregation at different geographic scales).

With that in mind, the incorporation of transport poverty becomes vital. Even though it does not on its own explain contemporary segregation, it is an important factor to consider (Lucas,

2011). The connectivity and disconnect analyses on reach confirm the findings by Lucas (2011) in how the density of the low-income areas mean that the people residing there are less affected by transport (un)availability compared to rural people. As there is a significant density of buildings in the areas of study, connectivity in here is high. However, beyond the boundaries of the study areas, the reach analyses show the areas' condition as islands. Wherein they are separated from most other areas through physical barriers, particularly inhibited by lack of availability and accessibility of (private or public) motorised means of transportation. Which means that a significant number of people in these low-income areas have their mobility significantly reduced as they can only travel so far, and then might also be further inhibited by roads and tracks they cannot cross (motorways, railways etc.).

As per the segregation study, it is also clear that high concentration of Black-Africans in the low-income, highly segregated areas are indicative of the race-class distinction unfolding in the city after apartheid. Access to adequate and affordable transportation then becomes a vital contributing factor in lifting people out of poverty and integrating them with the rest of the municipality. With existing options being either unreliable, unsafe, and/or too costly to be realistically employed by the majority population in the low-income areas (Lucas, 2011).

In the theoretical sections on car dependence and transport poverty, it was explained how the rise of more affluent groups, particularly middle-income groups, results in the growth of and expanded government subsidies to automobile industries and car infrastructure. Often this comes at the cost of non-car owners being further isolated as funding and investment is prioritised for industries perceived to accommodate consumption of affluent groups whose consumption/production patterns the state interprets to be directly contributing to modernisation. The isolation of non-car owners is further demonstrated by the fixation of policy makers on high-tech solutions and efficiency savings, instead of providing low-income groups (most of whom do not own private motor vehicles) with what they actually need (Lucas, 2011), that need being transportation (Theodore et al., 2017). As highlighted by Mattioli et al. (2017), the mismatches[10] in what drives transport poverty manifest themselves particularly in the case of Pretoria-Tshwane. The general assumption being that affluent people live in the urban centres, and low-income groups are confined to peripheries. Pretoria-Tshwane signify a

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[10] Generally urban centres are populated by affluent groups, and less affluent groups are confined to peripheries. Mismatches then are when these generalisations do not hold true.

mismatch here as the most affluent groups are primarily in south-east of the city (where affluent Whites suburbanised to). The historical central business district sees less concentration of middle- to high-income groups. Similarly, each of the districts and townships within the metropolitan municipality have to varying extents their own urban centres with more formal economic and residential structures, to be surrounded by their own periphery areas with informal structures of both types (the informal settlements also often fall outside of the jurisdiction what the municipality will administer).

The islands then perpetrate isolation in spatial way, distinct from just keeping people socially separated. Labour from the study areas are seasonally/periodically employed as needed within the industrial, commercial and agricultural sectors far beyond the reach of residential local environment (Horn, 2021, p.86; Theodore et al., 2017) which means that these day labourers have to commit to either spending significant parts of their week away from families, or spending substantial part of their day on commutes (which are often unfeasible from safety, cost, or time perspectives) (Theodore et al., 2017). When formal employment opportunities (like industrial parks) are present near the areas of high segregation, it has been shown that these function as key drivers for de-segregation (Hamann & Horn, 2015). But this is rare, with a large quantity of the residents of these areas employed as day labourers, often living with their families back home, and then migrating for work on a daily, weekly or other temporal basis (Lucas, 2011; Theodore et al., 2017), segregation is then maintained as a certain groups exclusion and separateness is continued.

The rapid growth of the Metropolitan Municipality from the outset after apartheid has created a cities within a city, all dependent on one another to some regard, particularly the peripheries (the areas of study) on the centre (Pretoria and Centurion which has seen the most targeted development initiatives (Horn, 2021, p.97)). In part then the function of the Black-African population as a reserve army of labour before and during apartheid, can in some regards then be understood to be replicated with present spatial configuration, even if it is no longer done to "[…] administer to the needs of the white man" as formulated by the Stallard Commission behind the original Native Land Act (Maharaj, 2020, p.41). This transition from racial-residential to a race-class segregation entailed that the spatial organisation originating from the standards and rules laid out by Whites during the colonial and apartheid eras (Davies, 1981), has been able to persist today (Hamann & Horn, 2015; Horn, 2021, p.98; Maharaj, 2020, p.48). In Pretoria-Tshwane this phenomenon becomes further reinforced by the official municipal

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development initiatives (discussed in the background), primarily focusing on the southern half of the city (Horn, 2021, p.98).

The often decentralised and underfunded northern development initiatives fail to reach the effectiveness needed to supplement the needs of that area. A result of the neoliberal urban planning initiatives which forced South African cities to become focused on turning a profit, rather than providing services and facilitating integration between the districts and townships. Even if the municipal government has largely moved on from these programmes, there effects are still felt as developmental initiatives are often delegated to local organisations (who lack the grander perspective to coordinate development at a smaller scale). Development within the municipality then go beyond what is doable by the metropolitan government and would require assistance from either the provincial or national government (Horn, 2021, p.96). The lack of opportunity for development on part of the metropolitan government becomes exacerbated with the continuous enlargement of the city's boundaries, overstretching an already overburdened and financially constrained administration (Horn, 2021, p.98). As result the isolated residential islands persist, without any clear vision for how this isolation will be mended (Horn, 2021, p.96).

Conclusion

The continuation of social exclusion on the race-class basis following the end of apartheid and racial-residential segregation has profound impact on the city and its people. The halting of city-wide integration projects left a large section of Pretoria-Tshwane's Black-African low-income population cut off from significant parts of the rest of the metropolitan municipality. Accessibility to transportation is a strong indicator for class in South Africa, with vehicle ownership perceived as a greater sign of affluence than owning a residence. This notion stems from the abysmally low availability and accessibility transportation for low-income groups residing in highly segregated areas. A group who as a result must resort to walking as the primary means of transportation. Particularly in relation to their employment situation, wherein a large number are day labourers. That means that they commute long distances from home and often must be without their families for extended periods of time. Without access to reliable, safe, and affordable means of transportation, these people are either forcefully separated from their families or must spend extortionate amounts of their income on paratransit alternatives that often unsafe and/or unreliable.

The aforementioned effects are further reinforced by the legacy of the urban spatial reorganisation left behind from apartheid. A significant contributor to the race-class segregation occurring contemporarily. While segregation research has been largely focused on the United Statesian setting, with numerous indices built specially for the that context. This reflects in the indices in how they often only measure segregation between two groups (Whites and African-Americans). Doing this is problematic as cities are rarely segregated between just two population groups (especially today) in the United States, South Africa, or anywhere else. The limitation of previous studies by relying too much on aspatial or euclidean-distance analyses ends up ignoring the material reality.

Pretoria-Tshwane having significant prevalence of transport poverty, necessitates incorporating a method which accounts for both eucledian proximity and physical/corporal connectivity. In this study conducting spatial analyses of reach through the SPC method, utilising both measurements, has ensured that physical barriers (irrespective of type) could be accounted for. These analyses were complimented by calculating the segregation indices DI and DI(m) for both Sub and Main Place levels, so as to understand variations both between groups and at varied scales.

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The analyses concluded that the former group- and homeland areas (the areas of study), function contemporarily as residential islands, wherein the population there is confined to fairly monocultural land-use, surrounded to large extents by various physical barriers. The prevalence of transport poverty throughout the study areas has clear implications for the reach of residents' local environment, both in terms of proximity to other areas, but also connectivity along road networks. Physical barriers have been shown to not only inhibit movement, but also push residential expansion in directions other than towards the metropolitan centres (Pretoria and Centurion). This has also meant that the reach from the local environment, at intervals up to 4km, has shown that connectivity was often inhibited through or by physical barriers. Either through cut-offs by inaccessible roads/tracks or by a lack of roads to bridge formal with informal areas together. The latter has most likely to do with that the city generally does not administer informal areas, hence availability of services (like roads) is varied and of questionable quality. That undeniably becomes a factor which has a contributed to the continued separation of districts within CTMM from one another, and perpetuation of social exclusion. This then serves to explain how certain pockets of the city's population remain both segregated and, despite changes in the population composition, including even partial decreases in segregation of most neighbouring districts (either at main or sub place levels).

Grappling with this requires substantial resources either from the provincial or national government as has been stated by [previous research](#), and whether present development initiatives have had an effect can only really be confirmed through research on new census data. The recent release of Census 2022 data, which will hopefully soon be made available (at the time of writing) at scales larger than provinces. The implications of which are great, as it means that predictions and various estimates from previous research can finally be confirmed or refuted. The city and its districts have undoubtedly continued to expand between the time of the censuses, so comparison between the two will be valuable for understanding future trajectories.

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