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Application of rules of transportation planning based on principles of transport justice developed by Karel Martens in Windhoek

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ABSTRACT

Transportation planning over the years focused on providing mobility for car users. The focus on mobility has left people who cannot afford automobiles without access to different activities within their societies. The lack of access, in turn, resulted in social exclusion. In the book 'Transport Justice' Martens showed that the distinct social meaning of the transport good lies in the accessibility. And therefore, accessibility should be the focus of transportation planning to mitigate lack of access and in turn social exclusion. Moreover, Martens developed principles of justice for transportation planning which focuses on identifying groups of people experiencing accessibility shortfalls to help planners focus resources towards those people who are socially excluded due to inadequate transportation systems. This paper aimed to use the principles of justice for transportation planning to identify population groups experiencing insufficient accessibility in the City of Windhoek by assessing potential mobility and accessibility in the city. Additionally, the paper aimed to evaluate how well the rules apply to a small city with a different land use and transport system to the Amsterdam case study from the book 'Transport Justice'. To assess the transport system, the population of Windhoek was divided into groups based on location, income, and modal split. The accessibility levels and potential mobility levels for each population group per mode were then determined using four accessibility measures and the Potential Mobility Index (PMI-score). The groups were then assigned under 50%, 30%, and 10% accessibility thresholds based on their respective accessibility levels. Under each threshold, groups that contributed the most to the unfairness of the transportation system were identified and ranked based on their respective Accessibility Fairness Index scores (AFI).

The results showed that most public transport dependent population groups contributed to the Windhoek transportation system unfairness. These groups are located in Havana, Okuryangava, Wanaheda, and Goreangab at the fringes of the city with low-income residents. Even with limited data, the application of the principles to Windhoek yielded an insightful overview of accessibility in within the city that showed gross inequalities in accessibility to jobs between the car owners and public transport users and between low income and high-income earners. The application of the principles of justice for transportation planning produced comprehensible insight on the effects of the transportation system on accessibility to employment in Windhoek. The insight has shown that theory and principles developed by Martens can be useful in the African context where there are significant disparities in accessibility.

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ACRONYMS AND ABBREVIATIONS

AFI	Accessibility Fairness index
ArcGIS	Aeronautical Reconnaissance Coverage Geographic Information System
B	Bus
C	Car
CBD	Central Business District
CFI	Corporate Finance Institute
CUM	Cumulative Gravity
EXP	Exponential Gravity Power
GIZ	Geutsche Gesellschaft fur Internationale Zusammenarbeit
INV	Inverse Gravity Power
Nampol	Namibian Police Force
PMI	Potential Mobility Index
SUTMP	Sustainable Urban Transportation Master Plan
TAZ	Transport Activity Zone
T	Taxi
INTALInC	International Network for Transport and Accessibility in Low income Communities
WHO	World Health Organisation
PT	Public Transportation

CHAPTER 1 INTRODUCTION

1.1 BACKGROUND AND CONTEXT

Transportation is aimed at providing access to opportunities over space, however, transport systems are conventionally planned and evaluated on motor travel conditions measured using factors such as travel time, speed, and level of service while overlooking accessibility factors (Litman, 2017), and transportation externalities such as motor vehicle fatalities, pollution, and social exclusion. This traditional way of planning has been criticized and has led to new ways of planning namely: transportation planning for sustainability and transportation planning for accessibility. Transportation planning for sustainability aims to reduce the environmental effects caused by car-based transport systems. Consequently, the approach remains focused on car users and how to change their travel patterns. Transportation planning for accessibility, on the other hand, focuses on ensuring people have access to destinations offering different opportunities (Martens, 2017). It puts people and justice at the centre of transportation planning. Focusing on people ensures that most people if not everyone has a means through the transportation system to access various activities. When people do not have access, they are deprived of participation in activities such as health services, democratic processes, education, and employment; they are socially excluded (Burchardt et al. as cited in Preston & Rajé, 2007).

Social exclusion caused by accessibility inequalities customarily affects the poor (Martens, 2017, Lucas, 2016). The urban poor face a high burden in accessing transport services to access opportunities. Affordability of transportation services significantly affects the accessibility of low-income households, and although low-income households may be able to go to work, they may not be able to participate in shopping, school trips, and friendly visits because of high transport costs, therefore becoming socially excluded (Carruthers, Dick, & Saurkar, 2005; Tyler, 2004 Burchardt et al. as cited in Preston & Rajé, 2007). Social exclusion furthermore stems from the relationship between transport and land use (Mazaza, 2002). There is a constant increase in cities' populations across the globe, however, the land use form and transport system are not conducive to increasing population. Spatial mismatch due to shift of low-wage jobs to the suburbs, racial discrimination in housing markets, and weak transportation links, especially for public transportation (Kain, 1960, as cited in Blumenberg, 2003) have contributed significantly to the accessibility and mobility disparities occurring today. Thus, the solution to social exclusion should incorporate working to understand the relationship between land use and transportation.

Martens (2017) has explicitly developed principles of justice for transportation guided by theories of justice and particulars of transportation in the book 'Transport Justice'. The principles aim to help experts and decision-makers alike analyse transportation systems and provide intervention which makes transportation systems just and fair for all people. Ultimately, Martens (2017) developed a substantive and prescriptive theory of justice in the domain of transportation. It is a theory that pertains to knowledge of land use dynamics and transportation planning as it should be. The theory presents the distribution of accessibility as a transportation good and steps on how to fairly distribute it. It was however made clear that the approach is not a blueprint nor a finished product. Although it is comprehensive, it requires refinements based on its foundation, exploration of further consequences, and practical application. It is the aim of this study to explore the application of the theory and its principles to the transportation system of Windhoek and to contribute to the body of work based on the principles of justice for transportation planning as set out by Martens.

1.2 PROBLEM STATEMENT AND RESEARCH RATIONALE

Inequalities in transportation have been documented concerning health, women, income, land use, and transportation systems with the aim to have transportation policies and planning procedures changed to address the inequalities. Transportation planning and policies have focused on car mobility for a long time, and that has left parts of the population with no access to cars in transportation poverty (Tyler, 2004). This population often predominantly consists of the poor, because the majority of the transportation infrastructure investments are economic growth driven and, thus they favour the wealthy who own cars and make the most car-based trips (Lucas, Mattioli, Verlinghieri, & Guzman, 2016).

In recent years, some African cities have experienced rapid exponential population growth with planning for such growth proving to be grossly inadequate due to urban immigration. The cities' transportation infrastructures have not adapted to the changing population densities well (Stucki, 2014). African nations' post-colonialism adopted development models based on conditions from outside Africa, from advanced economies that were vastly different from African realities. Moreover, a vast majority of transportation infrastructure investments have been politically influenced (Middleton, 2016), and so the countries' national funds were invested in projects that have not been inclusive and at times widened the inequality gap.

Some cities have made efforts to address inequality as it relates to transportation, however for those that did not make an effort for reasons such as lack of financial support, poor planning, and lack of technical capacity (Stucki, 2014), they have left populations, especially the urban poor and rural residents, excluded from activity participation due to lack of adequate accessibility and mobility. Mobility gaps in Africa are evident: while the elite enjoy hypermobility, most are caught in remoteness and poverty (Pirie, 2009), unable to access transport services or have no options for transport services. In African cities, the majority of people use non-motorized transportation and share the roads and sidewalks with street vendors and motorized vehicles (Middleton, 2016). This is mostly the case in the middle to low-income areas and economic centres. Cyclists and pedestrians should not be sharing pavements with motor vehicles, however, there is often a lack of adequate non-motorised transport infrastructure, and therefore, they are left with no choice (INTALInC, 2019).

Disparities in transportation are a consequence of transportation planning and so they can be addressed through improving planning methods. Martens (2017) developed principles of justice for transportation planning that can be used to make transportation investments people-centred to address issues of mobility and accessibility shortfalls. The principles of justice for transportation planning were developed to impart fairness and social justice in transport planning. The steps developed by Martens provide a ranking of populations experiencing accessibility shortfalls which highlights the groups of people who need to be prioritised when transportation investments are made.

In his book "Transport Justice", Martens did a case study on Amsterdam to demonstrate the application of transportation planning based on principles of justice. It has not been applied to different transportation systems yet. It is thus the aim of this study to conduct a case study in the City of Windhoek in line with the principles of transport planning for justice. The study will analyse how well the rules apply to a different transport system, in one of the smaller developing African cities, Windhoek, Namibia. Windhoek is different from Amsterdam, in terms of land use patterns, access and availability of mobility options, and therefore suits well as an alternative case to identifying populations with accessibility shortfalls. The results of the study will be insightful to the City of Windhoek in understanding how the deficiency of the city's transportation system affects different populations of Windhoek. The study will also show how each of the different transport services serves the population and which of them needs accessibility improvements.

1.3 OBJECTIVES OF THE INVESTIGATION

The study aims to identify and rank population groups within Windhoek experiencing the least accessibility to employment opportunities within the city through evaluating the fairness of the Windhoek transportation system and its transportation modes using the principles of justice for transportation planning. The study further evaluates how well the principles of justice apply to a small city in a developing country context with significantly different land use and transport system context.

1.4 SPECIFIC OBJECTIVES

1. Translate and interpret the Martens' theory of transportation planning based on principles of justice to a developing country context
2. Examine literature on social justice, social exclusion, and accessibility.
3. Define and operationalize appropriate potential accessibility and potential mobility measures for the context
4. Calculate potential mobility and accessibility shortfalls for the case study of Windhoek, Namibia
5. Identify possible causes of these shortfalls and solutions
6. Evaluate the application of the theory of transport justice to a developing city

1.5 LIMITATIONS

The study was limited to the technical analysis part of the proposed theory of transportation planning based on the principles of justice which constitutes steps one to six. The limitation was due to limited data on public transport transfer times, public transport frequencies, and the time, as well as funds to carry out a democratic deliberation process, was a barrier. Data, as mentioned, is needed to find the causes of accessibility shortfalls. The technical steps identify the populations experiencing accessibility shortfalls which can be caused by poor transport links, lack of transport services, poorly located services, and congestion to mention a few. Beyond the identification of population groups, further investigation into the causes is required. Additionally, Martens pointed out that some of the steps are not sufficiently developed and thus steps beyond those illustrated by Martens were left out of this study as well.

Furthermore, the study only used morning peak hour as a time-based factor due to the absence of off-peak hours (4:30 to 5:30 pm) and afternoon peak hour traffic data. Data collection such as traffic counts for off-peak hours and afternoon peak hours and input from affected groups has cost implications which the study could not cover.

1.6 STRUCTURE OF THE PAPER

Chapter 1: Introduces the concepts of social exclusion, accessibility, mobility, and Marten's just approach to transportation planning. The chapter further presents the motivation and objectives of the research.

Chapter 2: Gives a theoretical background based on the literature review on social exclusion, mobility, accessibility, transport justice, and transportation planning.

Chapter 3: Presents the steps of transportation planning with principles of justice as given by Martens and explains how these steps were followed to evaluate the Windhoek transportation system fairness.

Chapter 4: Presents the results and the interpretation of those results for the Windhoek as they relate to social exclusion, land use, and accessibility deficiency.

Chapter 5: This chapter puts the results and interpretation of the results into perspective and gives possible and recommended solutions to tackle accessibility shortfalls in Windhoek. As well as recommendations for further research.

Chapter 6: Concludes the study and gives suggestions for further research.

CHAPTER 2 LITERATURE REVIEW

2.1 DEFINING SOCIAL JUSTICE

Societies are communities of people living in close proximity to each other for greater survival. Within a society, when an individual takes on an activity, the participation of like-minded members of society is often wanted for the activity to be feasible (Tyler, 2004). Some of the core activities society members may wish to participate in relate to leisure, education, health, business, and democratic processes. To engage like-minded people in an activity, a commonplace for congregation must be identified. If any individual belonging to a society is denied access or has no access to the place of congregation where the activity occurs, they are said not to have full membership of that society (Tyler, 2004). The deprivation of participation in activities is termed social exclusion (Burchardt et al. as cited in Preston & Rajé, 2007). The term originated from French literature of the 1970s in which it referred to the administrative exclusion by the state. Decades later, it has been used interchangeably with poverty. However, the difference is that poverty is a result of social exclusion. When an individual is excluded from participating in activities, they may remain below a threshold living standard and thus are said to experience poverty (Kamruzzaman et al, 2016). Factors that contribute to social exclusion include differentials in access to information, training opportunities, socio-economic circumstances, and access to employment, shopping, and recreation (Urry, 2016, p. 21). Social exclusion can be voluntary or involuntary. Although the term is always looked at as bad, Barry (2002) argues that might be limiting in the conception of people's choice because the cause of concern with social exclusion arises from factors that groups of people or individuals cannot control.

Society has designed itself to give limited access to fundamental basics to the people who are at a disadvantage. Poor people, disabled people, older people, and young people are excluded from the full participation of the modern aspects of life, and as a result, they often lose out on the benefits of living within the society while shouldering consequences of living in the same society (Tyler, 2004). It is unjust that some people get socially excluded due to social systems failing to accommodate their needs (Tyler, 2004). Burchardt et al. (2002, p230 as cited in Kamruzzaman et al., 2016) stated that "an individual is socially excluded if (a) he or she is geographically resident in society and (b) he or she does not participate in the normal activities of citizens in that society". The reference to a location in the definition shows that distance can impact participation, following that lack of participation has been found to be a result of a lack of suitable transportation or access to activities or both (Tyler, 2004).

In the face of social exclusion, some societies have looked to attain social justice. Social justice is often understood and interpreted according to time, location, and individuals the conversation concerns (Harvey, 2010). In navigating definitions of social justice authors, theorists and people at large have termed it to be the distribution of benefits and risks, equality, same rights, and fair access to opportunities (Litman & Brenman, 2012; Farrington & Farrington, 2005; Jennings, 2015). Harvey (2010) has put forth that lack of a fixed definition enhances our ability to comprehend the world as it changes and this is what is seen in looking at how social justice has been applied to education, health care, employment, and transportation. Social justice requires social inclusion; the equitable participation of people in society.

2.2 THEORIES OF SOCIETAL JUSTICE

The subject of social justice has been discussed for decades. During the 18th and 19th century the subject took a boost from the European enlightenment encouraged by political, economic and social change (Sen, 2009). Different theories of justice have since been developed aiming to answer the question 'what is a just society?' in how goods and services are distributed amongst people. Theories of social justice have taken different approaches in addressing the question; the comparative approach to justice and the transcendental approach to justice. The comparative approach pursued by authors Smith, Condorcet, Wollstonecraft, Bentham, Marx, J. S. Mill, Arrow and Sen (Ege, Igersheim, & Le Chapelain, 2014) identifies which societal arrangements are less just and which ones are more just without focusing on an entirely just end state. In contrast, "transcendental" approach led by the works of Hobbes and followed by the work of Jean-Jacques Rousseau and more recently by the work of John Rawls focuses on unedifying a perfectly just societal alternative (Martens 2017, p 38; Sen 2006; Ege et al., 2014).

The theory of justice, according to Rawls, is called 'justice as fairness'. The work of Rawls has since become central in political philosophy; however, it has not been without criticism. In characterizing justice as fairness, Rawls began by stating that principles of justice are established by members of society while ignorant of their respective individual preferences and characteristics (Sen, 2006). According to Rawls (2009), the veil of ignorance ensures that no one is advantaged or disadvantaged in the chosen principles by the contingency of social circumstances or natural chance. No one can design principles in their favour and thus the resultant principles of justice are from a fair bargain and hence justice as fairness.

In criticism of the 'justice as fairness', Sen criticized that the transcendental approach is not sufficient because it creates a wide gap between just and unjust, this may leave a society to be classified as unjust even after the implementation of interventions for justice-enhancement (Sen, 2006). For example, if water is provided to all rural areas in Namibia, the Namibian society would still be considered as unjust because of other unresolved social problems. When using a transcendental theory, it is difficult to answer and observe advancing justice as the approach only focuses on a perfectly just world. These answers are far from how discussions of justice are conducted in the world. The discussions focus on ways to advance justice or reduce injustice by remedying different inequalities seeking one perfect solution.

Furthermore, the approach does not give guidance on arranging two alternatives which are both considered unjust (Sen, 2006). According to Sen (2006), the transcendental approach is both unnecessary and unsatisfactory and that it would be more justified for the comparative approach to be used because alternatives can be ranked to find the best option. He continues to argue that even if a comparison is used under the guidelines of a transcendental theory it will not lead to the identification of the best alternative because it is not possible without the complete and transitive ordering of all alternatives, which are not always known (Sen, 2006 & Martens, 2017). He further put it that transcendental is not necessary for comparisons of justice, arguing that relative assessment of two alternatives is a matter between the two and there is no need to include a third alternative which may be completely different. Sen thus calls for a robust comparative approach to replace the traditional transcendental approach.

Comparison is embedded in decision making concerning policies, investments, and strategies in transportation planning. However, the comparative approach is argued not to be sufficient in the transportation domain as it is much more difficult to reach a fair agreement when alternatives are not as black and white such as the examples used by Sen (2006). Martens (2017) has argued that the comparative approach suggested by Sen only holds when there is a significant difference between the current social state and the ideal social state. A theory of justice does not need to give complete justice, but it should be able to identify which position is farther out of the possible ideal position, this can be achieved through the incorporation of the transcendental approach (Martens 2017).

2.3 PRINCIPLES OF JUSTICE

In the quest of finding principles of justice that apply to the transportation domain, Martens considered the distributive theory of justice outlined by Michael Walzer in ‘Spheres of Justice: A Defence of Pluralism and Equality’ (2008). According to Walzer (2008), the distribution of goods in a society is based on the value of the goods as depicted by that society. Distribution of goods may thus not be based on a single criterion, and that is why Walzer developed distributive spheres for goods with distinct social meaning which cannot be distributed through the criterion of free exchange such as education and health. The distinct social meaning of transportation lies in accessibility (Martens, 2012; Pereira, Schwanen, & Banister, 2016). Martens (2012) has thus advocated for transportation to have a sphere of distribution as it has social meaning and accessibility should be autonomous to be justly distributed through maximizing the average accessibility level with a range of constraints. This means the height of the floor constraint is always in relation to the maximal accessibility level of the best-off person. Martens (2017) explained that the application of these principles can assist decision-makers select alternatives that maximize average accessibility while ensuring that the gap in accessibility between different population groups remains in an acceptable range. Equality is the commonly applied distributive principle of goods however it is not seen as applicable to transportation because of the inevitable inequality in accessibility brought forth by the unavoidable creation of centres and peripherals in space (Martens, 2012).

2.4 JUSTICE IN TRANSPORTATION

The growing search for social justice to end social exclusion has brought researchers to closely look at the role of transportation in social exclusion and how it can be used to bring about social justice. People experiencing a lack of participation due to transportation are defined as transport disadvantaged. Transport disadvantage is a result of lack of access to opportunities and access to transport options (Kamruzzaman et al., 2016). Accessibility is defined as the potential of opportunities for interaction (Martens 2017; Litman 2011). It denotes the ease of reaching opportunities in different locations with a transport system and the ability to overcome spatial separation (Morris, Dumple, & Wigan, 1978; Kamruzzaman et al., 2016). Accessibility incorporates mobility, land use, and a person's available resources. Accessibility is thus a multi-dimensional measure and varies over time and that being so, it is not always easy to measure (Litman, 2011). Mobility is the measure of the transport means and efficiency in ease of movement. These means are infrastructure and transportation services people use to access different opportunities (Kamruzzaman et al., 2016; Tyler, 2004).

The design of transportation infrastructure and organisation of transport services can increase social exclusion through mobility difficulties to potential users such as poor connections to locations, high cost for reaching numerous destinations, lack of security at stops, lack of safety on the road and the design and management of stations (Church, Frost, & Sullivan, 2000; Schwanen, et al., 2015). Church et al. (2000) concluded in 'Transport and social exclusion in London', that increasing accessibility depends on combating those aspects in individuals' journeys at either end.

For decades mobility for the automobile has meant providing more roads and widening existing ones. This resulted in numerous transport externalities such as separation of communities by highways. The separation of communities has lowered mobility and accessibility levels for communities reliant on non-motorised transport due to high risk of crossing the roads, waiting time to cross the roads, and increased travel times to reach road crossings (Geurs & van Wee, 2004 as cited in Ciommo & Shiftan, 2017, p140). It has also contributed to air pollution, traffic congestion, and road traffic fatalities (Taylor & Sloman, 2008; Quiros, Kerhners, & Avner, 2019). These transport burdens often deeply affect the most marginalized populations while they benefit the least from mobility advances (Gössling, 2016). Although hypermobility has given better access to people, it has also created less accessibility and mobility for others (Pirie, 2009).

Besides the impact of hypermobility, one of the factors contributing to inaccessibility is land use. There is a rapid increase in urban populations which is causing cities to sprawl outwards, particularly forcing the poor and low-income earners to live at the peripherals of the cities. Peripheral living conditions are customarily poor due to poor municipal services, including transportation. It is thus often difficult for those living at the fringe to access services and opportunities due to lack of cars, high transit fare due to the distance and inability to effectively use non-motorized transport due to the distance to the city centre (Vasconcellos, 2001). That lack of access to opportunities caused by spatial separation brings about social exclusion (Preston & Rajé, 2007) in conjunction with separation caused by factors such as age, gender, ethnicity, and income (Ciommo & Shiftan, 2017; Urry, 2016, p. 23). Therefore, Lucas (as cited by Dimitrov, 2010) notes that not everyone is experiencing exclusion because of transportation and thus transportation alone cannot solve exclusion issues, but it is essential for facilitating social inclusion. Social exclusion is not only due to one factor but an interaction of factors (Lucas et al., 2016), and so addressing social exclusion should be a robust approach across different government agencies.

2.5 TRANSPORT JUSTICE IN AFRICA

Accessibility and mobility gaps in the African transportation system are widespread both in rural and urban areas. There are those with cars and those that walk long distances and travel in crowded vehicles, from their rural homes to access primary and social opportunities. These journeys expose people to a high risk of car fatalities and exposure to, at times, harsh weather conditions. These journeys are also tiresome and can be argued to reduce the quality of life often for children walking long distances to school and arriving exhausted, and expecting mothers having to deal with emergencies (Pirie, 2009; Jennings, 2015). Africa has the least number of car ownership accompanied by a disproportionately high number of motor vehicle deaths. Statistics show Africa has 2 % ownership of the world's cars and 16% of road deaths, of which 38% accounts for pedestrians (WHO, 2013). This is due to walking being the most used form of mobility and pedestrians are not shielded from the effects of a motorized society.

A large part of immobility in the African context is due to the lack of infrastructure for public transport, for non-motorised transport and motorised transport to remote areas. Although transportation investments in infrastructure have been a priority in Africa (Pirie, 2009), the investments are commonly motivated by economic benefits (Lucas et al., 2016), and thus transportation infrastructures are popularly designed to benefit the automobile users and this has served people of the higher income bracket because they own more cars and thus make more trips (Ciommo & Shiftan, 2017).

African cities have been growing at what is seen to be a high rate. Consequently, city authorities have not been able to provide basic services to poor city immigrants. There are harsh realities faced by those moving to cities. A city's accessibility levels are a product of its land-use pattern and efficiency of the transport system. And how well the two are interconnected determines how much access to opportunities the residents have (Quiros, Kerhners, & Avner, 2019). For most cities, urban sprawl has occurred. The urban poor live at the edges of the cities far from employment opportunities, health care, public services, and with poor air quality (Pirie, 2009; Pendakur, 2005). When the poor make trips, they face unsafe travel conditions, public transport violence, and poor-quality services. The majority of public transportation is privately owned and governed by inadequate governments' regulatory systems. There is a lack of personnel to enforce laws and regulate daily operations (Pendakur, 2005). Equivalent to Maslow's hierarchy of needs, the needs of passengers can be ranked from safety, then speed, then ease, then comfort and at the top positive experience (Hagen, 2015). For the urban poor, their basic transportation needs are not satisfied.

Conditions of public transportation led to a large number of people desiring to move away from public transportation by buying cars. Having a car has thus become a social status as it is highly tied to escaping the public transport system by increased income. Over time, cars have become less costly due to high supply (Banister, 2008), and a significant number of people bought cars which led to congestion in cities and more environmental externalities. Congestion, poor transportation infrastructure, and high fuel prices have become a reality for all car owners (Pirie, 2009). Thus, those that escape the reality of public transportation exacerbate the negative effects of the automobile-dependent transportation system that is inefficient and inequitable (Litman, 2014), and they also take on the cost of car ownership. Although car ownership has been shown to alleviate accessibility shortfalls, for low to middle-income households it can be buying into transport poverty because they are forced to consume more travel costs than they can afford (Currie, 2011, p. 22).

The gap between the rich and the poor, the mobile and the immobile in Africa is staggering. In Namibia and South Africa, the segregation of apartheid policies rooted in the separation of people by their ethnicity and race using land use and transportation is still felt. In post-colonial times the segregation is supported by building roads to those living at the edge of the cities far from employment and not providing affordable housing close to jobs. This has kept people segregated. Those that cannot afford to pay the price to travel the distance are left out and those that can spend a large portion of their income on travel, this concern has been expressed over the routing of South Africa's Gautrain and the Johannesburg Rea Vaya BRT (Jennings, 2015). The routes are criticised for running through already served communities and locating terminals away from marginalised communities that they aimed to serve.

In the study 'Livelihoods, daily mobility, and poverty in Sub-Saharan Africa', (Bryceson, Mbara, & Maunder, 2010), it was found that low-income earners make more shopping trips than high-income earners because they buy in small amounts and frequently. In the urban context, this exposes them to the harsh public transportation system more than necessary and increases their transportation expenditure. They are thus forced to make the most out of each trip (INTALInC, 2019). For the middle-income families' occasional travels for social visits or family emergencies can cause significant financial setbacks.

African governments have limited resources and numerous issues to be solved. The ability to narrow down investments to the groups that essentially need them would thus help focus resources. It will, however, take strong political will to deliver just transportation infrastructure and spatial development (Middleton, 2016). Venter (2016) has argued that intergovernmental relations and effective regulations can ensure complimentary development towards more accessible cities on the continent.

2.6 TRANSPORTATION PLANNING AND TRANSPORT JUSTICE

Because of the influence of transportation on social exclusion, the question of equitable distribution of transport seeped into literature. With the understanding that the effects of transportation on exclusion, mobility, and accessibility are integrated into assessing transportation investments and policies, the following is an examination of the influence of transportation planning on social inclusion and consequently social justice.

Social justice strives for equitable distribution of benefits and burdens (Miller, 2001) through practices that develop social inclusion. Farrington and Farrington (2005) interpret social inclusion as the participation of people in a society's reasonable activities based on the distribution of benefits and burdens in that society. Social justice is relative to each society. This relativism translates to the amount of equitable access expected in a society. For example, in the western context access to a theatre might be considered a reasonable normal activity, however, in rural Namibia or an urban town such as Oshakati, access to a theatre may not at all be considered normal, because it is not part of the social fabric there. Not only is access relative to whole societies, but it is also relative to groups of people and individuals within societies. Plant (1998 as cited in Farrington & Farrington, 2005) argued that distributive justice requires political judgment and so societies have to develop their range of needs that should be met by public expenditure to achieve what they embrace as social justice.

Relativity in the distribution of benefits in society also applies to the geographical location of people. Those that live in rural areas tend to experience the least access to services (Linard et al., 2012). Pirie (2009) describes the rural population groups in Africa as the kinetic underclass. Approximately 60% of the African population reside in rural areas (World Bank, 2018). That is 60 % of people with limited access to education and health care because they struggle to afford transportation and have limited transportation options and infrastructure. In a study conducted in Kenya and Tanzania aimed at developing rural transport service indicators, one of the concerns with rural transport services raised by both users and operators is the effects of weather on the operations (Starkey, et al., 2012). According to the study, the operators at times change the routes to avoid flooded roads without notice to the users or stop operations completely. And thus, during the rainy seasons, the users have the least transport service available and the operators lose out on income.

Porter (2007) argued that the lack of access to opportunities is particularly felt by women, most of whom have to walk long distances to access markets for income generation. Limited income has lifelong consequences not only to the women but their families as well. Money gives access to education, health care, and food. The lack of access to markets thus creates a cycle of poverty. In addition to women, another demographic that is disproportionately affected by the unequal distribution of transportation to rural areas are girls. Porter (2007) notes that in a village in Malawi on days when there are markets, most girls miss school to transport goods to the markets and parents sometimes decide to pull their girls out of school when they have to travel long distances in the dark to be on time. This hinders their educational development which in turn affects their employability, making them susceptible to poverty. Moreover, the lack of transportation options means most people, especially women and girls, carry heavy loads on their heads which has health implications for their spines (Jones, et al., 2016). It is thus evident that providing rural residents with mobility for access to services can improve poverty and reduce health risks (Starkey et al., 2002). Although accessibility shortfalls have consequences in all urban forms, rural residents at times cannot resort to non-motorised transportation because of the distances and thus they tend to be the most disadvantaged people by lack of accessibility.

In a continuous attempt to improve access to rural areas governments route high-speed highway through rural areas, this, however, has exposed people to car-related pollution and accidents (Jones, et al., 2016), while not particularly benefiting from the infrastructure because they are not accompanied by transportation services. Although the burdens of accessibility in the rural and urban may be similar, the degree to which mobility is available to the two varies. Rural residents often do not have transport services while urban areas may have expensive public transportation. Currie (2011) stated that public transportation requires high densities and mixed-use to be practical and financially viable. This can often deflect transportation investments to the cities because of the high population density. In most developing countries the rural areas are filled with low income or unemployed people and at project appraisals the costs out weight the benefits in favour of urban investments.

Farrington & Farrington (2005) note that policies aimed at social inclusion have viewed the spatial aspects as incidental of structural factors such as poverty, income, age, and gender, consequently overlooking poverty of access. Further, they noted that although access poverty can be a result of factors such as age, gender, or income, considering access poverty as a factor explicitly inserts spatial consideration in policies designed to address social justice.

Transport policies guide investments and planning within the transportation sector. Policies play a role in shaping the social and spatial structure of cities. According to Litman (2014), policies are considered equitable when they favour excluded people economically, socially and through mobility. When policies and investments do not include those excluded at the time they are described as unjust, and it means certain persons are shouldering more burden than others or less advantaged than others (Miller, 2001), inequitably so. In recent years, transport policies such as the Namibia Transport Policy (Ministry of Works and Transport, 2018) have included equitability, however, there are no clear steps on how it will be measured. This is not unique to Namibia, South African transportation policies reflect an understanding of transport user needs, addressing land use and transportation issues, yet in major transportation projects aimed at increasing accessibility to the urban poor such as the Gautrain and Rea Vaya BRT and MyCiti, it has been found that these services primarily serve the affluent. The questionable routings mentioned above, coupled with the relationship between the fares and the target market is said to be of concern as well (Jennings, 2015, INTALInC, 2019). This leaves the urban poor to continue reliance on minibus taxis which requires them to walk long distances to taxi ranks. Taking a closer look at the Windhoek taxi service, it is convenient for the middle to high earning citizens because there is always an option to get dropped off at one's doorstep for double the price. This type of benefit does not come with the bus system. As the city is situated in the region with the highest number of crimes (Nampol, 2014), it is an essential safety measure for those that can afford it. Despite the majority of the Windhoek population living within 400 -700 m of public transport stops, safety, security, and perceived safety and security are compromised (GIZ, 2013).

Litman categorised the distribution of transportation benefits and burdens by policies and investments into three equity classes, horizontal equity; the fair distribution of goods between groups or individuals, vertical equity; fair distribution of goods amongst social classes, and with regards to levels of mobility (Litman 2014; van Wee & Geurs, 2011). The equity types overlap because space and people by way of transportation investments are affected by both (Karner, 2016). For a long time, evaluation of transportation planning has revolved around vertical equity relating to mobility, concurrently ignoring that people want access and not movement (Grengs, 2018). Mobility indicators give insight into how well the transportation system functions without input on how it affects households. Moreover, the focus on transport-related resources such as cars, infrastructure, and proximity to stations does not give a full representation of people's capacity to utilize those resources.

It is not common for the accessibility indicator to be included in transport investment evaluations (van Wee & Geurs, 2011). Instead, often a cost-benefit analysis (CBA) with monetary value expressed as timesaving is included as noted by several authors (Mackie, Worley, & Eliasson, 2014; Niehaus, Galilea, & Hurtubia, 2016; Courture, Saxe, & Miller, 2016). The time saving is based on the number of trips that are taken as the value of time and thus communities with more car ownership benefit more and the projects affecting them are likely to get a go-ahead. Using travel behaviour parameters overlooks the suppressed desire for travel for the less mobile population. It is difficult to account for trips not taken due to a lack of funds. This is a distribution defect of the CBA which leads to inequitable decisions (Martens, 2017). In addition, Beukers et al., (2012, as sited in Courture et al., 2016) note that the tool is used too late in the planning process and that prioritization of projects should occur earlier in the process to avoid a few inherent transportation planning prejudices.

Further, transport's social impacts can be difficult to evaluate with CBA because there are various types, impacts, measurement units, and categories of people to consider (Litman, 2014). Social impacts overlap within environmental and economic impacts and thus it can be complicated to account for them in a CBA as it avoids double counting. Criticism of the CBA has brought researcher to suggest other methods of evaluating projects in transportation planning such as basing ridership on past similar projects rather than models, replacing time savings and value of time in the analysis with changes in land value, social cost-benefit analysis and cost-effectiveness analysis (Martens, 2017).

While policies are part of transportation planning that gives the directive to where the focus in investment should be, transportation modelling focuses on future transport demand for infrastructure needs. Transport modelling supports transportation planning because transport planning is said to be only as good as the issues focused on in the models and the implementation of the models. Models are mathematical and often require large amounts of data (Ortúzar & Willumsen, 2011). Transportation modelling is and has been focusing on maximizing mobility for a long time. The four-step model is the largely accepted support tool for transport planning, and it is widely available as a proprietary transport planning software. The model forecasts future travel demand in four steps based on current travel patterns. The model has been criticized for reasons such as being aggregated, having a lack of consideration for non-motorized transport, not considering the interdependency of travellers, limited choice set for trip distribution, and dependency on trend extrapolation instead of developing a vision towards a rational goal (Mladenovic & Trifunovic, 2014). However, besides criticism over decades, the four-step model has remained in use because it is easy to use and understand. It is not as data demanding as the new methods such as activity-based model, tour-based model, land-use models, and dynamic network models. So, because it is not data-intensive, it works out cheaper and viable for use in places where travel surveys are not conducted (Mladenovic & Trifunovic, 2014; Martens, 2006). Subsequently, because of limited data combined with the model's high criticisms, model predictions are likely to incorrectly represent the transport reality that is aimed for theoretically (Ortúzar & Willumsen, 2011).

In the review paper 'Measures of Transport-Related Social Exclusion: A Critical Review of the Literature' Kamruzzaman (2016) identified various indicators of transport-related social exclusion from research. It was found that most of the researchers used area mobility and area accessibility as measures to identify transport-related social exclusion. The area mobility and accessibility measures evaluate how the transport system and land use can potentially enable participation in activities. The measures are aggregated, and although these measures often help develop transport policy responses, area mobility and area accessibility measures have been found to be limited in indicating individual accessibility. Therefore, Preston & Raje (2007) suggested a matrix of area accessibility, area mobility, and individual mobility as a schema for identifying both concentrated and scattered social inclusion and exclusion.

The rural population is most affected by a lack of accessibility, with women and girls in the African context shouldering the burdens of lack of mobility and accessibility. Transportation planning overtime time adopted the trends, politics, environmental concerns, and policies of the present (Bhuyan et al., 2019). However, it is evident now that transportation planning should not be an adoptive process but one that is integrated into planning across various fields because it is essential in providing access. Farrington & Farrington (2005) discussed placing accessibility central in the social justice and social exclusion agenda by analysing accessibility as a policy element. They recognized that accessibility can play a role in combating social exclusion when policy development and interrogation are integrated. Accessibility based planning tools can provide a clear direction for policymakers aiming to address social justice issues. And so, utilitarian evaluation methods just as the CBA should be expanded or replaced with evaluation methods that address accessibility.

2.7 MEASURING ACCESSIBILITY

Planning based on transport justice requires technical agents to be able to measure accessibility as it is the social good of the transportation domain. Decision-makers need to be able to identify the groups of people below a decided upon accessibility threshold.

In examining accessibility, the measure to be used depends on the purpose and situation (Kwan, 1998). When measuring accessibility, different components of accessibility to be put into account are (van Wee et al., 2013);

1. Transportation; focused on the transport system.

2. Temporal component; this considers the time of the day and time available to people to partake in activities.

3. Person component; considers how individuals' income, physical abilities, needs, interests, and education influence their accessibility levels.

4. Land-Use component; relates to the spatial distribution of opportunities and quantifies the supply and demand for opportunities.

Accessibility measures which are generally used incorporate two or more accessibility components and have been put in four categories which are generally used (van Wee et al., 2013);

1. Infrastructure based accessibility measures; used in transportation planning and solely focuses on supply and demand of infrastructures.

2. Utility-based accessibility measures; focus on persons' benefits from the spatial distribution of activities. It is based on the utility theory; people choose the option that maximizes their utility (Makri & Carolin, 1969).

3. Location-based accessibility measures; these are typically macro-level measures that analysis access to an opportunity such as employment between origins within a specified travel time interval such as cumulative and gravity-based accessibility measures (Kwan, 1998; Makri & Carolin, 1969).

4. Person-based accessibility measures; focused on how easily a person can access activity locations (Kwan, 1998).

The measures capture different aspects of accessibility, and hence there should be no expectation to get the same results from different measures when analysing the same data. It was however found that results generated from the same data using gravity-based measures and cumulative measures can be closely related, but not to results from a space-time measure (Bhat, et al., 2001; Kwan, 1998). Cumulative and gravity-based measures do not require massive data, and they are well palatable to both planners and policymakers (van Wee et al., 2013; Kamruzzaman et al., 2016; Geurs, 2006). Even so, the measures have been criticized for assuming accessibility throughout a zone is the same as accessibility at the zone centroid. The measures are also limited in capturing personal accessibility because of the aggregated nature (Kwan, 1998; Kamruzzaman et al., 2016). The level of disaggregation that is desirable to planners can be achieved through personal accessibility measures for they are theoretically advanced, they capture interpersonal differences in access using multiple locations, considering trip chainage and accounting for interpersonal variation in cost and time (Neutens et al., 2010). Unfortunately, for many, it is a challenging task because they require extensive data (van Wee et al., 2013).

When choosing an accessibility measure, it is good to note the following guidelines and to consider them to some degree (Morris et al., 1978):

1. The indicator should incorporate an element of spatial separation, which is responsive to changes in the performance of the transport system.

2. The measure should have sound behavioural foundations.

3. The indicator should be technically feasible and operationally simple.

4. The measure should be easy to interpret, and preferably be intelligible to the layman.

Several authors have studied accessibility to various services using varying measures and indicators. These studies have evaluated access provided by transportation as it relates to mostly income and employment (Krizek et al., 2009; Golub & Martens, 2014; Guzman et al., 2017). This is an indication of how strongly personal finances are believed to affect access to opportunities.

Joubert, Ziemke, & Nagel (2015) compared results of econometric accessibility indicator using a gravity measure and a household-based accessibility measure based on expert knowledge and levels of acceptability and using scores representing the transport-land use system to measure accessibility in Nelson Mandela Bay Metropolitan. They determined that the two measures gave similar results notably so because the econometric accessibility measure required lower input, few assumptions, and no local expert knowledge while the house-hold measure required OSM data, census data, travel survey, and infrastructure data. The similar results go to show how minimal data can give insightful information on accessibility. It can, however, be argued that only using the econometric indicator limits information on possible causes and solutions. Nonetheless, they conclude that both indicators are suitable for evaluating the transport-land use system and its impact.

John Stanley, et al. (2011) used a logit model with observed and unobserved heterogeneity in investing the factors which increase people's chance of becoming socially excluded in Melbourne. The study found that low mobility is positively correlated with the likelihood of social exclusion, while high income and, connection with community are positively correlated with a lower risk of social exclusion.

Peralta-Quiros et al. (2019) in assessing accessibility in multiple African countries used the Lorenz curves and Gini coefficients to represent accessibility distribution in the cities. The Gini coefficient is the ratio that captures how far situations depart from perfect equality. The higher the ratio is, the more unequal the situation is from the perfect situation which in the study was average accessibility. The study showed that Cape Town had the highest ratio compared to the other cities. South Africa has the highest income Gini coefficient in the world (Wolrd Bank, 2019), and this can be attributed to the unequal distribution of access to employment and lasting effects of apartheid. The Gini coefficient does give insight into the distribution of accessibility; however, it does not capture localised accessibility. The Gini coefficient has limitations (CFI, 2020), the measure can provide a similar coefficient for areas with different accessibility distribution when the income levels are the same. The Gini coefficient also implies that accessibility is transferable. The measure lumps everyone together which overshadows how severely the inaccessibility affects certain groups of people.

Martens' methodology, used in this study, differs from the above exemplified studies. The methodology welcomes accessibility thresholds to be set through deliberation between experts and citizens of the society in question. Although the accessibility measures for the methodology are as those used by others such as gravity measure, they are complemented by the measure of potential mobility which expresses the influence the transportation system has on the levels of accessibility for different population groups (Martens, 2017). Additionally, Martens developed the AFI that is used to rank the severity of accessibility shortfalls based on accessibility levels experienced and the number of people affected. As mentioned above there are concerns over aggregation with accessibility measures, the grouping step in Martens' methodology allows the planner to choose how aggregated the analysis can be depending on available time and financial resources.

2.8 MEASURING MOBILITY

As discussed above, transport disadvantage is not only a function of lack of accessibility, but it is also well affected by mobility (Kamruzzaman et al., 2016). Mobility is multi-dimensional and can be understood through examining car ownership, travel time, travel distance, and driver's license (Preston & Raje, 2007), infrastructure, and transport services.

According to Litman (2003), mobility is measured by quantifying person-km, travel speed, level of service, and traffic count data. These indicators quantify automobile and transit speeds between origins and destinations. Mobility measures consider the means to travel as the goals and not a means to an end. Using mobility to measure the level of service for transport systems thus gives inadequate information about origins and destinations and henceforth limited solutions to improving access (Litman, 2003). The solutions provided by mobility evaluations have included an increase in infrastructure capacity and speed. Over the years these have disproportionately favoured private automobiles, leading to exclusion for the walking population and transit users. The level of service indicator, when used as a tool to approve infill development, can discourage authorities from approving proposals out of fear of congestion without considering the opportunity of access to jobs and services to surrounding residents. The projects are often shifted to the suburbs, further from the low-income groups (Grengs, 2018).

To understand and explain the contribution of transport networks to accessibility, the transport network structure, and the availability of modes used by a group of people can be examined. In an effort to explain the contribution of transport networks to accessibility, Martens (2007; 2017) developed the Potential Mobility Index (PMI). Potential mobility is the capacity and freedom for a person to overcome distance in space (Sager, 2005). This capacity may not always be realised. The PMI indicator is the quotient of the aerial distance and travel time between origins and their destinations capturing the geometric design and speed of the network for different modes available (see Chapter 3; Equation 1).

Martens (2007; 2017) argued that this is a better indicator of how the transport network affects accessibility, unlike the level of service measure. This is because it links travel time to the lowest possible distance between two points. To illustrate, if an area only has access to the highway through a long and non-congested secondary road, using the level of service measure may show that, that area does not experience poor accessibility. However, the use of PMI may reveal poor accessibility because it considers the possible shortest distance to an area to travel time to the area. The index is also useful in comparing accessibility to areas irrespective of their location in the study area as well as comparing travel by communities irrespective of generated travel by said communities (Martens, 2007).

In ‘Transport Justice’, Martens (2017) aimed to show how decision-makers can evaluate transportation situations by providing steps leading to the identification of groups of people who are accessibility poor and to which level their accessibility can be raised to be so that it is considered as efficient. Additionally, Martens (2017) outlined a fair financing scheme for the transportation domain. The core of the scheme consists of user fees based on the principle of marginal cost pricing. The user fees can be used to cover initial capital investment, operations, and maintenance of transportation infrastructure or services. The user fees are to be supplemented by a fair taxation scheme (Martens, 2017). The fair tax is aimed at subsidising those that fall below sufficient accessibility levels because of transportation costs and improving the transportation system when it is causing people to experience insufficient accessibility levels (Martens, 2017). Vanoutrive & Coopera (2019) gave credit to Martens for highlighting the relationship between transportation and justice and focusing on accessibility poverty. However, they found that the theory set out by Martens does not explain why the outcome of the domain of free exchange (the domain of sufficiency) is fair. Vanoutrive & Coopera (2019) argue that self-financing might change spatial patterns and people in the insufficiency domain, transport disadvantaged people, may end up in the most unwanted neighbourhoods. They further state that the production of transport services was overlooked by implying that in the domain of sufficiency, any improvement in transportation can only occur if they are self-financing.

CHAPTER 3 METHODOLOGY

Martens (2017), in his book titled 'Transport Justice', explained and laid out the principles and steps for the planning and design of transport systems based on principles of justice with a case study for Amsterdam. Following these principles, this chapter will explain these steps as they will be used to evaluate the fairness of Windhoek's transport system. The chapter also discusses the data and the implementation followed in the study.

3.1 OVERVIEW

Martens established steps for planners to carry out transportation planning based on the principles of justice which are well explored in his book and summarised in Figure 1. From the steps in Figure 1, this study carried out steps one to six following the guidance of the research methodology presented in chapters eight and nine in ' Transport Justice'. The six steps begin with the division of the overall study population into groups that may be expected to distinctly differ in the levels of accessibility they experience. The second and third steps encompass calculations of accessibility and potential mobility levels with the use of four accessibility measures and an index for mobility, the Potential Mobility Index (PMI). The results from the potential mobility and accessibility assessments are used to plot the different population groups, as distinguished in step one, on the accessibility and potential mobility coordinate system. This is repeated for all accessibility measures. In the fourth step accessibility and potential mobility, thresholds are established. Thresholds in this study were based on average accessibility levels for the car groups calculated in the study. After the thresholds are established, groups that fall simultaneously below each accessibility threshold, and the potential mobility threshold, are identified as groups experiencing sub-standard accessibility and mobility.

In step five, the Accessibility Fairness Index for each group is calculated under each accessibility threshold and measure. The final step then ranks population groups according to their contribution to the fairness of the region or city's transportation system. The last four steps, step seven, eight, nine, and ten are concerned with identifying causes of accessibility shortfalls, finding solutions to those causes, evaluating the solution using a cost-effectiveness method, and lastly implementation of solutions and monitoring how they affect the population groups experiencing sub-standard accessibility and potential mobility. The last four steps were beyond the scope of this study because they require further investigations which include community participation, experts, and systematic analyses based on extensive data on the transportation system and land use. The next section discusses, in more detail, the steps followed.

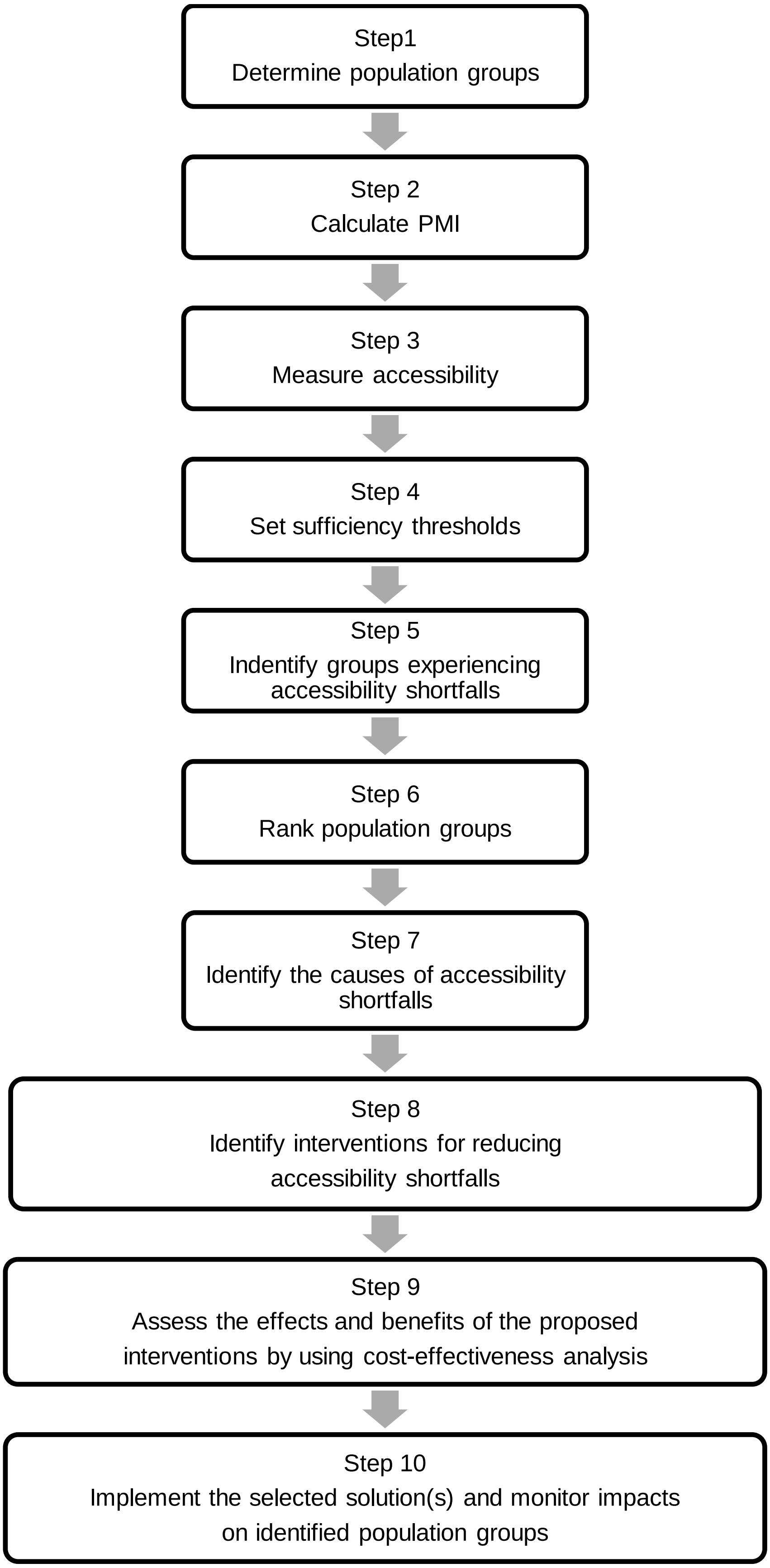

Figure 1: Transportation planning for justice principles

3.2 DATA COLLECTION

Data on land use, traffic, and socioeconomic factors is essential in assessing a transport system's fairness. The data provides essential information on spatial interaction and spatial mobility. This study relied on the National Census for all population data. In Namibia, a population census is conducted every ten years (Namibia Statistics Agency, 2013). The most recent census was conducted in 2011, and hence the 2011 data will be used as a basis for the study. There has not been a travel survey included in the census surveys or done separately for Windhoek and the rest of Namibia to date. These surveys give data useful in understanding travel behaviour and can be used to establish parameters such as travel impedance. However, a traffic survey was done in Windhoek for the SUTMP in 2012 (GIZ, 2013). With the understanding that not many areas conduct travel surveys, the data required for the first six steps of transportation planning based on principles of justice is minimal. The data includes population size, population income classes, travel times to all surrounding zones, and aerial distances between all zones (Martens, 2017). Essential sources for this study included a tour-based transport demand model, maps, and the 'Sustainable Urban Transportation Master Plan' (SUTMP) developed by GIZ in partnership with the City of Windhoek Municipality for the Windhoek, Okahandja, and Rehoboth transportation system in the year 2013. The data for all modes is based only on morning peak hours defined as 7:00-8:00 am. The model also provided modal travel times and employment data per transport analysis zone (TAZ). The Windhoek transportation model consisted of 257 TAZs and 23 main zones within Windhoek.

3.3 DESK STUDY

A GIS package, ArcGIS Pro, was used to extract aerial distance data between all TAZs, and for mapping of the spatial pattern of accessibility deficiency. The Windhoek map developed by GIZ was imported into ArcGIS Pro and the polygonal zone areas were converted to central points which were used to calculate aerial distances between points representing zones using the ArcGIS 'near distance' feature.

3.4 DETERMINING POPULATION GROUPS

The "Transport Justice' theory aims to identify groups of people living below a set accessibility and potential mobility threshold. In the Amsterdam case study (Martens, 2017), the population was divided into two groups, a car-based population group and public transport population groups per TAZ. It was then assumed that 14.8% of the population that belonged to the low-income group relied on public transport while the rest of the population had access to a car. The social-economic structure of zones in Windhoek is very different from Amsterdam. Amsterdam is a city in the Netherlands, a developed country. A high percentage of the bottom income quintile groups live in the most urbanized parts of the city (Martens, 2017). This is an indication that they have made a trade-off between high-cost housing and high transport fares. Very opposite to Amsterdam, Windhoek is situated in a developing country, and the low-income groups of Windhoek live at the fringes of the city despite the inadequate public transportation system and housing. Additionally, high-income residents live entirely separate from low-income residents. That is one of the effects of apartheid policies. Consequently, different modal splits for zones were used based on the main mode per zone, as shown in Figure 2, and economic status, as shown in Figure 3 below.

At the time of data collection (2011), Windhoek had a population of 320 691 people, 86 609 jobs, 257 TAZs, and 23 main zones. The main zones are made up of differently sized TAZs. They are also based on neighbourhoods. People in the same neighbourhood may likely experience the same accessibility levels, and thus it would be interesting to see how many TAZs in a main zone experience different accessibility.

For the accessibility analysis, the population was grouped into 257 groups of car-based population groups, bus-based population groups, and taxi-based groups. The car-based population groups were based on the number of people with a car per household, as indicated under the main zones' constituencies in Table 1. It should be noted that the SUMPT report outlined the main zones differently from those in the 2011 Census report; therefore some of the main zones names in Table 1 do not make part of the 23 main zones used in this study. After determining the car-based population percentage, the remaining percentage was divided into bus and taxi-based population groups.

For zones with bus use as the main mode as per SUMPT report shown in Figure 2, 50% of the remaining population (after the car-based population) was allocated as bus users, while for zones with taxis as the main mode, only 20% of the remaining population (after the car-based population) was allocated as bus users. At the time of the Windhoek transport model, there were 55 operational municipal buses. These buses did not meet the demand at the time, and so an assumption that more than 50% of the remaining population in bus-based zones accounted for bus users would be far from reality. To illustrate 43.8% of the Khomasdal (taxi is the main mode in this zone) population are car users, 11.6% (20% of the remaining 52.2%) are bus users, and 45% are taxi users (80% of 52.2%).

The determination of population groups was thus based on car ownership, income per zone, and modal split. Martens (2017) stated that car ownership is useful in determining population groups, however, it is also problematic. This is because, especially amongst low-income communities, there might be forced car ownership due to a lack of transportation options. Households that choose to buy a car despite the financial burden they will incur may be trading accessibility shortfalls for income poverty. Additionally, there may be people who voluntarily do not own a car. The former may lead to underestimation of people who rely on public transport, and the latter may lead to overestimation of accessibility deficiencies (Martens, 2017). Martens (2017) argued that using income level is more reliable because income determines the transport options available to people. However, because only car ownership data was specific to different zones, it was used as a base for group determination together with general income categorization and modal split per zone.

Table 1: Constituency population data

Residential areas (main zones)	Constituencies	Number Household[1]	Number of households with cars [2]	Percentage of households with cars[3]
Greys Block Soweto Maroella Freedomland A small part Wanahenda.	John Pandeni	5050	1881	37.25
2-5 and 7-11 of the suburb Katutura[4]	Katutura Central	5603	1401	25.00
Extensions 1, 6, and 19 of the suburb Katutura	Katutura East	4229	1158	27.38
Khomasdal, Katutura, and Otjomuise.	Khomasdal	8843	3870	43.76
Eastern part of Hakahana	Moses ||Garoëb	13008	1475	11.34
Wanaheda Greenwell Matongo, Goreangab	Samora Machel	13021	2935	22.54
Eastern portion of the Hakahana	Tobias Hainyeko	12428	1681	13.53
Auasblick , Avis, Klein Windhoek Ludwigsdorf Luxury Hill, Olympia, Suiderhof	Windhoek East	8103	6916	85.35
Outside of Windhoek City	Windhoek Rural	5316	1218	22.91
Windhoek North Windhoek West, Dorado Park, Dorado Valley Khomasdal Proper, Hochland Park Pioneers Park, Academia, Cimbabecia, Rocky Crest	Windhoek West	13837	9906	71.59

1 Source:Data from Census 2011 (Namibia Statistics Agency, 2013)
2 Source:Data from Census 2011 (Namibia Statistics Agency, 2013) and the percentage calculated by author
3 The percentages of household with cars was applied to each TAZs based on the constituency their main zones falls in.
4 Some main zones fall in more than one constituency, and thus averages were used for those main zones.

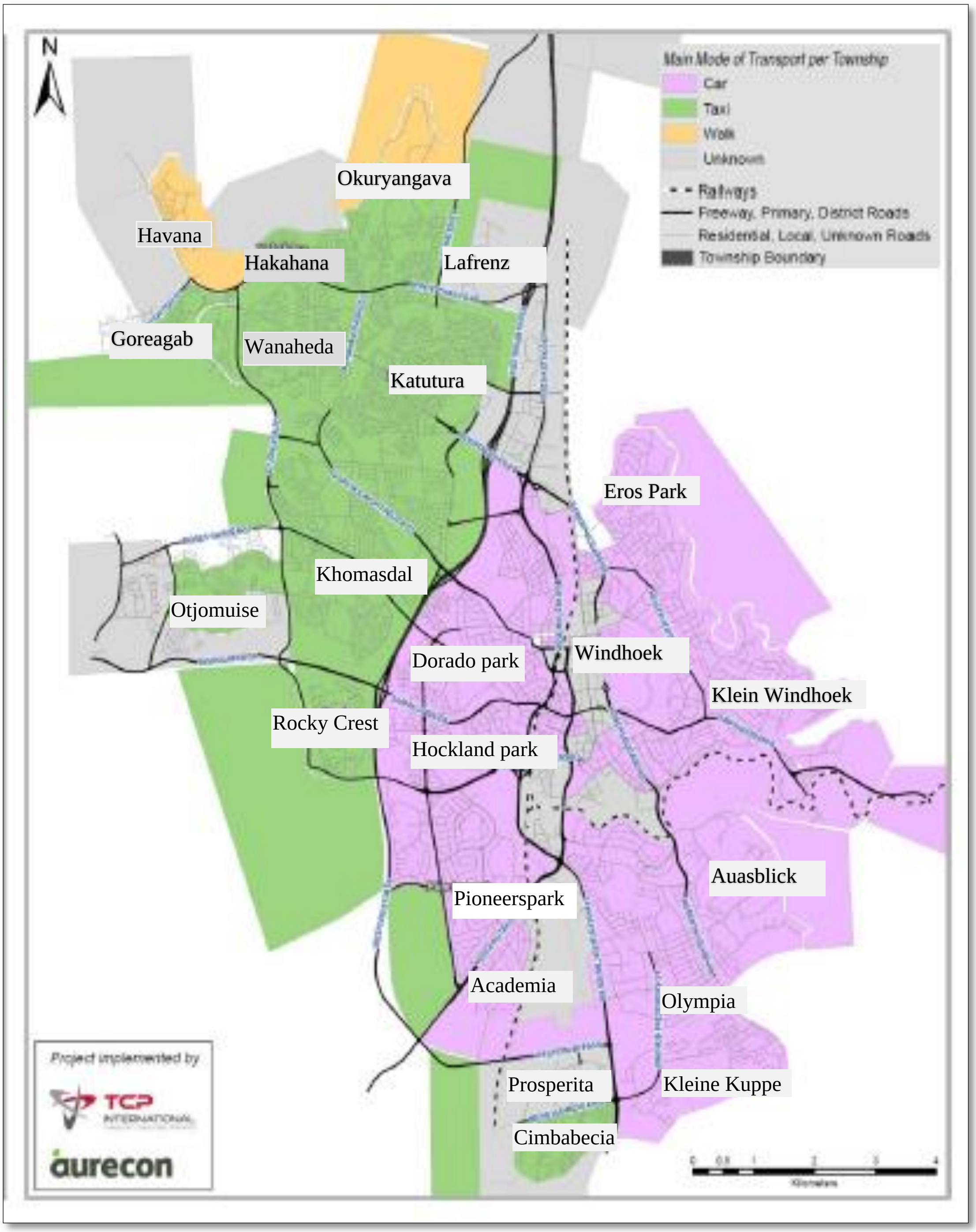

Figure 2: Main Mode per main zone (GIZ, 2013)

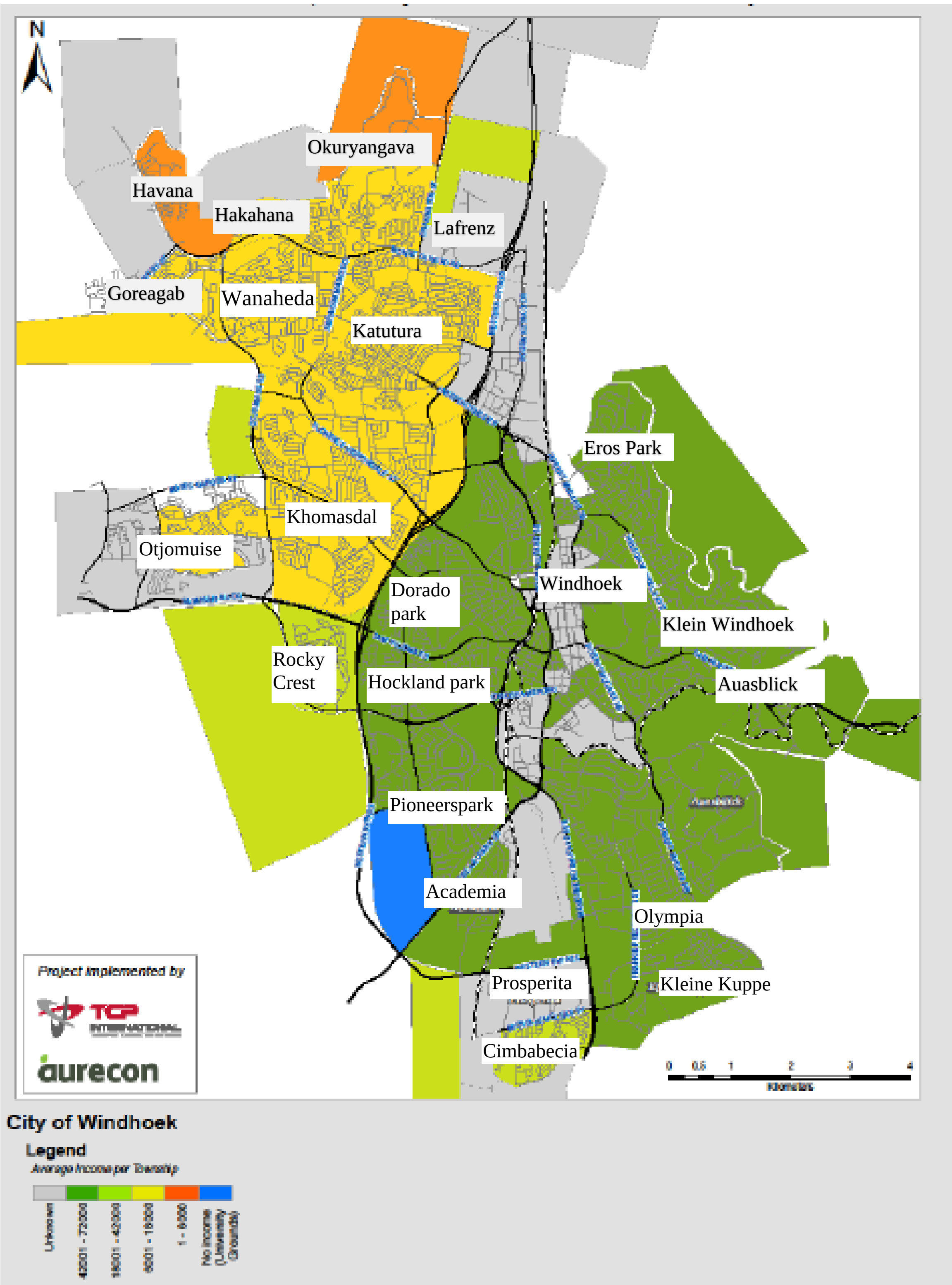

Figure 3: Average income per main zone (GIZ, 2013)

Figures 2 and 3 show the spatial representation of income groups and main modes for all neighbourhoods in Windhoek (2013). The high-income neighbourhoods' main mode of transportation was a car, middle-income neighbourhoods mainly used sedan taxis, and the low-income neighbourhood mainly walked. This shows a direct effect of income on the transport services or options available to people. High income gives people access to the most effective transport option, which in turn gives people access to more opportunities for financial growth. And the opposite is experienced by those that rely on an underserved public and non-motorized transport system. In this way, the gap between the have and the have nots is continuously widening.

3.5 MEASURING POTENTIAL MOBILITY AND ACCESSIBILITY

The second step of the transportation planning for justice principles entails the measurement of potential mobility and accessibility levels as experienced by the different population group determined in step one.

The potential mobility and accessibility levels were juxtaposed on set axes, shown in Figure 4 (Martens, 2017), with potential mobility on the horizontal axis and accessibility on the vertical axis. The axes are a continuum from high to low levels which created a coordinate system of four quadrants. When a population's potential mobility and accessibility levels were placed in the coordinate system, in quadrant one (bottom-left) it is identified as a group experiencing insufficient accessibility and mobility. And it is thus a group that is entitled to accessibility improvements first because its accessibility shortfalls are caused by insufficient transportation system to an extent. Groups that fall in the second quadrant experience insufficient mobility and sufficient accessibility, groups that fall in the third quadrant experience sufficient mobility and accessibility, while the groups which fall in the fourth quadrant experience insufficient accessibility and sufficient mobility.

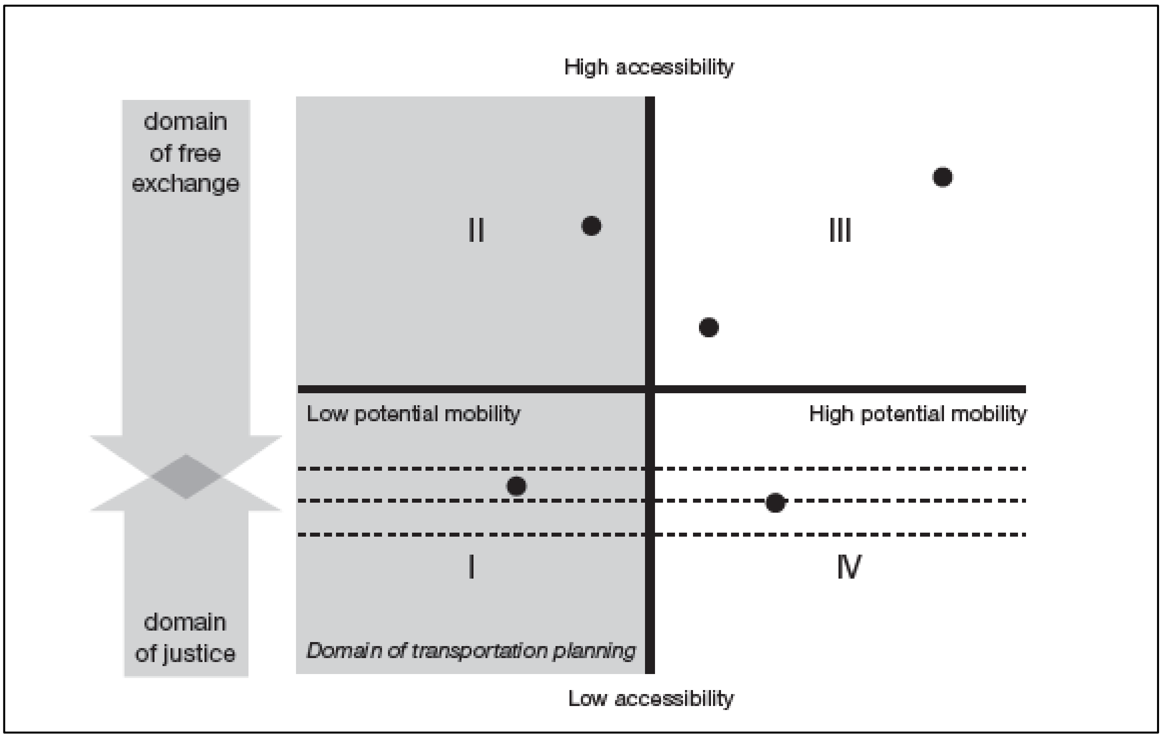

Figure 4: The coordinate system of potential mobility (horizontal axis) and accessibility (vertical axis)

The data points in Figure 4 represent population groups based on their calculated PMI and accessibility levels. The dashed lines indicate the accessibility sufficiency threshold and the solid lines represent the average potential mobility (horizontal) and average accessibility (vertical).

3.6 POTENTIAL MOBILITY

Potential mobility is the ability for one to compress space-time to participate in desired activities using the transportation system available (Kaufmann, 2016). It reveals the impact of the transport system on accessibility to select areas in the study (Martens, 2017). Martens (2017) developed the Potential Mobility Index (PMI) to measure potential mobility. The PMI formula is shown in Equation 1.

Equation 1: Potential mobility

$$PMI(i,m) = \frac{1}{n} * \sum_{j=1}^{n} \frac{d(i,j)}{t(i,j,m)} \forall i,m$$

PMI (i,m) = average aerial speed for mode m in zone i
d(i,j) = aerial distance between zone i and zone j
t(i,j,m) = travel time on the transport network between zone i and zone j by mode m
n: the number of zones considered.

(Martens, 2017)

With the use of the GIS-based aerial distance (Euclidean distance) and travel times during AM peak hour obtained from the PTV VISUM transport model, PMI-scores for 257 zones were calculated using Microsoft Excel for each mode of transport.

3.7 MEASURING ACCESSIBILITY

Accessibility levels experienced by different population groups are governed by multiple aspects which include land use, transport fare, distance and travel time, and how these relate to essential activities such as employment, education, health care, and shops. To gain a substantial understanding of accessibility levels experienced, it is ideal for measuring access to different activities to encompass people's interest in a range of opportunities. Martens (2017) recommended using various spatial scales and at different times of the day to capture the changes in accessibility levels. For instance, access to the shops may be better during off-peak hours due to less congestion on the roads. The lack of comprehensive data at different times of the day limited the study to morning peak hours.

The principles of justice for transportation planning aim to identify groups of people experiencing similar accessibility levels, this requires aggregated accessibility measures such as the inverse gravity-based accessibility measure, the exponential power gravity accessibility measure, and the cumulative accessibility measures respectively. In this study accessibility levels measured were limited to the accessibility to employment, during the morning peak hour (between 7 and 8 am), conducted at two travel time thresholds for cumulative accessibility measures (30 min and 15 min) and two gravity-based accessibility measures; inverse and exponential power gravity accessibility measures for all TAZs as shown in Equations 2 to 4 below. The average travel time in Windhoek during peak hour based on all modes is 23 min (9 min for cars, 48 min for buses and 13 min for taxis) and that informed the use of 30 min and 15 min time thresholds.

Equation 2: Inverse power gravity accessibility measure

$$A(i,m) = \sum W_j t_{i,j,m}^{-\alpha} \, \forall i,m$$

Equation 3: Exponential gravity accessibility measure

$$A(i,m) = \sum W_j e^{-\beta t_{i,j,m}} \, \forall i,m$$

Equation 4: Cumulative accessibility measure

$$A(i,m) = \sum W_j \left(1 - \frac{t_{i,j,m}}{T_{i,j,m}}\right) \forall i,m$$

$$T(i,j,m) \leq 30 \text{ (min)}$$

A(i) = zone accessibility level

α = Travel impedance parameter

t_{ijm} = travel time in min between zone i and j for mode m

β = region's travel impedance

W_j = Number of opportunities in destination zone

T_{ijm} = Travel time threshold

(Kwan, 1998)

The estimates for this study were selected as 0.8 for the inverse power function and 0.22 of the exponential function as proposed by Kwan (1998). In the study, Kwan (1998) outlined estimates that can be used in the absence of calibrated parameters.

3.8 SUFFICIENCY THRESHOLDS

The next step entailed the determination of sufficiency thresholds, which represent levels of accessibility and mobility below which a population group can be said to experience a difference in insufficient levels of accessibility and mobility from the groups above the threshold.

Martens (2017) presented two approaches for setting sufficiency thresholds; an approach basing sufficiency thresholds on the relationship between accessibility levels and activity participation, and a pragmatic approach in which sufficiency thresholds are defined as a percentage of the average accessibility level of the region/city. There is, however, no empirical understanding of the relationship between activity participation and accessibility levels, and thus the former approach could not be used, and hence this study embraced the pragmatic approach.

The average accessibility levels for car users was used as the average accessibility level for Windhoek. The average car accessibility was used as the base mode because it is the desired mode based on the history of transportation planning that has focused on enhancing mobility for car users over the decades. And as a result, cars today are assumed to have better mobility and in turn better accessibility.

A range of sufficiency thresholds of 10%, 30%, and 50% of the average car-based accessibility was chosen for this study. Based on the accessibility levels results from step three, the bus groups comparatively experienced the lowest levels of accessibility, which meant that these groups likely fall below the same accessibility thresholds. This has thus informed the use of only three sufficiency thresholds. Furthermore, the three sufficiency thresholds were chosen to avoid having one random result and to rigorously capture the difference in experienced accessibility levels (Martens, 2017).

In addition to investigating how far groups fall below average accessibility when deciding which population groups are warranted transportation investment based on the transportation system, planners can look at PMI-scores. The lower the PMI-score experienced by a population group; the more transportation investments are warranted for that population group. Because there was no democratic deliberation in this study, the average PMI of car-based population groups was used as the region's average PMI level; the sufficiency level for potential mobility. The car was the dominant mode in the region at the time. It was thus assumed that car users had the mobility level desired by most people.

3.9 IDENTIFYING GROUPS EXPERIENCING ACCESSIBILITY SHORTFALLS

After plotting the sufficiency thresholds, groups that fall under every threshold were identified for each threshold and each accessibility measure. This is done by identifying each group that falls under each threshold within quadrant one and calculating the percentage of groups under each threshold for each accessibility measure, and the percentage of population sizes affected as well, as seen in Table 3 in Section 4.4. These groups were identified from twelve assessments across four accessibility measures and three sufficiency thresholds.

3.10 ACCESSIBILITY FAIRNESS INDEX

It is not always possible to address accessibility shortfalls for all the population groups because of budget limitations. Hence it is necessary to identify which population groups experiencing shortfalls to prioritize. To establish fairness, the accessibility fairness index (AFI) was used to determine the prevalence and intensity of accessibility shortfalls amongst population groups. The index was adopted from a poverty measure index developed by Foster, Greer, and Thorbecke (1984 as cited in Martens 2017, p 160).

The aim of this step was thus to calculate the Accessibility Fairness Index (AFI) of the region that represents the fairness of the city's transportation system using Equation 5. This step also allows planners to identify population groups that contribute the most to this index and consequently may be more deserving of improvements for accessibility. The index takes into account the size of the population groups, the exact accessibility level experienced by the groups, and the share of groups experiencing accessibility shortfalls.

Equation 5: Accessibility Deficiency Index

$$AFI_i = \frac{1}{N} \sum_{i=1}^{q} p_i \left(\frac{z_a - y_i}{z_a} \right)^2 \forall i$$

AFI_i: zone contribution to the region's accessibility deficiency
N: represents the total population in region r
q: the number of groups in region r experiencing accessibility levels below the sufficiency threshold z_a
p_i: the size of the i -th group in number of persons
y_i: the accessibility level experienced by the i -th group below the sufficiency threshold z_a
(Martens, 2017)

The lower a group is below the accessibility threshold; the more accessibility shortfalls are experienced and the larger the weight it contributes to the overall measurement of accessibility. The index ranges between 0-1, the closer to one it is the more severe the population group is experiencing accessibility shortfalls. Although accessibility is multi-faceted, it does not mean AFI should not strongly aid decision-makers in the process of making a project priority list (Martens, 2017).

The AFIs were assessed for car-based, bus-based, taxi-based population groups separately for 50%, 30%, and 10% accessibility threshold for all the accessibility measures during peak hour. The percentage of each population groups' contribution to the AFI per assessment was calculated to show how much each population group contributed to the region's accessibility deficiency. The population group with the highest contribution should thus in principle be first considered for accessibility improvements.

3.11 RANKING GROUPS

The groups falling below the accessibility thresholds were ranked based on the average percentage contribution to the Accessibility Fairness Index under each accessibility threshold. The average percentage contribution was calculated as the total percentage contribution per group under each accessibility threshold for each accessibility measure divided by the total number of accessibility measures.

CHAPTER 4 RESULTS AND DISCUSSION

This chapter presents the desk study findings and the analysis of the results from the execution of transportation planning with principles of justice. The chapter starts with information on Windhoek and the city's transportation system, followed by the results and the interpretation of the results.

4.1 ABOUT THE STUDY AREA

Windhoek is the capital city of Namibia. It is geographically situated in the centre of Namibia. At the time of data collection, the combined population of the 257 transport analysis zones was 320 691 inhabitants, and the employment opportunities summed to 86 609 jobs. The North to North-West part of the city is densely populated with a high number of informal housing as it is occupied by the low-income group of the population. The Eastern sides of the city have low densities with single-family households occupied by high-income earners, while the west and the south have an average population density with middle-income earners.

Employment opportunities from public administration, to businesses, to retail and different institutions are mainly situated in the city centre, while the industrial jobs are situated in the North and South of the city. Many low paying jobs which include housekeeping, babysitting, and yard work are situated in the Southern and Eastern residential areas. People living in the Northern parts of the city must travel across the city through the city centre to access these jobs. This spatial mismatch is a result of the apartheid era, during which the land use, freeways, and railways tracks were used to separate people by race. The Western bypass (highway) separates the low-income household and high-income households. This is seen in Figure 3 (see Chapter 3).

The city centre is surrounded by residential areas all around, which goes to indicate a strong mono-centric urban form. This urban form is commonly found in cities in developing countries (Cervero, 2013). The mono-centric urban design and transport network of Windhoek does not support walking and cycling throughout the city. There are no pedestrianized zones and cycling lanes. Nevertheless, non-motorized transport is the most affordable to 87% of the population, and because of lack of safety and facilities for non-motorized transport, low-income households spent 24% of their disposable income on mobility needs (GIZ, 2013). In 2016 people who spend less than N$ 520.80 monthly were considered poor. At the time a taxi cost N$10 one way. N$ 520.80 was thus a rudimentary representation of living costs which has possibly skewed policymaking.

In addition to lack of infrastructure for transportation, Windhoek, and Namibia at large has had a housing crisis for years. As mentioned above, historically, Namibia was an apartheid state of South Africa's apartheid regime. During that time the apartheid government policies ensure that the urban centres are reserved for the white minorities, while the black labour force was housed at settlements with inferior services, limited space to expand, and limited land ownership rights (Remmert & Ndhlovu, 2018). Upon independence, Namibia was faced with deep racial segregation and inequalities. Today, property prices have escalated to a point where the middle-income population finds it challenging to purchase properties or land and resort to long term renting. The car has become the first asset of choice. The housing crisis coupled with the lack of transport options is thus exacerbating car use.

4.1.1 POPULATION INCOME

The SUTMP report categorized the population of Windhoek into six income groups as presented in Table 2 (GIZ, 2013), and Figure 3 (see Chapter 3) gives a spatial representation of where people in different income groups live. From Figure 3, one can see how the highway separates the high-income groups from the middle to low-income groups. Additionally, the income groups' spatial representation in Figure 3 shows that the city centre is surrounded by high-income groups. This often occurs because of the high value of land close to the CBD and thus affordable only to the high-income groups. The middle to low-income earners often trade-off proximity to jobs for low land costs. This also means they take on high transportation costs.

Table 2: Income grouping

	Income (N$/month)
Unknown	
1	42 001 - 72 000
2	18 001 - 42 000
3	6 001 - 18 000
4	1 - 6 000
No income	0

4.1.2 TRANSPORT SYSTEM

From 2013, Windhoek has had an extensive transport network of approximately 812 km with sealed roads in the urban areas, and gravel roads in the informal settlements. Outside residential areas the roads are one directionally single to double lanes with 8-13 m width which deliver comfortable speeds to motor vehicles, several of which deliver fast access to the suburbs. The speed limit for the entire network is 60 km/h except for the residential areas were the speed limit in some areas is reduced to 40 km/h and the western bypass with a speed limit between 80-120 km/h (GIZ, 2013).

The network has had no reserved lanes or shared right of way for bus operations. At the time, in 2013, there were only 160 bus stops in the city, 85% of which had no timetables and bus stop signs. Most of the population has had access to the stops within 400-700m walking distance. The bus operation started in the north-western area to the city centre and south-eastern areas and vice-visa in the afternoon from Monday to Friday. There were thus no bus services during the day and on weekends. The bus network also did not make provision for interchanges anywhere; as a result, each of the 79 buses travelled approximately 49 km/day including distance from and to the depot. This was extremely below international bus travel of approximately 6700 km/day per bus (GIZ, 2013). Today, bus operations in Windhoek remain the same.

Because of the above reasons, the commonly used public transportation is the taxi service. In cities like Cape Town, the public taxis are the minibus taxis; however, in Windhoek, taxis are sedan taxis. They operate at any given time of day and are owned by different private individuals. A taxi can only cater to 4 passengers per trip; hence, to meet the demand, there are many taxis. Taxis operating like private cars is not sustainable because of high fuel consumption per person, high pollution per person, high accident rates caused by taxis operating like private cars commonly stopping and picking up people at random areas, and an increase in traffic. It is also not safe for passengers as it is hard to regulate who is driving a particular taxi at any given time.

In addressing the relationship between the transport network and land use for the city, the GIZ team proposed robust new transport policies, a BRT, a rail public transport system, and improving non-motorized infrastructure over time. By changing the transportation system, the Sustainable Urban Transportation Master Plan aims to influence land use, because of the connection between land use and transportation that is inevitable. Although this may increase mobility, change in the overall individual accessibility can only be measured using multiple aspects. However, those experiencing subpar accessibility levels due to high travel times can get improved accessibility levels.

4.2 DATA AND POPULATION GROUPS

The first step in examining the fairness of a transportation system using transportation planning based on principles of justice aims to categorize the population in the region of study into groups according to the level of accessibility they might be experiencing based on factors such as residential location and income. The categorization in principle can only be based on data that is publicly available to ensure that no individual freedoms are infringed upon (Rawl, 2009). The public information available for Windhoek was limited to the zonal level of income, residential location, level of car ownership per household, and the zonal modal split. This eliminated the use of accessibility measures; the time-space measures which account for differences between persons could thus not be used in this study. The study on Windhoek was confined to an aggregated level of accessibility analysis which, according to Martens (2017) is satisfactory, because transportation planning with principles of justice aims to identify population groups that are experiencing accessibility shortfalls and not focused on individuals' accessibility shortfalls.

Windhoek is a developing city with 87% of the population seen as low-income earners (GIZ, 2013). The city's bus system, at the time of the research for the SUTMP report and data collection, was unable to meet the city's demand. It was thus practically incorrect to assume everyone used the bus, hence bus usage was limited to zones of middle to low-income residential locations. Although the bus routes go all over the city, one cannot ignore that some people may not at all use the bus especially the high-income households, because there were not enough buses in the city and possibly other underserved passenger needs such as security, safety, convenience and speed (Hagen & Sauren, 2014). The data from the PTV Visum transport model developed by GIZ was used in ArcGIS Pro to create spatial maps shown in Figure 5 below, representing the spatial distribution of the population of Windhoek.

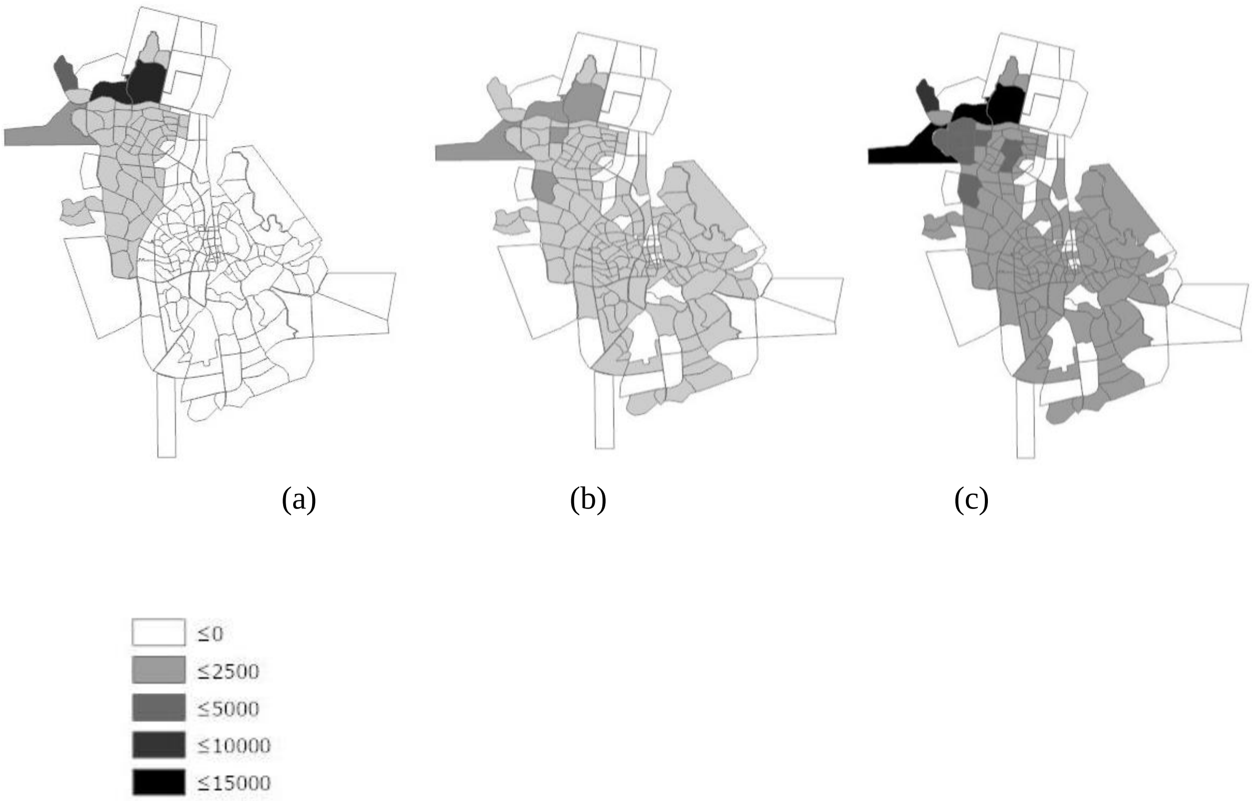

Figure 5: Number of people for each population group per zone in Windhoek for (a) bus-based population groups, (b) car-based population groups, and (c) taxi-based population groups.

The graphical representations in Figure 5 show the population distribution per group over the zones. In 2011, The north-western parts of the city were densely populated and occupied by low-middle income households. People located in that area are at the fringe of the city, and they are more prone to accessibility and mobility shortfalls because they have a long distance to overcome to access opportunities mainly located in the CBD. The spatial maps show that these zones are mainly occupied by bus and taxi-based users. However, unlike the taxi-based groups, all bus-based population groups are located in those north-western zones. This shows that the majority of people living at the fringe of the city are not making a trade-off between land costs in the city and high travel costs. They simply cannot afford both high land costs close to the CBD and vehicles.

4.3 POTENTIAL MOBILITY AND ACCESSIBILITY

The accessibility levels for all population groups from exponential, inverse, and cumulative accessibility measures and potential mobility indexes are graphically shown in Figures 6 to 9 below. The graphs additionally show the four quadrants created by the average car-based accessibility and average car-based potential mobility axes, as well as the accessibility sufficiency threshold lines for 50%, 30%, and 10% accessibility sufficiency thresholds.

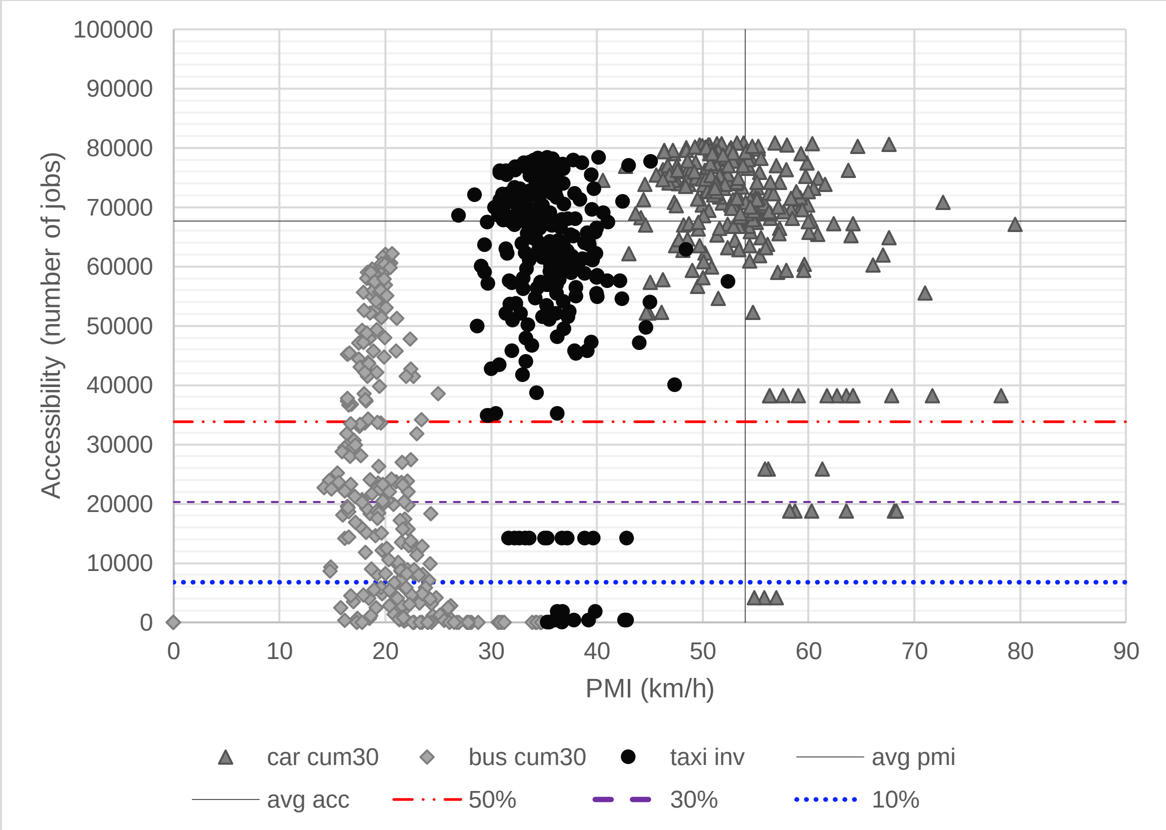

Figure 6: Representation of potential mobility and accessibility to employment as experienced by different population groups at peak hour for a 30 min threshold cumulative accessibility measure.

Figure 6 shows that bus users experience 20 km/h average potential mobility which is only 38% of average potential mobility experienced by car users. And taxi users experience 38km/h on average which is 66% of average potential mobility experienced by car users.

The average accessibility level experienced by bus-based population groups is 35% of the average accessibility levels experienced by the car-based population groups, and taxi-based population groups experience 87% of the average accessibility levels experienced by car-based population groups for a 30 min threshold cumulative accessibility measure during peak hour. The percentages translate to 23 672 jobs for bus-based population groups, 59 084 jobs for taxi-based population groups to 67 666 jobs for car users during peak hours within a 30 min threshold. Based on the average PMI for each mode, it is evident that the transport system is not serving bus users well and transportation investments should first focus on improving bus users' mobility.

There are 771 (257*3) dots in the graph representing population groups. During morning peak hours, those that are car-based and those that travel by taxi have a roughly comparable situation because taxis in Windhoek are mainly sedans. However, the taxi-based groups fall between the first and second quadrant, and this goes to show that even though the taxis are sedans, their potential mobility does not equate to that of private sedan cars. This can be attributed to the unconventional operations of the sedan taxi in Windhoek. They stop anywhere to fill the seats and that potentially increases travel time for taxis. The bus-based population groups experience the lowest potential mobility and accessibility levels. All the 257 bus-based population groups fall within the first quadrant for the 30 min threshold cumulative accessibility measure during morning peak hour, which means the poor relationship between transportation and land use has resulted in below-average potential mobility and accessibility levels for them.

Different from the other groups and as expected, the car-based population groups fall within all the four quadrants. 173 of 257 car-based population groups experience above-average accessibility levels, and 153 population groups fall above-average potential mobility (quadrant three and four). 33 car-based population groups fall in quadrant one. It is important to note that the average PMI and average accessibility level for car-based groups make up the average PMI and average accessibility sufficiency levels axis. Thus, some car-based population groups fall below average PMI and average accessibility levels. This can be different if different levels of sufficient accessibility and potential mobility are determined perhaps though a democratic deliberation. And in that democratic deliberation sufficiency levels are likely to be higher, which would broaden the investigation into causes and solutions, consequently requiring more resources to carry out transportation planning with principles of justice (Martens, 2017).

When the threshold travel time was reduced to 15 min, accessibility levels dropped as expected, as shown in Figure 7 below. All the taxi-based population groups fall into the first quadrant. Again, this shows how travel time affects two similar vehicles because of the way they are operated. The patterns for potential mobility and accessibility levels shown in Figures 6 and 7 give a substantial insight on the disparities in accessibility levels experienced by public transport users in comparison to car users, and disparities within the public transport users' category itself. Similar patterns of potential mobility and accessibility levels are observed within the results of inverse and exponential gravity accessibility measures in Figures 8 and 9 below. As expected, the results of the different accessibility measures are not the same.

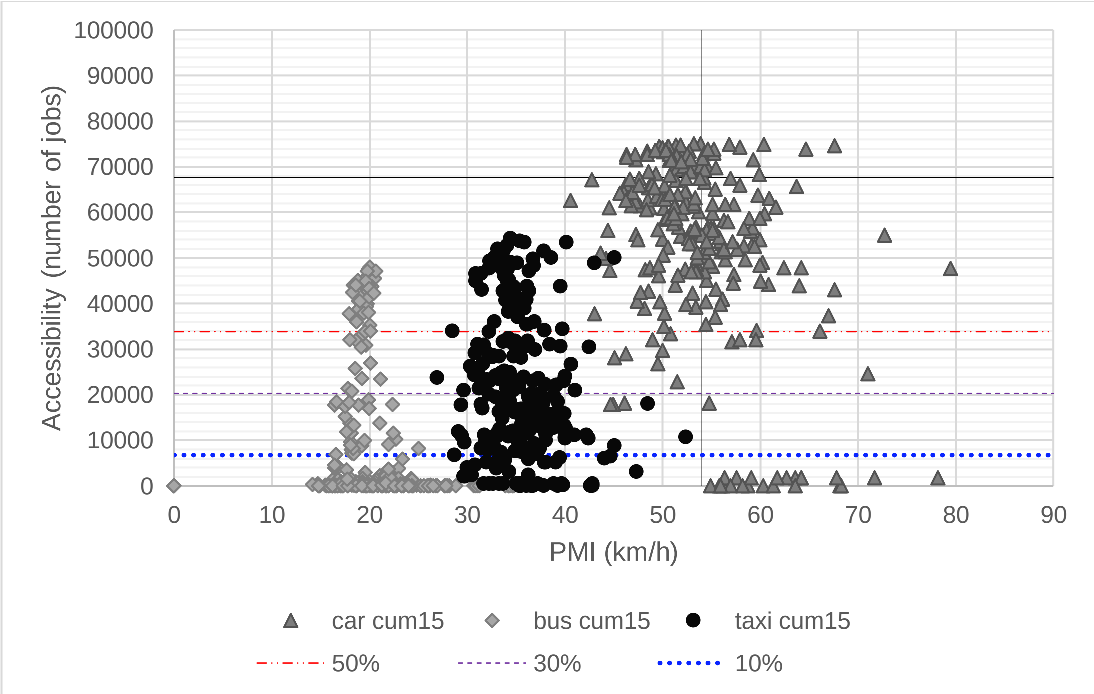

Figure 7: Representation of potential mobility and accessibility to employment for 15 min threshold travel time for the cumulative accessibility during peak hour.

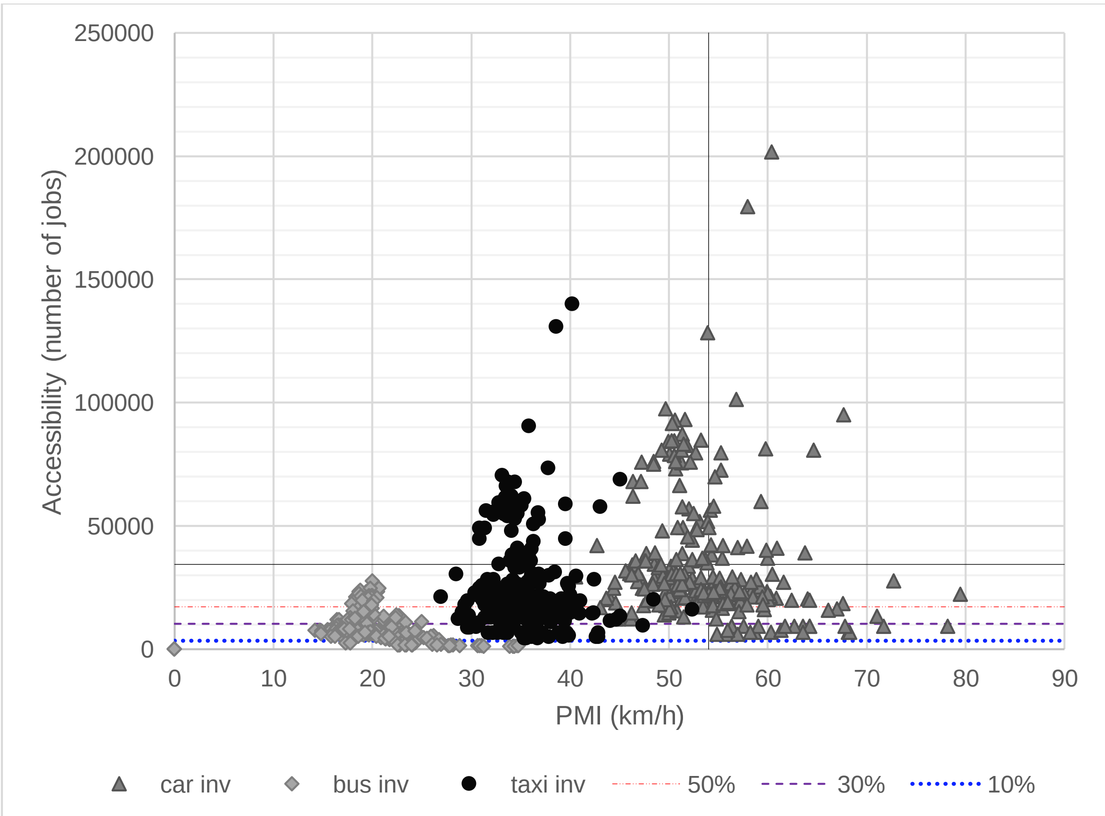

Figure 8: Representation of potential mobility and accessibility to employment as experienced by different population groups at peak hour for inverse power gravity accessibility measure.

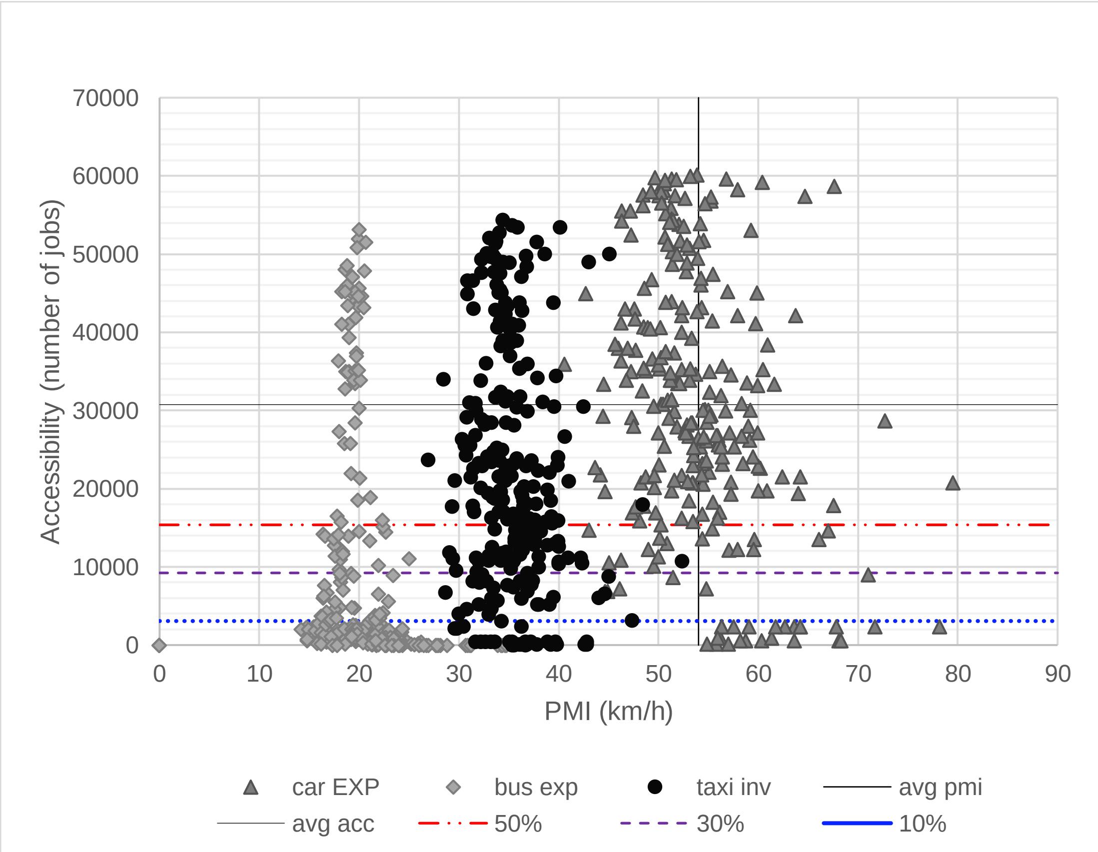

Figure 9: Representation of potential mobility and accessibility to employment as experienced by different population groups at peak hours for an exponential power gravity accessibility measure.

The most affected people are low-income people living at the peripherals of the city. Although there is no depiction of the off-peak accessibility condition due to lack of data, in 2012 Windhoek did not have scheduled buses running during the off-peak time and thus the accessibility for bused based population groups can only be assumed to be worse off during off-peak (4:30 to 5:30 pm) and weekends. On the other hand, the taxi-based population groups can be assumed to be better off as there is less traffic on the roads during off-peak hours, which can result in shorter travel time.

4.4 POPULATION GROUPS 'ENTITLED' TO ACCESSIBILITY IMPROVEMENTS

Although several population groups fall below the average accessibility, they are all not experiencing equal accessibility shortfalls. With the use of accessibility thresholds, 50 %, 30% 10% of the average car accessibility level, the severity of accessibility shortfalls experienced by the groups was assessed by determining where they fall within the thresholds and the number of people affected. The results are shown in Table 3 and Figures 10 to 13.

Table 3: Groups entitled to improvements

	Car				**Bus**				**Taxi**			
Thresh Hold (%)	Inv	Exp	Cum30	Cum15	Inv	Exp	Cum30	Cum15	Inv	Exp	Cum30	Cum15
	Number of groups below accessibility threshold											
50	13	12	0	4	219	207	177	214	107	101	24	175
30	0	4	0	0	185	188	133	201	32	58	24	103
10	0	0	0	0	31	156	78	180	0	28	12	35
	Percentage of groups below accessibility threshold (%)											
50	5.1	4.7	0.0	1.6	85.2	80.5	68.9	83.3	41.6	39.3	9.3	68.1
30	0.0	1.6	0.0	0.0	72.0	73.2	51.8	78.2	12.5	22.6	9.3	40.1
10	0.0	0.0	0.0	0.0	12.1	60.7	30.4	70.0	0.0	10.9	4.7	13.6
	Number of people below accessibility threshold											
50	5928	3583	0	2168	58582	58582	58582	58582	109572	108424	0	137113
30	0	2168	0	0	58582	58582	57055	58582	8139	52200	0	111545
10	0	0	0	0	0	58143	45262	58582	0	7635	0	8591
	Percentage of people below accessibility threshold (%)											
50	1.8	1.1	0.0	0.7	18.3	18.3	18.3	18.3	34.2	33.8	0.0	42.8
30	0.0	0.7	0.0	0.0	18.3	18.3	17.8	18.3	2.5	16.3	0.0	34.8
10	0.0	0.0	0.0	0.0	0.0	18.1	14.1	18.3	0.0	2.4	0.0	2.7

Table 3 shows that bus-based population groups have the highest number of groups below each threshold. Observation below each threshold shows that the percentage of groups is higher than the percentage of people experiencing below-average mobility and accessibility. This is due to some groups not having residents at the time of data collection and the unequal distribution of people over space. Low-income areas at the northern outskirts of the city are densely populated while middle to high-income areas are sparsely populated (see Figure 2 in Appendix A).

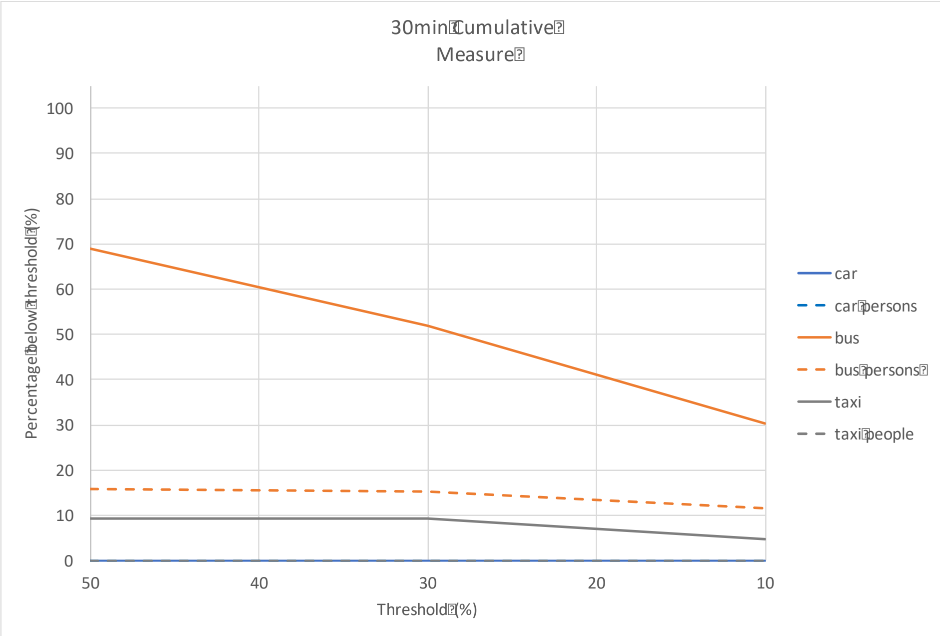

Figure 10: The percentage of total population groups falling under each threshold for the 30 min threshold cumulative accessibility measure and the percentage of people affected

Figure 10 above shows the percentage of groups and people in the groups experiencing shortfalls in the first quadrant for each accessibility threshold for the 30 min cumulative accessibility measure. The bus-based population groups have the highest percentage of people experiencing accessibility shortfalls below all thresholds. The percentage of the population sizes of bus-based population groups experiencing shortfalls is lower than the percentages of groups. This shows that even when the number of groups is high, the number of people affected can be significantly low because of the uneven spatial distribution of people.

With each decrease in accessibility sufficiency threshold, there is a decrease in the number of groups and number of people. Under the 50% threshold for the 30min cumulative measure, there are 0 car-based groups (0%), 24 taxi groups (9%), and 177 bus-based groups (69%). And under the 10% accessibility sufficiency threshold there are 78 out of 257 bus-based population groups which translates to 11.6% of the groups representing 45 262 people of the 320 683 people in Windhoek. When it comes to taxi-based population groups, less than 5% of the groups fall under the 10% accessibility sufficiency threshold for the 30 min cumulative accessibility measure and represent zero people because these groups have no residents. And for the car-based population groups, no groups are falling below the 10% accessibility sufficiency threshold.

A similar pattern for bus-based accessibility is shown for the inverse power accessibility measure in Figure 11. Looking at the taxi-based population groups on the inverse power measure graph (Figure 11), there are more taxi users at 50% threshold than bus-based users at the 50% threshold even though bus-based groups have a higher percentage of groups at the 50% threshold. This pattern is similarly repeated for taxi-based and bus-based groups in the exponential power gravity measure graph and 15 min cumulative measure graph shown in Figure 11 and 12. In addition, different to the 30 min cumulative measure results for car-based groups, there are 3 583 people (1.1%) and 5 928 (1.8%)

people below 50% sufficiency threshold for the inverse and exponential power gravity measures respectively from a total of 13 and 12 groups.

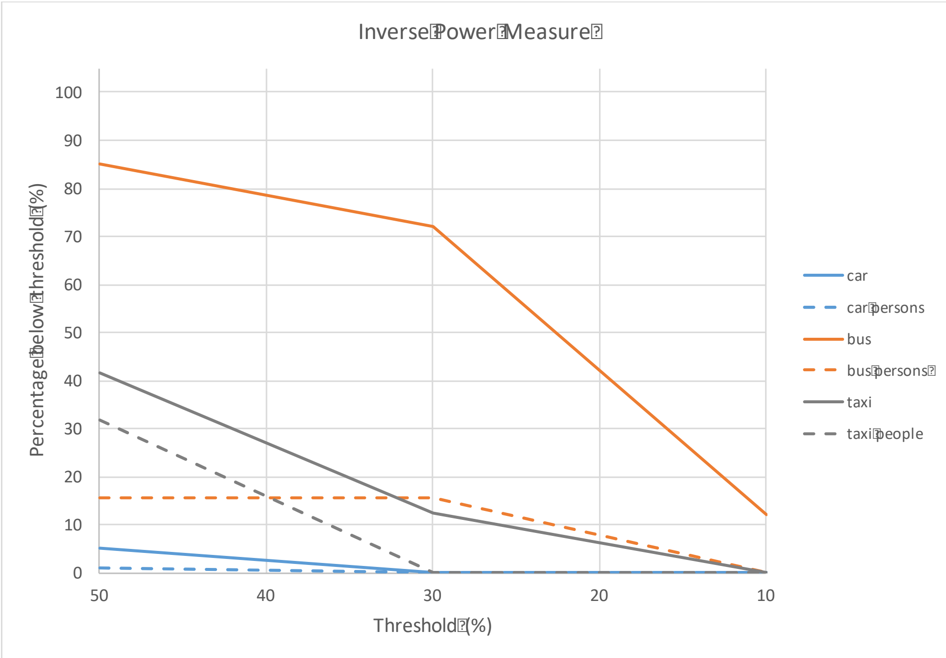

Figure 11: The percentage of total population groups which fall under each accessibility threshold for the inverse power accessibility measure and the percentage of people affected

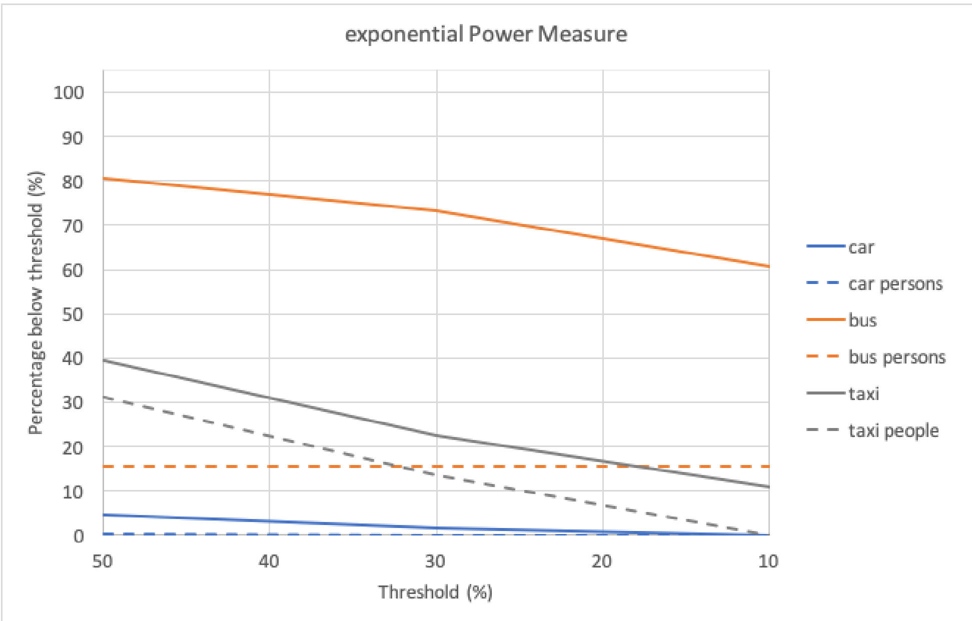

Figure 12: The percentage of total population groups that fall under each accessibility threshold for the exponential power gravity accessibility measure and the percentage of people affected.

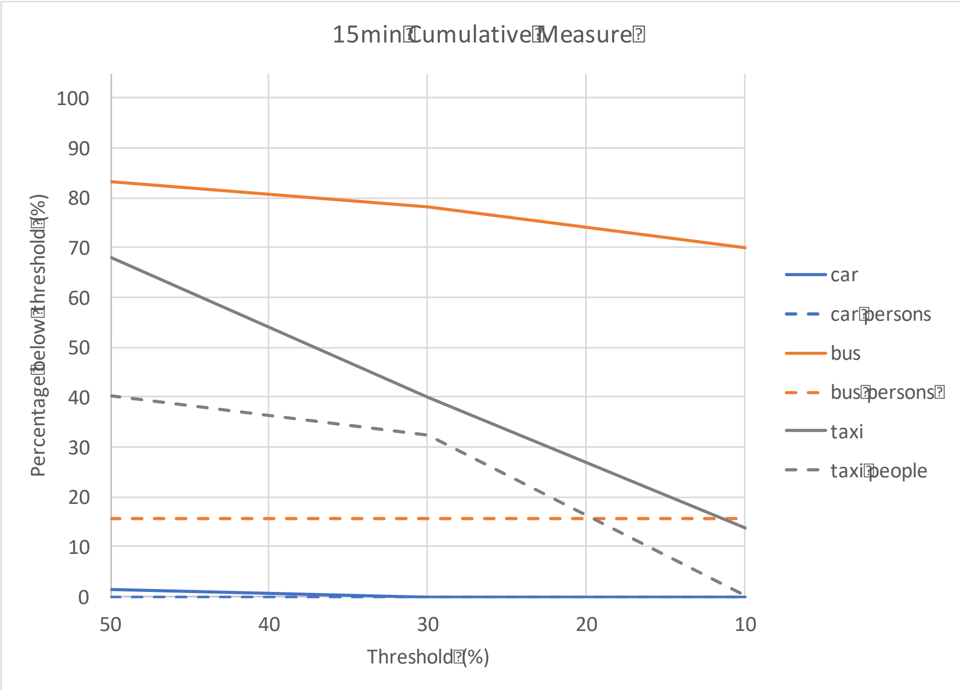

Figure 13: The percentage of total population groups that fall under each accessibility threshold for the 15min cumulative accessibility measure and the percentage of people affected.

The 15min cumulative measure results in Figure 13 show that at 50% sufficiency threshold the number of taxi-based groups increased from 24 in the 30 min cumulative accessibility measure to 175 groups which represent 137 113 people under the 15min accessibility threshold. This shows how time affects the taxi operation in Windhoek during peak hours. There is, however, no change for bus-based groups from 30min to 15min cumulative measure analysis.

4.5 CONTRIBUTION TO THE ACCESSIBILITY SUFFICIENCY

The previous steps and results have shown that the public transport-based population groups experience lower levels of accessibility, especially the bus-based population groups. Following that, an analysis of groups' contribution to accessibility deficiency in Windhoek at the time was done by determination of the Accessibility Fairness Index (AFI). The AFI considers accessibility levels and the number of people with accessibility levels below each sufficiency threshold to show the intensity of the accessibility shortfalls. This section presents the share of population groups' contribution to overall accessibility deficiency based on each sufficiency threshold during peak hour per accessibility measure.

4.5.1 BUS-BASED AFI

Figure 14 shows the share of bus-based population groups' contribution to overall accessibility deficiency at 50% 30% and 10% accessibility thresholds for the exponential power gravity accessibility measure. The numbers of groups below each accessibility threshold for bus-based population groups are 50%: n=207, 30%: n=188, 10%: n=157 and approximately 65% of the groups under each accessibility threshold contribute nothing to the accessibility deficiency because there are no residents allocated to that bus-based group or there were no residents during the 2011 census. Approximately 25% of the groups that are contributing to accessibility deficiency for each threshold contribute less than 1% across all thresholds. And approximately 5% of the groups contribute 1-5% to accessibility deficiency for each accessibility threshold.

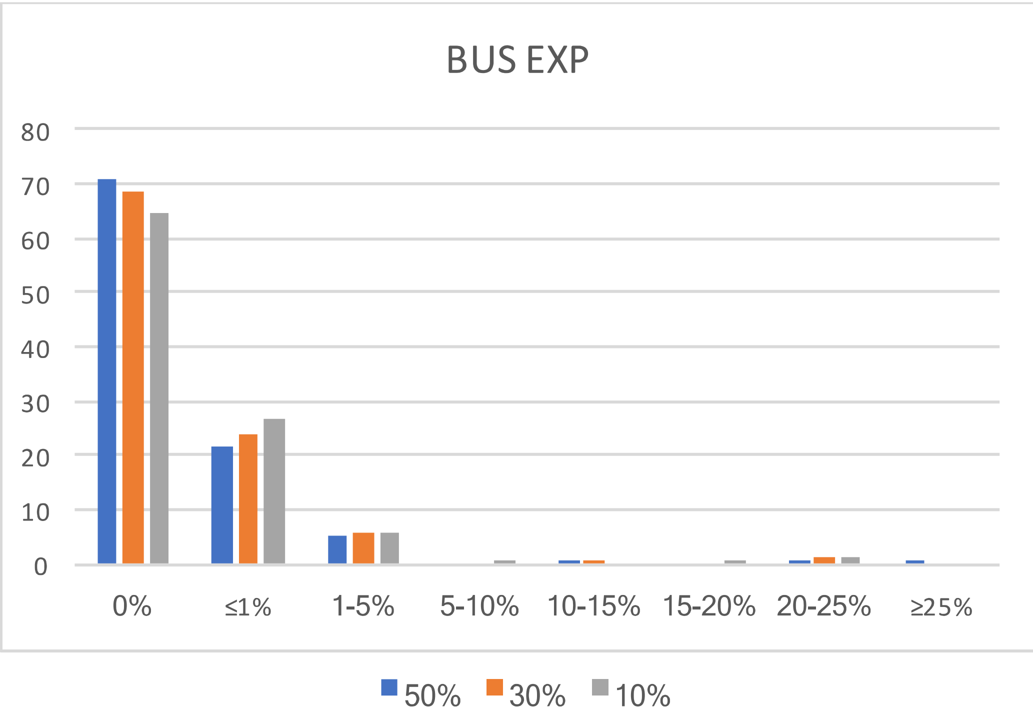

Figure 14: Share of bus-based population groups' contribution to overall accessibility deficiency under each accessibility thresholds for the exponential power during peak hour.

50% 30% 10%

Figure 14

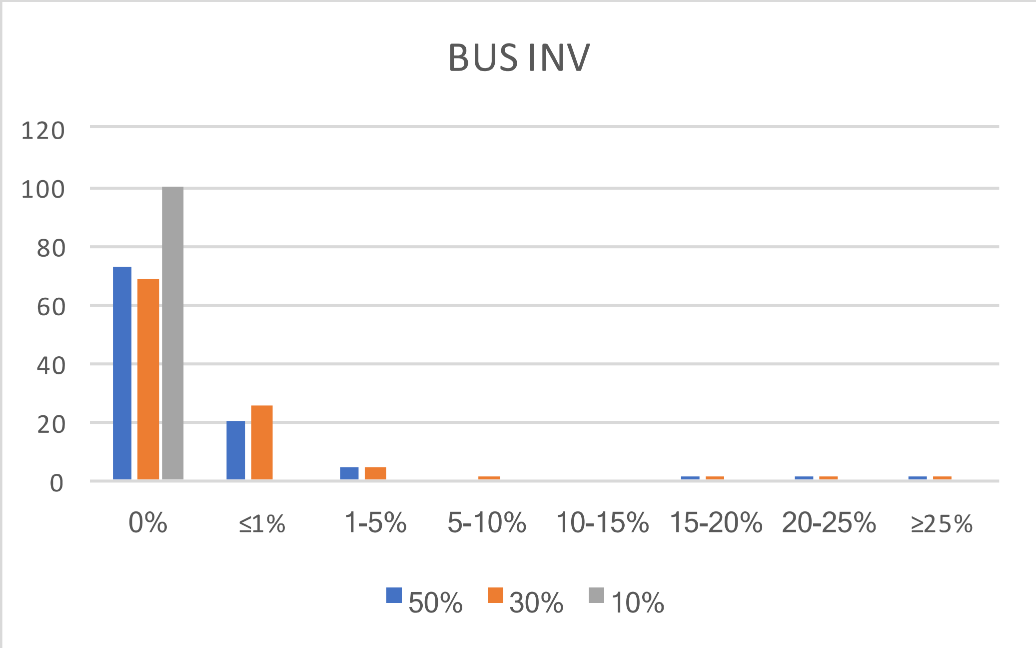

Figure 15: Share of bus-based population groups' contribution to overall accessibility deficiency under each accessibility threshold for the inverse power during peak hour.

The accessibility deficiency contribution for the bus-based population groups analysed using the inverse power gravity measure is shown in Figure 15. With this accessibility measure, there are no bus-based population groups that fall under the 10% accessibility threshold which contributes to accessibility deficiency because these groups had no population using buses and thus it has resulted in zero contribution to the city's accessibility deficiency.

Under the 50% accessibility threshold, 20% of the groups contribute less than 1%. Moving from the 50% accessibility threshold to 30% accessibility threshold there is a visible increase in contribution to accessibility deficiency at each percentage because when the number of groups decreases the contribution of groups goes up (Martens, 2017). For instance, 45 groups under the 50% threshold make up 22% of groups, while 45 groups under the 30% accessibility threshold make up 24% of the groups under that threshold. This pattern is visible in results for the 30 min and 15 min cumulative accessibility measure in Figures 16 and 17 as well.

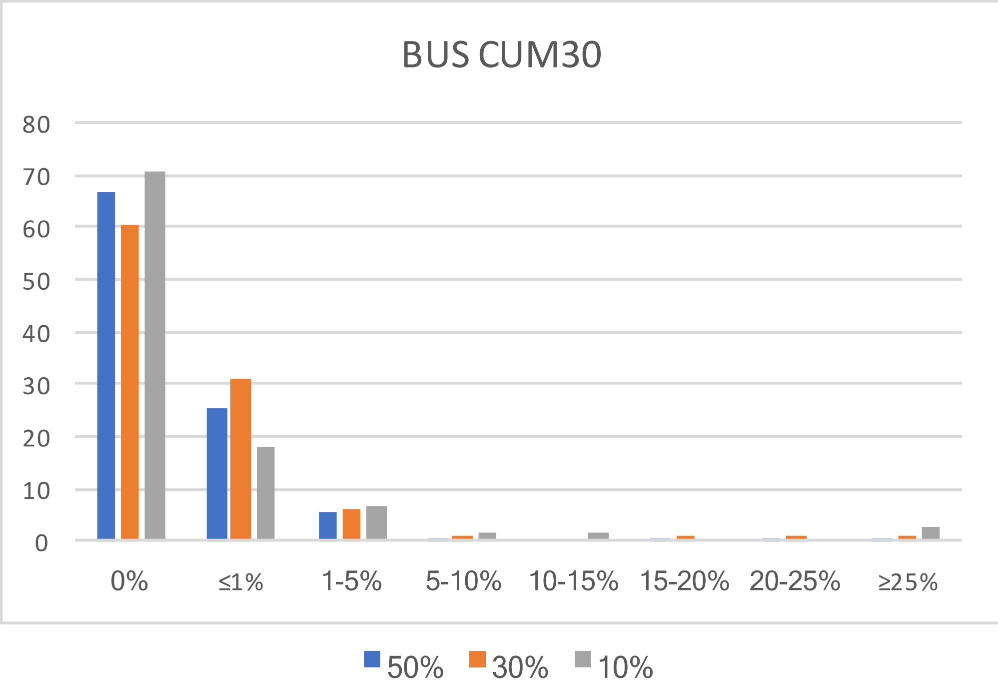

Figure 16: the share of bus-based population groups' contribution to overall accessibility deficiency under each accessibility threshold for the 30 min cumulative accessibility measure during peak hour.

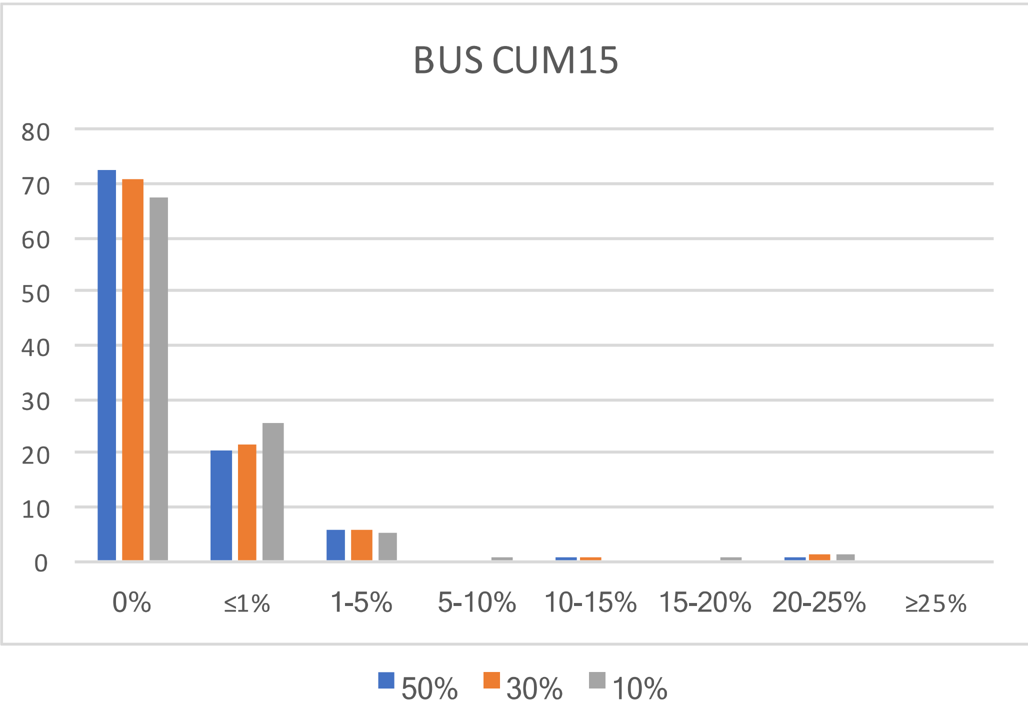

Figure 17: the share of bus-based population groups contribution to overall accessibility deficiency under each accessibility threshold for the 15 min cumulative accessibility measure during peak hour

4.5.2 CAR-BASED AFI

Figure 18 below represents the share of car-based population groups' contribution to overall accessibility deficiency based on 50%, 30%, 10% of the average car-based accessibility thresholds for the inverse power accessibility measure during peak hour. Observed in Figure 18, no groups are falling below 30% and 10% accessibility thresholds contribute to the city's accessibility deficiency. This is similar to the results from the 30min and 15 min cumulative accessibility measures results shown in Figures 19 and 20. And for the exponential power measure shown in Figure 21, one group under the 30% accessibility threshold contributes more than 25% and represents 25% of the groups. Because only four car-based groups are falling below the 30% accessibility threshold for the exponential measure, one group's contribution weighs more than if there were many groups.

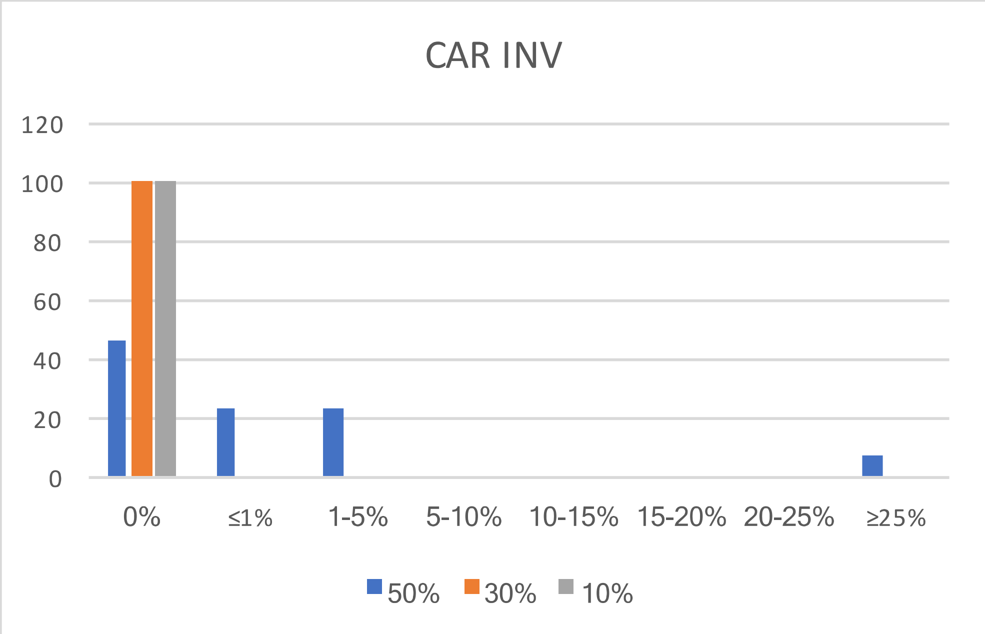

Figure 18: the share of car-based population groups contribution to overall accessibility deficiency under each accessibility threshold for the exponential inverse gravity accessibility measure during peak hour.

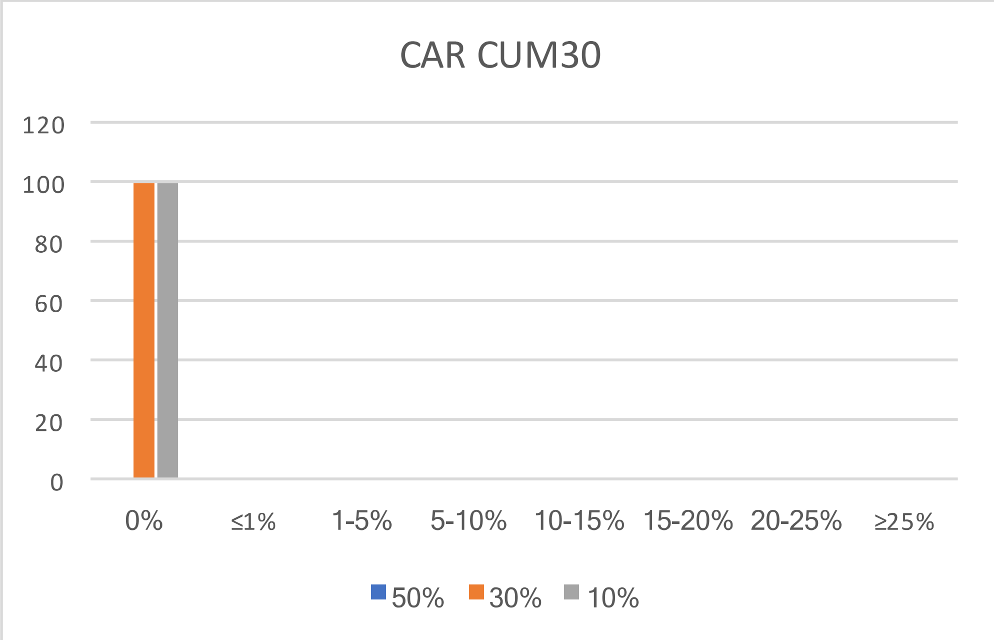

Figure 19: the share of car-based population groups contribution to overall accessibility deficiency under each accessibility threshold for the 30 min cumulative accessibility measure during peak hour.

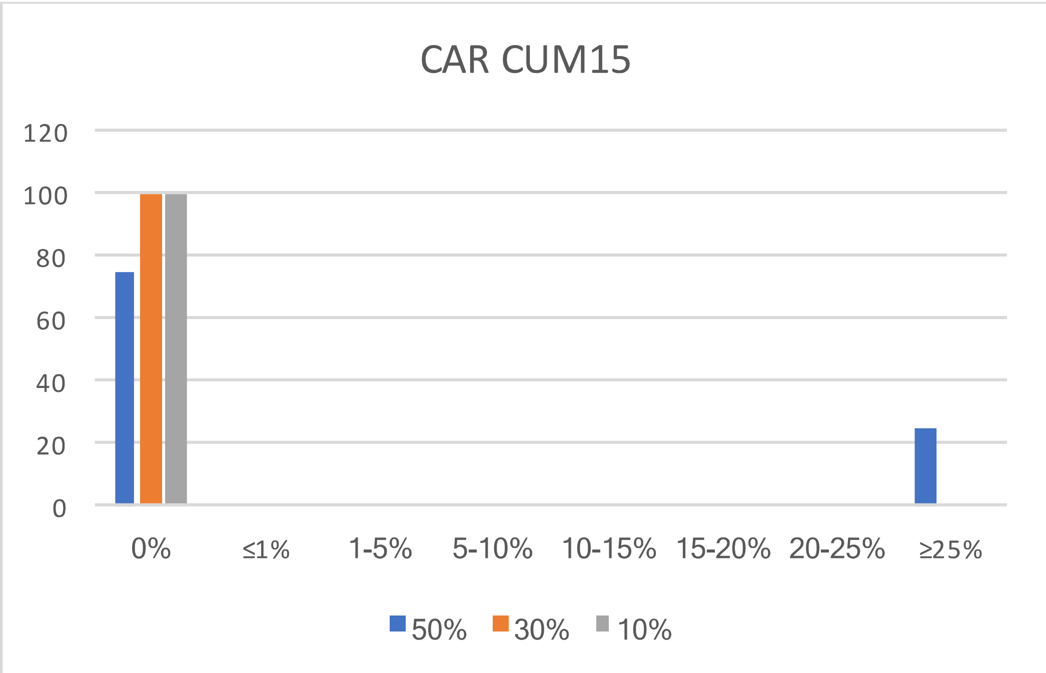

Figure 20: the share of car-based population groups contribution to overall accessibility deficiency under each accessibility threshold for the 15 min cumulative accessibility measure during peak hour.

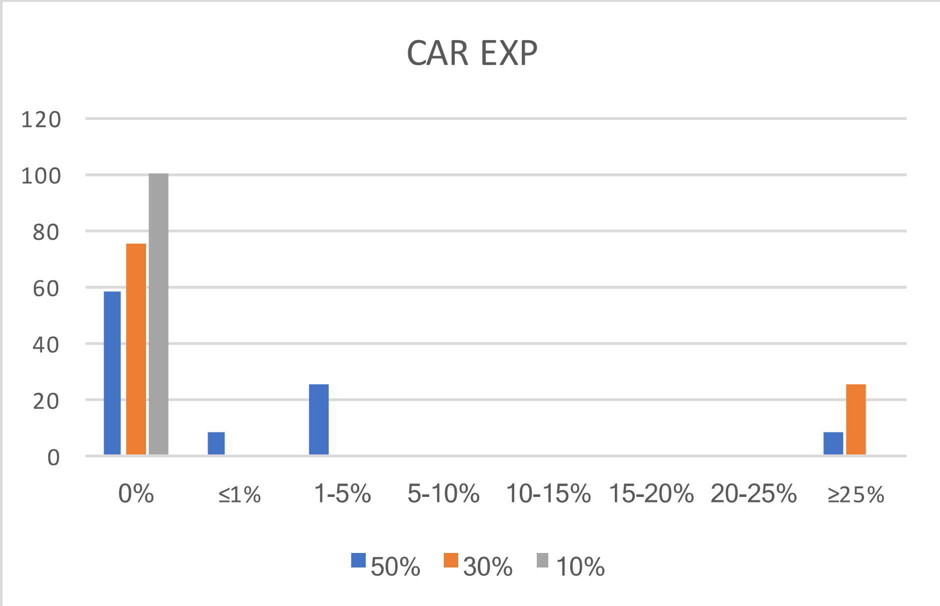

Figure 21: Share of car-based population groups contribution to overall accessibility deficiency under each accessibility threshold for the exponential power gravity accessibility measure during peak hour.

4.5.3 TAXI AFI

For the taxi-based groups, the numbers of groups experiencing accessibility shortfalls per accessibility threshold based on the exponential power accessibility measure are 50%: n=101, 30%:n=58 10%:n=28. As seen in Figure 22, most of the groups across all the sufficiency thresholds contribute nothing to accessibility deficiency.

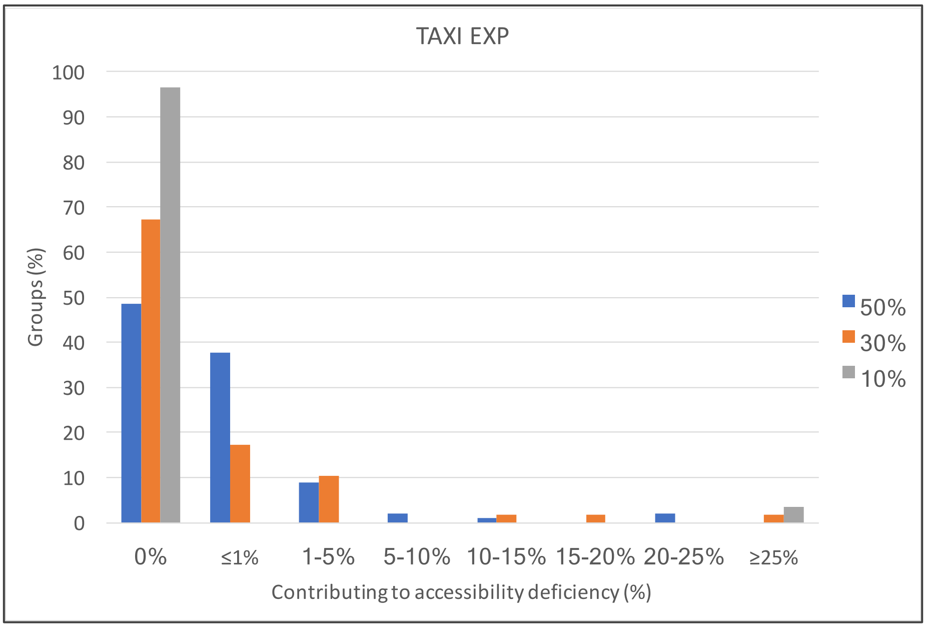

Figure 22: Share of taxi-based population groups contribution to overall accessibility deficiency under each accessibility threshold for the exponential power accessibility measure during peak hour.

Under the 30 min cumulative measure, there are no taxi-based population groups under any of the accessibility threshold contributing to accessibility deficiency. However, when the travel time threshold is lowered to 15 min for the cumulative measure, 88 groups of the 175 group falling below the 50% accessibility threshold, contribute 50% to accessibility deficiency. 103 groups fall below 30%, and 35 groups fall below the 10% accessibility threshold, and as the contribution percentage increases, the percentage of groups contributing decreases for all accessibility thresholds as seen in Figure 23 below.

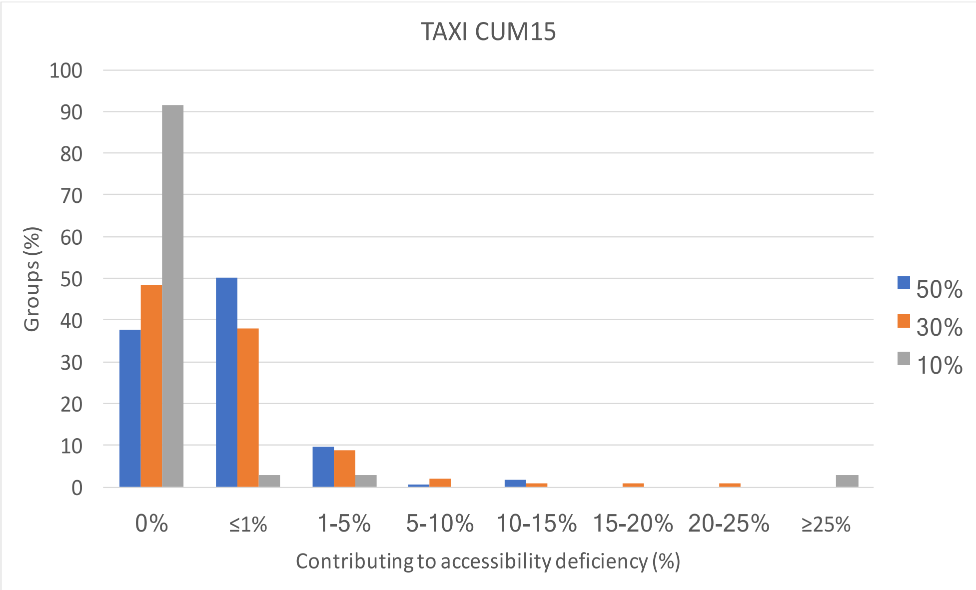

Figure 23: the share of taxi-based population groups contribution to overall accessibility deficiency under each accessibility threshold for the 15 min cumulative accessibility measure during peak hour.

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Figure 24 shows the share for taxi-based groups to overall accessibility deficiency results from the inverse power measure during peak hours, and no groups are contributing under the 10% sufficiency threshold as there are no taxi groups experiencing accessibility levels below the 10% sufficiency threshold. Most groups contribute between 0-1% under the 50% sufficiency threshold.

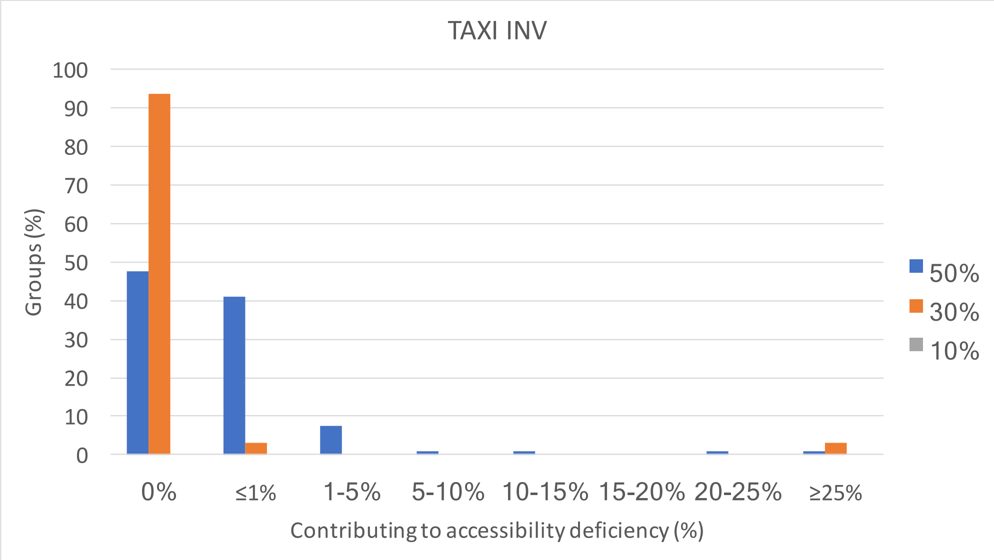

Figure 24: the share of taxi-based population groups contribution to overall accessibility deficiency under each accessibility threshold for the inverse power accessibility measure during peak hour

Accessibility measures give different accessibility levels, the number of groups contributing to accessibility deficiency and the percentages they contribute are not the same, however looking at the graphs in Figures 22, 23 and 24 representing taxi-based populations the pattern is quite similar across the 15 min cumulative accessibility measure, the inverse accessibility measure and the exponential accessibility measure. They all show that most of the groups contribute nothing to the accessibility deficiency and the higher contribution after 0% is between 0% and 5%.

Figures 25 to 27 below show the spatial pattern of population groups' average percentage contribution to accessibility deficiency in the city. These maps give a clear picture of were the groups that are contributing to the accessibility deficiency are located.

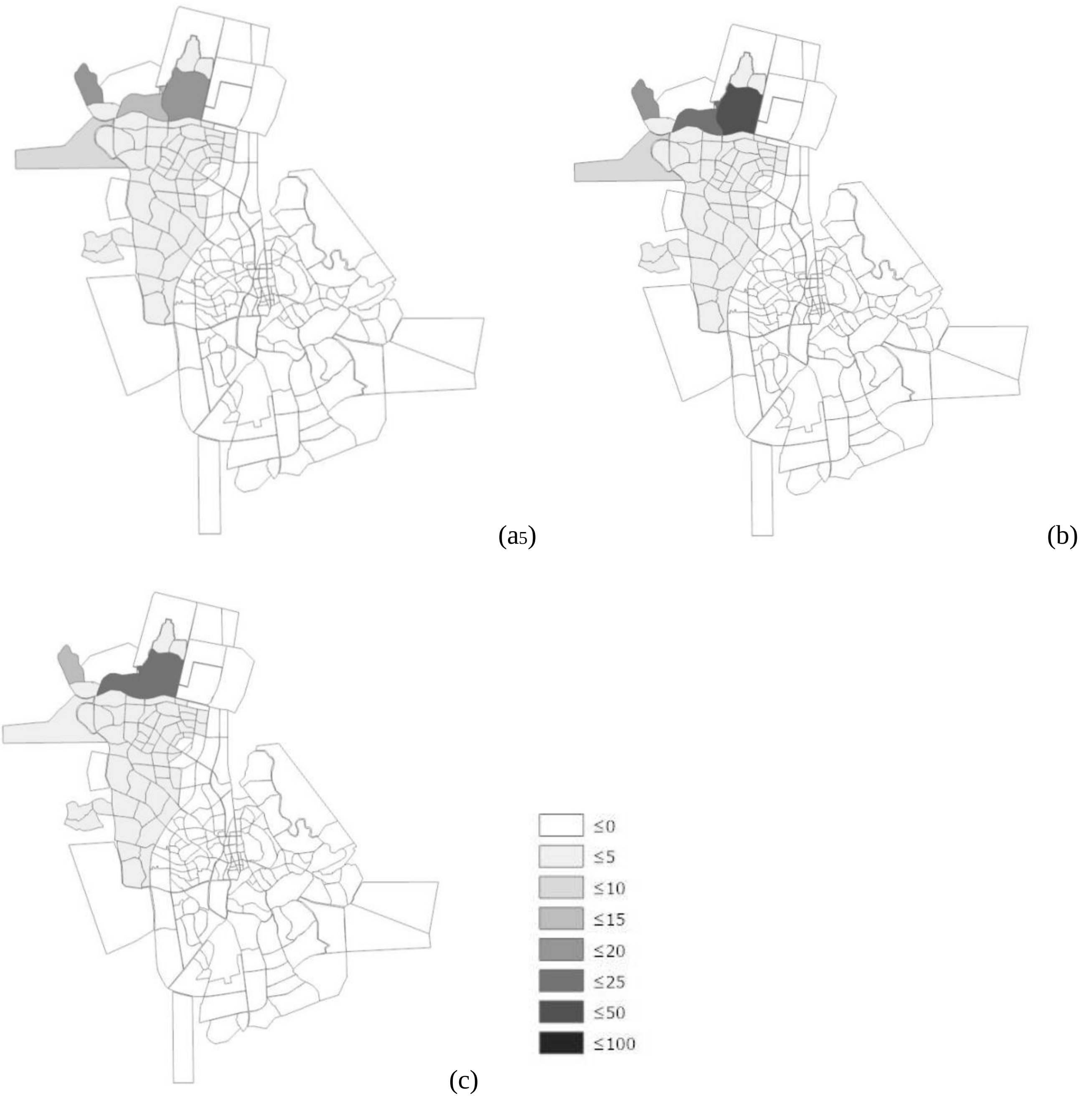

Figure 25: Spatial pattern of the percentage contribution to accessibility deficiency of the city by bus-based population groups for (a) 10% (b) 30% and (c) 50% sufficiency thresholds for all accessibility thresholds

[5] Elisenhiem is not shown in the maps because it had no population in 2011 and thus makes no contribution to the accessibility deficiency. See Appendix A for the full map.

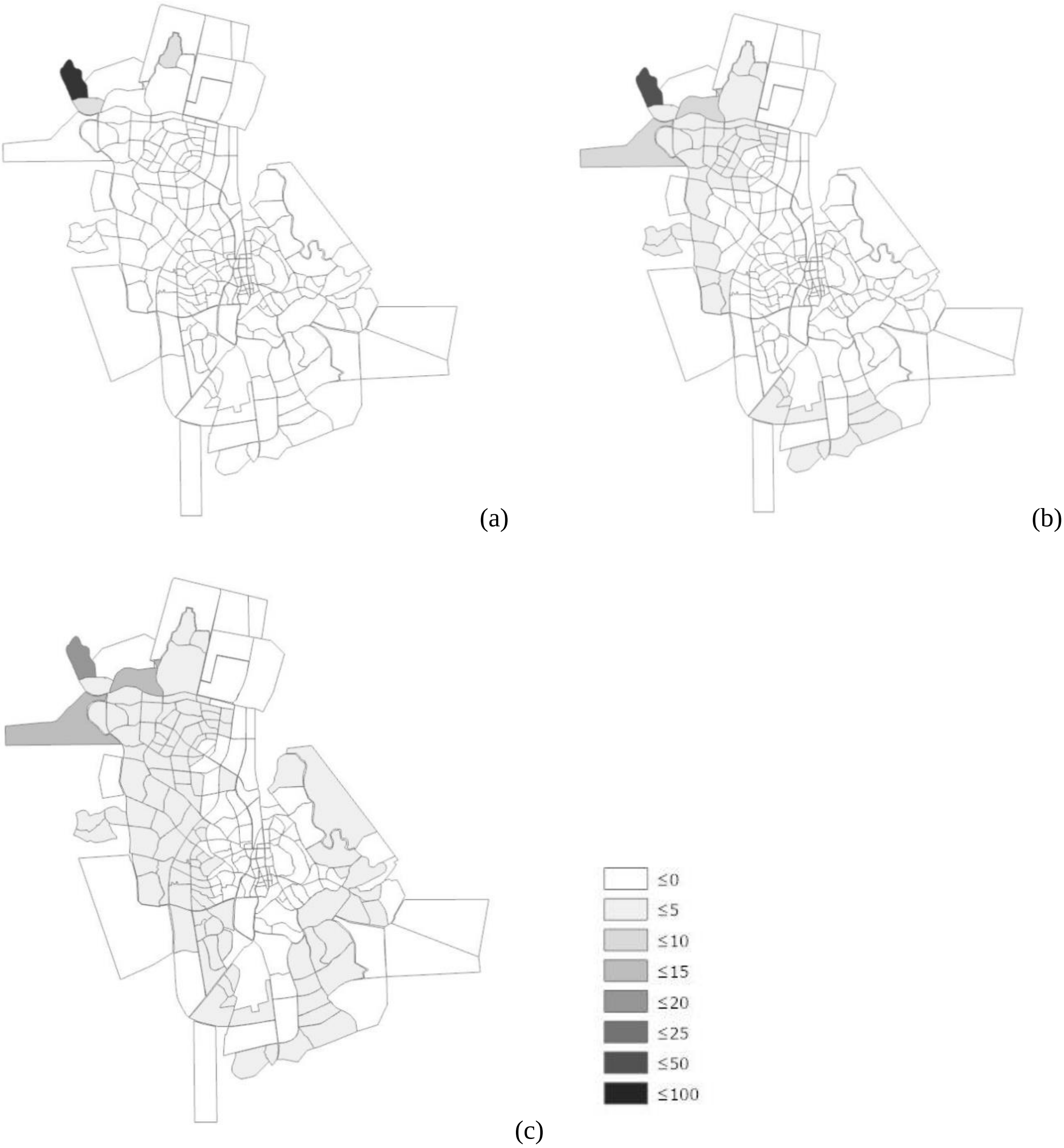

Figure 26: Spatial pattern of the percentage contribution to accessibility deficiency of the city by taxi-based population groups for (a) 10% (b) 30% and (c) 50% sufficiency thresholds for all accessibility thresholds

Figure 27: Spatial pattern of the percentage contribution to accessibility deficiency of the city by car-based population groups for (a) 10% (b) 30% and (c) 50% sufficiency thresholds for all accessibility thresholds

Figures 25 to 27 show that most of the groups experiencing accessibility and mobility shortfalls to jobs contribute less than 5% to the overall accessibility deficiency of the city. Figure 25 shows that all 59 bus population groups with residents in 2011 contributed to the transportation system insufficiency under all accessibility sufficiency thresholds. Again, this shows how the transportation system of Windhoek underserves the bus-based population.

Different to the bus-based users, the number of taxi-based groups contributing to the transport system insufficiency of the city shown in Figure 26 decreases with each decrease in accessibility sufficiency thresholds. There are thus more taxi-based groups under the 50% sufficiency threshold than there are under the 30% and 10% accessibility sufficiency thresholds. Additionally, with a decrease in accessibility threshold from 50% to 10% the taxi-based groups contributing to the over AFI retract to the periphery of the city.

For the car-based population groups none of them contributes to the overall transport system insufficiency under the 10% accessibility threshold, one group is shown under the 30% threshold, and there are seven groups under the 50% threshold. The only group contributing more than 50% to accessibility deficiency of the city is a car-based group. This is because it is situated at the fringe of the city with a significant number of people and under the 15 min cumulative measure it is the only group below the 50% threshold. All those reasons combined, justify a high overall contribution. This demonstrates that even those that may have access to the prioritised mode of transport can experience accessibility shortfalls depending on where they live.

4.5.4 OVERALL AFI CONTRIBUTION TO ACCESSIBILITY DEFICIENCY

Figure 28 and Figure 29 below show that the bus-based populating groups contribute the most followed by the taxi based population groups, while the car-based population groups contribute less than 1%. The 30 min threshold cumulative measure shows that only the bus-based population groups contribute to the region's accessibility deficiency, as seen in Figure 30.

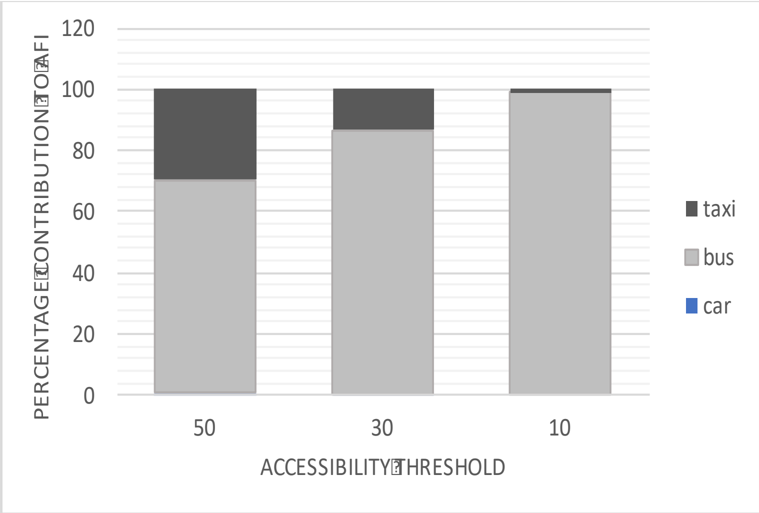

Figure 28: Contribution to the overall accessibility deficiency for each population group under different accessibility thresholds for the exponential gravity measure during peak hour.

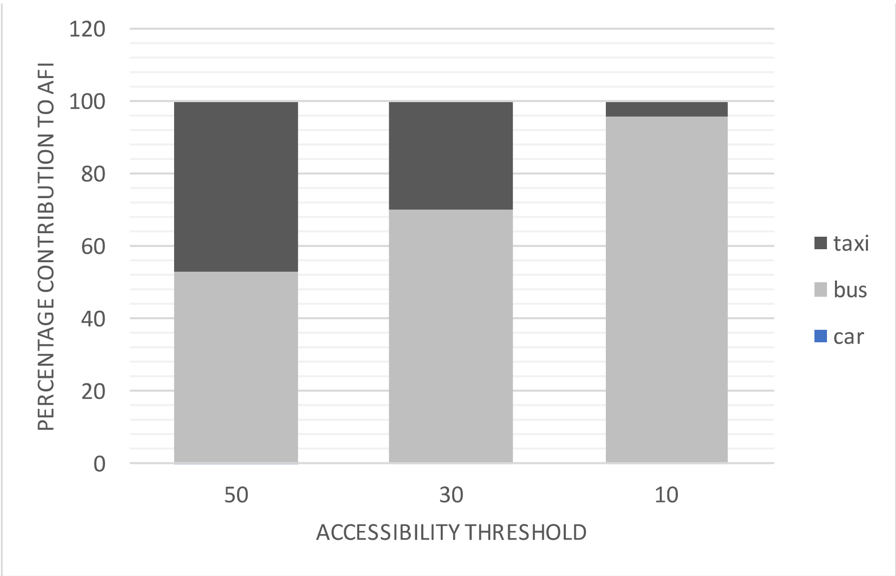

Figure 29: Contribution to the overall region's AFI for each population group under different accessibility thresholds for the 15 min cumulative accessibility measure during peak hour.

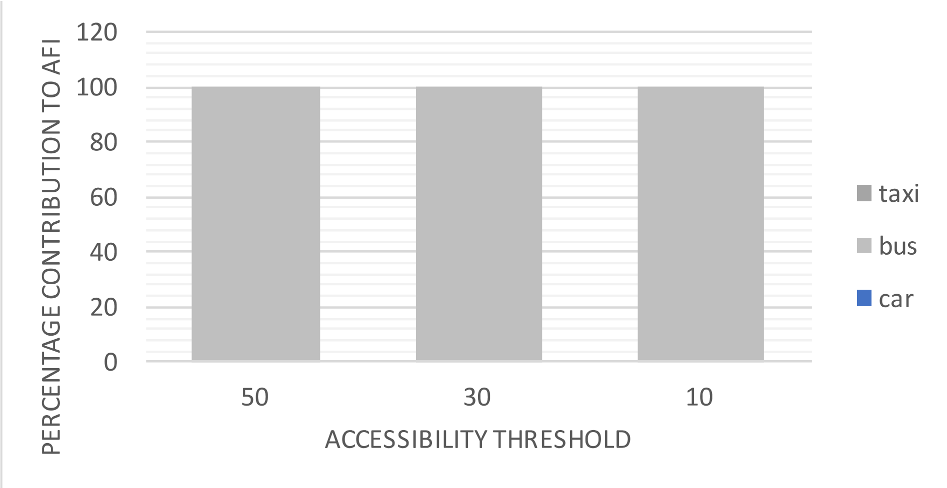

Figure 30: Contribution to the overall region's AFI for each population group under different accessibility thresholds for the 30 min cumulative accessibility measure during peak hour.

The inverse power gravity measure results, shown in Figure 31 below, similarly, to the results from the 15 min cumulative and exponential power thresholds, shows that moving from 50% to 30% sufficiency threshold, the bus-based groups' contribution to accessibility deficiency increases while the taxi-based groups decrease. Under the 10% sufficiency threshold, no groups are contributing to accessibility deficiency, because all the bus-based and taxi-based groups below the 10% sufficiency threshold for the inverse measure had no residents at the time.

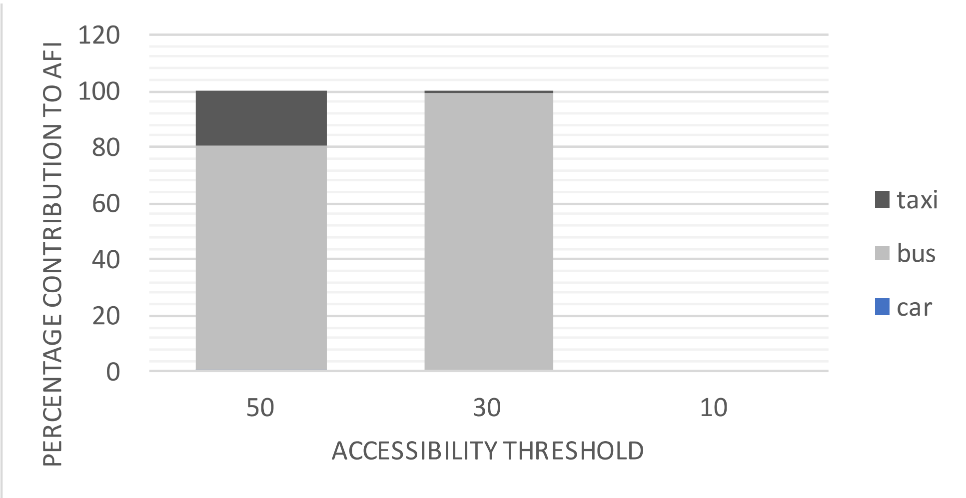

Figure 31: Contribution to the overall region's AFI for each population group under different accessibility thresholds for the inverse power gravity accessibility measure during peak hour.

4.6 PRIORITISING POPULATION GROUPS

The results from the above analyses have shown the accessibility levels experienced by the different groups based on different accessibility measures and accessibility thresholds. To find the groups to prioritize first in transportation improvements all the analyses were brought together to rank the population groups according to their percentage contribution to the overall accessibility deficiency within each accessibility threshold category based on the percentage contribution of their AFIs. This ranking of the groups is presented in Table 4 below per accessibility sufficiency threshold. The ranking of the groups is influenced not only by population sizes and accessibility levels, but they are also influenced by the number of accessibility measures used in the study and the type of accessibility measures. As seen in all the results leading up to the ranking of the groups for investment prioritisation, results from different accessibility measures have been different. Thus, if this study were to be conducted with different measures, the ranking below in Table 4 may not be the same.

Table 4: Ranking contribution of population groups to accessibility deficiency

50% Accessibility Threshold				30% Accessibility Threshold				10% Accessibility Threshold			
Mode	Main zone	Zone No.	AFI (%)	Mode	Main zone	Zone No.	AFI (%)	Mode	Main Zone	Zone No.	AFI (%)
C	Havana	610	65.4	T	Havana	610	44.32	T	Havana	610	49.61
B	Okuryangava	640	24.7	B	Okuryangava	640	25.7	B	Okuryangava	640	19.13
B	Okuryangava	630	22.2	C	Havana	610	25	B	Havana	610	17.38
T	Havana	610	15.6	B	Okuryangava	630	22.03	B	Okuryangava	630	14.57
B	Havana	610	15	B	Havana	610	16.73	B	Goreangab	100014	5.23
T	Okuryangava	630	13.9	T	Okuryangava	630	9.67	B	Wanaheda	60350	1.68
T	Goreangab	100014	10.2	T	Goreangab	100014	6.49	B	Okuryangava	660	1.52
B	Goreangab	100014	4.9	B	Goreangab	100014	5.36	B	Okuryangava	650	1.06
T	Okuryangava	640	4.6	T	Goreangab	60180	2.42	B	Goreangab	60180	1.05
T	Wanaheda	60350	4.1	B	Wanaheda	60350	2.24	B	Havana	620	1.04

The ranking in Table 4 only shows the top ten groups falling in the first quadrant, which contribute to the accessibility deficiency. The complete list is provided in Appendix A.

According to the ranking, a car-based population group based in a zone at the outskirts of the city tops the 50% sufficiency threshold list with a 65.4% contribution to the accessibility deficiency of Windhoek. 65.4% is also the highest contribution across all-sufficiency thresholds. This shows that even though the car is the prevailing mode, car users can experience insufficient accessibility to employment because of where they live relative to where employment opportunities are located. Additionally, taxi and bus-based groups from the same zone (Zone No: 610) rank numbers four and five under the 50% sufficiency threshold. This is a clear indication that a significant number of people living in that zone are experiencing sub-standard accessibility levels irrespective of the mode they use.

The top group under 30% and 10% is the taxi-based group based in zone 610 as well. Notably, all the top ten groups across all the sufficiency threshold rankings are located in zones at the fringe of the city in the same main zones. Furthermore, Table 4 shows that as the accessibility sufficiency thresholds decrease from 50% to 10% the number of groups bus-based in the top ten increases, and the number of taxi-based groups and car-based groups decreased. This shows that more bus-based groups experience the least accessibility levels. Throughout the results, there is a clear indication of bus-based population groups experiencing the lowest potential mobility and accessibility levels; it shows these are the groups that are entitled to transportation improvements first.

As noted at the beginning of this section, the ranking is influenced by the population size as well. As seen in the spatial maps provided in this study (see Figure 3) the zones in Windhoek are not of equal sizing and this has a direct effect on travel time, and population sizes and in turn the ranking of groups.

The ranking provided is useful to transport planning in prioritising transportation investment. The groups at the top of the list should be prioritized first. Investments for accessibility improvements do not need to focus on one group at a time. As seen in Table 4, all the groups in zone 610 are in the top 10 ranking and improving accessibility for those groups may mean providing an all-inclusive solution.

4.7 PRIORITISING POPULATION GROUPS FOR THE YEAR 2032

The Sustainable Urban Transportation Master Plan used a PTV Visum transport model to predict the modal share and impact of changes to the transportation system after infrastructure investments in the year 2032 when the SUTMP would have been fully implemented. The plan hopes to fully transform the Windhoek, Okahandja and Rehoboth transport systems by 2032. Based on the predicted travel times, the principles of justice for transportation planning were used to evaluate the impact of the SUTMP in 2032 on accessibility. The model provided public transport data inclusive of all public transport modes (bus, taxi, and rail). The number of car groups falling in the first quarter increased in 2032 under each accessibility measure. While the number of public transport groups was found to be less than the total number of bus population groups and the taxi population falling within the first quarter in 2012 for each accessibility measure. This shows improvement in accessibility from the implementation of the transportation infrastructure as laid out in the SUTMP report (GIZ, 2013). After the execution of the six principles of justice for transportation planning using the 2032 data set, the groups which may deserve accessibility investment prioritization are as listed in Table 5 below, for each accessibility threshold. The overall results of the 2032 analysis are presented in Appendix B.

Table 5: Ranking contribution of population groups to accessibility deficiency 2032

	Mode	Zone No.	Main Zone	AFI	Mode	Zone No.	Main Zone	AFI	Mode	Zone No.	Main Zone	AFI
1	C	100091	Elisenheim	9.9	C	100091	Elisenheim	65.8	C	100091	Elisenheim	50.0
2	PT[6]	610	Havana	5.8	PT	610	Havana	7.5	PT	100092	Elisenheim	9.9
3	C	100089	Elisenheim	5.2	PT	100074	Elisenheim	6.9	PT	100074	Elisenheim	9.6
4	PT	100075	Elisenheim	4.9	PT	100092	Elisenheim	6.8	PT	610	Havana	5.8
5	PT	630	Okuryangava	4.7	PT	100069	Elisenheim	6.1	PT	100069	Elisenheim	5.0
6	PT	100014	Goreangab	4.5	PT	100014	Goreangab	5.2	PT	100075	Elisenheim	4.9
7	C	100067	Elisenheim	4.1	PT	100083	Elisenheim	4.8	PT	100014	Goreangab	4.5
8	C	100077	Elisenheim	4.0	PT	100075	Elisenheim	4.7	PT	100091	Elisenheim	3.2
9	PT	640	Okuryangava	3.8	PT	100088	Elisenheim	3.5	PT	100083	Elisenheim	3.0
10	C	100072	Elisenheim	3.8	PT	100076	Elisenheim	3.3	PT	100093	Elisenheim	2.5
11	PT	100093	Elisenheim	3.6	PT	100093	Elisenheim	3.0	PT	100089	Elisenheim	2.5

6 Public transport

12	PT	100092	Elisenheim	3.3	PT	100091	Elisenheim	2.9	PT	100090	Elisenheim	2.5
13	PT	100069	Elisenheim	3.2	C	100089	Elisenheim	2.9	PT	100073	Elisenheim	2.4
14	PT	100083	Elisenheim	2.9	PT	100073	Elisenheim	2.8	PT	100088	Elisenheim	2.2
15	C	100084	Elisenheim	2.9	PT	100090	Elisenheim	2.7	PT	100086	Elisenheim	2.0
16	PT	100074	Elisenheim	2.9	PT	630	Okuryangava	2.7	PT	100067	Elisenheim	1.6
17	PT	100076	Elisenheim	2.8	C	100068	Elisenheim	2.4	PT	100071	Elisenheim	1.3
18	PT	100082	Elisenheim	2.8	PT	100089	Elisenheim	2.4	PT	100076	Elisenheim	1.1
19	C	100068	Elisenheim	2.7	PT	100086	Elisenheim	2.3	PT	100084	Elisenheim	1.1
20	PT	100088	Elisenheim	2.6	PT	100071	Elisenheim	2.2	PT	60350	Wanaheda	0.9

Table 5 shows the ranking of population groups based on their percentage contribution to the overall accessibility deficiency of the Windhoek transportation system. There is a noticeable decrease in the contribution of groups to the accessibility deficiency. The decrease shows an improvement in accessibility levels. The majority of the zones under the top ten are zones located in Elisenheim. Elisenheim is a middle to the high-income neighbourhood at the outskirts Windhoek; it is the furthest from the city centre. Car and public transport population groups from Elisenheim fall under each accessibility threshold; however, the number of car-based groups decreases with a decrease in accessibility threshold from 50% to 10% accessibility threshold. This shows that car population groups would still maintain better accessibility over public transport population groups in 2032.

The ranking of groups based on 2012 travel times data showed multiple groups from Havana, Okuryangava, and Goreangab main zones in the top ranking for groups most entitled to accessibility improvements. Table 5 shows that one group from each of those main zones would fall within the top ten in 2032. Based on those findings, the SUTMP for Windhoek shows to potentially create improvements in accessibility levels for low-income communities. It is however notable that the SUTMP is not based on principles of justice and the question follows whether parts of the solutions provided by the SUTMP may be unnecessary expenditure when principles of justice are considered.

CHAPTER 5 DISCUSSION

5.1 POPULATION GROUPS

The population of Windhoek is found to be unevenly distributed in numbers and income groups. The majority of low to middle-income population groups are located on the north to the north-western side of the city. In 2011, these groups made up 82% of the Windhoek population. While 18% of the population, made up of the high-income population groups, lived on the south to southwestern parts of the city, surrounding the CBD. The factors used to distinguish population groups were location, income level, and available mode of transportation.

The highest number of jobs are concentred in the CBD, thus based on the population groups' location, those closest to the CBD have the most access to jobs in the city. The spatial pattern of the city is a result of apartheid spatial disaggregation strategies. During the apartheid era, the black ethnic groups were moved to the outskirts of the town, and land was located to them per tribe. Further separation was implemented with the use of highways, and thus the low to middle-income groups live on one side of the Western bypass, and the high-income earners live on the other side. By the time apartheid ended, the CBD of the city was established, and land around it bought up. Those who lived in apartheid designated township remained there due to high land costs around the CBD. This is to say prolonged race issues are underlining where different population groups are located which should be factored into solutions to accessibility shortfalls. The apartheid era and its continued effects are not unique to Namibia and its towns, apartheid was practised in South Africa as well, and the inefficiency created by the physical separation of land uses is still experienced in both countries (Mazaza, 2002).

Due to the long-term effects of the apartheid system, transport systems have not evolved evenly in Windhoek. There are two very different public transportation services. The one service is a bus service and the other a sedan taxi service. Expectedly so, bus services were found to be dominantly used by the low to middle-income population groups, while all other population groups used the taxi service. The desk study has shown that Windhoek did not have enough buses to meet the demand, and thus the taxi service is the dominant public transport service for all income groups.

5.2 POTENTIAL MOBILITY

The results show that the bus-based population groups have the lowest PMI scores on average during morning peak hours. The average PMI scores for the bus-based groups was found to be 65% less than that of car-based population groups. Under the harshest sufficiency threshold, there are 180 bus-based population groups. Again, this indicates that the transport system does not sufficiently cater to bus use. The lack of bus lanes means buses are not shielded from congestion during peak hours making the bus transport service insufficient.

Additionally, it was reported that the number of buses did not match the demand (GIZ, 2013). Thus, not only is the bus transport service underserving those that make it on the bus on a given day, the bus service is not consistently and reliably accessible to users. As discussed, (see Chapter 2), lack of transport services is a mobility issue that causes social exclusion. Even though those that may be unable to catch the bus on a particular day may take a taxi, it means spending more on transport or extending travel time to work by walking which results in less accessibility to jobs and other activities. When more time or money is used to reach one activity, less time and money are available to participate in other activities.

While the car-based groups were found to experience the highest levels of potential mobility, at least 40% of the car-based groups were found to experience below-average potential mobility (car-based groups PMI average). Some of those groups are located close to the CBD. 52 car-based population groups falling below average potential mobility are located in close proximity to the CBD. This could be a result of peak hour traffic.

The taxi-based groups experience a 66% average potential mobility of the average potential mobility experienced by car-based population groups. This is because they are sedan taxies and the transportation system has been designed to optimise the use of cars. Taxis operate differently from single-occupancy vehicles; thus, the potential mobility of taxi-based population groups is lower than that of car-based population groups. Improvements for taxi-based groups can include infrastructure upgrades such as dedicated public transport lanes and stops to improve their operation in addition to policy changes to curb the random stopping.

5.3 ACCESSIBILITY

The study measured the number of job residents of Windhoek from each TAZ potentially have access to during the morning peak hour via the use of a car, public bus, or public taxi service. The transportation planning with principles of justice aims to determine groups of people experiencing accessibility shortfalls. That thus confined accessibility measures for the study to aggregated measures. The measures used were gravity and cumulative accessibility measures.

The results showed that accessibility levels for the exponential power gravity accessibility measure, the inverse power gravity accessibility measure and the 15 min threshold cumulative accessibility measure are quite similar. This observation supports Kwan's (1998) finding that the gravity and cumulative measures give similar results. The results from the 30 min threshold accessibility measure are quite different; they show significantly fewer population groups experiencing accessibility shortfalls. This is because the average travel time in Windhoek was found to be 9 min for cars, 48 min for buses and 13 min for taxis. Thirty min is thus a generous time threshold for the car and taxi-based groups to reach their destinations without much delay.

The factors used to determine accessibility levels are residential location, number of jobs at designated zones and transport network travel time per mode. The results show that on average, across all accessibility measures used in the study, car users have access to 72% and 31% more jobs than those that use buses and taxis. There is less of a gap between car and taxi because both modes are cars. This thus shows that Windhoek is a unimodal city. While most cities fight to curb private car use, Windhoek must curb the use of private cars and sedan which serve population groups across all income groups.

Curbing the use of sedan taxis with more sustainable public transport modes may result in the loss of many jobs for taxi drivers, and thus, it is crucial for planners to keep this in mind so that unemployment, which is a contributor to chain social exclusion, is not exacerbated.

Public transport bus users were found to experience the lowest accessibility levels — especially those at the fringe of the city. As discussed in Chapter 2, mobility affects accessibility and thus results showed that groups with mobility shortfalls experience accessibility shortfalls as was expected. Windhoek is a monocentric city; the transport system, as well as the residential location and mode of transport speed, are factors that have shown to lead to insufficient accessibility levels. The city's form contributes to the disproportionate accessibility shortfalls experienced by low-income groups. As seen in Figure 3 (see Chapter 3), the low-income groups living on the northern side of the city are furthest from the CBD, which essentially lowers their access to job opportunities.

5.4 CONTRIBUTION TO WINDHOEK'S ACCESSIBILITY DEFICIENCY

Contribution to the transport system's accessibility deficiency calculated with the use of AFI scores, measured how much each group contributes to the accessibility deficiency of the Windhoek transportation system. Each AFI score captured how many people are affected and the accessibility levels they experience. The results show (see chapter 4) that all the bus groups with citizens make some contribution to accessibility deficiency. Bus based population groups have the least number of people, however many of the bus-based groups experience the least accessibility levels, and thus the majority of them contribute to the accessibility deficiency of the city. The bus groups which make the most contributions are located in Havana, Okuryangava, Wanahenda, and Goreangab (see Table 4). These are townships located on the outskirts of the city where most new immigrants from rural areas settle and where the urban poor reside.

5.5 RANKING

The sixth step for transportation planning with principles of justice is the prioritisation of groups based on groups' average percentage contribution to accessibility deficiency. The results of this step (see chapter 4) showed that the highest contributing group under the 50% sufficiency threshold is a car-based group. It does not have the lowest accessibility levels or the highest number of residents in the Havana main zone; however, a few car groups are falling below the 50% sufficiency threshold, and thus each group contribution weighs more. The ranking of groups helps inform the decision-making process for accessibility prioritisation. However, Martens (2017), warns that because of the factors mentioned above-affecting contribution percentage, the list should be used with consideration of the number of people affected and the cost. Hence, the last four steps in transportation planning with principles of justice explore the causes of accessibility shortfalls, and how they can be solved efficiently. Nonetheless, up to step six, the results are insightful and give decision-makers a full picture of which groups' accessibility levels need to be improved.

5.6 CAUSES AND SOLUTION TO THE ACCESSIBILITY DEFICIENCY IN WINDHOEK

The fairness of the Windhoek transport system has been evaluated based on accessibility and potential mobility levels experienced by population groups across Windhoek. It was found that the groups experiencing insufficient accessibility and insufficient potential mobility which contribute the most to the unfairness of the transportation system are located in the poorest neighbourhoods (main zones) at the periphery of the city and they mainly rely on public transport for motorised movement, but realistically because of their income category, most of them walk. These neighbourhoods were found to be located close to each other. With that background, the possible causes and solutions are discussed shortly. Further investigations on the causes and possible interventions should be conducted using transportation planning with principles of justice steps seven to ten. The full application of the principles of justice for transportation planning is likely to be a costly exercise for a small economy. Data collection, democratic deliberations, and community participation are costly exercises, and thus initial funding of an exercise such as this might be an obstacle.

- Windhoek has a monocentric urban form, with the CBD towards the south of the city housing the highest number of jobs. This means those living in the northern parts of the city travel longer distances to access the jobs. During peak hour the flow of traffic is thus one-directional, and travel time is increased by congestion. More prominent activity centres thus need to be created around the city. This can be done by creating transport-oriented development. This can disperse trips (Cervero, 2013) and create a bidirectional traffic flow. Improving accessibility by linking infrastructure development and spatial planning can reduce congestion, pollution, and stimulate economic productivity which is an essential part of combating social exclusion (Middleton, 2016). Change stemming from improved land use and transport system is a long term goal that might not give political expedience thus the implementation of demonstrable short term transport demand measures may help keep the focus on the long term goals as leadership changes (Behrens, Del Mistro, & Ventel, 2007).

- The city does not have public transport dedicated lanes or right of way on the existing roads. And so, navigation during peak hour traffic, picking up and dropping people is a contributing factor to lower mobility and accessibility levels found to have been experienced by public transportation users in comparison to car users. Reducing road space for car traffic, and reallocating it to pedestrians, cyclists and buses can make taxi and bus operation more efficient.

- Walking is the prevailing mode in Windhoek because 87% of Windhoek residents fall in the low-income group (GIZ, 2013). Based on that, many people potentially experience lower accessibility levels to jobs than the bus-based groups. Solely improving the transport infrastructure may not increase activity participation in employment for many people. The solution to insufficient accessibility in Windhoek should thus go beyond transportation planning. It should include revision of land planning policies and actionable steps to correct the effects of the apartheid era. While people need to have mobility options, walking is a sustainable mode of transport and the desire and ability to walk to opportunities should be preserved and encouraged.

Windhoek thus far has a transportation master plan. It is, however, not based on principles of justice. It would be insightful to use principles of justice to monitor the progress of planning using multiple opportunities around the city. Barry argued (as cited in Farrington & Farrington, 2005) that social justice is an attribute of institutions. Often institutions such as the municipalities and ministries are tasked to distribute benefits and consequently the burdens. This study and optimistically, further studies on accessibility in Namibia can be used as a tool in ensuring that development is socially just. For example, knowing that low-income population groups located on the outskirts of the city experience insufficient accessibility can serve as motivation to focus mixed development in those areas.

Road authority, the managing body of roads in Namibia has a strategic plan with performance indicators measuring how much road networks they provide (Roads Authority, 2017). But there is no evaluation of the levels of accessibility that the current or proposed road networks may provide. As noted above, roads, especially in rural areas are provided for without transportation services and so even though access is considered, it is not prioritised. There is thus a research opportunity using the principles of justice on how the planned road networks will affect accessibility in the respective areas and if there are other alternatives that are more inclusive of those who cannot afford cars and their operational costs.

With additional data on the perception of travel time, what people feel they need access to the most, and off-peak and afternoon peak hour data, not only can the analysis in the six steps of the transportation planning with principles of justice be expanded, but additionally it will enable researchers and policy consultants to carry out the last four steps which require direct input from society to identify the real causes of accessibility shortfalls and the possible solutions. As mention before, data of that nature can be attained through a travel survey that should ideally be coupled with the census to optimise funds allocated to national surveys.

Beyond Namibia, African countries face a lack on many fronts such as education, health care, and employment. The principles of justice can serve as a tool to focus resources on the most disadvantaged groups. The methodology ensures to question the role transportation systems plays but does not confine solutions to the transportation sector. For example, the solution to lack of access to education can be either providing buses to the closest school or building schools close to the affected population groups. Additionally, the African Development Bank can use the methodology to evaluate which transportation projects to fund first by comparison of AFIs for different countries.

The methodology presented by Marten was found to be adaptive and easily scalable. It can be easily understood which makes it a desirable tool for multi-discipline planning necessary for robust investment in accessibility for communities. The methodology gives the planners control over the number of factors to investigate and the number of accessibility measures to use. Martens comprehensively provided a rationale for each chosen principle necessary to convince standardised planning institutions to invest in assessing accessibility.

5.7 RECOMMENDATIONS

Transportation infrastructure not only gives access to employment but access to other activities that are regarded as essential activities, such as emergency services, health care, education, food, and clothing (van Wee & Geurs, 2011). As noted earlier, most studies on accessibility have centred the measure around employment, this goes to show how important a source of income is for participation in other activities, access to services and activities such as health care and education are important in ensuring social inclusion, and further studies including more activities would provide a robust understanding of the role of transportation in the exclusion or inclusion of people in Windhoek. Furthermore, travel behaviour changes throughout the day, a study that is inclusive of different times can highlight this and show how access changes through a day. While people need to have access to activities, the trip home must be made in a reasonable amount of time relative to each society. The lack of data in this study for off-peak hour traffic has limited the understanding of accessibility during that time. Change takes time to plan and take effect, extensive data can inform subsequent design and policy that will direct equitable and sustainable transportation intervention over time. It is thus recommended that further accessibility studies of the city should include various time segments.

CHAPTER 6 CONCLUSION

The study has applied the principles of justice for transportation planning in assessing the fairness of the Windhoek transport system. The application has shown that data and background on the study area are important in determining the population groups, types of accessibility measures, accessibility thresholds, and mobility thresholds to be used in the study. Data concerning income, opportunities within the study area, car ownership, and traffic data was essential to the study. The use of the data required insight on the transportation nature of the area, for example, even though Windhoek has bus routes all around the city, not everyone uses buses and researchers must know that to adequately distinguish population groups and modes available. Although enough data was available to apply the principles of justice for transportation planning, the application was limited to employment opportunities during weekday morning peak hour, and hence the interpretation of the results, although insightful, was restrained. The application of the principles of justice for transportation planning in a developing country may thus pose a challenge because of data scarcity despite Marten (2017) having been conscious of data demands in developing the principles of justice for transportation planning.

The procedure was developed for people in the transportation planning sector and suggested that a democratic deliberation procedure with well informed and equally powered citizens makes sensible decisions (Martens, 2017). However, in this study and the Amsterdam case study, decisions were made by the individual researchers; thus, if this study were to be conducted with numerous decision-makers, the results might differ because they may draw different levels of sufficient accessibility thresholds within the region. The choice of who makes the decisions of the application of the principles is thus critical.

The application of the principles of justice in Windhoek, although limited to morning peak hour, employment opportunities, and six steps, was able to identify population groups experiencing insufficient accessibility due to deficiency of the transportation system. Three transport investment priority lists of groups entitled to accessibility improvements were created based on the Accessibility Fairness Index scores for 50%, 30%, and 10% accessibility thresholds. The top ten population groups in each list were found to be dominantly made up of the low-income earners living in Havana, Goreangab, Wanahenda, and Okuryangava neighbourhoods at the northern fringe of the city. These groups of people live the furthest from the CBD, where the highest number of jobs are located. Under the 50% and 30% priority groups, one car group located in Havana was ranked in the top ten and shared a substantial burden of overall accessibility deficiency. The principles incorporate a link between accessibility and transportation mode, and the results have shown that even those with access to a car can experience accessibility insufficiency based on where they are located in relation to opportunities. The principles do not assume because people may have access to a car; they reach sufficient accessibility. A fair chance of evaluation is given to all persons.

The results clearly show that transportation deficiency in Windhoek predominantly affects the northern part of the city where the urban poor and low to middle-income live. Besides deficiency in transportation, this is an indication of the role of land use and income in accessibility levels. Further investigations following the last four steps for the principles of justice are highly recommended to find suitable solutions. Accessibility is a multi-dimensional concept, although the study was able to show that through the use of multiple accessibility measures, it is recommended that an assessment of the transport fairness of Windhoek is carried out for other periods and opportunities to get a more thorough understanding. The study, through literature review, has shown that lack of accessibility, much like income, leads to social exclusion and consequently, poverty. Identification of groups of people experiencing accessibility shortfalls can thus be an indicator of potential poverty.

Transportation planning with principles of justice can help refocus and direct transportation infrastructure investment from political motives to uplifting the transport poor. The principles put people at the centre of development in relation to their socio-economic status, transport services available, and desired opportunities. It can be a tool to disconnect African transportation planning from the western commonly inherited practice of building more roads to solve mobility by accessibility and congestion. By identifying the services people need to equitability engage in activities than providing infrastructure that largely serves the affluent. The 60 million poor of Africa may not be able to own a car anytime soon, the mass use of the cars as it is, is unsustainable, however, that should not be the reason to delay providing equitable transportation to all over time. It is worth considering investing more in non-motorised transportation for Africa for sustainable, inclusive, and affordable transport systems.

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Appendix A

2012 Data

Table 1: Potential Mobility Index and Accessibility Levels (2012)

Car						Bus						Taxi					
TAZ no.	**PMI Car**	**Car Inv**	**Car Exp**	**Car Cum30**	**Car Cum15**	**TAZ no.**	**PMI Bus**	**Bus Inv**	**Bus Exp**	**Bus Cum30**	**Bus Cum15**	**TAZ no.**	**PMI Taxi**	**Taxi Inv**	**Taxi Exp**	**Taxi Cum30**	**Taxi Cum15**
1	517	73182	52249	79043	71477	1	20	20434	33456	51422	30873	1	34	54035	42805	75360	42805
2	47	75964	52484	79085	71562	2	19	20690	35018	52485	32480	2	32	56110	42974	75395	42974
3	60	201542	59191	80775	74942	3	20	25329	51945	61509	47621	3	40	139871	53414	78348	53414
4	58	179615	58269	80466	74322	4	19	23297	47126	59641	45009	4	39	130652	50009	77442	50009
5	54	128225	60160	80846	75084	5	19	23229	48078	59056	44151	5	36	90365	53399	78176	53399
6	52	93070	57487	80240	73871	6	19	22309	44879	58465	42582	6	34	67710	48991	77081	48991
7	52	56809	53856	79691	72773	7	20	18919	37373	58901	39941	7	35	41072	43788	76232	43788
8	54	56328	53938	79760	72911	8	20	16599	30304	56921	35273	8	36	40724	43806	76335	43806
9	51	75635	55911	79537	72465	9	21	23251	47902	60566	45471	9	34	55574	47544	76055	47544
11	48	76068	57583	80022	73434	11	19	22337	45679	58926	43916	11	32	55573	49361	76763	49361
12	50	78997	57485	79992	73374	12	19	22498	46016	59139	44451	12	33	54866	50011	76840	50011
14	50	97560	59770	80533	74457	14	18	21219	45204	58995	43981	14	33	70534	52021	77495	52021
15	51	87241	59667	80678	74747	15	19	23831	48531	59550	45099	15	34	62039	52711	77919	52711
16	53	84882	59974	80851	75092	16	20	27594	53135	62095	47958	16	35	60958	53664	78322	53664
17	50	84212	57995	80386	74162	17	20	20978	44018	60359	43158	17	33	60286	49659	77325	49659
18	68	95085	58653	80626	74644	18	20	18496	36975	58645	39317	18	45	68744	50044	77635	50044
19	57	101283	59618	80798	74986	19	20	21799	44619	60633	43802	19	38	73293	51521	77921	51521
20	51	78610	58150	80543	74477	20	20	20750	41874	59826	42278	20	34	56846	49369	77510	49369
21	51	84581	59030	80530	74450	21	21	24645	51547	62142	47063	21	34	60270	51360	77588	51360
22	52	82685	59555	80674	74739	22	20	24688	50823	61591	47097	22	34	52970	54343	78236	54343
24	46	67913	55544	79634	72660	24	20	21609	45680	60697	43842	24	31	49125	46573	76151	46573
101	50	84590	57925	80132	73654	101	19	20256	41056	58780	41881	101	34	61417	49738	76909	49738
102	48	75115	56206	79647	72686	102	18	19938	41080	57990	42387	102	32	54538	47657	76180	47657
131	51	93025	59443	80514	74419	131	20	21711	45179	60461	44893	131	34	67641	51625	77489	51625
132	49	80839	58024	80130	73651	132	19	22413	45244	58980	44035	132	33	59270	50063	76946	50063
231	47	67913	55544	79634	72660	231	20	20602	43455	59989	42671	231	31	48991	46599	76155	46599

7 Blue: Below average potential mobility

232	53	79688	57202	80004	73400	232	20	21792	43329	59351	41431	232	35	58381	48918	76748	48918
233	46	61915	54261	79369	72129	233	20	20917	44595	60411	43356	233	31	44788	44906	75751	44906
234	51	80848	54559	79460	72311	234	20	20902	43193	59812	42227	234	34	58671	45363	75899	45363
610	46	123486	72509	52308	18173	610	26	4518	6910	589	0	610	31	8926	2360	35158	2360
620	50	13945	10112	56673	26806	620	25	4763	120	1087	6	620	33	10082	3887	41705	3887

Table 2: Ranked contribution to overall accessibility deficiency (2012)

	Main Zone	**Zone No.**	**AFI contribution 50% Accessibility threshold**	**Main Zone**	**Zone No.**	**AFI contribution 30% Accessibility threshold**	**Main Zone**	**Zone No.**	**AFI contribution 10% Accessibility threshold**
1	Havana11	610	65.4	Havana	610	44.3	Havana	610	49.6
2	Okuryangava12	640	24.7	Okuryangava	640	25.7	Okuryangava	640	19.1
3	Okuryangava	630	22.2	Havana	610	25.0	Havana	610	17.4
4	Havana13	610	15.6	Okuryangava	630	22.0	Okuryangava	630	14.6
5	Havana	610	15.0	Havana	610	16.7	Goreangab	100014	5.2
6	Okuryangava	630	13.9	Okuryangava	630	9.7	Wanaheda	60350	1.7
7	Goreangab	100014	10.2	Goreangab	100014	6.5	Okuryangava	660	1.5
8	Goreangab	100014	4.9	Goreangab	100014	5.4	Okuryangava	650	1.1
9	Okuryangava	640	4.6	Goreangab	60180	2.4	Goreangab	60180	1.0
10	Wanaheda	60350	4.1	Wanaheda	60350	2.2	Havana	620	1.0
11	Goreangab	60180	3.3	Wanaheda	60350	2.0	Wanaheda	60340	0.8
12	Wanaheda	60340	2.4	Okuryangava	660	1.5	Wanaheda	60360	0.7
13	Wanaheda	60350	2.2	Okuryangava	640	1.4	Katutura	50070	0.7
14	Wanaheda	60360	2.0	Goreangab	60180	1.4	Wanaheda	60460	0.7
15	Katutura	50070	1.5	Wanaheda	60340	1.4	Khomasdal	90460	0.6
16	Wanaheda	60460	1.5	Katutura	50070	1.3	Katutura	30010	0.5
17	Katutura	50070	1.5	Wanaheda	60360	1.2	Khomasdal	40110	0.4
18	Okuryangava	660	1.4	Wanaheda	60340	1.1	Katutura	40060	0.4
19	Goreangab	60180	1.3	Wanaheda	60460	1.1	Khomasdal	90170	0.4
20	Katutura	20120	1.3	Havana	620	1.1	Khomasdal	40210	0.4
21	Wanaheda	60360	1.2	Okuryangava	650	1.0	Katutura	20120	0.3
22	Havana	620	1.2	Khomasdal	40110	1.0	Katutura	20240	0.3

8 Yellow: Below 50% accessibility threshold
9 Orange: Below 30% accessibility threshold
10 Green: Below 10% accessibility threshold
11 Dark grey : Car population groups
12 Light grey: Taxi Population
13 Grey: Taxi Population groups

23	Katutura	30010	1.1	Katutura	20120	0.9	Havana	620	0.3
24	Wanaheda	60340	1.1	Katutura	30010	0.9	Rocky Crest	90530	0.3
25	Khomasdal	40110	1.1	Havana	620	0.9	Katutura	50170	0.3
26	Wanaheda	60460	1.1	Wanaheda	60360	0.8	Katutura	20040	0.3
27	Havana	620	1.0	Katutura	40060	0.7	Katutura	30050	0.3
28	Kleine Kuppe	70380	1.0	Khomasdal	90460	0.7	Khomasdal	40400	0.3
29	Okuryangava	650	0.9	Katutura	20240	0.6	Wanaheda	40090	0.3
30	Katutura	30010	0.9	Okuryangava	660	0.6	Katutura	30100	0.2
31	Otjomuise	40340	0.9	Katutura	50170	0.6	Khomasdal	40450	0.2
32	Katutura	50170	0.8	Katutura	20040	0.6	Katutura	50040	0.2
33	Okuryangava	660	0.8	Okuryangava	650	0.6	Katutura	50010	0.2
34	Katutura	20170	0.8	Katutura	30050	0.6	Katutura	20190	0.2
35	Havana	620	0.8	Khomasdal	90170	0.6	Katutura	20010	0.2
36	Katutura	20240	0.8	Khomasdal	40400	0.6	Katutura	30150	0.2
37	Katutura	50170	0.7	Khomasdal	40210	0.6	Khomasdal	40430	0.2

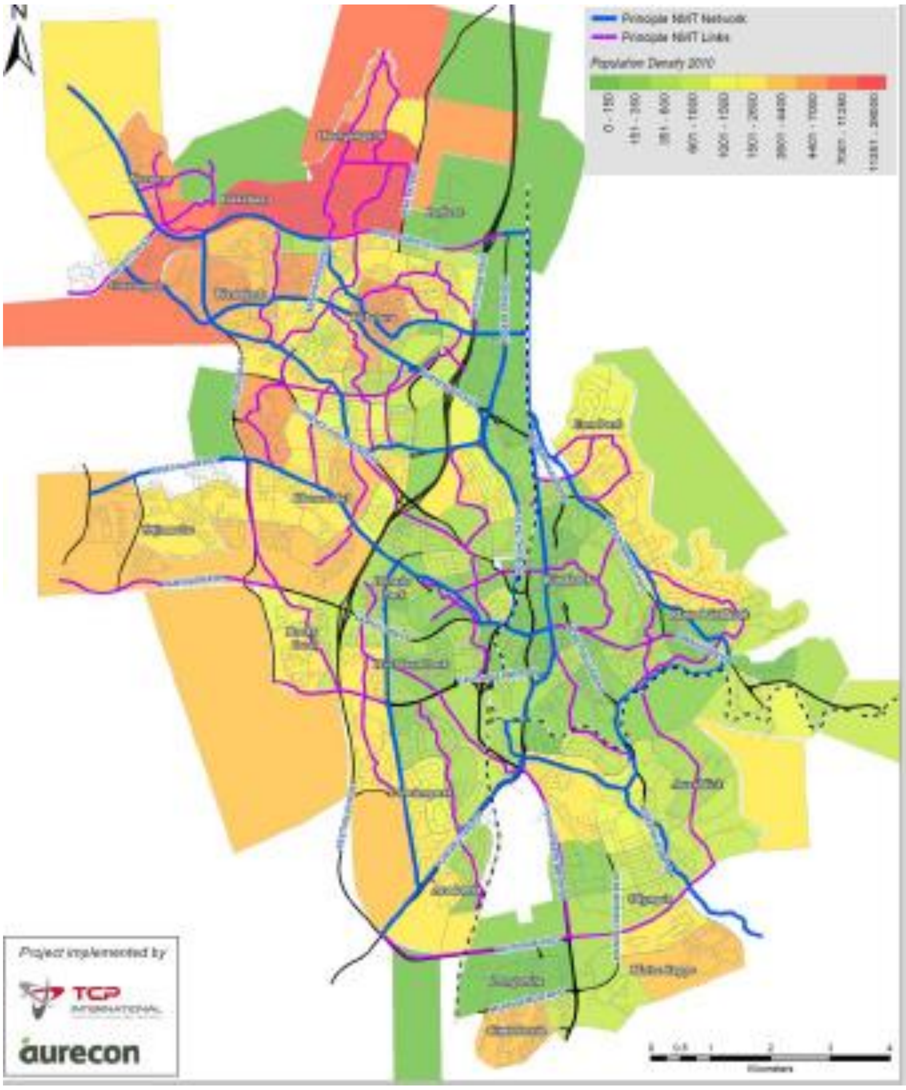

Figure 1: Population density (GIZ, 2013)

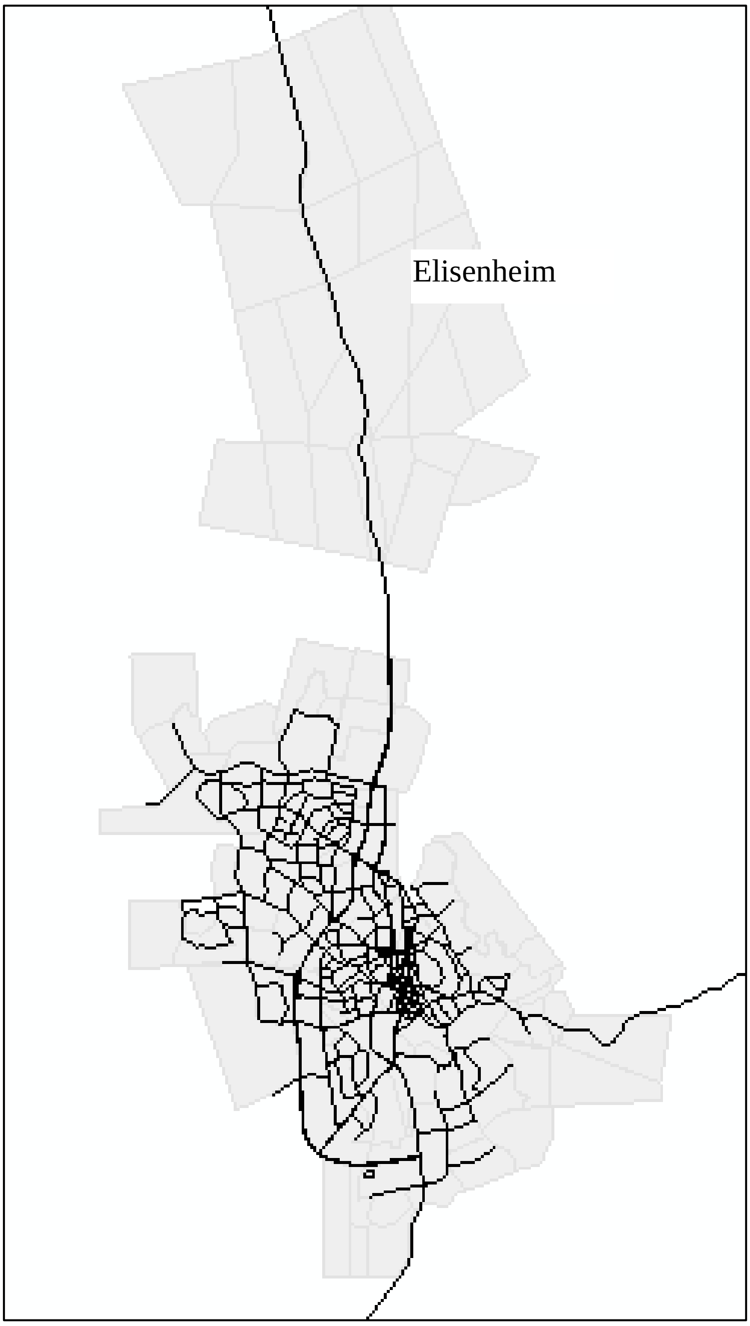

Figure 2: Windhoek TAZs and transport network

Appendix B

2032 Data

Table 3: Potential Mobility Index and Accessibility Levels (2032)

Car						PT					
TAZ no.	**PMI Car**	**Car Inv**	**Car Exp**	**Car Cum30**	**Car Cum15**	**TAZ no.**	**PMI PT**	**PT Inv**	**PT Exp**	**PT Cum30**	**PT Cum15**
1	45	82285	58896	116824	69768	1	19	31595	50353	73310	45884
2	42	83691	58071	116203	69425	2	18	32344	52851	74822	47016
3	51	191552	64290	117773	72477	3	19	37170	65611	81398	52926
4	52	180752	63596	117254	72120	4	20	38359	68968	82286	54820
5	45	95212	62592	116698	71656	5	19	37123	67661	81223	54069
6	46	96504	63358	116764	71982	6	18	33931	60599	77699	50492
7	47	65741	61328	117979	71330	7	19	29980	52331	78662	47402
8	49	65442	61609	118487	71477	8	19	29787	52430	78965	47887
9	46	86440	64070	114501	71119	9	20	34369	62111	78901	52553
11	43	84828	65087	115335	72271	11	18	34761	63348	77019	51809
12	45	90136	65441	115326	72303	12	19	35779	65335	78564	53369
14	45	107992	67359	116298	73177	14	19	40543	72805	81471	56148
15	44	93493	65666	116038	72604	15	17	36725	66447	74799	52006
16	46	88392	66171	117180	72986	16	19	39491	67768	80341	53350
17	44	94362	65694	117254	72800	17	18	33756	61565	78156	51347
18	62	104579	66358	118025	73121	18	18	33334	61003	79155	51489
19	51	113098	67871	118307	73723	19	18	33119	59932	77676	50478
20	45	82211	66071	118176	73251	20	18	33053	58803	79451	50052
21	45	94437	66995	117120	73183	21	19	39552	70691	81221	55343
22	46	89130	66844	117265	73184	22	18	38025	68173	79212	53808
24	42	78207	62741	114951	71322	24	18	34024	61500	78310	51511
101	45	95383	65734	115789	72410	101	19	36300	65415	79657	52990
102	44	86655	64198	114658	71607	102	18	32417	59471	75793	50789
131	45	102496	66634	116301	72898	131	19	35814	63409	79539	52003
132	44	91350	65720	115568	72451	132	19	37392	68078	79951	54417
231	42	78207	62741	114951	71322	231	19	33681	61110	78303	51616
232	47	91125	65468	115729	72045	232	19	33680	60525	78489	51799
233	41	68922	60860	114338	70327	233	18	31777	57627	78018	50313
234	45	85673	61843	114946	70602	234	18	30436	54006	76923	48679
610	40	19819	9058	74024	8951	610	19	10918	1065	13448	13
620	43	22561	13502	83721	18171	620	18	11605	1677	19122	56

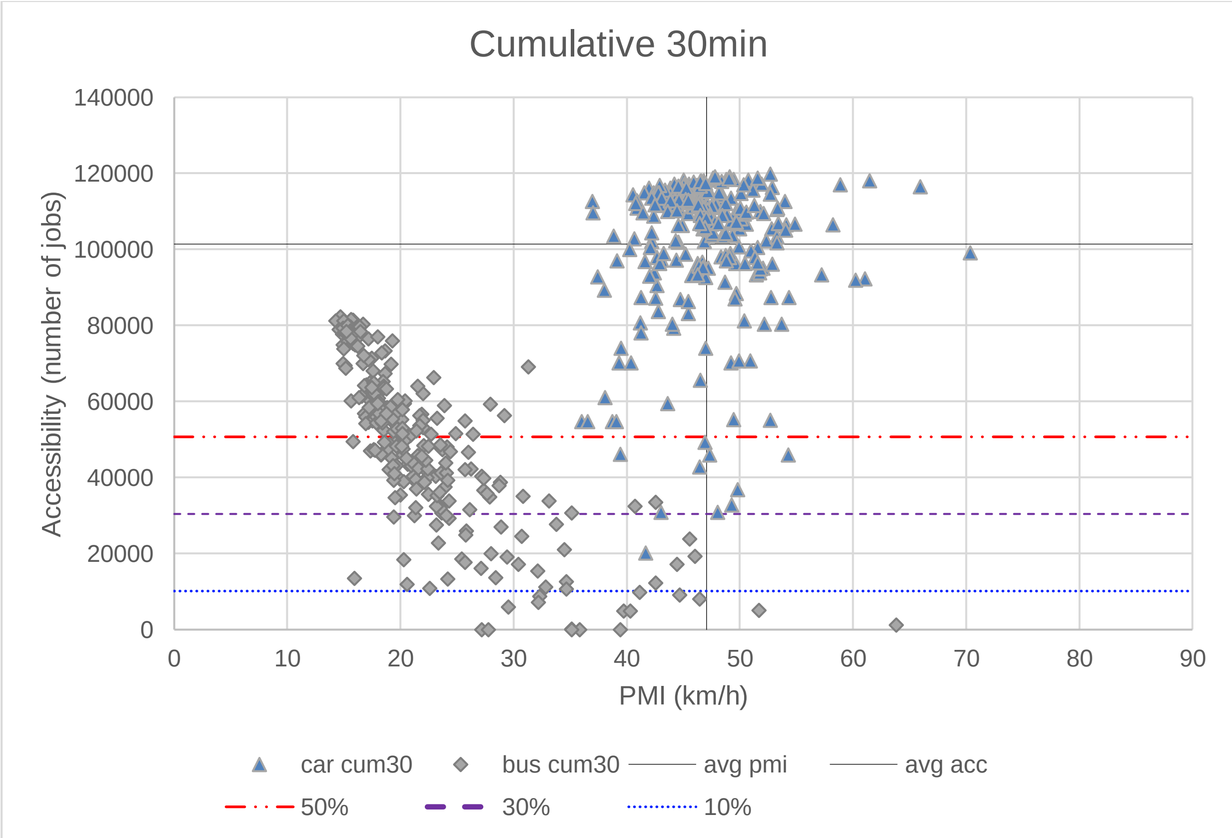

Figure 3: Representation of potential mobility and accessibility to employment as experienced by different population groups at peak hour for car-based, bus-based and taxi-based population groups for a 30 min threshold cumulative accessibility measure.

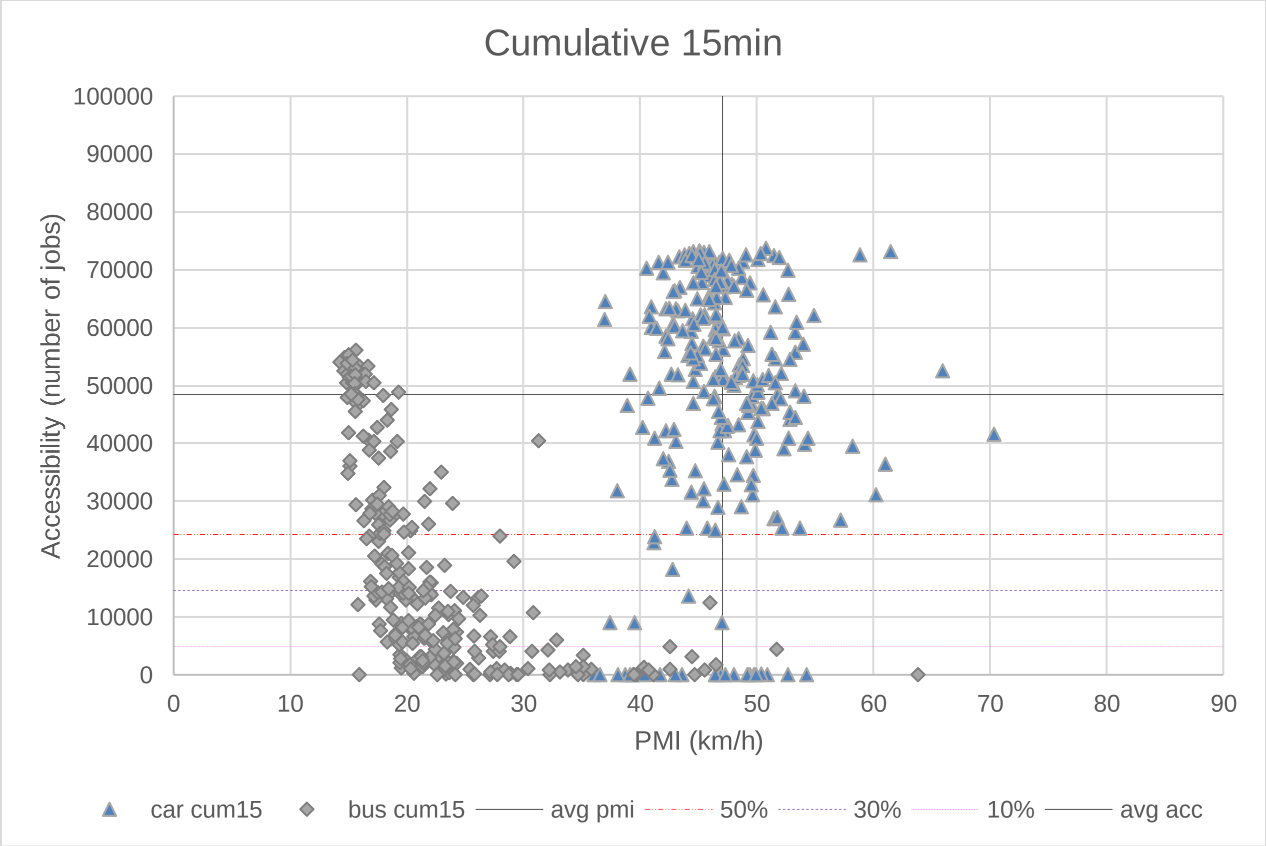

Figure 4:Representation of potential mobility and accessibility to employment as experienced by different population groups at peak hour for car-based, bus-based and taxi-based population groups for a 15 min threshold cumulative accessibility measure.

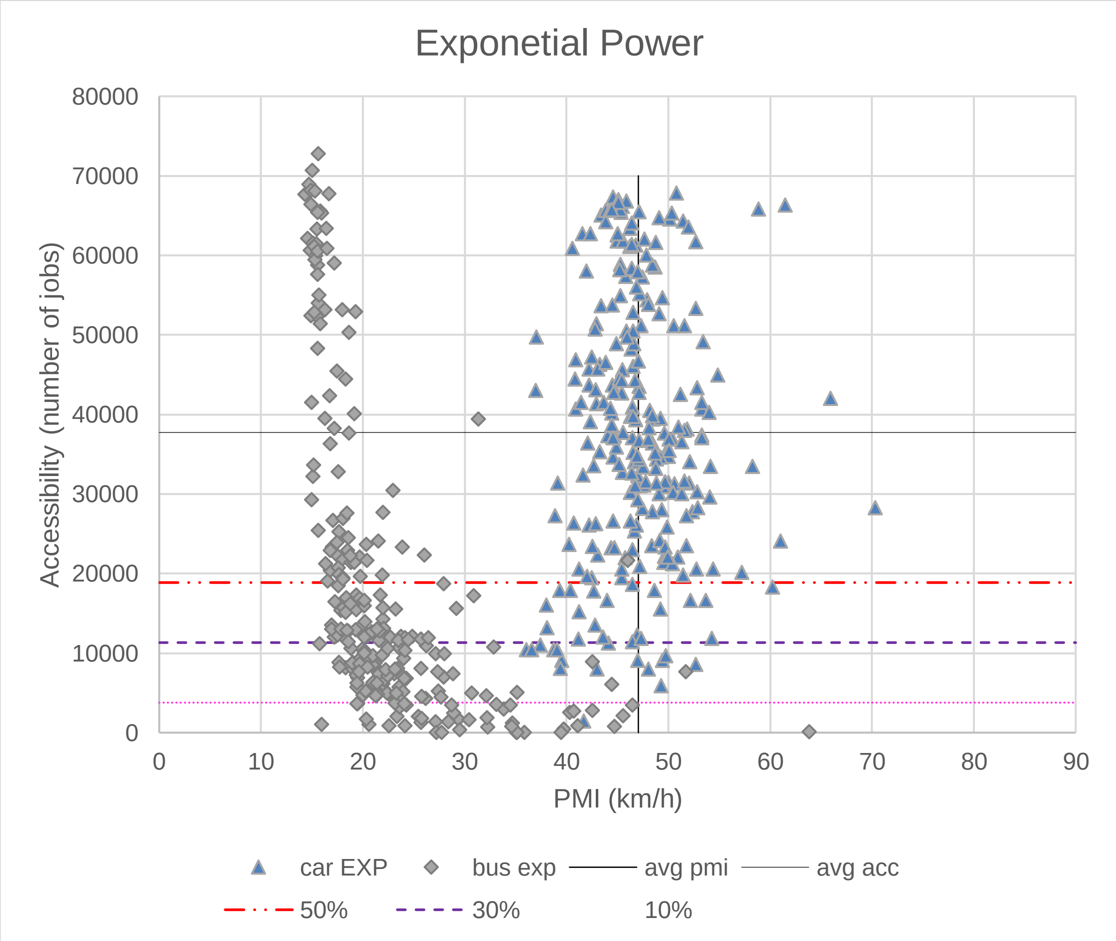

Figure 5: Representation of potential mobility and accessibility to employment as experienced by different population groups at peak hour for car-based, bus-based and taxi-based population groups for an exponential accessibility measure.

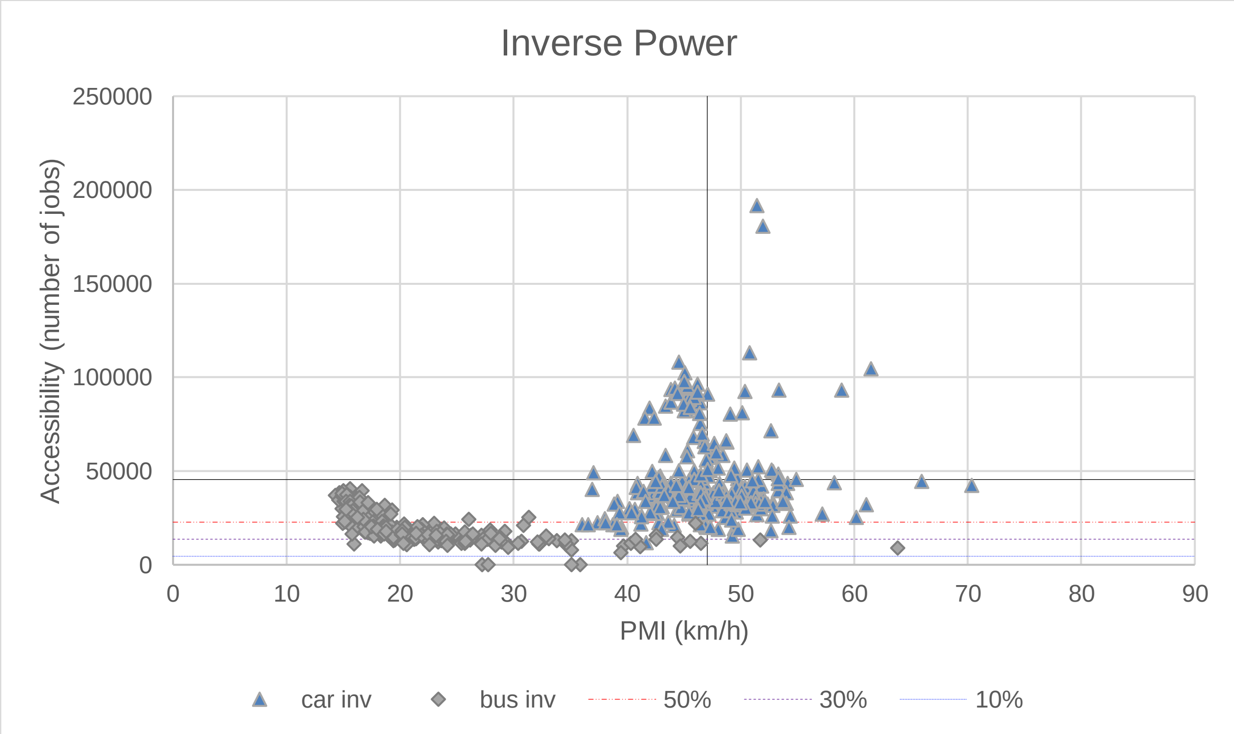

Figure 6: Representation of potential mobility and accessibility to employment as experienced by different population groups at peak hour for car-based, bus-based and taxi-based population groups for an inverse accessibility measure.

Table 4: Ranked contribution to overall accessibility deficiency (2032)

	Main Zone	Zone No.	AFI contribution 50% Accessibility threshold	Main Zone	Zone No.	AFI contribution 30% Accessibility threshold	Main Zone	Zone No.	AFI contribution 10% Accessibility threshold
1	Elisenheim	100091	9.9	Elisenheim	100091	65.8	Elisenheim	100091	50.0
2	Havana	610	5.8	Havana	610	7.5	Elisenheim	100092	9.9
3	Elisenheim	100089	5.2	Elisenheim	100074	6.9	Elisenheim	100074	9.6
4	Elisenheim	100075	4.9	Elisenheim	100092	6.8	Havana	610	5.8
5	Okuryangava	630	4.7	Elisenheim	100069	6.1	Elisenheim	100069	5.0
6	Goreangab	100014	4.5	Goreangab	100014	5.2	Elisenheim	100075	4.9
7	Elisenheim	100067	4.1	Elisenheim	100083	4.8	Goreangab	100014	4.5
8	Elisenheim	100077	4.0	Elisenheim	100075	4.7	Elisenheim	100091	3.2
9	Okuryangava	640	3.8	Elisenheim	100088	3.5	Elisenheim	100083	3.0
10	Elisenheim	100072	3.8	Elisenheim	100076	3.3	Elisenheim	100093	2.5
11	Elisenheim	100093	3.6	Elisenheim	100093	3.0	Elisenheim	100089	2.5
12	Elisenheim	100092	3.3	Elisenheim	100091	2.9	Elisenheim	100090	2.5

13	Elisenheim	100069	3.2	Elisenheim	100089	2.9	Elisenheim	100073	2.4
14	Elisenheim	100083	2.9	Elisenheim	100073	2.8	Elisenheim	100088	2.2
15	Elisenheim	100084	2.9	Elisenheim	100090	2.7	Elisenheim	100086	2.0
16	Elisenheim	100074	2.9	Okuryangava	630	2.7	Elisenheim	100067	1.6
17	Elisenheim	100076	2.8	Elisenheim	100068	2.4	Elisenheim	100071	1.3
18	Elisenheim	100082	2.8	Elisenheim	100089	2.4	Elisenheim	100076	1.1
19	Elisenheim	100068	2.7	Elisenheim	100086	2.3	Elisenheim	100084	1.1
20	Elisenheim	100088	2.6	Elisenheim	100071	2.2	Wanaheda	60350	0.9
21	Havana	610	2.5	Elisenheim	100082	2.1	Goreangab	60180	0.9
22	Elisenheim	100072	2.4	Elisenheim	100067	1.8	Lafrenz	100051	0.8
23	Elisenheim	100077	2.3	Elisenheim	100077	1.8	Elisenheim	100068	0.8
24	Elisenheim	100067	2.3	Elisenheim	100072	1.6	Elisenheim	100095	0.7
25	Elisenheim	100090	2.1	Okuryangava	640	1.5	Elisenheim	100087	0.7
26	Elisenheim	100085	2.0	Elisenheim	100084	1.4	Okuryangava	630	0.6
27	Elisenheim	100073	2.0	Elisenheim	100087	1.4	Elisenheim	100072	0.4
28	Elisenheim	100076	1.9	Elisenheim	100094	1.3	Wanaheda	60460	0.4
29	Elisenheim	100087	1.9	Lafrenz	100051	1.2	Lafrenz	100052	0.3
30	Elisenheim	100070	1.8	Wanaheda	60350	1.1	Khomasdal	40110	0.3
31	Elisenheim	100086	1.8	Elisenheim	100085	1.1	Havana	620	0.3
32	Elisenheim	100084	1.8	Goreangab	60180	1.1	Wanaheda	60360	0.3
33	Elisenheim	100095	1.7	Havana	610	1.1	Khomasdal	40210	0.2
34	Elisenheim	100087	1.7	Elisenheim	100070	1.0	Wanaheda	60340	0.2
35	Elisenheim	100094	1.6	Elisenheim	100095	0.8	Otjomuise	40340	0.1
36	Wanaheda	60350	1.5	Elisenheim	100068	0.8	Katutura	40060	0.1
37	Elisenheim	100089	1.4	Elisenheim	100067	0.6	Elisenheim	100085	0.1