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Bachelor thesis

Urban car-free mobility

Analysis of the applicability of a mobility concept without private cars for the Maun Science Park Botswana

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Abstract

Across the globe, urban areas experience the phenomena of rising road-congestion, air pollution and car accidents. These are just a few popular quantified effects that arise due to rapid, uncoordinated urbanization on a car-centric city layout. There is an urgent need to consider new concepts of urban mobility development to combat these negative effects. Car-free mobility is one notion adopted in diverse formats by numerous cities to create a more inclusive, just, healthy, and sustainable urban life. The focus of this thesis is to examine whether a car-free mobility concept is applicable to the Maun Science Park, Botswana. Therefore, the idea of car-free mobility, its positive aspects as well as its constraints, are described first. This illustrates the complexity of urban transport planning as it is intertwined with urban land-use, political vision and people's perceptions and behaviors. Secondly, examples and strategies on how to change existing structures are presented. Following this, the smart developments in the field of sustainable urban mobility are considered to provide an insight into their assets and drawbacks. Then the local mobility conditions are examined before the car-free concept is exemplarily applied to the Maun Science Park via scenario construction. These scenarios give a first vision of how a car-free concept can be applied to the MSP and additionally provide a starting point for future strategic planning as well as inspiration for other cities to follow along.

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List of abbreviations

BEN Bicycling Empowerment Network

BRT Bus Rapid Transit

ITDP Institute for Transport and Development Policy

MaaS Mobility as a Service

MSP Maun Science Park

NMT Non-motorized-transport

P.v.c. Personal video communication

STA Sustainable Transport Africa

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1 Introduction

Can "car-free" be the future for urban mobility? For decades, the private car was perceived to be the technology of tomorrow, the ultimate goal of individual mobility (M. Nieuwenhuijsen et al., 2018, p. 4; Urry et al., 2017, p. 7ff). Until recently, this car-centric lifestyle has experienced a constant upswing. It represented success and freedom and found as a necessity for a modern economy and society to flourish. Today, the car is dominating the mobility infrastructure, forcing other modes of transport off-road and modelling cities to fit it. However, the car is no longer the road to process and modernity (Doheim et al., 2020, Chapter 10; M. J. Nieuwenhuijsen & Khreis, 2016, Chapter 11; Urry et al., 2017, p. 19ff). The rising number of cars on this planet, with an estimated amount of 2 billion until the year 2040, comes with too many downturns to be desirable for a sustainable future (World Economic Forum, 2016). Negative impacts on the community, health, safety, equity and biodiversity are increasing. Affording the exclusive mobility of using a private car which is only accessible for few, diminishes the mobility of other, less privileged people who are dependent on public transport (Pirie, 2009, p. 22ff). Slowly, the cracks in the car-dominating cities around the world begin to evolve, making way for new concepts and perceptions of how future mobility could look like (Doheim et al., 2020, Chapter 10; M. J. Nieuwenhuijsen & Khreis, 2016, Chapter 11; Urry et al., 2017, Chapter 14ff). One increasingly popular trend both in theory and practice is making urban areas car-free. The ecologic, economic, social and health benefits are predominating. A car-free mobility infrastructure has not only the power to decrease pollution or the heat island effect, it can also increase physical activity, access to opportunity and can change the cultural status of individual mobility, marking a just, healthy and sustainable future.

1.1 Purpose and objective

This bachelor thesis picks up at this point and critically examines the concept of urban car-free mobility as well as arguments in favour of and constraints against it. Additionally, current smart mobility developments are analyzed in order to exemplarily apply these ideas to the Maun Science Park (MSP) in Botswana. The MSP is a project taking place on a newly developed land that is located in the heart of the existing city of Maun (inRES, 2020). Its aim is to become the blueprint for community development in Africa and beyond. To achieve that, it addresses local and global challenges by applying smart ideas and solutions for a future city. To be a role model of sustainability, various aspects of a city must be considered, mobility and its infrastructure being one of them. Maun's population is constantly increasing and is thus in danger of a rising demand for commuting with no proper public transport implemented, clearing the way for car-centric mobility. The answer "If I could have a car, mobility will be easy" (s. Appx. 4) of a Motswana in regard to my question what would make mobility in Maun easier for him, during a seminar about the MSP prior to this thesis, underlines the relevance of this aspect and motivated this research subject. Therefore, to fulfill the aspiration of the MSP, a sustainable mobility concept for the whole of Maun must be developed and the functionality and attractiveness of more sustainable modes of transport must be improved. Especially, as Maun has a great potential for improved mobility infrastructure and thus, should be included in the sustainable mobility concept of the MSP. For that reason, advances in mobility need to be examined and possible scenarios in harmony with the

surrounding city of Maun need to be analyzed where the focus lies on the possibility of a car-free MSP marking low carbon mobility.

The challenges that urbanization poses on mobility and the history and meaning of individual mobility are addressed in this thesis. Before deconstructing its potential and constraints, urban car-free mobility is defined. Subsequently, developments in sustainable urban mobility are introduced. Furthermore, the demography of the MSP and the existing mobility infrastructure of Maun is examined. As there is no research available on the mobility habits of the inhabitants of Maun, a sample survey and interviews are run to get a first-hand insight into the mobility experience of Maun's inhabitants. The thesis concludes in two possible sustainable mobility scenarios for the MSP which are linked to the surrounding city of Maun. The objective of this thesis is to evaluate if the MSP could be car-free and how this could look like for the MSP as well as for the whole of Maun. The research findings construct a basis for decision making when the mobility infrastructure of the MSP will be determined in the future.

1.2 Methodology

To allow a substantiated analysis of the applicability of a mobility concept without private cars in the MSP, the following mixed method of qualitative and quantitative research is implemented as illustrated in Figure 1. The first part consists of a qualitative literature review on urbanization, the development of individual mobility and the definition of urban car-free mobility. The reasons in favour and the constraints of urban car-free mobility, as well as the smart development in sustainable urban mobility, are also qualitatively analyzed within the literature review. Because of the wide variety of literature in this field, the selected subjects discussed in chapter 3, 4 and 5 only give a partial overview of it. The selection is based on its great popularity in literature and its relevance for the conceptional design of scenarios for the MSP. With hardly any regional studies on urbanization and urban mobility in Botswana, the first five chapters were mostly examined on an international scene. Also, the available, Africa specific literature, focuses mainly on the large urban areas and often disregards cultural and socio-economic aspects beyond demography. This missing data marks a significant research gap.

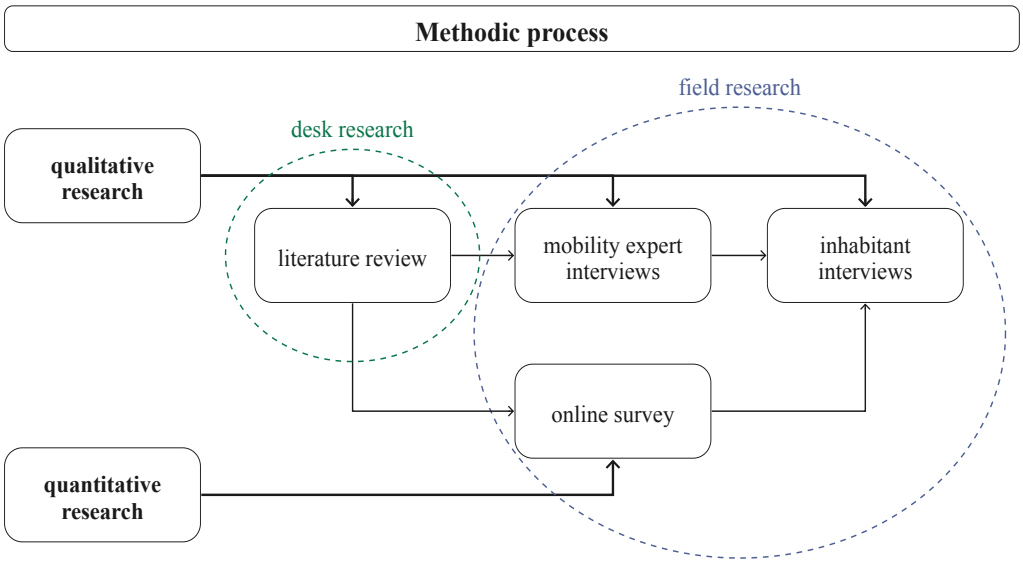


Figure 1: Methodic process

Thus, to support the desk research findings and to expand them, field research via mobility expert interviews was carried out. No contradiction between the experts' input and the literature was found. The interviews were semi-structured and virtually conducted with Henry Kamau, a director and founder of Sustainable Transport Africa in Nairobi, Kenya; Timothy Mosdell, the general manager and CEO of the Bicycling Empowerment Network in Cape Town, South Africa, and Stanley Chanzu, a transport planning associate at the Institute for Transport and Development Policy in Nairobi, Kenya in November 2020. The goal of the interviews was to answer the question of how mobility infrastructure could look like without private cars. On this basis, immersing questions regarding the challenges and changes of public transport, active mobility and car-free mobility specifically in Africa were asked. This enabled a linkage of the mostly geographically unspecific literature findings of the desk research and the trends and conditions in Africa in chapter 3, 4 and 5. The transcripts and detailed information about the interviewees can be viewed on request.

In the course of the literature review, it became evident that the mobility condition and its social, cultural and economic aspects are understudied in Botswana and non-existent in Maun. To still gain first-hand insights into the mobility situation in Maun, also despite the pandemic in 2020/21 that restricted local field research in Maun, a sample online survey with inhabitants was carried out. The questionnaire of this survey was distributed via social media platforms such as LinkedIn and Facebook. On both platforms, a total of 60 people that live in Maun were directly contacted. Additionally, the survey was distributed to 41 local Facebook groups to increase the reach. In the online survey 56 people participated of which around 60% are female and 40% male. Almost 60% of the participants are in the age range of 25-45 and around 30% are in the age range of 45-65. Further, around 43% of respondents were employed full-time, 32% were self-employed and 14% unemployed. The survey has an error margin of 13.2% and a confidence coefficient of 95%. Due to the limitation of resources and time, the missing randomness of the participants and the few answers, the findings from this quantitative research are not representative but enable an insight into the local conditions. The questions asked in the survey are targeted to gain basic information about the mobility in Maun, the mobility habits of the people and their perception of the car. The type of questions was influenced by other mobility surveys conducted such as the 'Europeans Satisfaction with Urban Transport' report requested by the European Commission and the 'Measuring Public Transport Satisfaction from User Surveys' from R. Imam (Imam, 2014; TNS Political & Social, 2014). A sample questionnaire and the results of the survey are provided in Appendix 1 and the data analysis in chapter 6.

On top of the online survey, semi-structured interviews with six inhabitants were conducted to get a more personal and detailed description of the mobility in Maun. The interviewees consist of three woman and three men that also took part in the online survey and volunteered for a more in-depth interview. Via video call, questions based on those which were already addressed in the online survey were asked to fill in the blank of how mobility in Maun looks like and how they experience it. A more detailed insight into the conditions, habits, wishes and needs in Maun was not sufficiently accomplishable in the amount of time and the limited resources of this thesis. Nonetheless, these findings are backed up by data and surveys conducted in Botswana and Gaborone, as well as photo documentation via Google Street View. The transcripts of the interviews can be viewed on request.

Through qualitative research, the idea and the location of the MSP are described. As a basis for the conclusion, answering the question of how applicable car-free mobility can be in the MSP, two scenarios are exemplary constructed along the guidelines of Schwenker and Wulf (2013) and are based on the findings of the desk research, online survey and interviews conducted during this thesis. The scenarios do not claim precise prediction and their extent and nature are consequently rather speculative as they are constricted by the lack of available local data, time and resources.

2 Concept of urban car-free mobility

This chapter illustrates the linkage between urbanization and mobility. Urbanization shapes the way people move within cities. Therefore, it is important to understand how urbanization is defined and what implications are connected with it. In an effort to do so, the development of the car as well as the definition of urban car-free mobility is discussed.

2.1 Urbanization and its consequences

Urbanization is a global development induced by rapid population growth and is shaped by the demography and physical geography of a region as well as by economic, political and social forces (Appelhans, 2015, p.23; Paramasivam & Arumugavelu, 2020, p.2). Characteristics of urbanization are the progress in energy and resource consumption, wide-spread land use and increasing population. It converts rural into urban settlements whilst changing the built environment and spatial distribution of the area. In addition to that, urbanization triggers a shift in livelihood, behavior and culture (United Nation Department of Economic and Social Affairs, 2019, p.10ff). Urbanization appears in different forms and with different speed across the globe, with Africa marking the lowest urbanization rate worldwide with 43% in 2019 (Statista, 2020). Yet, the highest urbanization is observed in small towns and intermediate cities in Africa and is estimated to intensify further (Habitat III, 2016, p. 11; Ministry of Lands and Housing, 2014, p. 4f). However, the drivers and dynamics of urbanization are complex and differentiated in every city (Appelhans, 2015, p. 23; Potts, 2012, p. 11ff). Thus, deepened research needs to be conducted to fully understand the progress and consequences of urbanization in Africa.

Nonetheless, one common dynamic of uncontrolled urbanization is urban sprawl which is especially relevant for this research as it strongly influences mobility habits (Shrivastava, 2020, p.1112). 'Urban sprawl' describes the spread out of urban areas (Paramasivam & Arumugavelu, 2020, p. 1). It is characterized by low-density housing; aligned with the American dream to have own property, living in a big house detached from other people (Łucka, 2018, p. 20). Urban sprawl is accompanied by high and inefficient land usage due to fragmented low-density development, weakening the advantages of urban areas. The increased distances in a sprawled settlement also enhance car-dependent mobility (Cervero, 2013, p. 2f). This, in particular, leads to a rise in private car ownership if the public transport and non-motorized-transport (NMT) are not developed alongside (Łucka, 2018, p. 19; Shrivastava & Singh, 2020, p. 1112). Functional separation of urban areas thereby reinforced the deterioration of NMT and public transport usage (Ortegon-Sanchez et al., 2017, p. 3f). Consequentially, almost all mobility-related activities rely on the car whereas other modes of transport are forced off the road (Urry et al., 2017, p. 7f). With a dominating car-centric transport infrastructure, and without the provision of adequate public transport and shared road space for NMT, urban sprawl further widens the gap of urban mobility supply and demand (Cervero, 2013, p.3f). Besides that, car-centric individual mobility is deeply rooted in our societies whilst coming with a high cost, namely degrading the environment, equity, community, health and safety of cities (Paramasivam & Arumugavelu, 2020, p. 4ff; Shrivastava & Singh, 2020, p. 1112f).

2.2 History of car-centric individual mobility

As of the early 1900s, horse carriages have made a place for motorized vehicles (Urry et al., 2017, p. 7). The combination of cheap oil and Fordism[1] lead to the car quickly being established as the dominant mode of transport. Since then, cities have increasingly been designed to suit the car. The car is a complex assembly rather than a single unit. It consists of tangible properties, such as components and resources, as well as intangible ones that both shape the mobility we know today. Mobility not only includes roads, cars or buses but also includes properties, such as perceptions, ideas and wishes of people. Mobility nowadays is, among other things, shaped by status and financial means. Thus, in the course of its development, the car transformed and still transforms environments, economics and societies (Ortegon-Sanchez et al., 2017, p. 3f; Urry et al., 2017, p. 7). As Urry et al. put it; "Until recently, this car system has had much forward momentum, spreading and bending almost every society to its will" (Urry et al., 2017, p. 8).

Nowadays it is, consequentially, difficult to picture a world without cars (Ortegon-Sanchez et al., 2017, p. 3ff). However, as the negative effects, for instance congestion, air pollution and road accidents, have risen, transport policies of some cities have redirected their focus on NMT and public transport. Despite the developed conceptions of the car and the resistance against car-free mobility, gaps are opening that counter these trends (M. Nieuwenhuijsen et al., 2018, p. 4f; Ortegon-Sanchez et al., 2017, p. 4ff; Pirie, 2009, p. 27f; Urry et al., 2017, p. 14ff). Although sales revenues are still directing the objectives of the car industry, they are increasingly conscious of the environmental, social and economic drawbacks. Today, non-petrol-based fuel types and technologies are researched and tested. Car-centric mobility is no longer sensed as the only way forward. Also, transport planning policies gradually sway towards car-lite, car-restraint or even car-free intentions. Rebranding mobility towards NMT and public transport, not only by policymakers and the car industry but also by society, is underway (Sims & Schaeffer, 2014, p. 613; Urry et al., 2017, p. 14ff).

Younger generations, for example, are pushing the development of collaborative economy, such as renting on-demand instead of buying goods and services. There are aspirations to transfer this trend onto mobility behavior as well (Wong et al., 2018, p. 16). The change in work habits, social life and shopping trends, that increasingly conceptualized online and virtual media, will also change mobility needs and its status in the long run. Thus, it is crucial to flank this beginning transition towards less car-dependent urban mobility with the best possible means, such as setting positive incentives, ensuring a functional and supportive transport infrastructure and fostering acceptance (Ortegon-Sanchez et al., 2017, p. 3).

2.3 Definition of urban car-free mobility

In alignment with the openness for new ways of life, sustainable approaches in transport planning must be given more consideration to handle urbanization, its induced urban sprawl and its negative effect on urban mobility (Cervero, 2013, p. 2). A possible remedy is densification, decentralization and a resilient urban transport system in which car-

[1] Fordism is as a specific form of operation organization targeted on mass production. Thereby, shift systems allow maximum usage of labor power and thus low-cost standardized products being sold on large scale (Hudson, 2009).

dependency is obliterated (M. Nieuwenhuijsen et al., 2018, p. 5; Orvañanos Murguía, 2018, p. 10). In this research, the concept of "car-free" mobility is, aligned to Nieuwenhuijsen (2018), focusing on the reduction or even exclusion of the necessity of private cars within urban centres. At the same time, it does not implicate the outright elimination of all motorized vehicles (M. Nieuwenhuijsen et al., 2018, p. 3ff). It may still include public transport, emergency vehicles, goods and services delivery, car-sharing options or even self-driving cars. Urban car-free mobility rather implies a hierarchy of modes in which pedestrians are the priority. In descending order, the bicycle, public transport and the private car follow within that hierarchy, with the private car having the least priority (Orvañanos Murguía, 2018, p. 8). Besides, the remaining motorized vehicles within that concept are aspired to consist of the most sustainable options such as electric cars (M. Nieuwenhuijsen et al., 2018, p. 3). The term "car-lite" compared to "car-free" implies a less restrictive suspension of car usage or ownership (Foletta & Henderson, 2016, p. 1). The concept "car-free" includes heavier restrictions, such as closed off streets for cars, whereas the concept "car-lite" only discourages car usage by reducing traffic speed, for instance.

The goal of urban car-free mobility is to reduce the negative environmental and socio-economic impact of a car-dependent system as it is nowadays manifested in most cities worldwide (Kone, 2020, p. 189). The attractiveness of private car usage is to be decreased and the attractiveness of sustainable modes to be increased (Ortegon-Sanchez et al., 2017, p. 7). A resilient, low carbon, healthy and socially just transport system aspires to provide incentives in order to make NMT and public transport more convenient than the private car. This can be achieved by optimizing the NMT and public transport infrastructure towards a multimodal transit-oriented development (Friman & Olsson, 2020, p. 178). Hence, offering valuable alternatives to the car, changing mindsets and fostering the motivation to change transportation habits is crucial. Through a wide range of mode options, less car-dependency can be induced as the needs and wishes of individuals can be met and thus, freedom of choice can be incorporated (Orvañanos Murguía, 2018, p. 8). The objective is a transition from car-dependent, unequal and unsustainable mobility towards inclusive and accessible mobility which works for all, regardless of the availability of a private car (M. Nieuwenhuijsen et al., 2018, p. 4).

Since there are hardly car-free cities, besides Venice island in Italy for instance, there is few empirical research on the changes resulting from such a transition (Urry et al., 2017, p. 18). Thus, further research to understand the full impact of car-free mobility needs to be conducted. However, in the course of this research, there are several pieces of research mentioned that include examples of cities that have pedestrianized areas or have car-free days like Addis Abeba, Bologna, Johannesburg, Madrid and Mexico City, only to name a few (Doheim et al., 2020, Chapter 10). They give an insight into the consequences urban car-free mobility might have and show that a conglomerate of diverse initiatives is needed to facilitate car-free mobility and to overcome potential barriers associated with it (Ortegon-Sanchez et al., 2017, p. 7).

3 Reasons for urban car-free mobility

The following section discusses the need for urban car-free mobility in light of the current global transportation situation. It illustrates the opportunities of urban car-free mobility as it could be a possible remedy for the negative effects of the prevailing car-dependent mobility. These effects are expanding environmentally, economically and socially and pose challenges to the efficiency and sustainability of urban mobility. Urban car-free mobility, on the other hand, holds many opportunities to refocus on sustainability and to leapfrog into an equal, healthy, safe and clean urban mobility. As mentioned before, there is no real-life experience regarding total urban car-free mobility transitions in Africa available which means that the exact outcomes are not scientifically proven and can only be assumed based on similar experiences.

3.1 Reinforcing equity and quality of life

Car-dependent urban mobility is not democratic and not beneficial to everyone. It fosters the need for a car and enhances urban sprawl even more while further diminishing the mobility of those who cannot afford it (Haq & Schwela, 2012, p. 46; Pirie, 2009, p. 23ff). People are getting increasingly isolated as the distances are enlarging the journeys become a bigger effort, more time-consuming and costly. When no means of transport other than the car are available to access necessities such as education, jobs and retail or health services, the transportation system is insufficient and unequal (Haq & Schwela, 2012, p. 46; M. Nieuwenhuijsen et al., 2018, p. 3ff). As Nieuwenhuijsen says "the gains by those who can profit from the infrastructure for cars comes at the expense of those who do not use them" (M. Nieuwenhuijsen et al., 2018, p. 3). Segregation prevents people from participating in society, depending not only on their economic situation but also on their physical, social, religious or ethnical characteristics (M. Nieuwenhuijsen et al., 2018, p. 3f; Pirie, 2009, p. 30). The lack of access results in social exclusion, unemployment, deterioration of health and dissatisfaction.

The described mobility gap between rich and poor in Africa is especially severe, resulting in the less privileged having to walk long distances to access opportunities, costing them precious time and energy (Pirie, 2009, p. 22; H. Kamau, p.v.c, Nov. 27, 2020). In the interview with H. Kamau and T. Mosdell, it was mentioned that due to financial constraint, people need to walk many kilometers per day to reach opportunities, resulting in security issues as they often have no other choice than walking even when it's still or already dark (H. Kamau, p.v.c, Nov. 27, 2020; T. Mosdell, p.v.c., Nov. 30, 2020). With a greater focus on active mobility and the intensification of public transport, the journey time could be shortened and the mobility made more affordable (Cervero, 2014, p. 180; Pirie, 2009, p. 30). This can enhance individual mobility and freedom of choice which in turn is beneficial to equality and life satisfaction (Friman & Olsson, 2020, p. 172).

In addition to that, communities are currently being shaped and often detached by road networks and urban sprawl as anonymity displaces social interaction (Cheshmehzangi & Butters, 2016, p. 69; Łucka, 2018, p. 19; WHO, 2009, p. 22). Valuable space that could be used otherwise is occupied by parking spaces and roads, fragmenting the city (Czarnecki, 2018, p. 58; Urry et al., 2017, p. 11). The free movement of pedestrian and cyclists is complicated (Paramasivam & Arumugavelu, 2020, p. 6; WHO, 2009, p. 22). Many congested areas can become localities of crime and social unrest which has a direct impact on social health and well-being. Through a shift from private cars to NMT and

public transport preconditions for a high standard of quality of life can be given as it equals the access to opportunities (M. Nieuwenhuijsen et al., 2018, p. 7). Space that was formerly lost by a car-centric infrastructure can be regained for the people (Urry et al., 2017, p. 17). Moreover, social interaction and inclusion are fostered (M. J. Nieuwenhuijsen & Khreis, 2016, p. 256). Taking the relationship between mobility and feelings into account whilst planning and repurposing road infrastructure for NMT and public transport can revive these crucial social functions.

3.2 Increasing safety and health

Additionally to inequality, rising motorization leads to an increase in traffic congestion, air and noise pollution, road accidents and physical inactivity which impair the health (Haq & Schwela, 2012, p. 1; WHO, 2018a). Globally there are 1.35 million road traffic deaths each year, being the 8th leading cause of death (WHO, 2018a, p. 4ff). For children, traffic death is the 1st leading cause as they are one of the most vulnerable groups when walking to school without a proper pedestrian infrastructure, for instance. Africa has the highest road traffic death rates worldwide with 26.6 death per 100.000 people. Furthermore, 44% of those road traffic deaths are amongst pedestrians and cyclists. This illustrates that the mobility infrastructure is laid out to suit the car and does not reflect the fundamental needs to protect NMT users. Consequentially, the lack of safe and affordable transport as well as the lack of adequate NMT infrastructure discriminates and threatens the most vulnerable groups of society. With a decrease in motorized vehicles, a rapid decline in NMT road accidents would follow (M. J. Nieuwenhuijsen & Khreis, 2016, p. 255).

Besides road accidents, many poor people are exposed to high levels of urban air pollution as they live close to the biggest and busiest roads (Haq & Schwela, 2012, p. 1). This can cause severe health risks as the pollutants affect the reproductive functions and the nervous-, immune- and endocrine-system negatively. Another drawback of car-dependency is the decrease in physical activity. Globally, a sedentary lifestyle is estimated to be responsible for 3.2 million deaths each year (WHO, 2009, p. 3). Physical inactivity might lead to ischaemic heart disease, a stroke, diabetes, breast and colon cancer as well as depression and anxiety (WHO, 2009, p. 21, 2018b). With urban car-free mobility, physical activity would increase and the psychology and fitness of people would improve as well as their sense of freedom and relaxation fostered (M. J. Nieuwenhuijsen & Khreis, 2016, p. 256).

3.3 Mitigating climate change

Mobility is not only inseparably linked to health but also to climate change (Price, 2016, p. 2). The transport sector accounts for 24% of direct CO2 emissions worldwide with road vehicles being responsible for nearly three-quarters of CO2 emission which stresses the need for a sustainable modal shift and improvement in mobility efficiency (IEA, 2020; Sims & Schaeffer, 2014, p. 603). The transport sector generated 8.2 Gt of direct CO2 emissions in 2018 alone, from which passenger road vehicles account for the biggest share of 3.6 Gt of CO2 emissions and the trend is upward (IEA, 2019, 2020). A higher car-dependency induced by sprawl further increases the utilization of fossil fuels and thus a higher discharge of CO2 emissions (Kone, 2020, p. 189; Paramasivam & Arumugavelu, 2020, p. 6). Moreover, the urban heat island effect, due to the removal of vegetation for the expansion of road networks, is intensifying with increased urbanization and car-

dependency (M. J. Nieuwenhuijsen & Khreis, 2016, p. 245ff). This amplifies in higher urban temperatures, having a direct impact on human health and reinforcing the effect of climate change.

By centering the transport planning less on private vehicles but rather on NMT and public transport the CO2 emissions can be decreased by up to 43% (Price, 2016, p. 2). Private vehicle usage can be reduced by 50% whilst making way for low-carbon mobility modes. The consequential decrease in CO2 emissions would not only result in climate change mitigation but also in the reduction of the direct and indirect effects of climate change (M. J. Nieuwenhuijsen & Khreis, 2016, p. 256). Hence, urban car-free mobility can lessen the resulting economic, social and environmental damage connected with climate change, such as heatwaves or water scarcity. Besides, more space can be used to introduce green corridors that weaken the urban heat island effect (M. J. Nieuwenhuijsen & Khreis, 2016, p. 245ff).

The points above illustrate that there is an urgent need to improve the transportation sector (Cervero, 2013, p. 2; Shrivastava & Singh, 2020, p. 1112). To handle urban sprawl and its consequences, future urban mobility must prioritize more sustainable modes of transport. A paradigm shift is needed to decarbonize the sector, reduce costs and create socially just urban mobility. As Kone put it; "the car-free city is a new concept that every city has to adopt for a better tomorrow" (Kone, 2020, p. 185). The possible solution of urban car-free mobility requires facilitators improving alternative modes of transport and supporting car-free mobility as its introduction comes with many obstacles to overcome (M. Nieuwenhuijsen et al., 2018, p. 5).

4 Potential and constraints of urban car-free mobility

The transition to urban-car-free mobility is not straightforward and constraints are faced in multiple areas. Although the previous chapter has illustrated several reasons to promote mobility aside from a car-centric infrastructure some constraints need to be considered to address the concept critically. Therefore, in the course of this chapter, the challenges and chances in urban land use, public transport and NMT infrastructure, mindset and acceptance as well as data collection and analysis are discussed.

4.1 Strategic urban land use

Urban sprawl and a car-centric lifestyle have led to the centralization of activities rather than to mixed and dense urban land use (Orvañanos Murguía, 2018, p. 10). The challenge is to change these solidified urban environments into more compact but decentralized ones (Doheim et al., 2020, p. 258f). This can decrease the need for a private vehicle as goods and services would no longer be centralized in one specific point but would rather be locally accessible in the neighborhood with NMT or public transport (Banister, 2011, p. 1541; Doheim et al., 2020, p. 259). NMT especially becomes more attractive and is encouraged when distances are reduced and could consequently decrease the imperative for cars. In addition to that, a densified and decentralized urban environment would decrease the overall demand for mobility (Friman & Olsson, 2020, p. 178).

Further, in order to develop more sustainable urban mobility, the integration of mixed land use and high capacity transportation is crucial (Suzuki et al., 2013, p. 3). Land prices often increase around areas of high mobility, such as main streets and transit stops which gradually drive low-income housing to the outskirts of cities (Łucka, 2018, p. 19; Suzuki et al., 2013, p. 19). The often insufficient transport infrastructure lacks connection and is thereby excluding and depreciating people with lower incomes even further (Cervero, 2013, p. 8). Especially in developing countries, some people cannot afford other options than walking (Cervero, 2013, p. 5). For those captive walkers, an improved urban land usage would enhance their mobility and thus, their opportunities and quality of life. Decentralization can assists equal accessibility and can consequentially also reduce car-dependency (Doheim et al., 2020, p. 259).

Considering these aspects, a strong and supportive national and local governance is needed which coordinates and funds the planning and enforcement of densifying and decentralization measures (Suzuki et al., 2013, p. 15). With regional knowledge at hand and the cooperation with local stakeholders, accountability and strong leadership for long term sustainable development is fostered. Strategies and measures need to align with the local conditions as the regional topography can pose another challenge to urban land use and thus to the optimization of urban mobility (Orvañanos Murguía, 2018, p. 10; Suzuki et al., 2013, p. 15f). Man-made-barriers, for instance roads without proper crossing or bridges, disconnect continuity and hence pose difficulties for NMT (Orvañanos Murguía, 2018, p. 16). Natural barriers such as water bodies, for example rivers as well as a hilly landscapes, have the same effect. In Addis Abeba for instance, the hilly landscape inhibits the utilization of NMT (Doheim et al., 2020, p. 257). Hence, a high-quality and well-thought-out city layout and transportation infrastructure and service need to be planned, financed and implemented as well as land pricing regulated and adjusted to ensure coverage and accessibility (Doheim et al., 2020, p. 258; Suzuki et al., 2013, p. 17ff).

An obstacle to overcome is that in developing countries long term planning strategies are often missing (Suzuki et al., 2013, p. 8). As Suzuki et al. put it; "Motivated by the need to see results while current city leaders are still in office, city administrations and transit agencies often adopt a short-term, narrow focus" (Suzuki et al., 2013, p. 8) but fail to induce sustainable long-term vision and change. Shortage of planning and coordination on the municipal level, silo behavior, administrative and financial limitations as well as poor urban planning and supporting mechanisms for restructuring urban design hinder enhanced urban mobility. Therefore, mobility patterns are mostly determined by uncontrolled urban growth instead of defining the urban design in consideration of mobility needs (Suzuki et al., 2013, p. 14). However, proactive urban land use management is necessary to densify and decentralize urban living as to enable urban-car-free mobility (Doheim et al., 2020, p. 258; Suzuki et al., 2013, p. 20).

4.2 Funding of public transport infrastructure

Another essential prerequisite that facilitates a transition towards urban car-free mobility suggested by Nieuwenhuijsen (2018) is political management and vision (M. Nieuwenhuijsen et al., 2018, p. 6). Thus, recognizing that political vision must engage with the environmental, social and economic aspects of mobility collectively as a continuing investment in roads solely doesn't seem to solve the present mobility problems (Cervero, 2013, p. 8; Walters, 2008, p. 98; S. Chanzu, p.v.c, Nov. 24, 2020). One aspect of this is the prioritization of political and financial investment in NMT and public transport rather than in modes with already high accessibility like cars (M. Nieuwenhuijsen et al., 2018, p. 6; Urry et al., 2017, p. 19ff). This means reducing external costs of mobility and scaling the benefits of sustainable modes of transport by redirecting funding towards these modes and rewarding eco-friendly, socially and economically equitable behavior (Cervero, 2013, p. 8).

Currently, developing countries face a shortage of investment in the transportation system (Doheim et al., 2020, p. 257). In Sub-Saharan Africa, government spending for any public transport other than road infrastructure is rare as "governments are too cash-strapped and under-staffed to mount and sustain effective and reliable mass transit services" (Cervero, 2013, p. 4). Merely few cities in developing countries have a fairly sufficient public transport infrastructure and most of them being covered through private and often informal operators (Doheim et al., 2020, p. 257). In Addis Abeba, for instance, the absence of such resources negatively impacts the transportation system. The lack of quality and quantity of the transport system leaves the demand for mobility unfulfilled as local buses only cover up to 35% of motorized rides. S. Chanzu and H. Kamau mentioned in the interviews that the current informal transportation system in many African cities, which hardly ever provide timetables, make it hard for people to plan and rely on it (S. Chanzu, p.v.c, Nov. 24, 2020; H. Kamau, p.v.c, Nov. 27, 2020). As they have to wait for an uncertain amount of time for buses to arrive, it makes more sense to use the private car when possible. Regardless of the fact whether transportation is privately or publicly owned, the business model of the transportation system must change from a passenger-based profit model to a kilometer-based profit model. The predominant form of payment per amount of passengers encourages the drivers to speed and to break rules to get an extra passenger in order to generate more income. A kilometer based business model, on the other hand, makes public transport more structured and reliable, less congested and less dangerous as the drivers do not have the pressure to find more passengers.

A resilient and safe transportation system that has sufficient geographical coverage must be installed first before the dependency of the car can be decreased by political measures (Doheim et al., 2020, p. 258). When public transport stations are, for example, situated in a radius of a five minutes walking distance, sustainable mobility behavior is improved and the usage of NMT and public transport is encouraged as well. Thus, to foster a modal shift and to establish an efficient, sustainable transport system which is less car-dependent, a paradigm shift from car-centric towards multimodal, demand driven and accessible transport planning policies is required (Banister, 2011, p. 1541; Olafsson et al., 2016, p. 124). Yet, H. Kamau noted that without governmental resources to establish such measures, informal transport will fill the demand gap in the transport system as it did in the past (H. Kamau, p.v.c, Nov. 27, 2020).

To further fund the public transport infrastructure usage, restrictive and supportive political measures can be implemented next to the establishment of a well-connected mixed-use transport system with wide coverage and frequency (Banister, 2011, p. 1541; Doheim et al., 2020, p. 258). Incentives rather than punishment should dominate the transport policies as they have greater societal acceptance and better political feasibility (Doheim et al., 2020, p. 259; Friman & Olsson, 2020, p. 167). Restrictive measures that discourage nonessential use of the private car and facilitate public transport usage include a motorized vehicle ban in city centers, limitations of parking and increased parking costs, taxations on vehicles and fuel or road pricing (Friman & Olsson, 2020, p. 167; Ortegon-Sanchez et al., 2017, p. 8). Further restrictions could be enforced in the number of driver licenses, car production or car ownership (Ortegon-Sanchez et al., 2017, p. 8; Urry et al., 2017, p. 19). However, these restrictive measures limit or even eliminate freedom of choice which mitigates the quality of life (Friman & Olsson, 2020, p. 168f). Therefore, T. Mosdell suggests that car-restrictive measures should only be implemented if a sufficient transport system is already established (T. Mosdell, p.v.c., Nov. 30, 2020).

Another constraint is that inadequate facilities, low frequency, high crowding, low safety from accidents and low vehicle roadworthiness drive people away from using public transport and with a growing middle class, people who can afford it switch to the car in an instance (Walters, 2008, p. 99). Thus, public transport policies also need to prevent current NMT and public transport users to shift (Orvañanos Murguía, 2018, p. 7; Walters, 2008, p. 99). In order to do so, public transport needs to be promoted and politically funded with a true political effort to change the persistent transport system (Cervero, 2013, p. 8; Orvañanos Murguía, 2018, p. 7; Walters, 2008, p. 99; H. Kamau, p.v.c, Nov. 27, 2020). The recommended supportive measures aim at people voluntarily switching and being rewarded for sustainable transport behavior without simultaneously decreasing their autonomy along the way (Friman & Olsson, 2020, p. 168f).

These incentives could include the provision of a resilient, flexible, multimodal, accessible, safe, affordable and reliable transport system as a basis (Doheim et al., 2020, p. 258ff; Pirie, 2009, p. 31). One example for fostering the usage of public transport, suggested by H. Kamau is making it more convenient through easy ticketing (H. Kamau, p.v.c, Nov. 27, 2020). Off-board, online ticketing that offers daily, weekly or monthly discount options increases its attractiveness. Also, security is an issue that can be tackled to foster public transport usage as many people prefer using a private car as it provides them higher personal safety. Through appointing security guards or the installation of cameras, the security of public transport can be increased as well as the willingness to use them.

The affordability of public transport is another barrier for the very poor in developing countries and poses a challenge to urban car-free mobility (Cervero, 2013, p. 8; Walters, 2008, p. 99). S. Chanzu mentioned that the fairs of private, informal transport are often demand-based and not regulated (S. Chanzu, p.v.c, Nov. 24, 2020). This means that fairs change depending on various factors, such as the weather conditions or rush hours. At peak hours fares are higher than off-peak fares, resulting in likewise fluctuations of the affordability of public transport. In the case of people not being able to afford public transport, they have to walk, cycle or wait for off-peak hours until they can use transportation again which poses a great challenge to equal access. Through governmental subsidies and fare regulation, this problem could be mitigated. However, H. Kamau also points out that those making decisions are also those who drive cars which is why public transport is mostly not made a priority in the political discourse (H. Kamau, p.v.c, Nov. 27, 2020).

4.3 Sufficient non-motorized transport infrastructure

The current transport infrastructure is constructed to meet the needs of the car although the majority of the mobility mode share is NMT and public transport as stated by S. Chanzu, H. Kamau and T. Mosdell (S. Chanzu, p.v.c, Nov. 24, 2020; H. Kamau, p.v.c, Nov. 27, 2020; T. Mosdell, p.v.c., Nov. 30, 2020). The cycle-infrastructure, prevailing in many cities, illustrates this disparity and the need to shift the focus of transport planning towards NMT. Although some countries in Africa have a high share of cyclist and dedicated cycling infrastructure, there are still many that lack such and hence, hinder the wide usage of the bicycle (Orvañanos Murguía, 2018, p. 29; H. Kamau, p.v.c, Nov. 27, 2020). Thereby S. Chanzu and H. Kamau noted that sometimes, even when cycle paths are available, motorized vehicles such as motorcycles occupy these dedicated areas (S. Chanzu, p.v.c, Nov. 24, 2020; H. Kamau, p.v.c, Nov. 27, 2020). This results in a lack of road space for cyclists, making it dangerous to use and consequently decreasing the number of people using the bicycle to commute. In the case of South Africa for instance, more people are walking than cycling as many people walk long distances even without sufficient infrastructure at hand, which is way harder for cyclists. With a proper infrastructure where cyclist get their share of the road and are protected from motorized travel, this may change. Road education and law enforcement additionally can increase road safety (Orvañanos Murguía, 2018, p. 25). Political will is here again a major driver. T. Mosdell remarks that without political and financial funding of NMT infrastructure, active modes will have a hard time to establish broadly (T. Mosdell, p.v.c., Nov. 30, 2020).

Thus, road space needs to refocus on NMT and its currently often still inadequate infrastructure (Doheim et al., 2020, p. 258ff; S. Chanzu, p.v.c, Nov. 24, 2020). That means building infrastructure and facilities for pedestrians and cyclists such as wide, marked and paved lanes, bike parking, green corridors, shelters, crossings, streetlights and meeting the needs of disadvantaged and disabled (Ortegon-Sanchez et al., 2017, p. 7; Orvañanos Murguía, 2018; Urry et al., 2017, p. 20). S. Chanzu mentioned that when sufficient infrastructure is missing and shelters, for instance, are not provided, it is a challenge to use anything other than the car under adverse weather conditions (S. Chanzu, p.v.c, Nov. 24, 2020). Through green street design and landscaping, shade and protection can be provided through trees and the effects of adverse weather conditions can be mitigated (Orvañanos Murguía, 2018, p. 23f; S. Chanzu, p.v.c, Nov. 24, 2020). Vegetation reduces the heat island effect and cleans the air which increases climate

comfort (Orvañanos Murguía, 2018, p. 23). This can have a significant effect on NMT usages as people cover greater distances by foot and bike when the environment is comfortable and pleasant.

The simplification and changing of the choice architecture through signposting bike or pedestrian lanes, which increases their visibility and wayfinding, can nurture active mobility further (Friman & Olsson, 2020, p. 169f). Drainages are relevant as to hinder flooding that can make NMT usage impossible (Orvañanos Murguía, 2018, p. 23). The removal of obstacles, such as open drains or potholes, is important as it would otherwise discourage NMT usage (Orvañanos Murguía, 2018, p. 15). The lighting of pedestrian and cycle paths as well as public transport infrastructure is fundamental for comfort and safety (Orvañanos Murguía, 2018, p. 22; H. Kamau, p.v.c, Nov. 27, 2020). In addition to that, activity is increased by lighting as people walk and bike outside longer, generating higher economic turnover (Orvañanos Murguía, 2018, p. 20ff). The accessibility to the transportation system must be secured by stairways, bridges and ramps to overcome topographical barriers. For cyclists especially the road surface is important as cycle pavement works best with a smooth surface combined with nonslip qualities (Orvañanos Murguía, 2018, p. 33).

Further measures that foster the usage of NMT are traffic calming through speed bumps or raised crossing at low volume roads (Orvañanos Murguía, 2018, p. 37). These measures can be effective especially when combined with making the usage of NMT a desirable experience by increasing road space and promoting urban densification (Orvañanos Murguía, 2018, p. 10ff). Urban centers, areas of service facilities as well as recreational areas, such as parks, are priority NMT areas. Pedestrianizing those priority areas within a city has great potential for urban-car free mobility (Orvañanos Murguía, 2018, p. 43). H. Kamau noted that whilst it does not pose a challenge for most people to use active modes of transport, elderly and disabled must be taken into account and sufficient facilities need to be implemented for them (H. Kamau, p.v.c, Nov. 27, 2020). In Nairobi, several streets have already been pedestrianized such as the Aga Khan Walk street for instance (Njeru & Isami, 2018; S. Chanzu, p.v.c, Nov. 24, 2020, p. 175ff). The car-free streets are a success although shop keeper have been concerned that the number of customers would decrease when the street is closed off to traffic (Orvañanos Murguía, 2018, p. 42; H. Kamau, p.v.c, Nov. 27, 2020). It turned out to be beneficial for them as more costumer were recorded.

Superblocks in Barcelona are another example of car-free areas. Within one superblock there are nine building blocks wherein cars are restricted. The limited vehicles that are allowed need to move at minimal speeds of 10km/h (M. Nieuwenhuijsen et al., 2018, p. 12). For such concepts the NMT pathways and facilities must be interconnected with public transport as to sufficiently improve the city's mobility and not to cut-off the inhabitants from the rest of the city (Orvañanos Murguía, 2018, p. 45f). The intermodal connection increases the efficiency of the transport system as it increases the catchment area. Apart from Nairobi and Barcelona, similar car-free or car-calmed roads and areas have been introduced in many cities across the globe, including Copenhagen, Oslo, London and Paris, just to name a few (Doheim et al., 2020, Chapter 10).

4.4 Acceptance and mindset change

The acceptance of car-free mobility especially is an essential point as the alteration of the mindset and perception of the people is a major challenge (M. Nieuwenhuijsen et al., 2018, p. 2). It is a fundamental desire of people to achieve autonomy, independence, self-determination and freedom of choice and it is nowadays often gained by owning a car (Friman & Olsson, 2020, p. 167). The ease and convenience of mobility with a private car is enviable by those who cannot afford it as they are extradited to an insufficient transportation system not meeting these desires (Pirie, 2009, p. 23ff). The car is often the most suitable choice as the urban layout is fitted for the car with an absence of alternative options (Friman & Olsson, 2020, p. 167). This results in education, occupation, goods and services or leisure activities often only being accessible by car, making it a necessity to own one. Thus, the car is consistently established as a crucial premise to participate in society and move comfortably in a city (M. Nieuwenhuijsen et al., 2018, p. 4).

It is perceived that the higher the personal mobility the better (Pirie, 2009, p. 27). As Cheshmehzangi and Butters describe it, the aspiration in developing countries to own a car "is a seemingly unstoppable ambition" (Cheshmehzangi & Butters, 2016, p. 69). Sustainability is thereby mostly not considered (Pirie, 2009, p. 27). News, social media and companies promote private car ownership as desirable, strengthen this mindset and portray active and public transport as a second-best and primitive alternative. T. Mosdell mentioned that this mindset is difficult to overcome as active modes are often counter aspirational by some people that historically connect it with poverty and limited mobility (T. Mosdell, p.v.c., Nov. 30, 2020).

Sometimes, there is a pure necessity to travel by private transport in order to transport goods and services as well as to ensure the accessibility for immobile people or covering remote, long-distance journeys (M. Nieuwenhuijsen et al., 2018, p. 5; Sims & Schaeffer, 2014, p. 8). Though, apart from that, there is a symbolic function attached to the car which is expressed through values, such as status, power, masculinity and success, as well as through aesthetics, speed, safety and superiority (Cheshmehzangi & Butters, 2016, p. 69; Friman & Olsson, 2020, p. 167; Pirie, 2009, p. 23; Sims & Schaeffer, 2014, p. 8). The ambition to own a car is universal and highly persistent in Africa too (Pirie, 2009, p. 23; H. Kamau, p.v.c, Nov. 27, 2020). The conception mentioned by Pirie, "You are what you drive" (Pirie, 2009, p. 27f) is challenging to subtend and to annul. Furthermore, there is a psychological barrier hindering some people to abandon the personal space of a private car (Wong et al., 2018, p. 6). In Denmark for instance, concepts such as ride-sharing are negatively associated with issues of safety, social awkwardness or even social marginalization (Sovacool & Griffiths, 2020, p. 4). Our upbringing, teaching us to never get into a car with a stranger, is rooted deeply within us. Hence, convincing the people acquainted to car-centric mobility of the benefits to switch to NMT and public transport is a challenge (M. Nieuwenhuijsen et al., 2018, p. 13).

Also, asking disadvantaged people thriving for high mobility to abandon their aspirations is a defiance (Pirie, 2009, p. 32). Pursuing some impersonal and invisible political objectives of social equality and environmental as well as economic sustainability does not further encourage the willingness for personal constraints. However, without the willingness of the individual to change their mobility behavior the implementation of urban car-free mobility will have a hard time (Friman & Olsson, 2020, p. 179; M. Nieuwenhuijsen et al., 2018, p. 14). Pirie says "Moralizing car ownership and use is no small matter" (Pirie, 2009, p. 32) and thus altering those well-established travel patterns

and aspirations will need time, patience and proper incentives (M. Nieuwenhuijsen et al., 2018, p. 14). H. Kamau says that with a proper transport infrastructure in place, a momentum can be created that reduces car-ownership and fosters a shift towards public transport and NMT (H. Kamau, p.v.c, Nov. 27, 2020). Especially as perceptions are changing, the younger generation does not seem as persistent to own a car themselves. With a lack of transport infrastructure supporting more sustainable modes, however, the necessity to own a car might be inevitable.

To deal with this grand issue of acceptance and perception, the participation and involvement of the people affected in those transformation processes is crucial (Doheim et al., 2020, p. 259; Orvañanos Murguía, 2018, p. 51). In the long run, the transition to more sustainable transport options requires a framework that identifies and meets the needs of the people rather than stripping them off their autonomy and thereon minimizing their quality of life (Friman & Olsson, 2020, p. 169). As Doheim, Farag and Badawi put it "the core concept of successful car-free city transformation is based on putting people first" (Doheim et al., 2020, p. 259ff). The inclusion of the ideas and wishes of the people in the transport planning as well as their understanding and support for it is the backbone of a prosperous shift towards urban car-free mobility.

To ensure such, awareness is to be raised and people to be incorporated in decision-making processes before final decisions are made by governments. Discussions and idea-sharing with diverse stakeholders, such as local inhabitants and businesses, the car industry, the government and non-governmental organization, can further facilitate acceptance (Doheim et al., 2020, p. 259ff; M. Nieuwenhuijsen et al., 2018, p. 8). H. Kamau gave the South Africa's recapitalization program, which aimed at the restructuring of the public transport system, as an example for that (H. Kamau, p.v.c, Nov. 27, 2020). Thereby public transport operators, functioning as important stakeholders, were involved in the process of the ideation phase and decision making of the new transport system to prevent resistance (Walters, 2008, p. 98ff; H. Kamau, p.v.c, Nov. 27, 2020). There were also compensated for their loss and retrained to fit the new system. In the case of South Africa, these measures had the biggest success for a smooth transformation of the transport system.

Further, pre-initiatives, for example car-free days or information campaigns, illustrate the social and environmental advantages of urban car-free living and could help to amplify a car-free moral foundation (Doheim et al., 2020, p. 259ff; Urry et al., 2017, p. 21f; S. Chanzu, p.v.c, Nov. 24, 2020). Promotional campaigns that deal with the challenges of urban car-free mobility through education and engagement are another way forward (Orvañanos Murguía, 2018, p. 51ff). Establishing a national cycle team as an advocacy group, conducting bike-repair workshops or implementing seminars for traffic education in schools, functioning as capacity building measures, are just a few examples of the initiatives that can be done (Orvañanos Murguía, 2018, p. 51ff; S. Chanzu, p.v.c, Nov. 24, 2020). Further, benchmarking with best practices in global standards or simply between other cities or countries can encourage car-free mobility behavior (Doheim et al., 2020, p. 259ff; Pirie, 2009, p. 31). To increase public acceptance, well-communicated goals, their implementation, effectiveness and success must be evaluated and published (Doheim et al., 2020, p. 259ff; Friman & Olsson, 2020, p. 171).

These measures help to increase knowledge, foster motivation and encourage people to use more NMT and public transport (Friman & Olsson, 2020, p. 178; Orvañanos Murguía,

2018, p. 51ff). They are a chance to root a positive image of NMT and public transport and to shake off obsolete perceptions of them being a mode of transport for the poor or a second-best alternative (Orvañanos Murguía, 2018, p. 51ff; S. Chanzu, p.v.c, Nov. 24, 2020). As S. Chanzu and H. Kamau put it; it must be illustrated that it's a choice rather than a condition that your financial situation accounts for (S. Chanzu, p.v.c, Nov. 24, 2020; H. Kamau, p.v.c, Nov. 27, 2020). The right branding of NMT and public transport is a key aspect.

4.5 Data as a fundament for planning

To design urban car-free mobility, the local conditions of each city must be understood (M. Nieuwenhuijsen et al., 2018, p. 7f). This can be done through the collection and analysis of data. These data include primary, fundamental information on demographics like the age, gender, income patterns and urban land use such as population density, diversity, occupation and services distribution. Other data that must be considered are mobility patterns of people like the distances travelled, the mode shares and the accessibility to transport infrastructure. Also, data on the environmental and health condition, such as noise and air pollution, heat island effect, traffic crashes, health and physical activity status must be examined. Social composition regarding attitudes, culture and economic activity like employment rates and job creation are interesting aspects as well. These data allow the comprehension of the status quo and how multiple parameters are interrelated and influenced by one another (M. Nieuwenhuijsen et al., 2018, p. 7f; Olafsson et al., 2016, p. 124). They provide a valuable basis for estimating and constructing car-free mobility scenarios as they highlight the present deficits and prospects of a city.

Moreover, the analysis of data enables the synthesis of different thematic fields uncovering previously unknown circumstances (M. Nieuwenhuijsen et al., 2018, p. 7f). One example that illustrates how the analysis of data can give unexpected insights, is the research conducted about the correlation of cultural values and cycling in Bamako, Mali in 2002 (Pochet, 2002, p. 5). The research showed that cultural values influence the mobility behavior in Bamako heavily as 95% of men were able to ride a bike but merely 50% of women haven't learned to ride a bike in the first place due to negative perception of cycling. Moreover, data collection and analysis are necessary to evaluate the measures in the course of transitioning towards car-free mobility by benchmarking it to the situation prior (M. Nieuwenhuijsen et al., 2018, p. 7f). This enables transparency and accountability which increases the acceptance of car-free policies and measures as it makes them more defensible. The probability of acceptance and a resulting behavior change is higher when political measures are based on data (Banister, 2011, p. 1542). Feedback loops must be carried out that review the current condition and implemented measure as they allow constant improvement (Friman & Olsson, 2020, p. 171).

Data can offer valuable clues about the demand for mobility and thus, insight into which measures help to meet the needs and wishes of the people (Banister, 2011, p. 1542; M. Nieuwenhuijsen et al., 2018, p. 8; T. Mosdell, p.v.c., Nov. 30, 2020). Understanding the demand side and not solely planning the transport system theoretically from a, most probably car-driving, planners' point of view is crucial for transforming the mobility sector. The collection of data, however, is mostly weak in realization (M. Nieuwenhuijsen et al., 2018, p. 8). In practice, policymaking is often constraint by the lack of relevant data which is why data collection must be propagated.

5 Smart developments towards sustainable urban mobility

Multiple smart[2] urban mobility developments can contribute to a less car-dependent lifestyle and to increased transport efficiency. Electrification of bicycles, autonomous vehicles, sharing technologies, micro-transit as well as bus rapid transit and mobility as a service are examples of that but do not claim completeness. In the following chapter, these smart developments are presented with their assets and drawbacks.

5.1 E-bikes

E-bikes can cover short-distance trips formerly done by the car without requiring a high physical effort (Olafsson et al., 2016, p. 123; Söderberg et al., 2020, p. 7). In a study in Sweden, the introduction of e-bikes to the transport system reduced car usage by 21% (Söderberg et al., 2020, p. 9). Depending on cycling infrastructure and its interruptions, the speed of a cyclist can be as low as 10km/h or up to 30km/h at perfect cycling conditions (Orvañanos Murguía, 2018, p. 9). Thus, single trips with distances of approximately 15km radius from home are already considered manageable with a conventional bike. Cargo-bikes, in addition to that, can carry large purchases as well as children; bypassing the need for a car for minor shopping activities (Urry et al., 2017, p. 27). Nevertheless, for transporting large goods and in regard of the mobility of constricted persons, the car is still essential (Söderberg et al., 2020, p. 9). E-bikes are not seen as an outright substitution of traditional motorized transport but rather as a link in a chain of a sustainable, multimodal transport system (Gauthier et al., 2013, p. 25; Olafsson et al., 2016, p. 123).

E-bikes are cheap to maintain and are also easy, fast and convenient to use (De Vries & Jenman, 2006, p. 93; Söderberg et al., 2020, p. 8f). They also come with environmental advantages as they have lower emissions compared to any other motorized mode of transport (De Vries & Jenman, 2006, p. 94; S. Chanzu, p.v.c, Nov. 24, 2020). In addition to that, e-bikes do not emit noise or air pollution but rather enhance physical activity and health (Gauthier et al., 2013, p. 14; Söderberg et al., 2020, p. 8f). E-bikes also support wellbeing as people move outdoors. Further, T. Mosdell noted that they have the potential to bypass the spatial division of rich and poor by enabling poorer people who mostly live in the outskirts of cities to access opportunities (T. Mosdell, p.v.c., Nov. 30, 2020)

Although e-bikes are an opportunity for urban sustainable mobility development, they have not picked up in Africa yet (De Vries & Jenman, 2006, p. 93; S. Chanzu, p.v.c, Nov. 24, 2020; T. Mosdell, p.v.c., Nov. 30, 2020). Cycling is less accepted in Africa and often hard to do without the proper cycling infrastructure (T. Mosdell, p.v.c., Nov. 30, 2020). Weather conditions and the risk of theft are other discouraging factors for people to use e-bikes (Söderberg et al., 2020, p. 8f). Unfavorably, many people cannot afford the sum of money needed for the initial purchase of an e-bike, hindering the uptake of privately owned e-bikes (De Vries & Jenman, 2006, p. 95; T. Mosdell, p.v.c., Nov. 30, 2020). T. Mosdell mentioned that even the retail price for conventional bicycles are often too high (T. Mosdell, p.v.c., Nov. 30, 2020). He also brought up that in South Africa for instance, the e-bike market is rapidly growing but became socially one-sided. Mostly people of the

[2] According to S. Nagy and C. Csiszár smart mobility represents two segments in this thesis; innovative solutions and development of current services (Nagy & Csiszár, 2020, p. 118).

wealthy middle class are driving e-bikes for recreation rather than blue-collar workers in the poorer communities for commuting. Consequentially, the lack of access to credit forces people to walk or use public transport rather than using the bicycle.

To exhilarate e-bike but also conventional bicycle usage for commuting, a proper and safe cycle infrastructure, that is nowadays often still lacking in African cities, needs to be set in place first (De Vries & Jenman, 2006, p. 96). Without a well-connected and maintained cycle path network, e-bikes and conventional bicycles will have a hard time establishing. A continuous cycling highway, for instance, encourages cycling as it enables higher speeds, safety and convenience (Doheim et al., 2020, p. 255; Söderberg et al., 2020, p. 9). It connects multiple desirable destinations like home, work, goods and services as well as public transport stations. In addition to that, secure parking facilities must be available as theft is a major issue (Doheim et al., 2020, p. 236; H. Kamau, p.v.c, Nov. 27, 2020).

5.2 Autonomous vehicles

The automatization of vehicles is another emerging technology (Wong et al., 2018, p. 4). Autonomous vehicles or `smart´ vehicles use information communication and technology and thus, can function driverless (Contreras-Castillo et al., 2019, p. 9). The vehicle makes decisions by monitoring its surrounding via sensors and analyzing the data received from it. Up to date, no fully automated car is on the market although many manufacturers, such as Ford, Google, Mercedes-Benz, Tesla and Uber promote marketability in the coming years (Bucsky, 2018, p. 42; Contreras-Castillo et al., 2019, p. 11). Futurist technologies currently researched and under development also include the commercialization of autonomous taxis on the ground and in midair (Wong et al., 2018, p. 6ff).

The advantages of automatized vehicles are claimed to be increased safety, decreased congestion, fewer car accidents and improved fuel and travel efficiency (Bucsky, 2018, p. 42; Contreras-Castillo et al., 2019, p. 9). In addition to that, it can increase the mobility of the disabled and elderly as it assists them with applications such as voice control and health assessments in case of emergencies (Contreras-Castillo et al., 2019, p. 11). Especially when private transport and urban logistics are combined, the capacity of the vehicles could be fully utilized (Bucsky, 2018, p. 48). An example of such increased capacity occurs when automatized vehicles are used as taxis during day-time and for delivery services in off-peak hours or at night-time. Value is added when automatized vehicles are set in the context of ride-sourcing and electrification as costs, space usage and emissions can be cut back (Bucsky, 2018, p. 48; Freudendal-Pedersen et al., 2019, p. 8).

However, the positive impact of vehicle automatization on car usage and ownership and thus on congestion, health, emissions and accessibility are controversial (M. Nieuwenhuijsen et al., 2018, p. 16; Wong et al., 2018, p. 4). Similarly, electrification of transportation is a strong and important current development in urban mobility but does not lead to a paradigm shift in car usage and ownership (Wong et al., 2018, p. 6). Autonomous cars may decrease the number of cars within urban areas, traffic congestion and urban space but it may also lead to a rise in mobility demand (M. Nieuwenhuijsen et al., 2018, p. 16). As Nieuwenhujsen said, the kilometers driven might step up since travelling with autonomous vehicles might make mobility as convenient as using the elevator. This comparison implies the phenomenon that people would rather wait than

covering short distances by physical activity, resulting in less use of active transportation and an intensification of the negative effects of car-usage.

5.3 Sharing schemes

Sharing technologies are also up-and-coming (Urry et al., 2017, p. 19f). Uber, Lyft, Hailo and many more companies are popping up in cities, offering app-based access to bikes, e-bikes, e-scooters, cars and even rides, to meet the flexibility demand of the people (Sovacool & Griffiths, 2020, p. 4; Wong et al., 2018, p. 2; Zarif et al., 2019, p. 2f). There are two types of shared mobility, the sharing of vehicles and the sharing of rides. Ride-sharing improves mobility efficiency because it increases the occupancy of a vehicle as journeys of multiple people who go in the same direction match (Wong et al., 2018, p. 2). When ride-sharing is scaled, it results in the microtransit scheme described in chapter 5.4.

On the other hand, vehicle-sharing technologies implicate that the vehicle can be picked up, used and dropped off somewhere else on demand and the payment is based on time or distance travelled (Sovacool & Griffiths, 2020, p. 4). The acceptance of vehicle-sharing is high as people can benefit using the offered modes whenever and wherever they want without having the cost of purchasing or owing them themselves (Doheim et al., 2020, p. 237). It enables people who initially lacked access to bicycles to access this mode of transport too (Doheim et al., 2020, p. 255; Gauthier et al., 2013, p. 14). Another positive factor is that places that were not reachable by foot formerly can be now easily accessed and first- or last-mile connection in alignment with the public transport served. Further, in the case of car-sharing about 6 to 20 cars can be replaced with one car shared which results in better utilization of the vehicles (Doheim et al., 2020, p. 244).

Yet, although car-sharing technologies in particular have a positive effect on traffic congestion and ease the demand for parking, they do not reduce the impact of a car-dependent infrastructure on society, equity, safety or the environment (Ortegon-Sanchez et al., 2017, p. 13; S. Chanzu, p.v.c, Nov. 24, 2020). Thus, S. Chanzu pointed out that car-sharing should not substitute the existing public transport system but provide an extension of it (S. Chanzu, p.v.c, Nov. 24, 2020). Further, the accessibility and utilization of all-sharing schemes are dependent on its affordability. Prices need to be low to compete with the available options on the market to be widely used. Also, T. Mosdell mentioned that security measures need to be set in place to hinder theft as it was a major issue in a bike-share pilot program in South Africa (T. Mosdell, p.v.c., Nov. 30, 2020).

Without going deeper into the positive and negative aspects of various sharing technologies, the key take-away is that all sharing technologies hold similar traits (Ortegon-Sanchez et al., 2017, p. 12f; Wong et al., 2018, p. 2f; Zarif et al., 2019, p. 7ff). They increase accessibility and have the potential to complement the existing public transport system. Though, motorized sharing technologies also threaten active mobility and the use of public transport as they might lead to a substitution rather than an expansion of these modes of transport. It also comes with a conflict of public space, safety issues and lessened mobility inclusiveness that must be taken into account and balanced.

5.4 Microtransit

Ride-sharing, also known as ride-sourcing or -hailing, is the most common form of microtransit which the company Uber is widely known for, for instance (Wong et al., 2018,

p. 2f). It is a collaborative mobility that functions like shared taxis, transporting a couple of people in a typical four-seater or more recently in larger vehicles like minivans. The latter option is a scaled form of ride-sharing imitating public transport. The growing demand in digitalized, personalized and flexible door-to-door mobility led to a gap in mobility service that was, next to the car, filled by such ride-sourcing schemes (Wong et al., 2018, p. 11f). Modern forms of microtransit are supplemented by an app-based application where the user can see the rides available in real-time via GPS tracking (Sovacool & Griffiths, 2020, p. 4; Wong et al., 2018, p. 2).

Although ride-sourcing increases personal mobility efficiency and point-to-point transportation, it also reinforces congestion and deviates the emphasis from public transport and NMT (Wong et al., 2018, p. 2). With upfront calculated fares, online payments and feedback options, modern microtransit makes it hard for conventional taxis and public transport to compete (Sovacool & Griffiths, 2020, p. 4; Wong et al., 2018, p. 2). The destructive development of people using direct, personalized transport rather than intermodal public transport is promoted (Wong et al., 2018, p. 11ff). This decreases the volume of people using public transport and in turn making it more difficult for governments to keep fares low. Gradually uncontrolled, private microtransit works against and in competition to public transport. As a result, mobility is successively detached further away from sustainability and makes the transport system increasingly unequal as costly peak hour demand is outsourced to private contractors. Further, microtransit implies low occupancy and hence more required road space.

Thus, to utilize the potential of all modes, not only microtransit, they must be linked and inter-coordinated for the transportation system to get more sustainable (Wong et al., 2018, p. 13f). Within this complimentary transport network, the first and last-mile connection is covered by intermediate modes in less dense areas and mass transport by public transport in dense areas. In addition to that, intermediate modes can assist at peak hours, decreasing the need for higher public transport vehicle requirements. Examples of intermediate modes are microtransit, ride-sharing, car-pooling, car- and bike-sharing and also the conventional or autonomous taxis (Wong et al., 2018, p. 10). Public transport includes metro, light rail, bus, minibuses and bus rapid transit.

5.5 Bus rapid transit

Another development of urban mobility is the bus rapid transit (BRT) system. It is a public transport system run by buses on dedicated lanes (Friman & Olsson, 2020, p. 166; Vermeiren et al., 2015, p. 14). It aims at high-quality standards which are simple to implement at reasonable cost. Through off-board payment, reliable timetables, covered boarding stations and security measures, the efficiency and quality of public transport is significantly increased (Friman & Olsson, 2020, p. 166; Orvañanos Murguía, 2018, p. 46; H. Kamau, p.v.c, Nov. 27, 2020). The electrification of the BRT bus fleet is another opportunity to increase the environmental benefits of BRT systems and cut emissions as well as noise and air pollution (Welle & Avelleda, 2020; H. Kamau, p.v.c, Nov. 27, 2020)

BRT corridors are mostly situated on arterial roads in busy urban areas (Orvañanos Murguía, 2018, p. 48). Buses are given priority next to NMT, enhancing the travel speed and reliability of them (Friman & Olsson, 2020, p. 166; Orvañanos Murguía, 2018, p. 48). H. Kamau noted in the interview that the users of BRT can reach their destinations far ahead of other road-users which, consequently, decreases the benefit to travel by

private car (H. Kamau, p.v.c, Nov. 27, 2020). To reduce the prejudice, public transport only being for lower-class people, the image of the BRT must be appealing whilst the fares are to be kept low as to include accessibility of poorer communities (Orvañanos Murguía, 2018, p. 48; H. Kamau, p.v.c, Nov. 27, 2020). Government subsidies are means to promote that (Vermeiren et al., 2015).

BRT systems are especially fitting for small to intermediate-sized cities as it shapes the future transport system and the land-use pattern alike (Cervero, 2013, p. 17f). It is a chance for developing countries and cities to leap-frog into more sustainable mobility and urbanization development. The higher the density the better for a mass transit system like BRT. With a growing population and densification, this is given in many developing cities. BRT corridors have already been introduced in 5 African cities including Lagos, Cape Town, Johannesburg, Pretoria and Dar es Salaam and are considered in Addis Abeba, Kampala and Nairobi to name a few (Global BRT Data, 2020; Orvañanos Murguía, 2018, p. 46). Worldwide, BRT systems have been implemented in 176 cities, Curitiba being one of the first to implement it in the year of 1974 (Global BRT Data, 2020; Torres, 2016, p. 2).

The capability of a BRT system depends on its intermodal integration in the transport system (Orvañanos Murguía, 2018, p. 45). Generally, all types of mode must be connected effectively. Facilitating high-quality infrastructure and their connection improves accessibility, flexibility and resilience of the whole transport system, although the transport infrastructure should not be designed solely for intermodal transport (Orvañanos Murguía, 2018, p. 48; Vermeiren et al., 2015, p. 21). When pedestrian paths and cycle lanes would only be designed for intermodal transport and not planned continuously, social exclusion may be induced and accessibility declined.

5.6 Mobility as a Service

One data-based technology solution combining all transport modes is the concept of Mobility as a Service (MaaS) (Wong et al., 2018, p. 15). It is a demand and integrated transport management tool that facilitates the composition of a personalized, most efficient journey digitally while considering all available transport modes and simultaneously supplying digital, off-board payment (Matyas & Kamargianni, 2018, p. 1525; Wong et al., 2018, p. 13ff). The interconnection of public transport, NMT and intermediate modes enable a more efficient allocation of the available modes and infrastructure. It also improves the individual mobility experience as it makes transport planning simpler and provides the first and last mile (Wong et al., 2018, p. 13ff). Here again, data needs to be collected and analyzed first as to quantify and to understand the complex mobility behavior of people and consequently shift mobility away from the private car (Matyas & Kamargianni, 2018, p. 1526). Information and communication technologies make their way into the transportation sector setting the starting point for smart mobility as they connect the mentioned technologies and transport systems in this chapter (Freudendal-Pedersen et al., 2019, p. 11).

Through customized prepaid daily, weekly or monthly mobility plans with fixed rates, the individual preferences and mobility behavior of people can be satisfied (Matyas & Kamargianni, 2018, p. 1526ff). Combined subscriptions make fares cheaper and quick changes therein make the mobility experience carefree. This can impact mobility behavior significantly as people with such a subscription tend to use the included mode options

more often whilst their car usage decreases. Helsinki, for instance, was one of the first cities to introduce this concept with the aim to make private car usage within the city unnecessary (Urry et al., 2017, p. 19). Thereupon the start-up MaaS Global developed an app-based facility to provide individual multimodal transport planning, known as of Mobility as a Service (Whim, n.d.). According to the CEO of MaaS Global, the most expensive fare for unlimited usage of all modes in this service in Helsinki is still cheaper than the cost of a private car (The Agility Effect, 2020). Such MaaS providers are existent in various forms; "UbiGo" in Sweden, for instance, rewards sustainable transport choices with bonus points, fostering sustainable mobility behaviour even further (Friman & Olsson, 2020, p. 171f). These implementations illustrate the benefit of MaaS as a driving force for less car-dependency and more sustainability in the transport sector.

6 Urban village of Botswana: Maun

In the following chapter, the city of Maun and its mobility infrastructure is illustrated. To understand the situation at hand better, the geography of Maun is briefly discussed. Following, the general mobility infrastructure of Botswana is described. Finally, the private car, public transport and NMT conditions in Maun are illustrated via the findings of a field research conducted in the course of this thesis.

6.1 Geography and urbanization

Maun lies in the Ngamiland East District of Botswana south of the Okavango Delta as seen in Figure 2 (Ringrose et al., 2003, p. 305; Statistics Botswana, 2019, pp. 9, 43). Through the city flows the Thamalakane River as it is visible in Figure 3. Maun is 945m above sea level and is determined by a hot semi-arid climate as classified by Koppen-Geiger with an annual temperature of 22.4°C and an annual rainfall of 450mm (DWD, n.d.; Statistics Botswana, 2015a, p. 18f). Maun has warm winters with mean monthly temperatures above 15°C and summer temperatures around 30°C (Statistics Botswana, 2015a, p. 20f). In the winter months, between May and September, there is hardly any rain with its lowest precipitation of 0mm; in the summer months, on the other hand, most of the rain falls, peaking in January with 140mm precipitation (Statistics Botswana, 2015a, p. 16f). The vegetation in Maun is majorly mopane woodlands and shrublands dominated by the transect with the Kalahari, making the soil very sandyx as seen in Figure 4 (Ringrose et al., 2003, pp. 301f, 305). With its sub-tropical location, Maun is vulnerable to the consequences of climate change as the semi-arid conditions of the country make the environment especially fragile (Ministry of Lands and Housing, 2014, p. 20).

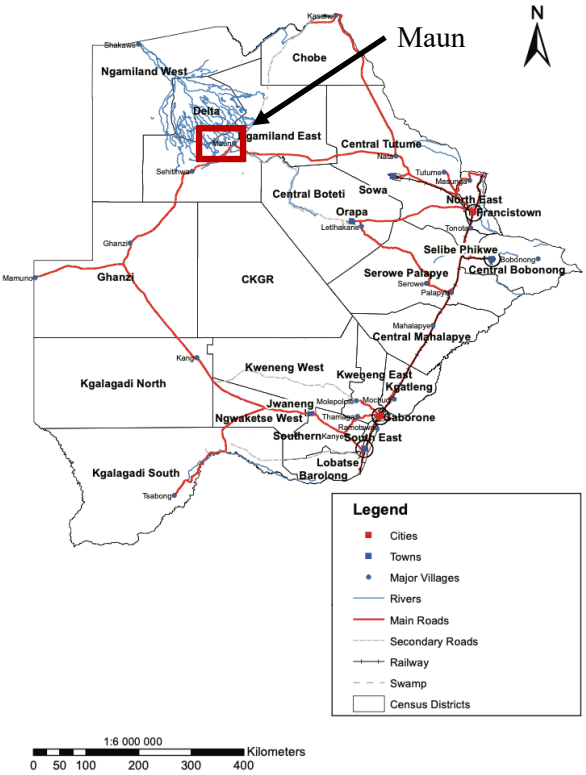


Figure 2: Botswana Census Districts (Source: Statistics Botswana, 2018, p. 9, location name highlighted)

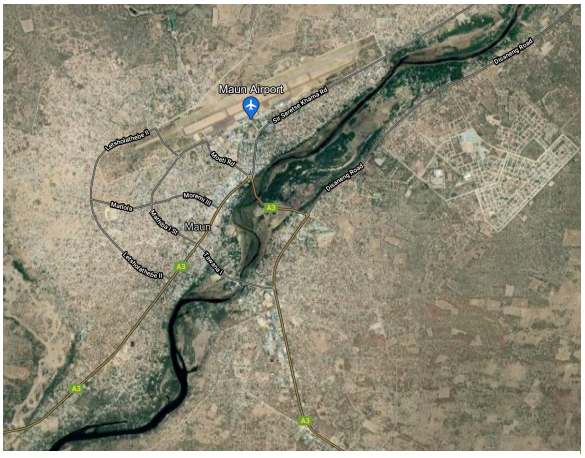


Figure 3: Streets of Maun (Source: Google Maps, 2021)

Figure 4: Vegetation in Maun (Source: J. Huber, 2007)

In Botswana, all settlements with a population exceeding 5.000 inhabitants are classified as urban areas when 75% of the labor force is outside the agricultural sector (Ministry of Lands and Housing, 2014, p. 3). Maun is an urban village with a population of 60.263 inhabitants (Ringrose et al., 2003, p. 305; Statistics Botswana, 2019, pp. 9, 43). Generally, Botswana's rural population is constantly decreasing, making up 96,7% of its population in 1964 and only 29,8% in 2019 (The World Bank, 2018). Simultaneously, the urban population in Botswana is projected to increase from about 1.297.287 inhabitants in 2011 to about 2.081.732 inhabitants in 2026 (Statistics, 2015, p.16). In Botswana, urbanization arises due to multiple factors such as rural-urban migration, population growth and settlement reclassification from rural to urban areas (Ministry of Lands and Housing, 2014, p. 4).

Urban sprawl is also a continuing condition in Botswana due to predominate low-density housing, rural-urban inequalities and free or cheap peri-urban tribal land (Ministry of Lands and Housing, 2014, p. 15ff). The lack of compact urban development and mixed land-use further increases distances and the growing motorization challenges urban mobility in Botswana's urban areas further. Maun is highly sprawled although it consists of a few slightly more densified areas such as the mall area as seen in Figure 5. The spread-outness of Maun with its predominance of low-density housing in particular is visible in Figure 6. In Botswana, the planning of urban areas is mostly the responsibility of local governments (Ministry of Lands and Housing, 2014, p. 16f). The constraint therein is the lack of qualified personnel to manage such. An effort is made to enhance sustainable urban planning and design on multiple political levels. Weak points thereby include lack of capacity, uncoordinated planning, limited resources of local authorities and weak building regulations as well as little implementation of urban design beyond theoretical planning.

Figure 5: Maun city center (Source: Google Maps, 2021)

Figure 6: Urban sprawl in Maun (Source: Google Maps, 2021)

6.2 Mobility condition of Botswana

Overall, Botswana has a total road network density of 43km/1000km^2 land area which is one of the lowest compared to other low- and middle-income countries in Africa (Briceño-Garmendia & Pushak, 2011, p. 11). On the other hand, the yearly vehicle registration in Botswana has increased by nearly 50% since 2008 (Statistics Botswana, 2020,

p. 17). Thereby, the vehicle registration specifically in Maun was at 248 vehicles from a total of 10.326 in Botswana in the first quarter of 2020 (Statistics Botswana, 2020, p. 21). However, in the second quarter of 2020, only 156 of 5.281 vehicles were registered in Maun as registration offices were closed due to Covid 19 (Statistics Botswana, 2020, pp. 17, 21). From these 156 vehicles registered, 102 vehicles were private cars (Statistics Botswana, 2020, p. 21).

Concerning the restrained road infrastructure in Botswana, the rise in motorization gradually poses challenges to urban centers (Ranko & Bolaane, 2011, p. 275). This, for instance, is experienced in Gaborone, the capital of Botswana, where inadequate road infrastructure, such as traffic lights, are a major obstacle to a coordinated road flow as they often malfunction which leads to congestion and road accidents (Ministry of Lands and Housing, 2014, p. 24). A study conducted by Bashingi et al. in Gaborone in 2017 highlights that exhilarated private car-ownership and -dependency decreases mobility as traffic congestion and urban sprawl increases (Bashingi et al., 2020, p. 441; Ministry of Lands and Housing, 2014, p. 15). It illustrates that nowadays almost 60% of commuters in Gaborone get delayed by traffic daily (Bashingi et al., 2020, p. 439). Moreover, the study illustrates that with an increased private car-usage only the urban poor depend on public transport which makes them more vulnerable to its shortcoming (Bashingi et al., 2019, p. 437ff). It also shows that private transport is desirable for its flexibility and convenience which are factors public transport is missing (Bashingi et al., 2019, p. 437ff). This was underlined in the study as more than 56% of people answered that they would use more public transport if it was safer (Bashingi et al., 2020, p. 441f). Also, a reduction of the fares would encourage people to shift to public transport. The biggest factor, however, is convenience, when public transport could offer an on-demand, door-to-door service almost 70% of people in Gaborone would start using it (Bashingi et al., 2020, p. 441f). The supply of travel information such as timetables would be another facilitator. Thus, safety, convenience and reliability are identified as driving factors in order to achieve a modal shift in Gaborone (Bashingi et al., 2020, p. 441f).

The study conducted by Ranko & Bolaane in 2011 underlines these findings and further indicates that the NMT infrastructure in Gaborone is inadequate. The lack of safe and continuous pedestrian and cycle lanes leaves these modes to share the road with motorized transport noted in both surveys (Bashingi et al., 2020, p. 435f; Ranko & Bolaane, 2011, p. 279). This hinders people in Gaborone to use NMT with merely 0.2% of trips made by bicycle and some 30.30% by foot (Ranko & Bolaane, 2011, p. 279). Other negative effects mentioned include noise and air pollution, fuel wastage as well as physical and psychological health impact, to name a few (Ranko & Bolaane, 2011, p. 278).

The threat of road accidents in Botswana is also highlighted in the 2018 `Global Status Report on Road Safety´ from the WHO. It estimates the number of fatal road accidents in Botswana at 535, although Botswana only reported 444 road fatalities in their statistics (Statistics Botswana, 2019, p. 34; WHO, 2018a, p. 110). It also illustrates that 25% of road fatalities in Botswana are pedestrians, 2% are cyclists, and the other 73% are drivers and passengers of motorized vehicles (WHO, 2018a, p. 110). The study of Mphela in Bostwana in 2020 highlights that road accidents increase simultaneously with the number of vehicles as well as the road activity (Mphela, 2020, p. 7ff). Further, it states that the number of road accidents is likely to rise with the distance traveled, which is inevitable with the continuing urban sprawl in Botswana's urban centers. It is also concluded that the road design is a major aspect to road safety. Another health factor, next to road

accidents, that is connected with car-centric mobility is the decrease in physical activity. In Botswana, 20% of adults over the age of 18 are under the risk of physical inactivity which increases the chances of getting diseases and negative psychological consequences according to the WHO (WHO, 2009, p. 21, 2018b).

The environmental drawback of a car-dependent transport system is observable by various aspects, such as petroleum usage, CO2 emissions and air pollution. In Botswana, currently 90% of petroleum is consumed by road transport (Ministry of Environment; Natural Resources Conservation and Tourism, 2019, pp. 21, 52). Hence, the transport sector in Botswana accounts for 1985.096517 Gg CO2 emissions (Ministry of Environment; Natural Resources Conservation and Tourism, 2019, pp. 21, 52). Thereby Botswana is exceeding the WHO guideline level of annual particular matter concentration of 2.5 by a multiple of two, causing respiratory diseases and a reduction in life expectancy (WHO, 2009, p. 12, 2018b). An issue is that most vehicles in Botswana are second-hand, having a negative impact on emissions (Statistics Botswana, 2020, p. 19). In the year 2020 second-hand vehicles were around 76% of first registered vehicles, with almost all of them originating from Japan (Statistics Botswana, 2020, p. 19).

6.3 Field research result: Mobility condition of Maun

In the following subchapters, data of independent field research in Maun is presented. As there is not enough detailed data about the demography and mobility infrastructure of Maun, an online survey with 56 participants and personal interviews with six inhabitants of Maun as well as a photo documentation via Google Street View were conducted. The field research results from this study are not representative but serve as a sample for delivering first insights into the situation at hand and are underlined by the literature review in the prior subchapter.

The low-density road network of Botswana, for example, is also persistent in Maun as there is only one arterial road (A3) going through the city and few paved roads crossing it as visible in Figure 3. The remaining roads, connecting the residential areas, are sand roads which can be seen in Figure 7 and Figure 8. Besides, two bridges are crossing the river, connecting the two parts of Maun (Figure 3). In the online survey conducted in the course of this thesis, 22% of respondents stated that they do not like the road infrastructure in Maun (s. Appx. A1.4). They mention obstacles, such as sand roads, potholes, excessive installation of speed humps, malfunctioning traffic lights and insufficient road network with too little bridges crossing the river. Another 6% do not like the spread-outness of the city whereas 10% of respondents value the short distances in Maun (see Figure 11).

Figure 7: Paved & unpaved roads of Maun (Source: Google Street View, 2012)

Figure 8: Sand roads of Maun (Source: Google Maps, 2021)

The mobility within Maun consists of traditional donkey carriages, walking, biking, minibuses, sporadic car-pooling, taxis and private cars (s. Appx. A1.3). The study also illustrates that the majority[3] of respondents use the private car as the main mode of transport as visualized in Figure 9. Taxis and walking are the second and third most used mode of transport. Donkey carts and car-pool are not used at all by the respondents of the online survey. Thereby, the inhabitants that were interviewed in the course of this research, stated that with the increasing motorization, donkey carts disappear rapidly from the roads of Maun (s. Appxs. A3.4, A3.6). Contradictory to the online survey that conveys that most people drive private cars, the interviewees perceive that most people in Maun still use public transport as a main mode of transport (s. Appxs. A3.2, A3.3, A3.5, A3.6). This dissonance might be explained by the demography of the surveyed people as mentioned in the methodology of this thesis.

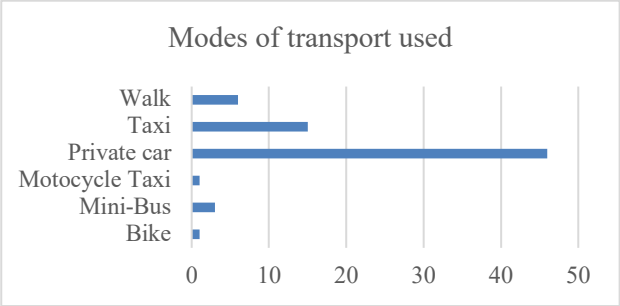


Figure 9: Modes of transport used (Source: Appx. A1.3)

6.4 Field research result: Car-dependency

The overall increase in vehicle registration in Botswana and the high share of private cars mentioned align with the perception of the interviewees that the car-ownership in Maun is increasing (s. Appxs. A3.1, A3.2, A3.5). In the online survey, the trend of increasing aspirations to own a private car is underpinned as 71% of the 56 respondents indicate that they already own a car as seen in Figure 10 (s. Appx. A1.2). The remaining 29% wish to own a car, whilst none of the respondents negate the wish to own a car. Thereby, 34% of respondents would like to own a car for convenience as it is easier to move around town by private car than by other modes of transport as seen in Figure 12. Independence is another aspect stated by 22% of respondents. Further, the mere requirement to own a car to access goods and services, to handle the spread outness of the city and to ensure the reliability that the public transport is not able to provide, are each named by 17% of respondents as a reason. The private car is considered to be by far the safest, most comfortable and time-efficient mode of transport compared to walking, biking or using public transport (s. Appx. A1.4). In addition to that, all interviewees illustrated that the private car is usually considered as a status symbol as outer appearance is important which makes it aspirational for many people (s. Appxs. A3.1, A3.2, A3.4, A3.5, A3.6). Also, one interviewee illustrated a mentality of freedom connected to the private car by citing a friend who said; “what I love about Botswana is that everywhere is road” (s. Appx. A3.4). Besides, the privacy of a private car compared to the discomfort of crowded public transport is mentioned in favor of it (s. Appx. A3.3).

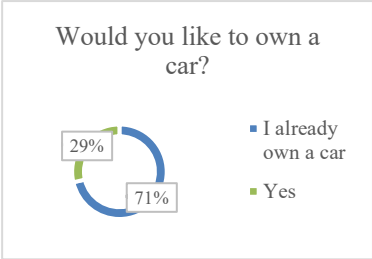


Figure 10: Private car ownership (Source: Appx. A1.2)

Other than the findings in Gaborone by Bashingi et al. (2017), the online survey in Maun shows that more than half of the respondents commute less than 30 minutes, almost 13%

[3] In this research the majority consist of more than 80% of respondents.

less than an hour and merely 7% of respondents more than an hour in total per day. Therefrom, 25% of respondents are unemployed or work from home (s. Appx. A1.2). Besides, almost half of respondents like the little traffic and the easy movement within Maun as seen in Figure 11: (s. Appx. A1.4). Despite these findings, 23% of respondents stated that traffic congestion gradually deranges mobility in Maun. All interviewees in the study mentioned that although traffic congestion is still limited, it exists and is increasing over the years and with more people acquiring private cars (s. Appx. A3). Thereby, the traffic congestion mainly occurs in rush hours, in the city center and at traffic nodes, such as the roundabout or the two bridges crossing the Thamalakane River. Similar to the congestion issue in Gaborone discussed earlier, malfunctioning traffic lights are another aspect mentioned by the interviewees to cause congestion as well as road accidents in Maun (s. Appx. A3.2, A3.4). In the online survey and the interviews conducted in Maun, especially the animals on the road were mentioned as a worry and as a cause of accidents, facilitated due to the lack of streetlights (s. Appxs. A1.4, A3.1, A3.4). In addition to that, drunken driving has been noted by two of the interviewees as a threat to road safety (s. Appxs. A3.1, A3.4).

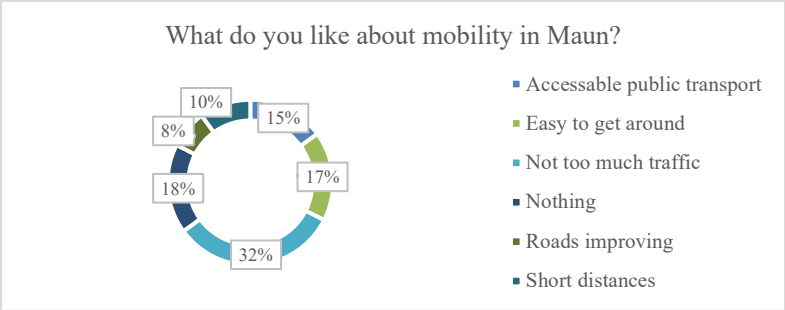


Figure 11: What do you like about mobility in Maun? (Source: Appx. A1.4)

Based on the discussion with the interviewees of the study, the predominance of imported second-hand cars is also the case in Maun and due to the low cost, it increasingly tempts people to acquire a private car (s. Appx. A3). Thereby, critics might even argue that foreign businesses dump their polluting and unsafe throw-outs in Africa (Pirie, 2009, p. 26, s. Appx. A3.4).

6.5 Field research result: Public transport sufficiency

According to the study conducted in Maun, informal, privately owned transport providers fulfill the function of the public transport in Maun as it is predominant in many developing cities in Africa (s. Appx. A3). This type of public transport in Maun is majorly represented by taxis. As seen in Figure 9, they are also the second most used mode of transport by the respondents of the online survey (s. Appx. A1.2). In the interviews, mini-buses were described as the second pillar of the public transport system in Maun (s. Appx. A3). In the online survey, about 15% of respondents (see also Figure 11) considered the accessibility of the public transport system in Maun as a positive aspect of its mobility infrastructure (s. Appx. A1.4). Public transport is perceived to be moderately safe, comfortable to use, time-efficient, rather cost-efficient and clean by the respondents of the online survey as well as the interviewees (s. Appxs. A1.4, A3.2, A3.3, A3.5, A3.6). One interviewee mentioned, that especially during

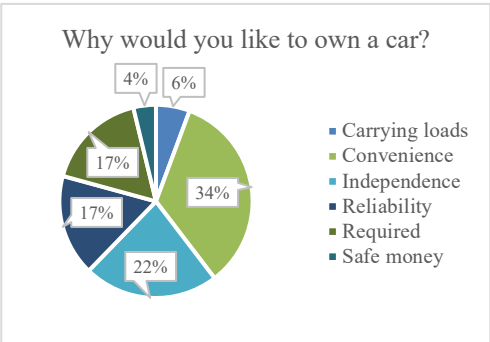


Figure 12: Why would you like a car? (Source: Appx. A1.2)

the current pandemic, the taxis are liable regarding the provision of hygiene measures, such as sanitizers, temperature measuring and bookkeeping of the passengers (s. Appx. A3.2).

During the interviews it became clear that the taxis and mini-buses, also called combis, circulate the city on set routes and mainly operate on the paved main roads (s. Appx. A3). There is a central bus rank for intercity travel but there are no dedicated taxis or mini-bus stops within Maun which means that a passenger can be picked-up and dropped-off anywhere along the route. Unfortunately, the exact routes were not retrievable in the course of this research. To fetch a taxi or a mini-bus, the interviewees describe the procedure and experience as following: The person wanting to access public transport must walk to the main road as they usually not operate on unpaved, sand roads (see Figure 13) that dominate in the housing districts, as mentioned in chapter 6.2 (s. Appx. A3). On the main road, the person has to wait for a taxi or a mini-bus to pass by and then raise their hand to indicate their interest in taking a ride. Finally, the driver must be asked which route they are serving as there is no signposting on the taxis or mini-buses that allow the identification of the route.

Figure 13: Paved and unpaved roads in Maun (Source: Google Street View, 2012)

The interviewees stated that the cost of taking a taxi or a mini-bus is around 5 pula (approx. 0,40€) in the case that the taxi is shared (s. Appxs. A3.1, A3.2, A3.3, A3.4). A shared taxi implicates, that along with you, other people who share a similar route are picked-up and dropped-off as well (s. Appxs. A3.1, A.3.2, A3.4). Thus, the taxi might not take the fastest and shortest route to the desired destination and the service is not door-to-door, it is rather pursued to reach the closest point on the main road to the final destination (s. Appx. A3). When using this form of public transport, several taxis or mini-buses might have to be interchanged to reach the final destination as they only operate on their set routes. In more remote places, the chance of getting a taxi is little which makes a fast, wide and cheap use of public transport almost impossible. People must pay special rates when going or coming from remote places further off the main road or the set routes. Often, the taxis need to be called to come to the pick-up location as they do not cruse around these areas normally. A special rate is also applicable when a single, individualized trip is requested where no other people join the ride, and the fastest way is to be pursued. These special trips cost around 20-35 pula (approx. 1,50-2,50€) (s. Appxs. A3.1, A3.3, A3.4, A3.6).

For all public transport options in Maun, two interviewees mentioned that depending on the route and occupancy of the vehicles, waiting times can get extended as one has to ask their way through taxis or mini-buses passing by (s. Appxs. A3.1, A3.4). A lack of timetables, fluctuating availability and cost according to weekdays or weekend, weather conditions and day- or night-time make the public transport system unreliable and inconsistent (s. Appx. A3). These aspects mentioned by the interviewees are stated as major reasons for two of them to not use public transport in Maun but rather use their private car (s. Appxs. A3.1, A3.2). Also, although none of the respondents of the online survey

answered that they do not want to own a car, some voices where raised, stating that they would prefer a car-free mobility, but the public transport's lacking sufficiency does not allow such a change (s. Appx. A1.2).

Furthermore, the interviewees stated that mini-buses are less used and their numbers are starkly decreasing in Maun because of the long waiting times whilst using them, as they only take off when fully occupied (s. Appx. A3). Also, the crowding and lack of ventilation in mini-buses are considered repelling. This is substantiated in the online survey where merely 5% of respondents used this mode of transport (see Figure 9). Taxis, on the other hand, are infamous for their rowdy driving behavior, lack of customer service and expensive special fares in the online survey as well as with the interviewees (s. Appxs. A1.4, A3). Considering that, 30% of respondents in the online survey mention taxis when asked what they do not like about the mobility in Maun as seen in Figure 14 (s. Appx. A1.4). Also, the high quantity of taxis is perceived negatively by the interviewees as the taxi drivers consequentially have to fight for customers which facilitates their inconsidered driving behavior further (s. Appx. A3). The high number of taxis in Maun is explained by two interviewees as a cause of illegal license sharing between the taxi drivers (s. Appxs. A3.1, A3.4). The participants in the online survey further mentioned that the mobility options they miss in Maun include modern mobility technologies, such as car-pooling, sharing systems, autonomous shuttles as well as a conventional bus system in Maun (s. Appx. A1.3).

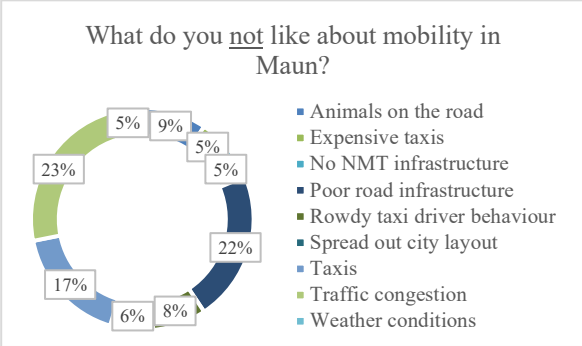


Figure 14: What do you not like about mobility in Maun? (Source: Appx. A1.4)

Through the interviews in Maun, the impression is received that public transport is mostly used by those who are not able to afford a private car but want to benefit of not having to carry loads, like shopping bags, or being exposed to the weather whilst going to work or taking their kids to school (s. Appx. A3). Thereby, many people in Maun are perceived to still be captive public transport users as the costs of a private car are too high for many even though second-hand cars make the purchase of a private car increasingly affordable.

Figure 15: Lack of NMT infrastructure (Source: Google Street View, 2012)

6.6 Field research result: Non-motorized transport integrity

Similar to the findings in Gaborone, the interviews conducted with inhabitants of Maun illustrate that hardly any people cycle in Maun (s. Appx. A3). Besides, when individual people cycle it is usually for recreation rather than commuting. Also, in the online survey, out of 56 people only 1 person stated that they typically move around town by bike and merely 6 people walk as seen in Figure 9 (s. Appx. A1.2). According to the interviewees,

walking is more common, typically with kids walking to school, people walking to work or simply to the main roads to access public transport (s. Appx. A3). Besides, the online survey in Maun has shown that walking is perceived as rather safe and comfortable to use whereas biking is perceived as not really safe and comfortable to use (s. Appx. A1.4). Further, walking is perceived to be not time-efficient at all, but rather as the most cost-efficient mode of transport closely followed by cycling. In summary, it is, nonetheless, visible that the car is experienced as the most reasonable choice compared to NMT or public transport when the costs are disregarded.

In alignment with the findings of the study in Gaborone by Ranko and Bolaane, the study in Maun indicates that the main challenge for NMT usage in Maun is the lack infrastructure (s. Appxs. A1.3, A3). In the survey, almost 45% of respondents indicated that Maun misses basic NMT infrastructure. The lack of NMT infrastructure, as seen in Figure 15, and its impact on active mobility is emphasized and explained by the interviewees with several aspects (s. Appx. A3). Firstly, the interviewees pointed out that there are no dedicated, paved cycling lanes making Maun not suitable and sufficient for cycling. This forces cyclist to share the road space either with motorized vehicles on the paved and sand road or with the pedestrians mostly on unpaved sidewalks as seen in Figure 16. When choosing to ride on the paved road, the cyclist is exposed to all motorized vehicles that, according to the interviewees, show limited consciousness towards cyclists. Since no protection through basic facilities, such as signposting, streetlights or even bike storages, is provided, cyclists, consequentially, feel uncomfortable and unsafe. When cyclists share the road with pedestrians, on the other hand, they have to drive on unpaved roads, struggling with the sandy ground as seen in Figure 17. Off the few paved main roads, where sand roads are predominant, they have to deal with both issues at the same time, sharing the road with motorized vehicles and coping with the sandy ground. The interviews also conveyed that, although cycling as a sport is picking up in Botswana, the culture of using bicycles for commuting is missing. Further, the widespread usage of the bicycle is hindered because not many people can afford the purchase of a bicycle as it demands available credit.

Figure 16: Lack of cycle infrastructure (Source: Google Street View, 2012)

Although Maun is considered walkable by the interviewees, they have highlighted that there are no continuous, connected sidewalks provided for pedestrians in Maun (s. Appx. A3). In their point of view, the lack of pavement of sidewalks and facilities like crossings, streetlights or signage consequentially pose a challenge for anybody wanting to or having to walk. One interviewee mentioned that particularly disabled people have a hard time being mobile because of the sandy roads and the lack of provision of ramps and similar installations (s. Appx. A3.1). The weather conditions are also mentioned by the interviewees as a constraint for the NMT usage (s. Appx.

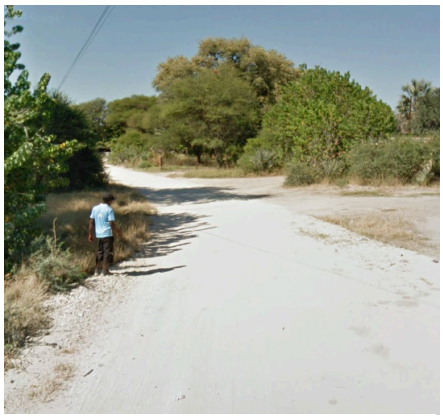


Figure 17: Maun's sandy roads (Source: Google Street View, 2012)

A3). The high temperatures and strong rainfalls in the raining season hinder active mobility further as people choose comfort over the stress and strains connected with it. Besides, the spread-outness of Maun makes it difficult for people to access goods and services by foot, leaving most people walking only minor distances. Nevertheless, captive walkers still have to take the time and effort of walking long distances to participate in society and access jobs and opportunities as they cannot afford public transport or let alone a private car.

On the other hand, an interviewee mentioned that the physical effort to walk or cycle is lightened as Maun is rather flat, which is also seen in the Figures in this chapter (s. Appx. A3.4). Further, some interviewees perceive walking within the city center as pleasant and consider it as a good complementation to the car as traffic is flowing slowly in these areas (s. Appx. A3.4, A3.5). The social interaction and being outside in nature whilst walking is another positive aspect mentioned by another interviewee (s. Appx. A3.1). Although hardly any streetlights are provided, being outside in the dark is not considered unsafe and animal interaction is not perceived as a problem in Maun (s. Appx. A3). Further, an interviewee highlighted that with a lot of people still walking, it is regarded to be a piece of the culture of Batswana (s. Appx. A3.5). The interviewee B. Phenyo said that "It´s part of our life" (s. Appx. A3.5) rather than something considered as a burden of the poor.

Figure 18: Lack of pedestrian infrastructure (Source: Google Street View, 2012)

As the surveys in Gaborone which is referred to and the study within this thesis have shown, it is relevant and urgent to move towards more sustainable urban mobility planning in order to remedy the insufficiency of the transport system. Another reason is to enable more active and environmentally conscious mobility in Maun. In addition, to make suggestions for the mobility in the MSP, it is fundamental to understand the mobility infrastructure of Maun too as they are to be connected. Therefore, to accomplish the goal of holistic sustainable mobility in Maun with the MSP in its core, the mobility issues mentioned above must be addressed.

7 Maun Science Park: A blueprint for Africa and beyond

In the first part of this chapter, the concept of the MSP is described in order to understand which aspects have to be addressed in the course of its creation. Secondly, scenarios of urban car-free mobility in the MSP in connection with the surrounding city of Maun are described. These scenarios enable a better understanding of how urban car-free mobility can be applied in the MSP.

7.1 Idea and location

The Maun Science Park is designed to become a self-sufficient, resilient, sustainably managed urban district (inRES, 2020). It should become a role model for future life on earth and the symbiotic coexistence of humans, animals and the environment with the help of the most modern technologies and infrastructure. The MSP project is led by Dr. Mokgweetsi E.K. Masisi, President of the Republic of Botswana and the Paramount Chief Tawana Moremi, and has been approved by the Cabinet as part of the national digital transformation strategy of Botswana. It is to be a unique opportunity for a state-of-the-art project for sustainable and affordable living in Botswana and a chance to deal with the local and global challenges of urbanization, governance and climate change.

Research and educational institutions from all over the world work on the realization of this vision (inRES, 2020). A future research center as well as an accelerator facility in the MSP is planned to do so further and to merge modern digital solutions with local tribal culture and knowledge. The outcome aims at creating a living laboratory that develops the ecological interplay between humans and the environment. Next to that, 25 smart homes are to be created as a 'Smart Living Lab' which serves as a modal habitat that can be scaled and adopted by other cities. The president of Botswana states that "the outcome of this project will become a blueprint for Africa and yes, the world" (Dr. Mokgweetsi E.K. Masisi, 2020, nn. 3:23-3:29). A high-speed network infrastructure, innovation and research platforms, international resources to support its operations, data collection and sharing as well as the usage of 4IR[4] technologies enable a sustainable living. To meet this goal, smart solutions in various fields, such as energy and water supply, construction, sanitation and waste management, transportation, agriculture, healthcare, social justice, education and digitalization, must be tackled. Thereby, the real-life setting of the project, as well as the local community engagement, could facilitate the development of relevant, tailor-made solutions to local challenges. The quality of life of the people of Maun is to be improved by the MSP whilst preserving the unique natural habitat of the area. It is a distinct opportunity for capacity building as it fosters local and global co-creation, the education of the youth and thus, the shift from a resource-based towards a knowledge-based economy in Botswana.

[4] The Fourth Industrial Revolution, is a term introduced by K. Schwab, which describes a era where humans move between digital domains and offline reality with the use of connected technology. It is distinguished by a merge of technologies with the physical, digital, and biological spheres (Schwab, 2016).

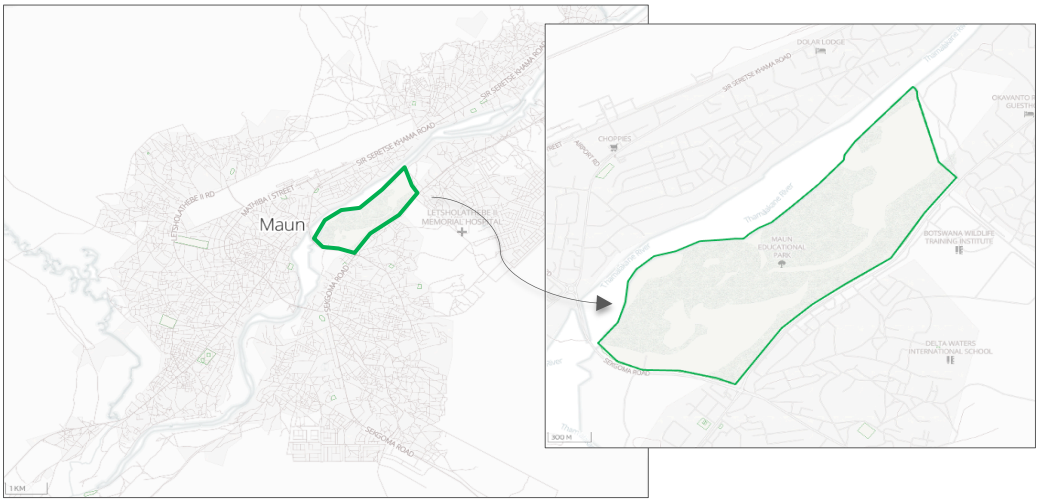


Figure 19: The Maun Educational Park (Source: Open Street Map, n.d., location zoomed in and highlighted)

In the city of Maun, the former Maun Educational Park is the basis for the project and will be the location of the Maun Science Park as seen in Figure 19 (Tjinyeka, 2020). It lies in the core of the city, southwest of the Thamalakane River with a total area of around 2.5km^2 or 250 hectares when measured in Google Maps (2021). In Figure 20, it is also seen that the vegetation in the future MSP is largely unaltered which means that the naturally predominant vegetation of mopane woodlands and shrublands of the area persists (Ringrose et al., 2003, pp. 301f, 305). This fragile habitat is to be preserved in the course of the MSP creation and coincide with the future urban life in the MSP (inRES, 2020).

Figure 20: Vegetation in the Maun Educational Park (Source: Google Maps, n.d., location highlighted)

The next chapter provides two scenarios that support the idea of the MSP specifically in the field of mobility. Through the conceptional design of urban car-free mobility in the MSP in connection with the surrounding city of Maun, its applicability is analyzed.

7.2 Two scenarios of urban car-free mobility

Mobility is one aspect that needs to be addressed to fulfill the sustainability goals of the MSP as described prior. However, the data on the mobility conditions in Maun, which are illustrated in chapter 6, highlight the shortcomings of the mobility system in Maun and its car-centric layout. Hardly any provision for pedestrians and no provision for cyclists are provided within the transport infrastructure, clearly prioritizing the private car. No incentives to use public transport or NMT, in combination with unreliable, uncomfortable and pricey public transport, further intensify the dependency on a private car. The aspirations to own a car are thereby another factor strengthening the car-centric lifestyle. The analysis also depicts that Maun lies behind the ambitions of Gaborone

regarding a transition into a more sustainable transport system and is thus trailing behind in a global and national sustainable mobility context. However, the positive conditions of a flat topography and the culture of walking is an instrumental basis for NMT usage. Also, the still high share of public transport users is subsidiary for a transition towards sustainable mobility.

Nonetheless, to meet the aspiration of the MSP and to be a state-of-the-art project for sustainable and affordable living in Botswana, a strategy for the mobility transition in Maun must be evaluated. Only with the mobility of the complete city being improved in the long run, the mobility within the MSP can be viewed as sustainable successfully. For though, without the inclusion of the surrounding city of Maun, the trend of increasing car-dependency will intensify. An effect could be an MSP which is increasingly isolated as well as unconnected and unrelated to the surrounding city and its people. Disparities between rich and poor could enlarge, urban sprawl and car-dependency could increase and likewise all its negative effects.

Therefore, the applicability of mobility in the MSP without private cars is staged in this chapter via the development of scenarios. The scenarios are constructed according to Schwenker and Wulf (2013). The goal is to enable long term strategic planning with the help of the scenarios as they illustrate how the future may develop with a certain set of influencing factors (Schwenker & Wulf, 2013). In doing so, two scenarios that try to answer the question of how urban car-free mobility can be applied in the MSP in the next

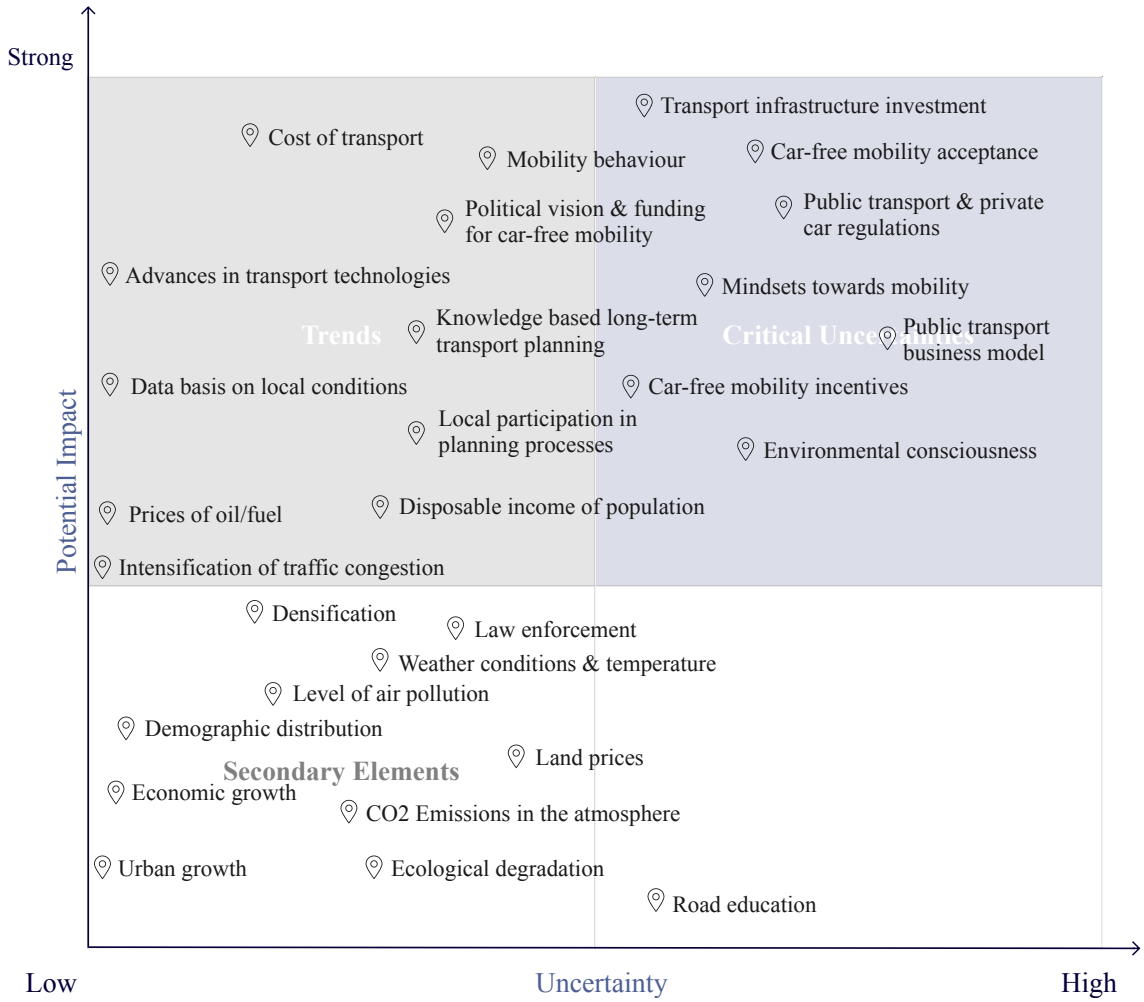


Figure 21: Impact/Uncertainty Grid

15 years whilst improving the mobility situation in Maun as a whole are developed more deeply. The scenarios do not intend to be a precise prediction or forecast, but they rather stimulate creative thinking by developing possible future outcomes. Thereby the lack of available local data poses constraints regarding the scenario development process.

Based on the knowledge gained in the course of the desk research as well as in the interviews with African mobility experts and inhabitants of Maun, the critical uncertainties and trends in Figure 21 are identified to have an impact on the applicability of mobility in the MSP without private cars. Thereby these factors are clustered according to their degree of impact. The two uncertainties that form the basis for the scenario development are 'transport infrastructure investment' and 'car-free mobility acceptance' as they have the biggest impact on the scenario outcome. Based on these two uncertainties the four scenarios are differentiated by scaling their positive and negative development as seen in the Scenario Matrix (Figure 22).

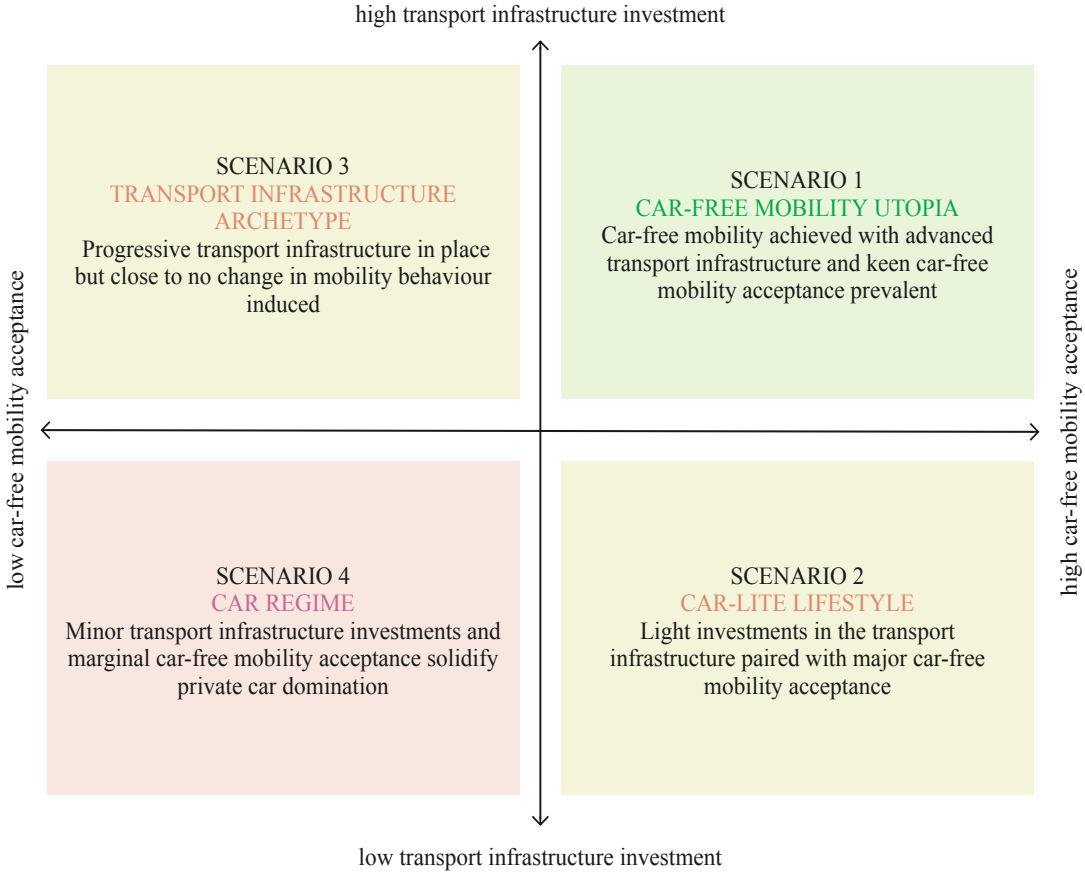


Figure 22: Scenario Matrix

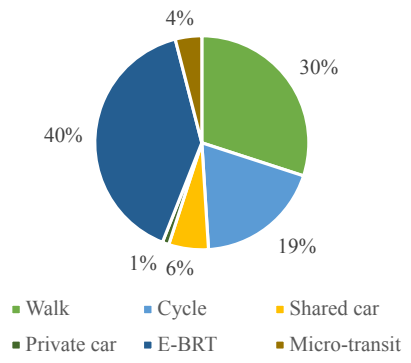
Exemplary scenario 1 and scenario 2 are further developed and described in the factsheets in the next two pages. These factsheets exemplify a possible future of the mobility in the MSP and the rest of Maun but do not demand sufficiency. The two scenarios have in common that they both have a high car-free mobility acceptance. Scenario 1 thereby marks a disruptive, fast change in transport infrastructure investment with rather hard measures accompanying its implementation. On the other hand, scenario 2 introduces a smooth realignment of transport infrastructure investment correlating with soft measures.

SCENARIO 1 **CAR-FREE MOBILITY UTOPIA**

Data

- 19 e-bike & cargo-bike stations
- 9 e-car-sharing stations
- 2 newly employed urban planner
- 80% increase in transport infrastructure investment
- 50% higher environmental consciousness
- 70% more road pavement
- 40% more economic turnover
- 50% less car-accidents
- 80% less air pollution

Mobility Share



Scenario description

> Car-free mobility is achieved in the MSP and the parts of the surrounding city of Maun.

> Maun is densified due to the increased space-efficiency and mixed land use. Former unused space was infilled and in every ward commercial businesses provide basic services, reducing the need to commute.

> The MSP and the urban centre of Maun is fully pedestrianised which led to an increase of economic turnover for the shop keepers. The regained space in Maun's centre is a revegetated locality for recreation.

> The main road of Maun is a one way system with a speed limit of 30km/h. In residential areas the speed-limit is at 10km/h. Speed-cameras are installed across town. Parking around the car-free areas are with costs. Enforcement of traffic regulations are strictly implemented.

> An advanced transport infrastructure is in place. It offers Mobility as a Service which includes a e-BRT system and micro-transit as well as e-bike, cargo-bike and e-car-sharing options. Surveillance cameras and lighting at the stations provide a secure environment. In the MSP autonomous e-vehicles are piloted as delivery service in off-peak hours and as taxi during peak hours.

> The former privately owned transport operators are transferred to the now government owned public transport system. The drivers must take specific road education and have a fixed income.

> Geographical coverage is provided as all BRT nodes, representing fixed stops, are accessible within 5 minutes walking distance. Park&Ride options for commuters are available.

> The cost of public transport is affordable for anyone. Daily, weekly, monthly and yearly multimodal fixed fairs are offered and can be purchased online. Sustainable transport choices are rewarded with bonus points granting benefits. Subsidies for the purchase of a bike or e-bike are offered by the city.

> Proper NMT infrastructure such as lighting, shelters, crossings, signposting and streetlights as well as green street design caters a pleasurable walking and biking experience. Drainages prevent flooding during the rainy season. Bike garages and bike lock-up stations are set up across town.

> There are dedicated NMT lanes with a continuous NMT-highway within Maun. A cycle and pedestrian bridge across the Thamalakane River is built between the MSP and the northern bank of Maun.

> There is a bike-repair workshop and a bike school in the MSP offering free courses. The local schools are incorporating these in the study curriculum.

> Regular events such as cycling competitions, 'mobility weeks' with new advances in transport technologies as well as hackathons on sustainable mobility and sustainability-festivals are held in Maun. Regular information campaigns promoting NMT and public transport are aired.

> There is a high environmental conciouseness and positive mindset towards car-free mobility among the inhabitants.

> Through constant costumer engagement and extensive user education the e-BRT system has a modern, efficient, reliable, convenient, comfortable and safe service branding and high popularity.

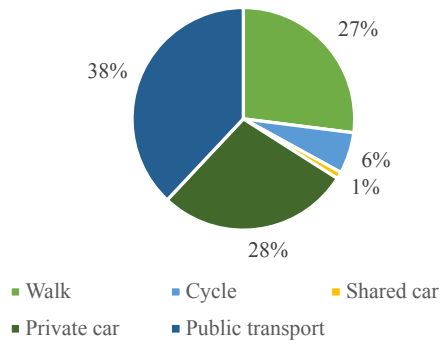
> Constant data collection of the mobility habits of the inhabitants of Maun is conducted as well as regular feedbackloops with the local population on the situation at hand.

SCENARIO 2 **CAR-LITE LIFESTYLE**

Data

- 2 e-bike & cargo-bike stations
- 1 e-car-sharing station
- 30% increase in transport infrastructure investment
- 50% higher environmental consciousness
- 20% more road pavement
- 25% more economic turnover
- 15% less car-accidents
- 10% less air pollution

Mobility Share



Scenario description

> Car-lite mobility is present in the MSP and parts of the surrounding city of Maun.

> In the urban centre of Maun NMT-users are given priority with a bigger road share. Next public transport is prioritised. Private cars have limited road space and reduced parking space with costs.

> The MSP is car-free expect public transport and shared resident e-cars.

> A modified transport infrastructure is available as stronger regulations are set in place. Private operators work kilometer-based and fixed stops and timetables for the minibuses are installed.

> A labelling of the operated routes are compulsory for taxis and mini-buses.

> Fixed public transport rates are defined and daily, weekly, monthly and yearly multimodal fairs offered.

> Through constant costumer engagement and user education the modernised public transport system has an efficient, reliable, convenient and comfortable service branding and high popularity.

> E-bike, cargo-bike and car-sharing options are offered solely in the MSP.

> Basic NMT infrastructure such as side-walks, shelters, crossings and streetlights cater a safe walking and biking experience. Bike lock-up stations are set-up across town to enhance security. Sign-posting of a bicycle lane on the paved roads underline the cyclists road space.

> Traffic calming measures such as speed bumps and raised crossings are implemented at the main road.

> There is a high environmental consciousness and positive mindset towards car-free mobility among the inhabitants.

> There is a bike-repair workshop and a bike school in the MSP offering courses. The local schools incorporating these in the study curriculum.

> Regular events such as cycling competitions, 'mobility weeks' with new advances in transport technologies as well as hackathons on sustainable mobility and sustainability festivals are held in Maun. Regular information campaigns promoting NMT and public transport are aired.

> Every first Sunday of the month there is a car-free initiative organised where the Maun's city centre is blocked for cars. A market with music and food brings the community and NMT usage together.

> The local Maun Cyclists group holds a yearly bike competition criss-crossing Maun and thereby engaging the public.

> Constant data collection of the mobility habits of the inhabitants of Maun is conducted as well as feedbackloops with the local population on the situation at hand.

In order to define a strategy from the scenarios, a strategy corridor that enables to derive a manual is needed. The Simplified Influence Diagram (Figure 23) demonstrates the influence of trends and the uncertainties on the two driving scenario dimensions of transport infrastructure investment and car-free mobility acceptance. Thus, the diagram illustrates the scope of action and thereby the strategy corridor.

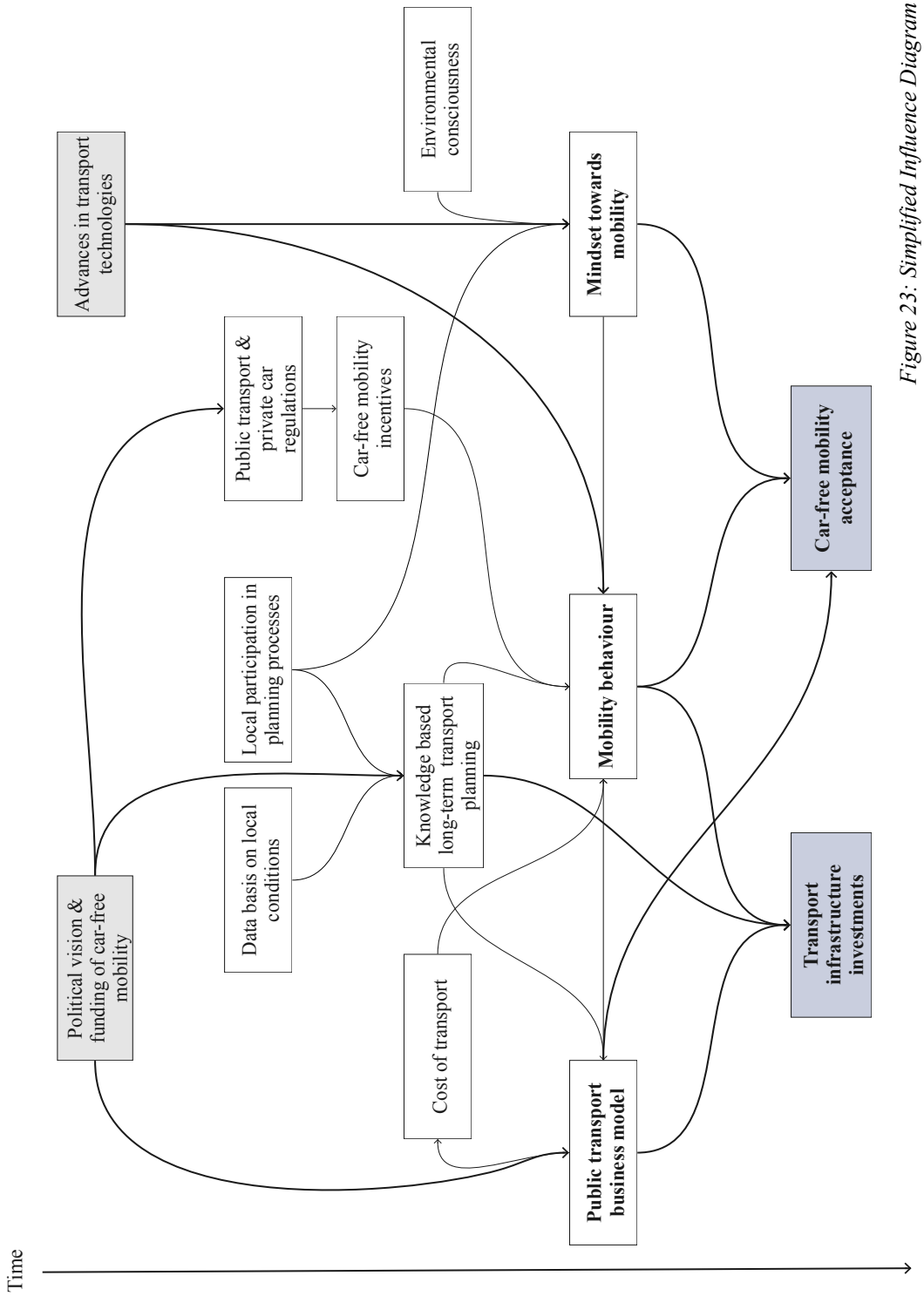


Figure 23: Simplified Influence Diagram

To drive the scenario dimensions positively, strategic actions for the trends and uncertainties must be determined. Through the definition of command variables of the indicators, as they are diagrammed in Table 1, a strategy manual of such kind can be developed. Due to the lack of data, the final strategy manual is not constructed in the course of this research but rather the favorable foundation is presented.

INFLUENCE FACTORS	**INDICATORS**
Political vision & funding of car-free mobility	Number of political initiatives on sustainable mobility
Data basis on local conditions	Data from Statistics Botswana about Maun
Local participation in planning processes	Number of conventions with local inhabitants and transport planners
Knowledge based long-term transport planning	Employment-rate of expert staff at municipal government
Public transport model	Percentage of government spending directed towards public transport
Cost of transport	Operator survey
Mobility behaviour	Percentage of mode share
Public transport & private car regulations	Number of pushing initiatives implemented
Car-free mobility incentives	Number of pulling initiatives implemented
Advances in transport technologies	Number of X technology in Maun (e.g. e-bikes)
Environmental consciousness	Inhabitant survey
Mindset towards mobility	Inhabitant survey

Table 1: Indicator Table

The influence factors and their indicators can then be used to monitor the status quo, to derive a strategic goal and monitor its implementation development. In accordance with Schwenker and Wulf (2013), the factors in the indicator table (Table 1) then can be monitored through a traffic light system. This fosters easy communication about the development of the external environment versus the scenario and thus allows fast adaption.

8 Conclusion

For decades, urban transport planning and political funding were oriented on individual mobility rather than on public transport and NMT. This led to a constant rigidification of a car-centric infrastructure and lifestyle which is further intensified by urban sprawl. This dominating reality will take time and effort to change but healthier, environmentally friendlier and more inclusive and just cities could evolve. There is an urgent need to do so in order to mitigate the negative effect of a car-centric lifestyle. A car-free mobility concept could be a solution and put the people and their needs and wishes into the center of urban planning whilst complying with environmental constraints.

This thesis aimed to evaluate the applicability of a car-free mobility concept in the MSP. Based on the quantitative and qualitative analysis, it can be concluded that transport infrastructure investment and car-free mobility acceptance are important factors to consider when targeting this concept implementation. The results indicate that the MSP can become car-free when influencing factors such as political vision, advances in transport technologies or environmental consciousness develop in a positive sustainability direction. Hence, it is not only economic factors that must be in the focus of the transformation process, but also people´s perceptions and wellbeing for a successful car-free concept to function. Through the scenarios, a picture is drawn of how such a concept can be applied. It stresses the importance of the incorporation of the entire city and its people in the process. It also illustrates that there are numerous potential outcomes of and approaches to the application of the car-free mobility concept. Thereby, the goal of the MSP to become a blueprint for Africa and beyond, despite not all influencing factors developing positively, can be reached if urban transport planning is integrated into social, economic and ecological urban development rather than being considered as a single subject. However, there are still numerous uncertainties when implementing a car-free mobility concept that are complex to manage.

While the data, time and resource limitations constrain the holism of the results of this thesis, the methodological approach of mixed-methods still provides new insights into the applicability of a car-free concept in the MSP. This is achieved by illustrating the concept of urban car-free mobility, the arguments both in favor of and against it as well as the constraints which make an application more difficult. The analysis of the reasons for urban car-free mobility, such as increased quality of life through better health and inclusion, and its limitations, such as inefficient land-use or inadequate public transport business models, deliver a fundamental overview of the status quo. It links the ideal conception to reality and looks at concepts and ideas of partially car-free cities or areas as examples and inspirations. However, these examples also raise the question of its transferability to Maun's specific transport system condition as it is undocumented to date.

Further, the evaluation of developments in sustainable urban mobility is neither exhaustive nor exclusive. It nonetheless critically depicts the chances for a less car-dependent lifestyle and higher transport efficiency as digitalization, electrification and automatization make their way into the transport sector. This is crucial as advances in mobility technologies enable a change of mobility behaviors and mindsets. Yet, technological advancements, such as autonomous vehicles or electric cars, are not a miracle cure to current mobility problems and also come with disadvantages. They even might hinder a sustainable transformation process when their use is not thought through strategically. If not

included in a holistic sustainable transport concept, the number of cars might simply continue to increase, physical activity decrease, and inclusiveness of access worsen.

The basis of high-quality data, was found to be lacking which, however, is of utmost importance for long-term sustainable urban development planning. The collection of sample data about the mobility conditions in Maun in this research is therefore vital for the assessment in this thesis and as a source of orientation. Through the sample survey and interviews, the car-centric transport system, insufficient public transport and nearly nonexistent NMT infrastructure of Maun were specified. Especially a first impression of the inhabitant's perception in Maun was gained and thereby the need for improvement in the transport sector confirmed. Yet, the potential to intercept before a car-centric lifestyle intensifies was also underlined as a culture of walking is persistent and still many people are using public transport. Based on that, exemplary scenarios were derived that picture urban mobility for Maun without private cars. These scenarios promote a better understanding of the influencing factors on car-free mobility and inspire to provide different approaches in order to achieve this goal of sustainable transport.

Further research is needed to determine the relationship between mobility behavior and the current mobility conditions in Maun to derive a mobility road map for the MSP. Hence, it is highly recommended to conduct more in-depth data collection and further field research to ensure a complete analysis of the demography and mobility infrastructure of Maun in correlation with the perception, wishes and needs of the inhabitants. Also, the impact of car-free measures on mobility patterns must be examined. Based on the conclusion of this thesis, practitioners should consider a more human-centred conceptualization of the MSP with strong local participation.

This thesis is independent research which is nonexistent to date as the examination of a possible car-free mobility infrastructure on the MSP was not yet dealt with in literature. It links car-free mobility concept findings with the local mobility conditions of Maun and illustrates the applicability of mobility without private cars and its barriers through scenarios. The result of this thesis is not meant to be a final say, but rather to justify the importance of further research and to function as a starting point for future strategic planning of the mobility concept of the MSP. The research findings construct a good theoretical and evidenced basis to argue for a car-free mobility vision that may seem utopian but that is inevitable, worthwhile and applicable, not only for the MSP and the surrounding city of Maun, but for many cities across the globe. It contributes an idea to the academic world that can be conveyed to other cities to venture into a new era of mobility that is inclusive, just, healthy and sustainable.

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Eidesstattliche Erklärung

Ich erkläre hiermit an Eides Statt, dass ich die vorstehende Bachelor-Thesis selbständig angefertigt und die benutzten Hilfsmittel sowie die befragten Personen und Institutionen vollständig angegeben habe.

[redacted]

22.03.2021

Ort, Datum

Unterschrift

Appendix: Maun online survey

Maun online survey

Sample size calculation:

$$Sample\ size = \frac{Z^2 * p * q}{e^2} = \frac{1.96^2 * 0.5 * 0.5}{0.132^2} = 55$$

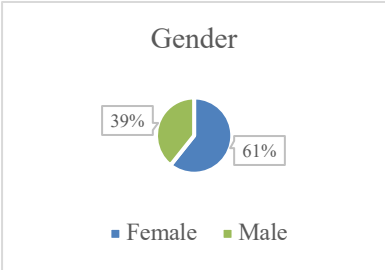
$N = population\ size = 60.263$
$e = Margin\ of\ error = 13.2\%$
$z = z - score = 1.96\ at\ the\ desired\ confidence\ level\ of\ 95\%$
$p = 0.5$
$q = 1 - p = 0.5$

The following layout of the online survey conducted in Maun represents all questions and answer-possibilities as well as their results. The sample size was 56 people, slightly more than necessary to achieve the margin error of 13.2% and desired confidence level of 95%.

Appendix 1: Demographic Data

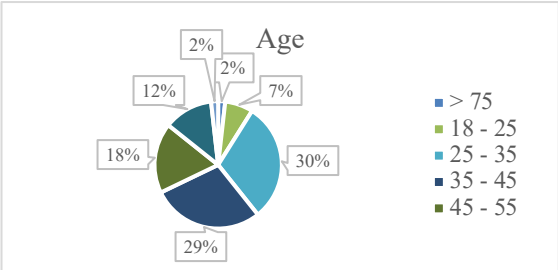
What is your gender?

Row Labels	Number of answers
Female	34
Male	22
Diverse	0
Grand Total	56



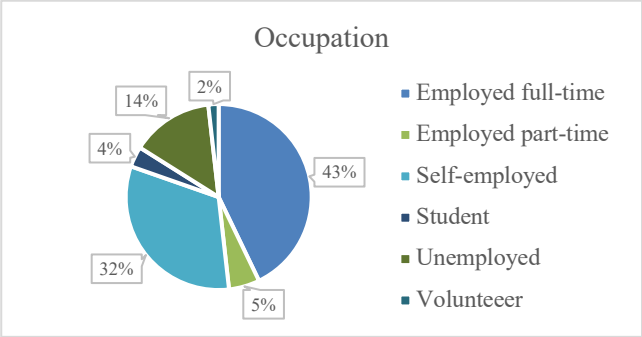
What is your age?

Row Labels	Number of answers
< 18	0
18 - 25	4
25 - 35	17
35 - 45	16
45 - 55	10
55 - 65	7
65 - 75	1
> 75	1
Grand Total	56



What is your occupation?

Row Labels	Number of answers
Employed full-time	24
Employed part-time	3
Self-employed	18
Student	2
Unemployed	8
Volunteer	1
Other (free text field)	-
Grand Total	56



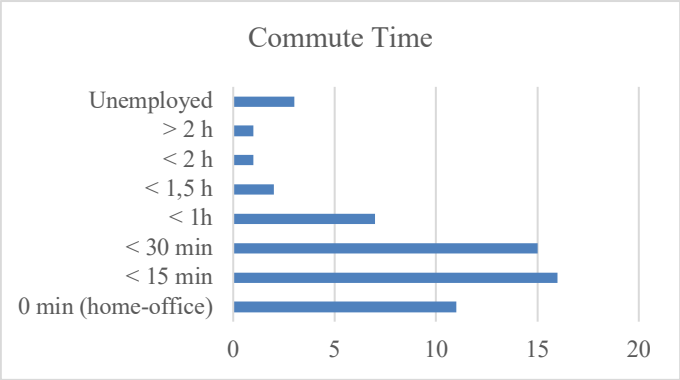
Appendix 2: Mobility Habits

How do you typically move around in Maun?

Row Labels	Number of answers
Bike	1
Mini-Bus	3
Motocycle Taxi	1
Private car	46
Taxi	15
Walk	6
Other (free text field)	-

How long do you usually commute to/from work? (in total per day)

Row Labels	Number of answers
0 min (home-office)	11
< 15 min	16
< 30 min	15
< 1h	7
< 1,5 h	2
< 2 h	1
> 2 h	1



Unemployed	3
Grand Total	56

Would you like to own a car?

Row Labels	Number of answers
I already own a car	40
Yes	16
No	0
Grand Total	56

Why would you like to own a car?

This was an open question with a free text field. The following table is a collocation of the free text answers.

Row Labels	Number of answers
Carrying loads	3
Convenience	18
Independence	12
Reliability	9
Required	9
Safe money	2
Grand Total	53

Free text field answers:
for easy transportation
We live on a farm and need transport on the farm and for town.
There is no public transport
Obviously mobility/convenience
I would actually prefer to get by without a car, but the long distances to shopping require it.
The easiest way to get around town is with a car
I already own a car
Convince
TO TRANSPORT MY KID EASILY TO SCHOOL WITHOUT WAITING FOR THE TAXI
I already own one
mobility
I already own a car
To own a car. Distance. Carrying load
Id prefer a good public transport system
I do

Not applicable
Self reliance
Independance
To easily move around various areas within Maun
To add to assets and to be able to move around easier
Where I stay taxis don't pass by very often
To be able to take my daughter to school and run a few errands..I also try to make money by selling food
I would prefere to not have a car if there was a good pubblic transport system
To save time in terms of going somewher and it will be reliable
Owned
Convenient
No proper walkways in maun and too hot
Ease of movement
Already own one
It will be much easier for me to travel
to move around easily
I have a car
To easily access where I want to go.
Ease of mobility, reliability of access to transport
Convenience
Easy access from point a to bat my own time and comfort of space with intruders
We live in the bush so we need a car to come to town!
I already own one and if I didn't I would need to have one due to my community involvement and my job
to avoid being late at work and especially during the rainy season its not easy to find a taxi and also if you find 1 they charge you more than the normal price
A CAR IS QUICKER THAN WAITING FOR A TAXI
I would like to own a car because i want to have easily access area fast under any weather condition without any restriction
I have one already. I do not have to crowd up with a lot of people in a vehicle. I can go whereever i want at any time.
I Own a car due to lack of public transport, taxis are not safe. Downsides of owning a car is the maintenance costs due to quality of cars available, roads and underqualified mechanics.
Covinence sake
No really good public transport in Maun
my work rely on it
Covid
Already have a car convenient to move around in my own time
I already have a car as discussed above
I have a car already
Because i want to save my money
That i spend on a taxi every time when I want to go somewhere
Convinence
I already do
I already own one

Appendix 3: Maun's mobility infrastructure

Now it´s not about you, but about mobility in Maun in general: What transportation options do you know of in Maun?

Row Labels	Number of answers
Animals	26
Bike	24
Bus	21
Car-pool	4
Mini-Bus	29
Motocycle taxi	2
Private car	43
Taxi	52
Walk	41
Other (free text field)	-

What mobility infrastructure are you missing in Maun?

Row Labels	Number of answers
Bike	18
Boat	8
Bus	14
Car pool	26
None	1
Self-driving shuttle	22
Sharing options (car,bike, e-scooter)	14
Walk	7
Other (free text field)	Tuk Tuk (1)

Appendix 4: Mobility experience

What is something you don´t like about mobility in Maun?

This was an open question with a free text field. The following table is a collocation of the free text answers.

Row Labels	Number of answers
Animals on the road	6
Expensive taxis	3
No NMT infrastructre	3
Poor road infrastructre	14
Rowdy taxi driver behaviour	5
Spread out city layout	4
Taxis	11
Traffic congestion	15
Weather conditions	3

Free text field answers:
Uber are too slow
Taxis are not properly adhering to Covid19 protocols, stray animals are a danger especially at night.
The livestock on the road and the bad roads.
Too many taxis
Don't understand?
Very fast and dangerous taxi drivers in Honda Fit's and Toyota Vitz's. They have killed two of my dogs already.
Bad roads and driver's, some roads have potholes. The taxi drivers are also the worst people on the road
Traffic has gotten worse
Reckless driving
IS BORING DURING RUSH HOUR EXPERIENCE,THE QUE IS LONG
Domestic animals on the road
tragic congestion and slow driving
It takes too long to move from one point to another due to roads that follow alignment of river. Also excessive installation of speed humps creates congestion
I cycle a lot. This is very dangerous in Maun as the road verge is very narrow. No facility for cyclists nor pedestrians. Drivers inconsiderate
Its very spread out and sand roads and hot weather are hard for cycling
Special taxi are expensive
To much traffic especially by shoprite old mall area.
Travic
Too many taxis!
Poor road infrastructure.
Not enough traffic lights

Roads
Some people are always speeding especially some taxis when they are competing for clients or customers
Taxis
That will be safaty wise
Congestion
Taxis
Poor road network and few bridges to cross the river
Took much traffic and taxis
Nothing
Untidy taxis
congested roads
bad road infrastructure leading to traffic at times
Others ares if you don't have a private car it's hard to get a public transport. For example people who stays in old Disaneng up to Matlapaneng Circle, during the day they are forced to pay for a special fee for transportation if they don't have their own private cars.
Too congested. Need alternative roads, not two main roads that get too busy
Mostly Gravel & Dirt Roads
Taxi drivers driving reckless
Too many taxis
It's a pity to use the car so much but the heat as well as being 10km out of town and other places I have to be at regularly are not really giving me the opportunity to use a bike...
too much traffic and 1 main road which is always congested
TOO MUCH TRAFFIC ON ROADS NOT DESIGNED FOR IT
Congestion of traffic at the fourways as well as by the new mall during lunch time and after work
Taxi drivers are terrible drivers
Amount of animals that are on the roads and the incompetence of a lot of the other drivers.
Weather forecast
Lack of sidewalks / cycling lanes / poor road conditions
its expensive
Animals on the road
Cost of fuel
None - its easy to get around in Maun
Lack of good roads
Mobility in is slow maun
Traffic is too much and getting a taxi ya 6p in th rank is difficult
Roads need improvement
potholes

What do you like about mobility in Maun?

This was an open question with a free text field. The following table is a collocation of the free text answers.

Row Labels	Number of answers
Accessable public transport	6
Easy to get around	7
Not too much traffic	13
Nothing	7
Roads improving	3
Short distances	4

Free text field answers:
high customer service
There is not too much traffic
Most drivers are friendly
Nothing.
Convenience/ not reliable on others/ freedom of movement.
I drive a lifted Land Cruiser 4WD with heavy steel bumpers, and their cars would get destroyed if they run into me.
It's easy to get around town, most places are within close proximity so no long driving periods
Easy to get anywhere i want
None
I LIKE IT IN THE EVENING BECAUSE U CAN FREELY MOVE
No traffic
nothing
less traffic on the outskirts
Not much. Too much traffic and congestion to be positive about mobility
generally traffic moves easily
Too many taxis
Everything is close
Every thing is close
New brick roads
Service outlets are found in one place this easy to move around them
Nothing
Easy to excess especially when you are around town
Maun is a small village traffic is moderate a person can quickly get to where they want to go
No traffic
Meeting other people and sharing ideas
Freedom
Short distances
No traffic lights
Tar not dirt roads
Public transport is readily accessible

Ease of access
its easy to access public transport e.g taxi are very easy to find
public transport is readily available
It's still a developing village and everyone is free to use the kind of mobility they see fit, comfortable and afford to use.
Lots of options eg taxis, buses private
Cheaper Taxi Special Rates
Taxi access
Not that busy most of the time (only at certain roads)
Since I often need to move around 3-4 times a day (also to take other passengers & stuff) it's great to have my own car
taxis are very helpful here in maun
AIRCONDITIONING
Mid month no traffic
There isnt much traffic
There is not too much traffic
Wildlife
Not too much traffic
It always available
Lesser traffic
Convenience of own transport
That its easy to get around
Nothing much
There is greater mobility of labour which means there is movement of workers
Nothing
Roads improving
not too congested

Which of the following modes of transport are safe to use?

Walk

Row Labels	Number of answers
moderate	28
not at all	5
very much	23
Grand Total	56

Bike

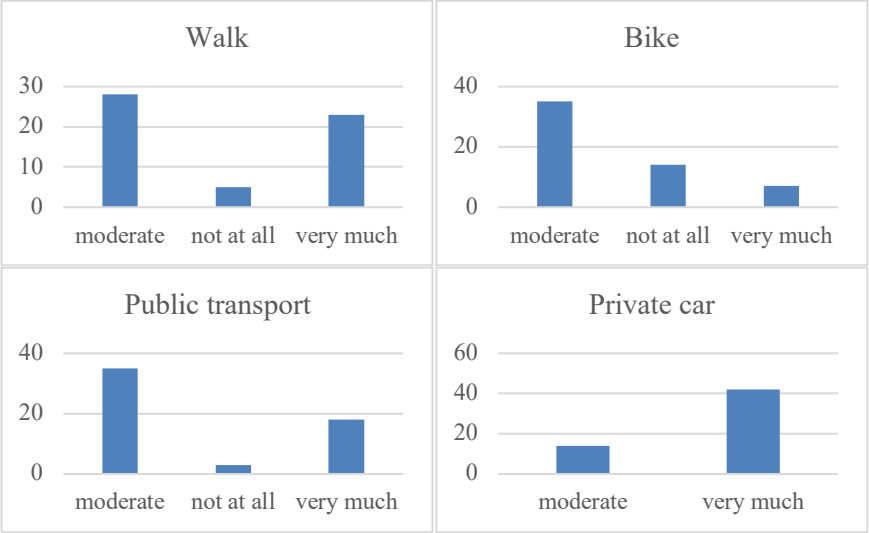
Row Labels	Number of answers
moderate	35
not at all	14
very much	7
Grand Total	56

Public transport

Row Labels	Number of answers
moderate	35
not at all	3
very much	18
Grand Total	56

Private car

Row Labels	Number of answers
moderate	14
very much	42
Grand Total	56



Which of the following modes of transport are comfortable to use?

Walk

Row Labels	Number of answers
moderate	22
not at all	14
very much	20
Grand Total	56

Bike

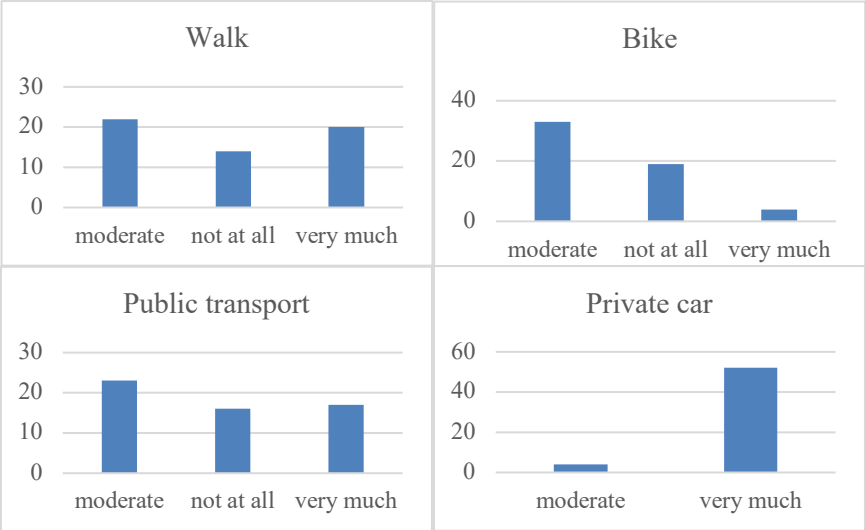
Row Labels	Number of answers
moderate	33
not at all	19
very much	4
Grand Total	56

Public transport

Row Labels	Number of answers
moderate	23
not at all	16
very much	17
Grand Total	56

Private car

Row Labels	Number of answers
moderate	4
very much	52
Grand Total	56



Which of the following modes of transport are time-efficient to use?

Walk

Row Labels	Number of answers
moderate	17
not at all	30
very much	9
Grand Total	56

Bike

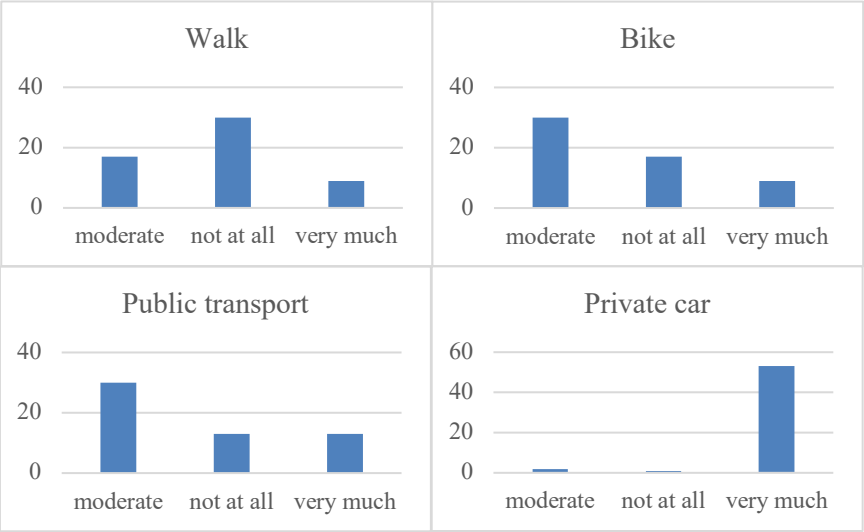
Row Labels	Number of answers
moderate	30
not at all	17
very much	9
Grand Total	56

Public transport

Row Labels	Number of answers
moderate	30
not at all	13
very much	13
Grand Total	56

Private car

Row Labels	Number of answers
moderate	2
not at all	1
very much	53
Grand Total	56



Which of the following modes of transport are cost-efficient to use?

Walk

Row Labels	Number of answers
moderate	3
not at all	5
very much	48
Grand Total	56

Bike

Row Labels	Number of answers
moderate	9
not at all	6
very much	41
Grand Total	56

Public transport

Row Labels	Number of answers
moderate	25
not at all	8
very much	23
Grand Total	56

Private car

Row Labels	Number of answers
moderate	28
not at all	11
very much	17
Grand Total	56