TU Delft

Delft University of Technology

Social inclusion through the urban lens

a comparative analysis of neighbourhoods of residential racial homogeneity and heterogeneity in Cape Town, South Africa

Nelson, Ruth Joan

Publication date
2022

Document Version
Final published version

Published in
Proceedings 13th International Space Syntax Symposium, SSS 2022

Citation (APA)
Nelson, R. J. (2022). Social inclusion through the urban lens: a comparative analysis of neighbourhoods of residential racial homogeneity and heterogeneity in Cape Town, South Africa. In A. van Nes, & R. E. de Koning (Eds.), *Proceedings 13th International Space Syntax Symposium, SSS 2022* Article 409 (Proceedings 13th International Space Syntax Symposium, SSS 2022). Western Norway University of Applied Sciences (HVL).

Important note
To cite this publication, please use the final published version (if applicable).
Please check the document version above.

Copyright
Other than for strictly personal use, it is not permitted to download, forward or distribute the text or part of it, without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license such as Creative Commons.

Takedown policy
Please contact us and provide details if you believe this document breaches copyrights.
We will remove access to the work immediately and investigate your claim.

This work is downloaded from Delft University of Technology.
For technical reasons the number of authors shown on this cover page is limited to a maximum of 10.

Green Open Access added to TU Delft Institutional Repository

'You share, we take care!' - Taverne project

https://www.openaccess.nl/en/you-share-we-take-care

Otherwise as indicated in the copyright section: the publisher is the copyright holder of this work and the author uses the Dutch legislation to make this work public.

409

Social inclusion through the urban lens:

a comparative analysis of neighbourhoods of residential racial homogeneity and heterogeneity in Cape Town, South Africa.

RUTH JOAN NELSON

TU DELFT, THE NETHERLANDS

ABSTRACT

The world is increasingly urbanising, more than half of the global population live within cities. The impact of COVID-19 is having devastating effects. The United Nations estimates that the pandemic will most likely elevate poverty and inequalities at a global scale. The World Bank's twin goals of ending extreme poverty and promoting prosperity and the United Nations' Sustainable Development Goals have deemed inclusive, resilient, and sustainable cities as global imperatives. Despite wide recognition, building inclusive cities remains a challenge.

Many studies of social inclusion are conducted at an individual or household scale, with little emphasis on the interaction between human dynamics and the spatial characteristics of cities. This article proposes a data driven framework for examining urban social inclusion through the profiling of neighbourhoods by combining spatial network measurements, transport, land use and socio-economic indicators in Cape Town, South Africa. The spatial unit of the neighbourhood is considered an important building block within cities and has especially historically important social and cultural connotations in South Africa. The results show that there are 4 types of neighbourhoods, Economically disadvantaged and marginalised, Affluent and exclusive, Semi residentially heterogeneous and Residentially heterogeneous. Neighbourhoods with increased residential racial heterogeneity, additionally, have access to higher levels of mixed land use, transport, and global closeness centrality. Furthermore, neither extremely high nor low-income neighbourhoods are found to be related to racial heterogeneity. The results enable the profiling and comparison of neighbourhoods, and it is envisioned that this evidence-based approach could support policy makers and urban planners within decision making processes.

KEYWORDS

Social inclusion, neighbourhoods, clustering, cities, racial heterogeneity

1 INTRODUCTION

Considering that more than half the world's population reside in cities, it has never been more important to develop better understandings of the interaction between social systems and the spatial configurations of city structures (Calafiore et al, 2021:1). For much of the 20th century social segregation was studied as a purely sociological phenomenon. However, recent advances in data access and computational power, have enabled the incorporation of many previously undocumented features and characteristics of cities, allowing for a new branch of urban analytics to emerge (Kandt and Batty, 2020:1).

Studies of social exclusion/inclusion are traditionally conducted at the household or individual scale, utilising survey data, such as the *Global Multidimensional Poverty Index*, or macro-economic indicators, such as the *Inclusive Development Index*. The novelty of this paper lies within the proposal of examining social inclusion explicitly through the lens of urbanity based on readily available open access data sets. This paper conceptually connects social segregation with social exclusion and directly relates these ideas to urban accessibility. The neighbourhood is chosen as the principal component of analysis as it is theorised as both an important spatial unit and social construct, specifically in the context of South Africa in which almost all neighbourhoods were historically zoned by race, prior to the ending of Apartheid in 1994. Relations between multidimensional indicators associated with neighbourhood characteristics are explored through well recognised approaches in data analytics and statistics, principally making use of the unsupervised classification algorithm, k-means clustering. The results reveal systemic insights into the perpetuation of social exclusion, through highlighting properties of the urban realm which may support or hinder a community's capability to meaningfully participate. Furthermore, they illustrate that there are significant differences between neighbourhood typologies relating to accessibility, which suggest the need for localised, area-based interventions, particularly within neighbourhoods which experience multiple forms of deprivation. Additionally, considering the historical divisions between neighbourhoods in South Africa, the identification of structural barriers that continue to perpetuate segregation is paramount. The primary research question is: *what is the relationship between regional spatial inequalities associated with social exclusion and demographically residentially racially heterogenous neighbourhoods?*

2 SOCIAL INCLUSION THROUGH AN URBAN LENS

This section is composed of three parts. It firstly contextualizes South African urban development within a global context of unequal development patterns. Secondly, it connects

sociological ideas of integration/ segregation and social inclusion/exclusion with accessibility. It specifically explores geographical conditions of cities which limit the ability of certain population groups to access resources and highlights the role of space as a mediating networked infrastructure. Finally, the neighbourhood is shown to be both an important social and urban phenomenon, especially in the context of South Africa, providing motivation for its choice as the unit of analysis. It is beyond the scope of this paper to comprehensively review all literature related to these topics; it rather seeks to highlight interconnections between these concepts.

2.1 Setting the urban context

The current state of global urban development is underscored by the *United Nations World Social Report* (2020) which documents vast global inequalities with clear spatial, economic, and social dimensions. Graham and Marvin (2001) within their seminal text, *Splintering Urbanism*, show how the contemporary development of premium global networked spaces, primarily connect the wealthy, whilst bypassing and excluding less powerful, minority groups. Within the Global South, these patterns are pronounced, due to a long history of uneven development propagated through colonialism and contemporary scarce financial incentives to connect the historically disadvantaged (Graham and Marvin, 2001; King, 2016).

Within South Africa, the persistence of produced, distorted settlement patterns characterized by social segregation and physical fragmentation is well documented (Parnell and Robinson 2012, State of South African Cities Report, 2016). Turok et al (2021:3) note that whilst there have been a range of local and national post-Apartheid urban frameworks developed on principles of connected city development, shortcomings in government policy have meant that implementation has been slow. Private investment into shopping malls, office parks and gated communities further enhance urban exclusionary processes (Foster, 2020). Congruently, many of the historical Central Business Districts (CBDs) are experiencing vast rates of decline (Visser and Kotze, 2007), as corporate businesses relocate to newer and more affluent urban areas, such as *Sandton* in *Johannesburg*. Rapid urbanisation places additional strain on authorities, resulting in the forced adoption of informal housing solutions by many new urban dwellers (Toth et al, 2021:10).

2.2 Linking segregation/integration & social inclusion/exclusion to accessibility

There is widespread documentation on segregation in South Africa (Davies, 1981; Turok, 2001; Pieterse, 2009) and internationally. In sociological literature measures of residential segregation reflect a long body of theoretical and empirical research on what segregation means and how best to measure it (Duncan and Duncan, 1955; James and Taeuber, 1985; Massey and Denton, 1988; Reardon and Bischoff, 2011). The term, social exclusion, emerged later. It was coined by former French Secretary of State for Social Action, René Lenoir (1974) and has subsequently become an area of focus across research disciplines. Whilst quantitative, sociological studies on segregation historically focus on measuring divisions between different groups, social exclusion, and inclusion studies, alternatively place an emphasis on the ability of a person/group to participate

fully within a society. Although there is no universally agreed definition for social exclusion, Levitas et al. (2007:9) identifies social exclusion as:

"The lack or denial of resources, rights, goods and services, and the inability to participate in the normal relationships and activities, available to the majority of people in a society, whether in economic, social, cultural or political arenas. It affects both the quality of life of individuals and the equity and cohesion of society as a whole."

Conversely social inclusion can be thought as the ability to access resources and to participate in normal relationships and activities. Recently researchers within accessibility research are linking studies of access with social inclusion, by drawing on popular social justice theories such as Amartya Sen's *capabilities approach* (Bantis and Haworth, 2020:2). Sen (1987:48) describes capabilities as "notions of freedom, in the positive sense: what real opportunities you have regarding the life you may lead". In essence, a capability is the *ability to achieve* and could be equated with access to substantive opportunities. Whilst, reaching opportunities becomes more than a function of how they are distributed in space (Pereira et al, 2017), understanding how access to them may be restricted or enhanced by the urban environment, is an important step.

Within space syntax, the city is articulated as a relational network. Space is conceived as intrinsic to human activity, allowing for localised and non-localised interactions (Hillier and Hanson, 1984; Hillier, 1996; Vaughan, 2007). As Hillier (1996) proposes through the theory of *natural movement*, the spatial network of the street layout produces attraction inequalities, which generate or restrict co-presence. Building on the concept of natural movement, the notion of a dual grid structure composed of foreground and background network of street configuration is developed (Hillier and Netto, 2001). The foreground network is morphogenetic, seeming to generate movement, maximizing co-presence. Movement rich locations, in turn attract movement rich land use (a condition also referred to as the *movement economy*, Hillier, 1996). Whereas the background network is conservative, minimizing natural co-presence, serving to reinforce socio-cultural stability.

Whilst co-presence does not necessarily translate into social integration, it may lead to social interaction (Hillier, 1989:11). Legeby (2013) shows that public space, even if it does not create direct interaction, has an impact on segregation. Public space offers capacity for bringing socially distant people together (Legeby, 2013; Legeby and Marcus, 2011). In social network theory, weak ties are known to be significant when job searching or trying to access new opportunities (Granovetter, 1973). A recent study by Toth et al (2021) reveals how online social network fragmentation is significantly higher in towns in which residential neighbourhoods are divided by physical barriers such as rivers and railroads, suggesting a direct correlation between social network divisions and morphological characteristics of space. Conversely, Jane Jacobs in her

seminal work, *Death and Life of Great American Cities* (1961), advocates the importance of active streets and land use diversity for stimulating vibrant neighbourhoods.

Church et al. (2000) emphasizes that factors which inhibit accessibility tend not to appear in isolation and are embedded within specific geographical contexts. Oviedo (2021) notes in his review of urban form in Latin America, that areas of economic activity tend to be far from where most middle and low-income populations live, leading to its own form of *spatial mismatch*. Disadvantaged communities are thus required to travel and pay more to access economic opportunities. Similar patterns of *spatial mismatch* can be observed within the context of South Africa. A recent study by Nelson (2021) shows how lower income neighbourhoods in Cape Town are geographically positioned far outside of the Central Business District (CBD) relying primarily on the paratransit minibus taxi system. Paratransit has emerged in many cities of the Global South, inclusive of Jakarta, São Paulo, and Mexico City (Cervero et al, 2007). The mere existence of paratransit on such a prolific scale suggests a widespread pattern in which the economically disadvantaged reside beyond the boundaries of formal infrastructure, relying on small scale operators to participate in everyday urban life.

To summarise, distribution effects in cities do have an impact on social exclusion (Van Wee and Geurs, 2011). There are direct links between social exclusion and accessibility (Lucas, 2012).

2.3 Measuring social exclusion: a neighbourhood focused approach

The brief review within the previous section illustrates the complex relationship between urban configuration and the perpetuation and reproduction of social exclusion within space. However, commonly recognised indices of social exclusion/ inclusion tend to be conducted on an individual or household scale. Examples include the *Global Multidimensional Poverty Index, The United Nations Human Development Index* and the *World Economic Forum Inclusive Development Index*. In contrast, this paper proposes an explicitly urban approach. The neighbourhood is chosen as the primary unit of analysis as in South Africa, prior to the ending of Apartheid in 1994, all neighbourhoods were zoned by race and more broadly have been shown to play an important role in mediating both macro (economic and political) and micro (individual and choice) processes (Sampson, 2019:7).

Many urban design models focus on the neighbourhood as essential building blocks of cities, these include, the *Neighbourhood Unit* (Clarence Perry), *Radburn Planning* (Clarence Stein) and the *Garden City* (Ebenezer Howard). The *Garden City*, proposed by Ebenezer Howard (1901), was to combine the best features of town and country life in a ring of satellites surrounding London, the idea being to create green neighbourhoods separated from the smog of the city. This movement spread across Britain, to the United States and to many of Britain's colonies, indeed including South Africa. Coetzer (2013:136), in his book *Building Apartheid*, specifically shows how the *Garden City Movement*, provided a rationalising discourse, prior to the implementation

of Apartheid in 1948, through which the question of where and how people should live was to be resolved in Cape Town through agglomerated, racially zoned suburbs, separated by greenbelts.

Within the social sciences there are also many conceptualisations of the neighbourhood. The Chicago School in the 1930s theorised a three-generation assimilation model from Ethnic Enclave to residentially integrated neighbourhoods. However, Peach (2001) and Massey and Denton (1998) demonstrate that the Chicago School failed to differentiate between the *Ethnic Enclave* and the *Ghetto*, which does not follow this model. *The Ghetto* is characterized by high concentrations of poor and minority residents and has been perpetually plagued by structurally induced problems of crime and physical disinvestment (Sampson, 2019). Sampson (2019:14) advocates that large and persistent racial disparities compounded by material and social deprivation, cannot be explained by only individual or family characteristics - the inequality is contextual in nature.

Clustering analysis, the primary method of analysis employed within this study, is a popular unsupervised machine learning technique which has recently been applied to several neighbourhood studies. Bobkova et al (2019) show that the methodology for developing neighbourhood types across three European cities is robust, as it picks up generally recognised spatial patterns. Delmelle (2016) employs clustering to examine socioeconomic changes within neighbourhoods over time, displaying it is as an effective method to monitor neighbourhood change.

2.4 Summary

Social inclusion is one of the principles underpinning the United Nations' *Sustainable Development Goals* (2015), however cities are struggling to translate this imperative into actionable policy. There are direct links between social inclusion and accessibility and a wide body of literature suggests that various properties embedded within the spatial configuration of cities may limit or enhance a community's capability to participate. Social inclusion is highly contextual and perpetual social exclusion and inequality cannot be explained only by the condition of an individual or household. Therefore, this paper proposes an explicitly urban lens. Neighbourhoods, specifically in South Africa, have important historical physical, social, and cultural connotations and thus are selected as the primary unit of analysis. K-means clustering is used to identify relations between multidimensional indicators as it is shown to be a robust method that can pick up both social and spatial categories.

3 DATASETS AND METHODS

The research requires a methodological approach that can encompass both physical and behavioural aspects. The precise descriptions offered by the evidence-based research techniques of space syntax allow for a configurational understanding of both the spatial and social aspects of this study. Space syntax is centralised on the idea that the structure of space is a product and in

turn influencer of social structures and interaction (Dhanini et al, 2017:56). The approach focuses on four dimensions:

- Land-use composition
- Transport
- Street network configuration
- Socio-economic factors

Indicators within these dimensions are aggregated to the spatial unit of the neighbourhood. This data is inputted into the algorithm, k-means clustering, which categorises the neighbourhoods, forming a baseline from which to compare them. The methodological framework is depicted below.

What is the relationship between regional spatial inequalities associated with social exclusion and demographically residentially racially integrated neighbourhoods?

1. Preparation of Data:

A. Geolocation of variables

Category	Variable
Socio-economic	Mean Income
	Neighbourhood Diversity Index
Land use	Mixed Land use
	Residential Land use
	Business Land use
	Community Land use
Transport	Minibus Taxi Stops
	BRT stops
	Railway stops
Street network access	Mean centrality Radius Rn

B. Normalisation of variables — Insuring all the variables are at a standard scale

2. Analysis:

C. K-means Cluster Analysis

D. Methods to determine optimal number of clusters — The Silhouette Score

3. Comparison:

E. Statistical exploration of neighbourhood categories

3.1 Data Preparation

The primary source of socio-economic data is derived from the South African National Census (2011). Census data is aggregated to the scale of the neighbourhood. The neighbourhood scale is defined by the administrative boundary lines of each neighbourhood as demarcated by the local government. The principal source of spatial data is the Cape Town Open data Portal.

3.1.1 Neighbourhood Diversity Index

The *Neighbourhood Diversity Index* (*ND Index*) (Maly, 2000) is employed as a measure of demographic racial integration. The author acknowledges that all indices are, to some degree, artificial constructs each with their own limitations. This particular index was selected as it allows researchers to include multiple racial categories, whilst referencing the racial composition of the larger geographic area that the neighbourhood is placed within (Maly, 2000:37). The Index is applied to Cape Town's neighbourhoods and inverted so that the higher values correspond to higher levels of residential racial integration (visualised in figure 1). An important aspect of the *ND* formula is that the absolute values are applied, in other words, if there is an instance in which a larger value is subtracted from a smaller value, the negative sign is disregarded. The different racial groups are defined as per the Census, including, White, Black, Coloured, Indian and Other. The race, Coloured, is not to be confused with the American term - it is the official and accepted name for people of a mixed-race background within South Africa.

Neighbourhood Diversity Index:

ND = (Cw - Tw) + (Cb - Tb) + (Cc - Tc) + (Ci - ti) + (Co - To)

Cw = city wide percentage of White people (16% in Cape Town)
Cb = city wide percentage of Black people (39% in Cape Town)
Cc = city wide percentage of Coloured people (42% in Cape Town)
Ci = city wide percentage of Indian people (1% in Cape Town)
Co = city wide percentage of Other people (2% in Cape Town)

Tw = neighbourhood percentage of White people
Tb = neighbourhood percentage of Black people
Tc = neighbourhood percentage of Coloured people
Ti = neighbourhood percentage of Indian people
To = neighbourhood percentage of Other people

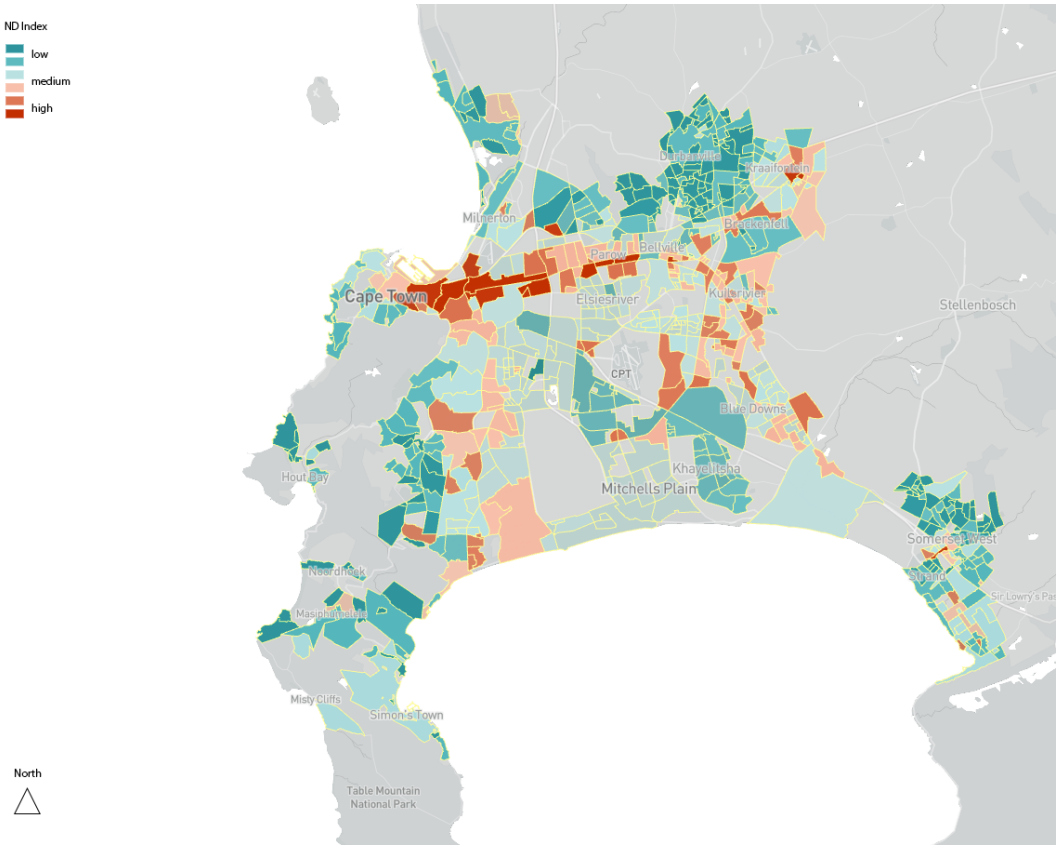

Figure 1: Neighbourhood Diversity Index illustrating residential racial diversity

3.1.2 Income

Income, alongside the ND Index, provides deeper insights into the socio-economic structuring of a neighbourhood. The income data, derived from *Statistics South Africa*, is structured so that all adult people who reside in each neighbourhood were counted and placed within specified ranges of received income per month, for example “0-200’ or ‘200-400’ etc. The average income is then calculated through taking the median in the range and multiplying it by the number of people within that range, then summing the different values per adult person and dividing that by the total number of adult persons within the neighbourhood to derive an estimated mean. Figure 2 depicts the income distribution.

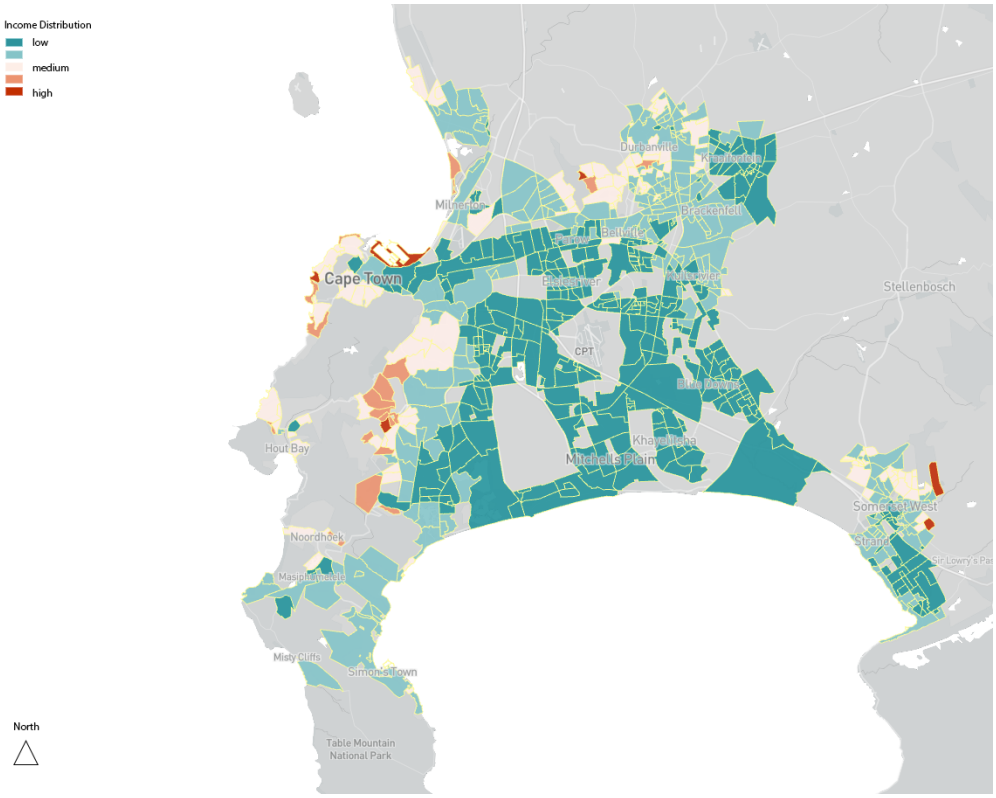

Figure 2: Income Distribution

3.1.3 Land Use

Land use diversity is considered an important factor for social resilience (Jacobs, 1961; Klinenberg, 2002). To understand the nature of land use composition, land use zoning data is obtained from the City of Cape Town's Open Data Portal. Business, Mixed, Residential and Community land are quantified for each neighbourhood, as percentages of the total land use available within that neighbourhood. Figure 3displays concentrations of Residential land use.

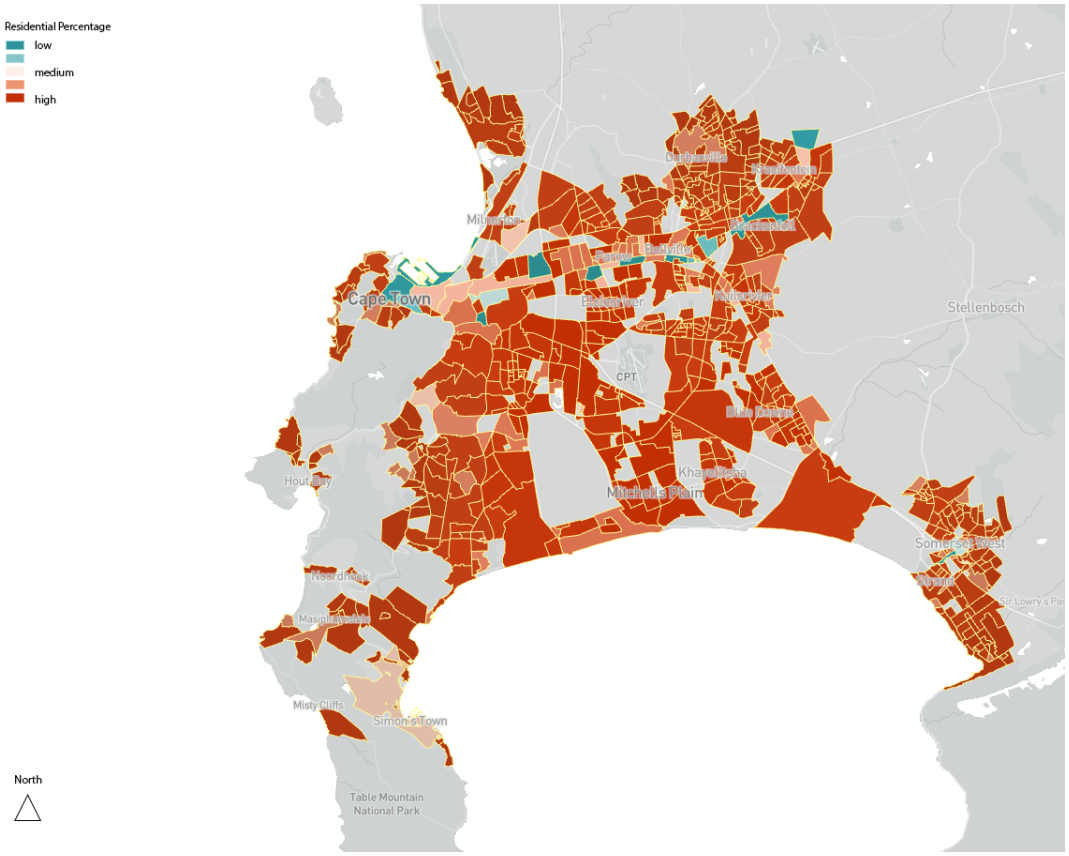

Figure 3: Residential land use

3.1.4 Transport

The availability of transport connections aid critical insights into potential accessibility within and beyond a neighbourhood (Lucas, 2019; Bocarejo S and Oviedo, 2012). Three modes of public transport are selected the Railway, Myciti Bus Rapid Transit (BRT) and paratransit Minibus Taxi System. The Railway and the BRT are formal modes of transport, the locations of their stops and stations are obtained from the *City of Cape Town's Open Data Portal*. The exact location of the paratransit minibus taxi routes, stops and ranks are derived from data sets gleaned in the form of geolocated shapefiles by the company, *Whereismytransport*. who conducted a private survey.

The frequency of stops and stations of each mode of transport are aggregated as counts per neighbourhood and utilised as an indicator of transport access. Figure 4 displays the distribution of Railway stations.

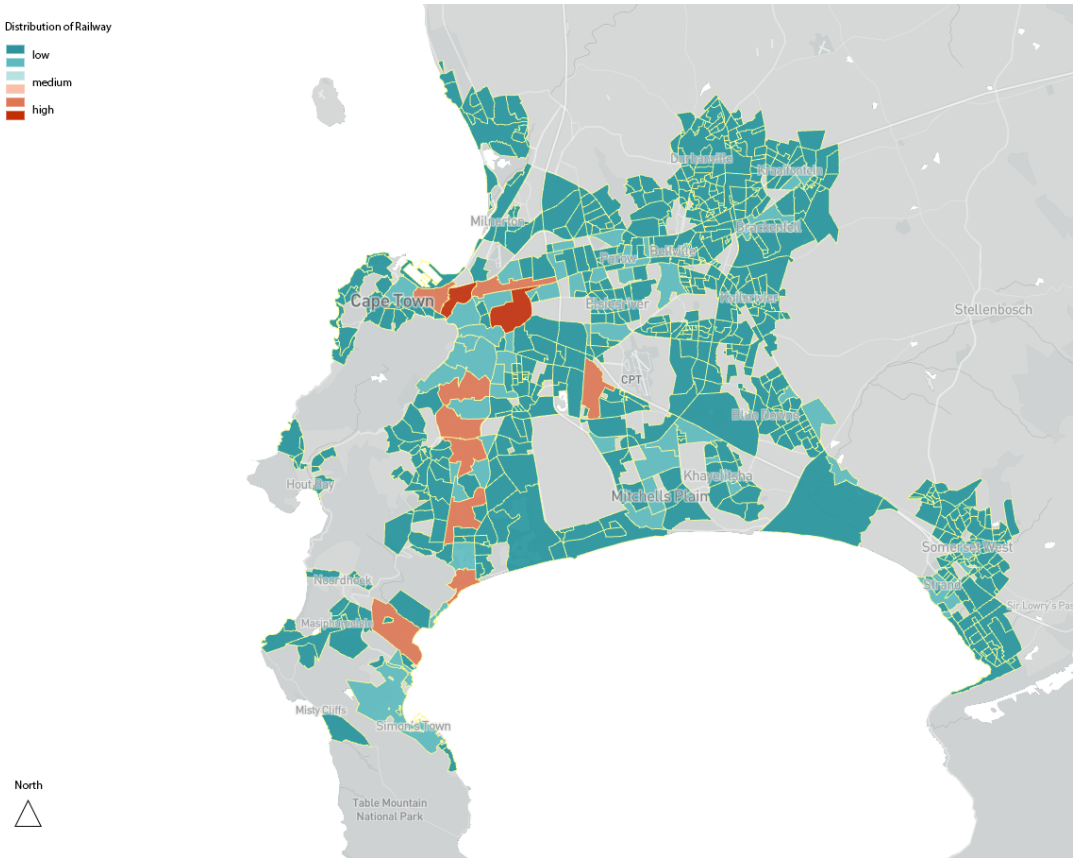

Figure 4: Distribution of Railway Stations

3.1.5 Street network accessibility

Street network accessibility is estimated through angular segment analysis. Angular segment analysis allows for the calculation of the relative Integration levels of a street network. Integration refers to angular *closeness centrality*, which measures the reciprocal of the sum of the shortest path between every origin to every destination, in other words the potential of movement to a street segment (to-movement), due to its angular proximity to all other segments within a specified radius (Freeman, 1977; Hillier and Iida, 2005). The higher an integration value is for a street segment, the more likely it is to become a destination within the spatial network. This calculation is performed on a simplified Road Centre Line (RCL) map of Cape Town. The angular segment analysis is executed in *Depthmap* software and a range of radii are calculated and normalised. The mean value for each neighbourhood is computed and statistically correlated with the *ND Index*. The radii with the strongest correlation is Mean Normalised Integration (NAIN) at the global measure of Radius n. This indicates that the residential location of different racial categories of people, tends to correlate best with global closeness centrality, refer to figure 5.

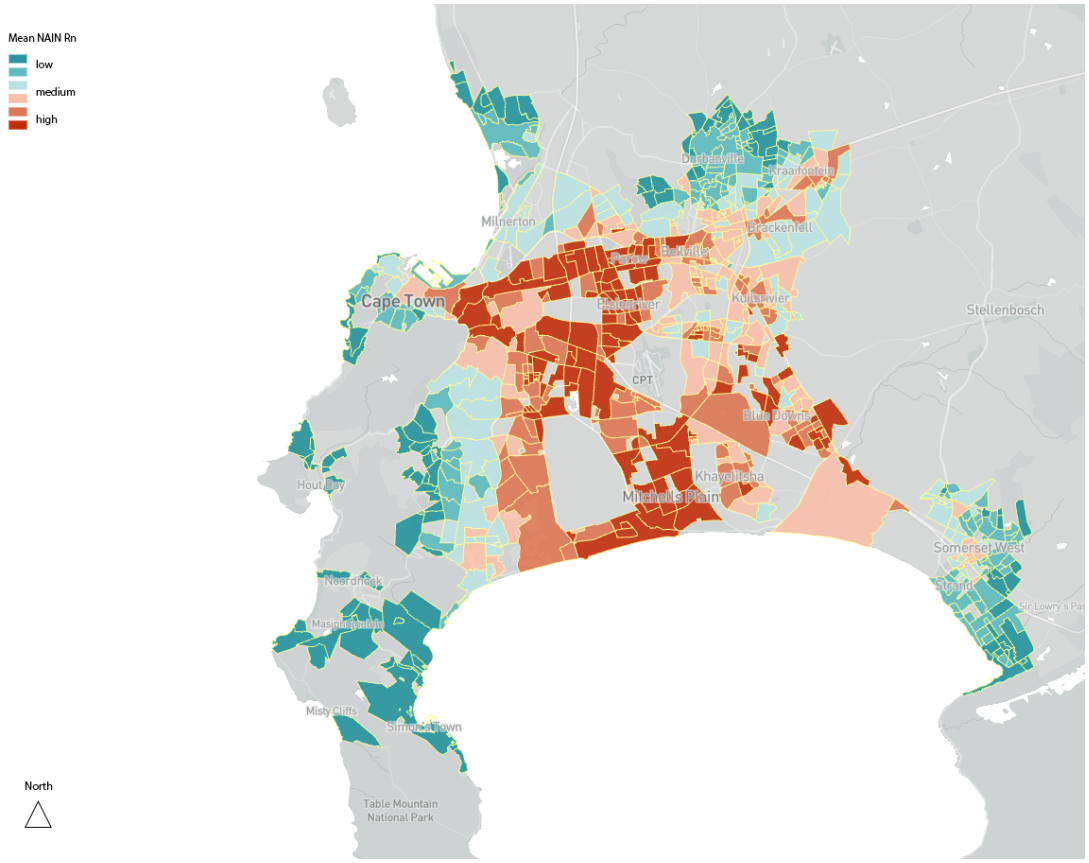

Figure 5: Mean NAIN Rn

3.1.6 Normalisation of variables

Clustering algorithms tend not to perform well when the input numerical attributes have different scales (Géron, 2017:63). Therefore, the indicators are normalised, which results in the values being shifted and rescaled to range from 0 to 1.

3.1.7 Outliers

The variables are checked for outliers that can potentially bias the results of the cluster analysis. Neighbourhoods which had very low population counts and consisted predominantly of agricultural land were removed from the dataset.

3.2 Data Analysis

3.2.1 Clustering analysis

K-means clustering is an established unsupervised machine learning technique used for classification, which enables the identification of various categories within a dataset (Geron, 2017). Unlabelled data is fed into the algorithm and then partitioned into groups or clusters based on the nearest mean (Geron, 2017:8). The way the algorithm works is that it clusters the data without knowing what the data represents. It finds categories through mean comparison, which reveals relationships between groups of variables. The choice of k-means clustering in this study has been based upon the following:

- It is a statistically well-established method for categorising data. In this case the requirement for categorisation is based on the need to understand relations between the different variables and how they manifest collectively in space.
- Previous research has shown it to be methodologically robust in developing neighbourhood typologies (Bobkova et al, 2019).
- K-means clustering is generally computationally faster than other algorithms.
- It can be updated over time and input with new variables (Demelle, 2016).
- Although k-means clustering can be spatially weighted to reflect each neighbourhood's relative position, the decision was made not to do this, as the space syntax values automatically allowed for the statistical inclusion of spatial configuration in the model.

3.2.2 Determining the optimal number of clusters

The k-means clustering algorithm requires validation to determine the optimal number of clusters. In this case, the Silhouette Score is used, for a comprehensive overview of this method refer to Rousseuw (1986). The Silhouette Score is calculated using the mean intra-cluster distance (a) and the mean nearest-cluster distance (b) for each sample. The best value is 1 and the worst value is -1. Values near 0 indicate overlapping clusters. Negative values generally indicate that a sample has been assigned to the wrong cluster, as a different cluster is more similar.

3.3 Statistical and visual comparison

The variations between the different categories of neighbourhoods are explored through statistical comparisons in choropleth maps and numeric graphs. Choropleth maps are thematic maps which illustrate variables in proportion to their measurement through a colour gradient.

4 RESULTS

The following section documents the key findings. It commences by presenting the optimal number of clusters and subsequently discusses the emergent categories of neighbourhoods.

For the first clustering analysis, all variables are imputed, and the optimal number of profiles identified are 4, as can be seen in the first map depicted in figure 6a. However, to ensure that the algorithm was not biased towards the ND Index, a second round of clustering analysis was computed without the ND Index and the results are almost identical, refer to the second map in figure 6b. This initial finding provides evidence that the urban configuration of the neighbourhood is indeed related to levels of residential racial diversity.

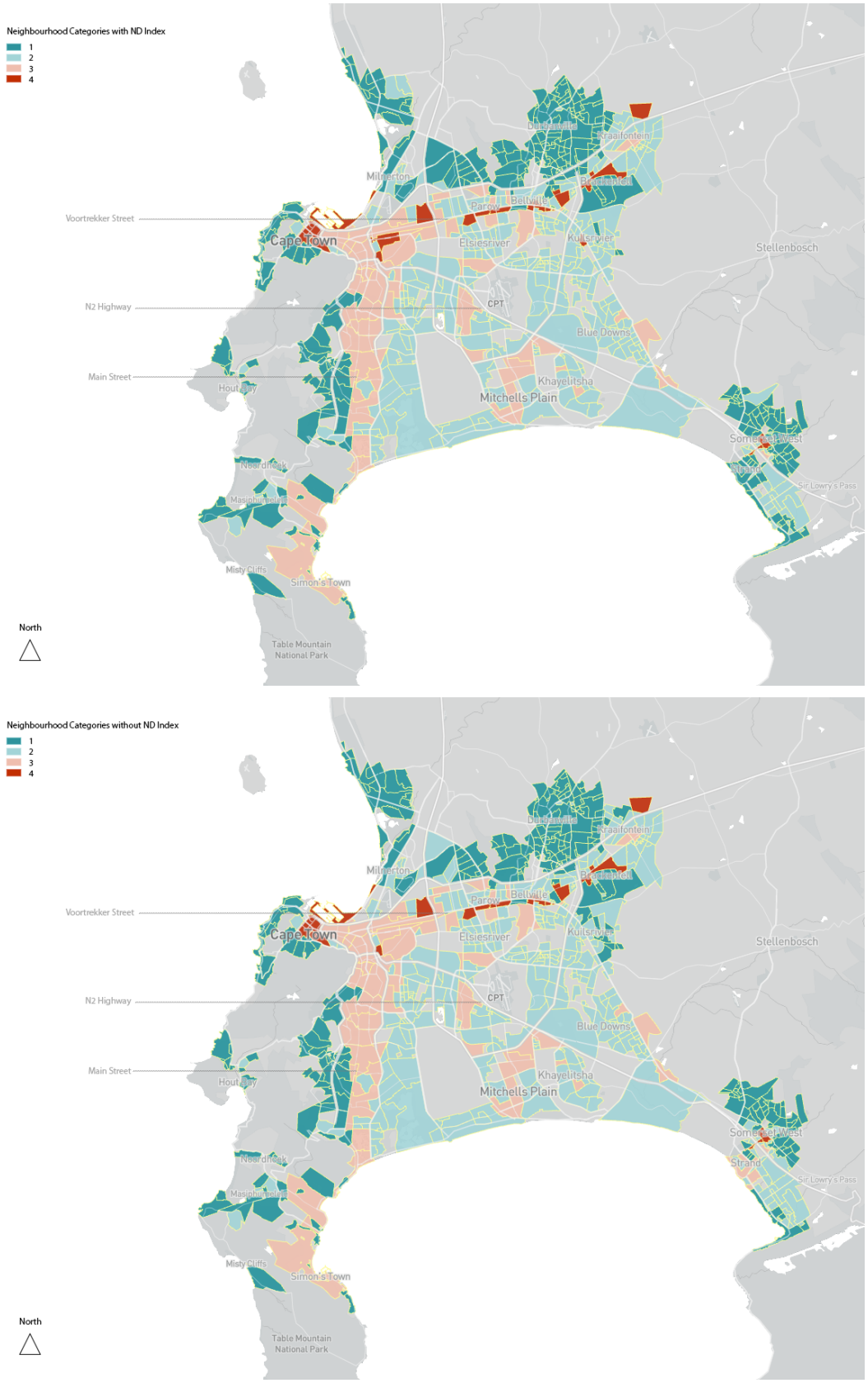

Figure 6: Results of the clustering analyses (A) with the *ND Index* and (B) without the *ND Index*

4.1 Category 1: Affluent and exclusive

Category 1 neighbourhoods, demarcated in figure 6a in dark Aqua, contain the second largest number of neighbourhoods. This category has a clear spatial geography, located along the base of the mountain and coastline. It is concentrated in wealth but possesses low accessibility both in public transportation and street network configuration. These neighbourhoods are characterised by the lowest average racial heterogeneity and land use which is predominantly residential. What this suggests, is that the wealthy are residing in highly isolated areas of the city. This conceptually links to Graham and Marvin's (2001) depiction of splintered urban centres and Foster's (2020) description of post-Apartheid urban development defined by private and exclusionary spaces. What is confirmed by the spatial configuration of these neighbourhoods, is that they are globally isolated, allowing them to exist as exclusive enclaves. The street configuration serves to conserve movement, as a background network, which has been theorised to reinforce socio-cultural stability (Hillier and Netto, 2001). Typical characteristics of these neighbourhoods are summarised in figure 7.

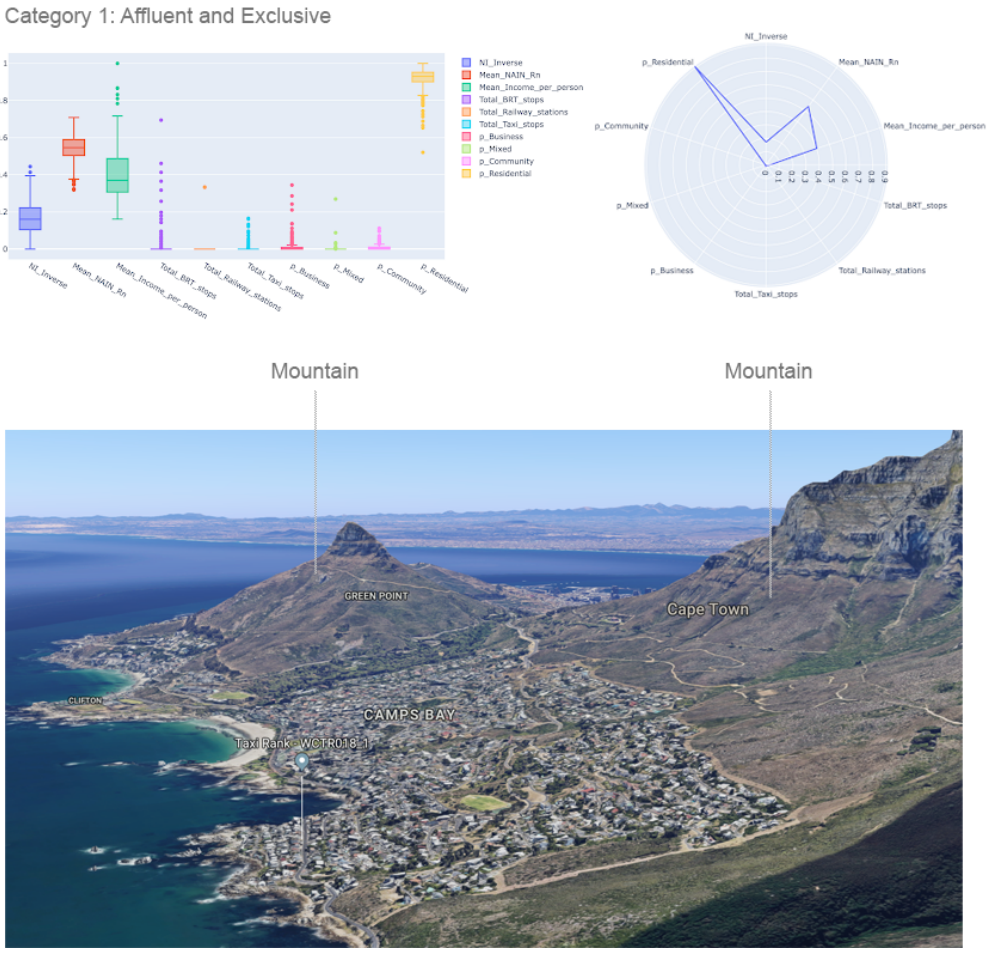

Figure 7: Typical Characteristics of Category 1 and Camps Bay

A typical example of a neighbourhood within this category is Camps Bay, depicted in figure 7. Camps Bay is nestled between the coastline and mountain, only accessible by motorised vehicles

through a few connecting roads. The work of Toth et al (2021), leads us to consider that these morphological barriers are reinforcing social network fragmentation and perpetuating social exclusion.

4.2 Category 2: Economically disadvantaged and marginalised

Category 2 contains the largest number of neighbourhoods and represents the economically disadvantaged. It, too, has a clear geography, for the most part located in an area known as the "cape flats", a name derived from its characteristically flat and sandy earth. The neighbourhood profiles signal that not only are these residents economically deprived, but they are also deprived in other dimensions. The land use is predominantly residential, indicating a lack of employment opportunities, confirming a *spatial mismatch*. These poorer residents probably do not own private vehicles and thus it can be construed that they rely on the paratransit minibus taxi, as they have no Railway stations and scarce access to the BRT. Interestingly, their global closeness centrality is generally high, in opposition to the affluent and wealthy neighbourhoods. This indicates that whilst these neighbourhoods have been socially and economically marginalised, the wealthier ones are more spatially segregated.

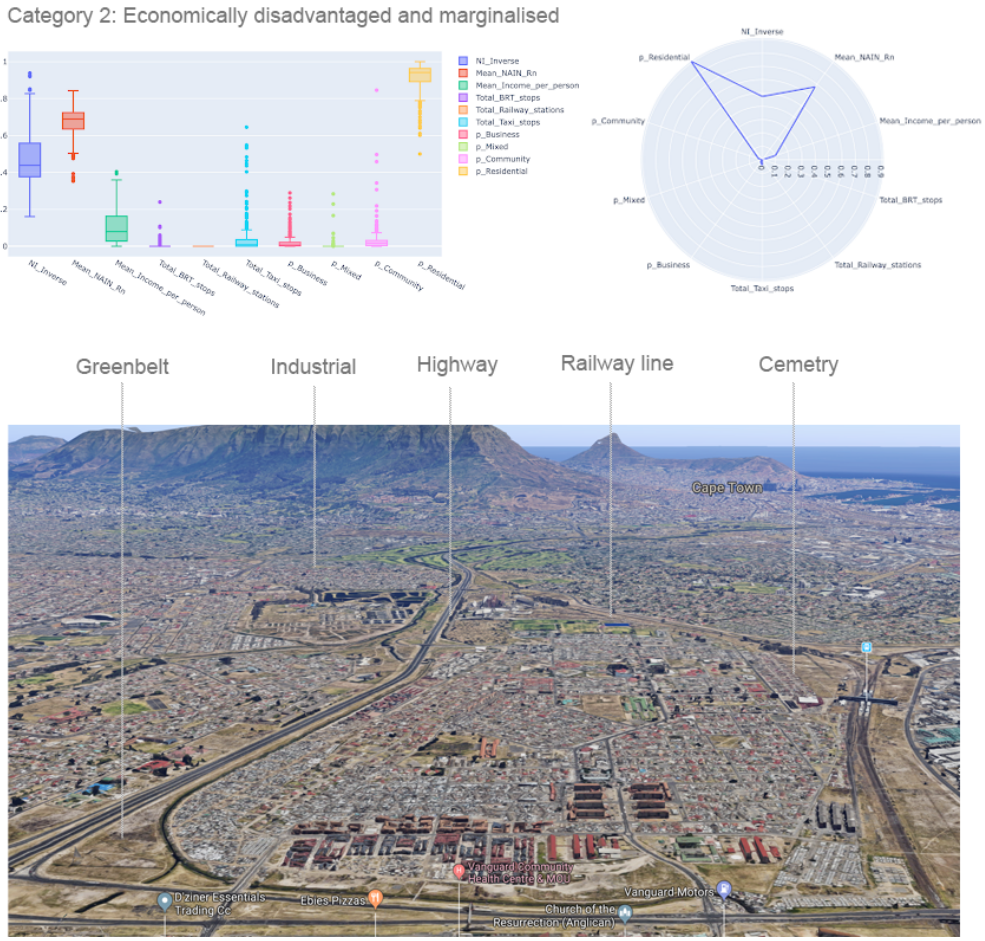

Figure 8: Category 2 and Langa

Thus, according to Hillier's (1996) theory of the movement economy, one would expect diverse land use within Category 2. However, as many of these neighbourhoods lie within zones that were classified as non-White during Apartheid, such as Khayelitsha and Mitchells Plain, they were historically considered not suitable for economic investment. The current land use zoning continues to reflect this, which suggests that it has not been sufficiently revised. Many of these neighborhoods could be likened to the American Ghetto, personified by perpetual segregation, multidimensional deprivation, and years of disinvestment (Samson, 2019). Typical characteristics of this category are visualised in figure 8.

A typical example of a neighbourhood in this category is Langa, originally designed on Garden City Principles (Coetzer, 2011). Langa is bounded by multiple man-made morphological barriers, including a highway, railway line, cemetery, industrial land use and green belt, effectively enclosing it in a kind of urban fortress. This is problematic, for even though Langa has a position of high global centrality, these barriers locally disconnect it from the surrounding urban fabric.

4.3 Category 3: Semi residentially integrated, with diverse transport

Category 3 neighbourhoods, depicted in peach in figure 6 are principally concentrated in the southern suburbs, and adjacent to the CBD. They serve as a kind of transition zone between the economically disadvantaged and affluent neighbourhoods. They contain higher levels of diverse land use and income, than Category 2. The pronounced difference between this category and the others, is increased access to transport. The accessibility of infrastructure has clear implications on a person's ability to participate fully within a society, which can contribute significantly to social inclusion (Lucas, 2019). Within these neighborhoods higher racial heterogeneity is observed. These neighbourhoods represent fertile ground for intermixing as possess more employment opportunities and transport options. Both factors appeal to diverse population groups and thus serve as attractors.

There are several neighborhoods in this category that are located in the townships of Khayelitsha and Mitchells Plain. It is found on closer inspection that those neighbourhoods, whilst located in historically marginalised zones, have locally centralized positions, with higher levels of mixed land use and transportation access, elevating them from the economically disadvantaged categorisation. Typical characteristics of these neighbourhoods are summarised in figure 9.

Wynberg is a typical neighbourhood within Category 3, displayed in figure 9. On examination, it is found to be continuously connected to the broader urban fabric by Main Street, which connects to the CBD. Main Street represents more than a path of movement, but a diverse space of social interaction and everyday life, lined with retail stores, services and sidewalks of pedestrians. The role of streets in attracting people and supporting activities has been highlighted in the works of Jacobs (1961) and Gehl (2010).

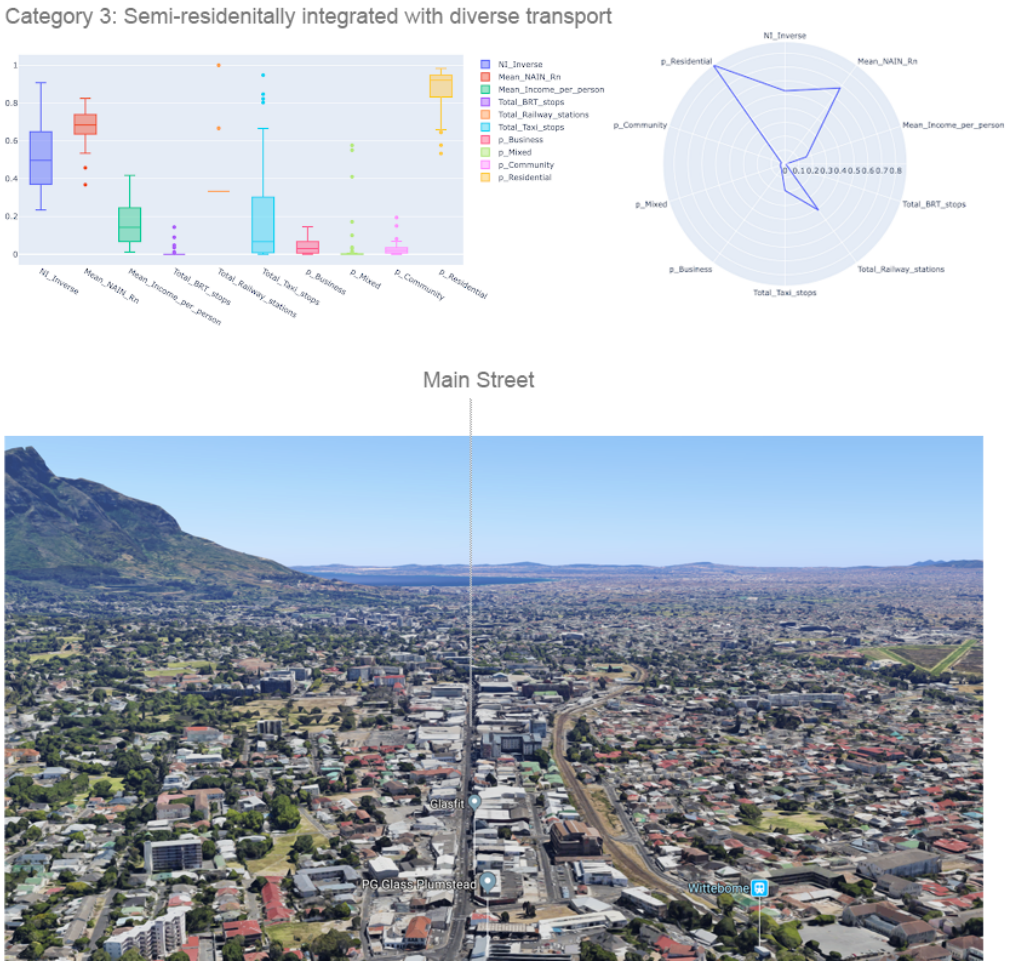

Figure 9: Category 3

4.4 Category 4: Residentially integrated, with diverse land use

Category 4 possesses the lowest number of neighbourhoods and concurrently has the maximum average racial diversity. Therefore, whilst the city remains predominantly segregated, there are certain areas in which residential racial diversity is emerging. This includes the Central Business District (CBD) and multiple neighbourhoods which are adjacent to Voortrekker Street (refer to figure 6). These neighbourhoods have decent access to the Minibus Taxi; however, the two truly significant indicator divergences are their heterogeneous land use and that they possess the highest mean closeness centrality out of all the categories. Category 4 reinforces the relation between land use diversity and residential racial diversity. These results illustrate the importance of relational thinking - residential mixing does not take place in a vacuum, it is situated within a particular context. Diversity is a key ingredient for urban resilience, safety and thriving neighbourhood life (Faharani, 2021). South Africa has a long history of segregation, which was reinforced by severe area-based zoning policies. These results indicate that land use heterogeneity and spatial accessibility are significant and should be considered within strategies for social inclusion.

The Central Business District (CBD) sits within this category. It is composed of a tight knitted, gridded structure, of walkable urban blocks. Most of the neighbourhoods in this category are connected to the CBD through Voortrekker Road (refer to figure 10). Voortrekker Road is lined with diverse land use and pedestrian sidewalks and therefore can be considered a street. Dewar and Todeschini (2004:87), make the distinction between a road and a street. The road, they argue, is mono-functional, existing for the single purpose of maximizing vehicular movement. A street, on the other hand, is a concept of multi-functionality, a social space, in which movement channels are public spaces of interaction.

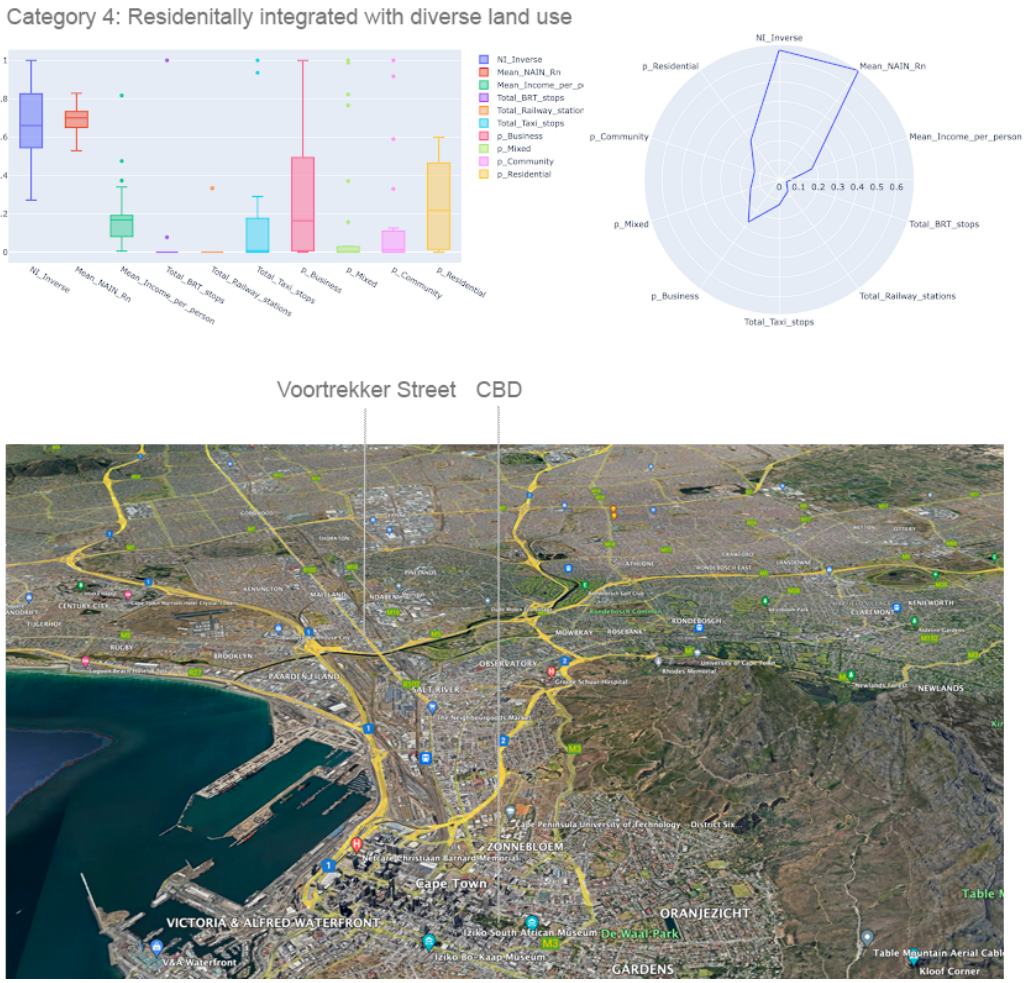

Figure 10: Category 4

5 DISCUSSION AND CONCLUSIONS

Sustainable urban development centred on social inclusion has become a global urban imperative, and yet it has been difficult for cities to implement programs which directly address this issue or even effectively measure or monitor it over time. This study has principally made three contributions:

1) A theoretical and empirical motivation for the examination of social inclusion through an urban lens and neighbourhood scale.

2) The development of a data driven approach which allows for the identification of systemic associations between multidimensional indicators.
3) The identification of categories of neighbourhoods that could be used to support local policies and monitor neighbourhood effects over time.

The following sections will discuss the contributions in more detail.

5.1 Motivation for examining urban social inclusion at a neighbourhood scale

Traditional studies and indices that monitor and measure social inclusion are usually conducted at the household or individual scale relying on survey data and mainly predominantly economic indicators. What this study has affirmed is that people who share a neighbourhood also share, to a certain degree, urban resources. The results align with Sampson's (2019:14) assertion that large and persistent racial disparities cannot be fully explained by only individual or family characteristics - these kinds of social problems are inherently contextual in nature.

The results emphasise that there are vastly different characteristics between neighbourhoods in Cape Town. Based on this, the neighbourhood spatial structure can be deemed to have an impact on a community's capability to participate and thus affect the freedom to live the life they may choose (Sen, 1987). It can be theorised that a neighbourhood, such as Wynberg, which is connected to the urban fabric by Main Street has greater opportunities for diverse social interaction than for example, Camps Bay that is connected by a road designed only for motor vehicles. Main Street serves not only as a path of movement, but an activity space and whilst this may not lead to direct interaction it has effects on segregation (Legeby, 2013). The structure of society is reproduced within space (Hillier and Hanson, 1984). Therefore, to foster more socially inclusive cities and societies, systemic, local geographical factors need to be considered.

5.2 Data driven approach and relational thinking

Traditional studies of social inclusion utilize survey data, whereas this study has employed readily available open data sets. Increased computational power and the rise of urban analytics in recent years has enabled this (Kandt and Batty, 2020).

This has allowed for a range of indicators to be included, that perhaps before were difficult to quantify. It has also reinforced that relational thinking, such as that embedded within urban theories like space syntax, is required when analysing social inclusion and racial heterogeneity within the city, to allow for an understanding of the systemic factors which reproduce these conditions. Although this research does not show causal relations between indicators, the neighbourhood categories which are more demographically racially integrated, congruently have higher levels of heterogeneous land use, public transport and global closeness centrality. This emphasizes the dynamic relationship between these categories of variables, if the problem was examined unilaterally, a holistic picture would not be achieved.

The two neighbourhood categories, which have the lowest levels of demographic racial integration, are also homogenous in land use and weakly connected through public transport. However, there are two conspicuous differences, firstly, the one category represents the affluent and wealthy and the other, the economically deprived. The second key difference is that the affluent neighbourhoods are spatially segregated possessing the lowest global closeness centrality values. If we refer to space syntax theory, we can conclude that the spatial configuration of the affluent neighbourhoods seeks to conserve co-presence, culturally reinforcing their exclusivity. It could even be argued that these residents are participating in a form of "voluntary exclusion". These residents most likely own private vehicles and thus can quickly move across the city by highway (refer to figure 6 to see how the main highway cuts through the city).

In the case of the economically disadvantaged neighbourhoods, their economic deprivation aligns with service and transport infrastructure deprivation, which is inherently more problematic. Contemporary neo-liberal urban investment patterns indicate little financial incentive to invest within economically disadvantaged neighbourhoods (Graham and Marvin, 2001). Despite these neighbourhoods possessing relatively high closeness centrality, the land use pattern does not reflect this. If the City aimed to encourage development within these areas, rezoning land use to mixed and economic categories, could incentivise developers. Transport is generally a complex issue, but there is consensus that it plays a role in achieving "equity of opportunity" (Van Wee and Geurs, 2011:355). The results show that increased access to transport, aligns with increased racial heterogeneity. They also show that transport is highly unevenly distributed. However, implementing large-scale transport reforms brings many challenges. The amount of negotiation required to smoothly transition informal services as part of the government-led system, may be the greatest and most underestimated challenge in the Global South. However, it is well known that integrated, multi-modal transport systems inclusive of semi-formal, informal, and formal services working together, have the potential to better serve users' needs, improve a city's productivity and foster a more inclusive society.

5.3 Categories of neighbourhood

Four categories of neighbourhoods are identified: Affluent and Exclusive, Economically disadvantaged and Marginalised, Semi-residentially Integrated, with diverse transport and Residentially Integrated, with diverse land use.

The advantage of these categories is that they articulate localised differences. A one city approach to social inclusion, therefore, would not be appropriate, as different kinds of neighbourhoods have different needs. Within the more racially segregated neighbourhoods, buffer zones are observed, both man-made, in the case of Langa, and natural, in the case of Camps Bay. Toth et al (2021), show how physical segregation aligns with social network segregation and this study illustrates that physical segregation is congruent with residential racial segregation. Whereas the majority of neighbourhoods in Categories 3 and 4 are connected by

Main and Voortrekker Street, which serve as more than merely paths of movement, but activity zones and public spaces. The use of buffer zones was established to be key in the formation of the Apartheid City (Davies, 1981:69). Therefore, an emphasis needs to be placed on the cultivation of local, physical connectors.

5.4 Conclusion

Access to transport, services, employment, and social opportunities have true social and economic benefits. Communities share these benefits by the virtue of the spatial characteristics of their neighbourhoods. This study presents a quantitative approach for studying social inclusion through an explicitly urban lens based on multi-dimensional indicators. It is envisioned that this framework could be applied in other contexts and further developed. We need both place and person-based interventions to effect durable change (Samson, 2019). If the commitments for creating inclusive cities are to be realised, the use of multi-dimensional, relational, and localised approaches to understand systemic factors that perpetuate social exclusion and segregation within cities is imperative.

REFERENCES

Bantis, T., Haworth, J. 2020. *Assessing transport related social exclusion using a capabilities approach to accessibility framework: A dynamic Bayesian network approach*. Journal of Transport Geography, 1-29

Bocarejo S., J.P., Oviedo H., D.R., 2012. *Transport accessibility and social inequities: a tool for identification of mobility needs and evaluation of transport investments*. Journal of Transport Geography 24, 142–154.

Bobkova, E., Berghauser Pont, M., Marcus, L. 2019. *Towards analytical typologies of plot systems: Quantitative profile of five European cities*. Environment and Planning B: Urban Analytics and City Science 48, 604–620. https://doi.org/10.1177/2399808319880902

Burkov, A. 2019. *The Hundred-Page Machine Learning Book*.

Calafiore, A. Palmer, G. Comber, S. Arribas-Bel, D. Singleton, A. 2021. *A geographic data science framework for the functional and contextual analysis of human dynamics within global cities*. Computers, Environment and Urban Systems 85.

Cape Town Open Data Portal, https://web1.capetown.gov.za/web1/OpenDataPortal/ (accessed 8.1.2021).

Church, A. Frost, M. Sullivan, K. 2000. *Transport and social exclusion in London.* Transport Policy. p195-205.

Coetzer, N. 2016. *Building apartheid: on architecture and order in imperial Cape Town*. London: Routledge.

Dhanani, A., Tarkhanyan, L., Vaughan, L., 2017. *Estimating pedestrian demand for active transport evaluation and planning*. Transportation Research Part A: Policy and Practice 103, 54–69. https://doi.org/10.1016/j.tra.2017.05.020

Davies, R.J. 1981. *The spatial formation of the South African City*. GeoJournal 2, 59–72. https://doi.org/10.1007/BF00196325

Dewar, D. Todeschini, F. 2004. *Rethinking Urban Transport After Modernism - lessons from South Africa*. Ashgate Publishers: London.

Delmelle, E. 2016. *Mapping the DNA of Urban Neighborhoods: Clustering Longitudinal Sequences of Neighborhood Socioeconomic Change*. Annals of the American Association of Geographers. 106. 36-56. 10.1080/00045608.2015.1096188.

Duncan, O.D., Duncan, B. 1955. *A Methodological Analysis of Segregation Indexes*. American Sociological Review 20, 210–217. https://doi.org/10.2307/2088328

Foster, K. 2020. *Smarten Up: Paths to bottom-up smart cities and the risks of top-down smart governance*. In *Smart Cities Paper Series:Smart Governance in South African Cities 2020.* https://www.sacities.net/wpcontent/uploads/2020/10/Smart_Cities_Papers_Volume_1_Final-Draft.pdf accessed on 25.11.2021

Freeman, L.C., 1977. *A Set of Measures of Centrality Based on Betweenness*. Sociometry 40, 35–41. https://doi.org/10.2307/3033543

Gehl, J. 2010. *Cities for People*. Washington, DC : Island Press

Graham, S., Marvin, S., 2001. *Splintering Urbanism. Networked infrastructures, technological mobilities and the urban condition.*

Granovetter, M.S. 1973. *The Strength of Weak Ties*. American Journal of Sociology 78, 1360–1380.

Hanson, J., Hillier, B., 1987. *The architecture of community: some new proposals on the social consequences of architectural and planning decisions*. Architecture and Behaviour , 3 (3) pp. 251-273.

Hillier, B. 1996. *Space is the machine: a configurational theory of architecture*. London: Press Syndicate of the University of Cambridge

Hillier, B., 1989. *The architecture of the urban object*. Ekistics 56, 5–21.

Hillier, B., Hanson, J., 1984. *The Social Logic of Space*. Cambridge University Press, Cambridge. https://doi.org/10.1017/CBO9780511597237

Hillier B., Iida S. 2005. *Network and Psychological Effects in Urban Movement*. In: Cohn A.G., Mark D.M. (eds) Spatial Information Theory. COSIT 2005. Lecture Notes in Computer Science, vol 3693. Springer, Berlin, Heidelberg. https://doi.org/10.1007/11556114_30

Hillier, B. Netto, V. 2002. *Society seen through the prism of space: outline of a theory of society and space*. URBAN DESIGN International, 7 (3-4). pp. 181-203. ISSN 13575317 7. https://doi.org/10.1057/palgrave.udi.9000077

Hillier, B. Penn, A. Hanson, J. Grajewski, T. Xu, J. 1993. *Natural Movement: Or, Configuration and Attraction in Urban Pedestrian Movement.* Environment and Planning B: Planning and Design, Volume: 20 issue: 1, page(s): 29-66

Jacobs, J. (1961). *The Death and Life of Great American Cities*. New York: Random House.

James, D.R., Taeuber, K.E., 1985. *Measures of Segregation*. Sociological Methodology 15, 1–32. https://doi.org/10.2307/270845

Kandt, J. Batty, M. 2020. *Smart cities, big data, and urban policy: Towards urban analytics for the long run*. Cities. 109.

Klinenberg, E., 2015. *Heat Wave: A Social Autopsy of Disaster in Chicago*. University of Chicago Press, Chicago, IL.

Legeby, A., Marcus, L. 2011. *Does the urban structure of Swedish cities inhibit the sharing of public space?.* Built Environment 37, 155–169.

Legeby, A. 2013. *Patterns of co-presence: Spatial configuration and social segregation.* PhD Thesis

Levitas, R., Pantazis, C., Fahmy, E., Gordon, D., Lloyd, E., Patsios, D. 2007 . *The Multidimensional Analysis of Social Exclusion.* Department of Sociology and School for Social Policy Townsend Centre for the International Study of Poverty and Bristol Institute for Public Affairs University of Bristol

Lucas, K. 2019. A *new evolution for transport-related social exclusion research?* Journal of Transport Geography, Celebrating 25 years of Journal of Transport Geography 81, 102529. https://doi.org/10.1016/j.jtrangeo.2019.102529

Lucas, K., 2012. *Transport and social exclusion: Where are we now?* Transport Policy 20, 105–113.

Maly, M.T. 2000. *The Neighborhood Diversity Index: A Complementary Measure of Racial Residential Settlement*. Journal of Urban Affairs 22, 37–47. https://doi.org/10.1111/0735-2166.00038

Massey, D.S., Denton, N.A., 1998. *American Apartheid: Segregation and the Making of the Underclass.*

Massey, D.S., Denton, N.A., 1988. *The Dimensions of Residential Segregation*. Social Forces 67, 281–315. https://doi.org/10.2307/2579183

Nelson, R.J., 2021. *The spatial and social logic of the Minibus Taxi network: how access may support social inclusion in Cape Town, South Africa*. Applied Mobilities 0, 1–25. https://doi.org/10.1080/23800127.2021.1926054

Oviedo, D., 2021. *Chapter Five - Making the links between accessibility, social and spatial inequality, and social exclusion: A framework for cities in Latin America*, in: Pereira, R.H.M., Boisjoly, G. (Eds.), Advances in Transport Policy and Planning, Social Issues in Transport Planning. Academic Press, pp. 135–172. https://doi.org/10.1016/bs.atpp.2021.07.001

Parnell, S., Robinson, J., 2012. *(Re)theorizing Cities from the Global South: Looking Beyond Neoliberalism*. Urban Geography 33, 593–617. https://doi.org/10.2747/0272-3638.33.4.593

Peach, C. 2001. *The Ethnic Enclave and the Ghetto*. Lincoln Institute of Land Policy Conference Paper

Pereira, R.H.M., Schwanen, T., Banister, D., 2017. *Distributive justice and equity in transportation*. Transport Reviews 37, 170–191. https://doi.org/10.1080/01441647.2016.1257660

Pieterse, E. 2013. *Post-Apartheid Geographies*. *African Centre for Cities.* https:// www.africancentreforcities.net/post-apartheid-geographies/ Accessed on

Rousseeuw, P.J., 1987. *Silhouettes: A graphical aid to the interpretation and validation of cluster analysis*. Journal of Computational and Applied Mathematics 20, 53–65. https://doi.org/10.1016/0377-0427(87)90125-7

Reardon, S.F., Bischoff, K., 2011. *Income Inequality and Income Segregation*. American Journal of Sociology 116, 1092–1153. https://doi.org/10.1086/657114

Sampson RJ. *Neighbourhood effects and beyond: Explaining the paradoxes of inequality in the changing American metropoli*s. Urban Studies. 2019;56(1):3-32. doi:10.1177/0042098018795363

Sen, A. 1987. *The Standard of Living: The Tanner Lectures on Human Values*. Cambridge: Cambridge University Press.

Smith, R., 1998. *Discovering Stable Racial Integration*. Journal of Urban Affairs 20, 1–25. https://doi.org/10.1111/j.1467-9906.1998.tb00407.x

The State of the South African Cities Report, http://www.socr.co.za/wp-content/uploads/2016/06/SoCR16-Main-Report-online.pdf, Accessed on 25.11.2021

Tóth, G., Wachs, J., Di Clemente, R., Jakobi, Á., Ságvári, B., Kertész, J., Lengyel, B., 2021. *Inequality is rising where social network segregation interacts with urban topology*. Nat Commun 12, 1143. https://doi.org/10.1038/s41467-021-21465-0

Turok, I., 2001. *Persistent Polarisation Post-Apartheid? Progress towards Urban Integration in Cape Town*. Urban Studies 38, 2349–2377. https://doi.org/10.1080/00420980120094551

Turok, I. Visagie, J. Scheba, A. 2021. *Social Housing and Upward Mobility in South Africa.* Report number: 191. Affiliation: Agence Française de Développement (AFD)

United Nations, 2016. *World Social Report 2020: Leaving no one behind: the imperative of inclusive development*. UN.

United Nations, 2020. *World Social Report 2020: Inequality in a Rapidly Changing World*. UN. https://doi.org/10.18356/7f5d0efc-en

Vaughan, L., 2007. *The spatial syntax of urban segregation*. Progress in Planning 67, 205–294. https://doi.org/10.1016/j.progress.2007.03.001

Vereinte Nationen (Ed.), 2016. *Leaving no one behind: the imperative of inclusive development, Report on the world social situation*. United Nations, New York, NY.

Wee, B. van, Wee, B. van, Geurs, K., 2011. *Discussing Equity and Social Exclusion in Accessibility Evaluations*. European Journal of Transport and Infrastructure Research 11. https://doi.org/10.18757/ejtir.2011.11.4.2940

Wilson, W.J., 1996. *When Work Disappears*. Political Science Quarterly 111, 567–595. https://doi.org/10.2307/2152085