Considering Strava data as a tool for planning bicycle- friendly spaces

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PREFACE

First and above all, I thank God for providing me with wonderful opportunities in life and for being my strength and guide in the writing of this dissertation.

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ABSTRACT

Transportation planning is confronted with various challenges as a result of increasing populations, urbanisation and increasing traffic congestion. The recent “green movement” further urges planners to rethink city planning and transportation planning to enhance public health and sustainability objectives; such include the need to consider Non- Motorised Transport (NMT) as a component of spatial planning approaches.

Developing countries face even more complexities, as poverty increases the need of public transport and NMT options. This is also true for South Africa, where the need and role of NMT is increasing. Cycling, as NMT mode, is especially gaining importance, in terms of the benefits it provides to both cities and communities. However, data to substantiate the planning of bicycle-friendly spaces are limited, especially in South Africa, making it difficult to conduct evidence-base-research.

In an attempt to enhance the planning of bicycle- friendly spaces within a local South African context, this research considers Strava data (a geo- location mobile service) and related web-based approaches to identify 1) cycling patterns, 2) user (cyclist) preferences and 3) best practices relating to the planning of bicycle- friendly spaces.

Key terms:

Non- Motorised Transport (NMT)
Bicycle- friendly spaces
Cycling patterns
Strava data

OPSOMMING

Vervoerbeplanning word gekonfronteer deur verskeie uitdagings as gevolg van ’n toename in populasie, verstedeliking en verkeer- kongestie. Die onlangse "groenbeweging" motiveer beplanners om stadsbeplanning en vervoerbeplanning te heroorweeg ten einde openbare gesondheid- en volhoubaarheidsdoelwitte te verbeter; soos die noodsaaklikheid om Nie-Gemotoriseerde Vervoer (NGV) te oorweeg as 'n komponent van ruimtelike-beplanningsbenaderings.

Ontwikkelende lande word meer uitgedaag met verhoogde armoede, asook ’n groter behoefte aan openbare vervoer en NGV- opsies. Dit geld ook vir Suid-Afrika, waar die behoefte en rol van NGV toeneem. Fietsry as ‘n NGV- opsie word veral belangrik beskou in terme van die voordele wat dit aan beide stede en gemeenskappe bied. Data wat die beplanning van fietsry- vriendelike ruimtes ondersteun is egter beperk, veral in Suid-Afrika, wat bewys- gebaseerde navorsing bemoeilik.

In 'n poging om die beplanning van fietsry- vriendelike ruimtes te verbeter, oorweeg hierdie navorsing Strava- data ('n geo- ruimtelike diens) en verwante webgebaseerde benaderings om 1) fietsry-patrone, 2) gebruikers- (fietsryer) voorkeure en 3) beste praktyke met betrekking tot die beplanning van fietsry- vriendelike ruimtes te bepaal.

Sleutelterme:

Nie- Gemotoriseerde Vervoer (NGV)
Fietsry- vriendelike ruimtes
Fietsrypatrone
Strava data

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CHAPTER 1: INTRODUCTION

Transportation planning is confronted with various challenges as a result of increasing populations, urbanisation and increasing traffic congestion (United Nations, 2010:106). The recent "green movement" further urges planners to rethink city planning and transportation planning to enhance public health and sustainability objectives (UN Habitat, 2013:14); such include the need to consider Non- Motorised Transport (NMT) as a component of spatial planning approaches.

This chapter provides a clear and detailed structure of the research conducted, focused on considering Strava data as a tool for enhancing the planning of bicycle- friendly spaces. This research topic originated in 2016 as part of research conducted for the partial completion of the degree B.Art et Scien. The research was furthered as a Master's dissertation and expanded in terms of depth and width, and presented accordingly. The structure of Chapter 1 is captured in Figure 1-1.

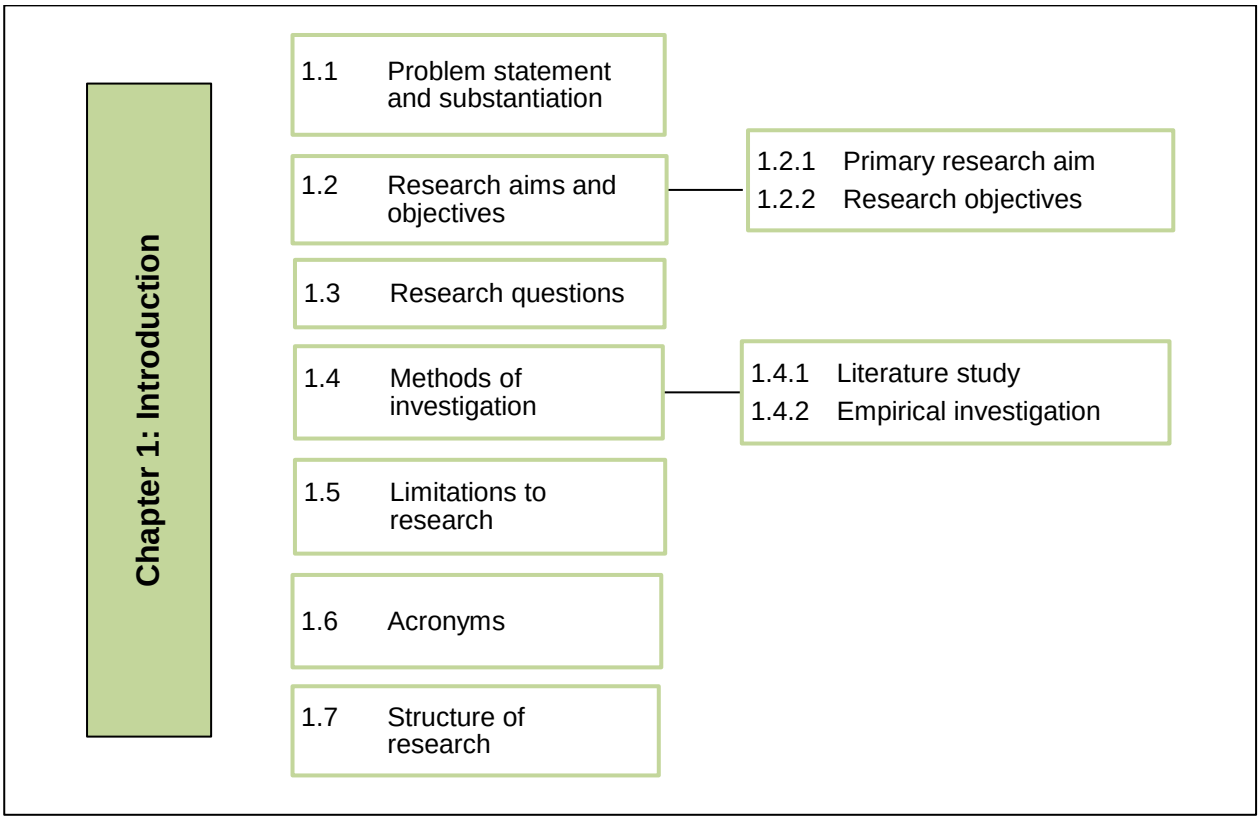


Figure 1-1: Structure of Chapter 1.

Source: Own creation (2017).

1.1 Problem statement and substantiation

Transportation planning is confronted with various challenges as a result of increasing populations, urbanisation and increasing motorised traffic congestion (United Nations, 2010:106). The recent "green movement" further urges planners to rethink city planning and transportation planning to enhance public health and sustainability objectives (UN Habitat, 2013:14); such include the need to consider Non- Motorised Transport (NMT) as a component of spatial planning approaches.

Developing countries face even more complexities, as poverty increases the need of public transport and NMT options (UN Habitat, 2013:14). This is also true for South Africa, where the need and role of NMT is increasing (PGWC, 2009). Cycling, as NMT mode, is especially gaining importance, in terms of the benefits it provides to both cities and communities (Koh & Wong, 2012). However, data to substantiate the planning of bicycle- friendly spaces are limited, especially in South Africa, making it difficult to conduct evidence-base-research (Selala & Musakwa, 2016).

1.2 Research aims and objectives

1.2.1 Primary research aim

In an attempt to enhance bicycle- friendly planning approaches, this research considers Strava data (a geo- location mobile service) and related web-based approaches to identify 1) bicycle usage patterns, 2) user (cyclist) preferences and 3) best practices relating to the planning of bicycle- friendly spaces.

1.2.2 Research objectives

The research objectives include:

- Consider the need and importance of planning for NMT as a component of spatial planning approaches.
- Identify various bicycle- friendly planning approaches in support of NMT.
- Conduct a comparative analysis on international and local case studies, employing Strava data and web-based approaches, in order to identify best practices.
- Consider the local environment and opportunities to translate best practices to local context.
- Consider the findings of the research in an attempt to plan bicycle- friendly spaces in other cities.
- Provide relevant recommendations to guide the planning of bicycle- friendly spaces for the Potchefstroom case study with Strava data substantiation.

1.3 Research questions

The research questions include:

- Why should NMT be included as a component of spatial planning approaches?
- How could bicycle- friendly planning approaches support NMT?
- Which best practices for bicycle- friendly planning approaches can be identified through conducting a comparative analysis on international and local case studies, employing Strava data and web-based approaches?
- How can best practices be translated to the local context?
- How can the findings of the research contribute to the planning of bicycle- friendly spaces in other cities?

1.4 Methods of investigation

The research methodology comprised of a literature study and empirical investigation. Certain conclusions were drawn and recommendations were made from these investigations.

1.4.1 Literature study

The literature review will consider and investigate the following themes in context of this research:

Defining the importance and need of NMT: The transportation sector is partially responsible for public health problems in cities, as a result of increased greenhouse gas emissions, air pollution and road accidents (United Nations, 2010:106) resulting from increasing populations and urbanisation. Recent studies suggest that public transport and NMT are gaining importance as the preferred modes of transport in cities, as such are beneficial to both people and the planet (UN Habitat, 2013:14). The importance and need of NMT will thus be explained and placed in context of broader spatial planning approaches.

Investigating the significance of NMT in developing countries: The United Nations (2010:106) stated that the most evident transport problem of cities in developing countries is traffic congestion since there is an increase in private vehicles dominating city roads. This section will consider the significance of NMT for developing countries. The status of NMT in South Africa will also be captured.

Focussing on cycling as a NMT mode: The health agenda initiated as a mascot for green and sustainable transportation (Koh & Wong, 2012). The local South African current reality suggests that cycling has a further role to fulfil in terms of mobility, substantiated by the benefits that it

provides for NMT users. As such, the planning of bicycle- friendly spaces should be considered in a South African context (PGWC, 2009). This section will thus consider cycling as NMT mode, and reflect on the planning of bicycle- friendly spaces as a component of broader city planning objectives.

Theory based sampling will be employed as part of a qualitative enquiry into the planning of bicycle- friendly spaces and various design elements will be identified as crucial elements to consider for enhancing the planning of such spaces.

1.4.2 Empirical investigation

This research will employ both a qualitative and quantitative research approach.

Firstly, a case study analysis will be conducted to evaluate international and local case studies, including Amsterdam, Copenhagen, Cape Town- and Johannesburg. These cases were purposefully selected based on their planning approaches and vision to develop bicycle- friendly spaces. These cases will be evaluated based on 1) bicycle usage patterns as obtained through Strava data and 2) user (cyclist) preferences, identified through web-based approaches (Google Earth, street view analysis) in order to draw conclusions with regard to 3) planning best practices relating to bicycle- friendly spaces.

Accordingly, the current reality of the Potchefstroom local case study will be evaluated in terms of 1) bicycle usage patterns, utilising Strava data in order to identify core bicycle routes within the Potchefstroom area and in terms of 2) user (cyclist) preferences. Chapter 6 attempts to evaluate the local Potchefstroom case study in order to identify opportunities for intervention and provide relevant recommendations to guide the planning of bicycle- friendly spaces for the Potchefstroom area with Strava data substantiation. This chapter considers Strava data as a tool for enhancing the planning of bicycle- friendly spaces, applicable to different urban contexts. The international best practices would be considered and translated to the local context to offer possible solutions to plan for bicycle- friendly spaces.

The results of this research will be used as point of departure for planning bicycle-friendly spaces in similar areas, illustrating the use of Strava data and web-based approaches to substantiate such.

1.5 Limitations to research

This research considers the planning of bicycle-friendly spaces from a spatial perspective, linked to evidence-based research and the availability of data (Strava data and web-based approaches) to substantiate such. Although various factors influence the planning and sustainability of bicycle-friendly spaces, this research focus on the use of specific open sources to provide data and inform the planning process.

1.6 Acronyms

The following table includes all the acronyms used in this research study.

Table 1-1: Acronyms

Acronym:	Meaning:
BRT	Bus Rapid Transit System
CBD	Central Business District
CCTV	Closed- Circuit Television
CSIR	The Council for Scientific and Industrial Research
DFA	Development Facilitation Act
DRDLR	Department of Rural Development and Land Reform
ECN	Energy research Centre of the Netherlands
EMF	Environmental Management Framework
GHG	Greenhouse Gas Emissions
GIZ	German Society for International Cooperation (German: Deutsche Gesellschaft für Internationale Zusammenarbeit)
GPS	Global Positioning System
HELI	Health and Environment Linkages Initiative
IDP	Integrated Development Plan
ITP	Integrated Transport Plan
JUCA	Johannesburg Urban Cyclists Association

Acronym:	Meaning:
LDO	Land Development Objective
MSA	Municipal Systems Act
NATMAP	National Transport Master Plan
NHTS	National Household Travel Survey
NLTA	National Land Transport Act
NLTSF	National Land Transport Strategic Framework
NMT	Non- Motorised Transport
NRTA	National Road Traffic Act
PGWC	Provincial Government of the Western Cape
PLTF	Provincial Land Transport Framework
RISFSA	Road Infrastructure Strategic Framework for South Africa
SALGA	South African Local Government Association
SDF	Spatial Development Framework
SDG	Sustainable Development Goals
SPLUMA	Spatial Planning and Land Use Management Act
UN	United Nations
UNEP	United Nations Environmental Programme
WHO	World Health Organisation

Source: Own Creation (2017).

1.7 Structure of research

The following Figure 1-2 illustrates the structure for the remainder of this research study.

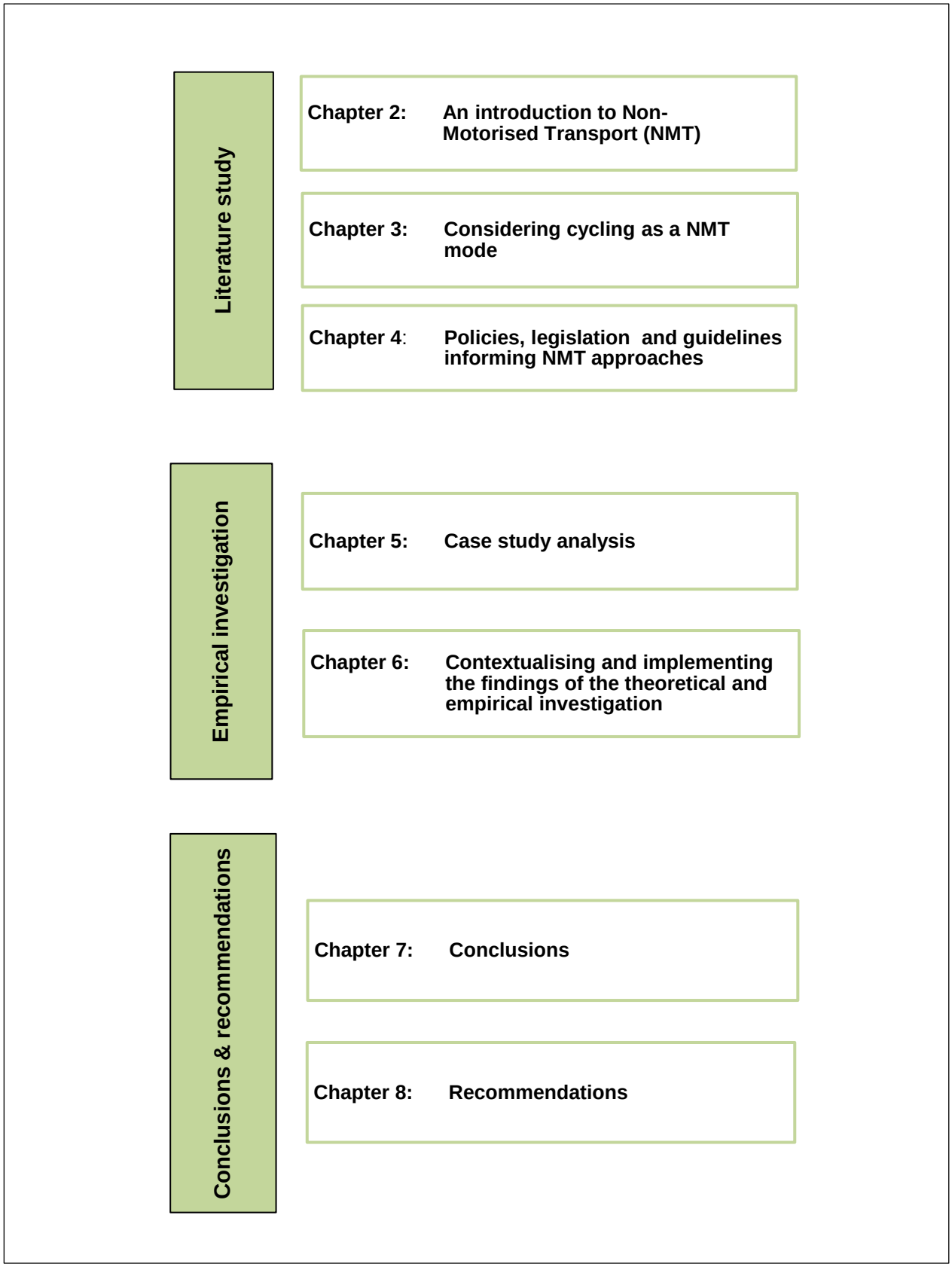


Figure 1-2: Structure of the research study.

Source: Own creation (2017)

CHAPTER 2: AN INTRODUCTION TO NON- MOTORISED TRANSPORT

The transportation sector is partially responsible for public health problems in cities, as a result of increased greenhouse gas emissions, air pollution and road accidents (United Nations, 2010), resulting from increasing populations and urbanisation. The United Nations (2010:106) stated that the most evident transport problem of cities in developing countries is traffic congestion since there is an increase in private vehicles dominating city roads. The transportation sector is essential for urban planning as transportation provides accessibility to goods, services, jobs, educational opportunities, family, social interaction and economic activities (Department of Transport, 2008). Recent studies suggest that public transport and NMT are gaining importance as the preferred modes of transport in cities, as such are beneficial to both people and the planet (UN Habitat, 2013:14).

In this chapter, the importance and need of Non- Motorised Transport (NMT) will be explained and placed in context of broader spatial planning approaches. This chapter will also consider the significance of NMT for developing countries, with specific attention to NMT in South Africa. The structure of Chapter 2 is captured in Figure 2-1.

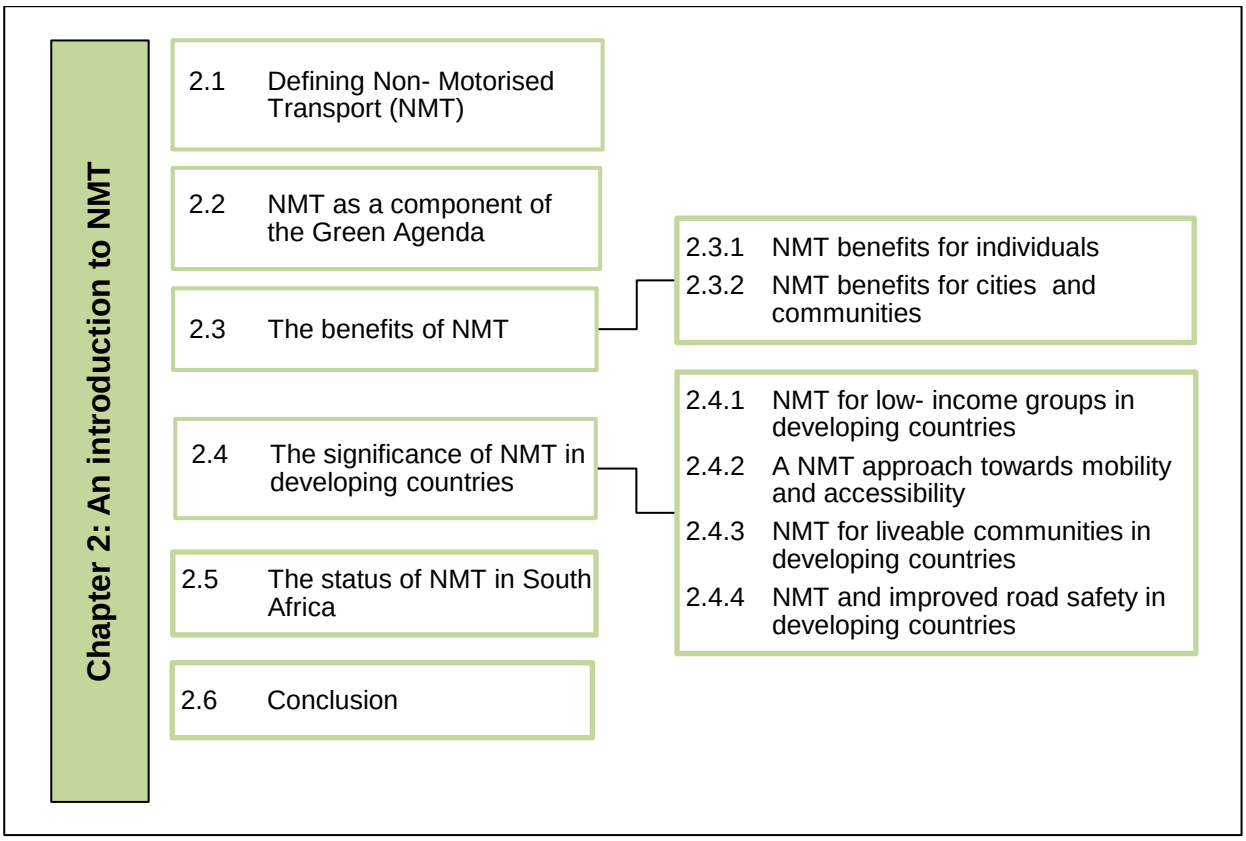


Figure 2-2: Structure of Chapter 2.

Source: Own creation (2017).

2.1 Defining Non- Motorised Transport (NMT)

Transportation provides accessibility to goods, services, jobs, educational opportunities, family, social interaction and economic activities; therefore detailed and integrated transport planning is essential for city development (Department of Transport, 2008). Urban planning problems would also be difficult to address without planning for transportation. Such planning problems include economic growth, quality of life, energy conservation, social opportunities, public safety and poverty (Department of Transport, 2008). According to Servaas (2000:10), NMT is an essential component of urban transportation planning in developing countries worldwide.

NMT, generally, refers to any mode of transport that relies on energy that is not produced by an engine (Angira, 2013:14). According to Angira (2013:14), walking or cycling is an example of this type of energy, using human effort as an energy source. NMT also refers to a considerable broader variety of transport modes other than walking and cycling; such as skateboarding, horse riding or using animals for transport, with the use of wagons and trailers (Baufeldt, 2016:10). The definition of NMT according to Angira (2013:14) includes any mode of transportation that provides mobility by methods other than motorised vehicles. Walking is considered as the primary NMT mode for individuals that form part of journeys made by private motorised vehicles or public transport (PGWC, 2009:2). Cycling as a NMT mode has the potential to serve a lot of journeys but is less prevalent than walking. Other NMT modes are used for recreation, personal mobility and transport of goods, and should also be considered in transport planning (PGWC, 2009:2). The following table captures the different types of NMT modes.

Table 2-1: Different types of NMT modes.

Type of NMT mode:	Illustration:	NMT mode description
Walking	 Source: AAA Exchange (2017).	Walking is considered as the primary transport mode for most individuals in cities, especially for cities in Africa (PPMC, 2014).
Cycling	 Source: UCLA Transportation (2015).	Cycling as a NMT mode is mostly used for short-distance trips, with city journeys up to 7.5 km (Climate Tech Wiki, 2006).

Type of NMT mode:	Illustration:	NMT mode description
Skateboarding	 Source: Intelligent travel (2013).	Skateboarding has recently expanded from recreational purposes into a mode of transportation. Skateboarders seem to use roadways as much as other NMT users (Walker, 2013).
Horse riding / using animals for transport	 Source: Reisbauer (2016).	Animal transportation is essential for supplying communities with resources. It therefore serves as a vital mode for poor communities. (Reisbauer, 2016).
Roller-skating	 Source: National Capital Commission (2017).	Roller- skating is a form of recreational activity as well as a sport, and may well serve as a NMT mode (National Capital Commission, 2017).
Hand carts	 Source: Timmons (2011).	Hand carts are designed for transport, using two wheels and usually pulled or pushed by individuals (Timmons, 2011).
Wheelchair travel	 Source: Masterfile (2017).	Wheelchair users and handicapped individuals prefers to use wheelchairs as their mode of transport as it could save time in planning their journeys (Travel Characteristics Survey, 2002).
Rickshaws	 Source: Fietstaxi Tilburg (2017).	Rickshaws are commonly used as a mode of urban transport, both as a vehicle for hire and for private use in many cities around the world.

Source: Own Creation (2017).

The development of NMT is essential for encouraging sustainable, integrated and inclusive urban transport. “Universal design” is an essential concept for pursuing this perspective, which recognises that mobility and accessibility are mainly determined by the built environment (Gauteng 25-Year Integrated Transport Master Plan, 2013:1). The concept of universal design proposes that the built environment should accommodate all transport users, rather than assuming that the community should accommodate for the built environment. (Gauteng 25-Year Integrated Transport Master Plan, 2013:1).

NMT plays an important role in the provision of sustainable, affordable and environmentally friendly transportation systems in developing countries (Ethekwini Municipality, 2013:1), as will be elaborated in Chapter 3. As a mode of transport, NMT is accessible to most individuals in cities (Department of Transport, 2008:9). Lower- income and transport- disadvantaged individuals, such as the handicapped, young and elderly benefit significantly from improvements in NMT facilities (Global Transport Knowledge Practice, 2013).

2.2 NMT as a component of the Green Agenda

Climate change and environmental sustainability are rapidly becoming priorities on the global green agenda (City of Johannesburg, 2009). Lindfield & Steinberg (2012) expressed the opinion that adaption measures will be required to manage efforts to reduce emissions and cope with the adverse concerns of climate change. Lindfield & Steinberg (2012) further proposed the idea of directing the green agenda toward efficient, compact, and multifunctional urban areas. It thus focuses on developing “green” urban infrastructure services such as the provision of water, waste management, sanitation services, energy sources, and transportation (Lindfield & Steinberg, 2012).

According to Yulin & Zhenyu (2010) sustainable transport, also known as “green transport”, refers to any mode of transport with low impact on the environment that includes walking and cycling, transit orientated development, green vehicles, private vehicle sharing, developing urban transport systems that are fuel- efficient, and encourage healthy lifestyles. Yulin & Zhenyu (2010) identified a green transport hierarchy (Figure 2-2), in which different modes of passenger transport are classified based on how environmentally friendly each mode is.

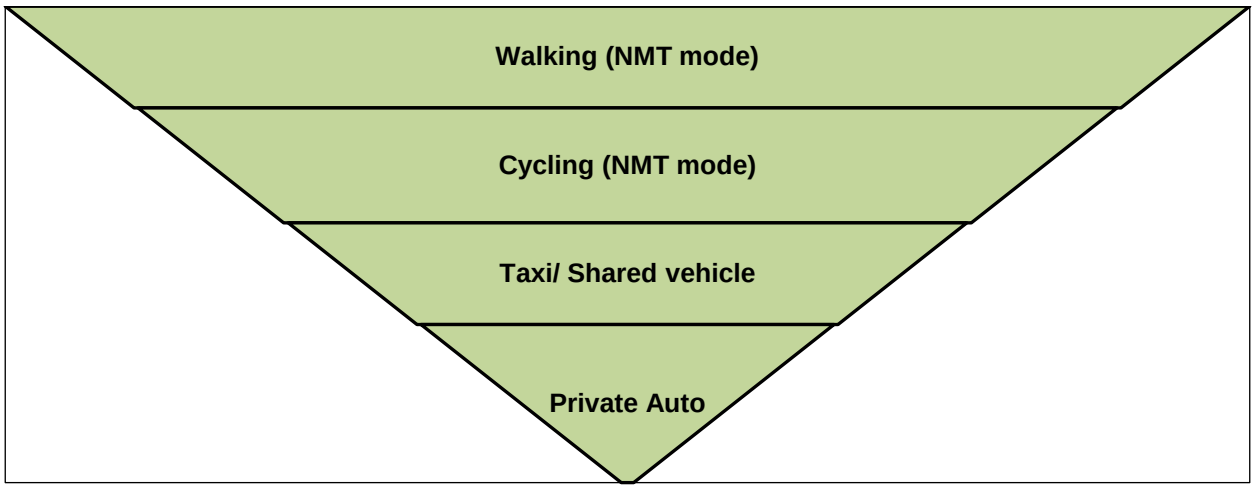


Figure 2-2: Hierarchy of environmental- friendly transport modes.
Source: Own creation (2017) based on Cohen (2016).

This hierarchy illustrates that walking is considered the greenest mode of transport, followed by cycling; public transport, car sharing, and ultimately private vehicle use (Yulin & Zhenyu. 2010). Yulin & Zhenyu (2010) found that sustainable transport systems are safe, accessible, environment-friendly, and affordable. NMT, especially cycling and walking, is supportive of sustainable or green transport (Labuschagne, 2011:4).

NMT provides a sustainable alternative option to the private- motorised vehicle and has an important role to play in reducing traffic congestion, reducing carbon emissions and improving air quality (City of Johannesburg, 2009). In addition, NMT supports an environmentally- friendly transport system for mobility of people and goods (Vadi, 2014). The development of NMT is an essential element in successfully encouraging integrated, sustainable and inclusive urban transport, according to Vadi (2014). The following Figure 2-3 shows an approach to achieve green/sustainable urban transport using NMT.

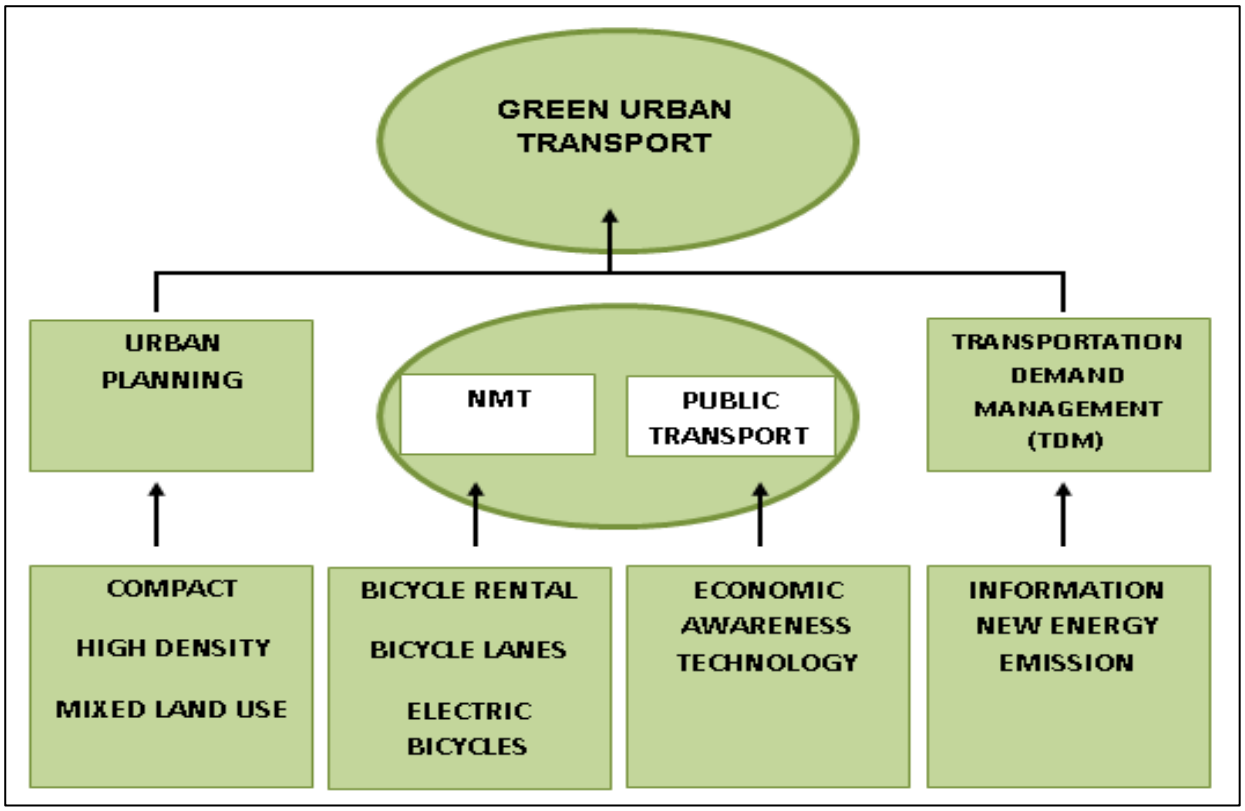


Figure 2-3: An approach to achieve green or sustainable urban transport using NMT. Source: Own Creation (2017) based on Yulin & Zhenyu (2010)

Figure 2-3 shows the key factors and their interrelation that affects green urban transport. Firstly, motorised transport modes can be reduced effectively through urban planning. Secondly, create a shift towards an environmental- friendly transport mode such as public transport or NMT. Thirdly, vehicle technology and the energy efficiency of other transport modes should frequently be improved (Yulin & Zhenyu. 2010).

2.3 The benefits of NMT

NMT is considered as the most basic form of transport in the transportation system and is also recognised as an essential component of the system due to the benefits that it provides for cities and individuals (City of Johannesburg, 2009). The benefits of NMT may thus be separated on 2 scales; 1) benefits for individuals; and 2) benefits for cities and communities.

2.3.1 NMT benefits for individuals

Benefits for individuals generally include increased accessibility, improved health conditions, cost savings, more travel options and increased conditions for road safety (City of Johannesburg, 2009) According to Litman (2010), high rates of dependency on motorised transport may affect health problems for individuals in a city. The dependency on motorised transport and the health of

individuals may also result in higher rates of road traffic accidents (Litman, 2010). The FIA foundation (2016:2) found that NMT has major health benefits, serving to promote physical activity of individuals. According to FIA Foundation (2016:2), NMT development may reduce the amount of 3.7 million deaths that has been caused by air pollution each year, and has been identified as the most effective strategy for improving safety and health conditions for individuals (Litman, 2010).

Angira (2013) found that regular physical activity due to the use of NMT modes provides major health benefits for individuals. For example, a small increase in light to moderate activity, such as regular bicycle rides or 30-minute walks, may produce major benefits among individuals that are least active (Angira, 2013). Litman (2010) identified the following health benefits with relating to NMT on a daily basis for individuals:

- NMT reduces the risk of developing coronary heart disease.
- NMT reduces the risk of becoming obese.
- NMT reduces the risk of developing adult diabetes.
- NMT helps to maintain bone mass and in that way also protects against osteoporosis.
- NMT improves mobility, balance, strength and endurance of individuals.
- NMT relieves the symptoms of depression and anxiety, and increases self-esteem and general psychological health.

Angira (2013) indicated that increased levels of NMT may have a great impact on a city's sense of liveability by creating safe and friendly areas for individuals to work and live. Similarly, Baufeldt (2016) stated that safety benefits for developing NMT facilities include lower risk of road fatalities, collisions, and injuries. It has been shown that cyclists and pedestrians often bypass road traffic and congestion, and in some cases may even reach their destination faster than if they had driven a motorised vehicle (Angira, 2013). Many journeys in cities are less than three miles in length, yet 72% of these short journeys are made in motorised vehicles. NMT facilities ensure that individuals have a variety of transportation options apart from motorised vehicles. NMT facilities may also increase a sense of independence for some individuals, such as the elderly, scholars, individuals with disabilities, and others without an alternative mode of transport (Angira, 2013).

According to Angira (2013), NMT provide options for individuals that would like to save transportation costs. NMT facility improvements may also reduce consumer expenditures on public transport fares, exercise equipment and motorised vehicles. These savings can total hundreds and thousands of rands annually per capita (Litman, 2017). Table 2-2 indicates a summary of NMT benefits for individuals.

Table 2-2: Summary of NMT benefits for individuals.

NMT Impact Category	Description
Improved NMT conditions	Benefits from improved NMT conditions.
User benefits	Increased user comfort, safety, convenience and accessibility.
Option value	Benefits of having alternative mobility options available.
Safety value	Increased conditions for NMT user road safety.
Increase NMT Activity	Benefits from increased NMT activity.
Fitness and health	Improved public fitness and health.
Reduced Vehicle Travel	Benefits from reduced private vehicle use and ownership.
Vehicle cost savings	Consumer savings from reduced vehicle use and ownership.
Parking cost savings	Reduced parking problems and facility cost savings.

Source: Own Creation based on Litman (2011).

2.3.2 NMT benefits for cities and communities

The City and County of Denver (2017) stated that community planning is essential for city development. With regard to community planning, NMT contributes to the vibrancy and liveability of communities (Transport for Cape Town, 2005:2). In this sense, NMT creates social conditions and economic opportunities by supporting city initiatives in terms of economic and social transformation. NMT strategies generally consist of social and economic opportunities that are promoted by low-cost transport initiatives and NMT infrastructure development (Transport for Cape Town, 2005:2). In meeting the demands of a developing city, a city has to develop and support NMT modes and liveable communities (City of Tshwane, 2015).

According to Victoria Transport Policy Institute (2015), communities experience significant NMT increases and related motorised travel reductions as a result of improved NMT facilities. NMT is an attractive mode of transport for relatively short travel distances, which makes up the largest share of city journeys (ECN, 2006:1). Litman (2011) indicated that an increase in NMT activities could provide various benefits for cities. Table 2-3 illustrates several NMT benefits for cities.

Table 2-3: NMT benefits for cities

NMT Benefits for cities		
A reduction in traffic congestion.  Source: Aussie Pete (2010).	Energy conservation.  Source: LinkedIn (2016).	Community health improvements.  Source: HAP (2017).
A reduction in carbon emissions.  Source: The Green Optimistic (2010).	Upgraded mobility for NMT users.  Source: 9 India (2016).	Local economic development.  Source: Norhatan (2015).

Source: Own Creation (2017) based on Litman (2011).

With rising congestion and pollution problems in cities, there is greater work needed to be done in regard with NMT development (Gwala, 2006). NMT development is often an essential element of encouraging clean transport in cities (ECN, 2006:1). According to the FIA foundation (2016:2), cyclists and pedestrians take up considerable less space in cities than of motorised vehicles. These NMT modes could assist in reducing traffic congestion thus is it necessary to develop NMT facilities for cities (FIA foundation, 2016:2).

The Department of Transport (2008) mentioned that NMT is available to most individuals. It provides access for cyclists and pedestrians while encouraging local movement in cities. NMT holds equality benefits for communities that support these journeys. By improving the efficiency, convenience and safety of NMT journeys the transportation system becomes more equitable, such as the users' transport experiences (Baufeldt, 2016). NMT facilities are especially essential in meeting the demands of the more socio- economically vulnerable individuals of communities that depend on NMT (Baufeldt, 2016). It is assumed that NMT is the main transport mode for poor communities and contributes to a significant source of income for some of them (Angira, 2013). In cases where NMT is the main transport mode for poor communities to travel to work, a city has to accommodate different social classes of a community in order for successful economic functioning (Angira, 2013).

Additionally, NMT journeys have a variety of socio-economic benefits that addresses equality concerns (Baufeldt, 2016). Increased mobility and accessibility of NMT journeys would address equality problems of vulnerable individuals in communities (Baufeldt, 2016). Table 2-4 indicates a summary of NMT benefits for cities and communities.

Table 2-4: Summary of NMT benefits for Cities and Communities.

NMT Impact Category	Description
Improved NMT conditions	Benefits from improved NMT conditions.
Equity objectives	Benefits to economically, socially or physically disadvantaged individuals.
Reduced Vehicle Travel	Benefits from reduced private vehicle use and ownership
Congestion reduction	Reduced traffic congestion from motorised transport on congested roadways.
Reduced challenge effect	Improved NMT conditions due to reduced traffic speeds and volumes.
Roadway cost savings	Reduced roadway construction, maintenance and operating costs.
Energy conservation	Economic and environmental benefits from reduced energy consumption.
Pollution reductions	Economic and environmental benefits from reduced air, noise and water pollution.
Land Use Impacts	Benefits from support for strategic land use objectives
Pavement area	May reduce road and parking facility land requirements.
Development patterns	Helps create more accessible, compact, mixed, infill development (smart growth).
Economic Development	Benefits from increased productivity and employment
Increased productivity	Increased economic productivity by improving accessibility and reducing costs.
Labour productivity	Improved access to education and employment, particularly by disadvantaged workers.
Shifts spending	Shifts spending from vehicles and fuel to goods with more regional economic value.
Support specific industries	Support specific industries such as retail and tourism.

Source: Own Creation based on Litman (2011).

It is evident from this section that NMT has an important role to fulfil in encouraging sustainable, integrated and inclusive urban transport, especially when considering benefits that it provides for both cities and individuals. Despite these benefits, urban areas in developed and developing countries have become increasingly motorised- dominated and less sustainable (Pojani & Stead, 2015:2). The United Nations (2010:106) stated that the most evident transport problem of cities in developing countries is traffic congestion since there is an increase in private vehicles dominating city roads. The following section will consider the significance of NMT for developing countries. The status of NMT in South Africa will also be captured.

2.4 The significance of NMT in developing countries

Urban transport systems in developing countries are deteriorating due to the high rates of urbanisation and rapid motorisation (Angira, 2013). These cities are facing problems such as traffic congestion, environmental pollution, health problems, increasing fuel costs, and longer travel distances due to city sprawl (Rastogi, 2011). Therefore, urban population growth is an important element in determining the demand and supply of transport in developing countries. With the effect of city sprawl and growth, the transport demand may increase as distances to services and workplace becomes more dispersed (Angira 2013).

The UN Habitat (2013:5) mentioned that urban transport demand challenges in developing countries are greater than ever. This is particularly the case where motorised transport is growing at higher rates than infrastructure development (UN Habitat, 2013:5). Urban areas in developed and developing countries have become increasingly motorised- dominated and less sustainable (Pojani & Stead, 2015:2). This dictated the need for developing countries to develop, implement and promote NMT as an alternative transport option (Ethekwini Municipality, 2013:1). NMT forms part of a solution for planners to develop alternative modes of transport for developing countries, according to Rastogi (2011). NMT also improves transport mobility and accessibility especially in the poor- serviced areas by integrating NMT into the development of socio- economic activities within developing countries (Ethekwini Municipality, 2013:1).

NMT as a mode of transport is beneficial and sustainable for both developing and developed countries (Baufeldt, 2016:4). The following themes are essential for discussing the importance and significance of NMT for developing countries.

2.4.1 NMT for low- income groups in developing countries.

The transport needs of various income groups are generally different and conflicting in nature, thus creating a difficult and complex task for sustainable development in the transport sector (Angira, 2013). This can be seen where communities have to either walk or cycle to their workplaces due to the unaffordability in private motorised transport or public transport.

Poor families in cities of developing countries generally spend 20% of their monthly income on public transport, while middle- income families do not even spend half as much for their transport needs (Kaltheier, 2002:4). Some individuals may find these transport modes affordable, but might have safety or security concerns due to sexual harassment or other forms of criminal actions, and/or due to inappropriate transport infrastructure (UN Habitat, 2013:5). The lack of transport among poor families reduces their ability to earn higher incomes, access to health care, and education (Kaltheier, 2002:4). Urban mobility, however, represents an essential element in combating poverty and creating better living standards for poor communities. Perschon (2001:8) mentioned that NMT satisfies the basic transport needs for poor communities by considering the social aspects that NMT provides.

NMT supports affordable, sustainable and environmentally friendly transport systems for developed and developing countries worldwide (Ethekwini Municipality, 2013:1). For some low-income communities, NMT is the only mode of transport available for individuals to access schools, service centres, employment opportunities and commercial nodes (Ethekwini Municipality, 2013:1). Research indicates that NMT is an important element in low- income and smaller cities, capturing up to 90% of all city journeys (UN Habitat, 2013:4). These cities call for NMT investments where they are most needed for mobility. Investing in NMT infrastructure is a more equitable and sustainable usage of scarce funds for these lower- income cities (UN Habitat, 2013:5).

2.4.2 A NMT approach towards mobility and accessibility

Urban poverty with interrelated aspects such as high rates of urbanisation is a noticeable problem in the developing world (Joshi, 2014). Urban accessibility is an additional aspect that determines essential links between labour markets, housing and other amenities. Poor people in developing countries face daily complexities with regard to their mobility options regarding existing transport systems (Joshi, 2014). NMT infrastructure provision enables poor communities to access facilities such as hospitals and schools by means of cheaper and safer mobility options. In addition, NMT infrastructure contributes towards connecting households to public transportation systems (Department of Environmental Affairs, 2017).

Developing countries also faces mobility challenges, despite higher levels of urban transport mobility worldwide (UN Habitat, 2013:11). Sustainable urban transport systems may provide solutions for these challenges by means of creating accessible, safe and environment- friendly modes of transport (Tiwari, 1999). Tiwari (1999) suggested that redesigning city roads will ensure safe and convenient environments for NMT mode users. It will also improve the mobility of public transport and increase corridor traffic volumes.

Gwala (2006) linked NMT to the concept of 'complete streets' where the use of the roadway is redefined. This concept focuses on the demanding outcomes of a transportation system that supports safe NMT conditions for individuals (Gwala, 2006). The concept of 'complete streets' breaks down the traditional split between public transport, freeways, cycling, and walking. The 'modal hierarchy' approach supports this concept by suggesting a paradigm shift in the NMT planning approach (Gauteng Department of Roads and Transport, 2013). For example, to design the roadway according to a scheme that prioritises NMT. Figure 2-4 illustrates an operational classification according to the modal hierarchy approach.

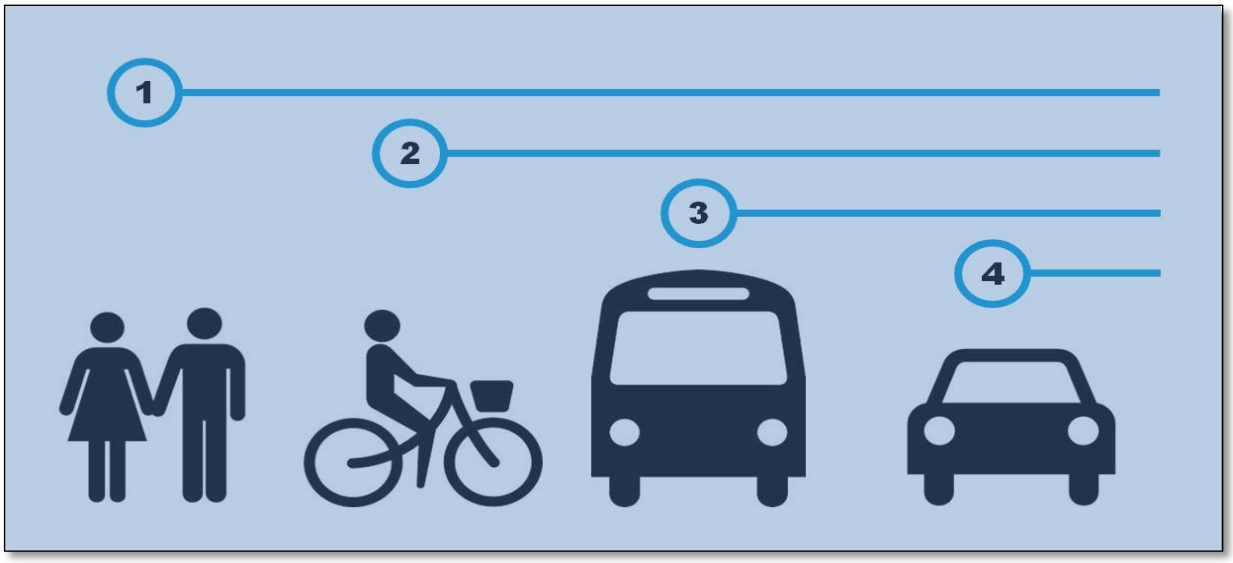


Figure 2-4: An operational classification according to the modal hierarchy approach. Source: Gauteng Department of Roads and Transport (2013).

This multi- modal transport approach is defined by using more than one transport mode for journeys, especially when transferring between different modes on a journey (Van Nes, 2002). This transport approach could resolve transportation problems with respect to the deteriorating accessibility of urban centres, continuing congestion, and environmental impact (Van Nes, 2002). Many cities in developing countries call for investments in green public transport such as NMT. Lindfield & Steinberg (2012:58) identified NMT mode investments as a possible solution to improve the mobility of transport in developing countries. NMT enhances transport mobility and accessibility

by means of integrating NMT into the transport system and into infrastructure and land use planning (Guitink, 1996). A community designed for NMT should include the following elements for encouraging accessible transportation (Department of Transport, 2008):

- A compact city that ensures convenient travel distances.
- Human scale designs.
- Connection with other streets for direct travel.
- Functional and attractive NMT facilities.
- Effective safety strategies to control motorised and NMT traffic.

NMT, and particularly walking, is the main mode of transport in most cities of developing countries (UN Habitat, 2013:6). The majority of low- income cities travel by means of NMT, not by choice, but rather driven by the lack of affordable and accessible alternative transport modes. Cycling as a NMT mode also provides mobility needs to some of the individuals in cities of developing countries (UN Habitat, 2013:6).

2.4.3 NMT for liveable communities in developing countries.

A liveable city provides adequate facilities and spaces that enhance the quality of life for communities (BMZ, 2016:15). Urban mobility plays an important role to address liveability in cities of developing countries (Eco Mobility, 2016). Baufeldt (2016:14) defined liveability to include factors such as health levels, sense of safety, access to services, cost of living, mobility, accessibility, and social interactions. Noles (2016) identified the following transportation objectives in order to achieve the goal for creating a liveable community.

- Increase the safety and health of road users through the development of transportation projects that will provide more travel options and complete streets.
- Promote reinvestment in vacant or underutilised properties through development concepts supported by multi- modal transportation systems.
- Provide communities with reliable and safe transportation options that improve quality of life.

According to GIZ (2014), lower dependence on motorised transport, reduced air pollution and safer facilities for pedestrians and cyclists will create more and better liveability for communities. The potential value of NMT is often undervalued as a mode of transport for developing countries (Baufeldt, 2016:4). NMT and the benefits that it provides have become an important element for ensuring liveable cities in developing countries (Baufeldt, 2016:14). However, the high rates of urbanisation in developing countries place tremendous pressure on planners to create liveable

cities (BMZ, 2016:2). The need for NMT facilities should be considered when planning liveable cities for developing countries (BMZ, 2016:2).

2.4.4 NMT and improved road safety in developing countries.

The number of road casualties in cities of developing countries is exceptionally high (Rietveld, 2001:13). The negative effects of motorised transport can be seen with the high number of road injuries and fatalities in cities, particularly in developing countries (Baufeldt, 2016:4). According to Baufeldt (2016), high rates of road fatalities and injuries should be addressed with appropriate transport planning actions in developing countries. NMT modes such as walking and cycling contribute to about 47% of all urban journeys in developing countries (UN Environment, 2016). Despite the high percentage of individuals relying on NMT, there is a gap between what individuals need and the allocation of funding for NMT development. This gap weakens the mobility of cyclists and pedestrians, forcing them to risk their lives travelling to work or school (UN Environment, 2016).

NMT users are often exposed to fast- moving, careless and aggressive motorised transport users, causing high rates of road accidents involving cyclists or pedestrians (The Kenya Alliance of Resident Associations, 2015). Road accidents claim more than 500 000 lives each year around the world. An estimated 70% of these deaths occur in developing countries, 65% of deaths involve pedestrians and 35% of pedestrian deaths are children (Hossain, 2005:1). According to Hossain (2005:1) road accidents would be the third greatest cause of death and disability by the year 2020. These high pedestrian deaths may occur as a result of inadequate NMT facilities (The Kenya Alliance of Resident Associations, 2015). The abovementioned statistics justifies the need for developing countries to focus more on facilitating people movement and not only vehicles (The Kenya Alliance of Resident Associations, 2015).

Pucher & Buehler (2007) found that an increase in NMT journeys would decrease NMT fatalities in developing countries. Both developed and developing countries have proven a positive effect of NMT facilities on fatalities and injuries. Pucher & Buehler (2007) revealed that an increase in walking or cycling would decrease the risk of a motorist to collide with them (Baufeldt, 2016:12). Separation between NMT and motorised transport will also improve transport safety in cities of developing countries (Rietveld, 2001:13).

2.5 The status of NMT in South Africa

The United Nations and its international partners have invested in numerous strategies that would assist the shift towards sustainable transport. South Africa supports this shift and has

acknowledged the importance of planning for sustainable transport (City of Tshwane, 2015:56). There has recently been an increase in the number of NMT guidelines, frameworks, policies and strategies in South Africa (Labuschangne & Ribbens, 2014). Unfortunately, the lack of data limits the effect of monitoring the current NMT interventions in South Africa.

The expansion of infrastructure for NMT and public transport has been neglected in cities of South Africa (Department of Environmental Affairs, 2017). The most South Africans are dependent on public transport, which is often considered as too expensive for poor communities. Transport costs for these communities contribute to more than 30% of their monthly expenses and are thus a major burden (Department of Environmental Affairs, 2017).

The majority of transport journeys in South Africa range from motorised transport on paved roads to walking on unpaved roads. For that reason, walking is considered as the only transport option for most individuals (Department of Transport, 2008:9). Despite the high rates of motorisation in South Africa, many individuals depend on NMT. According to The Department of Transport (2008:9), NMT is the most affordable- and economical mode of transport for individuals. Therefore, these modes attract more commuters over shorter journeys in South African cities (Gwala, 2006). The use of NMT modes is more common among lower- income users in South Africa (PGWC, 2009). This is particularly true where the proportion of NMT users decline as income increases (Gwala, 2006). Planners in South Africa are attempting to address this problem of inequity in transport provision and city development (PGWC, 2009:5). South Africa is currently facing a number of challenges that involve NMT users in the road environment (Labuschagne & Ribbens, 2014). These challenges that are experienced by NMT users is summarised accordingly:

- The NMT road environment is lacking infrastructure to provide safe and accessible passage.
- The road network provides limited or no space for NMT users, especially cyclists.
- Many road networks are incomplete, leaving NMT users stranded alongside roads.
- Planning for motorised user needs are prioritised above NMT user needs in transport and land use planning processes.
- The funds for providing and maintaining NMT infrastructure are limited.
- NMT road users are facing major safety challenges in terms of road crossings and major road junctions.
- The NMT road environment is lacking a sense of security caused by inadequate street lighting and poor vegetation management.
- NMT facilities are inconvenient to use due to poor infrastructure management.
- Universal Design principles are generally not applied in the road environment and consequently prevent NMT mobility for the elderly and children.

NMT modes such as walking and cycling is promoted as healthy, safe and effective forms of transport options, together with the provision of adequate NMT infrastructure (Department of Environmental Affairs, 2017). The Department of Environmental Affairs and other related departments are committed to promote economic, social and environmental development through NMT implementation programmes. NMT infrastructure is considered a basic criterion for encouraging individuals in South Africa to walk or cycle (Department of Environmental Affairs, 2017). NMT in South Africa is often an additional consideration in transport planning. As a result, cities in South Africa indicate little evidence of consistent NMT planning and infrastructure development (Gauteng 25-Year Integrated Transport Master Plan, 2013). The status of NMT in South Africa reveals a number of problems to be considered as part of the NMT planning approach (City of Tshwane, 2015). The Gauteng 25-Year Integrated Transport Master Plan (2013) revealed that:

- More than 23% of individuals in many parts of Gauteng Province walk to work.
- More than 90% of scholars walk to their destinations.
- Other individuals walk to public transport systems as a mode of their journeys.
- Pedestrians are involved in more than 40% of all road fatalities in South Africa.

NMT facility development in South Africa showed improved safety levels for both cyclists and pedestrians in urban communities (Baufeldt, 2016:4). According to Baufeldt (2016), safety is a major concern for most NMT users in South Africa. Other NMT concerns are related to steep slopes, climate conditions, high traffic volumes and unsafe crossings (Department of Transport, 2008:11). As traffic volumes and traffic density increase, NMT users find it more challenging to share the roads; and ultimately result in higher rates of NMT casualties (Labuschagne & Ribbens, 2014). NMT users in South Africa travel at a high risk, as they have to share the roadway with motorised transport modes (City of Tshwane, 2015). Research shows that there are higher casualty figures among NMT users in South Africa (City of Tshwane, 2015). The status of NMT in South Africa relating to road accidents or fatalities highlights the ultimate problem for successful NMT implementation.

The main types of NMT users in South Africa are pedestrians and cyclists (Baufeldt, 2016:6). In addition, NMT benefits for pedestrians are much greater than that of cyclists according to Baufeldt (2016). This indicates that NMT facilities for cyclists are not adequate for cycling in urban areas of South Africa. According to Baufeldt (2016:6), the need for NMT facilities in cities of South Africa should, however, be investigated and developed.

2.6 Conclusion

Chapter 2 considered the importance of NMT with specific attention to the benefits that it provides for both cities and individuals. This chapter found that NMT has an important role to fulfil in encouraging sustainable, integrated and inclusive urban transport, especially when considering benefits that it provides for both cities and individuals. Lower- income and transport- disadvantaged individuals, such as the handicapped, young and elderly also benefit significantly from NMT development. It can also be concluded that NMT, especially cycling and walking, is supportive of sustainable or green transport.

Chapter 2 also considered the significance of NMT for developing countries, furthermore capturing the status of NMT in South Africa. It was found that urban transport systems in developing countries are deteriorating due to the high rates of urbanisation and rapid motorisation. The advantages of NMT for developing countries were mainly linked to urban mobility, accessibility, road safety, liveable communities, and low-income groups. There is, however, a need for developing countries to develop, implement and promote NMT as an alternative transport option. This is particularly true for South Africa, where there is a need for NMT development in urban areas of South Africa. The lack of data, however, limits the effect of monitoring the current NMT interventions in South Africa. NMT should, however, be supported by a “modal hierarchy” planning approach that suggests in designing the road function according to a scheme that prioritises NMT-modes. Cycling, as a NMT mode, holds unique challenges, opportunities and planning challenges. The significance of cycling as a NMT mode will thus be described in the following chapter.

CHAPTER 3: CONSIDERING CYCLING AS A NMT MODE

The health agenda initiated as a mascot for green and sustainable transportation (Koh & Wong, 2012). The local South African current reality suggests that cycling has a further role to fulfil in terms of mobility, substantiated by the benefits that it provides for NMT users. As such, the planning of bicycle- friendly spaces should be considered in a South African context (PGWC, 2009). This chapter will discuss cycling as an important NMT mode, bicycle- friendly planning spaces as part of city planning and bicycle- friendly design guidelines. Theory based sampling as part of a qualitative enquiry into bicycle- friendly planning approaches will be conducted to identify elements to support the planning of such spaces, and to be used for further empirical investigation of this research. The structure of Chapter 3 is captured in Figure 3-1.

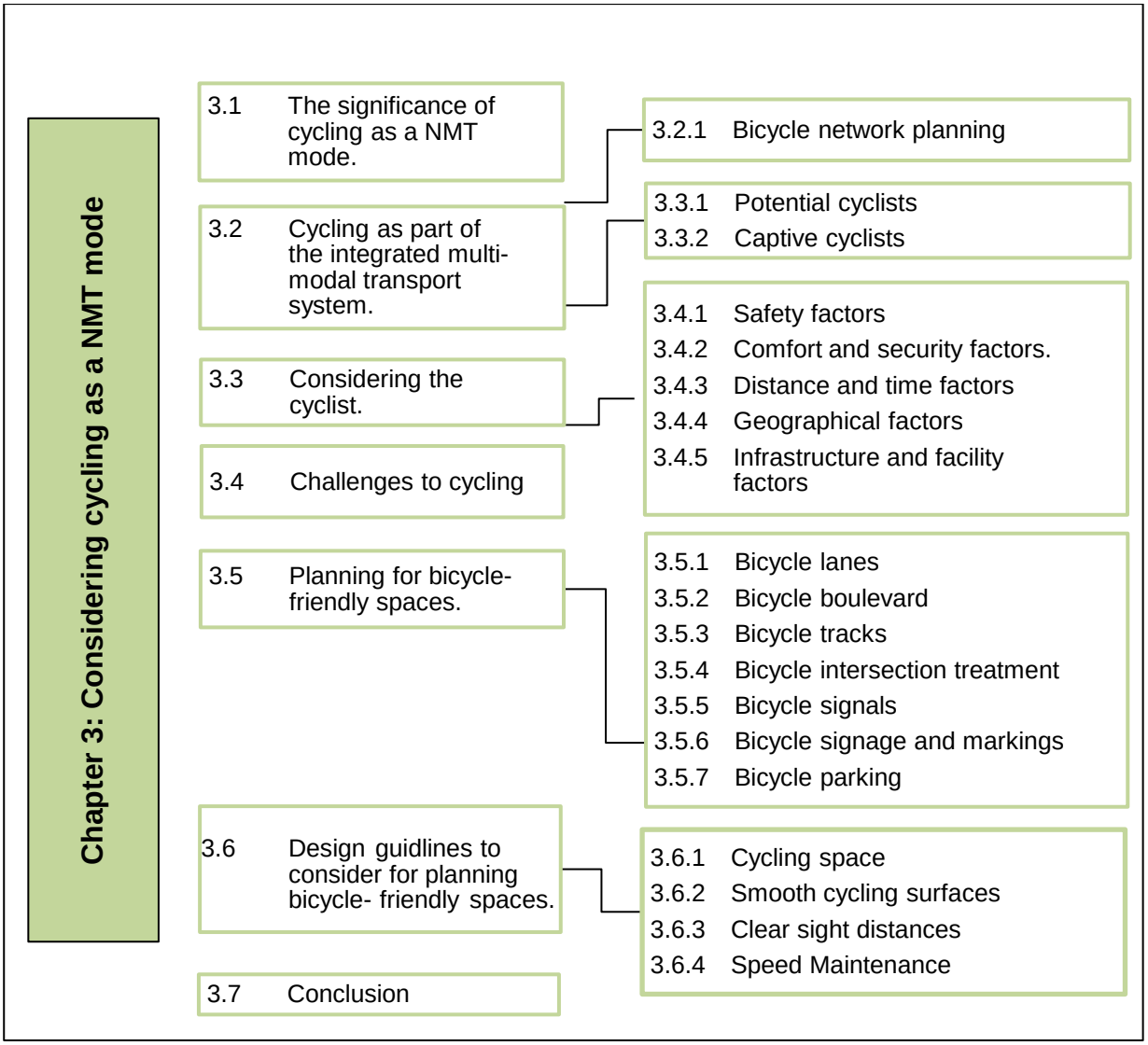


Figure 3-1: Structure of Chapter 3.

Source: Own creation (2017).

3.1 The significance of cycling as a NMT mode

Considering the significance of cycling as a NMT mode and the benefits that it provides for cities and individuals, it is evident that cycling should be emphasised as part of spatial planning and transportation planning approaches. Cycling is an essential NMT mode considering the economic, environmental, health and social benefits that it provides for cities (Urban Redevelopment Authority, 2013). The Urban Redevelopment Authority (2013) identified cycling as an accessible mode of transport, especially for short journeys and journeys to public transport modes. Cycling in the previous century was used for commuting, sport or recreational activities (Pape, 2015). Today, cycling has an extensive impact, with reference to economic development, climate change, tourism and city planning (Pape, 2015).

According to Kristinsdóttir (2012), cycling is considered as a social, convenient, healthy and affordable mode of transport for most individuals. Many individuals experience a sense of independency and flexibility when cycling (Kristinsdóttir, 2012). Cycling furthermore provides a mode of environmentally- friendly, accessible and affordable transport. Advani (2006:2) suggests that lifestyle changes need to be encouraged to improve health and reduce greenhouse gas emissions in cities. This requires a significant increase in the share of bicycle journeys by meeting the demands of cyclists (Advani, 2006:2).

Cycling serves as the most efficient mode of transport over short to medium journeys in a city, for purposes such as cycling to school, shops and public transport (National Department of Transport, 2010). As a result, some individuals use bicycles for all journeys (Huizinga, 2017). Cycling is often a top ranked transport need among low- income households (Perschon, 2001:20). It provides a luxury of personal mobility for individuals, particularly in developing countries. Bicycles and their basic design simplify the manner in which cyclists can repair and maintain them. In addition to satisfying the basic human transport needs, cycling provides individuals with a greater choice of transport options (Perschon, 2001:20). Cycling may save crucial time and personal effort compared to walking as a mode of transport. It also places less pressure on a national transport budget while simultaneously providing benefits for an economy (Perschon, 2001:20).

Large projects of cycling infrastructure have been implemented in continents such as; South America; Europe; Asia; and North America (National Department of Transport, 2010). These projects are supplemented by awareness and educational programmes for cyclists. Cycling as a mode of transport is growing at high rates in some European countries (The World Bank, 2016). European cyclists identified cost- savings, time- savings and flexibility as the main advantages of cycling (The World Bank, 2016). The major disadvantages for these cyclists were the risk of thefts and assaults, a lack of bicycle lanes, and the danger of vehicle drivers' respect for traffic laws.

Large journey distances and topography were also deciding factors among these cyclists (The World Bank, 2016).

In 2010, London launched the “Boris Bike” - London’s bicycle hire scheme. This scheme indicated that cycling was no longer just for a minority of cycling enthusiasts but also an efficient, healthy and sustainable transport mode for cities worldwide (Henley, 2013). Currently, there are more than 8000 Boris Bikes and 550 bicycle docking stations in Central London. In Figure 3-2 the Mayor of London, Boris Johnson was pictured launching Boris Bikes.

Figure 3-2: Illustration of London’s Borris Bike bicycle hire scheme.
Source: Duell (2013).

Henley (2013) believes that cycling may be the catalyst for a 21st -century urban renaissance. Cycling offers the chance for cities to build bicycle- friendly infrastructure that will contribute to major health improvements (Henley, 2013). According to Henley (2013) cycling- development may provide healthier populations and longer life expectancies, which would take pressure off health services and thus create national economic benefits. It would thus also reduce energy consumption (Henley, 2013). Toderian (2014) mentioned that the sizeable amount of space that motorised vehicles demand is the greatest mobility challenge in cities. Toderian (2014) pointed out that urban densities, mixed- land use and personal mobility choices are the only mobility solutions that depend on much less energy. Cities are defined as places where many individuals and activities are situated near each other (Litman, 2014). Policies that favour space- efficient modes in cities may experience liveability benefits and economic success (Litman, 2014).

"The scarcity of space per person is part of the very definition of a city, as distinct from suburbia or rural area, so the efficiency with which transport options use that space will always be the paramount issue" (Walker, 2012).

Space- efficient transport modes in cities are identified as walking, cycling, and public transport (Litman, 2014). These modes are described as truly inviting transport options for cities and communities (Toderian, 2014). Figure 3-3 illustrates the amount of space required to transport 40 of the same passengers by car, bus or bicycle.

Figure 3-3: Amount of space required to transport 40 of the same passengers by car, bus or bicycle.
Source: Toderian (2014).

When we observe these images, it is clear that private motorised vehicles are not efficient when it comes to utilisation of space on city streets. Subsequently, private motorised vehicles use a lot of space for relatively few passengers. It is evident from Figure 3-3 that public transport (buses) and cycling are considerably more space- efficient transport modes than private motorised vehicles. It is, however, important to prioritise cycling as a NMT mode in cities (Toderian, 2014). Sorrel (2016) stated that cycling improves air quality which may ultimately benefit an entire community, not only cyclists. There is a rising demand for cycling mobility with growing cycling activities worldwide (Pape, 2015). As the population in urban areas is expected to increase much more, there is a greater need for cities to achieve better and adequate sustainable urban transportation. Many cities consider the development of cycling infrastructure as a solution to create sustainable urban mobility (Pape, 2015). While pedestrians are the more common and dominant NMT user type, cycling has significant advantages in terms of time, space and energy efficiencies. Therefore, cycling should also be encouraged as an essential NMT mode for city development (Baufeldt,

2016:10). Cycling also contribute towards a healthy lifestyle, implying benefits to both individuals, and cities, as explained accordingly.

Table 3-1: Benefits of cycling for individuals

Benefits of cycling for individuals	
Benefits	**Description**
Health and fitness benefits	➢ Cycling increases cardiovascular fitness. ➢ Cycling increases muscle strength and flexibility. ➢ Cycling improves human joint mobility. ➢ Cycling decreases stress levels. ➢ Cycling improves body posture and coordination. ➢ Cycling strengthens human bones. ➢ Cycling decreases body fat levels. ➢ Cycling prevents the risk of diseases. ➢ Cycling reduces anxiety and depression. ➢ Cycling lowers the risk of cancer. ➢ Cycling prevents and reduces arthritis. ➢ Cycling controls human diabetes. ➢ Cycling increases stamina, strength and aerobic fitness.
Travel time- efficient	➢ Cycling saves crucial travel time for short journeys. ➢ Cycling replaces inactive driving time with healthy exercise.
Personal finance benefits	➢ Cycling saves money on transportation costs.

Source: Own creation (2017) based on the findings of Organic Information Services (2017), Victoria State Government (2013) and Bicycle NSW (2016).

Table 3-2: Benefits of cycling for cities and communities

Benefits of cycling for cities and communities	
Benefits	**Description**
Economic benefits	➢ Cycling puts less pressure on the national transportation budget. ➢ Bicycle- friendly spaces enhance tourism. ➢ Cycling takes pressure off health care spending. ➢ Cycling contributes to spontaneous and impulsive shopping. ➢ Bicycle- friendly spaces slows down traffic, therefore businesses receive more customers. ➢ Cycling provides more jobs from bicycle facility construction.

Environmental benefits	➢ Cycling is an energy sufficient transport mode. ➢ Cycling reduces greenhouse gas emissions. ➢ Cycling reduces the effect of climate change on cities. ➢ Cycling reduces traffic congestion. ➢ Cycling lessen city noises.
Social benefits	➢ Cycling provides transport for poor communities to work and school. ➢ Cycling provides an alternative mobility option. ➢ Cycling is an affordable mode of transport.
Health benefits	➢ Cycling contributes to longer life expectancies. ➢ Cycling takes pressure off health services ➢ Cycling decreases health risks of road users.
Safety benefits	➢ Bicycle facilities reduce conflicts between motorised and NMT ➢ users. ➢ Bicycle- friendly roads slow down traffic by 30 km/h. ➢ Bicycle- friendly facilities which separate bicyclists from motor vehicles prevent accidents and fatalities.

Source: Own creation (2017) based on the findings of Huizinga (2017), Litman (2014), Sorrel (2016), Kristinsdóttir (2012), Massachusetts Bicycle Coalition (2013), Bicycle NSW (2016), Organic Information Services (2017).

Considering the significance of cycling as a NMT mode and the benefits that it provides for cities and individuals captured in Table 3-1 and Table 3-2, it is evident that cycling should be emphasised as part of spatial planning and transportation planning approaches.

3.2 Cycling as part of the integrated multi- modal transport system

Transportation planning has become more multi- modal and comprehensive in the recent years, due to a broader range of transport options (Litman, 2014). Multi- modal planning refers to the planning of various transport modes and links among different modes (Litman, 2014). A number of cities have developed a transportation hierarchy that prioritises resource- efficient modes over motorised transport, particularly in congested cities (Litman, 2014). An integrated transport system refers to a multi- modal transport system where a variety of transport modes are efficiently connected (Tripathy, 2011). A transport system is considered to be effective and efficient with safe feeder modes (Kumar & Parida, 2011). Cycling and walking are seen as sustainable, low- cost feeder modes to a multi- modal transport system (Kumar & Parida, 2011). The capacity of each

transport mode has to be developed to meet its particular demand within the overall demand for all transport modes (Tripathy, 2011).

This hierarchy provides a foundation for shifting emphasis in road space allocation, funding and transport planning to favour more efficient modes (Litman, 2014).

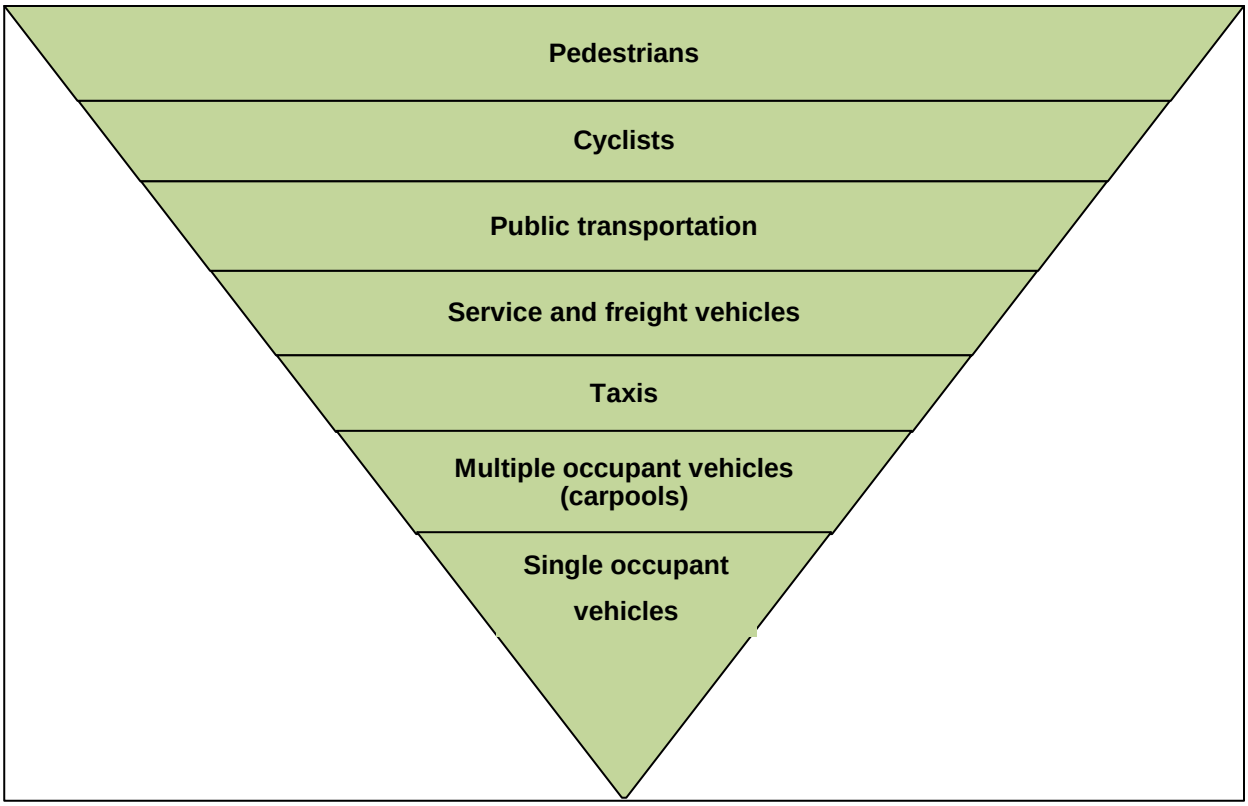


Figure 3-4: Green transportation hierarchy.
Source: Own creation (2017) based on the findings of Litman (2014).

A multi- modal transport system is an integrated approach that combines all components of urban transport into a single system (Kumar & Parida, 2011). It provides an extensive range of transport options for commuters and efficient use of available transport resources and infrastructure for improved mobility (Kumar & Parida, 2011). The result is a multi- modal transportation system that ensures a better quality of life (City of West Melbourne, 2010). Cycling is one of the most efficient transport modes for shorter urban journeys (City of West Melbourne, 2010). The availability of bicycle- friendly facilities plays an important role in encouraging cycling as a transport mode. For the purpose of this study, it is essential for planners to understand the significance of cycling and the allocation of bicycle- friendly spaces within a multi- modal transport system. A bicycle- friendly network also forms part of such larger multi- modal transport system. The City of West Melbourne (2010) mentioned that a good bicycle network may substitute the share of shorter motorised-vehicle journeys by cycling journeys, as described accordingly.

3.2.1 Bicycle network planning

Cycling should be an integral part of all transportation planning approaches (The New Zealand Transport Agency, 2004). A bicycle network is designed to meet the demands of current cyclists as well as potential and future cyclists (Tyson's Corner Bicycle Master Plan, 2016). The quality of cycling as a transport mode depends on whether complete bicycle- routes are available. Unavailable or uncompleted bicycle- routes could be a decisive deterrent to cycling (Tyson's Corner Bicycle Master Plan, 2016). It is therefore essential to develop a coherent network of bicycle facilities in cities. A network is coherent when most origins and destinations of transport journeys are connected (Tyson's Corner Bicycle Master Plan, 2016). All the roads and streets provided in an urban transport network should be considered potential bicycle- routes, unless they are specifically designed for motorised- vehicle mobility. It is therefore essential to provide bicycle-friendly facilities on all roads and streets that have the potential of attracting large volumes cyclists. A good bicycle- network design should meet the following basic demands of cyclists (South African National Department of Transport, 2003):

- Security. The cycling environment should make cyclists feel secure and safe. Facilities should not be located in isolated areas where there is a high security risk.
- Traffic safety. Cyclist exposure to vehicular traffic should be minimised for safer journeys.
- Accessibility. The bicycle- network should be accessible to all cyclists, including individuals with disabilities.
- Convenience. The bicycle- network should be convenient to use. Cyclists desire direct, continuous, fast and convenient cycling routes.
- Comfort. The bicycle- network should be comfortable to use with gentle gradients.
- Environment. Cyclists prefer environments that are attractive for cycling.
- Economy. The bicycle- network should be economical and affordable.

A bicycle- network should be designed to enhance connectivity between transport origins and destinations, and to overcome challenges to cycling (South African National Department of Transport, 2003). Connectivity for cyclists can be achieved when an "open" road network is provided in contrast to the "closed" system (South African National Department of Transport, 2003). An open network allows traffic movement in many ways, while these movements are limited in a closed network.

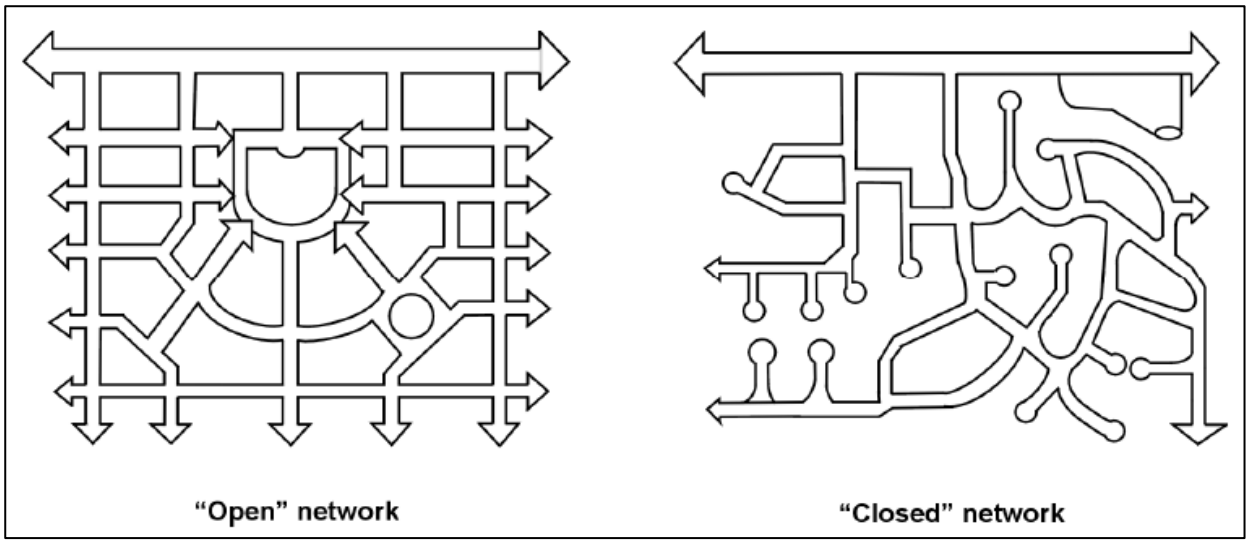


Figure 3-5: Open and closed road networks

Source: South African National Department of Transport (2003).

An open bicycle- network allows traffic to disperse to a myriad of local streets, whereas a closed network discourages traffic from using lower order streets and centres traffic on limited numbers of high order roads (South African National Department of Transport, 2003). An open bicycle-network encourages community access and provides greater accessibility to cyclists (South African National Department of Transport, 2003). A closed system, in contrast, discourages through traffic from using the local street system, therefore encourages accessibility while the residential quality is ensured by restricting vehicular access in the area (South African National Department of Transport, 2003).

3.3 Considering the cyclist

Cycling offers a great potential to reduce the dependence on motorised transport for lengthier distances that are not suitable for walking (PGWC, 2009). The value of specific cycling- needs are therefore worth mentioning. Different cyclists have different varieties of experience, confidence, and attitude levels (PGWC, 2009). At one extreme is the tough commuter; at the other extreme are children cycling for the first time and elderly cyclists that may be hesitant about cycling. Among these types is a wide range of cyclists with varying levels of confidence and experience (PGWC, 2009). These cyclists are primarily classified into two broad categories namely captive- and potential cyclists, as described accordingly (Shakti Sustainable Energy, 2009).

3.3.1 Potential cyclists

There is a latent demand for potential cyclists (cyclists by choice) due to the lack of dedicated bicycle- infrastructure in cities (Shakti Sustainable Energy, 2009). These cyclists mostly include

scholars since one- third of journeys are of educational purpose (Shakti Sustainable Energy, 2009). Housewives, young adults, and the elderly are also considered as potential cyclists with the availability of safe and good bicycle- infrastructure (Shakti Sustainable Energy, 2009). In addition, cycling for recreational and sporting purposes also forms part of the category 'potential cyclists'. A British study revealed that the recreational cyclists generally travel longer distances to work and may additionally have access to a privately owned vehicle (Kristinsdóttir, 2012). They cycle primarily for leisure purposes and pleasant cycling experiences. Recreational cyclists are generally less constrained by journey- time. Popular recreation cycling destinations include attractive routes with lower traffic volumes and speeds (New Zealand Transport Agency, 2004). These cyclists prefer; cycling comfort; good road surfaces; minimal gradients; a high degree of safety and security; pleasant routes, attractive environments; shelter from bad weather; and parking facilities (New Zealand Transport Agency, 2004).

Sporting cyclists are confident in most roadway conditions, and will not hesitate to use a faster route with significant traffic volumes than a safer slower route (PGWC, 2009). Scholars require segregated, direct routes from residential areas to schools, even where an on road solution is available (PGWC, 2009). Children should be expected in all residential areas and on most recreational cycling routes (PGWC, 2009:46). Recreational cyclists cycle for leisure or pleasure and prefer short trips. Yang (2013) mentions that they are more sensitive to basic bicycle- friendly facilities and sceneries.

3.3.2 Captive cyclists

Captive cyclists are bound by economic constraints and have no alternative transport choice besides cycling (Shakti Sustainable Energy, 2009). Indian cities for example are dominated by captive cyclists. Captive cyclists mostly include cycling for commuter- and utility purposes. Commuters cycle from home to workplaces and prefer cycling among slower traffic volumes with shorter travel times (Yang, 2013). In other words, their preferred cycling routes are destination-based choices. This means that they may be pressured to reach their work destination in time (Yang, 2013). According to The New Zealand Transport Agency (2004), these cyclists prefer; high-quality road surfaces; direct and coherent routes; minimal journey delays; facilities that give them their own space; crossings that minimise conflicts with other traffic; good lighting for evening trips; secure parking; and facilities for changing clothes, lockers and showers.

Utility cyclists alternatively may call for cycling- segregation at busy crossings and on roads with high traffic speed (PGWC, 2009). Utility cyclists also travel more slowly than commuting cyclists (PGWC, 2009). 'Cyclists of specialised equipment' refers to disabled individuals using trailer-cycles, tandems, hand-cranked machines, and tricycles. This group of cyclists require bicycle-

friendly spaces that are not restricted by sharp bends, pinch- points or any other obstacles that may force cyclists to dismount (PGWC, 2009).

Safety has been considered as the most significant factor on cyclists' decision to cycle (Wang, et.al, 2014). Other important factors considered as challenges to cycling include dangerous traffic conditions, absence of bicycle- parking facilities, and poor lighting conditions at night (Wang, et.al, 2014). The presence of bicycle- friendly spaces may encourage cycling as a mode of transport and improve the safety and comfort of captive cyclists (Wang, et.al, 2014). Bicycle- friendly infrastructure should address the safety and the perception of safety for cyclists (Shakti Sustainable Energy, 2009). In order to understand the different cycling needs and preferences, it is essential to study the different types of cyclists (Geller, 2009). This will also provide the basic information for planning bicycle- friendly spaces in cities. As such, these cyclist types will provide an understanding of the target market to be considered in the bicycle- friendly planning process (Geller, 2009). A well-designed cycle facility will be attractive to a wide spectrum of captive and potential cyclists. The objective should cater for as wide a spectrum as possible, taking in to account the locality and other contextual considerations. It should, however, be recognised that not all modes can be accommodated by all facilities (PGWC, 2009).

3.4 Challenges to cycling

Challenges to cycling are defined as the factors that prevent individuals to cycle or prevent individuals from cycling more often (Manaugh, et.al, 2013). Countries across Asia, Europe and Africa have shown extensive popularity of cycling as part of their sustainable transportation strategies. However, several negative factors have prevented individuals from considering cycling as a transport mode in these countries (Angira, 2013). There are many reasons why individuals chose certain transport modes other than cycling (Cycling Embassy of Great Britain, 2016). The safety, comfort, and efficiency of cycling are identified as particular challenges to cycling (Angira, 2013). Many studies have identified other factors that may also serve as a challenge to cycling as a mode of transport, as described accordingly (Manaugh, et.al, 2013).

3.4.1 Safety factors

Safety is considered by individuals as the main challenge to cycling and also as a deterrent factor for cycling to school more often (Cycling Embassy of Great Britain, 2016). It is also considered as the number one reason for regular and occasional cyclists to cycle less (Cycling Embassy of Great Britain, 2016). Safety is an essential problem in transport policies to encourage the use of NMT modes, such as cycling (Department of Transport, 2008). Safer transport networks would provide opportunities for substitution towards NMT modes (Department of Transport, 2008). There are,

however, a number of ways to improve the safety of transport networks by providing adequate infrastructure (Department of Transport, 2008).

In Great Britain, the main challenge to cycling is the perception that their roads are too uncomfortable and unsafe, due to high volumes and speeds of motorised transport (Cycling Embassy of Great Britain, 2016). According to Walsh (2014), roads were initially not built for motorised transport; however, today motorised transport dominates city roads. Walsh (2014) mentioned that dangerous driving of motorised vehicles is the most likely reason for individuals to cycle less. In addition to traffic safety, the lack of social safety also discourages cycling as a mode of transport in many cities (Department of Transport, 2008). The introduction of social safety as a design criterion in the planning of infrastructure for NMT modes will improve the social safety problem (Department of Transport, 2008).

A British survey revealed that the main reason for an uncomfortable cycling experience is the risk or danger of accidents involving other transport modes (Kristinsdóttir, 2012). This is particularly true where a large percentage of all road fatalities in Africa and Asia involve pedestrians and cyclists (Angira, 2013:30). Cycling in Kenya is a relatively dangerous mode of transport as cyclists are barely visible. Motorists generally do not consider these cyclists as equals in terms of access to road space (Angira, 2013:30). The Cycling Embassy of Great Britain (2016) identified a number of negative associations with cycling that indicate notable safety concerns for cyclists, including the desire for more bicycle- lanes to feel safer and the need to negotiate challenging road crossings. Both cyclists and motorised vehicle users are more comfortable on roads with separated bicycle-friendly facilities than shared road space (Cycling Embassy of Great Britain, 2016). In particular, roads with separated bicycle- lanes are popular amongst all cyclist groups in Britain. The Cycling Embassy of Great Britain (2016) found that 65% of cyclists that does not cycle on a regular basis would be more likely to cycle if roads were made safer through planning bicycle- friendly spaces.

3.4.2 Comfort and security factors

British researchers found that discomfort is a major deterrent to cycling that may result in an unpleasant cycling experience (Kristinsdóttir, 2012). Unpleasant cycling experiences due to traffic, darkness or the scenery are identified as aspects that contribute to discomfort and security problems for cyclists (Kristinsdóttir, 2012). Angira (2013) stated that street environments in African cities do not provide adequate NMT storage facilities, lighting, and direct sight lines to secure cyclists' comfort. This creates an attractive street environment for criminal activities that is unsafe for pedestrians and cyclists, especially during the night (Angira, 2013:30). The lack of bicycle-parking facilities near major destination points in cities such as; libraries, shops, retail centres and banks may also determine a cyclists' comfort (Angira, 2013). Safe and convenient bicycle parking

is especially important to consider for creating a street environment with a sense of security and safety for cyclists. This will allow cycling to be a more comfortable mode of transport for individuals (Angira, 2013).

A poorly designed street environment may increase the fearful attitude that individuals have towards cycling as a mode of transport (Cheyne, et.al, 2015). A lack of surveillance, overgrown vegetation, poor facility maintenance and poor lighting all contribute to poor designed urban environments (Cheyne, et.al, 2015). The fear of bicycle theft in addition to the concerns of cyclists' personal safety and security also serves as a common challenge to cycling (Cheyne, et.al, 2015).

3.4.3 Distance and time factors

"It is not surprising that the perception of distance as a deterrent to cycling increases with actual distance" (Manaugh, et.al, 2013)

Despite the fact that overall distance of cycling is a challenge for all individuals, the actual distance that individuals recognise to be a challenge varies by gender (Manaugh, et.al, 2013). It is found that the variance in the proportion of males and females who mentioned distance as a challenge to cycling increases at around 7.5 km, with 63% of females 'strongly agreeing' that distance is a challenge to cycling at 7.5 km, compared to 50% for males at the same distance (Manaugh, et.al, 2013). Angira (2013) proposed the idea that convenience- based journeys to destination points should be short distances (Angira, 2013).

Similarly, Cheyne, et.al, (2015) also found that distance is a major challenge to cycling. Large cycling distances are considered as a significant factor in parents' decisions to allow their children to cycle to school. Since both cycling and walking are considerable slower modes than motorised transport, time may also be a deterrent factor to cycling. A lack of time is frequently cited by individuals as the main reason for using public and motorised transport instead of cycling (Cheyne, et.al, 2015).

A compact city is known as a city of short distances that encourages increased residential density, enhanced public transport, and mixed land use (Bicycle Network, 2016). Planning for a more compact city will ensure an urban form that encourages cycling as a short and time- efficient mode of transport (Bicycle Network, 2016).

3.4.4 Geographical factors

"I'd argue that the feeling of rain on your face and the exhilaration of successfully climbing a steep hill is part of the fun of cycling. Unsurprisingly, this view is not shared by all" (Walsh, 2014).

A study in the Netherland observed that topography was a major challenge to cycling, with cities on undulating land showing much lower cycling rates than flatter areas (Cheyne, et.al, 2015). Other studies supported this statement that topography has a negative influence on the participation rates of cycling (Cheyne, et.al, 2015). More studies have furthermore revealed that geographical conditions play an important part in cycling participation rates, such as the climate, topography and weather conditions (Kristinsdóttir, 2012). Hills and weather conditions are referred as major deterrents to cycling; however, they are limited to a small area, affecting only a minority of urban journeys (Cycling Embassy of Great Britain, 2016). According to Kristinsdóttir (2012), the most common challenge to cycling is bad weather, such as cold or rainy conditions.

An internet- based survey identified unpleasant weather and reduced daylight hours in the winter as challenges to cycling. These results were more noticeable among cyclists than non- cyclists (Cheyne, et.al, 2015). The University of Edinburgh (2015) interviewed 100 students on the factors that will prevent them from cycling. Only 7 out of 100 students recognised weather as a challenge to cycling. Most students acknowledge that there is nothing that can be done with bad weather conditions (University of Edinburgh, 2015). Some individuals mentioned that weather is not a challenge, because they would have also dealt with the weather conditions by means of walking (University of Edinburgh, 2015).

3.4.5 Infrastructure and facility factors

"If cycling is to be a transportation mode for all, huge improvements to infrastructure are required" (Walsh, 2014).

A lack of infrastructure with inter-related safety concerns has posed a significant challenge to cycling as a mode of transport (Cheyne, et.al, 2015). This infrastructure includes; bicycle paths- and lanes, street design, and design of road crossings (Cheyne, et.al, 2015). Bicycle parking facilities provide cyclists with a sense of security and safety when cycling (Angira, 2013). Bicycle parking is therefore an important infrastructure consideration in the planning of bicycle- friendly spaces (Angira, 2013).

The provision for bicycle parking, bicycle lanes, or shower facilities do not exist In African cities according to Angira (2013). These facilities are essential for persuading daily commuters to switch from using a private motorised vehicle to cycling. Cheyne, et.al, (2015) mentioned a study where

88% of respondents reported that the provision of bicycle- lanes would be a major factor in encouraging them to cycle. For all cycling groups, safety was the most significant challenge to cycling in general and for particular trips (Cycling Embassy of Great Britain, 2016). This suggests that, applied actions to increase cycling safety and improve the provision of cycling facilities will be the most effective strategy to encourage cycling (Cycling Embassy of Great Britain, 2016).

3.5 Planning for bicycle- friendly spaces

The previous section identified major challenges in planning for cycling as a mode of transport. A lack of safety conditions for cyclists has been identified as a major cycling challenge for individuals. Based on the findings of the previous section, it can be assumed that the planning of bicycle-friendly spaces may encourage cycling as a mode of transport, as it creates safer cycling opportunities for individuals.

Streets generally consist of more than 80% of public space in cities, but often fail to provide safe bicycle- friendly spaces (National Association of City Transportation Officials, 2017). High levels of cycling can be seen in many attractive and modern cities throughout Europe and the United Kingdom (Cycle Nation, 2014). Cycling offers these cities with pleasant streetscapes, healthy lifestyles, and efficient transport mobility. The Cycle Nation (2014) mentioned that high quality of bicycle- friendly spaces, separated from motorised- vehicles is essential for enabling high levels of cycling. Development of bicycle- friendly spaces and street renewals should encourage a third of all individuals to cycle as part of their journeys, according to the Cycle Nation (2014). In addition, many individuals dislike cycling amongst traffic, or sharing the roadway with pedestrians. Therefore the primary condition for encouraging cycling as an efficient transport option is to provide dedicated bicycle- friendly spaces for cycling that offers some degree of protection from motorised traffic (Cycle Nation, 2014). There are thus various types of bicycle- friendly spaces to consider when planning for cycling, as described accordingly.

3.5.1 Bicycle- lanes

A bicycle- lane is a marked space in the roadway for exclusive use of cyclists (Igarta, 2010). It provides an objective boundary of the cycling zone (Furth, 2009), and creates separation between motorised- vehicle users and cyclists (Igarta, 2010). Research shows that cyclists feel more comfortable and relaxed cycling in bicycle- lanes alongside passing motorised- vehicles (Furth, 2009). The marked space of bicycle- lanes helps motorists to determine cyclists' lateral position in advance, and accordingly makes it easier for motorists to determine the space required to pass cyclists safely (Furth, 2009). It has also been found that a marked bicycle- lane increases motorists' confidence to overtake cyclists (Furth, 2009). Cyclists are not required to use a bicycle-

lane when available to them (Bike Arlington, 2017). Furthermore, cyclists may choose to cycle outside a bicycle- lane if the lane is blocked, or if the lane is unsafe for cycling or for any other reason (Bike Arlington, 2017). Motorists, however, may not stop, drive or park in bicycle- lanes. Motorists may not drive, stop or park in a bicycle- lane (Bike Arlington, 2017). There are many criteria that inform the decision to develop bicycle- lanes or other spaces. Most importantly, streets ought to be wide enough to accommodate bicycle- lanes in addition to the regular motorised- travel lanes (Bike Arlington, 2017).

Table 3-3: Various types of bicycle- lanes.

Type of bicycle- lanes	Description
Basic bicycle- lane 	Bicycle- lanes designate an exclusive space for cyclists through the use of painted road markings. Bicycle- lanes are located adjacent to motorised-vehicle travel lanes and flows in the same direction as vehicular traffic. ➢ Increases cyclists' comfort & confidence on busy streets. ➢ Increases total street capacity. ➢ Visually reminds motorists of cyclists. ➢ Provides access to cyclists on major through streets. ➢ Clarifies lane use for motorists and cyclists. ➢ The visual lane separation increases cyclist's comfort.
Buffered bicycle- lane 	A buffered bicycle- lane provides a buffer to increase the space between travel- and bicycle lanes, and or parked vehicles. It is either curbed- side painted bicycle lanes or parallel- parked vehicle- side painted lanes. The painted buffered lines are intended to encourage motorised- vehicle users not to encroach on bicycle- lanes. ➢ Greater shy distance between vehicles and bicycles. ➢ More space for cyclists without being mistaken for vehicle parking lanes. ➢ Appeals to more cyclists as it increases perceived safety. ➢ Provides space for cyclists to pass without encroaching into the vehicle- travel lane. ➢ Parking side buffer: Provides cyclists with space to avoid the "dooring zone" of parked vehicles.

Type of bicycle- lanes	Description
Contra- flow bicycle- lanes 	Contra- flow bicycle- lanes are painted lanes in which cyclists may cycle against the direction of vehicular traffic. For example, on a one way street in which cyclists are supposed to cycle in the same direction as the vehicles, cyclists may cycle against vehicular traffic in their lanes. It is thus a one-way street for motorised- vehicles that includes an opposite-direction bicycle only lane. ➢ Provides connectivity and access for cyclists. ➢ Decreases journey distances for cyclists. ➢ Allows cyclists to use safer and less trafficked streets. ➢ Encourages cyclists not to use alternative routes.
Bicycle- lanes on one- way streets 	These lanes are basic bicycle- lanes which flow in the direction of vehicular traffic on one- way streets. ➢ Avoids potential bicycle- lane conflicts. ➢ Improves cyclist's visibility by motorists. ➢ Minimizes "door zone" conflicts.

Source: Own creation based on Initiative for bicycle & pedestrian innovation (2016), Lusk (2016), Bike Arlington (2017), and Igarta (2010).

3.5.2 Bicycle Boulevard

Bicycle boulevards are designated streets for cyclists, designed to give priority to cyclists (National Association of City Transportation Officials, 2017). Bicycle boulevards allows local motorised-vehicle traffic, but discourages cut- through motorised traffic (City of Berkeley, 2000). These boulevards use pavement markings, signs, and speed and volume management measures to discourage through- trips by motorised vehicles and create safe, convenient bicycle crossings of busy arterial streets (National Association of City Transportation Officials, 2017).

Table 3-4: Bicycle Boulevard

Bicycle Boulevard	Description
	A bicycle boulevard also known as a neighbourhood greenway is a type of bikeway composed of a low-speed street which has been dedicated for cycling. ➢ Facilitates bicycle mobility. ➢ Provides safe crossings of high- volume roads. ➢ Provides an attractive and convenient shared roadway. ➢ Provides low- volume and low-speed streets ➢ Calms motorised traffic.

Source: Own creation based on Initiative for bicycle & pedestrian innovation (2016) and Igarta (2010).

3.5.3 Bicycle tracks

A bicycle track (protected bicycle- lane) is a bicycle- friendly space exclusive for cycling purposes. It is generally located adjacent to- but separated from- the roadway by means of physical challenges (Igarta, 2010). Bicycle tracks are physically separated from motorised traffic and detached from sidewalks (National Association of City Transportation Officials, 2017). They provide space for cycling that is separated from motorised vehicle travel lanes, sidewalks, and parking lanes. In conditions where on- street vehicular parking is acceptable, cycle tracks are in contrast to bicycle- lanes placed on the curb- side of the parking (National Association of City Transportation Officials, 2017). Bicycle tracks may be one-way or two-way, and may be at sidewalk level, at street level, or at an intermediate level. Bicycle tracks may offer higher security levels than bicycle- lanes and are also more attractive to communities (National Association of City Transportation Officials, 2017).

A bicycle track is typically located between the sidewalk and moving motorised vehicles or between the sidewalk and parked vehicles (Lusk, 2016). These tracks may be separated from the vehicular traffic by paint with delineator poles, low curbs, raised islands, mountable curbs, vegetation boxes, vegetation strips, or trees (Lusk, 2016).

Table 3-5: Type of bicycle tracks.

Type of bicycle tracks	Description
Bicycle tracks 	A bicycle track is a dedicated cycling space, physically separated from motorised traffic by means of physical challenges. ➢ Includes both separated and on-street bicycle-infrastructure. ➢ Located on curb-side of parked vehicles. ➢ Attractive to a variety cyclist types. ➢ Provides direct access to main street commercial areas. ➢ Significant separation from motorised traffic in the busiest areas of a town.
One- way protected bicycle track/ protected bicycle- lane 	One- way protected bicycle tracks provide physical separation between cyclists and motorised vehicles. This separation may be provided by means of plastic bollards, vegetation boxes, curbs, and vehicular parking. ➢ Protect cyclists from passing vehicular traffic. ➢ Increases perceived cycling comfort and safety. ➢ Comparatively low implementation costs.
Raised bicycle track 	Raised bicycle tracks are bicycle- friendly spaces that are vertically separated from motorised vehicular traffic. ➢ High grade of separation between cyclists and motorised vehicles. ➢ Provides some degree of separation from pedestrians. ➢ Mountable curb provision is provided for cycling.

Type of bicycle tracks	Description
Two- way bicycle track 	Two- way bicycle tracks are physically separated bicycle tracks on one side of the road that allows bicycle travel in both directions. ➢ Allows bicycle movement in both directions on one side of road. ➢ Offers a raised- or street level track. ➢ Considers driveways and cross- streets.

Source: Own creation based on Initiative for bicycle & pedestrian innovation (2016), Bike Arlington (2017), and Igarta (2010).

3.5.4 Bicycle- Intersection Treatment

A bicycle intersection is an at-grade road junction where cyclists are separated from motorised-vehicles travel. Bicycle- friendly intersections should reduce conflict between cyclists and motorised- vehicles by improving the level of visibility and facilitating awareness with competing transport modes (National Association of City Transportation Officials, 2017). The elements of a safe intersection for cyclists may include signage, colour, signal detection, medians, and pavement markings. The degree of mixing or separating cyclists from other modes is intended to reduce the risk of collisions and increase the comfort of cyclists (National Association of City Transportation Officials, 2017). The level of treatment required for cyclists at an intersection depends on the type of bicycle- friendly space used (National Association of City Transportation Officials, 2017). When planning intersections for cyclists, the goal is to accommodate their safety conditions within the available constraints. According to the New Zealand Transport Agency (2004), intersection design should ensure that:

- Intersections are suitable for cyclists of basic skill.
- Conflict areas between left-turning traffic and through cyclists are managed.
- Conflict points of transport modes are easily identified.
- Motorised vehicle users know where cyclists are expected to be on the road.

Table 3-6: Type of bicycle intersection treatments.

Type of bicycle intersection treatment	Description
Bicycle intersection 	A bicycle intersection is an at-grade road junction where cyclists are separated from motorised vehicles. ➢ Junctions where modes meet. ➢ Potential cause of transport conflicts. ➢ Needs clear right-of-way indication and high visibility. ➢ Increases cycling comfort and reduces risk for cyclists.
Bicycle boxes **(or advanced stop line)** 	A bicycle box is a reserved area for cyclists at the head of a traffic lane at a signalised intersection that provides cyclists with a visible and safe way to get ahead of queuing motorised traffic. ➢ Provides visibility for motorists and cyclists. ➢ Creates an opportunity for cyclists to get ahead of queuing traffic. ➢ Prevents “right-hook” collisions with turning vehicles. ➢ Gives cyclists priority over motorists. ➢ Enables left-turning cyclists to position themselves to the left prior to arriving at a green signal. ➢ Lessens nuisance from exhaust.
Intersection crossings 	Intersection crossing markings indicate the intended path that cyclists require to cross an intersection. ➢ Provide markings through an intersection. ➢ Guide cyclists through an intersection. ➢ Increases visibility for motorists. ➢ Raises awareness of conflict areas.

Type of bicycle intersection treatment	Description
Median Refuge Island 	A median refuge island is a raised island along the centreline of a roadway that narrows the width of a roadway in order to decrease motorised vehicle speeds. ➢ Provides a protected space for cyclists in centre of street. ➢ Reduces crossing length and exposure to motorised vehicles. ➢ Calms motorised traffic.
Combined bicycle- lanes/ Turn-lanes 	A combined bicycle- lane/ turn- lane places a suggested bicycle- lane inside the dedicated area of a motorised vehicle turn- lane. ➢ Places a suggested bicycle- lane within a motorised vehicle turn- lane. ➢ Provides signage to encourage proper positioning of cyclists. ➢ Reduces “right- hook” transport conflicts.
Bicycle track intersection approaches 	At an intersection, a bicycle track may shift into a conventional bicycle- lane or a combined bicycle-lane/ turn- lane. ➢ Joining bicycle tracks with motorised vehicles. ➢ Similar to conventional bicycle- lanes. ➢ Less expensive than implementing bicycle signals.

Source: Own creation based on Initiative for bicycle & pedestrian innovation (2016), Bike Arlington (2017), and Igarta (2010).

3.5.5 Bicycle Signals

Bicycle signals are positioned at intersections to facilitate cyclists in crossing roadways (National Association of City Transportation Officials, 2017). Bicycle signals make intersection crossings safer for cycling by instructing cyclists when to enter intersections and by restricting conflicts with motorised- vehicles (National Association of City Transportation Officials, 2017). A variety of factors determines the type of bicycle- signal to use for a particular intersection. These factors include speed limits, average everyday traffic, estimated traffic at intersections, and the configuration of planned or existing bicycle- friendly spaces (National Association of City Transportation Officials, 2017). Intersections with bicycle signals may also reduce cycling delays and discourage illegal and unsafe crossings for cyclists, according to the National Association of City Transportation Officials (2017).

Table 3-7: Types of bicycle signals.

Type of bicycle signals	Description
Bicycle signal heads 	Bicycle signal heads are comparable to conventional traffic signals, but consist of green, yellow, and red lenses with stencilled bicycle icons. They may be set up at signalised intersections to indicate bicycle signal phases. ➢ Indicates bicycle signal phases. ➢ Provides priority to cyclists over motorists. ➢ Simplifies cycling through difficult and complex intersections. ➢ Reduces cycling delays during high rates of vehicular traffic. ➢ Provides safe protected crossings for cyclists. ➢ Creates an attractive and low-stress journey for cyclists.
Bicycle detection signals 	Bicycle detection signals, such as push buttons may be used to highlight bicycle- friendly spaces for both cyclists and motorists. ➢ Activates traffic signals for cyclists. ➢ Guides motorists for detecting cyclists. ➢ Improves cycling efficiency and convenience.

Type of bicycle signals	Description
Hybrid signal (Hawk) 	A Hybrid signal/ Hawk beacon is a device to assist cyclists to safely cross busy streets. ➢ High- intensity activated Hawk. ➢ Improves bicycle route crossings at major intersections. ➢ Improve crossings with low side- street volumes.

Source: Own creation based on Initiative for bicycle & pedestrian innovation (2016), Bike Arlington (2017), and Igarta (2010).

3.5.6 Bicycle signage and markings

Bicycle signage and markings indicates the presence of designated bicycle- friendly spaces (National Association of City Transportation Officials, 2017). A number of bicycle specific signage provides motorised traffic with important instructions and information on bicycle- friendly spaces. Bicycle- way markings represent any element applied onto bicycle- friendly spaces in order to designate a particular right-of-way, potential conflict area, direction, or route option (National Association of City Transportation Officials, 2017). These markings may use particular materials, designs, and colours to create bicycle- friendly spaces. Bicycle signage and markings should provide high levels of visibility, instant identification, and consider both motorist and cyclist movements (National Association of City Transportation Officials, 2017). According to Furth (2009), bicycle signage includes several sub-categories, as described accordingly.

Table 3-8: Types of bicycle signs and markings.

Type of signs and markings	Description
Bicycle route way- finding 	Bicycle route way- finding directs cyclists to destinations using preferred routes. ➢ Provides comprehensive signs and markings. ➢ Guides cyclists to destinations along preferred routes. ➢ May include destination and estimated travel time. ➢ Encourages potential cyclists.
Coloured bicycle spaces 	Colour is applied to bicycle- friendly spaces to distinguish the space and to visibly assign right-of-way to cyclists. Motorists are expected to yield to cyclists in these spaces. Coloured bicycle spaces also reinforces the presence of bicycle- lanes in spaces where bicycle- friendly markings may not be noticed by motorists. ➢ Increases visibility. ➢ Identifies potential conflict areas. ➢ Provides a continuous space for cyclists. ➢ Provides safer merging of bicycles and motorised vehicle traffic. ➢ Increases cycling awareness.
Shared- lane markings (Sharrows) 	Sharrows are shared- lane markings painted on roadways to show motorists that the road should be shared with cyclists. Sharrows increases the visibility of the roadway as a dedicated space for cycling. It also guides cyclists with proper roadway positioning on streets where a separated space is desired but not feasible. ➢ Indicates a shared lane between motorists and cyclists. ➢ Pavement markings support the bicycle network. ➢ Provides roadway positioning for cyclists. ➢ Simulates the effect of bicycle- lanes on streets with constrained rights-of-way. ➢ Alerts motorists of the lateral location cyclists may occupy. ➢ Moves cyclists out of the “door zone” of parked vehicles. ➢ Encourages safe passing by motorists.

Source: Own creation based on Initiative for bicycle & pedestrian innovation (2016), Lusk (2016), Bike Arlington (2017), and Igarta (2010).

3.5.7 Bicycle parking

Bicycle parking is a key component in encouraging individuals to cycle (Bicycle Nation, 2014). Bicycle parking can be classified into short- term parking and long- term parking. Short- term parking serves business customers and visitors, while long- term parking serve employees, residents, students, and commuters (New Zealand Transport Agency, 2004). Bicycle- friendly parking spaces should be located in a convenient and secure location near the front door of shops or other destinations to encourage cycling as a mode of transport, particularly for short local journeys (Bicycle Nation, 2014). According to the City of Johannesburg (2006), bicycle- friendly parking spaces should consider the following provisions.

- Provide weather protection.
- Provide visible and sufficient signage towards bicycle parking spaces.
- Provide sufficient lighting at bicycle parking spaces.
- Provide convenient bicycle parking spaces near building entrances and close to transit stops.

Many individuals are discouraged to cycle due to a lack of bicycle- friendly parking spaces at cycling destinations (New Zealand Transport Agency, 2004). The type of bicycle- parking space depends on individuals' need for cycling security and convenience. The most common bicycle-parking type is the ability to lock bicycles to a cycle stand (New Zealand Transport Agency, 2004).

Table 3-9: Type of bicycle- parking spaces.

Type of bicycle parking	Description
Sidewalk bicycle racks 	Sidewalk bicycle racks are racks provided outside commercial locations for visitors and guests to park their bicycles.

Type of bicycle parking	Description
On-street bicycle corrals 	On- street bicycle corrals are rows of bicycle racks installed in the curb- side lane of a street instead of on the sidewalk. ➢ Installed in roadway parking lanes. ➢ Located where the bicycle parking demand is greater than bicycle parking on the sidewalk. ➢ Typically fits 8-12 bicycles per vehicle parking road space.
Bicycle lockers 	Bicycle lockers offer cyclists with fully- enclosed security for bicycle storage. ➢ Provides a locked storage box for a bicycle. ➢ Fits one bicycle. ➢ Highly secure bicycle parking. ➢ Provides traditional one-user-one-key or cardkey-operated electronic lockers that may serve multiple cyclists.

Source: Own creation based on the San Francisco Municipal Transportation Agency (2015).

3.6 Design guidelines to consider for planning bicycle- friendly spaces

There are a number of different design guidelines to consider for planning bicycle- friendly spaces. This section will discuss basic design guidelines for planning bicycle- friendly spaces, as well as bicycle- friendly layout dimensions for operational considerations when implementing these spaces. According to the Bicycle Network (2016), the basic bicycle- friendly design requirements for all cyclists, are:

3.6.1 Bicycle- friendly operating area,
3.6.2 Smooth cycling surfaces,
3.6.3 Clear sight distances, and
3.6.4 Speed maintenance.

3.6.1 Bicycle- friendly operating area

It is essential for planners and urban designers to understand the design and clearance requirements for bicycle- friendly operating areas in order to solve particular problems where the knowledge of minimum bicycle- space is required (Bicycle Network, 2016). The operating area of cyclists is relevant to the design of bicycle- friendly spaces. Not all cyclists can cycle in a straight line; therefore cyclists need adequate clearances to obstacles and to passing motorised vehicles (Bicycle Network, 2016). A suggested minimum 1.0 m wide envelope would allow for the width of a bicycle and for variation in cycling (Bicycle Network, 2016). There are various types and sizes of bicycles to consider when planning bicycle- friendly spaces, ranging from small children bicycles to larger adult bicycles. For design purposes, however, conservative dimensions are suggested that may provide for most bicycle types and sizes, as shown in Figure 4-6. The South African National Department of Transport (2003) suggested the following design dimensions.

- A clear vertical cycling height of 2.5 m.
- A 1.0 m wide corridor for cyclists to maintain their balance when cycling at low speeds.
- An additional 0.25 m of clearance on each side for cyclists to avoid obstacles, causing the basic width to increase to 1.5 m.
- A 3 m width is desirable for opposing cyclists to comfortably pass each other in an enclosed cycling operating area.

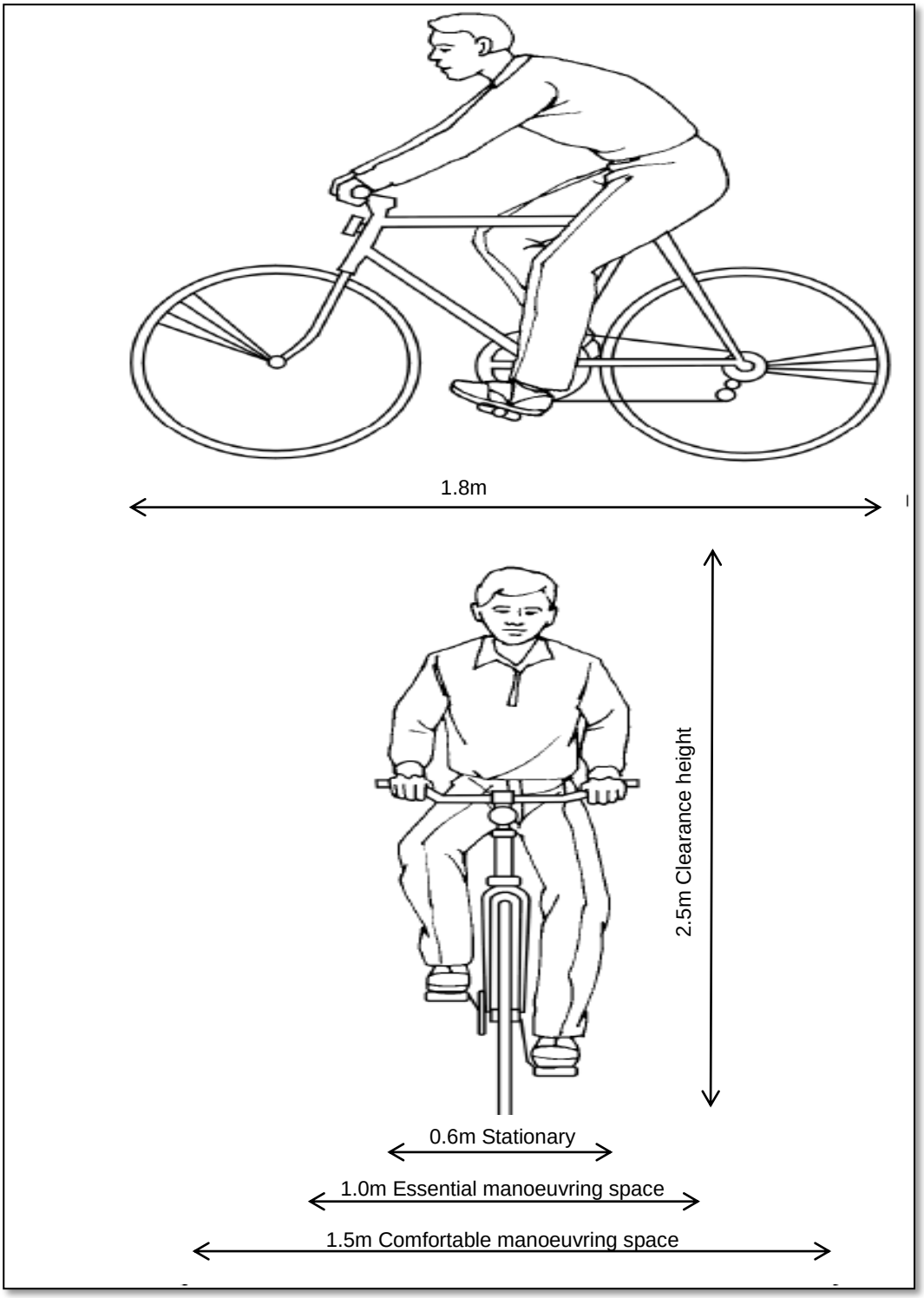


Figure 3-6: A bicycle- friendly operating area.

Source: South African National Department of Transport (2003).

3.6.2 Smooth cycling surfaces

Bicycles generally have no suspension and narrow tyres that are inflated to significant high pressures (South African National Department of Transport, 2003). Smooth cycling surfaces are therefore desirable for cyclists to experience effective, safe and comfortable cycling journeys (South African National Department of Transport, 2003). The Bicycle Network (2016) mentioned that cycling surfaces should desirably be smoother than surfaces for motorised- vehicle use. Designers should, however, consider the possibility of debris washing onto these surfaces from adjacent land (Bicycle Network, 2016). The cycling surfaces of particular concern for cyclists are:

- Uneven expansion and paving linkages.
- Concrete bicycle tracks where considerable upheaval has taken place,
- Potholes and uneven repairing on cycling surfaces.
- Debris or crushed aggregate that could induce skidding.
- Pavement drop-offs.
- Utilities such as manhole covers and drainage grates.

Figure 3-7: Example of low- maintenance, uneven bicycle- lanes.
Source: Fortin (2013).

3.6.3 Clear sight distances

It is important to consider the sight lines between cyclists and pedestrians with the aim of minimising user conflicts (Bicycle Network, 2016). Designers should, therefore, ensure that bicycle-friendly spaces are designed according to appropriate sight distance- requirements. The Bicycle Network (2016) mentioned that it is safer for cyclists to provide larger cycling curves with greater sight distances. Sufficient sight distances should provide cyclists with opportunities to see hazards and react accordingly (South African National Department of Transport, 2003). This is especially important with curves, where sight distances are reduced by trees and bushes adjacent to the route, as shown in Figure 3-8.

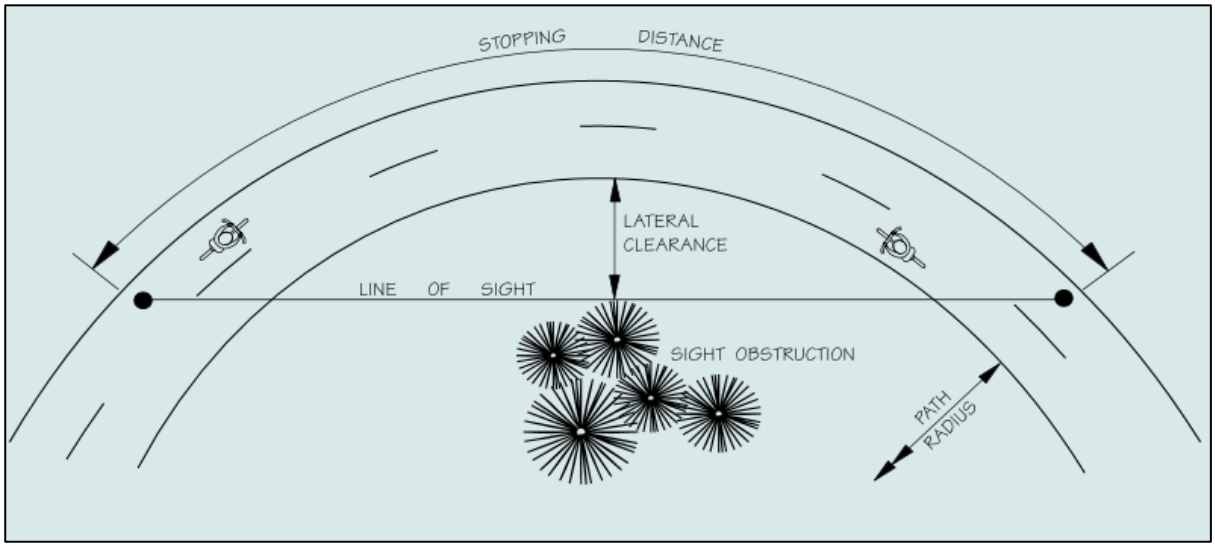


Figure 3-8: Sight distance and lateral clearances to obstructions.
Source: Bicycle Network (2016).

3.6.4 Speed Maintenance

For cycling to be the most effective mode of transport, cyclists should be able to maintain their travelling speed without slowing down or stopping (Bicycle Network, 2016). The design of various aspects of bicycle- friendly spaces depends on cycling speed. Cycling speed depends on many factors such as the type of bicycle used, type of cyclist, journey purpose, and gradients (South African National Department of Transport, 2003). According to the Bicycle Network (2016), steep cycling gradients could result in high downhill speeds, causing dangers for cyclists. In contrast, cyclists may also be forced to push their bicycles uphill or take alternative routes to avoid steep cycling gradients. As a result, cyclists pushing their bicycles may use more cycling space than those cycling (Bicycle Network, 2016). Bicycle- friendly spaces should thus be designed for relatively high speeds. Recommended design speeds for various grades are given in Table 3-10.

Table 3-10: Design speed for different downhill grades.

Downhill grades	Design speed
< 3%	30 km/h
3% to 7%	40 km/h
> 7%	50 km/h

Source: Own creation based on the South African National Department of Transport (2003).

3.7 Conclusion

From the literature considered in this chapter, it is evident that cycling is an essential NMT mode to be included as part of broader city and community planning. It was found that cycling serves as the most efficient mode of transport over short to medium journeys in a city, for purposes such as cycling to school, shops and public transport. Cycling may also save crucial time and personal effort compared to walking as a mode of transport, and is considerably more space- efficient than other transport modes. Many cities considered the development of cycling infrastructure as a solution to create sustainable urban mobility. A multi- modal transport system is, however, essential for developing a bicycle- friendly transport network.

Chapter 3 emphasised that the value of specific cycling- needs are worth considering for planning bicycle- friendly spaces. As such, cyclist types provide an understanding of the target market to be considered in the bicycle- friendly planning process. A well-designed cycle facility will be attractive to a wide spectrum of captive and potential cyclists. These cyclist types are however constraint by factors that may serve as a challenges to cycling as a mode of transport. These challenges suggest that cyclists would be more likely to cycle if roads were made safer through planning bicycle- friendly spaces. Accordingly, Chapter 3 identified various types of spaces and design guidelines to consider when planning for bicycle- friendly spaces.

Theory based sampling was employed as part of a qualitative enquiry into the planning of bicycle-friendly spaces and various design elements was identified as crucial elements to consider for enhancing the planning of such spaces. These elements were structured as a checklist with a ranking system, employed in the empirical section of this research to evaluate the identified case studies, and identify best practices from an international and local context. The theoretical derived design elements are captured in Table 3-11.

Table 3-11: Design elements for enhancing the planning of bicycle- friendly spaces.

Elements	Not visible in space	Visible to some extent	Best practice	Cross reference
Bicycle- lanes				**Refer to section 3.5.1**
Basic bicycle lane				Refer to section 3.5.1
Buffered bicycle lane				Refer to section 3.5.1
Contra- flow bicycle lane				Refer to section 3.5.1
Bicycle lane on one-way street				Refer to section 3.5.1
Bicycle Boulevards				**Refer to section 3.5.2**
Bicycle tracks				**Refer to section 3.5.3**
One- way protected bicycle track				
Raised bicycle track				
Two- way bicycle track				
Bicycle intersection treatment				**Refer to section 3.5.4**
Bicycle box				
Intersection crossing				
Median Refuge island				
Combined bicycle-lane/ turn- lane				
Bicycle track intersection approaches				
Bicycle signals				**Refer to section 3.5.5**
Bicycle signal heads				
Bicycle detection signals				
Hybrid signals				
Bicycle signage and markings				**Refer to section 3.5.6**
Bicycle route way- finding				
Coloured bicycle spaces				
Shared- lane markings (Sharrows)				
Bicycle parking facilities				**Refer to section 3.5.7**
Sidewalk bicycle racks				
On- street bicycle corrals				
Bicycle lockers				
Speed Maintenance (cycling topography)				**Refer to section 3.6.4**

Elements	Not visible in space	Visible to some extent	Best practice	Cross reference
Bicycle- friendly operating-space				**Refer to section 3.6.1**
Clear cycling sight- distances				**Refer to section 3.6.3**
Smooth cycling surfaces				**Refer to section 3.6.2**
Efficient lighting for cycling				**Refer to section 3.4.2**

Source: Own creation (2017) based on the theoretical findings of this study.

The following chapter will consider the legislation, policies and guidelines applicable to the development of NMT, especially bicycle- friendly planning, as perceived from an international and local perspective.

CHAPTER 4: LEGISLATION, POLICIES AND GUIDELINES INFORMING NMT APPROACHES

International experience indicates that a national cycling policy framework serves as an essential tool for encouraging cycling in urban areas (Department of Transport, 2009). A national cycling policy framework provides an integrated foundation for long- term development and implementation of cycling policies among many sectors and levels of the government (Department of Transport, 2009). National cycling strategies, however, allow governments to establish frameworks that support the development of cycling in their countries (Kuster, 2007). As a result, these strategies allow governments to send signals to regional and local authorities that cycling is important and that cycling should be considered in public policies (Kuster, 2007).

This chapter considers the transport legislation, policies and guidelines applicable to the development of NMT, especially bicycle- friendly planning, as perceived from an international and local perspective. The structure of Chapter 4 is captured in Figure 4-1.

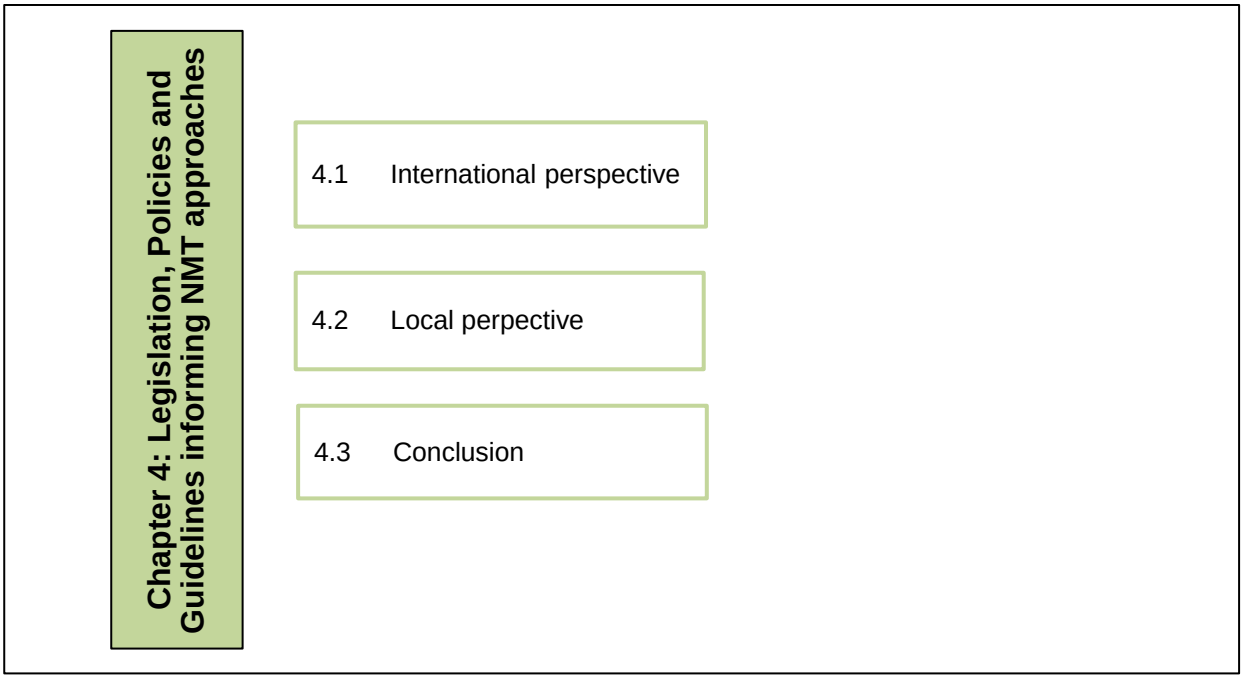


Figure 4-3: Structure of Chapter 4.

Source: Own creation (2017).

4.1 International perspective

Sachs (2012) mentioned that there is a worldwide growing demand for sustainable transport development. This is particularly true for countries where a lack of NMT infrastructure investments contribute to traffic accidents, unsafe roads, poor roadway designs, and climate change (UN Environment, 2016). Many jurisdictions worldwide are aiming to develop cycling as a NMT mode in order to benefit from the health and transport efficiency benefits that cycling provides (International Transport Forum, 2017). International strategies such as the UN Environmental Programme (UNEP), the Sustainable Development Goals (SDG), the World Health Organisation (WHO) and the Health and Environment Linkages Initiative (HELI) are among the largest initiatives worldwide to favour NMT development. The content of the overarching international initiatives are not transport specific but entails sustainable development agreements.

The UN Environment Programme (UNEP) mentioned that greater investment in sustainable transport infrastructure may well save lives and reduce carbon emissions from motorised transport (UN Environment, 2016). A UNEP report noted that 1.3 million individuals pass away every year from traffic accidents, of which 49% are motorcyclists, pedestrians, and cyclists. The UNEP therefore calls on countries to invest a larger part of their transport budgets on NMT infrastructure; especially on walking and cycling (UN Environment, 2016). The UNEP further urges countries to draft national and local policies for NMT (UN Environment, 2016).

In 2015, 193 world leaders agreed to 17 global Sustainable Development Goals (SDG's) of the United Nations that aim to protect the world, to end poverty, and to ensure prosperity for everyone as part of a new sustainable development agenda (UN Sustainable Development, 2017). One of these goals aims at making cities and human settlements inclusive, safe, resilient and sustainable. Accordingly, this goal also aims to provide access to safe, affordable, and sustainable transport systems for everyone by 2030 (UN Sustainable Development, 2017). The transport decisions that countries make have long- lasting impacts on urban development, urban form, and the climate. Therefore, sustainable NMT ought to be viewed and integrated as an essential component of sustainable development strategies (UN Sustainable Development, 2017).

Health and Environment Linkages Initiative (HELI) is a global effort by the World Health Organisation (WHO) and UNEP to support the actions of policymakers on environmental threats to health in developing countries (Health and Environment Linkages Initiative, 2017). HELI stated that transport demand management policies may support a more managed and balanced mix of public, NMT, and private motorised transport. These policies may well contribute to increased urban mobility, lower levels of carbon emissions, fewer NMT casualties and more "friendly" urban spaces for communities (Health and Environment Linkages Initiative, 2017). International urban

experiences recommend that a “healthy” urban transport system ought to include a substantial component of walking and cycling systems (Health and Environment Linkages Initiative, 2017). HELI prepared an international directory of sites relating to the sustainable development of urban environments. The particular sites relating to NMT and cycling include:

- SUTRA (Sustainable Urban Transportation);
- SUTP (Sustainable Urban Transport Project);
- ITDP (Institute for Transportation and Development Policy); and
- GTKP (Global Transport Knowledge Practice).

4.2 Local perspective

Over the previous decade, South Africa updated its NMT policies and legislation to enhance the development of NMT and to raise awareness thereof (Randall, 2016). This section provides a summary of legislation, policies and guidelines directing NMT, especially bicycle- friendly planning.

The Constitution of the Republic of South Africa, Act 108 of 1996 Section 85 (1) (b) assigned the Department of Transport to develop a transport policy for South Africa (Department of Transport, 2008). This, however, placed the responsibility on the Department of Transport to develop a transport policy to meet the mobility needs of all individuals and accordingly call for the need to develop a NMT Policy for South Africa (Department of Transport, 2008).

In 2008, South Africa published its first Draft NMT Policy (UN Environment, 2016), echoing both the White Paper on National Transport Policy of 1996 and National Land Transport Strategic Framework (NLTSF) with regards to raising awareness of NMT and promoting transport safety (Randall, 2016). This Draft NMT policy also provided a clear distinction between cycling and walking, with cycling receiving its own set of policy statements (Randall, 2016). Said guidelines are deemed an impetus for several guideline documents and manuals that followed relating to the implementation of NMT in South African cities. The Draft National NMT Transport Policy of 2008 provided the following cycling policy statements:

- Ensures that road infrastructure is improved to accommodate the cycling needs and that future road development incorporates cycling needs where necessary.
- Ensures that cycling is integrated into the transport network, and that this mode is included in new transportation policies.
- Ensures that will form part of the national transport master plan.

South Africa's Transport Strategy and Action Plan of 2007 is a central policy document on public transport, mentioning that NMT is an essential mode for the 'first mile' and 'last mile' of all journeys (UN Environment, 2016). The intention of this action plan was to improve high quality of NMT links to public transport. Both the National Road Traffic Act 93 of 1996 (NRTA) and the National Road Traffic Regulations of 2000 (NRT Regulations) made provision for the development of NMT (UN Environment, 2016). In addition, the Department of Transport developed a National Transport Master Plan (NATMAP) that includes and promotes the integration of NMT and public transport (UN Environment, 2016). The vision of the National Transport Master Plan reads as follows: "The NATMAP 2050 goal is to develop a dynamic; long-term; and sustainable land use/ multi- modal transportation system".

During 1987 and 1993, the Department of Transport published NMT manuals to address the particular needs of pedestrians and cyclists (Vanderschuren, et al. 2014). These manuals, however, became out- dated as a result of new technologies and improvements in the provision of NMT facilities. The Department of Transport additionally developed a practical and user- friendly manual; the "Pedestrian and Bicycle Facility Guidelines Manual of 2003". Since 2003, the transport landscape has been affected by significant changes in NMT policies and legislation (Vanderschuren, et al. 2014). The Department accordingly found it imperative to update the current manual to align with these changes and to effectively address the needs of all transport users (Vanderschuren, et al. 2014).

During 2014, the Department of Transport published a new NMT Facility Guideline Manual that serves as an update to the current Pedestrian and Bicycle Facility Guidelines of 2003 (Vanderschuren, et al. 2014). This 165-page illustrated document includes NMT direction on policy and legislation, maintenance, planning, pavement materials and draft designs (UN Environment, 2016). This new NMT guideline provides guidance on the planning and design for safe pedestrian, bicycle, and other alternative low carbon modes of transport (Vanderschuren, et al. 2014). Furthermore, the guideline aims to strengthen the provision of bicycle- and pedestrian friendly spaces, to improve the physical environment and safety of NMT users (Vanderschuren, et al. 2014). The NMT Facility guideline Manual of 2014 is aligned with the National Land Transport Act of 2009, the Road Traffic Act of 1996, the Moving South Africa Action Agenda (2020), the Road Infrastructure Strategic Framework of 2006 (RISFSA), the Shova Kalula Rollout Plan (2007), and the Municipal Integrated Development Plan (IDP).

Efficient transportation, as well as the shift towards greener transport, are continual trends in an ever evolving urbanised milieu. In responding to a stronger emphasis on sustainable transport, the NATMAP (2010: 36) recommends settlement planning, whereby less polluting, lower impact modes of transportation in the design of transportation systems and urban areas, should be prioritised. It offers the provision of pedestrian and cycling paths as attractive and safe alternatives to cars. Suleman et al.(2015:6) affirm that the transport sector is at present the most significant contributor to greenhouse gas (GHG) emissions in South African cities, in part, due to the legacy of apartheid-related spatial planning (refer to Figure 4-2). Cities are gradually embarking on a process of meeting a required paradigm shift, away from 'one person, one car economic development' towards eco-mobility, non- motorised/ low- carbon transit and urban mass transit systems. Achieving this paradigm shift will require new thinking about spatial planning and city morphology, and about commuting/ transportation at a societal level (Suleman et al, 2015:11).

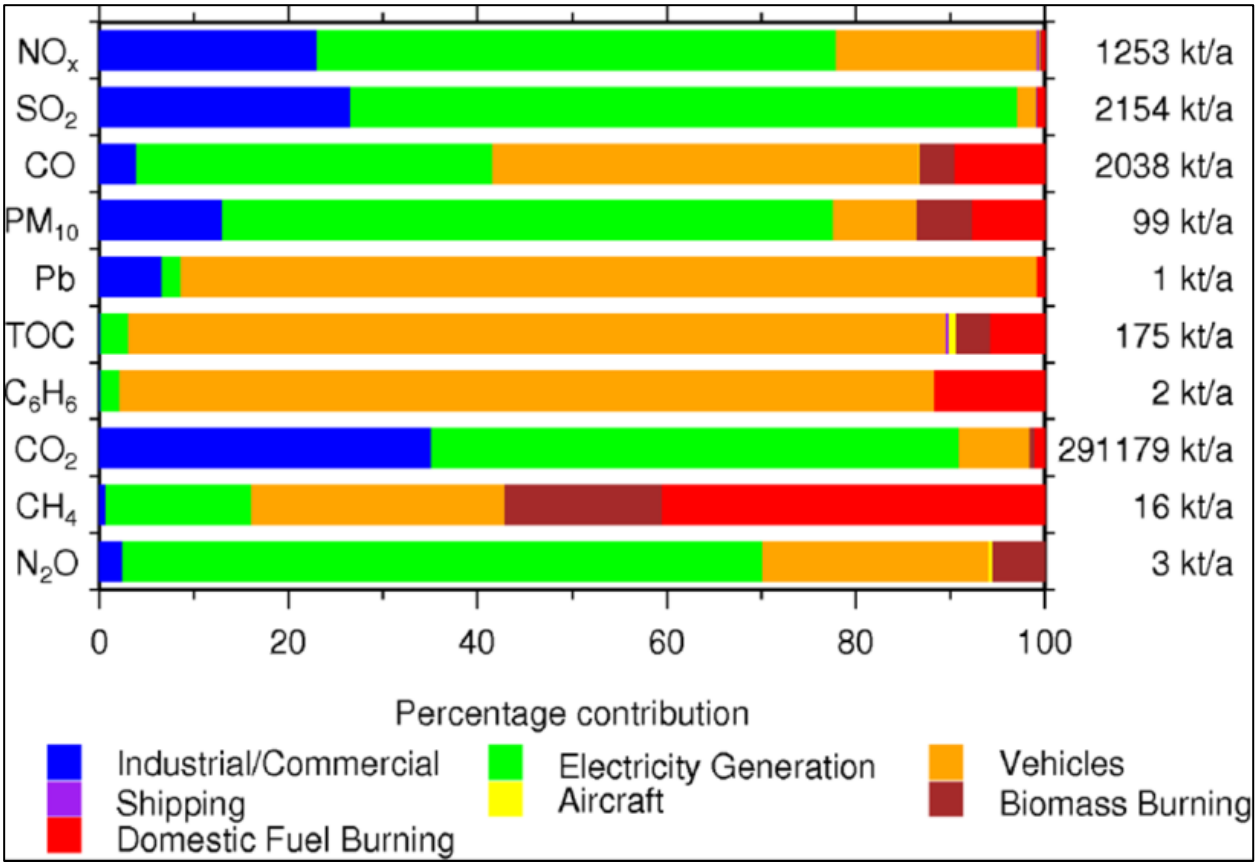


Figure 4-2: Combustion related air pollution sources contributing to total national emissions in South Africa

Source: Burger (2016:69)

Suleman et al. (2015:6) cautions that green transport infrastructure and services in cities should not be viewed as an ordinary endeavour. It requires strategic vision, multi-disciplinary skills and experience in integrated transport planning. It is stated that it will be a "key imperative for South

African cities to move away from privately owned cars towards mass public transport, cycling and walking". Recent policies are systematically employed in certain Cites resulting in the improvement of public transport through bus rapid transport (BRT), alternate fuel vehicles (both gas and electric), NMT upgrades such as cycle and walking lanes, and low emission zones (such as restricted NMT and public transport routes).

The "Complete Streets" design guideline, as an example of policy implementation, categorised streets into broader typologies that account for non-motorised road users (pedestrians, bicyclists, and public transport) as well as land use context and environmental factors (City of Johannesburg, 2014). The guidelines lament that NMT facilities should not be reduced during road upgrades and additionally proposes design criteria for the implementation of NMT. In further meeting policy requirements, the Gauteng 25-Year Integrated Transport Master Plan (2013) supports the greening of transport and reducing traffic congestion through popularising cycling and short distance walking trips to destinations; using NMT modes (walking and cycling) as feeder systems to public transport; applying travel demand management and transport system management; and using 'sustainable power sources' for transport facilities, amenities and equipment.

The shift towards green transport will not happen all at once, and options such as dual -fuel and hybrid-electric vehicles provide a means to manage the risk associated with switching to cleaner technologies. The private sector have already shown a willingness to invest in the technologies, infrastructure and services needed to accomplish this shift. In light of the public benefits associated with green transport, government needs to assist by creating demand and providing an enabling environment (Suleman et al. 2015:37).

The preceding sections dealt with legislation, policy and guidelines pertaining to transportation planning and its specific relevance to NMT. It is also deemed necessary to provide an overview on current planning legislation and guidelines, in determining whether appropriate emphasis is placed on settlement design, in attaining the requirements set by government to attain NMT. As the aim of this chapter is not to provide a detailed discussion on all possible legislation, policy and the development of the guidelines, directing NMT, emphasis will, in the ensuing section, be placed on the promulgated Spatial Planning and Land Use Management Act (SPLUMA, 2013). A broad overview of the most recently proposed Spatial Development Frameworks (SDFs) preparation guidelines in support of the act, in so far as direction to NMT is given, will also be delivered (Department of Rural Development and Land Reform, 2014).

Following a highly complicated and intricate framework for planning legislation, the SPLUMA was promulgated, amongst others, as an attempt to simplify planning legislation. The act set clear development principles whereby spatial imbalances must be addressed and land development

endeavoured in sustainable locations, limiting urban sprawl (SPLUMA, 2013). Implementing a well-planned public transportation network, supported by NMT and walkability principals, is seen by scholars as a significant step to densify cities and intercept continuous urban sprawl.

The Guidelines for Human Settlement Planning and Design, specifically proposed the Corridor Densification Option Model as a means to address spatial imbalances in South African Cities (Guidelines for Human Settlement Planning and Design, 2014:3). Identifying norms and standards, the SPLUMA suitably emphasises the significance of desirable settlement patterns and elaborates that the preparation of SDFs must allow for the integration of all sector policies (i.e. the Integrated Transport Plan), spatial integration and addressing spatial imbalances (SPLUMA, 2013:24). Even though NMT and walkability are not specifically mentioned as content of a municipal SDF, structuring and restructuring elements of the spatial form are mentioned "in the arrangement development corridors, activity spines and economic nodes". It is readily accepted that NMT and walkability are already included as significant tributary elements to public transport nodes that are provided on development corridors. Planning legislation, therefore, does not refer directly to NMT as a required component of municipal SDFs, but its implementation is strongly suggested. Provision is, however, made for a so-called "implementation plan" (SPLUMA, 2013:34) that must include all sectoral requirements; by implication also the spatial requirements in the ITP. It can thus be argued that, although the legislation does not address NMT in clear terms, it is indirectly emphasised as an element of urban reconstruction.

The aim of a SDF is not to identify or propose possible new or alternative land uses for all the involved erven; rather to provide general direction, guide decision-making and action over a multi-year period aiming at the creation of integrated and habitable cities, towns and residential areas. Although current and past planning legislation outlined in varying levels, the contents of a SDF, the preparation thereof is guided through a comprehensive set of guidelines that also advanced over time, parallel to planning legislation. Table 4-1 presents a broad overview of the historical course of SDF preparation guidelines.

Table 4-1: Broad overview of the historical course of SDF preparation guidelines.

Year	Legal Directives		Guidelines
1995	Development Facilitation Act (DFA)	Land Development Objectives) LDOs	CSIR: IDP Process Manual (1995)
1996	Amended Local Government Transitional Act	IDPs	
1999	Local Government: Municipal Demarcation Act 27 of 1998	Interim IDPs for newly demarcated Municipalities	

Year	Legal Directives		Guidelines
2000	Municipal Systems Act, 2000 (Act 32 of 2000) & Regulations for Amendment	IDP & Sector Plans (SDF is deemed a Sector Plan to the IDP)	▪ Initially CSIR IDP Guide Packs (Providing for SDF as a Sector Plan) ▪ Later DRDLR: Guidelines for the development of SDFs
2013 - 2017	Spatial Planning and Land Use Management Act & Municipal Systems Act	Preparation of SDF Preparation of IDPs	▪ 2013 SALGA: Guidelines to assist municipalities with the formulation of Spatial Development Framework ▪ 2014 DRDLR: Guidelines for the development of SDFs (not yet implemented)
2018	Future Reviews and Preparation of new SDFs will be conducted according the SPLUMA, the MSA and recently prepared SDF guidelines (2014) by the DRDLR		

Source: Own construction (2017).

Neither NMT nor walkability are pertinently referred to in the most recent guidelines; especially walkability. Reference is, however, made to NMT routes, comprising pedestrian walkways, cycle routes and seating, should "Area Action Plans" be prepared (Guidelines for Human Settlement Planning and Design, 2014:31). Dealing with the concepts of spatial justice, spatial sustainability and efficiency, the guidelines emphasise the provision of infrastructure and social services to ensure the creation of viable communities (Guidelines for Human Settlement Planning and Design 2014:13). Whether this serves as adequate guidance for planners in preparing SDFs, remains to be seen. It is perhaps the understanding of the DRDLR that the ITP, a further sector plan to the IDP, should deal with NMT in greater detail. It is unfortunately alarming to note that no significant references to NMT, in preparing spatial plans, associated with SDFs, are made. This serves as motivation for this study, lamenting the absence of proper guidelines for NMT in planning directives. It is concluded that SDF guidelines should perhaps, in greater detail, address NMT and walkability in the preparation of spatial maps; especially in urban areas where the support of public transport nodes and feeder routes thereto, are deemed a significant element in corridor development.

Various policies, legislation and regulations are utilised in an attempt to improve and maintain transportation and the influence it has on the built environment as a whole (Jansen van Rensburg & Schoeman, 2016). This section includes brief descriptions of the policies and legislations included in the following figures. Figure 4-3 provides a brief illustration of the legislative framework concerned.

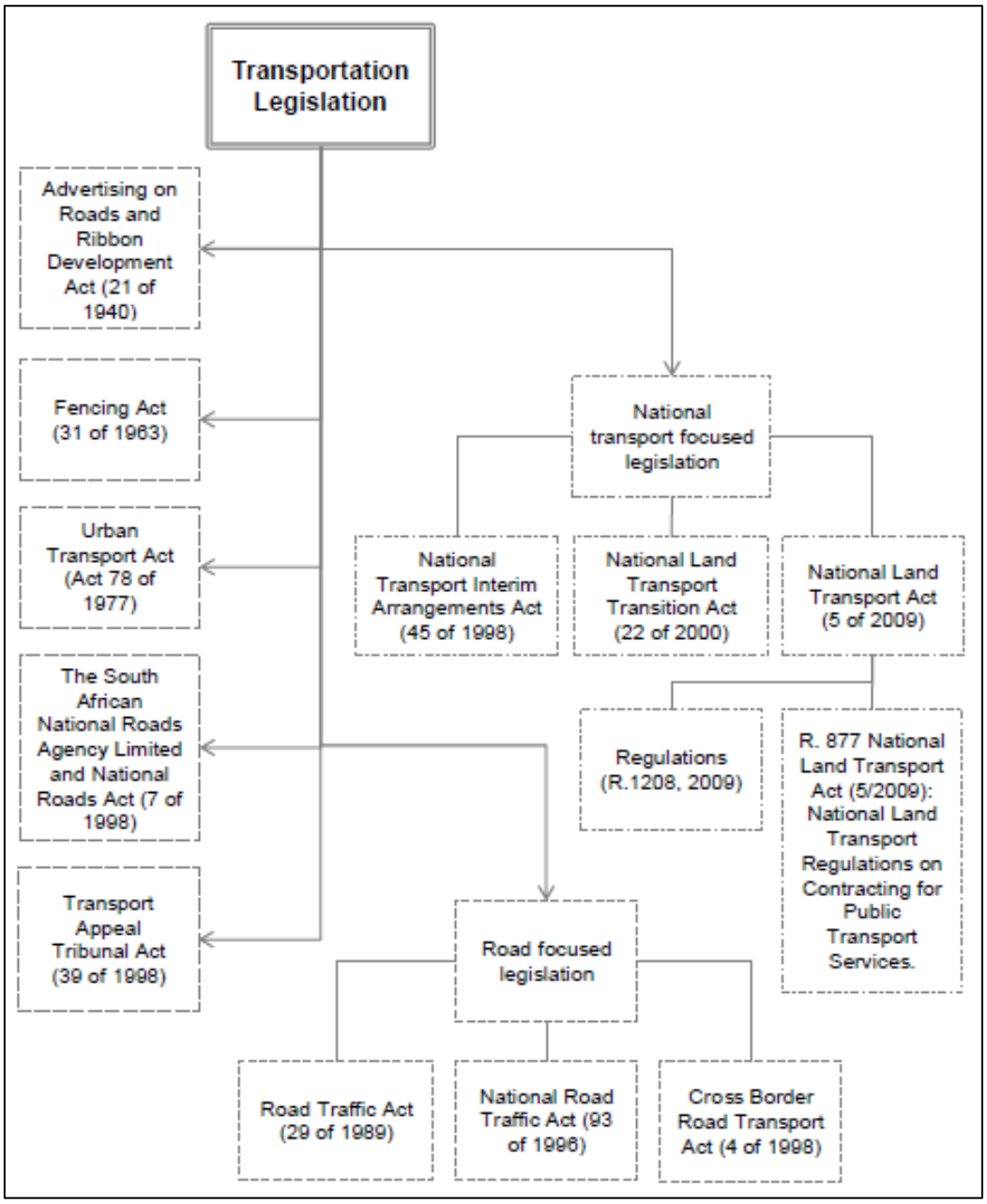


Figure 4-3: Transportation legislative framework - flow chart.

Source: Jansen van Rensburg & Schoeman (2016:185).

Figure 4-4 illustrates some of the policy framework included in transportation.

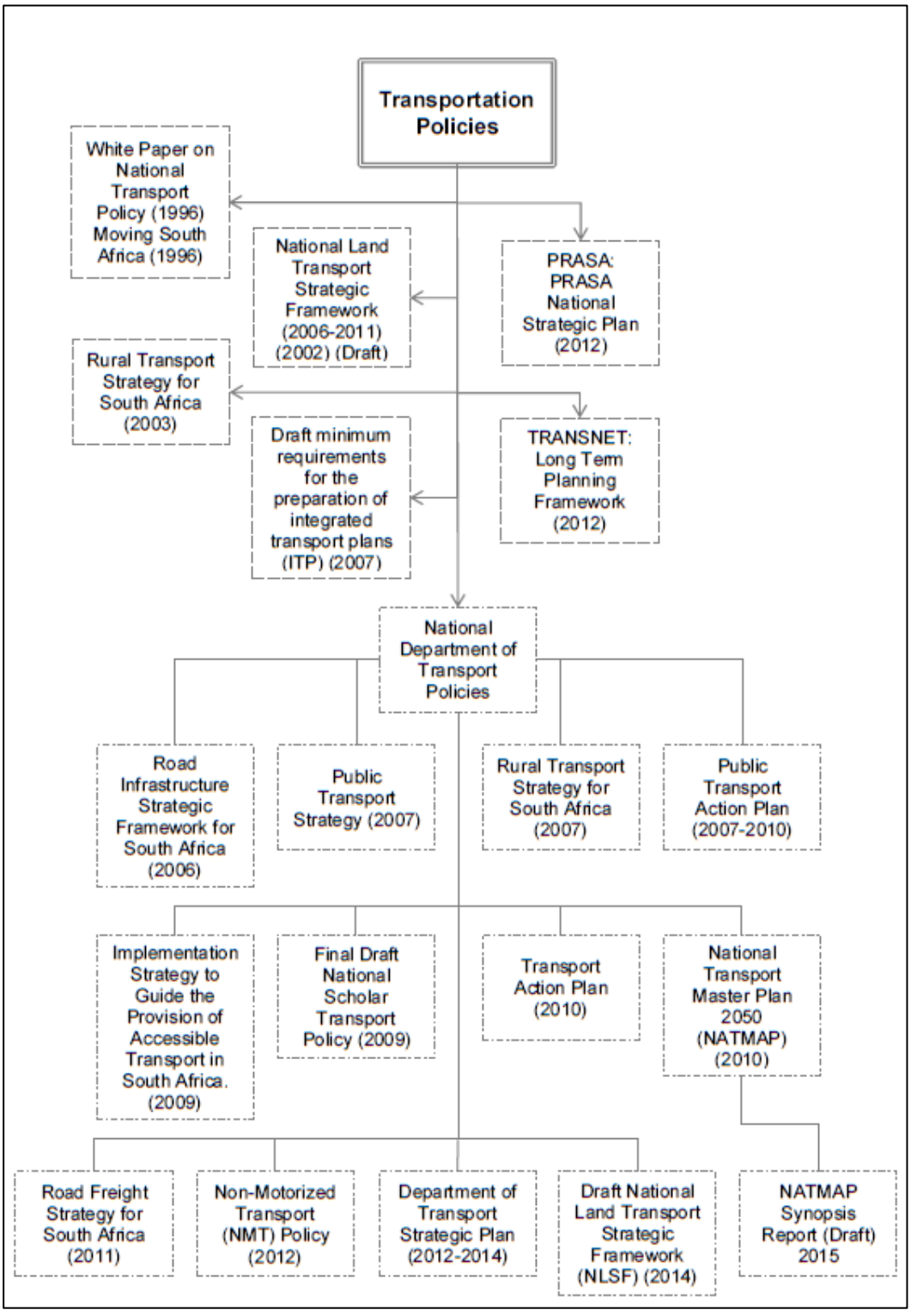


Figure 4-4: Transportation policy framework - flow chart.

Source: Jansen van Rensburg & Schoeman (2016:186).

A summary of the legislation and policies directing NMT and cycling in South Africa are summarised in Table 4-2.

Table 4-2: Policies and legislation guiding NMT and cycling in South Africa.

Policies	Description
White Paper on National Transport Policy of 1996	The 1996 White Paper on Transport Policy aims to enhance the development of sustainable modes of transport such as walking and cycling, public transport and animal-drawn transport. This will, however, reduce the dependence on private vehicle use in South Africa
National Land Transport Strategic Framework of 2015 (NLTSF)	This National Land Transport Strategic Framework (NLTSF) is a legal requirement in terms of National Land Transport Act, 2009, NLTA, (Act, No.5 of 2009), section 34. The current NLTSF of 2015 provides guidance on transport planning; more specifically on public transport, rural transport and road safety. Its NMT- objective is to promote high quality public transport networks where NMT is a basic provision in all transport planning and infrastructure projects.
Public Transport Strategy and Action Plan of 2007	The purpose of this document is to introduce public transport that would reduce undesirable walking distances and improve NMT links to public transport. It recognises NMT, particularly walking and cycling, as the most important modes of transport, and suggests several actions to improve NMT linkages by means of planning, design, implementation and maintenance.
Draft National NMT Policy of 2008	In 2008, South Africa published its first Draft NMT Policy, echoing both the White Paper on National Transport Policy of 1996 and National Land Transport Strategic Framework (NLTSF) with regards to raising awareness of NMT and promoting transport safety. This Draft NMT policy also provided a clear distinction is between cycling and walking, with cycling receiving its own set of policy statements. <u>The Draft National NMT Transport Policy of 2008 provided the following cycling policy statements:</u> ➢ Ensures that road infrastructure is improved to accommodate the cycling needs and that future road development incorporates cycling needs where necessary. ➢ Ensures that cycling is integrated into the transport network, and that this mode is included in new transportation policies. ➢ Ensures that will form part of the national transport master plan.

The NMT Facility Guideline Manual of 2014	The new NMT Facilities Guidelines Manual of 2014 supersedes the original 2003 version. This new manual provides guidance on the planning and design for safe pedestrian, bicycle, and other alternative low carbon modes of transport. Furthermore, the guideline will strengthen the provision of bicycle- and pedestrian friendly spaces to improve the physical environment and safety of NMT users. The document also provides guidance on the principles of bicycle parking and the best locations thereof.
Legislation	**Description**
National Road Traffic Act 93 of 1996 (NRTA)	The Non-Motorised Transport Policy of 2008 is governed by the National Road Traffic Act, Act 93 of 1996. The NRTA deals with issues such as vehicle and driver fitness, rules of the road, traffic signs and signals and related matters. It is also an offence to fail to obey a road traffic sign, unless directed to do so by a traffic officer.
National Road Traffic Regulations of 2000 (NRT Regulations)	The National Road Traffic Regulation has made an expression that affects and regulates NMT, especially cycling. The current regulation framework addresses the conditions and standards of several NMT aspects in relation to cycling and animal-drawn vehicles.
National Land Transport Act 5 of 2009 (NLTA)	Section 35 of the NLTA provides that each province ought to produce a Provincial Land Transport Framework (PLTF). This requires to be done according to the terms of the Regulations Relating to Minimum Requirements for the Preparation of Provincial Land Transport Frameworks, 2011. These Regulations provide that in preparing the PLTFs, NMT should be taken into account. The Regulations also provide that the PLTFs ought to contain a chapter on NMT and environmentally sustainable transport.
Spatial Planning and Land Use Management Act, 2013 (SPLUMA, 2013).	The act set clear development principles whereby spatial imbalances must be addressed and land development endeavoured in sustainable locations, limiting urban sprawl (SPLUMA, 2013). Identifying norms and standards, the SPLUMA suitably emphasises the significance of desirable settlement patterns and elaborates that the preparation of SDFs must allow for the integration of all sector policies (i.e. the Integrated Transport Plan), spatial integration and addressing spatial imbalances (SPLUMA, 2013:24). Provision is, however, made for a so-called "implementation plan" (SPLUMA, 2013:34) that must include all sectoral requirements; by implication also the spatial requirements in the ITP. It can thus be argued that, although the legislation does not address NMT in clear terms, it is indirectly emphasised as an element of urban reconstruction.

Source: Own creation (2017) based on the findings of Vanderschuren, et al. (2014), Randall (2016), Gwala (2007, and The Department of Transport (2008).

4.3 Conclusion

Chapter 4 considered the guiding policies and legislation applicable to the development of NMT, especially bicycle- friendly planning, as perceived from an international and local perspective.

From an international perspective, sustainable NMT ought to be viewed and integrated as an essential component of sustainable development strategies. International experience indicates that a national cycling policy framework serves as an essential tool for encouraging NMT and more specifically cycling in urban areas.

From a local perspective, no significant references to NMT, in preparing spatial plans, associated with SDFs, are made. This serves as motivation for this study, lamenting the absence of proper guidelines for NMT in planning directives. It is concluded that SDF guidelines should perhaps, in greater detail, address NMT and walkability in the preparation of spatial maps; especially in urban areas where the support of public transport nodes and feeder routes thereto, are deemed a significant element in corridor development. Neither NMT nor walkability are pertinently referred to in the most recent guidelines; especially walkability. Reference is, however, made to NMT routes, comprising pedestrian walkways, cycle routes and seating, should “Area Action Plans” be prepared.

The planning legislation applicable for informing NMT in South Africa does not directly refer to NMT guidelines. Planning policies are formed according to national legislation and outlines methods and principles that the government or any entity will use to achieve its legislative directive. Planning policies can therefore be locally implemented on different urban contexts. It can thus be said that SPLUMA (2013) does not address NMT in clear terms as the act is indirectly emphasised as an element of urban reconstruction. The NMT policies applicable for South Africa and local urban contexts can therefore be seen as the planning directives for guiding NMT.

This chapter captured the broad legislative and policy framework in which NMT operates and which should be acknowledged when considering the development of bicycle-friendly spaces within South African cities. The next chapter will investigate international and local case studies relating to the planning of bicycle-friendly spaces in order to identify best practices for enhancing the planning of future (and local) bicycle- friendly spaces.

CHAPTER 5: CASE STUDY ANALYSIS

The previous chapters captured the literature study of this research, whereas Chapter 5 introduces the empirical investigation.

This chapter aims to identify best practices in terms of bicycle usage and the design of bicycle-friendly spaces, as applied in the international case studies of Amsterdam and Copenhagen, and local case studies of Cape Town and Johannesburg. These cases were purposefully selected based on their planning approaches and vision to develop bicycle- friendly spaces. These cases will be evaluated based on 1) cycling patterns as obtained through Strava data and 2) user (cyclist) preferences, identified through web-based approaches (Google street view) and analysed according to theory based sampling of identified elements (Table 3-11) in order to draw conclusions with regard to 3) best practices relating to the planning of bicycle- friendly spaces. Figure 5-1 captures the structure of Chapter 5.

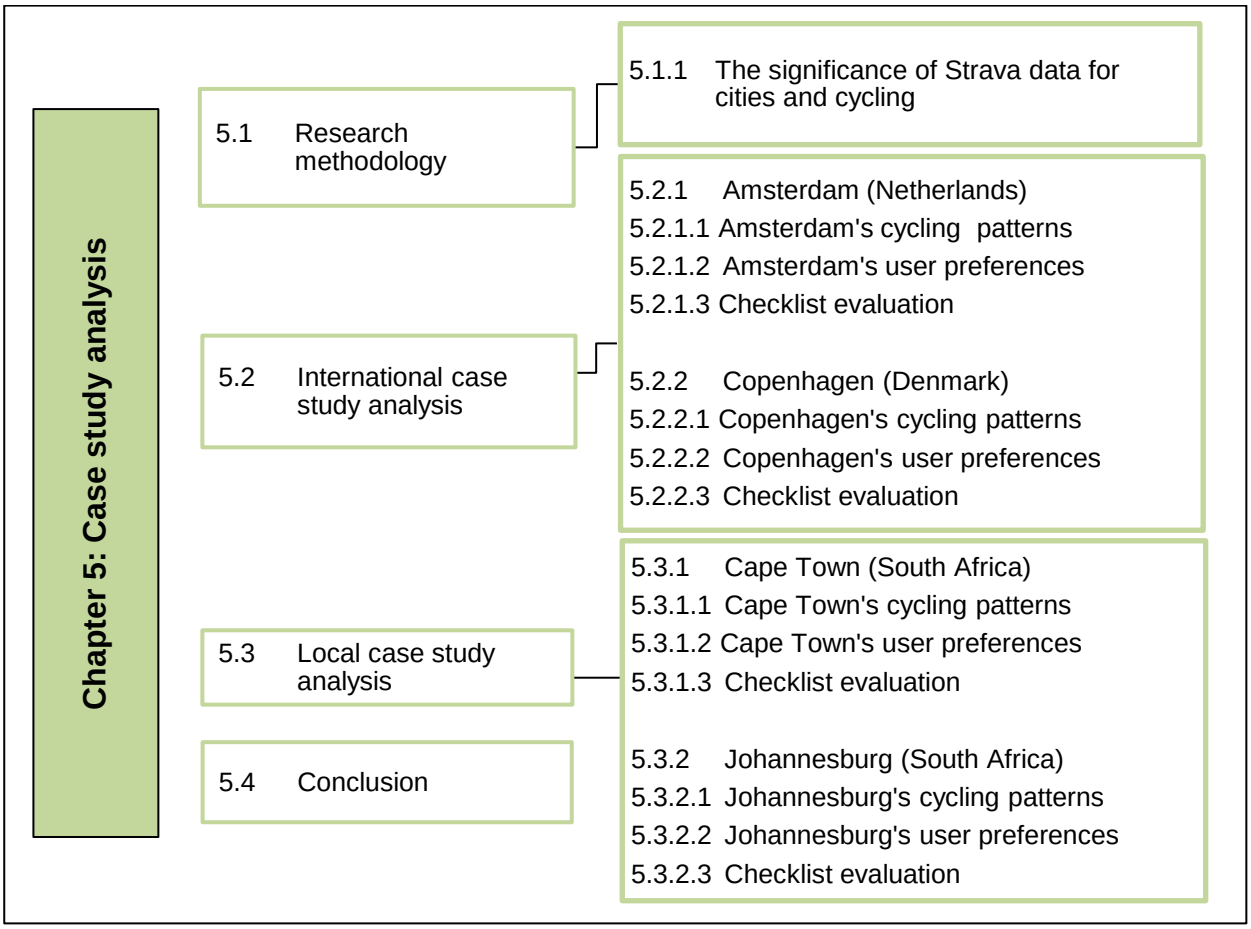


Figure 5-1: Structure of Chapter 5.

Source: Own creation (2017).

5.1 Research methodology

Four case study areas were selected for purposes of this research. Two international case studies (Copenhagen and Amstersdam), as motivated by the Copenhagenize Index (refer to 5.2), and two local case studies (Cape Town and Johannesburg), motivated by the research of Brightrock (2014), stating the focus of these cities to plan and develop bicycle- friendly areas (refer to 5.3). The research employs both quantitative and qualitative research methods and was structured in three phases. In the first phase the most prominent cycling areas and patterns were identified of the selected four case study areas, by employing secondary Strava data (refer to 5.1.1) for details on the significance of Strava data for cities and cycling). In the second phase, user (cyclist) preferences were captured through a qualitative enquiry of the Google street view of cycling areas and patterns identified in phase 1. These areas and patterns were analysed according to the theory based sampling of elements for enhancing the planning of bicycle- friendly spaces (Table 3-11) in order to inform phase 3 of the empirical research, namely to draw conclusions with regard to best practices relating to the planning of bicycle- friendly spaces.

5.1.1 The significance of Strava data for cities and cycling

Strava data is gaining importance as a research method to inform the planning and design of roads and movement corridors, as smart urban data provide insight into user preferences. By using an appropriate analysis, Strava data may lead to the start of a renaissance in sustainable transportation (Strava Metro, 2017). The number of GPS devices has considerably increased over the past 5 years, with cycling computers and mobile devices tracking movements (Cardiff by Bike, 2016). This data generated by GPS devices could be used to observe the areas of high movement activity to identify where cyclists prefer to cycle (Cardiff by Bike, 2016).

Strava data present a new approach to traditional retrospective surveys, bicycle- counting stations, and anecdotal evidence of cycling movements. With the advent of Strava, numerous qualitative data points (Go Bike, 2017) were initiated to track movement (Strava Metro, 2017) of individuals through the use of a GPS smartphone. These activities enable the analysis of movement and route preferences (Strava Metro, 2014). Strava receives more than 5 million activity uploads each week from Strava app users (Tremblay, 2016). This data are therefore significant for cities to understand how individuals choose to interact with road networks, bike paths and road crossings. Each journey mapped in Strava adds to the Strava database that may help cities to make important transportation decisions (Tremblay, 2016) and this data should be interpreted in order to inform planning and design of future city spaces. Figure 5-2 illustrates an example of the Strava mobile app.

Source: London Cyclist (2012)

Source: Priest (2015)

Figure 5-2: An example of the Strava mobile app.

Source: Own creation based on London Cyclist (2012) and Priest (2015).

Strava has an extensive data set that is presented as a global heat map (Cardiff by Bike, 2016). The Strava heat map visualises all Strava activities worldwide (Strava Metro, 2014) and allows Strava users to view popular and preferred cycling routes. Each cycling journey, therefore, acts as a digital vote on the global heat map that may inform city planning (Tremblay, 2016). The heat map illustrates the frequency (quantity) of cycling activity in a specific area (refer to Figure 5-3). Roads with minimal cycling activity have been filtered out; roads with low cycling usage are shown as blue lines; roads with higher cycling usage are shown as red lines of increasing width (Go Bike, 2017).

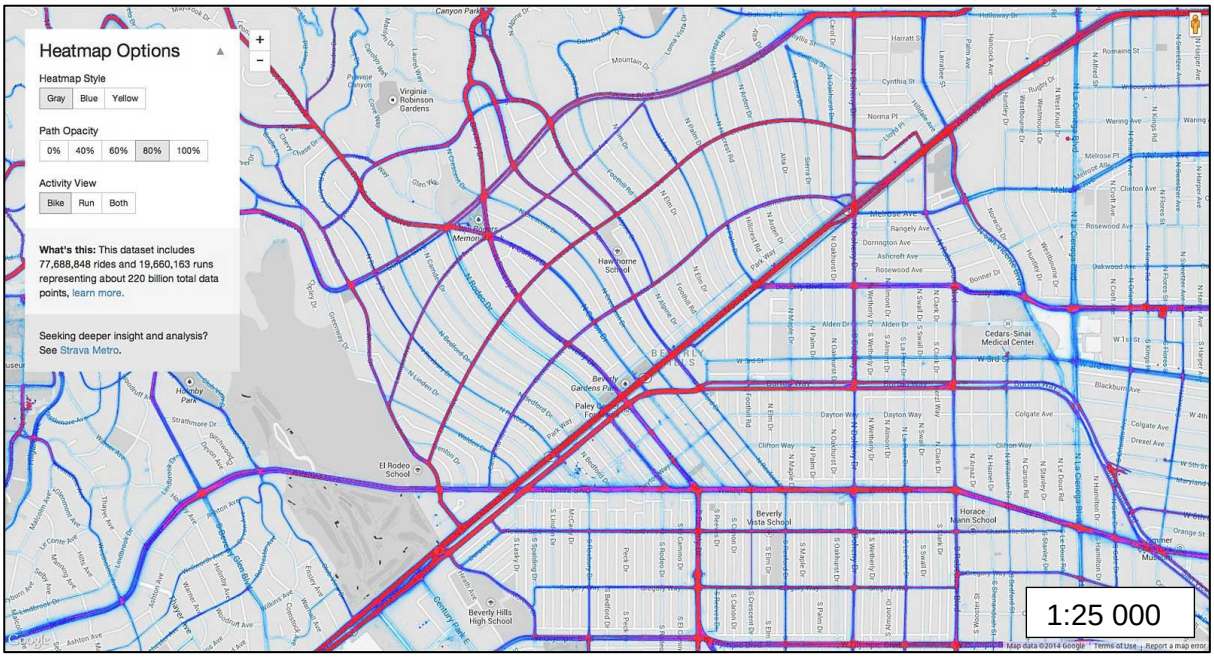


Figure 5-3: An example of a Strava heat map.

Source: Elliot (2014).

Walker (2016) stated that Strava heat maps capture 5-10% of all cycling activities in a city, although further research illustrated that Strava users tend to cycle on the same roads as non-Strava users (Alter, 2016). According to Strava Metro (2014), the Strava community consists of all types of cyclists and 50% of all cycling activities on Strava (in metro areas) are commuted; providing essential information on the transportation needs in cities (Strava Metro, 2014).

Gulley (2014) stated that cities may use Strava data to evaluate current cycling patterns and to manage bicycle- friendly spaces. Strava data can also be used by cities to appraise the effectiveness of new bicycle- friendly infrastructure, with before and after evaluations of the same routes that may display changes in cycling patterns (Gulley, 2014). Walker (2016) mentioned that Strava has received hundreds of requests for data from municipalities worldwide. About 76 cities around the world are using Strava Metro data, including major cities such as Glasgow, Reykjavik, Stockholm and Brisbane (Walker, 2016). For example, the city of Portland has used Strava data to gather information on cycling patterns (Evans- Cowley, 2015). Portland also used Strava data to identify areas where there is a need for cycling intersection improvements (Evans- Cowley, 2015). In Seattle, Strava's heat maps helped inform changes that encouraged an additional 14,000 cyclists to use the city's bicycle- lanes (Eldredge, 2016). One of Strava's goals is to leverage the millions of GPS- tracked activities uploaded by Strava users to help encourage and improve cycling as a transport mode in cities (Gourley, 2017). Figure 5-4 displays a worldwide heat map of the most prevalent Strava recorded activities.

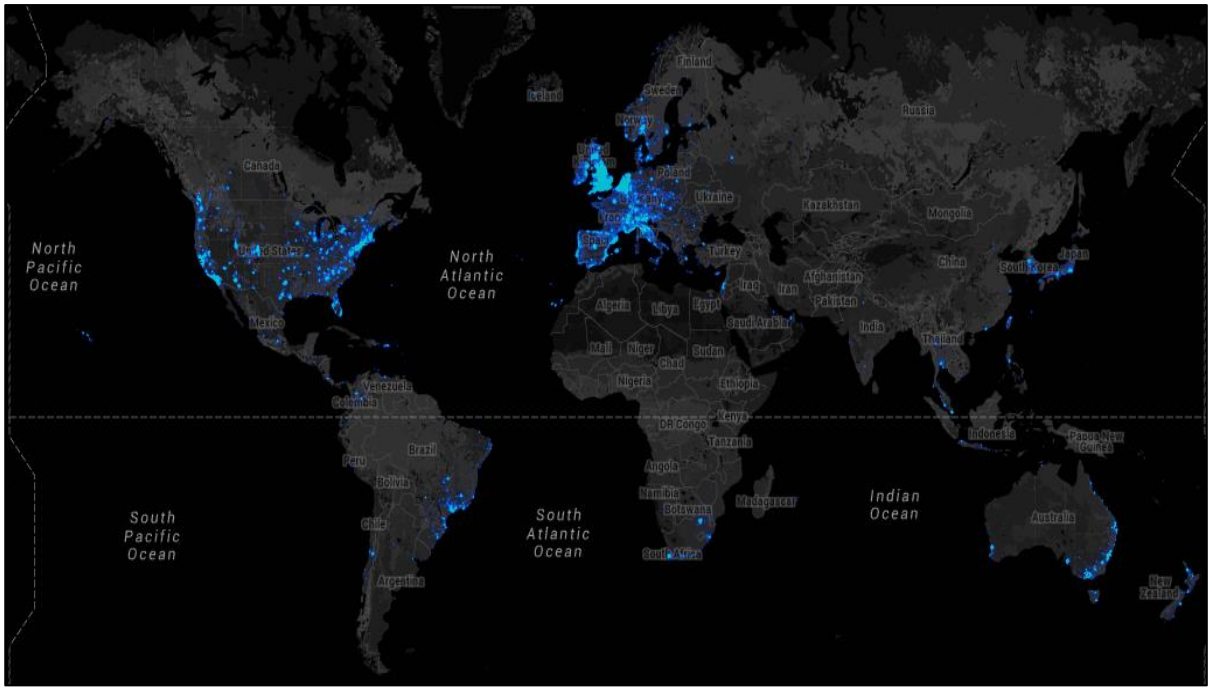


Figure 5-4: Most prevalent Strava recorded activities worldwide.
Source: Lee (2015).

Accordingly the selected case studies will be evaluated based on 1) cycling patterns as obtained through Strava data and 2) user (cyclist) preferences, identified through web-based approaches (Google street view) and analysed in terms of theory based sampling and identified elements (Table 3-11), in order to draw conclusions with regard to 3) best practices relating to the planning of bicycle- friendly spaces.

5.2 International case study analysis

The international case study analysis of this research will focus on Copenhagen and Amsterdam as best practices. Figure 5-5 shows the Copenhagenize Index of the top 20 bicycle- friendly cities in the world. This index ranked cities according to their efforts towards re-establishing cycling as a feasible, recognised and practical mode of transport (Copenhagenize Design Company, 2015). Copenhagen and Amsterdam are ranked as the best bicycle- friendly cities in the world according to the Copenhagenize index of bicycle- friendly cities, and will thus be evaluated accordingly (Copenhagenize Design Company, 2015). Figure 5-5 supports the statement that Copenhagen and Amsterdam are world leaders in supporting the development of bicycle- friendly spaces.

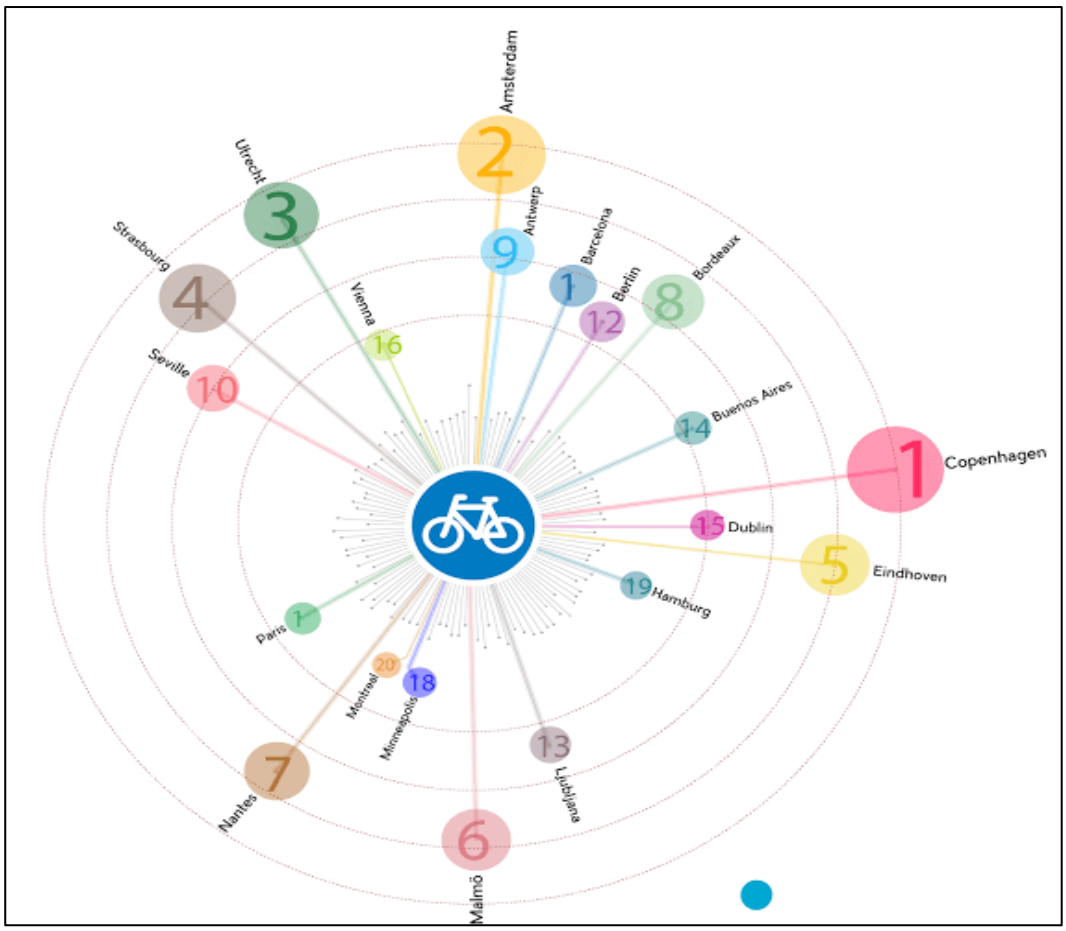


Figure 5-5: Copenhagenize index of bicycle- friendly cities

Source: Kidd (2015).

5.2.1 Amsterdam (Netherlands) case study

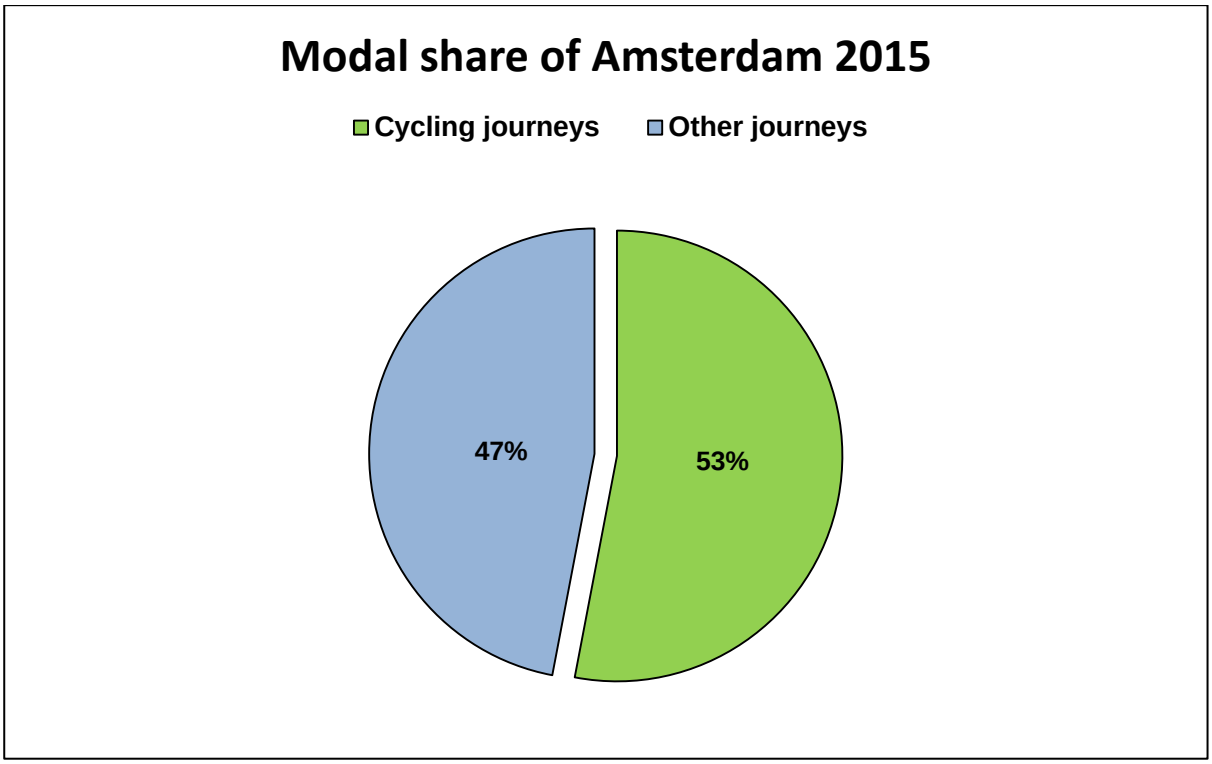
Amsterdam is the capital city of the Netherlands with a population of 851,373 (World Population Review, 2017). The city of Amsterdam is also the largest city in the Netherlands (Buehler, 2015). In this section, Amsterdam will be evaluated based on the city's bicycle- friendly planning approaches and vision to develop bicycle- friendly spaces. Figure 5-6 shows the location of Amsterdam, Netherlands.

Figure 5-6: The location of Amsterdam, Netherlands.

Source: Own creation based on Geology.com (2017).

According to the City of Amsterdam (2014), the majority of Amsterdam's individuals travel by means of cycling. Cycling is also considered as the most efficient mode of transport in Amsterdam (City of Amsterdam, 2014). In addition, cyclists in Amsterdam reach their destinations averagely 10% faster than motorists (City of Amsterdam, 2014). According to the Municipality of Amsterdam (2015), a transition to alternative transport modes may well make cities more sustainable. Amsterdam has shown that a switch to alternative transport modes is possible. Forty years ago, Amsterdam faced parking and congestion problems in the city (Municipality of Amsterdam, 2015). Gradually, cycling has become the most essential transport mode for Amsterdam. Amsterdam's transport policy primarily focuses on NMT modes (Buehler, 2015). Despite the fact that the city's main goal is to increase accessibility by all transport modes, sustainability concerns have favoured cycling in their transportation planning (Buehler, 2015).

Amsterdam's topography and densely built- up areas are ideal for cycling. Mixed land- use enabled communities to keep cycling journeys relatively short in the city. In 2008, cycling accounted for 38% of all journeys made in Amsterdam (Municipality of Amsterdam, 2015). Currently 53% of all journeys in Amsterdam are made by cycling as seen in Graph 5-1 (Municipality of Amsterdam, 2015).



Graph 5-1: Modal share of cycling in Amsterdam 2015

Source: Own creation (2017) based on the Municipality of Amsterdam (2015).

The city of Amsterdam has more bicycles than individuals and is therefore planning to increase the number of bicycle- friendly spaces (Berger, 2016). Smart city planning, investments in bicycle-friendly spaces and measures to reduce motorised traffic have contributed to Amsterdam's success (Municipality of Amsterdam, 2015). The Municipality of Amsterdam (2015) stated that Amsterdam wants to share its cycling expertise and experience with other cities worldwide. It is thus evident that cycling plays a significant role in Amsterdam's planning approaches and vision to develop bicycle- friendly spaces. For purposes of this research, the cycling patterns of Amsterdam was studied (5.2.1.1) to identify preferred cycling routes within the city and the related planning and design elements of these routes (5.2.1.2), to further inform best practices relating to the planning of bicycle- friendly spaces (5.2.1.3).

5.2.1.1 Amsterdam's cycling patterns

As mentioned in Chapter 5-1, Strava has an extensive data set that is presented by a global heat map. The cycling patterns are represented by bright lines on the heat map. The width of a line on the heat map visualises the amount of cycling activity in a specific area. Roads with minimal cycling activity have been filtered out; roads with low cycling usage are shown as blue lines; roads with higher cycling usage are shown as red lines of increasing width. Figure 5-7 illustrates the cycling patterns of Amsterdam, as obtained through Strava data.

Figure 5-7: Heat map of Amsterdam's cycling patterns as obtained through Strava data. Source: Strava Labs (2017).

In order to identify Amsterdam's most prevalent cycling patterns and ultimately draw conclusions regarding the preferred cycling routes and bicycle- friendly spaces within the CBD area, a simplified heat map were considered, as illustrated in Figure 5-8.

Figure 5-8: A simplified heat map of Amsterdam's most prevalent cycling patterns as obtained through Strava data.

Source: Strava Labs (2017).

Figure 5-8 illustrates Amsterdam's most prevalent cycling patterns. According to Google Maps (2017), these cycling patterns are recognised by the following streets in Amsterdam, as indicated alphabetically in Figure 5-8:

- A: Singel
- B: Prins Hendrikkade
- C: Geldersekade

Accordingly a visual analysis informed by Google Street View was used to analyse these streets and draw conclusions in terms of user preferences and specific design elements present in these areas.

5.2.1.2 Amsterdam's user (cyclist) preferences

The previous section identified the CBD cycling patterns of Amsterdam as obtained through Strava data. Accordingly Amsterdam's user preferences were obtained through a Google street view analysis in order to draw conclusions relating to the bicycle- friendly spaces used for each aforementioned cycling street. Table 5-1 captures the visual analysis and Amsterdam's user preferences as informed by Google street view.

Table 5-1: Amsterdam's user preferences

Bicycle- friendly spaces visual analysis	Identified user preferences
A: Singel	
	➢ Bicycle parking facilities ➢ Sidewalk bicycle racks ➢ Efficient lighting for cycling
	➢ Bicycle Boulevard ➢ Bicycle- friendly operating space ➢ Smooth cycling surfaces ➢ Clear sight distances ➢ Comfortable cycling topography

Bicycle- friendly spaces visual analysis	Identified user preferences
B: Prins Hendrikkade	
	➢ Bicycle track (Protected bicycle- lane) ➢ Two- way bicycle track ➢ Bicycle- friendly operating space ➢ Smooth cycling surfaces ➢ Clear sight distances ➢ Comfortable cycling topography ➢ Bicycle signage and markings ➢ Coloured bicycle spaces ➢ Bicycle route way- finding
	➢ Bicycle parking facilities ➢ Sidewalk bicycle racks
C: Geldersekade	
	➢ Bicycle Boulevard ➢ Bicycle- friendly operating space ➢ Smooth cycling surfaces ➢ Clear sight distances ➢ Comfortable cycling topography ➢ Bicycle parking facilities ➢ On- street bicycle corrals ➢ Efficient lighting for cycling

Source: Own creation (2017) based on Google Maps street view (2017).

Table 5-1 captured Amsterdam's user preferences through a Google street view analysis. Accordingly these areas were evaluated in terms of the theory based selection of identified design elements (Table 3-11), complied as a checklist approach with ranking system. Such were used to

inform on the best practices relating to the planning of bicycle- friendly spaces, as evident from the Amsterdam case study.

5.2.1.3 Best practice identification of Amsterdam's bicycle- friendly spaces.

Table 5-2 illustrates the evaluation of the spaces (streets) included in the Amsterdam case study in terms of the theory based selection and identified design elements.

Table 5-2: Best practice identification of Amsterdam's bicycle- friendly spaces.

Elements	Not visible in space	Visible to some extent	Best practice	Cross reference
Bicycle- lanes	✓			**Refer to section 3.5.1**
Basic bicycle lane	✓			Refer to section 3.5.1
Buffered bicycle lane	✓			Refer to section 3.5.1
Contra- flow bicycle lane	✓			Refer to section 3.5.1
Bicycle lane on one-way street	✓			Refer to section 3.5.1
Bicycle Boulevards			✓(A)(C)	**Refer to section 3.5.2**
Bicycle tracks			✓(B)	**Refer to section 3.5.3**
One- way protected bicycle track	✓			Refer to section 3.5.3
Raised bicycle track	✓			Refer to section 3.5.3
Two- way bicycle track			✓(B)	Refer to section 3.5.3
Bicycle intersection treatment	✓			**Refer to section 3.5.4**
Bicycle box	✓			Refer to section 3.5.4
Intersection crossing	✓			Refer to section 3.5.4
Median Refuge island	✓			Refer to section 3.5.4
Combined bicycle-lane/ turn-lane	✓			Refer to section 3.5.4
Bicycle track intersection approaches	✓			Refer to section 3.5.4
Bicycle signals	✓			**Refer to section 3.5.5**
Bicycle signal heads	✓			Refer to section 3.5.5
Bicycle detection signals	✓			Refer to section 3.5.5
Hybrid signals	✓			Refer to section 3.5.5
Bicycle signage and markings			✓(B)	**Refer to section 3.5.6**
Bicycle route way- finding			✓(B)	Refer to section 3.5.6

Elements	Not visible in space	Visible to some extent	Best practice	Cross reference
Coloured bicycle spaces			✓(B)	Refer to section 3.5.6
Shared- lane markings (Sharrows)	✓			Refer to section 3.5.6
Bicycle parking facilities			✓(A)(B)(C)	**Refer to section 3.5.7**
Sidewalk bicycle racks			✓(A)(B)	Refer to section 3.5.7
On- street bicycle corrals			✓(C)	Refer to section 3.5.7
Bicycle lockers	✓			Refer to section 3.5.7
Speed Maintenance (cycling topography)			✓(A)(B)(C)	**Refer to section 3.6.4**
Bicycle- friendly operating-space			✓(A)(B)(C)	**Refer to section 3.6.1**
Clear cycling sight-distances			✓(A)(B)(C)	**Refer to section 3.6.3**
Smooth cycling surfaces			✓(A)(B)(C)	**Refer to section 3.6.2**
Efficient lighting for cycling		✓(A)(B)(C)		**Refer to section 3.4.2**

Source: Own creation (2017) based on the theoretical findings of this study.

Based on the Amsterdam case study the following best practices could be identified to guide future planning of bicycle- friendly spaces:

- A: Bicycle Boulevard
  Bicycle parking facilities- Sidewalk bicycle racks
  Speed Maintenance
  Bicycle- friendly operating space
  Clear cycling sight distances
  Smooth cycling surfaces

- B: Bicycle track- Two- way bicycle track
  Bicycle signage and markings- Bicycle route way- finding; Coloured bicycle spaces
  Bicycle parking facilities- Sidewalk bicycle racks
  Speed Maintenance
  Bicycle- friendly operating space
  Clear cycling sight distances
  Smooth cycling surfaces

- C: Bicycle Boulevard
  Bicycle parking facilities- On- street bicycle corrals
  Speed Maintenance
  Bicycle- friendly operating space
  Clear cycling sight distances
  Smooth cycling surfaces

5.2.2 Copenhagen (Denmark) case study

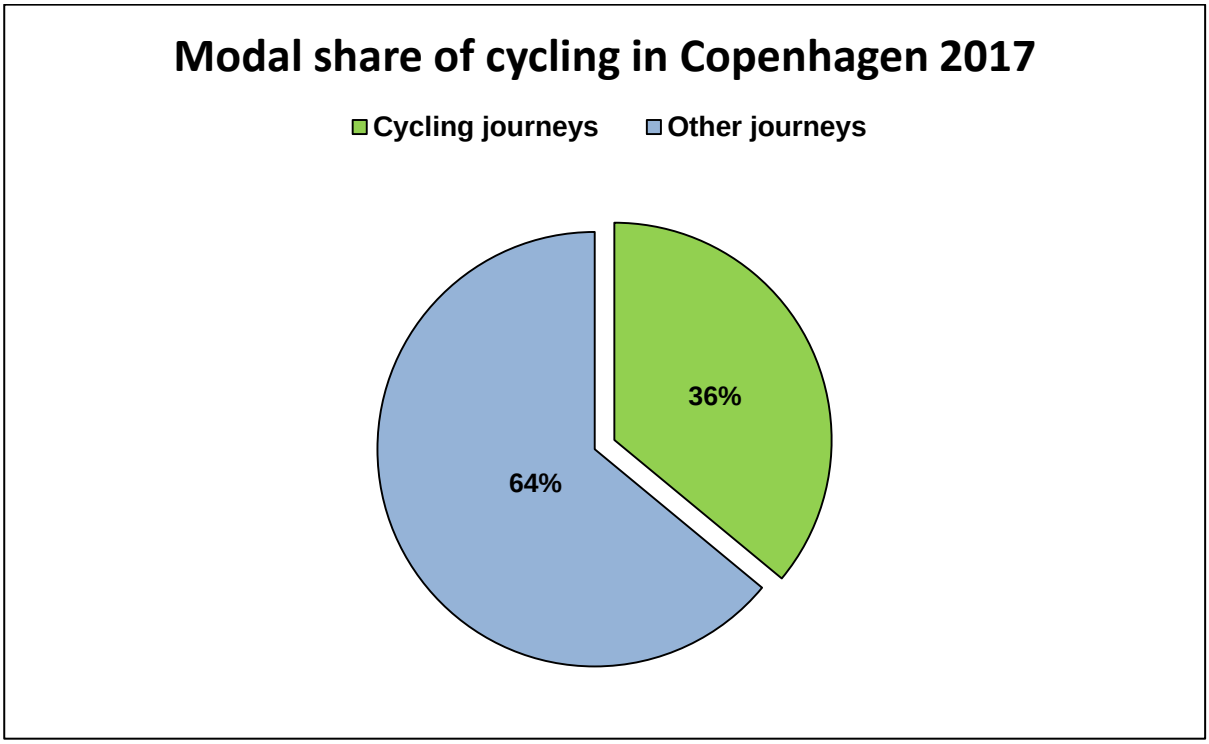
Copenhagen is the capital city of Denmark with a population of 583,000 (World Population Review, 2017). In 2016, Copenhagen was voted as the 'Best city for cyclists' and the world's most liveable city (Ministry of Foreign Affairs of Denmark, 2017). In this section, Copenhagen will be evaluated based on the city's bicycle- friendly planning approaches and vision to develop bicycle- friendly spaces. Figure 5-9 shows the location of Copenhagen, Denmark.

Figure 5-9: The location of Copenhagen, Denmark.

Source: Own creation (2017) based on Geology.com (2017).

Since the 1880s, Copenhagener's have been cycling to work as they found that cycling is the most efficient and environmentally friendly transport mode to travel around the city (Ministry of Foreign Affairs of Denmark, 2017). Cycling is also one of Denmark's traditions that Copenhagen has made integral to urban planning and design (City of Copenhagen, 2014). According to the City of Copenhagen (2014), urban planners have embraced the cycling culture in Copenhagen with urban solutions to accommodate the city's cyclists. Copenhagen is developing green ways through the city to ensure green transport and safe journeys for cyclists (Ministry of Foreign Affairs of Denmark, 2017). Copenhagen's vision is thus inspiring and may encourage sustainable transport for cities around the world (Ministry of Foreign Affairs of Denmark, 2017). In addition, Copenhagen is world famous for cycling and has globally inspired urban planners to make their cities more bicycle-friendly (City of Copenhagen, 2014).

The Ministry of Foreign Affairs of Denmark (2017) stated that cycling is the most popular mode of transport in Copenhagen and that 1.2 million kilometres are travelled everyday by cyclists in the city (Ministry of Foreign Affairs of Denmark, 2017). Currently 36% of all journeys in Copenhagen are made by cycling, as seen in Graph 5-2.



Graph 5-2: Modal share of cycling in Copenhagen 2017.
Source: Own creation (2017) based on the findings of the Cycling Embassy of Denmark (2017).

Some of the major cycling factors that determine why individuals choose to cycle in Copenhagen include; a good cycling infrastructure, enhanced safety, and shorter travel times (City of Copenhagen, 2014). The provision of more cycling space and separated cycling tracks are particular factors mentioned that would enhance the safety of cyclists in Copenhagen (City of Copenhagen, 2014). Cathcart- Keays (2016) pointed out that Copenhagen's efforts to develop a bicycle- friendly city have been successful. It is thus evident that cycling plays a significant role in Copenhagen's planning approaches and vision to develop bicycle- friendly spaces. For purposes of this research, the cycling patterns of Copenhagen was studied (5.2.2.1) to identify preferred cycling routes within the city and the related planning and design elements of these routes (5.2.2.2), to further inform best practices relating to the planning of bicycle- friendly spaces (5.2.2.3).

5.2.2.1 Copenhagen's cycling patterns

Zirulnick (2017) and O'Grady (2015) both mentioned that urban planners should pay attention to the preferred cycling routes in a city. In Copenhagen, planners have particularly paid attention to the city's cycling patterns and, where feasible, developed bicycle- friendly spaces along the preferred cycling routes (Zirulnick, 2017). Figure 5-10 illustrates the cycling patterns of Copenhagen, as obtained through Strava data.

Figure 5-10: Heat map of Copenhagen's cycling patterns as obtained through Strava data. Source: Strava Labs (2017).

In order to identify Copenhagen's most prevalent cycling patterns and ultimately draw conclusions regarding the preferred cycling routes and bicycle- friendly spaces within the CBD area, a simplified heat map were considered, as illustrated in Figure 5-11.

Figure 5-11: A simplified heat map of Copenhagen's most prevalent cycling patterns as obtained through Strava data.
Source: Strava Labs (2017).

Figure 5-11 illustrates Copenhagen's most prevalent cycling patterns in the CBD area. According to Google Maps (2017), these cycling patterns are recognised by the following streets in Copenhagen, as indicated alphabetically on Figure 5-11:

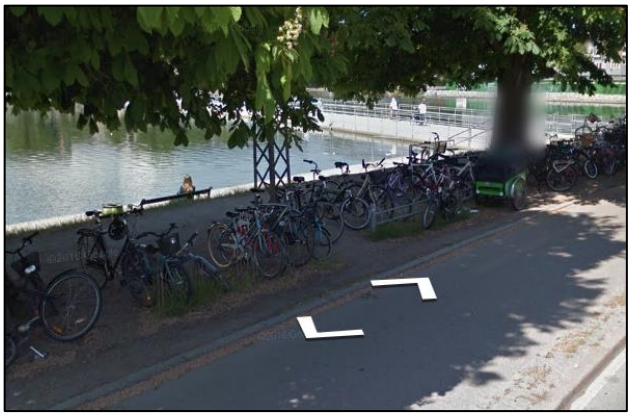
- A: Øster Søgade
- B: Gyldenløvesgade
- C: Kronprinsessegade

Accordingly a visual analysis informed by Google Street View was used to analyse these streets and draw conclusions in terms of user preferences and specific design elements present in these areas.

5.2.2.2 Copenhagen's user (cyclist) preferences

The previous section identified the CBD cycling patterns of Copenhagen as obtained through Strava data. Accordingly Copenhagen's user preferences were obtained through a Google street view analysis in order to draw conclusions relating to the bicycle- friendly spaces used for each aforementioned cycling street. Table 5-3 captures the visual analysis and Copenhagen's user preferences as informed by Google street view.

Table 5-3: Copenhagen's user preferences

Bicycle- friendly spaces visual analysis	Identified user preferences
A: Øster Søgade	
	➢ Bicycle- friendly operating space ➢ Smooth cycling surfaces ➢ Clear sight distances ➢ Comfortable cycling topography ➢ Bicycle track (Protected bicycle- lane) ➢ One- way protected bicycle track
	➢ Bicycle track (Protected bicycle- lane) ➢ One- way protected bicycle track ➢ Bicycle- friendly operating space ➢ Smooth cycling surfaces ➢ Comfortable cycling topography ➢ Bicycle parking facilities ➢ Sidewalk bicycle racks

Bicycle- friendly spaces visual analysis	Identified user preferences
B: Gyldenløvesgade	
 	➢ Bicycle track (Protected bicycle- lane) ➢ One- way protected bicycle track ➢ Bicycle- friendly operating space ➢ Smooth cycling surfaces ➢ Comfortable cycling topography ➢ Bicycle- lane ➢ Basic bicycle lane ➢ Bicycle- friendly operating space ➢ Smooth cycling surfaces ➢ Comfortable cycling topography ➢ Bicycle intersection treatment ➢ Intersection crossings ➢ Bicycle signage and markings ➢ Shared- lane markings
C: Kronprinsessegade	
 	➢ Bicycle track ➢ One- way protected bicycle track ➢ Bicycle- friendly operating space ➢ Smooth cycling surfaces ➢ Bicycle signage and markings ➢ Shared- lane markings ➢ Bicycle track ➢ One- way protected bicycle track ➢ Bicycle- friendly operating space ➢ Smooth cycling surfaces ➢ Comfortable cycling topography ➢ Bicycle intersection treatment ➢ Turn- lanes ➢ Bicycle parking facilities ➢ Sidewalk bicycle racks

Source: Own creation (2017) based on Google Maps street view (2017).

Table 5-3 captured Copenhagen's user preferences through a Google street view analysis. Accordingly these areas were evaluated in terms of the theory based selection of identified design elements (Table 3-11), complied as a checklist approach with ranking system. Such were used to inform on the best practices relating to the planning of bicycle- friendly spaces, as evident from the Copenhagen case study.

5.2.2.3 Best practice identification of Copenhagen's bicycle- friendly spaces

Table 5-4 illustrates the evaluation of the spaces (streets) included in the Copenhagen case study in terms of the theory based selection and identified design elements.

Table 5-4: Best practice identification of Copenhagen's bicycle- friendly spaces

Elements	Not visible in space	Visible to some extent	Best practice	Cross reference
Bicycle- lanes			✓(B)	**Refer to section 3.5.1**
Basic bicycle lane			✓(B)	Refer to section 3.5.1
Buffered bicycle lane	✓			Refer to section 3.5.1
Contra- flow bicycle lane	✓			Refer to section 3.5.1
Bicycle lane on one-way street	✓			Refer to section 3.5.1
Bicycle Boulevards	✓			**Refer to section 3.5.2**
Bicycle tracks			✓(A)(B)(C)	**Refer to section 3.5.3**
One- way protected bicycle track			✓(A)(B)(C)	Refer to section 3.5.3
Raised bicycle track	✓			Refer to section 3.5.3
Two- way bicycle track	✓			Refer to section 3.5.3
Bicycle intersection treatment			✓(B)(C)	**Refer to section 3.5.4**
Bicycle box	✓			Refer to section 3.5.4
Intersection crossing			✓(B)	Refer to section 3.5.4
Median Refuge island	✓			Refer to section 3.5.4
Combined bicycle-lane/ turn-lane			✓(C)	Refer to section 3.5.4
Bicycle track intersection approaches	✓			Refer to section 3.5.4
Bicycle signals	✓			**Refer to section 3.5.5**
Bicycle signal heads	✓			Refer to section 3.5.5
Bicycle detection signals	✓			Refer to section 3.5.5

Elements	Not visible in space	Visible to some extent	Best practice	Cross reference
Hybrid signals	✓			Refer to section 3.5.5
Bicycle signage and markings			✓(B)(C)	**Refer to section 3.5.6**
Bicycle route way- finding	✓			Refer to section 3.5.6
Coloured bicycle spaces	✓			Refer to section 3.5.6
Shared- lane markings (Sharrows)			✓(B)(C)	Refer to section 3.5.6
Bicycle parking facilities			✓(A)(C)	**Refer to section 3.5.7**
Sidewalk bicycle racks			✓(A)(C)	Refer to section 3.5.7
On- street bicycle corrals	✓			Refer to section 3.5.7
Bicycle lockers	✓			Refer to section 3.5.7
Speed Maintenance (cycling topography)			✓(A)(B)(C)	**Refer to section 3.6.4**
Bicycle- friendly operating- space			✓(A)(B)(C)	**Refer to section 3.6.1**
Clear cycling sight- distances			✓(A)(B)(C)	**Refer to section 3.6.3**
Smooth cycling surfaces			✓(A)(B)(C)	**Refer to section 3.6.2**
Efficient lighting for cycling		✓(C)		**Refer to section 3.4.2**

Source: Own creation (2017).

Based on the Copenhagen case study the following best practices could be identified to guide future planning of bicycle- friendly spaces:

- A: Bicycle track- One- way protected bicycle track
  Bicycle parking facilities- Sidewalk bicycle racks
  Speed Maintenance
  Bicycle- friendly operating space
  Clear cycling sight distance
  Smooth cycling surfaces

- B: Bicycle lane- Basic bicycle lane
  Bicycle track- One- way protected bicycle track
  Bicycle intersection treatment- Intersection crossing
  Bicycle signage and markings- Shared lane markings (Sharrows)
  Speed Maintenance
  Bicycle- friendly operating space
  Clear cycling sight distance
  Smooth cycling surfaces

- C: Bicycle track- One- way protected bicycle track
  Bicycle- intersection treatment- Combined bicycle-lane/ turn- lane
  Bicycle signage and markings- Shared lane markings (Sharrows)
  Bicycle parking facilities- Sidewalk bicycle racks
  Speed Maintenance
  Bicycle- friendly operating space
  Clear cycling sight distance
  Smooth cycling surfaces

5.3 Local case study analysis

The local case study analysis of this research focused on Johannesburg and Cape Town. According to Brightrock (2014), Cape Town and Johannesburg are on the rise of becoming bicycle-friendly cities in South Africa. Cape Town has shown its dedication towards developing bicycle-lanes, bicycle parking facilities, and other bicycle- friendly spaces (Amen, 2014). The popularity of cycling has also extended to other South African cities, such as the city of Johannesburg (Solés, 2014). Bicycle- lanes in Johannesburg have previously been built in order to encourage a cycling culture in the city (Morgan, 2017), but according to Davie (2013), Cape Town is leading in terms of the planning of its bicycle- friendly spaces in South Africa.

The National Household Travel Survey (NHTS) survey of 2013 found that the modal share of cycling in South Africa is 1.3% (Mervis, 2014). This survey is, however, not focussed on cycling only. Mervis (2014) mentioned that there are other cycling data available that may access the needs and challenges of cycling in South Africa (Mervis, 2014). For example, Strava has an extensive cycling data set that could be used for planning bicycle- friendly spaces in South Africa. Figure 5-12 shows the spatial pattern of South Africa's cycling activities as obtained through Strava data, as well as the locations of Johannesburg and Cape Town within this data set.

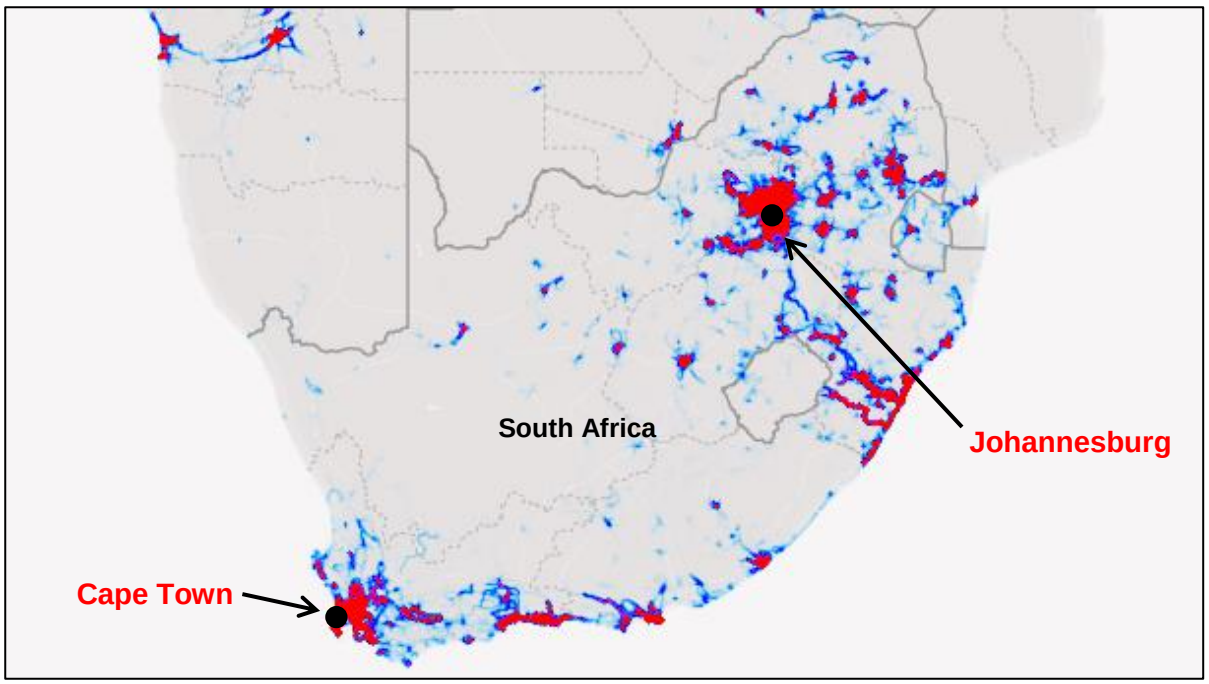


Figure 5-12: The spatial pattern of South Africa's cycling activities.
Source: Strava Labs (2017).

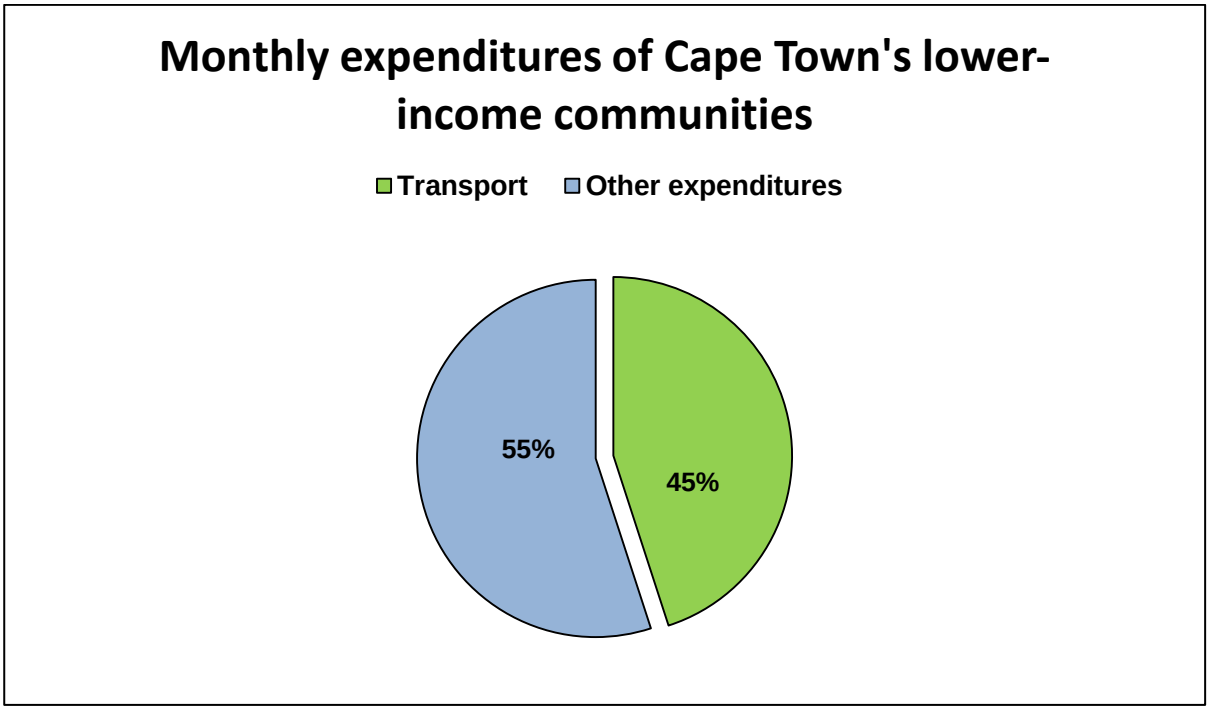
5.3.1 Cape Town (South Africa) local case study

Cape Town has a metropolitan population of 3.74 million people (World Population Review, 2017), and is one of the most bicycle- friendly cities in South Africa (City of Cape Town, 2017). In this section, Cape Town will be evaluated based on the city's bicycle- friendly planning approaches and vision to develop bicycle- friendly spaces. Figure 5-13 shows the location of Cape Town, South Africa.

Figure 5-13: The location of Cape Town, South Africa.
Source: Own creation based on Geology.com (2017).

Cape Town is one of South Africa's most bicycle- friendly cities (Dickinson, 2014) and is furthermore considered as one of the 15 best bicycle- friendly cities in the world (Brand South Africa, 2011). Cycling in Cape Town is an urban lifestyle and a healthy fashion that encourages more individuals to cycle daily (Solés, 2014). NMT and cycling are important aspects of Cape Town's vision to provide integrated public transport connections across the city (Davie, 2013).

Cape Town is also one of the few cities in South Africa that has a 'bicycle master plan' (City of Cape Town, 2017). This plan involves a long- term aim of developing bicycle- friendly spaces in the city bowl and the suburbs of Cape Town (Davie, 2013). The city has already developed 435 kilometres of bicycle- lanes and has a new intervention to colourise its bicycle- lanes to clearly indicate the cycling routes and the presence of cyclists to motorised vehicle users (City of Cape Town, 2017). Cape Town has also developed separated and high-quality bicycle tracks. According to Davie (2013), the city believes that the development of bicycle- friendly spaces will ensure safer cycling environments in the city (Davie, 2013). Chambers (2017) found that lower- income communities in Cape Town spend up to 45% of their monthly income on transport. Chambers (2017) further suggests that cycling could be an affordable transport alternative, provided that Cape Town improves cycling accessibility in these communities. Graph 5-3 shows the monthly transport expenditures of Cape Town's lower- income communities.



Graph 5-3: Transport expenditure of Cape Town's lower- income communities.
Source: Own creation (2017) based on the findings of Chambers (2017).

Cape Town will continue to encourage NMT with the development of additional bicycle- friendly spaces (Mervis, 2014). It is thus evident that cycling plays a significant role in Cape Town's planning approaches and vision to develop bicycle- friendly spaces. For purposes of this research, the cycling patterns of Cape Town was studied (5.3.1.1) to identify preferred cycling routes within the city and the related planning and design elements of these routes (5.3.1.2), to further inform best practices relating to the planning of bicycle- friendly spaces (5.3.1.3).

5.3.1.1 Cape Town's cycling patterns

In this section, a heat map of Cape Town's cycling patterns will be studied in order to identify the Cape Town's preferred cycling streets/ routes. Figure 5-14 illustrates the cycling patterns of Cape Town as obtained through Strava data.

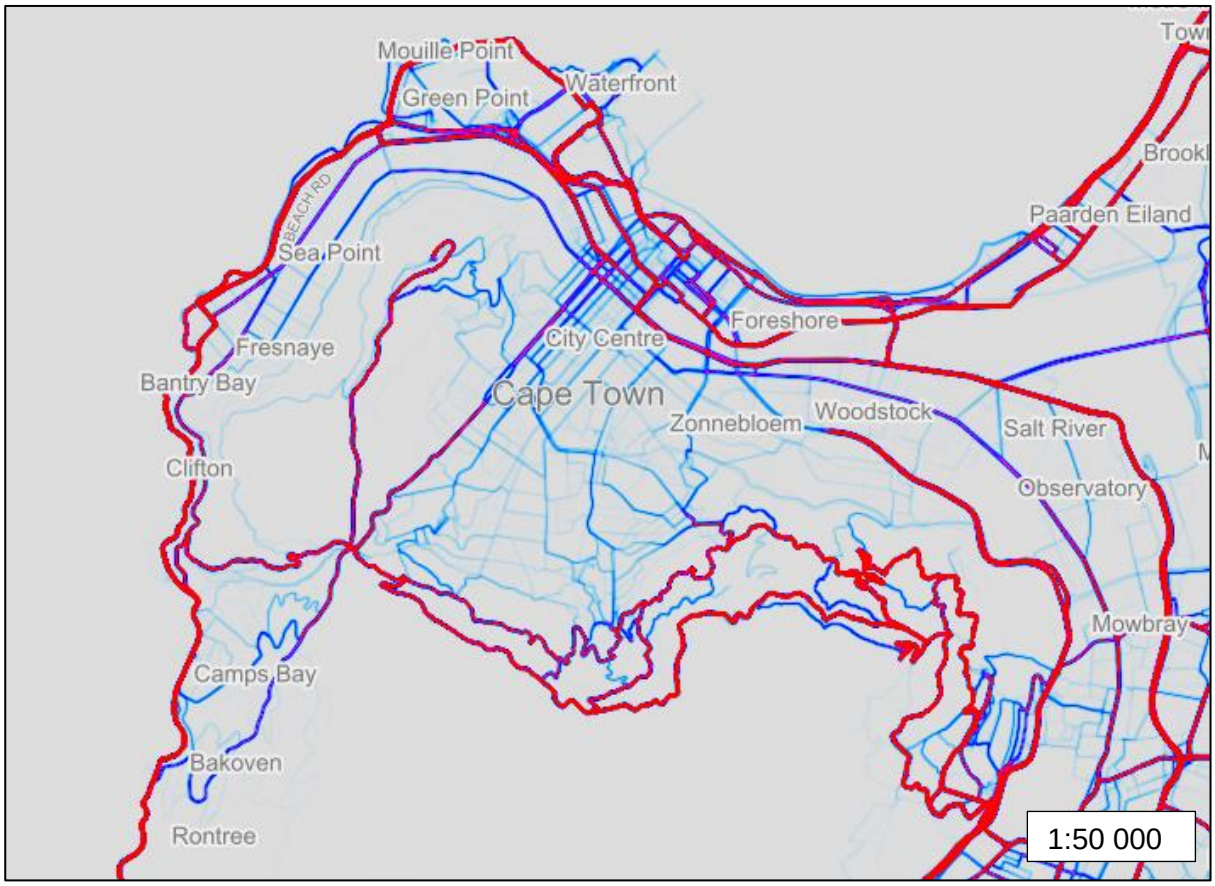


Figure 5-14: Heat map of Cape Town's cycling patterns as obtained through Strava data. Source: Strava Labs (2017).

In order to identify Cape Town's most prevalent cycling patterns and ultimately draw conclusions regarding the preferred cycling routes and bicycle- friendly spaces within the CBD area, a simplified heat map were considered, as illustrated in Figure 5-15.

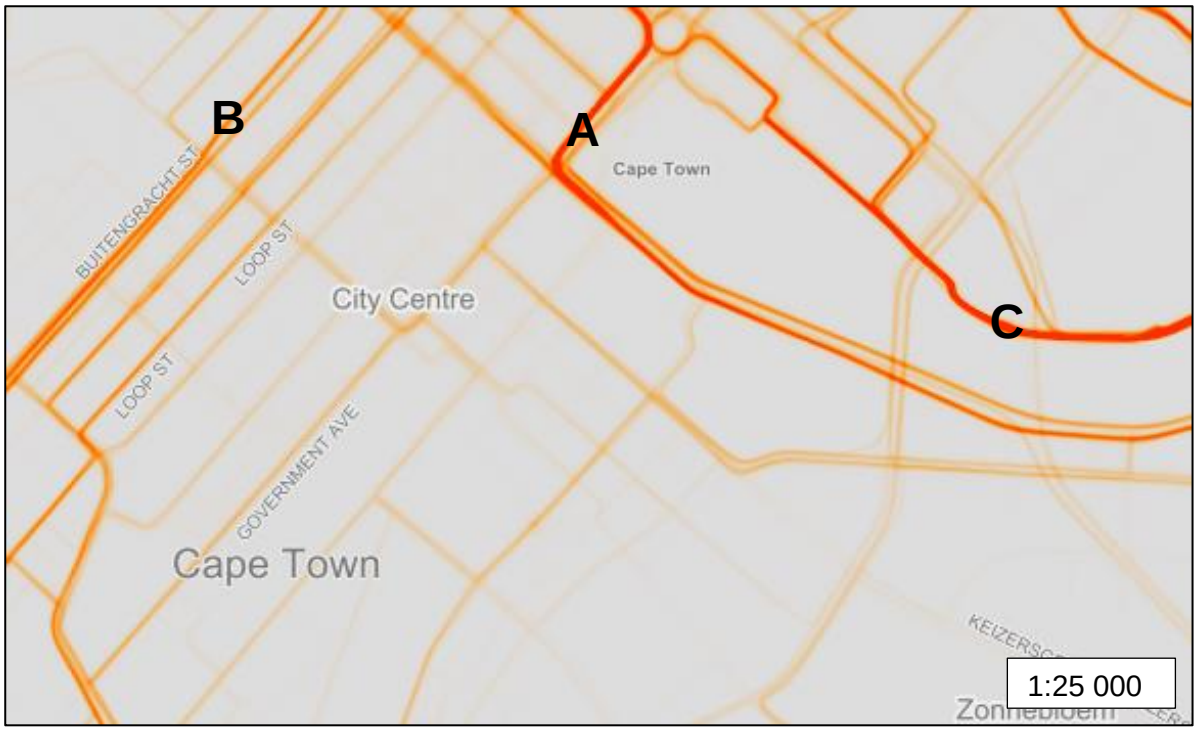


Figure 5-15: A simplified heat map of Cape Town's most prevalent cycling patterns as obtained through Strava data.
Source: Strava Labs (2017).

Figure 5-15 illustrates Cape Town's most prevalent cycling patterns. According to Google Maps (2017), these cycling patterns are recognised by the following streets in Cape Town, as indicated alphabetically on Figure 5-15:

- A: Adderley Street
- B: Buitengracht Street
- C: Old Marine Drive

Accordingly a visual analysis informed by Google Street View was used to analyse these streets and draw conclusions in terms of user preferences and specific design elements present in these areas.

5.3.1.2 Cape Town's user (cyclist) preferences

The previous section identified the cycling patterns of Cape Town as obtained through Strava data. This section will identify Cape Town's user preferences through a Google street view analysis in order to draw conclusions relating to the bicycle- friendly spaces used for each aforementioned cycling street. Table 5-5 captures the visual analysis and Cape Town's user preferences as informed by Google street view.

Table 5-5: Cape Town's user preferences

Bicycle- friendly spaces visual analysis	Identified user preferences
A: Adderley street	
	➢ Bicycle track ➢ Raised bicycle track ➢ Bicycle- friendly operating space ➢ Smooth cycling surfaces ➢ Comfortable cycling topography ➢ Clear sight distances ➢ Efficient lighting for cycling
B: Buitengracht Street	
	➢ Bicycle- friendly operating space ➢ Smooth cycling surfaces ➢ Comfortable cycling topography ➢ Clear sight distances

Bicycle- friendly spaces visual analysis	Identified user preferences
C: Old Marine Drive	
	➢ Bicycle track ➢ One- way protected bicycle track ➢ Raised bicycle track ➢ Bicycle- friendly operating space ➢ Smooth cycling surfaces ➢ Comfortable cycling topography ➢ Clear sight distances ➢ Bicycle signage and markings ➢ Bicycle route way- finding ➢ Shared- lane markings ➢ Efficient lighting for cycling
	➢ Bicycle track ➢ Two- way bicycle track ➢ Raised bicycle track ➢ Bicycle- friendly operating space ➢ Clear sight distances ➢ Smooth cycling surfaces ➢ Comfortable cycling topography
	➢ Bicycle track ➢ Two- way bicycle track ➢ Bicycle- friendly operating space ➢ Smooth cycling surfaces ➢ Comfortable cycling topography ➢ Clear sight distances ➢ Bicycle signage and markings ➢ Bicycle route way- finding

Source: Own creation (2017) based on Google Maps street view (2017).

Table 5-5 captured Cape Town's user preferences through a Google street view analysis. Accordingly these areas were evaluated in terms of the theory based selection of identified design elements (Table 3-11), complied as a checklist approach with ranking system. Such were used to

inform on the best practices relating to the planning of bicycle- friendly spaces, as evident from the Cape Town case study.

5.3.1.3 Best practice identification of Cape Town's bicycle- friendly spaces

Table 5-6 illustrates the evaluation of the spaces (streets) included in the Cape Town case study in terms of the theory based selection and identified design elements.

Table 5-6: Best practice identification of Cape Town's bicycle- friendly spaces

Elements	Not visible in space	Visible to some extent	Best practice	Cross reference
Bicycle- lanes	✓			**Refer to section 3.5.1**
Basic bicycle lane	✓			Refer to section 3.5.1
Buffered bicycle lane	✓			Refer to section 3.5.1
Contra- flow bicycle lane	✓			Refer to section 3.5.1
Bicycle lane on one-way street	✓			Refer to section 3.5.1
Bicycle Boulevards	✓			**Refer to section 3.5.2**
Bicycle tracks			✓(A)(C)	**Refer to section 3.5.3**
One- way protected bicycle track			✓(C)	Refer to section 3.5.3
Raised bicycle track			✓(A)(C)	Refer to section 3.5.3
Two- way bicycle track			✓(C)	Refer to section 3.5.3
Bicycle intersection treatment	✓			**Refer to section 3.5.4**
Bicycle box	✓			Refer to section 3.5.4
Intersection crossing	✓			Refer to section 3.5.4
Median Refuge island	✓			Refer to section 3.5.4
Combined bicycle-lane/ turn-lane	✓			Refer to section 3.5.4
Bicycle track intersection approaches	✓			Refer to section 3.5.4
Bicycle signals	✓			**Refer to section 3.5.5**
Bicycle signal heads	✓			Refer to section 3.5.5
Bicycle detection signals	✓			Refer to section 3.5.5
Hybrid signals	✓			Refer to section 3.5.5
Bicycle signage and markings		✓(C)		**Refer to section 3.5.6**
Bicycle route way- finding		✓(C)		Refer to section 3.5.6
Coloured bicycle spaces	✓			Refer to section 3.5.6

Elements	Not visible in space	Visible to some extent	Best practice	Cross reference
Shared- lane markings (Sharrows)		✓(C)		Refer to section 3.5.6
Bicycle parking facilities				**Refer to section 3.5.7**
Sidewalk bicycle racks	✓			Refer to section 3.5.7
On- street bicycle corrals	✓			Refer to section 3.5.7
Bicycle lockers	✓			Refer to section 3.5.7
Speed Maintenance (cycling topography)		✓(B)	✓(A)(C)	**Refer to section 3.6.4**
Bicycle- friendly operating- space			✓(A)(B)(C)	**Refer to section 3.6.1**
Clear cycling sight- distances			✓(A)(B)(C)	**Refer to section 3.6.3**
Smooth cycling surfaces		✓(B)	✓(A)(C)	**Refer to section 3.6.2**
Efficient lighting for cycling		✓(A)(B)(C)		**Refer to section 3.4.2**

Source: Own creation (2017).

Based on the Cape Town case study the following best practices could be identified to guide future planning of bicycle- friendly spaces:

- A: Bicycle track- Raised bicycle track
  Speed Maintenance
  Bicycle- friendly operating space
  Clear cycling sight distance
  Smooth cycling surfaces

- B: Bicycle- friendly operating space
  Clear cycling sight distance

- C: Bicycle tracks- One- way protected; Raised bicycle track; Two- way bicycle track
  Speed Maintenance
  Bicycle- friendly operating space
  Clear cycling sight distance
  Smooth cycling surfaces

5.3.2 Johannesburg (South Africa) local case study

Johannesburg has an estimated population of 4.4 million (World Population Review, 2017), and has a growing interest in planning bicycle- friendly spaces across the city (Leveque, 2014). In this section, Johannesburg will be evaluated based on the city's bicycle- friendly planning approaches and vision to develop bicycle- friendly spaces. Figure 5-16 shows the location of Johannesburg, South Africa.

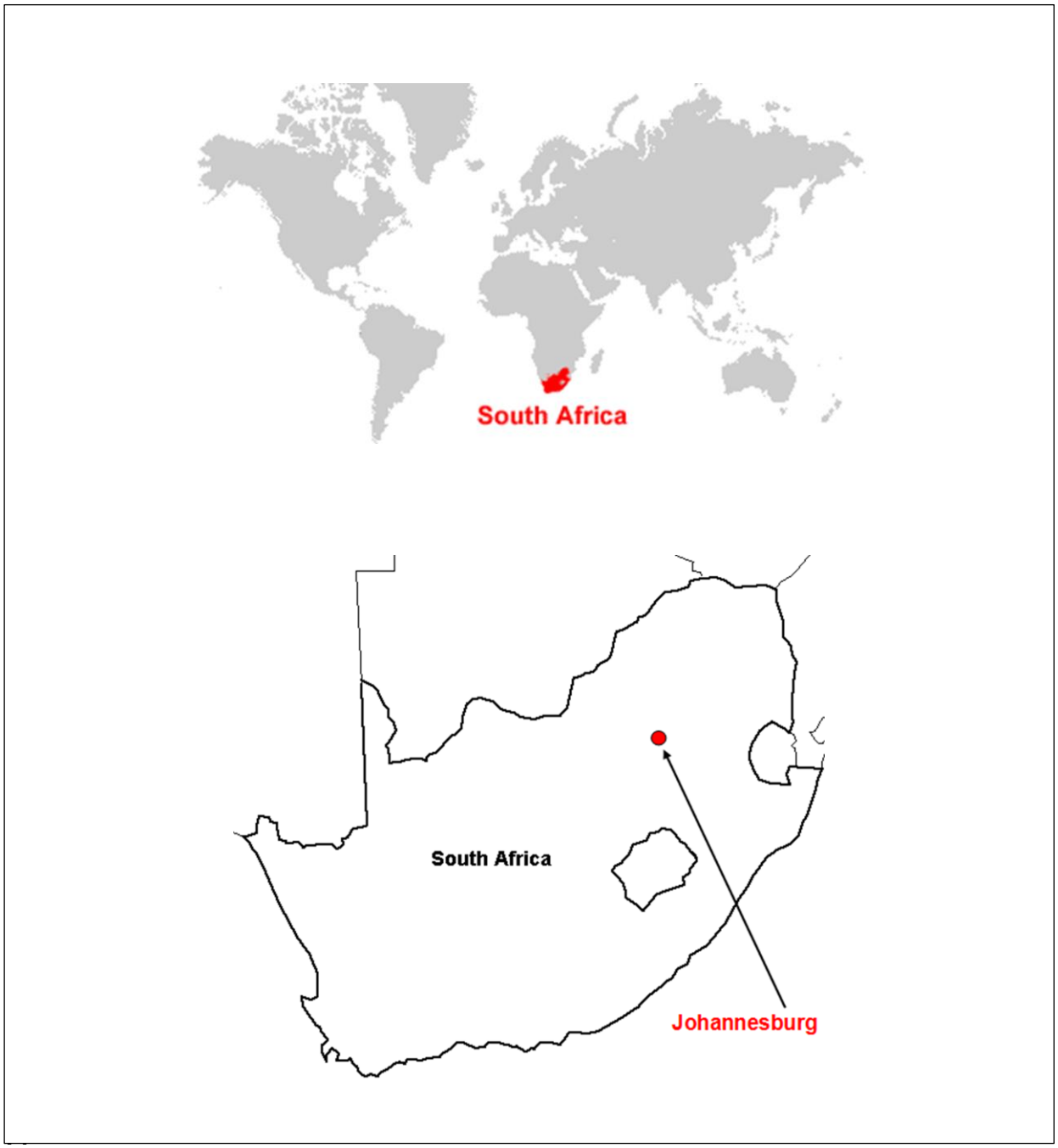


Figure 5-16: The location of Johannesburg, South Africa.

Source: Own creation (2017) based on Geology.com (2017).

Johannesburg is steadily developing into a bicycle- friendly city and has started to implement safe bicycle- friendly spaces across the city (Gauteng Tourism Authority, 2014). These bicycle-friendly spaces include the implementation of separated bicycle- lanes, signage and lighting. The city is also investing in upgraded lighting and CCTV to ensure safer cycling (Gauteng Tourism Authority, 2014).

The development of bicycle- friendly spaces in Johannesburg is intended to envision a commuter cycling culture. Subsequently, raising awareness of the undesirable economic, social, health and, environmental concerns of private- motorised vehicle dependency in the city (City of Johannesburg 2009). The city of Johannesburg has announced a number of strategies for developing bicycle-lanes dedicated to commuters (Leveque, 2014). For example, the Johannesburg Urban Cyclists Association (JUCA) has developed a cycling commuter map that shows roughly 100 kilometres of safer cycling routes (Leveque, 2014). JUCA promotes and defends cycling as a daily urban transport solution for the city of Johannesburg (JUCA, 2017). By following an active policy agenda, Johannesburg has shown great dedication in finding ways to introduce cycling as an alternative transport mode (Glenting, 2017).

For purposes of this research, the cycling patterns of Johannesburg was studied (5.3.2.1) to identify preferred cycling routes within the city and the related planning and design elements of these routes (5.3.2.2), to further inform best practices relating to the planning of bicycle- friendly spaces (5.3.2.3).

5.3.2.1 Johannesburg's cycling patterns

In this section, a heat map of Johannesburg's cycling patterns will be studied in order to identify the Johannesburg's preferred cycling streets/ routes. Figure 5-17 illustrates the cycling patterns of Johannesburg as obtained through Strava data.

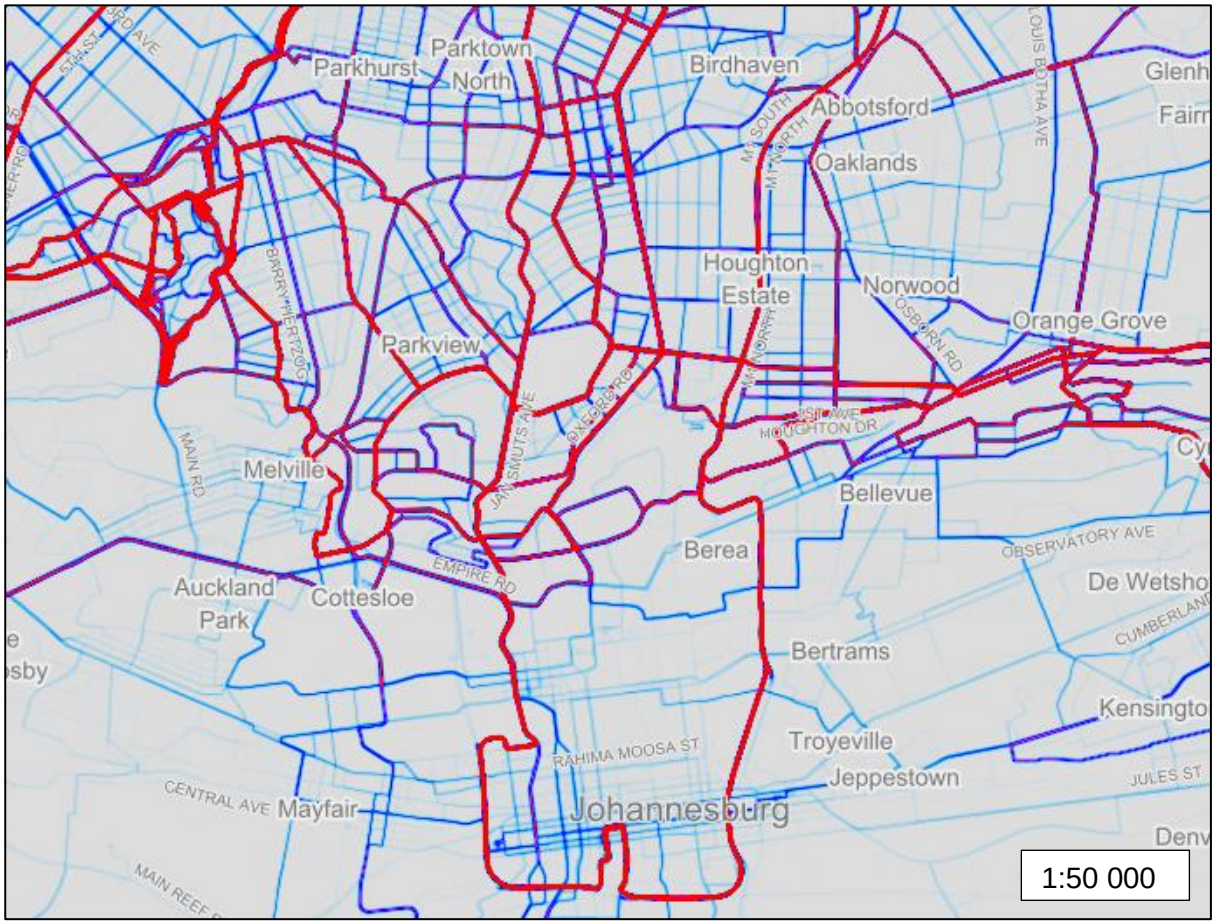


Figure 5-17: Heat map of Johannesburg's cycling patterns as obtained through Strava data. Source: Strava Labs (2017).

In order to identify Johannesburg's most prevalent cycling patterns and ultimately draw conclusions regarding the preferred cycling routes and bicycle- friendly spaces within the CBD area, a simplified heat map were considered, as illustrated in Figure 5-18.

Figure 5-18: A simplified heat map of Johannesburg's most prevalent cycling patterns as obtained through Strava data.
Source: Strava Labs (2017).

Figure 5-18 illustrates Johannesburg's most prevalent cycling patterns. According to Google Maps (2017), these cycling patterns are recognised by the following streets in Johannesburg, as indicated alphabetically on Figure 5-18:

- A: Francois Oberholzer Fwy
- B: Rissik Street
- C: Joe Slovo Drive

Accordingly a visual analysis informed by Google Street View was used to analyse these streets and draw conclusions in terms of user preferences and specific design elements present in these areas.

5.3.2.2 Johannesburg's user (cyclist) preferences

The previous section identified the cycling patterns of Johannesburg as obtained through Strava data. This section will identify Johannesburg's user preferences through a Google street view analysis in order to draw conclusions relating to the bicycle- friendly spaces used for each aforementioned cycling street. Table 5-7 captures the visual analysis and Johannesburg's user preferences as informed by Google street view.

Table 5-7: Johannesburg's user preferences

Bicycle- friendly spaces visual analysis	Identified user preferences
A: Francois Oberholzer Fwy	
	➢ Efficient lighting for cycling ➢ Clear sight distances
B: Rissik Street	
	➢ Efficient lighting for cycling ➢ Clear sight distances ➢ Smooth cycling surfaces

Bicycle- friendly spaces visual analysis	Identified user preferences
C: Joe Slovo Drive	
	➢ Efficient lighting for cycling ➢ Clear sight distances

Source: Own creation (2017) based on Google Maps street view (2017).

Table 5-7 captured Johannesburg's user preferences through a Google street view analysis. As seen in Table 5-7, there is a lack of bicycle- friendly spaces identified in the CBD of Johannesburg in contrast to the amount of bicycle- friendly spaces identified in Amsterdam, Copenhagen, and Cape Town.

The prevalent cycling patterns (Strava heat map) of Johannesburg's CBD are, however, data collected from the Telkom 94.7 cycle challenge. The Telkom 94.7 cycle challenge is the world's second-largest timed cycle race that is held annually, on the third Sunday of November in the city of Johannesburg. This cycle race thus gathers thousands of Strava data points each year that has a significant impact on the Strava heat map of Johannesburg. For the purposes of this research study, the identified routes of Johannesburg's most prevalent cycling patterns could not be used, since date does not reflect the daily usage patterns but were skewed due to an annual event.

As such, another set of routes were identified on the Strava heatmap. The following Figure 5-18 shows a heat map of Johannesburg's most prevalent cycling patterns in the CBD area as obtained through Strava data. The identified routes/ streets on the heat map of Figure 5-18 will overlook the data gathered from the Telkom 94.7 cycle race in Johannesburg. In order to identify Johannesburg's most prevalent cycling patterns and ultimately draw conclusions regarding the preferred cycling routes and bicycle- friendly spaces within the CBD area, a simplified heat map were considered, as illustrated in Figure 5-19.

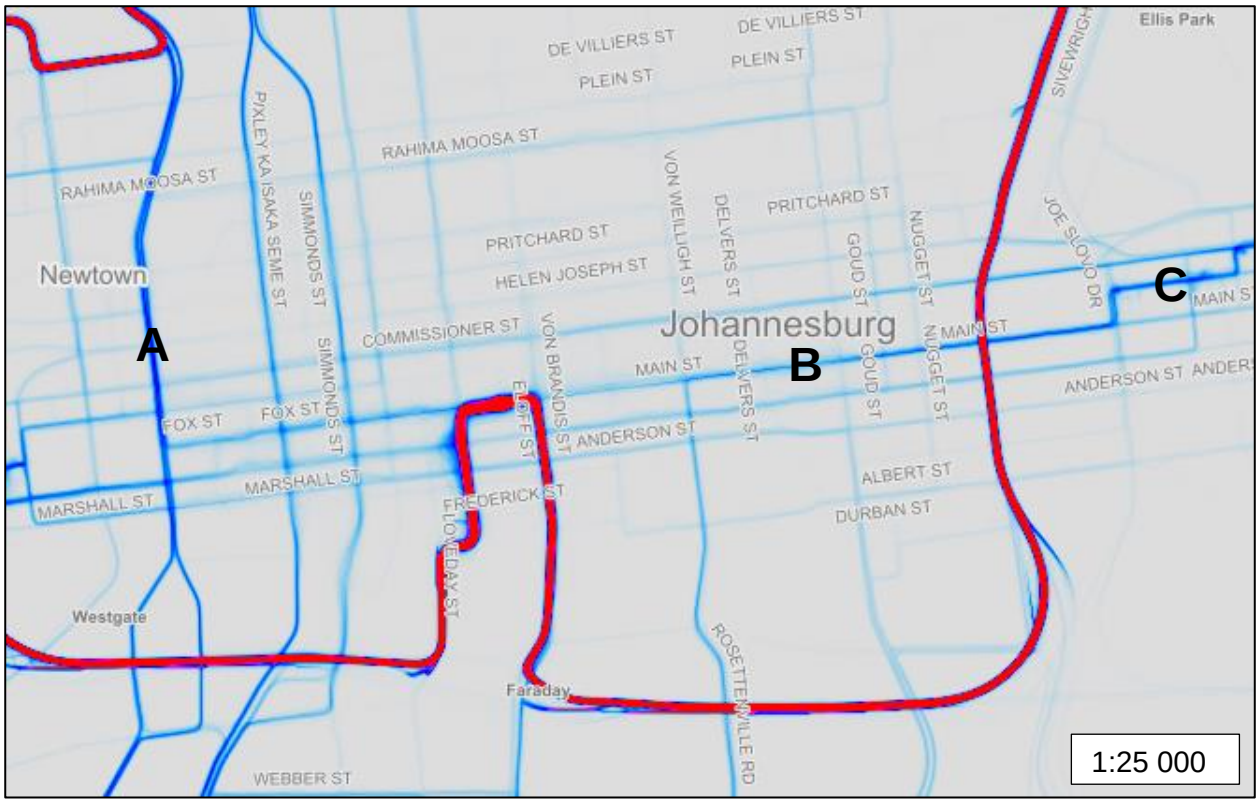


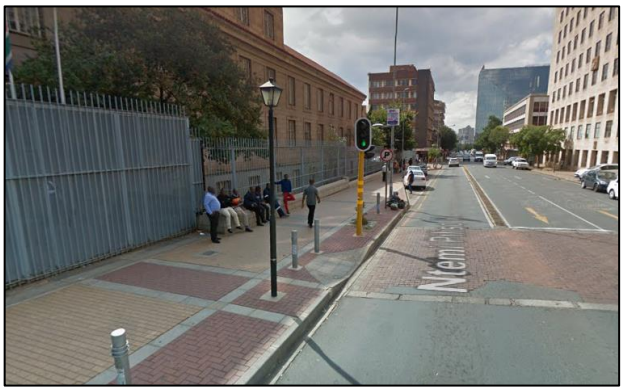
Figure 5-19: A heat map of Johannesburg's most prevalent cycling patterns as obtained through Strava data.
Source: Strava Labs (2017).

Figure 5-19 illustrates Johannesburg's most prevalent cycling patterns. According to Google Maps (2017), these cycling patterns are recognised by the following streets in Johannesburg, as indicated alphabetically on Figure 5-19:

- A: Ntemi Piliso Street
- B: Main Street
- C: Fox Street

Accordingly a visual analysis informed by Google Street View was used to analyse these streets and draw conclusions in terms of user preferences and specific design elements present in these areas. Table 5-8 captures the visual analysis and Johannesburg's user preferences as informed by Google street view.

Table 5-8: Johannesburg's user (cyclist) preferences

Bicycle- friendly spaces visual analysis	Identified user preferences
A: Ntemi Piliso Street	
	➢ Efficient lighting for cycling ➢ Clear sight distances ➢ Smooth cycling surfaces ➢ Comfortable cycling topography ➢ Bicycle intersection treatment ➢ Intersection crossing ➢ Bicycle signage and markings ➢ Coloured bicycle spaces ➢ Bicycle track ➢ One- way protected bicycle track
B: Main Street	
	➢ Clear sight distances ➢ Smooth cycling surfaces ➢ Comfortable cycling topography
C: Fox Street	
	➢ Efficient lighting for cycling ➢ Clear sight distances ➢ Smooth cycling surfaces ➢ Comfortable cycling topography ➢ Bicycle track ➢ One- way protected bicycle track

Source: Own creation (2017) based on Google Maps street view (2017).

Table 5-8 captured Johannesburg's user preferences through a Google street view analysis. Accordingly these areas were evaluated in terms of the theory based selection of identified design elements (Table 3-11), complied as a checklist approach with ranking system. Such were used to inform on the best practices relating to the planning of bicycle- friendly spaces, as evident from the Johannesburg case study.

5.3.2.3 Best practice identification of Johannesburg's bicycle- friendly spaces

Table 5-9 illustrates the evaluation of the spaces (streets) included in the Johannesburg case study in terms of the theory based selection and identified design elements.

Table 5-9: Best practice identification of Johannesburg's bicycle- friendly spaces

Elements	Not visible in space	Visible to some extent	Best practice	Cross reference
Bicycle- lanes	✓			**Refer to section 3.5.1**
Basic bicycle lane	✓			Refer to section 3.5.1
Buffered bicycle lane	✓			Refer to section 3.5.1
Contra- flow bicycle lane	✓			Refer to section 3.5.1
Bicycle lane on one-way street	✓			Refer to section 3.5.1
Bicycle Boulevards	✓			**Refer to section 3.5.2**
Bicycle tracks			✓(A)(C)	**Refer to section 3.5.3**
One- way protected bicycle track			✓(A)(C)	Refer to section 3.5.3
Raised bicycle track	✓			Refer to section 3.5.3
Two- way bicycle track	✓			Refer to section 3.5.3
Bicycle intersection treatment			✓(A)	**Refer to section 3.5.4**
Bicycle box	✓			Refer to section 3.5.4
Intersection crossing			✓(A)	Refer to section 3.5.4
Median Refuge island	✓			Refer to section 3.5.4
Combined bicycle-lane/ turn- lane	✓			Refer to section 3.5.4
Bicycle track intersection approaches	✓			Refer to section 3.5.4
Bicycle signals	✓			**Refer to section 3.5.5**
Bicycle signal heads	✓			Refer to section 3.5.5
Bicycle detection signals	✓			Refer to section 3.5.5
Hybrid signals	✓			Refer to section 3.5.5

Elements	Not visible in space	Visible to some extent	Best practice	Cross reference
Bicycle signage and markings			✓(A)	**Refer to section 3.5.6**
Bicycle route way- finding	✓			Refer to section 3.5.6
Coloured bicycle spaces			✓(A)	Refer to section 3.5.6
Shared- lane markings (Sharrows)	✓			Refer to section 3.5.6
Bicycle parking facilities	✓			**Refer to section 3.5.7**
Sidewalk bicycle racks	✓			Refer to section 3.5.7
On- street bicycle corrals	✓			Refer to section 3.5.7
Bicycle lockers	✓			Refer to section 3.5.7
Speed Maintenance (cycling topography)			✓(A)(B)(C)	**Refer to section 3.6.4**
Bicycle- friendly operating- space		✓(B)	✓(A)(C)	**Refer to section 3.6.1**
Clear cycling sight- distances			✓(A)(B)(C)	**Refer to section 3.6.3**
Smooth cycling surfaces		✓(B)	✓(A)(C)	**Refer to section 3.6.2**
Efficient lighting for cycling		✓(A)		**Refer to section 3.4.2**

Source: Own creation (2017).

Based on the Johannesburg case study the following best practices could be identified to guide future planning of bicycle- friendly spaces:

- A: Bicycle track- One- way protected bicycle track
  Bicycle intersection treatment- Intersection crossing
  Bicycle signage and markings- Coloured bicycle spaces
  Speed Maintenance
  Bicycle- friendly operating space
  Clear cycling sight distance
  Smooth cycling surfaces

- B: Speed Maintenance
  Bicycle- friendly operating space
  Clear cycling sight distance
  Smooth cycling surfaces

- C: Bicycle track- One- way protected bicycle track
  Speed Maintenance
  Bicycle- friendly operating space
  Clear cycling sight distance
  Smooth cycling surfaces

5.4 Conclusion

This section aimed to draw conclusions based on the findings of the empirical research conducted from Chapter 5. These conclusions informed recommendations for considering bicycle- friendly design elements to enhance the planning of bicycle- friendly spaces within the Potchefstroom case study and other relevant local areas of South Africa.

5.4.1 Comparative analysis of international and local case studies

From the research conducted in this chapter, it is evident that both the international and local case studies have proven to be admirable bicycle- friendly cities in their respective countries, based on their current bicycle- friendly spaces and usage thereof by a diversity of communities. A comparison was made on the different bicycle- friendly elements identified for both the international and local case studies, as seen in Table 5-10, to capture the frequency of usage of such within these case studies.

Table 5-10: Bicycle- friendly elements identified for both international and local case studies

Elements	International case studies (Amsterdam & Copenhagen)	Local case studies (Johannesburg & Cape Town)
Bicycle- lanes	1	0
Bicycle Boulevards	2	0
Bicycle tracks	4	6
Bicycle intersection treatment	2	1
Bicycle signals	0	0
Bicycle signage and markings	4	1
Bicycle parking facilities	5	0
Speed Maintenance (cycling topography)	6	5
Bicycle- friendly operating-space	6	5
Clear cycling sight- distances	6	6
Smooth cycling surfaces	6	4
Efficient lighting for cycling	0	0
Number of bicycle- friendly elements	**42**	**28**

Source: Own creation (2017)

Table 5-10 illustrated that both international and local case studies employed various bicycle-friendly elements identified for their respective preferred cycling routes, as obtained through Strava data. However, the international case studies illustrated a greater number of bicycle- friendly elements (42) compared to the number of bicycle- friendly elements (28) identified by the local case studies. Considering the statement that Copenhagen and Amsterdam are world leaders in supporting the development of bicycle- friendly spaces (refer to 5.2) might be reason why these figures are higher in the international cases. It might also indicate a further opportunity for local areas to explore more of these design guidelines and include such in the planning of future spaces, and to implement and promote NMT as an alternative transport option (refer to 2.4).

5.4.2 Identification of best practices

Table 5-11 captures the identified best practice for planning bicycle- friendly spaces, derived from the findings of Chapter 5. These conclusions serve as the basis for an attempt to recommend bicycle- friendly design elements that will enhance the planning of bicycle- friendly spaces within the Potchefstroom case study and local areas of South Africa.

Table 5-11: Best practice for planning bicycle- friendly spaces

Elements	International case studies		Local case studies		Identified best practice for planning bicycle-friendly spaces
	Amsterdam	Copenhagen	Cape Town	Johannesburg	
One- way protected bicycle track		ABC	C	AC	A, B, & C in Copenhagen are identified as the best case study for Bicycle tracks. Accordingly, It is evident that the One- way protected bicycle tracks in these streets contribute towards the bicycle-friendly spaces and prevalent Strava cycling patterns of Copenhagen. C in Cape Town & A, C in Johannesburg are identified as the best case study for Bicycle tracks. Accordingly, It is evident that the One- way protected bicycle tracks in these streets contribute towards the bicycle- friendly spaces and prevalent Strava cycling patterns of Johannesburg and Cape Town.
Intersection crossing		B		A	B in Copenhagen is identified as the best case study for Bicycle intersection treatment. Accordingly, It is evident that the Intersection crossings in Gyldenløvesgade (B) contribute towards the bicycle- friendly spaces and prevalent Strava cycling patterns of Copenhagen. A in Johannesburg is identified as the best case study for Bicycle intersection treatment. Accordingly, It is evident that the Intersection crossings in Ntemi Piliso (A) contribute towards the bicycle- friendly spaces and prevalent Strava cycling patterns of Johannesburg.
Coloured bicycle spaces	B			A	B in Amsterdam is identified as the best case study for Bicycle signage and markings. Accordingly, It is evident that the Coloured bicycle spaces in Prins Hendrikkade (B) contribute towards the bicycle-

Elements	International case studies		Local case studies		Identified best practice for planning bicycle-friendly spaces
	Amsterdam	Copenhagen	Cape Town	Johannesburg	
					friendly spaces and prevalent Strava cycling patterns of Amsterdam. A in Johannesburg is identified as the best case study for Bicycle intersection treatment. Accordingly, It is evident that the Coloured bicycle spaces in Ntemi Piliso (A) contribute towards the bicycle- friendly spaces and prevalent Strava cycling patterns of Johannesburg.
Speed maintenance (cycling topography)	ABC	ABC	AC	ABC	A, B & C in Amsterdam, and A, B & C in Copenhagen are identified as the best case studies for Speed Maintenance (cycling topography). Accordingly, It is evident that Speed Maintenance (cycling topography) in these streets contributes towards the bicycle- friendly spaces and prevalent Strava cycling patterns of Amsterdam and Copenhagen. A & C in Cape Town and A, B & C in Johannesburg are identified as the best case studies for Speed Maintenance (cycling topography). Accordingly, It is evident that Speed Maintenance (cycling topography) in these streets contributes towards the bicycle- friendly spaces and prevalent Strava cycling patterns of Johannesburg and Cape Town.
Bicycle- friendly operating- space	ABC	ABC	ABC	AC	A, B & C in Amsterdam, and A, B & C in Copenhagen are identified as the best case studies for Bicycle- friendly operating- space. Accordingly, It is evident that Bicycle- friendly operating- space in these streets contributes towards the bicycle-friendly spaces and prevalent Strava cycling patterns of Amsterdam and Copenhagen. A, B & C in Cape Town and A & C in Johannesburg are identified as the best case studies for Bicycle-

Elements	International case studies		Local case studies		Identified best practice for planning bicycle-friendly spaces
	Amsterdam	Copenhagen	Cape Town	Johannesburg	
					friendly operating- space. Accordingly, It is evident that Bicycle- friendly operating- space in these streets contributes towards the bicycle- friendly spaces and prevalent Strava cycling patterns of Johannesburg and Cape Town
Clear cycling sight-distances	ABC	ABC	ABC	ABC	A, B & C in Amsterdam, and A, B & C in Copenhagen are identified as the best case studies for Clear cycling sight- distances. Accordingly, It is evident that Clear cycling sight- distances in these streets contribute towards the bicycle- friendly spaces and prevalent Strava cycling patterns of Amsterdam and Copenhagen. A, B & C in Cape Town and A, B & C in Johannesburg are identified as the best case studies for Clear cycling sight- distances. Accordingly, It is evident that Clear cycling sight-distances in these streets contribute towards the bicycle- friendly spaces and prevalent Strava cycling patterns of Johannesburg and Cape Town.
Smooth cycling surfaces	ABC	ABC	AC	AC	A, B & C in Amsterdam, and A, B & C in Copenhagen are identified as the best case studies for Smooth cycling surfaces. Accordingly, It is evident that Smooth cycling surfaces in these streets contribute towards the bicycle- friendly spaces and prevalent Strava cycling patterns of Amsterdam and Copenhagen.

Elements	International case studies		Local case studies		Identified best practice for planning bicycle-friendly spaces
	Amsterdam	Copenhagen	Cape Town	Johannesburg	
					A & C in Cape Town and A & C in Johannesburg are identified as the best case studies for Smooth cycling surfaces. Accordingly, It is evident that Smooth cycling surfaces in these streets contribute towards the bicycle- friendly spaces and prevalent Strava cycling patterns of Johannesburg and Cape Town.

Source: Own creation (2017)

CHAPTER 6: CONTEXTUALISING AND IMPLEMENTING THE FINDINGS OF THE THEORETICAL AND EMPIRICAL INVESTIGATION

Chapter 5 identified best practices in terms of bicycle usage and the design of bicycle- friendly spaces, as applied in the international case studies of Amsterdam and Copenhagen, and local case studies of Cape Town and Johannesburg. Chapter 6 serves as a framework for planning local bicycle- friendly spaces based on the current reality of Potchefstroom. Potchefstroom as case study is evaluated in terms of 1) bicycle usage patterns, utilising Strava data to identify core bicycle routes within the Potchefstroom area and in terms of 2) user (cyclist) preferences.

Chapter 6 attempts to evaluate the local Potchefstroom case study in order to identify opportunities for intervention and provide relevant recommendations to guide the planning of bicycle- friendly spaces for the Potchefstroom area with Strava data substantiation. This chapter considers Strava data as a tool for enhancing the planning of bicycle- friendly spaces, applicable to different urban contexts.

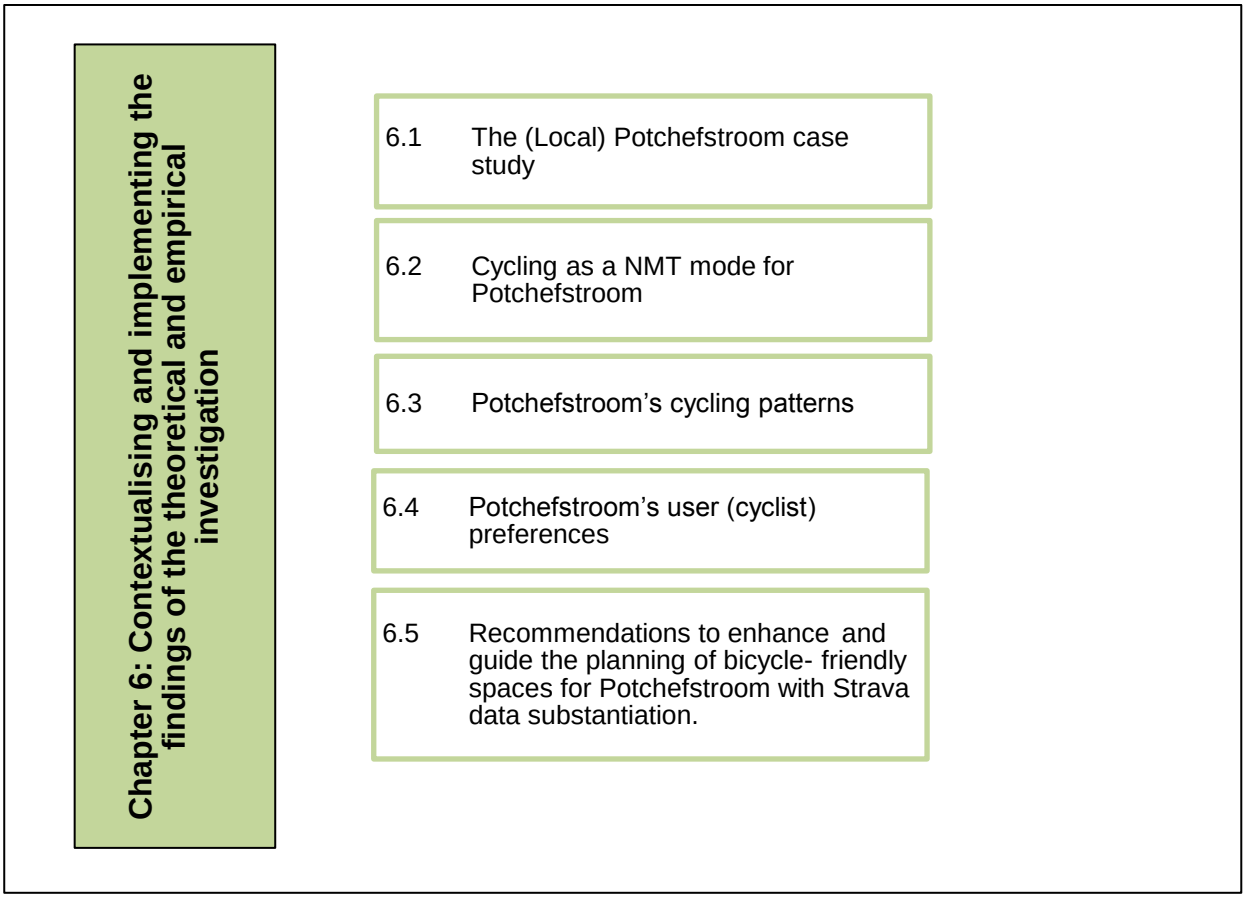


Figure 6-1: Structure of Chapter 6.

Source: Own creation (2017).

6.1 The (Local) Potchefstroom case study

Potchefstroom is located on the N12 corridor in the North West province of South Africa (Schoeman, 2013), and has an estimated population of 123,669 (World Population Review, 2017). Figure 6-2 shows the location of Potchefstroom, South Africa.

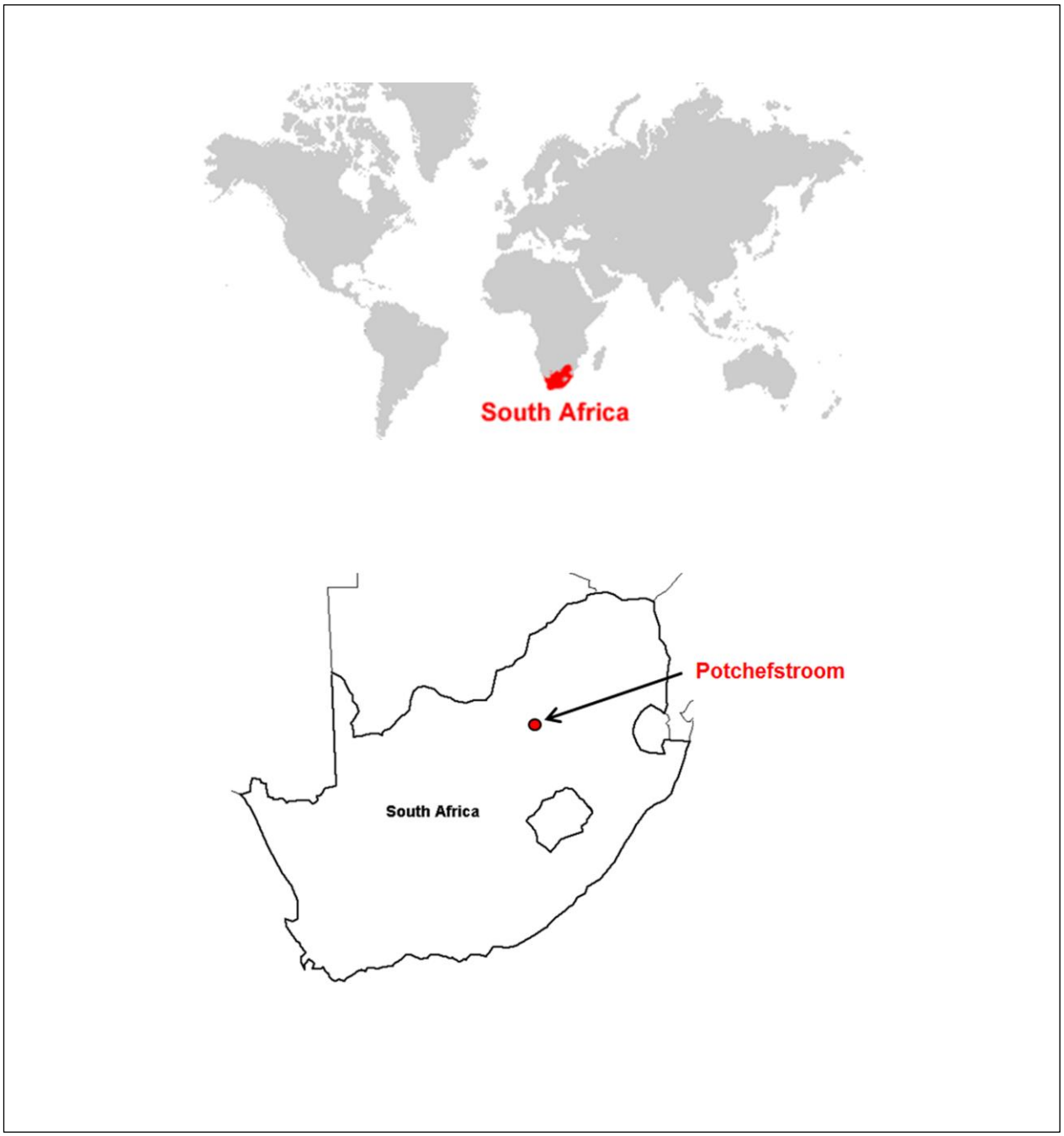


Figure 6-2: The location of Potchefstroom, South Africa.

Source: Own creation (2017) based on Geology.com (2017).

Potchefstroom is considered as the main urban area of the Tlokwe City Council and covers an area of approximately 2500km² (Tlokwe Draft IDP, 2016), and is situated along the Mooi Rivier that runs through the city. Figure 6-3 below illustrates the current spatial status and built form of the Potchefstroom area.

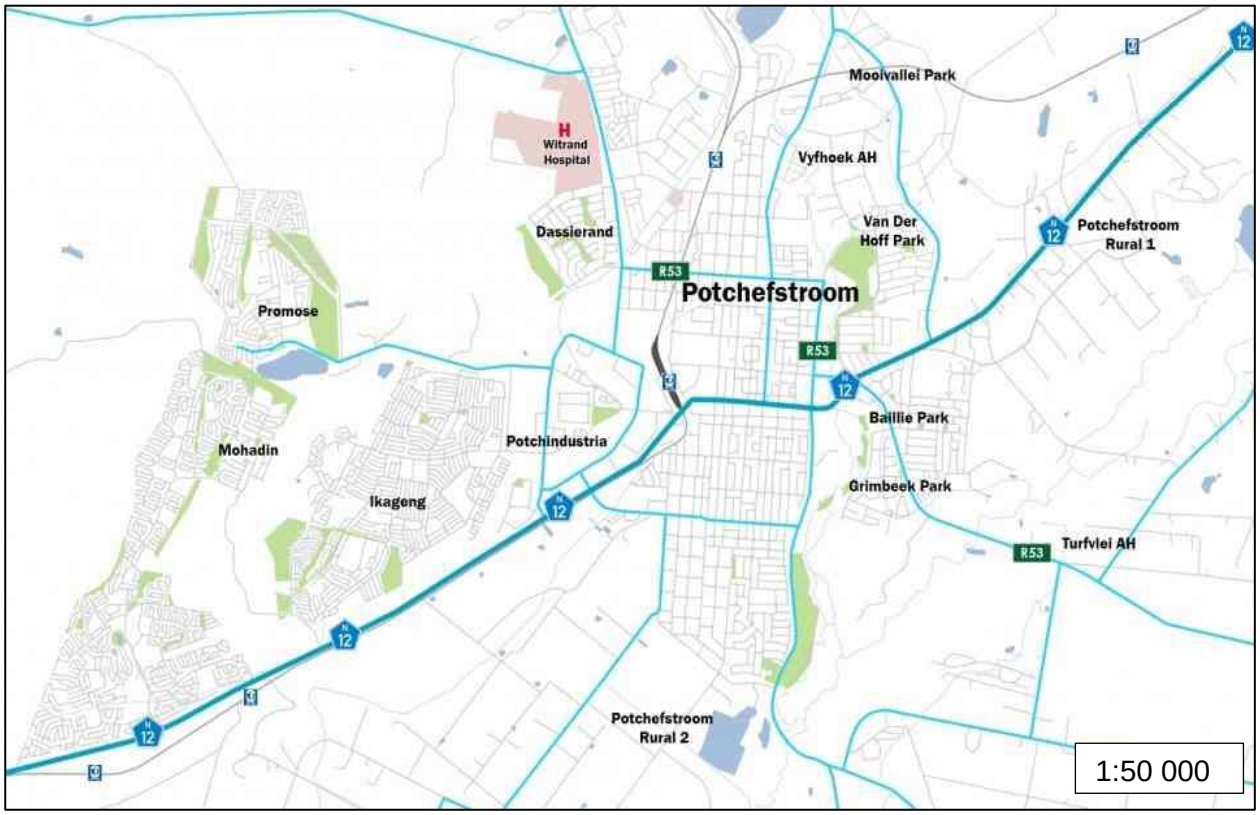


Figure 6-3: The current spatial status and built form of the Potchefstroom area.
Source: HolidayMapQ.com (2017).

Potchefstroom is the primary regional node in the North West Province and is known as an educational centre as it is home to the North West University and major educational schools (Tlokwe IDP, 2013). Accordingly, the city has experienced significant urbanisation and development (Tlokwe IDP, 2013). The population of Potchefstroom has therefore also increased by 34409 individuals in the last 5 years (Tlokwe Draft IDP, 2016).

Potchefstroom is recognised as an area within the North West Province that is facing substantial growth and development pressure (Tlokwe City EMF, 2010). Pressure factors for the city include urban sprawl, urbanisation, a demand for housing, and a backlog in infrastructure provision (Tlokwe City EMF, 2010). Potchefstroom may be considered as a number one priority investment area for the North West Province due to the location of the city and its positive physical attributes.

6.2 Cycling as a NMT mode for Potchefstroom

In 2013, the Tlokwe Municipality identified several transport challenges in Potchefstroom. These challenges manifested in the road transport network, institutional structure, NMT, private transport, freight transport, and land use integration with transport (Tlokwe IDP, 2013). The proposals for these challenges included the connection of roads and the upgrading and developing of interchanges to enhance transport accessibility in the city (Tlokwe IDP, 2013).

The Tlokwe City EMF (2010) mentioned that the potential for Potchefstroom to develop a large intermodal hub in the city should be investigated. With that said, the public transport of Potchefstroom has to be prioritised for mobility of individuals between residential and workplace areas, and for circulation in the CBD. An emphasis should, however, also be placed on the provision of pedestrian and cycling space in the local area of Potchefstroom (Tlokwe City EMF, 2010).

Schoeman & Cilliers (2016) conducted research, transport surveys and desk studies on the current transport reality and transport problems of Potchefstroom in order to ultimately formulate transport solutions for the city of Potchefstroom. The study discovered that there are no bicycle- friendly spaces provided for on the campus or surrounding areas of the North West University in Potchefstroom. Accordingly, it was found that bicycle- friendly spaces should be provided along the tar roads of Potchefstroom (Schoeman & Cilliers, 2016). Table 6-1 below shows the status quo and current reality of bicycle- friendly spaces in Potchefstroom.

Table 6-1: Status quo and current reality of bicycle- friendly spaces in Potchefstroom.

Description	Current reality in Potchefstroom
Bicycle lanes	Not provided for.
Other bicycle- friendly spaces	None

Source: Own creation (2017), based on the findings of Schoeman & Cilliers (2016).

With reference to Table 6-1 it is evident that there is a need for bicycle- friendly spaces in the city of Potchefstroom. This stipulated a need for the formulation of transport objectives and development guidelines for Potchefstroom, specifically with regards to planning bicycle- friendly spaces. Schoeman & Cilliers (2016) recommended that the safety of cyclists in Potchefstroom should be catered for by implementing bicycle lanes and other applicable bicycle- friendly spaces in the city. Potchefstroom's cycling patterns will be studied accordingly.

6.3 Potchefstroom's cycling patterns

In this section, a heat map of Potchefstroom's cycling patterns will be studied in order to identify the Potchefstroom's preferred cycling streets/ routes. Figure 6-4 illustrates the cycling patterns of Potchefstroom as obtained through Strava data.

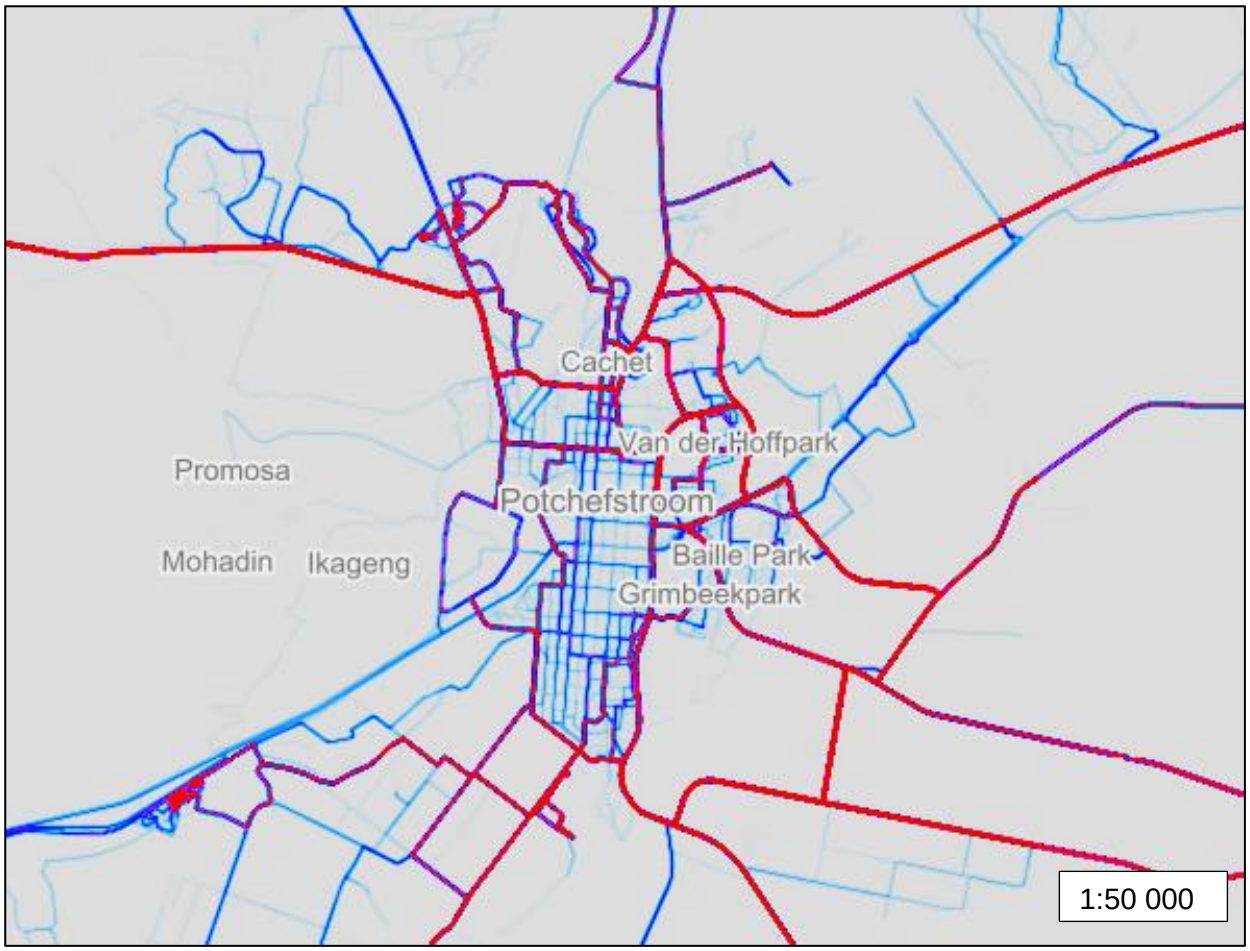


Figure 6-4: Heat map of Potchefstroom's cycling patterns as obtained through Strava data. Source: Strava Labs (2017).

In order to identify Potchefstroom's most prevalent cycling patterns and ultimately draw conclusions regarding the preferred cycling routes and bicycle- friendly spaces within the area, a simplified heat map were considered, as illustrated in Figure 6-5.

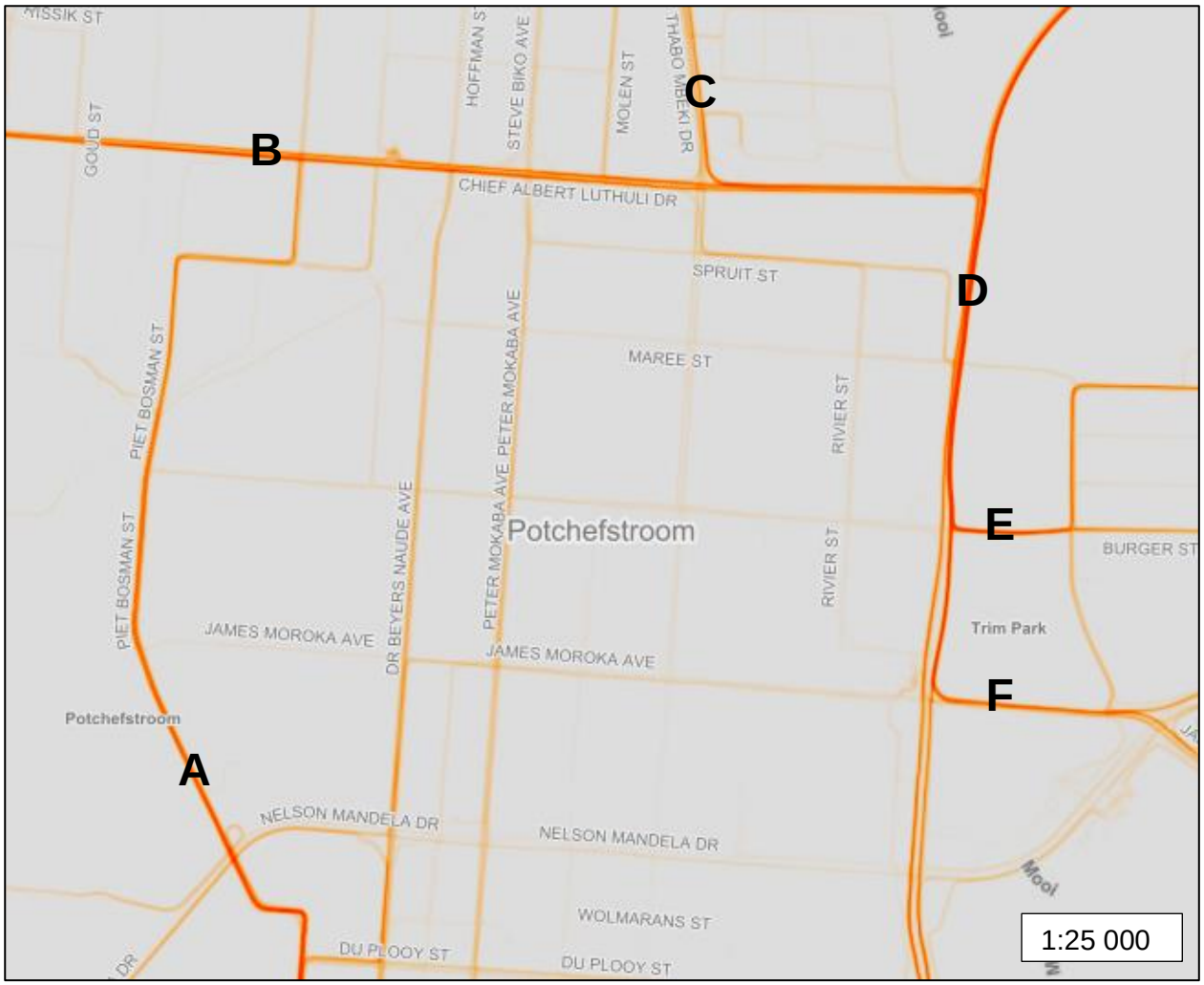


Figure 6-5: A simplified heat map of Potchefstroom's most prevalent cycling patterns as obtained through Strava data.
Source: Strava Labs (2017).

Figure 6-5 illustrates Potchefstroom's most prevalent cycling patterns. According to Google Maps (2017), these cycling patterns are recognised by the following streets in Potchefstroom, as indicated alphabetically on Figure 6-5:

- A: Piet Bosman Street
- B: Chief Albert Luthuli Street
- C: Thabo Mbeki Drive
- D: Govan Mbeki Avenue
- E: Retief Street
- F: James Morokalaan

Accordingly a visual analysis informed by Google Street View was used to analyse these streets and draw conclusions in terms of user preferences and specific design elements present in these areas.

6.4 Potchefstroom's user (cyclist) preferences

The previous section identified the cycling patterns of Potchefstroom as obtained through Strava data. This section will identify Potchefstroom's user preferences through a Google street view analysis in order to draw conclusions relating to the bicycle- friendly spaces used for each aforementioned cycling street. Table 6-2 captures the visual analysis and Potchefstroom's user (cyclist) preferences as informed by Google street view.

Table 6-2: Potchefstroom's user preferences

Bicycle- friendly spaces visual analysis	Identified user preferences
A: Piet Bosman Street	
	➢ No evidence of any bicycle-friendly spaces.
B: Chief Albert Luthuli Street	
	➢ No evidence of any bicycle-friendly spaces.
C: Thabo Mbeki Drive	
	➢ No evidence of any bicycle-friendly spaces.

Bicycle- friendly spaces visual analysis	Identified user preferences
D: Govan Mbeki Avenue	
	➢ Evidence of poor maintained bicycle-friendly lanes. ➢ These bicycle- lanes are considered dangerous for cyclists as it does not provide a bicycle- friendly operating space.
E: Retief Street	
	➢ No evidence of any bicycle- friendly spaces.
F: James Morokalaan	
	➢ No evidence of any bicycle- friendly spaces.

Source: Own creation (2017) based on Google Maps street view (2017).

Table 6-2 captured Potchefstroom's user preferences through a Google street view analysis. It is evident that there is a need for bicycle- friendly spaces in Potchefstroom based on the lack of such spaces on the city's preferred cycling routes as obtained through Strava data. The following section provides opportunities for interventions and recommendations to enhance and guide the planning of bicycle- friendly spaces for the preferred cycling routes/streets in Potchefstroom (refer to 6.2.3).

6.5 Recommendations to enhance and guide the planning of bicycle- friendly spaces for Potchefstroom with Strava data substantiation.

The best practices for planning bicycle- friendly spaces (refer to 5.4.2) derived from theory based sampling (refer to 3.8) serves as the basis for recommending bicycle- friendly design elements for enhancing the planning of bicycle- friendly spaces within the Potchefstroom case study and local areas of South Africa. In view of that, the following elements could contribute and enhance the planning of bicycle- friendly spaces in Potchefstroom:

- **One- way protected bicycle track** (cross-reference to section 3.5.3 for details)
- **Intersection crossing** (cross-reference to section 3.5.4 for details)
- **Coloured bicycle spaces** (cross-reference to section 3.5.6 for details)
- **Speed maintenance (cycling topography)** (cross-reference to section 3.6.4 for details)
- **Bicycle- friendly operating- space** (cross-reference to section 3.6.1 for details)
- **Clear cycling sight- distances** (cross-reference to section 3.6.3 for details)
- **Smooth cycling surfaces** (cross-reference to section 3.5.2 for details)

Table 6-2 in section 6.2.3 captured Potchefstroom's user (cyclist) preferences through a Google street view analysis. Table 6-3 will consider the preferred cycling streets/routes in Potchefstroom and recommend elements that will enhance and guide the planning of bicycle- friendly spaces for these streets/routes.

Table 6-3: Recommendations to enhance and guide the planning of bicycle- friendly spaces for Potchefstroom

Preferred cycling routes/streets in Potchefstroom with Strava data substantiation	**Recommended bicycle- friendly elements**
A: Piet Bosman Street	
	**<u>Recommended elements</u>** ➢ Intersection crossing ➢ Coloured bicycle spaces ➢ Bicycle- friendly operating- space ➢ Smooth cycling surfaces

Preferred cycling routes/streets in Potchefstroom with Strava data substantiation	Recommended bicycle- friendly elements
B: Chief Albert Luthuli Street	
	**<u>Recommended elements</u>** ➢ Intersection crossing ➢ Coloured bicycle spaces ➢ Bicycle- friendly operating- space ➢ Smooth cycling surfaces
C: Thabo Mbeki Drive	
	**<u>Recommended elements</u>** ➢ Intersection crossing ➢ Coloured bicycle spaces ➢ Bicycle- friendly operating- space ➢ Smooth cycling surfaces ➢ One- way protected bicycle track
D: Govan Mbeki Avenue	
	**<u>Recommended elements</u>** ➢ Intersection crossing ➢ Coloured bicycle spaces ➢ Bicycle- friendly operating- space ➢ Smooth cycling surfaces ➢ One- way protected bicycle track
E: Retief Street	
	**<u>Recommended elements</u>** ➢ Intersection crossing ➢ Coloured bicycle spaces ➢ Bicycle- friendly operating- space ➢ Smooth cycling surfaces ➢ One- way protected bicycle track

Preferred cycling routes/streets in Potchefstroom with Strava data substantiation	Recommended bicycle- friendly elements
F: James Morokalaan	
	**<u>Recommended elements</u>** ➢ Intersection crossing ➢ Coloured bicycle spaces ➢ Bicycle- friendly operating- space ➢ Smooth cycling surfaces

Source: Own creation (2017) based on Google Maps street view (2017).

CHAPTER 7: CONCLUSIONS

The purpose of this chapter is to draw conclusions based on the preceding theoretical and empirical investigations in an attempt to answer the research questions and objectives of the research, as captured in Chapter 1. Figure 7-1 captures the structure of Chapter 7.

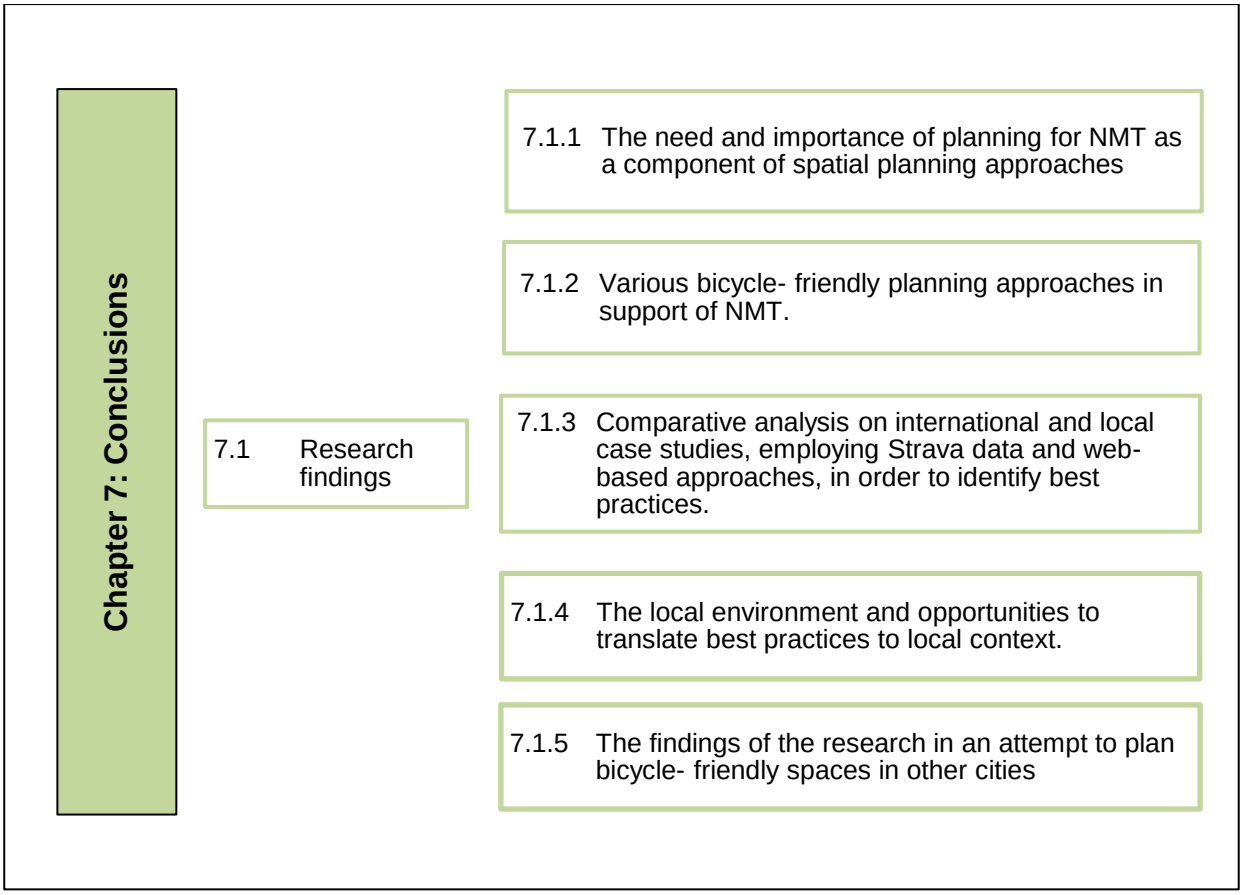


Figure 7-1: Structure of Chapter 7.

Source: Own creation (2017).

7.1 Research findings

The following conclusions were drawn as a result of the theoretical and empirical research conducted. These conclusions serve as a basis for recommending bicycle- friendly design elements for enhancing the planning of bicycle- friendly spaces applicable to different urban contexts.

7.1.1 The need and importance of planning for NMT as a component of spatial planning approaches

The need and importance of NMT were considered with specific attention to the benefits that it provides for both cities and individuals. NMT has an important role to fulfil in encouraging sustainable, integrated and inclusive urban transport, especially when considering benefits that it provides for both cities and individuals. Lower- income and transport- disadvantaged individuals, such as the handicapped, young and elderly also benefit significantly from NMT development. NMT provides a sustainable alternative option to the private- motorised vehicle and has an important role to play in reducing traffic congestion, reducing carbon emissions and improving air quality. With rising congestion and pollution problems in cities, there is greater work needed to be done in regard with NMT development. It can be concluded that NMT, especially cycling and walking, is supportive of sustainable or green transport.

The significance of NMT was also considered for developing countries, furthermore capturing the status of NMT in South Africa. Urban transport systems in developing countries are deteriorating due to the high rates of urbanisation and rapid motorisation. The advantages of NMT for developing countries are mainly linked to urban mobility, accessibility, road safety, liveable communities, and low-income groups. It can be concluded that there is a need for developing countries to develop, implement and promote NMT as an alternative transport option. This is particularly true for South Africa, where there is a need for NMT development in urban areas of South Africa. The lack of data, however, limits the effect of monitoring the current NMT interventions in South Africa. NMT should, however, be supported by a “modal hierarchy” planning approach that suggests in designing the road function according to a scheme that prioritises NMT-modes.

Cycling, as a NMT mode, holds unique challenges, opportunities and planning challenges. Cyclists take up considerable less space in cities than of motorised vehicles. In conclusion, NMT modes could assist in reducing traffic congestion and therefore is necessary to develop bicycle- friendly spaces and NMT facilities for cities.

7.1.2 Various bicycle- friendly planning approaches in support of NMT

With reference to the significance of cycling as a NMT mode and the benefits that it provides for cities and individuals, it can be concluded that cycling should be emphasised as part of spatial planning and transportation planning approaches. Cycling is an essential NMT mode considering the economic, environmental, health and social benefits that it provides for cities. Cycling can therefore be seen as an accessible mode of transport, especially for short journeys and journeys to

public transport modes. Furthermore, cycling has an extensive impact on economic development, climate change, tourism and city planning.

A conclusion can be drawn that cycling is an essential NMT mode to be included as part of broader spatial planning approaches. It was found that cycling serves as the most efficient mode of transport over short to medium journeys in a city, for purposes such as cycling to school, shops and public transport. Cycling may also save crucial time and personal effort compared to walking as a mode of transport, and is considerably more space- efficient than other transport modes. Many cities considered the development of cycling infrastructure as a solution to create sustainable urban mobility. A multi- modal transport system is essential for developing a bicycle- friendly transport network.

The value of specific cycling- needs are worth considering for planning bicycle- friendly spaces. As such, cyclist types provide an understanding of the target market to be considered in the bicycle-friendly planning process. A well-designed cycle facility will be attractive to a wide spectrum of captive and potential cyclists. These cyclist types are however constraint by factors that may serve as a challenges to cycling as a mode of transport. These challenges suggest that cyclists would be more likely to cycle if roads were made safer through planning bicycle- friendly spaces.

Development of bicycle- friendly spaces and street renewals should encourage a third of all individuals to cycle as part of their journeys. In addition, many individuals dislike cycling amongst traffic, or sharing the roadway with pedestrians. Therefore the primary condition for encouraging cycling as an efficient transport option is to provide dedicated bicycle- friendly spaces for cycling that offers some degree of protection from motorised traffic. The following types of spaces and design guidelines are in support of NMT when planning for bicycle- friendly spaces:

- **Bicycle- lanes** (cross-reference to section 3.5.1 for details)
- **Bicycle boulevards** (cross-reference to section 3.5.2 for details)
- **Bicycle tracks** (cross-reference to section 3.5.3 for details)
- **Bicycle intersection treatment** (cross-reference to section 3.5.4 for details)
- **Bicycle signals** (cross-reference to section 3.5.5 for details)
- **Bicycle signage and markings** (cross-reference to section 3.5.6 for details)
- **Bicycle parking facilities** (cross-reference to section 3.5.7 for details)
- **Speed maintenance** (cycling topography) (cross-reference to section 3.6.4 for details)
- **Bicycle- friendly operating- space** (cross-reference to section 3.6.1 for details)
- **Clear cycling sight- distances** (cross-reference to section 3.6.3 for details)
- **Smooth cycling surfaces** (cross-reference to section 3.6.2 for details)
- **Efficient lighting for cycling** (cross-reference to section 3.4.2 for details)

The broad legislative and policy framework in which NMT operates does not support and acknowledge specific design elements to enhance the planning of bicycle- friendly spaces within South African cities. International experience indicates that a national cycling policy framework serves as an essential tool for encouraging NMT and more specifically cycling in urban areas. From a local perspective, no significant references to NMT, in preparing spatial plans, associated with SDFs, are made. This serves as motivation for this study, lamenting the absence of proper guidelines for NMT in planning directives.

The planning legislation applicable for informing NMT in South Africa does not directly refer to NMT guidelines. Planning policies are, however, formed according to national legislation and can therefore be locally implemented on different urban contexts. It can thus be said that SPLUMA (2013) does not address NMT in clear terms as the act is indirectly emphasised as an element of urban reconstruction. The NMT policies applicable to South Africa and local urban contexts can therefore be seen as the planning directives for guiding NMT.

7.1.3 Comparative analysis on international and local case studies, employing Strava data and web-based approaches, in order to identify best practices.

It is evident from the research conducted that both the international and local case studies have proven to be admirable bicycle- friendly cities in their respective countries, based on their current bicycle- friendly spaces and usage thereof by a diversity of communities. A comparison captured the frequency of usage of the different bicycle- friendly elements within these case studies, as seen in Table 7-1.

Table 7-1: Bicycle- friendly elements identified for both international and local case studies

Elements	International case studies (Amsterdam & Copenhagen)	Local case studies (Johannesburg & Cape Town)
Bicycle- lanes	1	0
Bicycle boulevards	2	0
Bicycle tracks	4	6
Bicycle intersection treatment	2	1
Bicycle signals	0	0
Bicycle signage and markings	4	1
Bicycle parking facilities	5	0
Speed maintenance (cycling topography)	6	5
Bicycle- friendly operating-space	6	5

Elements	International case studies (Amsterdam & Copenhagen)	Local case studies (Johannesburg & Cape Town)
Clear cycling sight- distances	6	6
Smooth cycling surfaces	6	4
Efficient lighting for cycling	0	0
Number of bicycle- friendly elements	**42**	**28**

Source: Own creation (2017)

Both the international and local case studies support various bicycle- friendly elements for their respective preferred cycling routes, as obtained through Strava data and web-based approaches. The international case studies illustrated a greater number of bicycle- friendly elements (42) compared to the number of bicycle- friendly elements (28) identified by the local case studies. Copenhagen and Amsterdam are world leaders in supporting the development of bicycle- friendly spaces (refer to 5.2) and therefore adding to higher figures in the international cases. It indicates a further opportunity for local areas to explore more of these design guidelines and include such in the planning of future spaces, and to implement and promote NMT as an alternative transport option (refer to 2.4).

The empirical investigation of this study informed recommendations for considering bicycle-friendly design elements to enhance the planning of bicycle- friendly spaces within the relevant local areas of South Africa. The best practices for planning bicycle- friendly spaces (refer to 5.4.2) derived from theory based sampling (refer to 3.8) serves as the basis for recommending bicycle-friendly design elements for enhancing the planning of bicycle- friendly spaces within local areas of South Africa and in any other cities.

A conclusion can be drawn on the comparative analysis of the international and local case studies of this study. By employing Strava data and web-based approaches on international and local case studies, best practices can be identified in order to recommend bicycle- friendly design elements and ultimately enhance the planning of bicycle- friendly spaces for the local environment and any other cities.

7.1.4 The local environment and opportunities to translate best practices to local context

Bicycle- friendly spaces and various design elements are crucial elements to consider for enhancing the planning of such spaces. Table 7-2 below ranks and interprets the various identified bicycle- friendly elements according to the frequency of use of the international and local case studies, as obtained through Strava data and web-based approaches.

Table 7-2: Ranking and interpretation of bicycle- friendly elements according to frequency of use of case studies.

Ranking of elements according to frequency of use of case studies	Frequency of use of case studies	Local interpretation and possibilities for integration
Clear cycling sight- distances	12	Sufficient sight distances provide cyclists with opportunities to see hazards and react accordingly (refer to 3.6.3). Based on the high frequency of use of case studies, the provision of clear cycling sights distances should be integrated in a local urban transport system.
Speed maintenance (cycling topography)	11	Bicycle- friendly spaces designed for relatively high cycling speeds (refer to 3.6.4). Based on the high frequency of use of case studies, speed maintenance should be integrated in a local urban transport system.
Bicycle- friendly operating-space	11	Adequate clearances and operating space for cyclists to obstacles and to passing motorised vehicles (refer to 3.6.1). Based on the high frequency of use of case studies, the provision of bicycle- friendly operating spaces should be integrated in a local urban transport system.
Smooth cycling surfaces	10	Smooth cycling surfaces for cyclists to experience effective, safe and comfortable cycling journeys (refer to 3.6.2). Based on the high frequency of use of case studies, smooth cycling surfaces should be integrated in a local urban transport system.
Bicycle tracks	10	A bicycle track is a bicycle- friendly space that are physically separated from motorised traffic and detached from sidewalks (refer to 3.5.3). Based on the high frequency of use of case studies, bicycle tracks should be integrated in a local urban transport system.

Ranking of elements according to frequency of use of case studies	Frequency of use of case studies	Local interpretation and possibilities for integration
Bicycle parking facilities	5	Bicycle parking spaces located in a convenient and secure location for cyclists (refer to 3.5.7). Based on the considerable frequency of use of case studies, bicycle parking facilities may be integrated in a local urban transport system.
Bicycle signage and markings	5	Bicycle signage and markings indicates the presence of designated bicycle- friendly spaces (refer to 3.5.6). Based on the considerable frequency of use of case studies, the provision of bicycle signage and markings may be integrated in a local urban transport system.
Bicycle intersection treatment	3	Bicycle intersection is an at-grade road junction where cyclists are separated from motorised-vehicles travel (refer to 3.5.4). Based on the low frequency of use of case studies, the provision of bicycle intersection treatment should not be integrated in a local urban transport system.
Bicycle boulevards	2	Bicycle boulevards are designated streets for cyclists (refer to 3.5.2). Based on the low frequency of use of case studies, the provision of bicycle boulevards should not be integrated in a local urban transport system.
Bicycle- lanes	1	A bicycle- lane is a marked space in the roadway for exclusive use of cyclists (refer to 3.5.1). Based on the low frequency of use of case studies, the provision of bicycle lanes should not be integrated in a local urban transport system.
Bicycle signals	0	Bicycle- signals instruct cyclists when to enter intersections and restrict conflicts with motorised- vehicles (refer to 3.5.5). Based on the non- existing use of case studies, the provision of bicycle signals should not be integrated in a local urban transport system.
Efficient lighting for cycling	0	Poor lighting contributes to poorly designed urban environments (refer to 3.4.2). Based on the non- existing use of case studies, efficient lighting for cycling should not be integrated in a local urban transport system.

Source: Own creation (2017).

The ranked frequency of the usage of the above- mentioned design elements could be considered and integrated into the local bicycle- friendly spaces of South Africa and other cities in an attempt to enhance the planning of bicycle- friendly spaces in local (or international) urban contexts.

By contextualising and implementing the findings of the theoretical and empirical investigation, the local Potchefstroom case study was evaluated. This evaluation identified opportunities for the intervention of bicycle- friendly spaces in Potchefstroom. The best practices for planning bicycle-friendly spaces (refer to 5.4.2) derived from theory based sampling (refer to 3.8) served as the basis for recommending bicycle- friendly design elements for enhancing the planning of bicycle-friendly spaces within Potchefstroom. In view of that, the following elements are recommended to contribute and enhance the planning of bicycle- friendly spaces in Potchefstroom:

- **One- way protected bicycle track** (cross-reference to section 3.5.3 for details)
- **Intersection crossing** (cross-reference to section 3.5.4 for details)
- **Coloured bicycle spaces** (cross-reference to section 3.5.6 for details)
- **Speed maintenance (cycling topography)** (cross-reference to section 3.6.4 for details)
- **Bicycle- friendly operating- space** (cross-reference to section 3.6.1 for details)
- **Clear cycling sight- distances** (cross-reference to section 3.6.3 for details)
- **Smooth cycling surfaces** (cross-reference to section 3.5.2 for details)

7.1.5 The findings of the research in an attempt to plan bicycle- friendly spaces in other cities

NMT plays an important role in encouraging sustainable, integrated and inclusive urban transport, especially when considering benefits that it provides for both cities and individuals. With rising congestion and pollution problems in cities, work needed to be done in regard with NMT development. NMT, especially cycling and walking, is supportive of sustainable or green transport, thus there is a need for developing countries to develop, implement and promote NMT as an alternative transport option. NMT should, however, be supported by a “modal hierarchy” planning approach that suggests in designing the road function according to a scheme that prioritises NMT-modes.

NMT modes contribute in reducing traffic congestion and therefore are necessary to develop bicycle- friendly spaces and NMT facilities for cities. Cycling should be emphasised as part of spatial planning and transportation planning approaches as it is an essential NMT mode to be included as part of broader city and community planning. A multi- modal transport system is essential for developing a bicycle- friendly transport network. A well-designed cycle facility will be attractive to a wide spectrum of captive and potential cyclists. These challenges suggest that

cyclists would be more likely to cycle if roads were made safer through planning bicycle- friendly spaces. Therefore the primary condition for encouraging cycling as an efficient transport option is to provide dedicated bicycle- friendly spaces for cycling that offers some degree of protection from motorised traffic.

Many bicycle- friendly spaces and design guidelines are in support of NMT when planning for bicycle- friendly spaces, which include bicycle- lanes, bicycle boulevards, bicycle tracks, bicycle intersection treatment, bicycle signals, bicycle signage and markings, bicycle parking facilities, speed maintenance, bicycle- friendly operating- space, clear cycling sight- distances, smooth cycling surfaces, and efficient lighting for cycling.

A national cycling policy framework will serve as an essential tool for encouraging NMT and more specifically cycling in urban areas. From a local South African perspective, no significant references to NMT, in preparing spatial plans, associated with SDFs, are made. The NMT policies applicable for South Africa and local urban contexts can therefore be seen as the planning directives for guiding NMT. Both the international and local case studies support various bicycle-friendly elements for their respective preferred cycling routes, as obtained through Strava data and web-based approaches.

These best practices for planning bicycle- friendly spaces serve as the basis for recommending bicycle- friendly design elements for enhancing the planning of bicycle- friendly spaces within local areas of South Africa and in any other cities. By employing Strava data and web-based approaches on international and local case studies, best practices can be identified in order to recommend bicycle- friendly design elements and ultimately enhance the planning of bicycle-friendly spaces for the local environment and any other cities.

The above- mentioned conclusions serve as a basis for recommending bicycle- friendly design elements for enhancing the planning of bicycle- friendly spaces applicable to different urban contexts, as captured in Chapter 8.

CHAPTER 8: RECOMMENDATIONS

The final chapter of this research aims to provide planning recommendations in accordance with the conclusions formulated in the previous chapter. This chapter furthermore aims to provide relevant recommendations to enhance the planning of bicycle- friendly spaces applicable to different urban contexts, with specific reference to Strava data and related web-based approaches. Figure 8-1 captures the structure of Chapter 8.

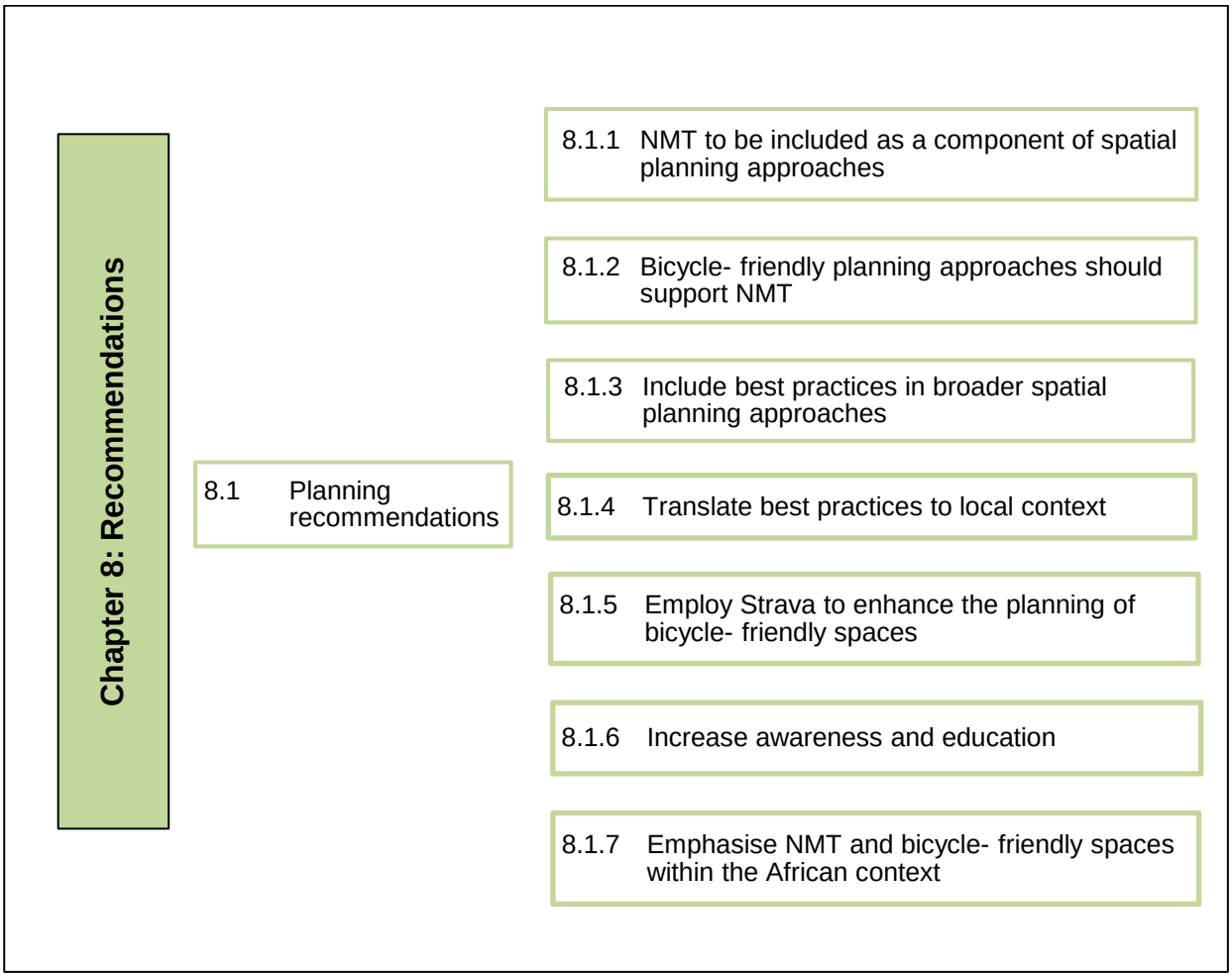


Figure 8-1: Structure of Chapter 8.

Source: Own creation (2017).

8.1 Planning recommendations

Accordingly planning recommendations are captured based on the theoretical and empirical investigation and respective conclusion drawn in preceding chapters.

8.1.1 NMT to be included as a component of spatial planning approaches

Based the conclusions made on NMT's important role to fulfil in encouraging sustainable, integrated and inclusive urban transport, especially when considering benefits that it provides for both cities and individuals in South Africa; the importance of planning for NMT as a component of spatial planning approaches should be considered.

Planners should be aware of the lower- income and transport- disadvantaged individuals, such as the handicapped, young and elderly that benefit significantly from NMT development. Improving access to NMT- facilities and for people with disabilities is a necessary element of attaining urban sustainable accessibility among these individuals in developing countries. With rising congestion and pollution problems in cities, there is greater work needed to be done in regard with NMT development. The implementation of NMT facilities, especially cycling and walking, will significantly support sustainable or green transport.

Urban planners should take into account that the development of NMT plays a significant role in the benefits that it offers in terms of urban mobility, accessibility, road safety, liveable communities, and low-income groups. There is thus a need for developing countries to develop, implement and promote NMT as an alternative transport option. It was concluded that the lack of data limits the effect of monitoring the current NMT interventions in South Africa. It is recommended that NMT should be supported by a "modal hierarchy" planning approach that suggests in designing the road function according to a scheme that prioritises NMT- modes.

Planners should also be made aware of alternative solutions as brought along by NMT modes. Provision should be made for accessing neighbourhoods by NMT. Small residential cells may be planned as "closed" networks, providing that NMT through- movement is facilitated. The primary public transport routes should thus be separated from the private motorised- based major road network.

To promote bicycle use in South Africa, there need to be adequate bicycle- friendly spaces for cycling journeys. The road hierarchy should promote NMT routes and, where possible, public transport should be prioritised. Transfers between multi- modal transport and services should be seamless, creating new standards for the design of transfer modes. Cycling, as a NMT- mode, needs to be incorporated into broad spatial- and transport planning, and accommodated in infrastructure improvement programmes. It is recommended that NMT needs to be guided by the following initiatives as part of spatial planning approaches:

- Integrate NMT approaches as part of broader spatial- and transport planning;
- Develop infrastructure that recognise NMT as an necessary mode of transport;

- Facilitate NMT as an input system towards other modes of transport;
- Distribute adequate and sustainable funding for promoting and developing NMT;
- Promote NMT as reliable, affordable, healthy, accessible and safe transport mode;
- Reduce the number of traffic accidents of exposed non- motorised road users;
- Ensure that the calming of traffic is part of the transport strategy for the area;
- Ensure that traffic calming is accommodated and applied at the appropriate road hierarchy level; and
- Promote road safety through the enhancement of NMT.

8.1.2 Bicycle- friendly planning approaches should support NMT

Cycling should be an integral part of all transportation planning. A bicycle network is designed to meet the demands of current cyclists as well as potential and future cyclists. The quality of cycling as a transport mode depends on whether bicycle- friendly spaces are available. Unavailable or uncompleted bicycle- bicycle friendly spaces are seen as challenges to cycling. A bicycle- network should be designed to enhance connectivity between transport origins and destinations, and to overcome challenges to cycling. It is therefore essential for planners to develop a coherent network of bicycle- friendly spaces in urban areas. The following design elements and user (cyclist) preferences should be considered by planners to design a good bicycle- network:

- **Bicycle- lanes** (cross-reference to section 3.5.1 for details)
- **Bicycle boulevards** (cross-reference to section 3.5.2 for details)
- **Bicycle tracks** (cross-reference to section 3.5.3 for details)
- **Bicycle intersection treatment** (cross-reference to section 3.5.4 for details)
- **Bicycle signals** (cross-reference to section 3.5.5 for details)
- **Bicycle signage and markings** (cross-reference to section 3.5.6 for details)
- **Bicycle parking facilities** (cross-reference to section 3.5.7 for details)
- **Speed maintenance** (cycling topography) (cross-reference to section 3.6.4 for details)
- **Bicycle- friendly operating- space** (cross-reference to section 3.6.1 for details)
- **Clear cycling sight- distances** (cross-reference to section 3.6.3 for details)
- **Smooth cycling surfaces** (cross-reference to section 3.6.2 for details)
- **Efficient lighting for cycling** (cross-reference to section 3.4.2 for details)

It is essential for planners and urban designers to understand the approaches to bicycle- friendly planning in order to solve particular cycling challenges and ultimately to support the development of NMT. It is recommended that the development of a bicycle- network with bicycle- friendly spaces should be integrated into larger land use planning and development projects in order to ultimately support NMT.

8.1.3 Include best practices in broader spatial planning approaches

It is evident from this research that cycling is an essential NMT mode to be included as part of broader spatial planning approaches. In the broader spatial planning process, planners are able to determine various challenges in different urban environments. With that said, spatial planning is complex in practice as it may not always follow a technical rational procedure from the original vision to the end- result.

In South Africa, broad spatial frameworks have become a standard form of planning. Spatial frameworks are neglected on ground level decision-making, and do not link sufficiently to land use management or to infrastructure planning. The study of best practices, however, forms part of spatial planning approaches that brings knowledge generated through research more centrally into planning practice; an approach called evidence- based practice. The role of evidence in guiding spatial planning is critical and one that has been well understood in the development of urban planning. Evidence- based practice can be more effective and accessible through the use of web-based approaches (i.e. Strava data) to planners for guiding spatial planning approaches.

By employing Strava data and web-based approaches on international and local case studies, best practices can be identified in order to recommend bicycle- friendly design elements and ultimately enhance the planning of bicycle- friendly spaces for the local environment and any other cities. Planners need to work largely around existing spatial patterns, and this requires a better understanding of different urban contexts. Best practices should therefore be included in broader spatial planning approaches.

8.1.4 Translate best practices to local context

The translation of best practices to local context can have a significant effect on enhancing the planning of bicycle- friendly spaces in different urban contexts. Merely presenting evidence- based practice will not necessarily lead to the application of the research findings. Translating best practices to local content conforms the planning approach to think global and act local.

In this research, the local Potchefstroom case study was evaluated by contextualising and implementing the findings of the literature study and empirical investigation (best practices). This evaluation identified opportunities for the intervention of bicycle- friendly spaces in Potchefstroom. The best practices for planning bicycle- friendly spaces derived from theory based sampling served as the basis for recommending bicycle- friendly design elements for enhancing the planning of bicycle- friendly spaces within Potchefstroom.

With the aim of enhancing bicycle- friendly planning approaches for other urban environments, Strava data and related web-based approaches can be considered to identify 1) bicycle usage patterns and 2) user (cyclist) preferences and 3) best practices relating to the planning of bicycle-friendly spaces.

8.1.5 Employ Strava to enhance the planning of bicycle- friendly spaces

Strava data is gaining importance as a research method to inform the planning and design of roads and movement corridors, as smart urban data provide insight into user (cyclist) preferences. Strava data is the start of a renaissance in planning for sustainable transportation. Strava data present a new approach to traditional retrospective surveys, bicycle- counting stations, and anecdotal evidence of cycling movements. Each journey mapped in Strava adds to the Strava database that may help cities to make important transportation decisions and this data should be interpreted in order to inform planning and design of future city spaces. Mapping the cycling patterns and trends from Strava data allows city managers, transportation planners, policy makers and other stakeholders to promote evidence- based infrastructure planning that will foster smart and sustainable cities.

The Strava heat map visualises all Strava activities worldwide and each cycling journey acts as a digital vote on the global heat map that informs city planning. The heat map illustrates the frequency (quantity) of cycling activity in a specific area. Cities and planners can thus use Strava data to evaluate current cycling patterns and to manage bicycle- friendly spaces.

The research study employed both quantitative and qualitative research methods and was structured in three phases. In the first phase the most prominent cycling areas and patterns were identified of the selected four case study areas, by employing secondary Strava data. In the second phase, user (cyclist) preferences were captured through a qualitative enquiry of the Google street view of cycling areas and patterns identified in phase 1. These areas and patterns were analysed according to the theory based sampling of elements for enhancing the planning of bicycle- friendly spaces in order to inform phase 3 of the empirical research, namely to draw conclusions with regard to best practices relating to the planning of bicycle- friendly spaces.

Plans for smart mobility through cycling are often hampered by lack of information on cycling patterns. Planners should thus consider Strava data as a tool for the planning of bicycle- friendly spaces as it is evident that this data can provide the necessary information to planners for enhancing the planning of bicycle- friendly spaces in different urban contexts.

8.1.6 Increase awareness and education

Urban data is the bedrock of the performance management programs that allow cities to ensure continuous improvement. Reliable urban data can facilitate interagency collaboration, improve partnerships with the private sector, and expand public engagement.

Historically urban planners have been educated and trained to work in a data poor environment. The world has entered a data rich environment, where people can have data on systems and behaviours for more frequent time increments and with a greater number of observations on a greater number of factors. Planners are, however, still being educated in methods that are suitable for a data poor environment. Planners need to be engaged in learning about emerging technology and utilising urban data, such as Strava data. Planners also need to embrace the potential of technology (i.e. Strava data) as a tool to achieve goals, such as reducing traffic congestion. Planners should therefore rise to the occasion, understanding how to best use technology to develop cities.

Education linked to gaining experience from international bicycle planning conferences and gatherings of local and international experts are opportunities to entrench NMT as a recognised and fully supported form of transport in South Africa. Participatory planning approaches, including local and international experts, should also be emphasised as an opportunity to entrench NMT as a recognised and fully supported form of transport.

It is evident from the local Potchefstroom case study that Strava data and other web- based approaches assisted in identifying areas in Potchefstroom where bicycle- friendly spaces should be implemented. These areas thus would not have been identified through any other approach. An increase of technology awareness and education on utilising Strava data/ urban data should be incorporated in order to ultimately enhance the planning of bicycle- friendly spaces for cities.

8.1.7 Emphasise NMT and bicycle- friendly spaces within the African context

It was found that urban transport systems in developing countries are deteriorating due to the high rates of urbanisation and rapid motorisation. The advantages of NMT for developing countries, especially within the African context are mainly linked to urban mobility, accessibility, road safety, liveable communities, and low-income groups. There is thus a need for developing countries to develop, implement and promote NMT as an alternative transport option, and particularly for South Africa where there is a need for NMT development in urban areas of South Africa. The lack of data, however, limits the effect of monitoring the current NMT interventions in South Africa. NMT could, however, be supported by Strava data and other related web- based approaches to enhance the planning of bicycle- friendly spaces. Ultimately this research confirms that Strava data could be a

valuable spatial planning tool to enhance the planning of bicycle- friendly spaces and areas as it contribute to the capturing of bicycle usage patterns, user (cyclist) preferences and evidently inform spatial planning.

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