Spatial planning approaches towards a more sustainable local transport network

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PREFACE

Firstly, I would like to thank God for allowing me to walk away from a potentially deadly situation, when I was involved in a "hit and run" accident and managed to survive.

Secondly, I would like to thank my lecturers for having enough patience after my accident, while supporting and trusting my decision. I also received excellent advice in this process of healing and working. I would like to thank Prof J.E. Drewes for his knowledge and the sacrifice of his time to see me. I would like to thank Dr M. van Aswegen for being a strong, motivational individual, who encouraged me to push forward. To my lecturers, I am so grateful to have had your support when I needed it most.

Thirdly, I would like to thank my parents, Sally and Roland Cullinan, for never giving up on me and supporting me in my decisions. I love you both and have a lot to thank you for, more than I can express in my acknowledgements

Fourthly, I would like to thank Jonathan Cullinan, my little brother. I would like to thank him for being a support foundation when I needed him most, just by being there for me. Without him I would not have accomplished what I did.

Fifthly, I would like to thank Michael John Nel for being there, always making me laugh and see the positive side, while motivating me in terms of sport. Arguments between us are few and far between; one thing that is sure is that you only make friends like this once in a lifetime.

I would also like to thank everyone who has had an impact on my life, both negatively and positively, because it made me who I am today. What I have learnt is that success in life comes when one simply refuses to give up, with goals so strong that obstacles, failure and loss only act as motivation.

ABSTRACT

The spatial planning and implementation of local transportation systems have been restricted by limited modal options. The purpose of transportation modes is to increase efficiency and move towards sustainable cities. Public transportation has been disregarded as a significant factor in cities and has led to the motor vehicle-dominated city. This causes congestion, inefficiency, decrease in productivity, increasing travel costs, increasing travel time, decreasing economic growth, numerous safety hazards, lack of sustainable transportation and environmental damage. The problem is evident in the lack of local multimodal transportation systems. This creates mass inefficiency, which is highly problematic for the urban spatial structure. The spatial implementation of transportation infrastructure is significant for mobility between the central business district (CBD) (places of employment) and residential areas. This is especially visible in the study area. Potchefstroom lacks effective spatial planning for local transportation systems and neglects pedestrians. The city is focused on spatial planning of road infrastructure, while lacking pedestrian walkways in various areas of development. There are no bicycle lanes, which forces cyclists to use road infrastructure intended for cars. This causes conflict and is highly unsafe. Potchefstroom lacks public transportation services and has resorted to the use of motor vehicles as the last option to achieve mobility. This has become problematic, since individuals walk and cycle despite lack of appropriate infrastructure. This city is also home to the North West University, which is surrounded by student accommodation in close proximity, hence the importance of facilities for cycling and walking.

The research aims to identify local transportation modes that could be spatially and practically implemented in the urban structure. The literature research aims to identify various urban and spatial models that have previously successfully been used. This would illustrate the principles of each spatial structure and the aims and objective of the design, thus creating a foundation for the various urban and spatial structures, which involves the principles of implementation. All the objectives were addressed throughout the research document (refer to Chapters 4, 6 and 8). The empirical research approach is based on a comparative analysis between the implementation of local transportation systems in developed countries and the principles for successful implementation. The comparative analysis approach attempts to identify various spatial implementations, tools, policies, land use and political aspects that are successfully implemented in a sustainable city. The results illustrate that the spatial integration of local transportation systems is highly significant when developing a sustainable city. Spatial integration of local transportation systems is seen as highly significant, but was not the only factor to be considered. The factors identified include the spatial layout of the development, the integration of the environment, the urban structure, the distance between the residential area and CBD district, available public transportation systems and a compact city structure. This has been illustrated in various urban models discussed in Chapter 3, which illustrate whether public transportation is required or if different sectors are within walking distance. Where all objectives have been addressed and explained extensively in chapter 8.

This research document presents first-world recommendations for sustainable implementation of transportation, as well as illustrating a preliminary design for the implementation of transportation systems within the spatial structure of Potchefstroom, South Africa.

Key words: Sustainable, Transportation, Spatial Structure, Potchefstroom, Urban Model, Pedestrian infrastructure, Bicycle infrastructure, Motor vehicles

OPSOMMING

Die ruimtelike beplanning en implementering van plaaslike vervoerstelsels is begrens tot 'n beperkte modale opsie. Die doel van vervoer is om doeltreffendheid te verhoog en volhoubare stede te ontwikkel. Vervoer is as 'n belangrike faktor in stede buite rekening gelaat en dit het gelei tot die oorheersing van die motorvoertuig in die stad. Dit veroorsaak opeenhoping, ondoeltreffendheid, afname in produktiwiteit, verhoogde reiskoste, verhoogde reistyd, verlaagde ekonomiese groei, talle veiligheidsrisiko's, 'n gebrek aan volhoubare vervoer en skade aan die omgewing. Die probleem word weerspieël in die gebrek aan plaaslike multimodale vervoerstelsels. Dit skep massa-ondoeltreffendheid wat baie problematies is vir die ruimtelike struktuur. Die ruimtelike implementering van vervoerinfrastruktuur is belangrik vir mobiliteit tussen die sentrale sakekern (SSK) en die woongebied. Potchefstroom het nie effektiewe ruimtelike beplanning toegepas nie en verwaarloos voetgangers. In Potchefstroom is uitgebreide ruimtelike beplanning van padinfrastruktuur onvoldoende, terwyl daar nie voetgangerpaadjies in verskillende ontwikkelingsvelde is nie. Daar is geen fietspaaie nie, wat fietsryers dwing om padinfrastruktuur vir motors te gebruik, wat konflik veroorsaak en baie onveilig is. Potchefstroom het nie openbare vervoerdienste nie en het die gebruik van motorvoertuie as die laaste opsie vir mobiliteit gebruik. Dit het problematies geraak, aangesien individue stap en fietsry sonder die nodige infrastruktuur. Die stad is ook die tuiste van die Noordwes-Universiteit, wat omring word deur studenteverblyf in die omgewing, vandaar die belangrikheid van fietsry en stap.

Die navorsing het ten doel om plaaslike vervoermetodes te identifiseer wat ruimtelik in die stedelike struktuur geïmplementeer kan word. Die literatuurnavorsing het ten doel om verskillende stedelike en ruimtelike modelle te identifiseer wat voorheen gebruik is. Dit illustreer die beginsels van elke ruimtelike struktuur en die doelstellings en oogmerke van die ontwerp. Dit vorm die basis vir verskillende stedelike en ruimtelike strukture, wat implementeringsbeginsels behels. In al die navorsingsdokumente geniet al die doelstellings aandag. Elke doelstelling word aan die einde van Hoofstukke 4, 6 en 8 bespreek. Die empiriese navorsingsbenadering is gebaseer op 'n vergelykende analise van die implementering van plaaslike vervoerstelsels in ontwikkelde lande en die beginsels vir suksesvolle implementering. Die vergelykende analise-benadering identifiseer verskillende ruimtelike implementerings, beleid, grondgebruik en politieke aspekte wat help om ’n volhoubare stad te ontwikkel. Die resultate toon dat die ruimtelike integrasie van plaaslike vervoerstelsels baie belangrik is vir die ontwikkeling van 'n volhoubare stad. Ruimtelike integrasie van plaaslike vervoerstelsels is as baie belangrik geag, maar was nie die enigste faktor nie. Die faktore wat geïdentifiseer is, word as die volgende beskou: die ruimtelike uitleg van die ontwikkeling, die integrasie van die omgewing, die stedelike struktuur, die afstand tussen die woongebied en die SSK, beskikbare

openbare vervoerstelsels en ’n kompakte stadstruktuur.Alle doelstellings is in hoofstuk 8 breedvoerig bespreek en uiteengesit.

Hierdie navorsingsdokument bied aanbevelings vir die eerste wêreld vir volhoubare implementering van vervoer, sowel as 'n voorlopige ontwerp vir die implementering van vervoerstelsels in die ruimtelike struktuur van Potchefstroom, Suid-Afrika.

Sleutelwoorde: Volhoubaar, vervoer, ruimtelike struktuur, Potchefstroom, stedelike model, voetgangerinfrastruktuur, fietsinfrastruktuur, motorvoertuie

TABLE OF CONTENTS

ABBREVIATIONS

Abbreviation	***Explanation***
CBD	Central Business District
BRT	Bus Rapid Transit
IDP	Integrated Development Plan
LRT	Light Rail Transit
SDF	Spatial Development Framework
SOV	Single-occupant Vehicle

Source: Own creation

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1 INTRODUCTION

1.1 Research context

The purpose of the research study is to identify more efficient spatial planning techniques through which transportation can be introduced locally, with minimal impact on the immediate environment. The study aims to identify specific transportation systems and implement them in local communities in the case study city, Potchefstroom. Spatial planning has devised many approaches to mobility of freight and passengers in various countries. The transport geography is specifically important to the spatial layout of communities and their transportation systems.

Transport geography is defined as the geography of transportation systems, which is a sub-discipline of geography and is concerned with the movement of freight, people and information. This seeks to link spatial constraints and attributes with the origin, the destination, the extent, the nature and the purpose of movements, according to Rodrigue et al. (2006:5).

Spatial planning should be used in coordination with economic, social, political and environmental impact factors. The research reported on in this dissertation addresses the spatial planning of transportation modes and seeks to decrease negative effects on the environment by carefully allocating various transportation modes to facilitate movement within a spatial plan effectively.

The spatial planning of transportation infrastructure is crucial for a city/town's efficiency and ability to link nodes of importance. A sustainable spatial layout comprises numerous intricate functions, identifying the need for a local transportation system. This can be effectively incorporated in the towns/cities situated in South Africa.

Sustainable transportation is a long-term investment in a more efficient and healthier lifestyle, with minimal implications for the environment. Spatial planning of public transportation should be seen as an easy alternative to establish a new sustainable transportation system. In South Africa there is public transportation, but it lacks the efficiency and maintenance to be seen as a long-term sustainable option. One of these options that has been implemented is called the bus rapid transit system (BRT); it is South Africa's first full rapid bus system (Rea Vaya Bus System) and is implemented in larger cities, such as Cape Town and George (Allen, 2013:3).

1.2 Research problem

The lack of spatial planning in the localised transportation system has in fact decreased productivity, because of lack of maintenance and development of transportation infrastructure. Individuals, both poor and rich, are affected by the matter and are forced to use private motor vehicles (Pillay, 2001:1-4), with no understanding of the effects of the use of these combustion vehicles on the environment.

Lack of focus of spatial planning on public transport has limited local transportation diversity, owing to the accommodation of only a single specific type of transportation (motor vehicles). This would inevitably increase the use of private vehicles, because of limited mobility infrastructure. There is inadequate accessibility to other transportation systems. Moreover, promoting the use of motor vehicles causes long-term damage to the environment. The associated health and safety implications also create problems for pedestrians and cyclists. The issues caused within the spatial planning of transportation systems is often characterised by lack of walkways, bicycle lanes and accessibility for other types of mobility. Transportation systems have become motor vehicle-orientated, owing to limited spatial planning, pointing to the need for future sustainability and conservation of the environment. The increasing population in Potchefstroom (as a local case study) has significantly increased the use of motor vehicles and has made it imperative to implement sustainable transportation systems. The spatial implementation of local transportation system is hampered by inadequate planning regarding aspects of implementation and focus on obtaining a sustainable spatial structure. The dominance of motor vehicle transportation has led to congestions on various freeways in Potchefstroom, which ultimately decreases productivity while simultaneously decreasing the quality of the environment.

1.3 Research aim and objectives

The research aims to address spatial planning of localised transportation systems and to indicate how it can be effectively implemented in towns/cities, while allowing for a more sustainable future. The goal is to implement various types of sustainable transportation systems in a spatial plan in the local environment

The research study seeks to improve the underlying spatial planning problem in localised transportation and the lack of diversity. The research will propose spatial design solutions and indicate how these can incorporate neglected localised transportation systems and counter the consequences of the continuous use of motor vehicles. This stresses the need for a greener spatial planning solution for sustainable local transportation systems. The green agenda is concerned about the continuous use of combustion-operated vehicles and their effect on the environment. The aim of spatial planning and localised transportation systems is identified through three significant objectives:

1. To evaluate the theoretical foundation of spatial planning tools and their impact on sustainable transport systems;

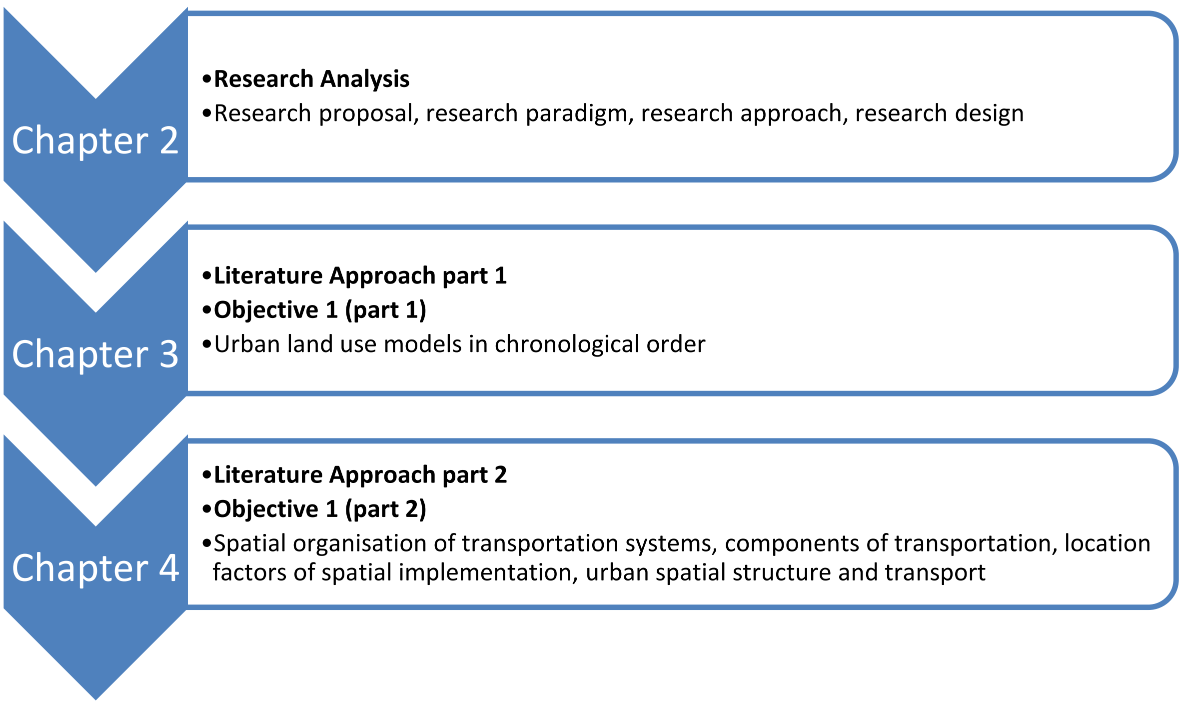
2. To evaluate the theoretical foundation of sustainable transport systems and international best practice; and
3. To provide solutions to improve the efficiency of local transportation modes in developing countries on a local (precinct) level.

1.4 Hypothesis

The hypothesis is based on the spatial implementation of local transportation systems and how this will directly transform the spatial plan to a more sustainable transport environment.

1.5 Chapter division

The research document will be composed of seven chapters. The research will contain two parts (Chapters 3 and 4) focused on the literature analysis. This will then be followed by Chapters 5 and 6, adopting an empirical approach. This will comprise an appropriate background desktop analysis of the functional urban model and how local transportation can be incorporated in each model. Chapter 7 will be based on recommendations on the implementation of local transportation modes throughout a spatial structure. The spatial implementation of transportation systems can determine the accessibility as well as economic success of the urban form. The chapters will be arranged as follows:



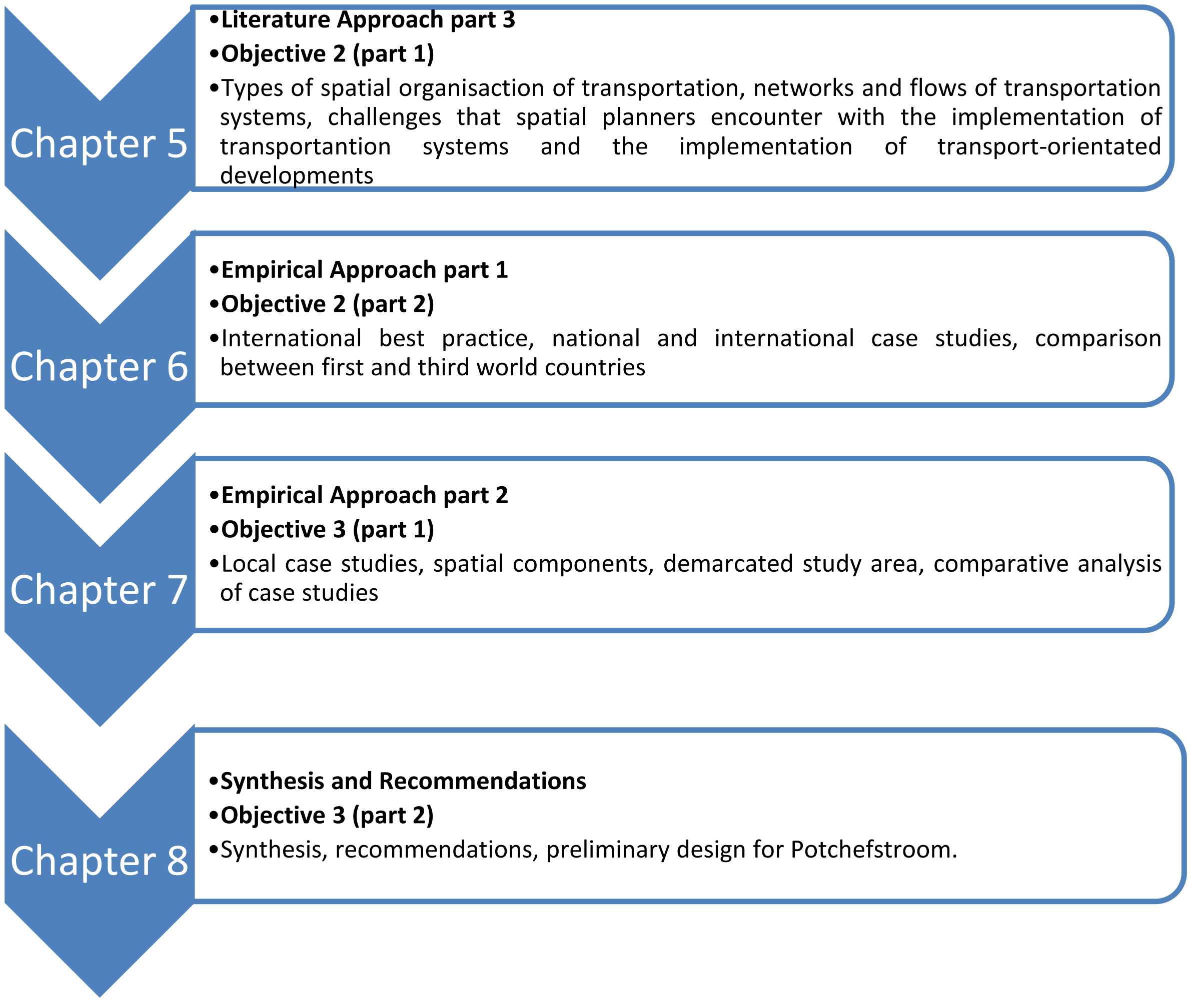


Figure 1-1 Chapter division

Source: Own creation

Chapter 2: This chapter will incorporate the research design and approaches that have been illustrated throughout the dissertation. This research document has been illustrated on a chronological literature review foundation. A chronological literature review describes each work in succession, starting with the earliest available information. These methods are typical in a chronological review; one has to group together the sources in the order of their publication date. The references will be illustrated in chronological order from the earliest available information to the most recently published. The chapter is used as the foundation to illustrate the layout of the dissertation. This is followed by a methodological paradigm approach. The next chapter will address the layout of the dissertation in terms of the research structure and initial interpretation of the methodology used throughout this document.

Chapter 3: This chapter will incorporate the first part of the literature research, illustrating the background of spatial planning and the various historical urban models in chronological order. This chapter is also identified as the beginning of obtaining objective one and will be combined with Chapter 4 to deal with the first objective. This will identify the adaptations in spatial planning. This chapter addresses the introduction of the literature research and how it focuses on the various urban forms, initiating a research-based solution for the spatial implementation of a local transportation system. This chapter is imperative to form a foundation for this desktop analysis dissertation. There are numerous models discussed, such as follows:

- ✓ Garden city model
- ✓ Concentric ring model
- ✓ Sector model
- ✓ Multiple nuclei model

The above models will help determine a foundation for sustainable cities; where one model lacks certain components, the other may compensate with viable solutions. Various models illustrate sustainable implementation strategies of transportation among land uses and effective functionality of sustainable transportation modes. These form a base for sustainable spatial planning of transportation and focus on factors that may initiate a decrease in efficiency, thus allowing one to avoid such situations throughout the development of new urban forms. This chapter relates directly to objective 1 of the study.

Chapter 4: This chapter will incorporate part two of the literature research, illustrating more modern-day spatial planning and incorporation of transportation systems. This chapter marks the end of dealing with objective 1, illustrating that it had been addressed throughout the chapters. This chapter is based on an analysis of Chapter 3, where challenges relating to the previous model had been identified. This will help identify the spatial planning challenges in each area. The challenges addressed illustrate efficient cooperation between various sectors of the spatial structure and how they interact. The challenges are illustrated in respect of sectoral integration, economics, and issues relating to the social and political structure of the urban model and the environment. This chapter analyses the various transportation systems and how they will function within the spatial structure. It illustrates the pros and cons of various transportation systems, as well as the various location factors that may influence the spatial structure. The ideology of this chapter is to create a multimodal framework of various transportation modes in the spatial structure and allow for a sustainable spatial structure.

This aspect of spatial planning is commonly not intensely analysed, but ideally could become an essential part of the functioning of urban forms. The various categories are highly significant in the development of a sustainable spatial structure and the locality of transportation systems.

Chapter 5: Chapter 5 marks the beginning of achieving objective 2, illustrating the intricate systems of transportation modes in urban structures. This involves two spatial structures, namely monocentric and polycentric spatial structures. These spatial structures are described and have unique traits; one has a single nucleus or CBD (monocentric), the other has two or more nuclei (polycentric) and can be identified as strong or weak, determined by a desired trait. This chapter marks the end of the literature analysis, focusing on the various spatial structures, flows, location factors and challenges faced by spatial planners. This chapter explains the network required for transportation systems and how these should function to create effective distribution among various sectors. It discusses the flow of transportation in the previously explained network, which includes the flow between transportation modes and congestion associated with poor transport planning. In the implementation of transportation systems into an urban structure, there are three transport components that play a role in the efficiency of the urban structure, as reflected in the figure below:

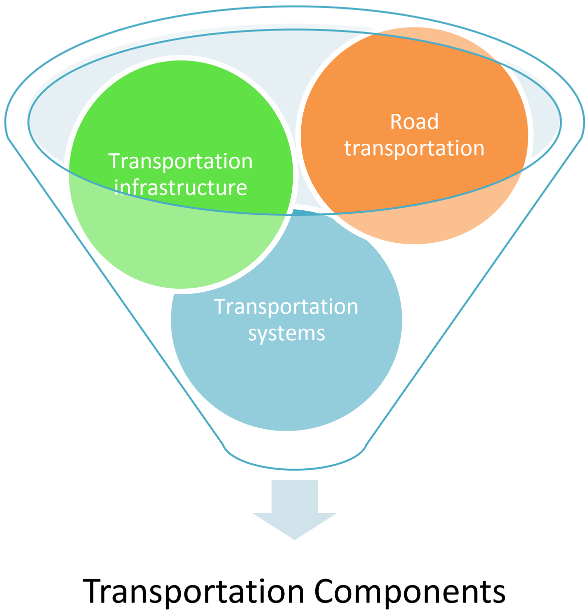


Figure 1-2 Transportation components

Source: Own creation

The above figure illustrates the components of transportation systems in an urban structure and how these are implemented according to the infrastructure. The components and the way in which they are implemented in the urban spatial structure are discussed in the following section. This interprets how transportation can function effectively or ineffectively, determined by the principles and components applied.

This chapter addresses several challenges of transportation planning and a solution, which involves transport-orientated developments (TOD), illustrating effective principles that can be practically implemented. These transportation-based developments have been implemented in various first world countries as well as third world countries. This chapter concludes the first section of the analysis to achieve objective 2.

Chapter 6: This chapter will incorporate the use of national and international case studies, and is seen as the end of the analysis to achieve objective 2. The chapter discusses various implementations of local transportation systems in each case study, addressing both first world and third world countries. The objective is to identify how local transportation systems function, as well as which transportation systems are effective and efficient. The first world case study gives a perspective on how sustainable transportation is implemented. The first world perspective and implementation are then addressed in two countries. This is then broken down into the spatial structure of cities (Adelaide, Australia; Odense, Denmark) in those countries. The ideology is to formulate a base of adequate transportation systems implemented without affecting efficiency and sustainability. The approach to analysing first world countries is to identify sustainable methods. The analysis of third world countries is intended to determine faults and problems with the implementation of transportation systems and the lack thereof. The third world perspective is identified in this chapter, and two third world country case studies are reported (Karachi, Pakistan; South Africa), which are broken down into two cities. South Africa is discussed in the following chapter, because of its correlation with national case studies and association with the designated study area. Chapter 6 will address the end of the research analysis of objective 2. This chapter also contains the analysis of third world spatial planning challenges and issues, in Pakistan and South Africa. Please refer to the figure below illustrating the layout of the case study analysis in chapter 6:

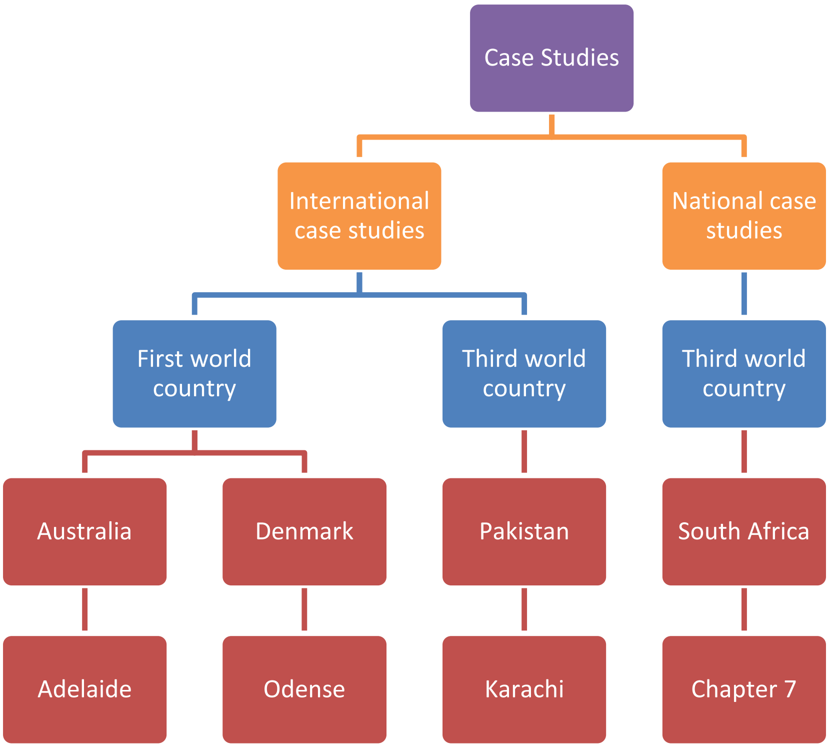


Figure 1-3 Layout of case studies

Source: Own creation

Studying both developed and developing countries will help identify particular reasons explaining why transportation systems function efficiently or inefficiently. The key aspects are identified through past mistakes, social problems, economic difficulties and spatial forms illustrated in developing countries. The opposite is seen in developed countries, where a particular approach is used to allow for the successful implementation of transportation systems throughout the spatial structure. The main purpose of this study is to identify approaches that would deteriorate the spatial structure and other approaches that may be successful in creating a sustainable spatial structure.

Chapter 7: This chapter identifies two local case studies in South Africa, in order to conduct a comparative analysis between the demarcated study area and the cities surrounding it. The study area addressed is Potchefstroom, which is situated in the North West province, South Africa. The other two case studies addressed in this chapter are the cities of George and Cape Town, which are situated in the Western Cape province and illustrate a local case study perspective. This chapter addresses the last objective (objective 3), beginning the investigation into the implementation of transportation and whether it can be practically implemented. This chapter makes a comparative analysis between the study area and local towns/cities that may be relevant for the implementation of local transportation systems, but are considered from a third world perspective. From a similar perspective as in chapter 6, the case studies will be analysed according to four components to determine if the demarcated study area can incorporate various transportation systems. The components are as follows:

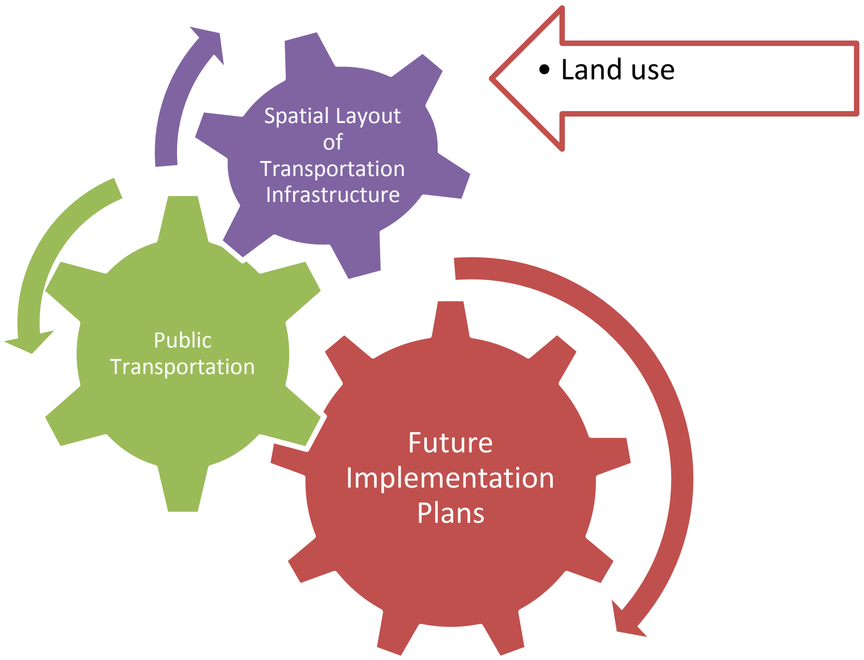


Figure 1-4 Four spatial components of comparison

Source: Own creation

The above figure illustrates the four spatial components of comparison in order to find compatibility in the practical implementation of transportation systems. As illustrated in the figure, land use is an important factor that often determines how transportation systems will be incorporated and effectively implemented. This is to allow ample connectivity between various sectors and land uses, working simultaneously to increase capital and economic growth. This would also determine the distance between residential and business districts, as well as how the other components would be implemented and work together to create an effective system to increase economic growth. A comparative analysis is done in the illustration of a comparative table. This compares various aspects of spatial implementation and land use between all national and international case studies. The comparative analysis compares third world countries with first world countries as well as the cities in them, to illustrate the difference between these countries in an effort to support the proposed recommendations illustrated in Chapter 8.

Chapter 8: This chapter will incorporate recommendations on spatial implementation and implementation in the demarcated study area. It forms the end of this research document and discusses the achievement of all three objectives; the last part of objective 3 is addressed. This chapter is based on the analysis done in Chapter 7, interpreting the spatial needs of the demarcated study area. The synthesis of Chapter 8 compares various aspects throughout the research study and contrasts found in each section mentioned in this research document. Aspects of spatial implementation of transportation were identified and coupled with other significant factors. This chapter illustrates all the objectives and gives a preliminary design for the spatial implementation of local transportation systems, which illustrates not only theoretical understanding, but also practical implementation. The preliminary design illustrates the recommendations proposed earlier in the chapter, while considering significant aspects (nodes, activity nodes, activity corridors, social and educational activities etc.) illustrated in annexure H of the research document. The following recommendations should be regarded as a foundation for the preliminary design with conscious implementation strategies and consideration of future sustainability:

Figure 1-5 Proposed recommendations for Potchefstroom

Source: Own creation

The above figure illustrates the proposed recommended categories, which should be considered when implementing transportation systems in the city of Potchefstroom. This is crucial to improve sustainability and efficiency. This will also reduce the environmental impact and improve the quality of life for residents. This will occur through the correct spatial implementation of local transportation systems, allowing for a sustainable city perspective.

The fact that spatial planning has been adapted in various towns and cities to accommodate the surrounding communities illustrates that the urban form can change. The type of implementation is significant for future sustainability. The ideology of developed countries is different from that of developing countries, but both seek the end result of sustainability. Potchefstroom has not obtained any type of public transportation and suffers from congestion and lack of facilities. The research identified that the above factors alone could not create a sustainable spatial plan, but integration and correct policy implementation could. This document addresses most significant aspects of sustainable transportation systems and formulates a preliminary design for implementing this multimodal system in Potchefstroom.

CHAPTER 2 RESEARCH METHODOLOGY

2.1 Research paradigm

The research paradigm concerns design for social research in the built environment. This study considers the systematic process of examining the implementation of mobility and its impact on the surrounding areas. Spatial planning is considered to be the backbone of planning and through the correct implementation of various modes of transportation can only enhance the natural and built environment through correct spatial implementation. The research will consider research design features in social research that have led to success with the implementation of planning and how incorrect implementation can affect the environment as a whole. The paradigm used throughout this study is known as the pragmatic paradigm, which is illustrated through a methodological paradigm of research.

The methodological paradigm of research approaches a source of data and determines how it can be effectively used, throughout the study (Du Toit & Mouton, 2011:1-4). The methodological approach systematically uses a process considering six facets, namely: (1) research content; (2) research aim; (3) research purpose; (4) methodological paradigm; (5) methodological approach and (6) source of data (Du Toit, & Mouton, 2011:131). The spatial content regarding the spatial planning perspective is identified through various articles in order to identify specific points of implementation. The spatial planning of transport modes can be seen as similar to the human body and how it is controlled through electrical pulses through the nerves in order to control the body's movements and allow it to operate efficiently (Hossain, 2018:1-2). The research aim is to identify possible implementable mobility systems throughout the spatial form by employing effective strategies, principles and guidelines. The research purpose is to improve mobility systems around the spatial structure, which would have a positive impact on economic growth and productivity, relieve congestion, increase the effectiveness of transportation between various nodes and improve public transport to decrease the number of single-occupant vehicles (SOV). The methodological paradigm is an interpretive social science. The methodological approach is identified through the use of qualitative data. The last consideration of the methodological approach is identified as the source under a primary source of data (case studies and field of data) illustrated through a comparative analysis (Du Toit, & Mouton, 2011:131). The concept is to understand that the nerve system is the transport routes and the mode of transport is the electrical impulse sent from the brain. If the wrong electrical impulse is sent by the brain (transport mode) it will not get the correct response from the body. The same is true of the nervous system (transport infrastructure): if the nerves are not correctly and efficiently distributed throughout the body, certain aspects of the body cannot receive the electrical impulse from the brain, resulting in no control or limited control over the body. The same concept is shown in spatial planning of transportation systems, where limited access to certain areas of development and decreasing mobility in the areas can cause a decrease in economic development and destructive quality of life and the environment, bringing development at a standstill.

The pragmatic paradigm uses a theoretical approach to qualitative data. This data could be classified as either primary or secondary data. The pragmatic paradigm uses a methodological paradigm and approach. This follows a chronological approach throughout the research document.

2.2 Research approach

The research approach through a methodological paradigm can be interpreted as either a post-positivist (not considered a pragmatic approach) or an interpretive social science (pragmatic) approach. This has an interpretive explanatory descriptive research purpose. The methodological approach has been identified by using a series of qualitative data in a primary and secondary core logic. The primary source of data is based on interpretation (ethnographical phenomenological and contextualisation), considered to be a hybrid approach to a theoretical study. The secondary source of data has been identified through interpretation (hermeneutical) data. The dissertation has been based on a deductive research approach, which focuses on facts of past spatial planning models and determines if local transportation systems were imperative in the development of sustainable cities (McDonagh, 1997:3).

The research approach is based on a methodological paradigm and a chronological literature review (Du Toit, & Mouton, 2011:132), in which international case studies are examined through a process of detecting similarities between various city transportation spatial plans. The international case study of various cities will be a desktop analysis of specific traits in spatial structure, allowing the researcher to identify elements of sustainable design. The elements or similarities in the developed countries will be used in the recommendations to adapt the spatial design to a functional spatial plan. The research approach aims to analyse the policy implementation and land use of areas. Through identifying the perceived problems of the developing cities, a solution could be implemented through the integration of various policies and spatial design. This could help to accomplish a sustainable city through imitating past implementation in developed cities. Figure 2-1 illustrates the various research designs and methodological paradigms between two dimensions:

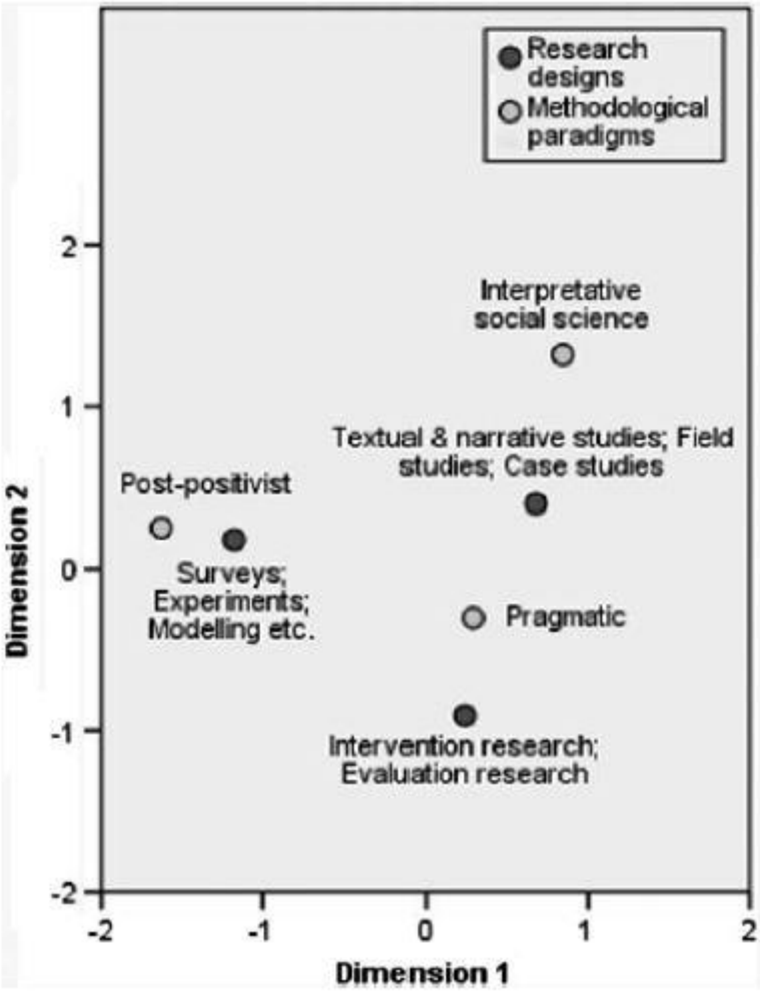


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Figure 2-1 Relationship between research designs and methodological paradigms.

Source: Du Toit, & Mouton, 2011:134

2.3 Research design

The research design is based on a pragmatic paradigm, which uses a methodological approach to the collection and illustration of qualitative data. The research design is illustrated through a primary source of data identified as interpretation (ethnographical, phenomenological and contextualisation). This is expressed through a series of case studies and theories implemented practically or theoretically through hypothesis, which aids in determining various implementable models, principles, guidelines, policies and potential ideas throughout the study, as well as possible challenges and problems that become evident through mobility and spatial implementation (Du Toit, & Mouton, 2011:132). Table 2-1 below illustrates the various approaches to methodological paradigms and various data sources:

Table 2-1 Research paradigms and the pragmatic approach

Design considerations						Research designs
Research context & Research aim	**Research purpose**	**Methodological paradigm**	**Methodological approach**	**Source of data**	**Core logic**	
Basic (towards applied) contexts Theoretical aims	Descriptive Explanatory	Post-positivist	Quantitative	Primary	Generalisation	**Surveys**
					Causal attribution	**Experiments**
				Secondary (numerical/spatial)	Prediction/illustration	**Modelling, simulation, mapping and visualisation**
	Interpretative Exploratory Descriptive	Interpretative social science (towards pragmatic)	Qualitative	Secondary (textual)	Interpretation (hermeneutical)	**Textual and narrative studies**
				Primary (towards hybrid)	Interpretation (ethnographical/ phenomenological)	**Field studies**
					Contextualisation	**Case studies**
Applied contexts Practical aims	Formative Evaluative	Pragmatic	Mixed-method (towards qualitative)	Hybrid	Intervention	**Intervention research**
					Evaluation	**Evaluation research**
	Emancipatory	Critical social science	Participatory	Primary	Participation/action	**PAR**
Basic contexts Meta-theoretical aims	Meta-analytical purposes	NA (Nonempirical)	NA (Nonempirical)	NA (Nonempirical)	Various core logics	**Metaresearch**

Source: Du Toit, & Mouton, 2011:132

CHAPTER 3 SPATIAL PLANNING - A REVIEW

3.1 Introduction

Urban land use models are spatial design guidelines whereby a community should be planned in order to achieve maximum efficiency, economic growth, environmental sustainability and other priorities considered by the planner and dictated by the community's needs (Shaw & Xin, 2003:105). This chapter is partly intended to achieve objective 1 (To evaluate the theoretical foundation of spatial planning tools and their impact on sustainable transport systems).There are many different urban land use models that can be compared. The integration of urban land use models and transport planning has become crucial in terms of environmental impact. The environment is under immense stress owing to transportation and the effects of spatial planning of urban land use models (Wegner, 1995:1-2). Transport policies and environmental provision are often the beginning of poor spatial planning, reflecting lack of awareness of future implications. The main concerns are the impact of the planning on urban land use and the impact of spatial transportation planning. The urban land use models discussed in this document are based on a series of theories and their implementation. This chapter will be the benchmark for the achievement of objective 1 through the evaluation of the theoretical foundation of spatial planning tools and their impact on sustainable transport systems to ensure sustainability.

3.2 Urban land use processes

To enable an evaluation of urban models, guidelines have to be established and promoted. These will evidently form the foundation on which models can be evaluated as very slow, slow, fast-changing and immediately changing with regard to their specific efficiency. The efficiency of the model has been based on spatial structure and the integrative nature of various land uses. This implies that urban models can be classified as ineffective or effective in accordance with functionality between sectors. The functionality of an urban model is based on the process of mobility, which enables collaboration between land use processes, but without mobility and distribution these processes cannot take place (Wegner, 1995:6-7; Shaw & Xin, 2003:104):

Focusing on the various urban models previously implemented, the processes could be regarded as anything from highly inefficient to highly efficient. These processes, as mentioned above, are identified by aspects of mobility in the urban model. These aspects of mobility and distribution are considered in terms of urban transportation, networks, communication and utility networks and encourage cooperation between the various land uses, which are regarded as a permanent physical structure of cities that is difficult to change. Large infrastructure that requires decades or more to construct is not abandoned or terminated. The guidelines that may help this transformation are identified in the spatial development of developed countries, for example Australia. Australia has created a series of implementable guidelines to improve mobility systems in the spatial structure (Adelaide City Council, 2012:30-63).

The urban model undergoes slow changes in terms of urban land use models, consisting of workplaces, households and buildings that may have a lifespan of up to 100 years and take numerous years for planning and completion of the project. The crucial understanding of this guideline is that workplaces (non-residential buildings), such as factories, warehouses, shopping centres or offices, universities and theatres, will survive and occupy the district for longer than the firms controlling them. The same concept is seen when houses continue to exist even when the households that used to live in them have left.

Fast changes in urban models refer to the employment and population of a community. Firms and businesses are closed down or are relocated, which helps create jobs in different areas or makes workers redundant, directly affecting employment rates, which can in turn affect economic growth by increasing or decreasing rapidly. Households will be created and suddenly grow or decline or be dissolved. Households will go through various cycles during which their consumption and location will change, leading to a change in their needs. This ultimately determines the distribution of the population.

Immediate change in urban land use models is considered to be joined and associated with transportation of goods and travel. The location of human activities in a space increases the demand, because of the transportation of goods. These interactions are normally seen as a volatile phenomenon of spatial urban development. This system can be adjusted within a few hours/minutes in terms of change in congestion or fluctuations in demand.

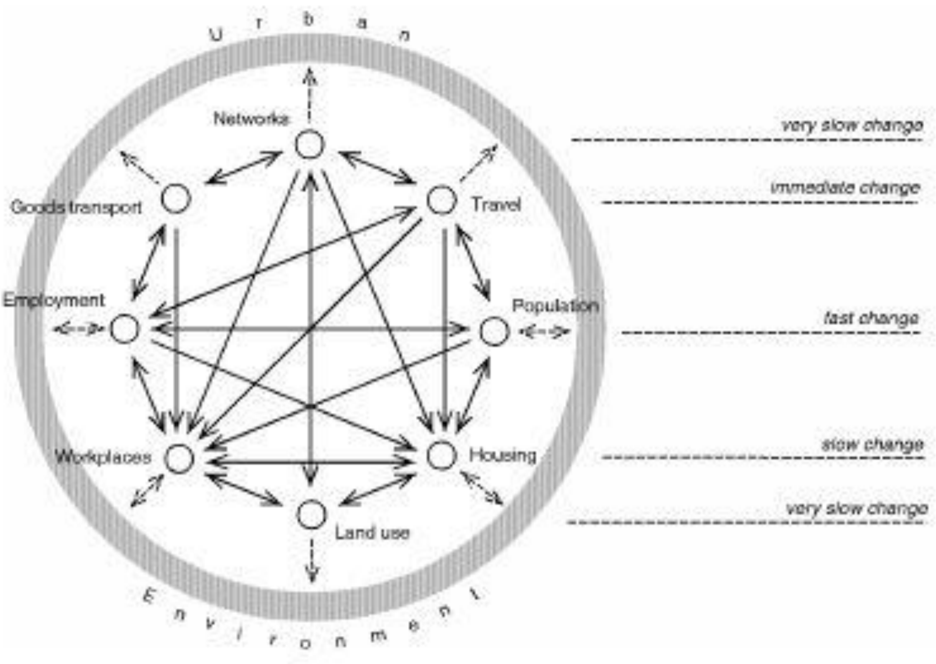

Figure 3-1 Urban land use model variations

Source: Wegner, 1995:6

In terms of urban land use models, 13 models were compared through Wagner's perspective. Each model had certain traits according to which the purpose of the spatial design differed. This perspective related to numerous geographical perspectives on formulating the ideal urban model. The models were also based on different policies, which allowed for a specific result from the spatial plan.

As a conclusive evaluation of the models and the policies implemented, when considering all 13 models, 12 models indicated that transportation improvements and lower travel costs would help to achieve their goal. The goals of each model differed or had some similarities with others, but the solution remained conclusive that transportation system improvements and decreasing travel costs would help initiate a foundation on which sustainability could be achieved.

3.3 Garden city model

As modern times adapt in pursuit of a sustainable future, failed previous urban models do not seem to play a significant role in spatial planning, but act as a reminder of mistakes. The green city model was presented by Howard in 1889 and has proven to be highly sustainable (Hurley, 2014; Clevenger & Andrews, 2017:5). The concept of this model was to preserve as much environmental "greenery" as possible. This allowed the urban model to benefit both the environment and people. This would ultimately affect the climate, in response to the increase in greenery and low emissions. Howard's model was a reflection of future traits without prior knowledge of modernisation. Howard had in fact identified the changing elements at the time and developed this model to illustrate a true urban sustainable model.

To understand the concept of the garden city fully, the vision of Howard is highly significant. Howard had based his vision on three aspects, namely recognising the problem, solving the problem and the methods through which this could take place. Howard had recognised the problem with urban design and land use, taking into account the overcrowding, poverty, crime, high mortality rate, congestion, land distribution, urban sprawl and ownership of land in the nineteenth century industrial city. He conceived the idea of dispersing the population of London to the north, where he planned to establish garden cities. Howard planned on achieving his goal through the nationalisation of rural, undeveloped land for development to be used for new communities, using a small-scale exemplary model (Phillips, 1970:15).

Ebenezer Howard had called this the "garden city of tomorrow" to achieve sustainable urban development. Howard had revolutionised three principles in his development of the garden city (Phillips, 1970:6, Parsons & Schuyler, 2003:531):

1. Scarce land was to be allocated to a specific use for potential users.
2. A better physical environment was to be created in an urban area, thus improving houses and transportation, creating more open spaces to be used for parks and more hygienic facilities, while preserving the environment, which was composed of a large variety of fauna as well as flora.
3. A better quality of life was to be ensured in communities and small functional towns. This would often consist of low-density new towns, since open environmental space was available.

This was considered to be the base of future planning of new towns. Modernisation had taken place, with no recommendations on incorporation into the garden city, because of assumptions that were made (Phillips, 1970:6-8, Parsons & Schuyler, 2003:531). Figure 3-2 below illustrates the garden city model and the assumptions that had been made: That human behaviour/nature, as well as the economy and society's values, would remain the same or at a constant. This led to an ideology that social changes may affect the future design. The final assumption was that the relationship between humankind and the natural environment would remain neutral, while focusing more strongly on the sustainability of the environment. These assumptions were adopted to create the garden city, but lacked principles on matters such as population growth, overuse of natural resources and spatial planning of land use after the city had reached its maximum capacity.

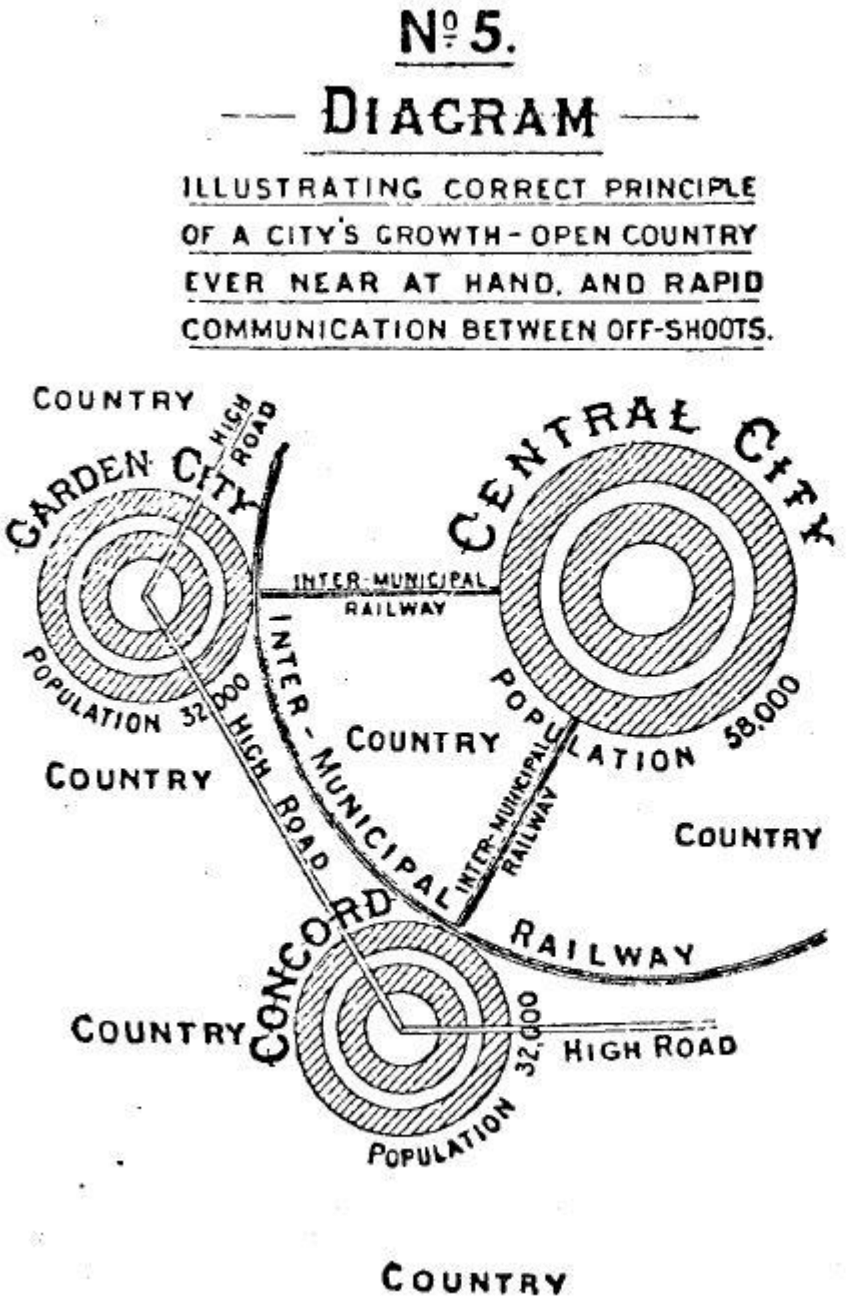

Figure 3-2 Garden city model

Source: Phillips, 1970:50

The garden city had been a significant point of spatial planning, which focused on the layout of the city and its land uses. The above discussions focused on the strengths of this land use model, as well as its weaknesses. The garden city concept has been used in some of the most sustainable/liveable cities in the world (see annexure D), including the cities of Adelaide and Canberra, Australia. The principles have been displayed in every successful spatial development, while adapting to modern city models.

3.4 Concentric ring model

The early stages of design of this theory of land use models were presented by Ernest Burgess in 1923. The theory behind the land use model was that numerous concentric rings would lead the growth of the city further outward from the centre ring. Burgess's theory was created from a previous design of development known as Von Thunen's. The design was initially created to represent rural land use and values century before Burgess. The model was created to illustrate the concept of a medieval village (McDonagh, 1997:1-2).

The most central ring is known as the central district or central business district (CBD), which consists of high-rent uses often occupied by office buildings, department stores and other retailers. The following concentric ring that surrounds the CBD has a variety of uses, including low-rent workers' residences, manufacturing, wholesaling, storage and similar activities. The immediate surrounding ring would also indirectly and directly improve activities in the central zone. The various concentric rings following the ring surrounding the CBD act as low-class wage earners' housing, followed by middle-class wage earners' residences and lastly the concentric ring on the fringe that is devoted to the higher/upper class's residential properties (McDonagh, 1997:2; Waugh, 2002:409).

At a later development phase within the concentric ring model theory, the CBD became known as the 100% spot, which included banks, the principal stores, theatres, hotels and office buildings. This area also became the focal point of commercial, social and civic life in the city. The Burgess urban land use model started to adapt and in time each concentric ring developed its own specific uses, while also being given specific labels to represent an individual concentric ring. As mentioned in the previous interpretation of the urban land use model, the innermost central ring was known as the CBD. The ring surrounding the CBD had then adapted to older homes, flats and other high-density housing, where factories and business establishments were encroaching, known as the transitional zone. The area surrounding the CBD was characterised by a high incidence of crime exerting a negative influence on the CBD, as well as an increase in urban sprawl and slums. Between the CBD and the transitional zone an invisible concentric ring would form in larger cities and would accommodate pawn shops, food courts, pool halls, strip joints, automotive supply shops, shoe repair shops, cheap restaurants and beer gardens (McDonagh, 1997:2).

The following concentric ring after the transitional zone is known as the inner ring of residential areas. The community residential area is situated in this ring and often attracts middle-wage workers from the CBD and transitional area, because of its affordability. The residential status in this ring consists of high-density units and small stands (flats or apartments). This ring is ideal for middle-class wage earners, owing to its distance from the CBD, and allows for easy commuting at an affordable rate. The concentric rings then verge outwards and allow for higher class wage earners to develop their housing on larger properties. This area can best be described as having low density, with more land cover and higher land value, owing to the distance from the factories, the business district and access to the environment.

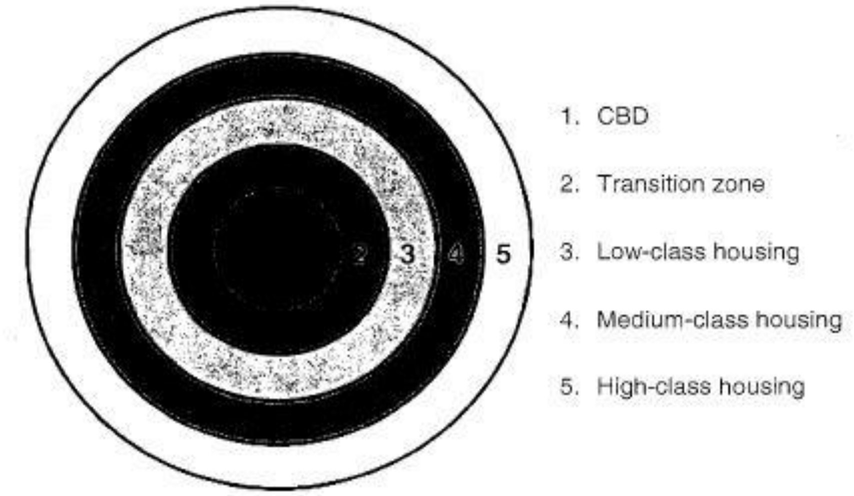

Figure 3-3 Concentric zone model

Source: Waugh, 2002:420

Burgess's concentric zone model had been adapted and as a result was composed of five concentric rings, which can be summarised as (Cilliers, 2010:15; Chaplin & Kaiser, 1979:32):

1. **Central business district.** This comprises the innermost ring containing the shops and offices. It is the main entertainment area and has the highest activity level in the city. This is where economic growth would expand from.
2. **Transition zone.** This is where the old buildings are situated; it is usually poverty-stricken and the inhabitants are poor and from the lower class. Factories invade this concentric ring because land value is low. Blue-collar workers live in this concentric ring
3. **Lower-class housing.** This is occupied by individuals who have escaped the transition zone, but are considered to be poor; because they live close to the CBD and transition zone, their travel costs are lower. This is a high-density area with low land value.
4. **Medium-class housing.** This is a housing zone where land value is higher than in the previous zones and it is characterised by private residences as well as apartments. This concentric ring is home to the more white-collar families.
5. **Higher-class housing**. This area has the highest land value, lowest density and is distant from the transitional zone and CBD.

Assumptions on how the urban land use model will function may have led to the downfall of the functioning of the city. It was assumed (Cilliers, 2010:15) that the lower class would live closer to the CBD, because of their lack of money and the proximity of the working area. The second assumption was that the land on which the city was developing was flat; the theory did not consider geographical features (mountains, rivers), causing implementation issues. The assumption was that transportation was equal in all directions from the core radiating outward, therefore did not prove to be of any significance to the developer of the theory. It was assumed that there would be little or no concentration on heavy industry and that it would not occur in future. Cities were assumed to be composed of well-defined ethnic groups and socio-economic areas. Older buildings would be found towards the inner part of the concentric model, while newer buildings would be situated on the outer concentric rings. Lastly Burgess stated that land value would be highest in the CBD of the model and would only decrease when radiating outwards, which would result in a zoning pattern for urban functions and land use.

One of the main problems with the concentric ring model is that it fails to recognise the impact of transportation routes, commuting time, topographical features and finally competing satellite urban centres on the distribution of land uses. The problem of the incorrect spatial implementation of transportation routes remains unchanged. In the concentric ring theory, traffic routes were recognised as attracting those from lower-class housing, because of the problems caused by traffic volumes. This would also attract lower-income occupiers, who could use the public transportation in close proximity to their homes, similar to the concentric rings model. This theory tends to alleviate the problem, but does underestimate its impact on the area.

The concentric ring model would have this effect in the era when it was created. The concentric ring model was designed in an era when motor vehicles had not yet been invented and heavy traffic did not occur, contrary to the modern-day model of urban land use. Traffic congestion in larger cities is often caused by the incorrect implementation of urban land use design, not considering that adaptation of the design is a general requirement. While travel cost may not be of serious concern to higher-class earners, travel and commuting are still time-consuming, thus decreasing productivity. This affects general economic growth over a period of time, which is detrimental to the urban model (McDonagh, 1997:3).

An additional problem raised in terms of geographical features is that these would often prevent radial development of urban settlements because of the influence and impact on surrounding towns/cities. Urban model design was based not only on one concentric ring formation that developed outwards in a radial movement; in fact, various urban model formations where created and this would affect the patterns and growth of other surrounding urban areas (McDonagh, 1997:3).

3.5 Sector model

This urban land use model was known as the sector or wedge theory and was developed by Hoyt during the 1930s. The theory was very successful in the sense that it resulted in more than 200 000 neighbourhood blocks in approximately 70 American cities. Since the city was unconstrained, the design of the wedge theory was likened to removing a slice of pie from the whole. The different sectors would each be regarded as a “slice”, which would extend from the business district to the outskirts of the city. The individual sectors were influenced by transportation routes. The transportation routes were situated on the boundaries between each sector. These boundary lines and transportation routes where known as the lines of least resistance. The design of this theory helped to create ribbon type street frontages. This led to the radial corridor theory (McDonagh, 1997:3). This urban design form was based on Burgess’s concentric ring design and was regarded as the second classic urban form of spatial planning. The general concept was to develop away from the CBD and segregate land uses in forms of sectors (Cilliers, 2010:16).

The sector theory also symbolises a concept of synergistic relationship between land uses, which in turn was used as an advantage since the sectors were next to one another. A former concept was also implemented by Hoyt, which was the city’s ability to expand and grow. The residential areas that accommodate the middle and higher class were able to develop properties in rural areas on the outskirts of the city without interfering with other sectors. While the middle class would occupy land where rent was paid for a flat or apartment complex, the higher class was able to buy properties and develop these (McDonagh, 1997:3-4).

The problem with the theory was that because of developing houses for middle- and upper-class residents, the land value increased, making it unaffordable for lower-class residents. Because of the markets and value of the land, middle- or lower-income houses were no longer viable.

Hoyts’s theory emphasises that topographical factors would be used to increase the value of housing; for example, waterfronts, land with a view, natural beauty and high ground would all increase profits on housing. Transportation routes were situated far from these areas and lower-income housing was placed close to industrial sites in order not to decrease land value (McDonagh, 1997:4). Hoyt had made assumptions based on the model, which were the same assumptions Burgess had made, but added three more, which seemed of some relevance (Chapin & Kaiser, 1979:35; Waugh, 2002;422):

- Higher-class individuals could afford more expensive modes of transportation, such as cars, and could afford to live further from industries. The idea was to situate the higher classes near main roads of transportation, since money was not an issue.
- The assumption was made that wealthier people could choose the best sites for development, therefore placing competition on the ability to pay.
- Similar land use would attract other similar land use; this led to the concentration of a specific form of land use while repelling any other land use, resulting in sector development.

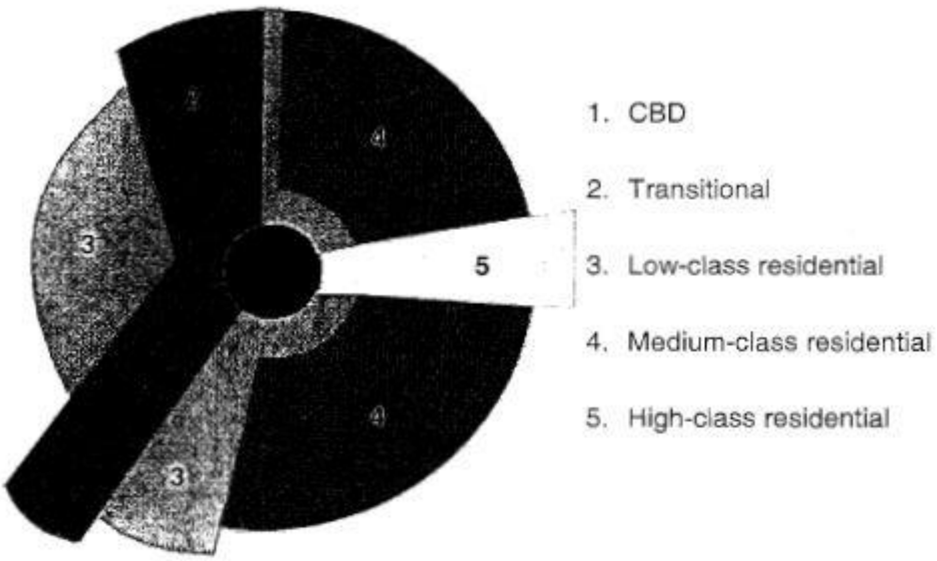

Figure 3-4 Sector model

Source: Waugh, 2002:422

An important factor that Hoyt had identified in the urban model was that transportation systems had contributed more than expected to spatial growth and functioning. This model had also been designed in the early stages of the combustion engine and vehicle ownership was relatively rare, considering the number of individuals who were able to afford such an expensive commodity. This implies that if transportation systems were seriously considered in the early stages of creation, they should be considered in terms of being a crucial promoter or cause of deterioration of urban growth.

3.6 Multiple nuclei model

Harris and Ullman analysed the concentric zone and sector urban land use models and realised that the perception of the model and the design did not include many aspects that might cause future problems. Their design was based on a realistic approach to the urban land use design model, which included the determining factors that may affect the urban design function. This model was in fact more complex than those of Burgess and Hoyt, but would shed more light on the general functioning of urban design. Harris and Ullman's model is regarded as the third and last classic urban model design in terms of the spatial design of cities (Johnson, 1967:170; Herbert, 1972:72). The multiple nuclei model was thus established as an original urban land use model in 1945 (Wegner, 1995:4).

The multiple nuclei urban land use design was used for very large cities and was considered to be an enlargement of Hoyt's design. This was due to the evolvement of the metropolitan area, which would grow to more than one business district and was located along major transportation routes at some distance from the CBD area. The nuclei (CBD) would develop a type of hierarchy, through which an equal rank would have been established through the types of land use. One of the main reasons it was regarded as a multiple nuclei model was the fact that cities were forever expanding and sometimes overrun; this would force commercial areas to act in terms of the nuclei, allowing the city to grow in a larger land use pattern (Wegner, 1995:4).

Time and distance became a problem in terms of the spatial planning of the model, causing the CBD to start playing other roles. The problem originated at the start of World War 2 (WW2), when motor vehicles became more important and the widespread development of transportation systems and construction of new streets became a general need. This resulted in urban congestion in the CBD. It was realised that traffic congestion could be prevented through public transportation systems, which could contribute immensely to the strength of the CBD (Wegner, 1995:4).

The assumptions made on the multiple nuclei model were based on Burgess and Hoyt's theories and the realisation of the consequent model was interpreted accordingly (Herbert, 1972:72; Chapin & Kaiser, 1979:36; Waugh, 2002;423; Pacione, 2005:145):

- Nuclei act as a growth point with their own unique main functions within the urban land form (city).
- Over a period of time each nucleus moves outwards in growth and they all merge as one large urban land form centre.
- Modern-day cities have a much more complex urban design and structure than the simple design illustrated by the models of Burgess and Hoyt.
- Cities/towns do not grow from a single nucleus, but from several independent nuclei.
- If the city becomes congested and too large, some functions may be dispersed into new nuclei.

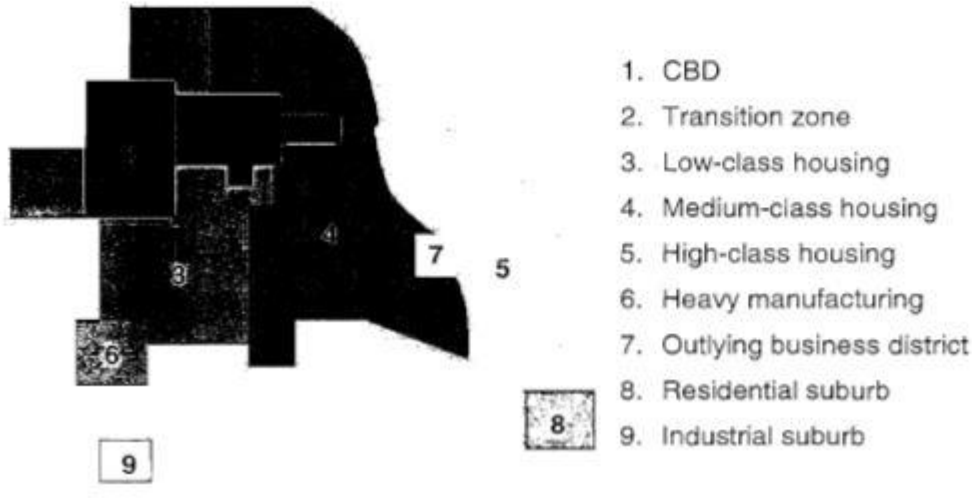

Figure 3-5 Multiple nuclei model

Source: Waugh, 2002:423

Harris and Ullman stated that not all cities can be ordered according to the same model, since each city may differ in some aspects, such as social, cultural and industrial circumstances. This defines the city's layout and may not accommodate the correct land uses in the appropriate areas (Pacione, 2005:145). The urban land use model created by Harris and Ullman was beneficial in that it responded to the need for maximum accessibility to the centre in order to keep land use separate to maintain land value and more importantly, for the purpose of decentralisation (Chapin & Kaiser, 1979:37). As a point of interest, nodes will develop on the periphery and extend outwards.

3.7 Adaptations of classic urban land use models

The interpretation and comparison of the above-mentioned classic urban development models resulted in the accusation that over time urban growth would result in a succession of different land uses. This was interpreted as meaning that the highest and best land use would occur for the correct purposes. The assumption was made that commercial areas, being constrained by various layers of surrounding land uses, would eventually expand and redevelop the neighbouring uses, which in turn would change the land to a commercial property (Wegner, 1995:5).

Through the adaptation of urban models, land use started to be based on land value and cost rather than the potential of the land itself; this filtered out lower/medium-class housing (Wegner, 1995:5). This means that housing for blue/white-collar workers was not developed, thus forcing them closer to industrial areas and closer to major transportation routes, where land value had decreased because of noise and air pollution. This also allowed them to gain access to the CBD because of the short distance and lower travel costs. Burgess and Hoyt both assumed that a conventional city would develop around a single nucleus. While Harris and Ullman acknowledged the assumptions made by Harris and Hoyt (Herbert, 1972:72), their model still portrayed that the highest order node was situated in the centre (Van der Merwe, 1989:142). The modern-day city has grown and adapted to many factorial changes and revolutionised the urban land use design, while accommodating major shopping centres and distant neighbourhoods. This has led to a complicated framework for the urban structure (Johnson, 1967:172; Mayer, 1969:33). The classic urban land use models have been modified several times. The relevance of six of these models will be interpreted and analysed according to the era in which they were designed. This will illustrate how urban land use models have adapted over a period of time:

- Mann's model of the urban structure
- Kearsley's modified Burgess model
- Vance's urban-realm model
- White's model of the 21st century city
- Davies' apartheid city model
- Simon's modernised apartheid city model
- Alonso's theory of land use.

3.8 Urban structure model

The first modern-day model that was modified was Mann's urban structure model, which was designed through the combination of the urban design models of Burgess and Hoyt. The urban land use model was presented in 1965 and was implemented in three industrial towns in Britain. Mann had included the concentric rings from Burgess's model and the sector factor from Hoyt's urban model (Johnson, 1967:169; Herbert, 1972; Waugh, 2002:422; Pacione, 2005:147). His model took into account air pollution from vehicles and industries, as well as wind factors that would determine the functionality of his urban design, while still allowing specific villages to access the CBD (Johnson, 1967; Waugh, 2002;423; 167).

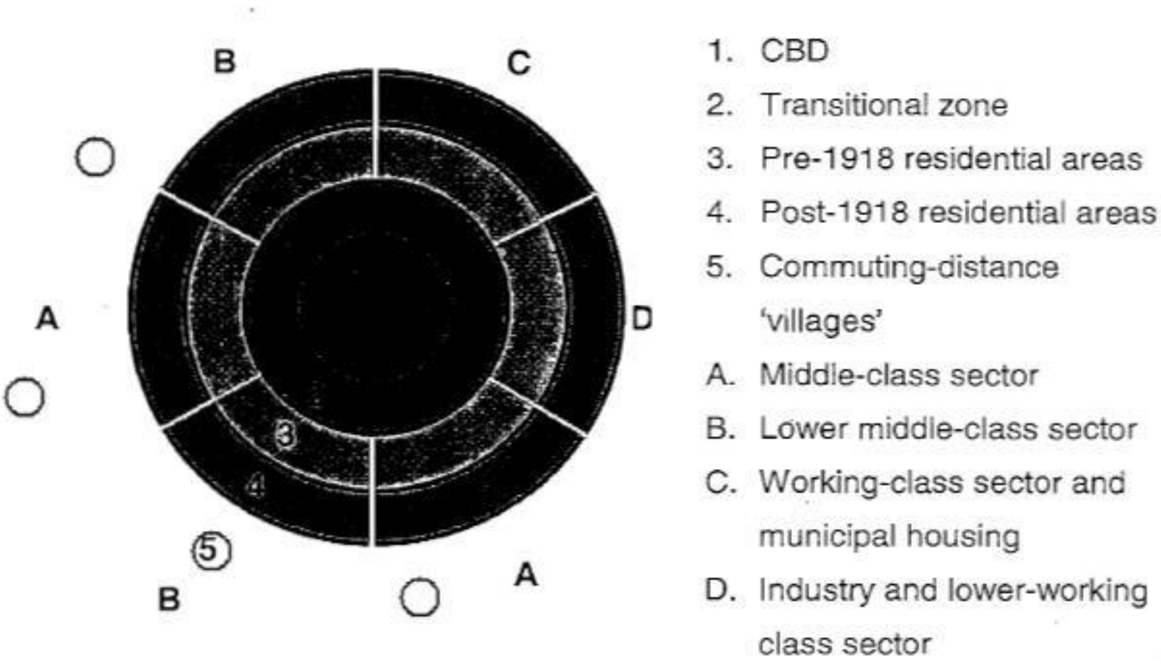

Figure 3-6 Urban structure model

Source: Waugh, 2002:423

Mann's model of the urban structure included certain points on which the model would be based, and how it would affect the cities' functioning. He collected important aspects of the design and summarised them into five crucial points that illustrate the importance of his urban design structure (Waugh, 2002:422; Pacione, 2005:147):

1. Higher-class housing would be situated away from the business district and industries because of the noise and pollution in close proximity to these. The land value would consequently be higher and the environment would be more pleasant.
2. Heavy industries would be situated along the main lines of communication and major transportation routes away from higher-class neighbourhoods.
3. The CBD was centred away from the transitional zone and was not concentric to the CBD, thus accommodating higher-class residential areas.
4. Lower-class housing would be situated close to industrial/business areas, owing to its low land value, high density and close proximity to work, thus lowering travel cost as well as the initial rental cost. This area was known as the "zone of older housing".
5. Slum clearance and gentrification are a phenomenon through which low-cost, physically deteriorated neighbourhoods undergo physical renovation or redevelopment and this increases property value. This leads to the development of large council estates and forces working-class groups to the periphery of the city. This strategy was implemented by the local government to eliminate slums and stop stagnation of the urban environment.

3.9 Modified concentric ring model of urban land use

The aim of this urban model was to replicate Burgess model, but to adjust the urban structure by taking into account the contemporary dimensions of urbanisation. This would then focus on the level of government involvement in the urban environment, slum clearance or elimination, sub-urbanisation, ghetto isolation and finally decentralised economic activities.

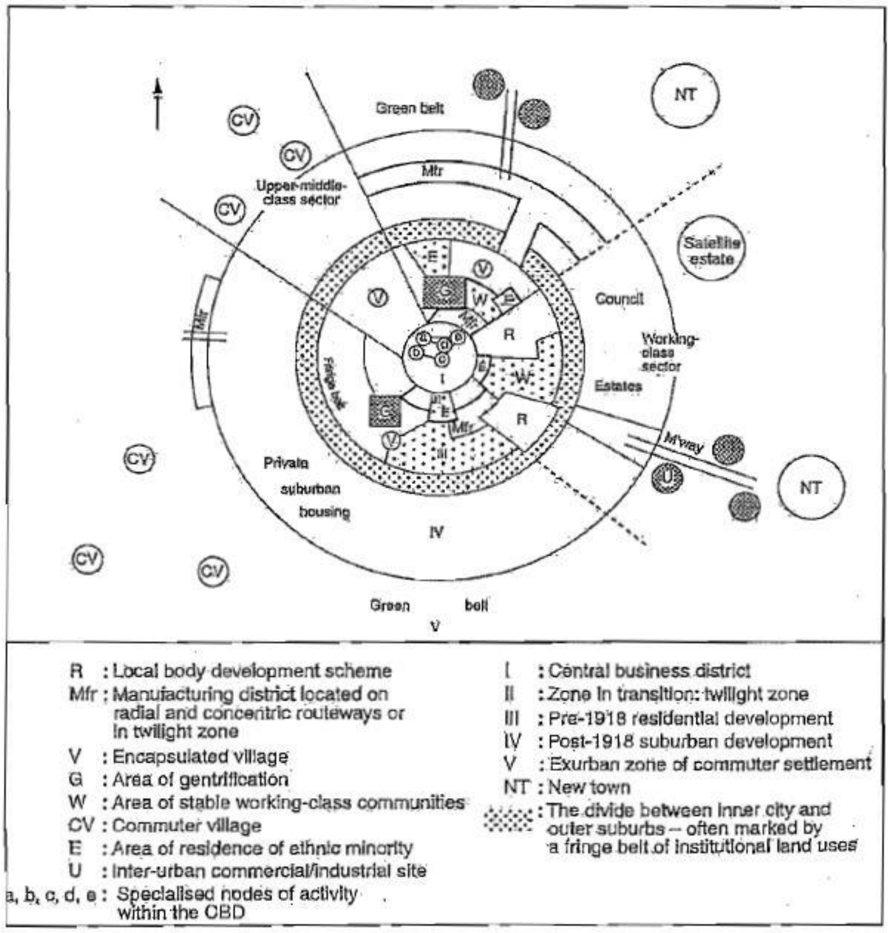

Figure 3-7 Modified concentric ring model of urban land use

Source: Waugh, 2002;423

The urban model that is represented in the figure above was presented in 1983. The model also illustrates satellite estates, new towns and council estates (Pacione, 2005:147). This model has been implemented in Britain based on the factors of minimising government houses and slums.

3.10 Urban realms model

Modernised urban land use structure models are all based on previous models in which mistakes were identified to create an urban model with minimal problems. Vance’s urban realms model is not an exception to the above statement; its foundation was laid by the more primitive urban land use model known as the multi-nuclei model. The model suggests that Vance had focused on self-sufficient areas where the focus was more strongly on traditional downtown areas. Vance's model also focused on urban growth and would often refer to new urban areas as "urban realms", hence the model's identity (Vance,1964:78; Cilliers, 2010:20).

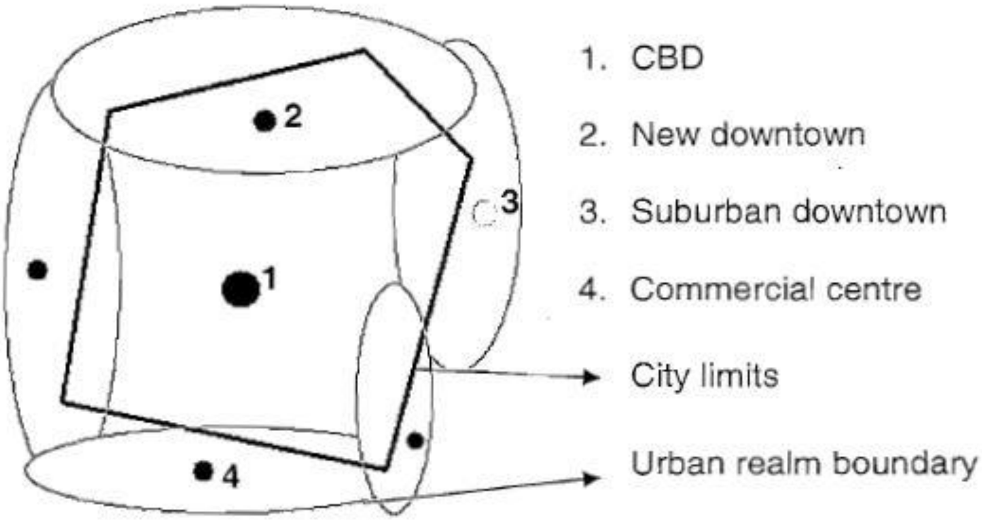

Figure 3-8 Urban realm model

Source: Vance, 1964

The urban model's identity had been based on five criteria according to the functioning of these specific factors (Lang & Nelson, 2007:6):

1. Topographical terrain
2. Size of the existing metropolis
3. Accessibility and interaction between realms
4. The economic activity of each realm
5. The accessibility of each realm.

The five criteria allowed the urban realms to shape themselves and to achieve horizontal growth as a result of Vance's proposed assumption. The urban realms incorporated buildings and corporate headquarters, including cultural and entertainment facilities, which suited the realm's cultural needs (Pacione, 2005:199).

3.11 The twenty-first-century city model

The twenty-first-century city model was based on the concentric zone model (White, 1987:236-242). The model was presented in 1987 as a revision of the concentric zone model. The proposed aim of White's model was the incorporation of certain modern traits that had been important for the urban land use structure. The traits that White incorporated were industrial development, social interaction, suburban residential areas, decentralisation of businesses as well as industries, increasing intervention in the hope of urban growth and motor vehicles or specific types of automobiles. This would allow for new trends to emerge in an urban land use structure (Pacione, 2005:198-199).

White's model of the twenty-first-century city had been created through the concept of the elements illustrated below (White, 1987:236-242; Pacione, 2005:198-199). The model comprised a core (first element) CBD district in its centre. The second ring, which surrounded the CBD district, was known as the zone of transition or zone of stagnation. The zone of stagnation would be occupied by manufacturing industries and other industrial factories. Owing to increasing manufacturing and industrial land use, land value would decrease and attract small pockets of poverty-stricken individuals. The model was also created with elite enclaves, allowing for the integration of various cultures. The third surrounding ring would often be used for the diffused middle class, which could afford higher land value, but not expensive land. The model would have various industrial anchors and public sector control, which could be accessed through multiple epicentres and corridors in it.

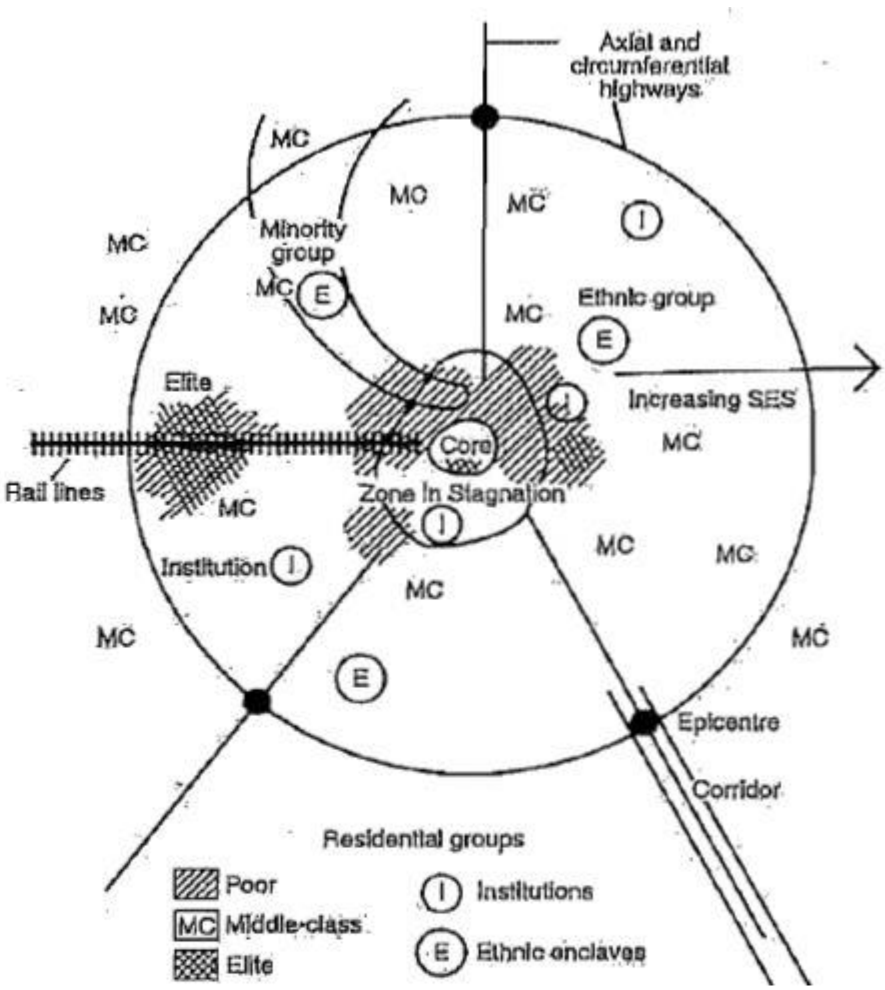

Figure 3-9 The twenty-first-century city model

Source (White, 1987

The concentric ring model contained the CBD. This element would remain the focal point of the actual metropolis. The purpose of the CBD has remained unchanged and despite its funtions becoming more complicated through years of adaption, it still consists of houses, financial institutions, corporate head departments and government buildings. According to White a few large department stores have been able to retain their flagship developments downtown, but the majority of retail stores have moved with the rest of the affluent population towards the suburban regions in hopes of keeping close to customers (Pacione, 2005:149).

White had identified from Burgess's assumptions that the CBD would eventually attract investors that would inevitably expand the CBD into the zone of transition. White identified the issue in response to Burgess's assumption and stated that the CBD would not expand outwards but rather vertically. He identified this as the zone of stagnation. This was due to increasing slums and highway issues, calling for drastic measures to deal with slum clearance and highway construction and led to the relocation of transport routes and warehouses to residential suburban areas. The older US industrial cities have considered revitalising the area for entertainment, developing cities (Dallas, Texas), shopping areas and residential communities (White, 1987:236-240; Pacione, 2005:148-149). This would lead to the zone of transition never being able to develop or function according to the urban design model of Burgess.

This specific element was illustrated by White to identify that different family groups are class-segregated on the periphery of society. This includes the homeless, addicts, the lower class, minorities and other dysfunctional families. These slums are often located in the inner city ring described by White as the zone of stagnation. White had also identified that the surrounding area would reflect people's status in the community, as well as their financial background (White, 1987:236-240).

The elite enclaves where higher-class individuals would live immediately identified the class of the area through the word White used (elite). These would be situated on the periphery of the city and would often attract wealthy individuals to purchase estates and property. This would happen because of the distance away from the industries and slums, which increased the value of the land, offered an immaculate view on nature and was characterised by low noise and crime rates. According to White the purpose of this zone was to avoid the problems associated with the metropolis and allow land value to increase, enabling higher-class individuals to purchase expensive property in the pursuit of calmer neighbourhoods. This element had been allocated the largest area in the model of the metropolis, which comprised an area spatially concentrated between the outer edge of the central city and the metropolitan fringe. This was known to be a suburban zone that was characterised by its socially diverse activities and had two important traits (White, 1987:236-240):

- This was considered to be the interior section of the model, where many families originally settled before going through the transition of moving to other dwellings. This attracted the interest of a majority of black middle-class workers. In this process a large number of African Americans would move to suburban areas and live relatively dispersed among other races.
- The outer division would consist of families with younger children and comprise spacious areas and segregated housing. This would be detached housing with gardens and this would also lead to nucleation of industries, businesses and social groups.

Industrial parks have an indirect or direct effect on the forming of the metropolis. Areas where these come into being may have numerous uses for development and can be used for hospitals, universities, businesses, industrial parks, offices and main corporate headquarters. This would influence residential and land use patterns and the way in which future development may have to take place (Pacione, 2005:148-149).

The evolution of urban design structures in the twenty-first century reveals that the modern-day metropolis has distinguishing features. The first feature has to do with the emergence of peripheral epicentres located at the outer beltway and axil axial superhighway, providing a range of transportation services towards the CBD. The second feature that is highly distinguishable is corridor development, which attracts intensive economic development.

3.12 Urban fabric model

The urban fabric model refers to the use of urban metabolisms as a way to understand and implement sustainable cities. This model refers to cities or urban structures as living organisms that undergo various metabolic processes (input and output). While organisms differ, so do cities and urban structures. The urban fabric model considers three different parts of cities, which constitute the basis of each city and relate to the different metabolic systems. These three parts of a city are regarded as the automobile, transit and walking urban fabrics, which require various forms of infrastructure within the urban structure. The urban fabrics model understands the metabolic process of input and output, which refers to the use of natural resources and development of open space. This can be regarded as a destructive component in the natural environment. This model does follow an ecologically extractive process, but can be reversed into understanding the implementation of sustainable cities. This model identifies improvements to cities as well as solutions that can be implemented. The model identifies that different urban fabrics have different urban metabolisms, but the urban fabric model is considered from the perspective of change, not necessarily as a static model that can only function with specific models. It focuses on regenerating the biosphere to repair damage being done or previously done by that specific urban structure (Thomson, 2016:37-42).

The urban fabrics model is created from three aspects of mobility, which are considered the typical aspects of cities in the urban fabric principle. The figure below illustrates the design of the urban fabric model, while considering the three main aspects of transit, automobiles and walkability (Thomson & Newman, 2018:218-219):

Figure 3-10 Urban fabrics model

Source: Thomson & Newman, 2018:219

The above figure illustrates the urban fabrics model, illustrating the three main urban fabrics (automobile, transit and walkability) and how these are implemented in an urban structure. This model represents potential solutions to regenerate urban structures (cities), in response to rapid growth in the human population. This illustrates major constraints in spatial development, due to rapid urbanisation taking place, which can be highly detrimental to both humans and the environment (pollution, decrease in natural resources, deterioration of natural environment). The model presented in the figure above is not a singular model designed from one perspective; with closer interpretation it can be identified that many models are represented in the urban fabrics model. With closer interpretation, one identifies the following:

❖ Use of circles

The use of circles and connected transportation routes, which was previously discussed in Chapter 3 (3.3). Howard's garden city design is based on the use of circles and nodes. The nodes comprise various concentric rings, which then illustrate the principles represented in the concentric ring model (3.4) and modified concentric ring model (3.9). The concentric ring model illustrates the use of various rings symbolising various sectors of an urban structure, but the urban fabrics model illustrates an area segregating a particular mobility system. This means that various sectors could correlate with different mobility systems (Phillips, 1970:50; Waugh, 2002;423).

❖ Regenerative design and urban fabrics

Urban structures form and expand with urbanisation and rapid human population growth, which forces the urban structure to expand, **covering** the environment slowly. The problem with these fairly basic events is the slow depletion of natural resources. The more rapidly the population grows, the higher the rate at which natural resources are depleted. The urban fabrics model has identified a solution using landscape architecture in the realm of developing urban structures. This model illustrates the typical Anthropocene, where the human population determines the climate and environment. The Anthropocene can affect the environment both negatively and positively, but in this age the effect is considered negative rather than positive. This is characterised by the rapid population growth of humans, as well as the waste and pollution created by the large population, but also has numerous other negative effects. This model considers the redesigning of urban areas, known as "regenerative cities", which are developed by landscape architects and apply to the whole urban system (Thomson & Newman, 2018:220-221). This urban model refers to various aspects of the ecological-infrastructure system of cities as these relate to urban metabolism. This helps to recognise cities and their potential opportunities regarding economic growth. **Three aspects** of cities that display regenerative traits are described below**:**

1. Has environmental ethics as an environmentally enhancing, restorative relationship between the cities and the natural systems they depend on.
2. Based renewable energy systems.
3. New lifestyle choices and economic opportunities which will encourage people to participate in this transformation process, which not only is efficient, but improves quality of life.

The above aspects represent the foundation of a regenerative city and are based on the concept of sustainable development. Rather than focusing on net worth in the present circumstances, the future should be considered to enable cities to build capital for future generations rather than using the remaining natural resources to gain profits. This is considered an investment in future growth rather than expenditure with no future in the urban structure. This supports the urban fabrics model concept of sustainable cities. Rather than growing economic capital with no future, one should grow natural capital to extend future growth.

The adoption of this model can lower ecological footprints, as illustrated in Australia. Australia demonstrates a huge ecological footprint, which is three times the global average. The model is not just a theoretical application, but considered to be a solution with practical implementations. The fact that makes the urban fabrics model significant among other models described in this chapter is its ability to interpret human behaviour and accommodate it according to the pattern as well as the predictability that humans exhibit. The urban fabrics model illustrates that it is possible to increase sustainability by decreasing waste and pollution. The process involves increasing renewable energy, recycling, decreasing cars per person and increasing the use of public transportation.

The theory of the urban fabrics model shows how transportation systems create city form and function. This theory was created from earlier models, which represent how transportation determines the urban form and functions within it. The urban fabrics model is created through three city fabric types, as identified above:

The walking city

The first city topology includes the simplest design and type of mobility (walking), which had been used predominantly in the 1850s. This type of transportation was classified as only one of the two types of mobility available in that era. The other type of transportation used was animal-powered transportation, which was used for longer distances (town-town travel), but was inefficient for short-distance travel. Individuals would use walking as a mobility system within the urban structure, although walking had been categorised as a slower type (3-4 km/hr) of transport. Walking also placed certain limitations on travel when distances increased beyond 3-4 km in the urban structure. The walking city had its own benefits regarding mobility, which can be described as the following (Pacione, 2005:789-790; Thomson & Newman, 2018:221-222):

1. Improving quality of life (health)
2. Little to no pollution
3. Simple and effective over short distances
4. Little to no maintenance
5. Used by all age groups
6. Preservation of the environment

7. Simple infrastructure.

The walking city was short-lived because of the need to travel between cities, the increasing population, and the need for efficient transport to carry masses of freight and increase productivity. This initiated a slow change from the walking city to the transit city.

The transit city

The transit city displayed an efficient urban fabric, which enabled the efficient movement of individuals and freight and was not restricted to short-term travel. The transit city originated between 1850 and 1950, and the objective was to link cities. The transit city had been confined to two main types of transportation, one of which was movement within the urban structure and the other linking urban structures. Close proximity transportation involved trams, which were used for fast/mass mobility of individuals within the (5-10 km) urban structure. The second type of transportation system involved trains, which also used rail infrastructure, but could travel between cities (40 km) efficiently with large numbers of passengers and large amounts of freight, making the system effective. While these rail-operated transportation systems could achieve greater mobility than walking and animal power, they could also achieve this at faster speeds and would often average between 10-20 km/hr, with some trains averaging 80 km/hr between cities (Rodrigue, et al., 2006:178; Thomson & Newman, 2018:222).

The use of trains and trams helped to support development corridors and offered an effective means of travel, but required a lot more maintenance that the walkable city did, while infrastructure was important within the transit city but not considered within the urban fabric of the walkable city. The fact that the benefits of the transit city outweighed its negative effect was considered to be an evolutionary step forward in the development of mobility. The use of trams/trains stimulated ideas on the use of SOVs in urban fabrics. This has brought about the automobile city since the 1950s.

The automobile city

The automobile city allowed a move versatile approach to development; it was not limited to rail and was not based on the common interest of masses of individuals, but rather on each individual. This allowed for more flexible movement throughout suburbs and urban structures. The automobile city could accommodate short-distance as well as long-distance travel, automatically making it a superior transportation system. The infrastructure for roads and facilities for vehicles would increase; more automobiles would be used instead of public transportation. This was due to the personalisation of mobility, where time was dictated according to each individual. The problem identified within the automobile city is in fact fairly common: as one transport service becomes more efficient and accessible than the other, it will be more frequently used while other transportation modes stagnate. The problem has been identified that in the automobile city SOVs will dominate the urban fabrics of the transportation system (Thomson & Newman, 2018:222).

The automobile city has become convenient for the individual, but lacks the incorporation of various other modes of transport, since automobiles are the most frequently used and most effective, so there is no need to use other modes of transport. This becomes rather problematic because of various congestion factors and in a chain result decreases productivity as well as efficiency. The urban fabrics model has identified the three common urban fabrics, but the point of focus is only created once understanding of human behaviour and thoughts is reached.

3.13 The Marchetti constant

The Marchetti constant is based on the anthropological invariants in travel behaviour. The model illustrates the travel time allocated to various transportation modes and illustrates that personal travel tends to be controlled by basic instincts rather than economic drive. The model focuses on human beings through a psychological perspective, which interprets humans' basic instinct to claim territory, while avoiding predators and finding a safe haven. The model follows a behaviour approach, looking at the broken-down animalistic human who seeks to acquire basic needs in order to thrive. This is relevant to the above urban fabrics model, where humans tend to choose the more efficient option regarding transportation. This is illustrated in the concept of the three urban fabrics (walking city, transit city and automobile city), which identifies that a human abandons all transport besides automobiles as a personal choice in transport. The figure below illustrates the Machetti model regarding anthropological invariants in travel behaviour and indicates how it applies to the distance travelled in each transportation mode (Marchetti, 1994:75-77):

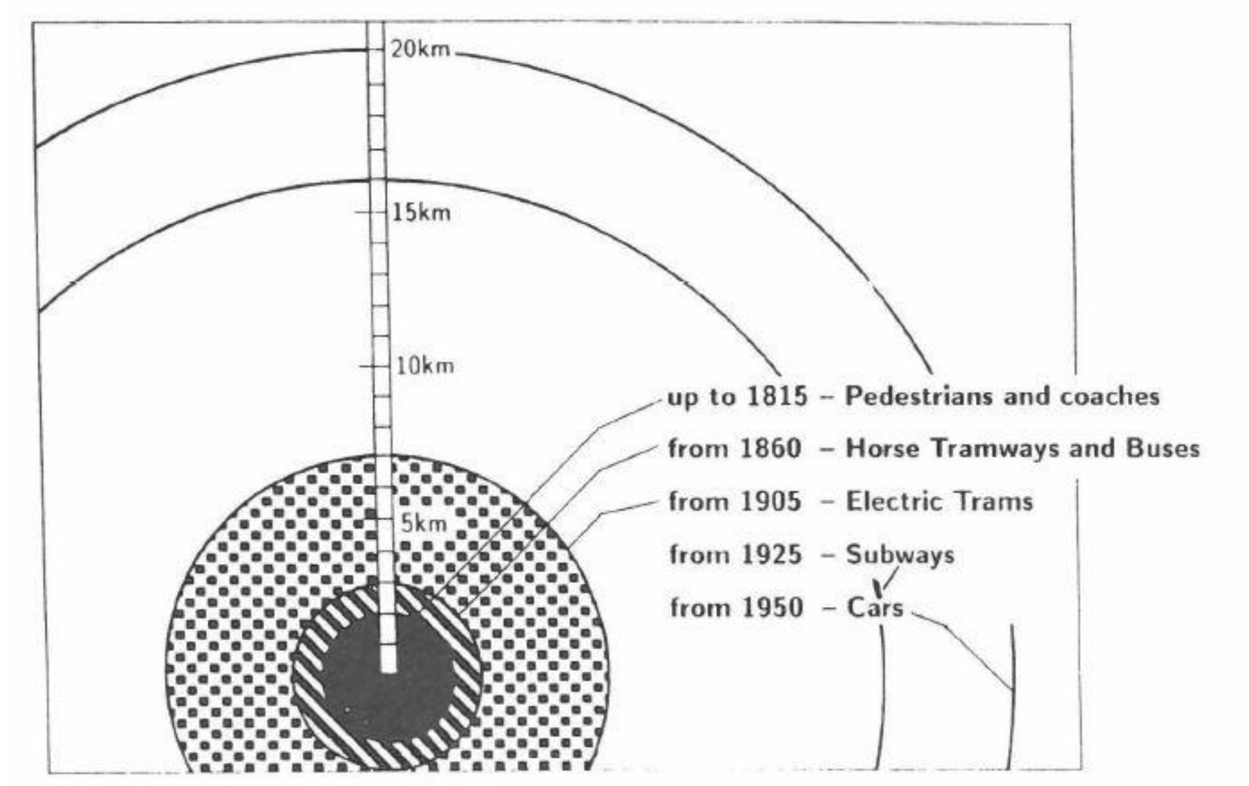

Figure 3-11 Anthropological invariants in travel behaviour

Source: Marchetti, 1994:77

The above model illustrates the various distances considered between various sectors. The model regarding the urban structure is very similar if not the same as the garden city model illustrated in Chapter 3 (3.3) and the same as the concentric ring theory (3.4), as well as the modified concentric ring model (3.9), while focusing on past models. The urban fabrics model (3.12), which illustrates the concentric rings regarding various modes of transport, is based on a larger scale than Marchetti's constant. This illustrates the implementation of the same urban structure with different methods of transport implementation.

The figure above not only illustrates the various distances and how these correspond with various modes of transportation within the urban structure, but also how the city has expanded and incorporated new transportation modes to accommodate its structure and size. The concept identified is ultimately to create compact cities. The above design is illustrated in Berlin. The CBD is only 2.5 km from the transitional zone (3.4), as identified in the concentric ring design, which is the reason for the walkable mobility system and the distance of implementation, while this model focuses on 5 km as the maximum distance travelled by walking. The Marchetti constant identifies that the centre or core of the city is the point that the largest number of individuals can reach in less than 30 minutes. The principles that the Marchetti constant exhibits are the following (Marchetti, 1994:76-78; Thomson & Newman, 2018:219):

1. Five kilometres is the maximum distance travelled by walking.
2. There are two and a half kilometres between the centre of the CBD and the transitional zone.
3. The urban structure is such that transportation can reach areas as far as 20 kilometres squared.
4. The principles apply to the political, economic and population zones and the physical size of the urban structure.
5. The centre of the city is defined as the point that the largest number of people can reach in less than 30 minutes.

The interest of the Marchetti constant was in implementing transportation in accordance with distance travelled. This determines the type of transportation required and the efficiency needed. The Marchetti constant incorporates higher-, middle- and lower-class individuals, which are also allocated to specific transportation modes. This can be correlated with the concentric ring model (3.4), which emphasises the various land use sectors.

3.14 Apartheid city model

This model was implemented in South Africa with the intention of political segregation of races. This model signifies the distribution and segregation of land uses in order to delegate sections of land to various races.

The apartheid city model was prevalent in the pre-apartheid era, when the segregation of racial groups was enforced by the government in order to stop social interaction between minority groups and white individuals (Davies, 1981; 59-72). The apartheid model was merely based on Hoyt's model and shows a structural resemblance. The apartheid model was implemented in South Africa, according to Simon (1989; 191). The apartheid city was implemented according to the 1950 Group Areas Act, which had been implemented to separate racial groups in South Africa (Christopher, 1984; 77; Simon; 1989; 191). The aspects relating to the segregation of racial groups were the following:

- African residential areas, known as townships, were initially separated from white settlements.
- The CBD consisted of white business owners.
- Other ethnic groups, such as Indians and coloureds, were situated adjacent to the African residential settlements.
- The industrial zone was used as a buffer to separate white from non-white ethnic groups.

- A secondary CBD was allowed for Indians and was located close to their residential area.
- The white residences (higher, middle and lower income) were situated around the white CBD.

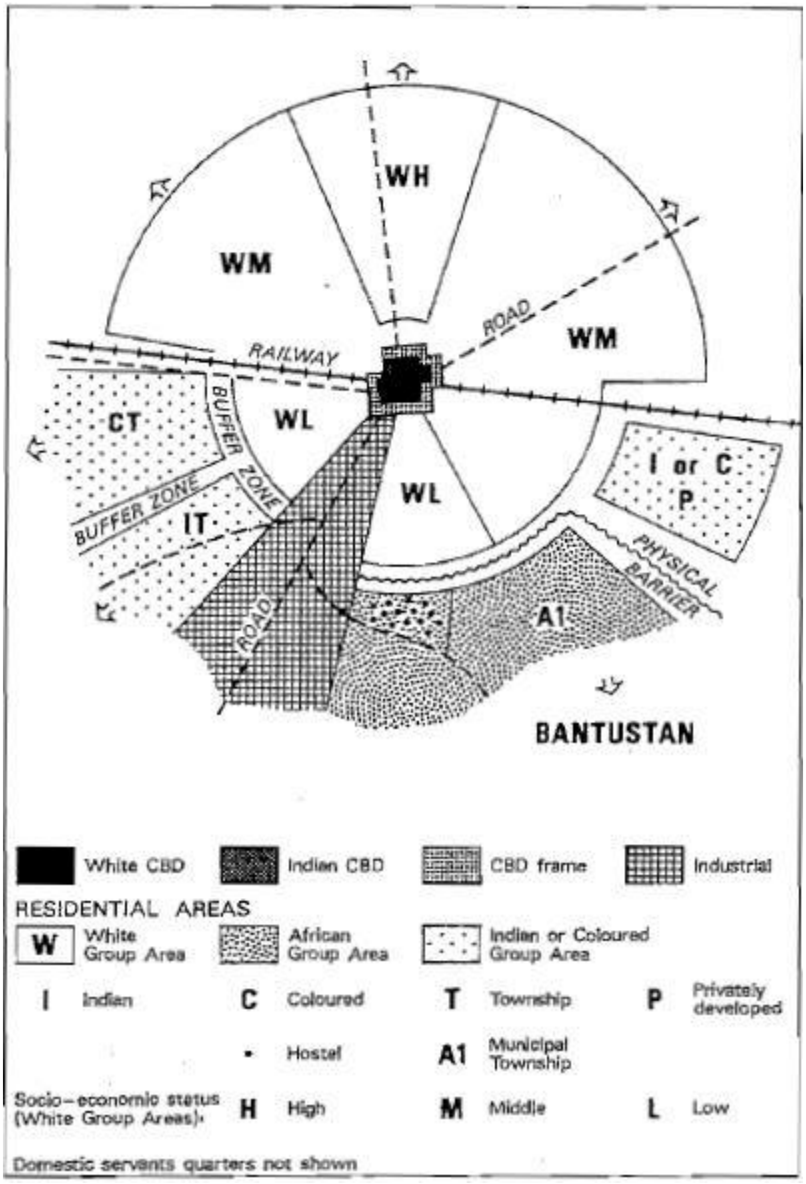

Figure 3-12 The apartheid city model

Source: Simon, 1989:192

The model had been formed through strong political ideologies, which led to the forceful removal of residents and being allocated to specific areas according to the model. This model removed the basic rights enforced by the constitution, which explains why it is is mostly frowned upon when discussed. In general terms, the apartheid city model focused on outward growth towards the periphery of the city. This feature of the urban design model has been seen as similar to the sector model, thus revealing the base concept of this urban model.

Modernised apartheid city model

In considering the apartheid city model, Simon had modified the model in hopes of eliminating its faults and allowing for better functioning of the urban model (1989). The modified apartheid model was designed to cope with the political environment and international pressure to place sanctions on South Africa (Simon, 1989:191). South African spatial development was revolutionised from that point; cities and towns would never be the same again. The aspects that had been revolutionised and had changed how South African cities/towns would function were the following (Simon, 1989:194-196):

- Free trade establishments were allowed outside the business district area.
- A multi-racial CBD was created and allowed all races in some areas of the CBD. This is known as an “open business district”.
- This allowed all races to conduct business regardless of the colour of their skin.

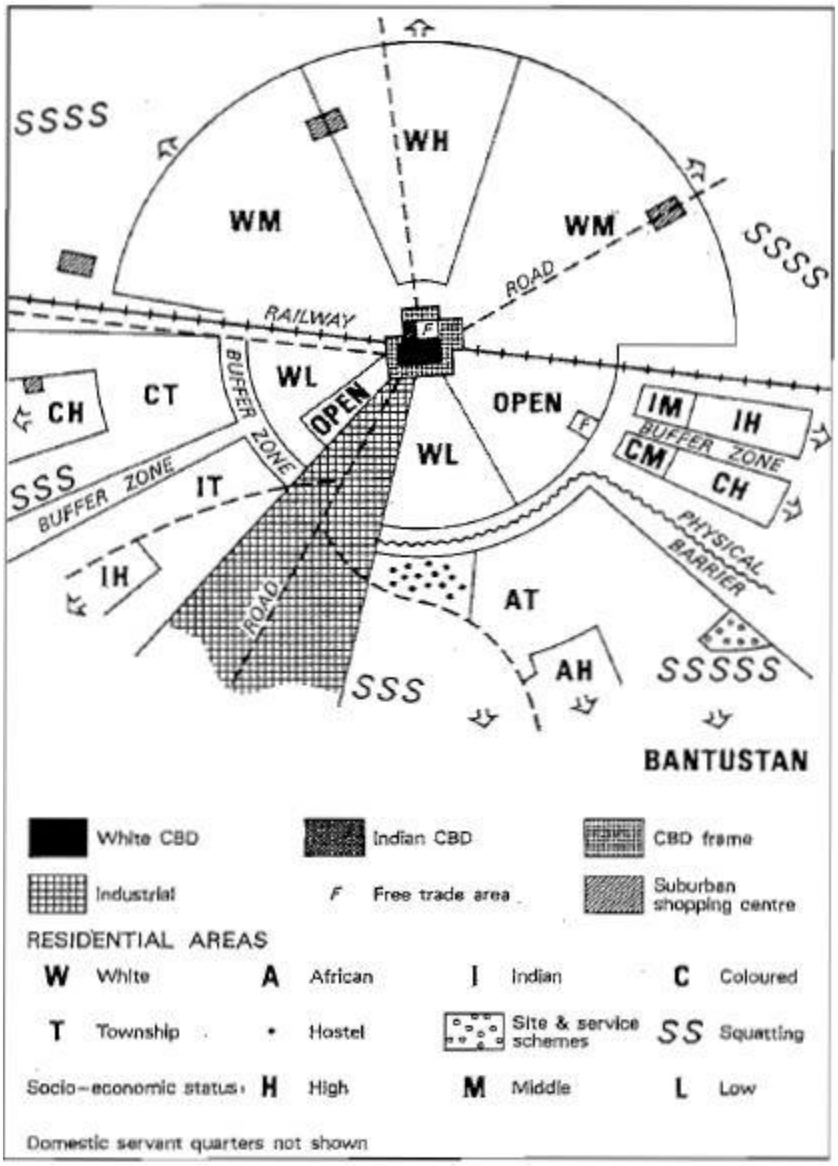

Figure 3-13 Modernised apartheid city model

Source: Simon, 1989:193

The modernised apartheid model had an impact on the earlier apartheid model observed by Davies in the following aspects (Simon, 1989:192-195):

- The modernised apartheid model changed the nature of the new shopping areas in the white residential areas.
- This affected commercial and business land use by decentralisation.
- Because of the new urban form and all racial groups being allowed into the white community, squatter camps would start appearing as a type of urban sprawl.

Research showed that throughout the centuries, urban land models had continuously changed and perfected their functions through the changing of structures. The Hoyt model was still primitive, but the concept had been maintained and illustrated in the Davis apartheid model.

Both models where based on the concept of core to periphery growth and reflected the evolutionary base of the Davis apartheid model. After the Davis apartheid model, Simon modernised the apartheid model, which appeared to eliminate the political pressure placed on the government by other countries. The Simon model had not been improved, but merely modified, to allow imports and exports to continue with other countries. This forced South Africa into certain circumstances, for example the numerous townships that developed around corridors. This caused other complications, such as crime, poverty and inequality. Urban sprawl and crime led to a decrease in land value and has played a large role in spatial planning development (Chapin & Kaiser, 1979:37). This is an example of economic forces that can change urban land use design.

3.15 Theory of agricultural land-use (land value)

The urban land use model illustrates that it is based on land value and purchase of the land as a follow-up (O'Kelly, & Bryan,1996:457-459). This entails that the land is sold to the individual who could give the highest bid and is based on financial power rather than functionality (Waugh, 2002:425). The best representation of this concept comes from an earlier model, which is not illustrated in the study, but is known as Von Thunen's rural land use model. The land vale may differ from area to area. Land value is highest in the CBD owing to the factors of accessibility and shortage of space, but could also be related to the factor of higher economic income. The concept of the land value model was that the further the land was from the CBD, the more inexpensive it would become. This was because of the development of residential settlement areas that were situated further from industries and noise barriers. Land that had been more accessible had also been subject to an increase in cost. This appears to be highly contradictory, but in view of the concept of financial power seems to be acceptable. Spatial planning of transportation units in this model illustrates that land adjacent to transportation routes would prove to have higher land value.

Transportation in this urban model proves to be a key aspect of its growth and functioning. The model identifies that land would usually be developed along main transportation routes and this will cause growth to expand outwards towards the periphery. This is known as horizontal growth. Spatial planning should consider the development of transportation units, owing to its importance in economic growth, accessibility, development, increasing urban sprawl, transport of passengers and freight (O'Kelly, & Bryan,1996:459-460).

The urban design models continue to be modernised in reaction to change. Alonso's theory of land value was based on the land value urban land use model. This model identified the difference between land value and land use. Alonso's model had a complex twist and consisted of seven stages (Pacione, 2005:146):

1. The first stage that is explained by Alonso is the phase in which the model enters the market in a process of bidding or buying land, while considering the distance from the city centre.
2. Under the same assumptions made by Burgess and the identical model as the Burgess model, there is only one CBD with no zoning restrictions.
3. It is assumed that buyers have knowledge of the value of the land and available transportation (Waugh, 2002:392). This assumes that the buyer will be fully capable and have enough money to spend on three main entities: transportation, land and other composite goods. Misunderstanding could arise about land that is more distant from the city centre being less expensive, yet transportation costs become more expensive, because of the distance as well as the fact that the volume of goods may fluctuate (Pacione, 2005:146).
4. Alonso has determined that the urban model is based on a bid-rent theory that considers two important elements. The first is the creation of a bid-theory curve, according to which the cost of the land and the related elements (transportation, distance, composite goods) would be cost-efficient or sustainable.
5. The bid-curve would then separate certain price ranges and determine the affordability for each group of individuals, while determining exterior factors, in essence to determine the most efficient location and land.
6. Each bid-curve is unique to each individual in order to obtain optimal results. Individuals bid for land and the highest bidder would then obtain the title deed for the land.
7. This bid-curve theory would then shape the urban structure and the assumption of expanding outwards towards cheaper, more accessible land.

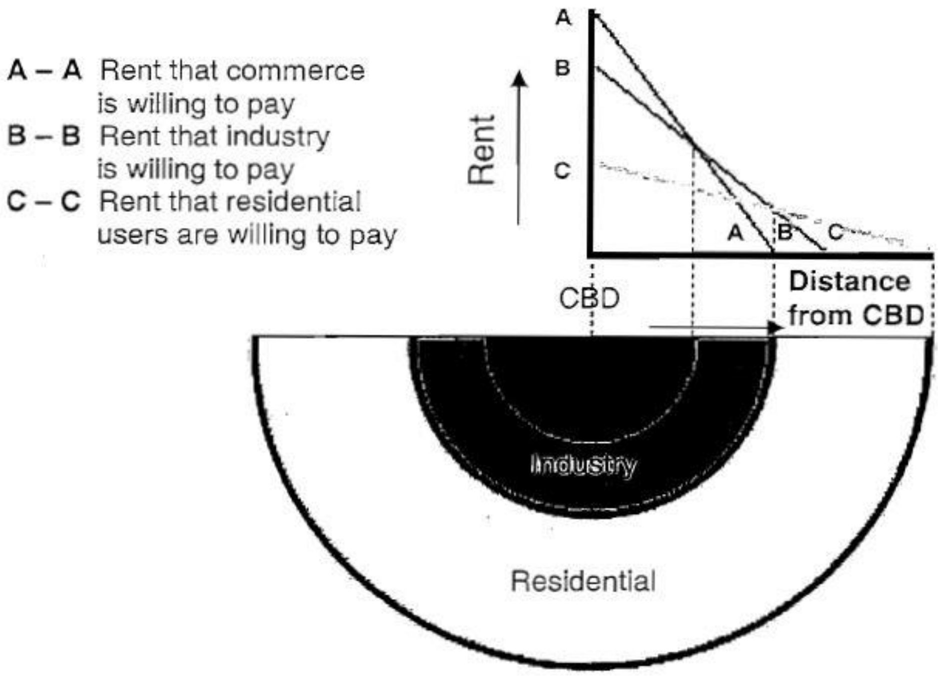

Figure 3-14 Bid-curve model (Alonso's model)

Source: Waugh, 2002:425

This model illustrates the cost and travel towards residential holdings and plays a role in identifying the gap between the lower, middle and higher classes. The illustration is seen in the affordability of transportation and distance needed to travel each day. Lower-class individuals would be more likely to stay in close proximity to their work than higher- or middle-class ones, because of the limited amount of money earned for their jobs. The middle class would be able to afford to use public transportation or motor vehicles, based on their income. The higher class would live on the outskirts of developments, where land is expensive but affordable to that class and transportation cost is not a particular problem.

3.16 Conclusion

This chapter represents various urban models and theories that help create a foundation for the urban structure and ways in which transportation modes are incorporated in the urban structure to improve productivity, efficiency and most importantly, sustainability.

The models illustrated above give insight into various methods of implementing transportation systems in a spatial structure. Some urban models offer a helpful perspective on how the implementation of various transportation systems can be achieved. This is illustrated in the concentric ring model and urban fabrics model (Thomson, 2016:37-42). Further analysis of the urban models design allows one to understand its background, illustrated in the garden city model (Hurley, 2014; Clevenger & Andrews, 2017:5). This corresponds with how land use had been segregated in past urban models, but also allows one to understand which mobility systems can be sustainably implemented to create sufficient functionality. The model that illustrates functionality between sectors is in fact the Marchetti constant, illustrating the use of a 30-minute time cap on travel between sectors.

Some models were politically based and did not have a sustainable objective. This can be illustrated with the apartheid city model, where sectors were divided, with no functionality or aim towards future sustainability (Christopher, 1984; 77; Simon; 1989; 191). This chapter identifies the relevant foundations for urban structures and deals partially with the first objective.

CHAPTER 4 COMPONENTS OF URBAN STRUCTURES

4.1 Introduction

The challenges facing spatial planning are continuously changing, owing to adaptations of urban settlements. The modern era is marked by multiple factors that need to be incorporated in urban settlements. These factors can influence the functioning of the urban framework in a positive or negative manner. The factors below can be considered an adaptation while continuously changing and influencing the spatial layout of cities (Joscelyne, 2015:1-3):

- Environmental pressure (conservation)
- Increased pollution levels
- Increasing population density
- Deteriorating environmental aspects (hygienic living)
- Increasing land utilisation
- Climate change.

In the past the environmental and social aspects would have been ignored, but because of the ever-increasing population and the need for sustainable urban functioning, laws and policies have been introduced that support spatial planning to benefit the entire community. The focus is not placed on the present circumstances, but on future spatial development. These strategic approaches are directly aimed at spatial planning of land and its proposed effect. The strategic approaches are incorporated and controlled by sectors and government institutions.

The largest challenge to spatial planners is the planning of land use. The potential direct impact of the distribution of land can affect the economy, environment and society. Spatial planning has developed a response to all social, environmental and economic issues, but because of the continuous adaptation of the modern-day city, future recommendations should already be considered (Meijers, & Burger, 2009:5-9). Understanding of spatial planning comes through the correct integration of sectors and a process-orientated approach, while sharing responsibilities among different levels of government (Joscelyne, 2015:8-10).

Spatial planning is an art through which vision, knowledge and correct incorporation bring various urban settlements to life, while maintaining productivity and self-reliant functioning. This can be compared to the human body that functions through nerves, organs, muscles and the skeletal structure that supports it. The body cannot function if one of its organs is removed, nor can it function without a skeletal structure/muscle function. The nerves allow electric signals to signal the human body to operate and if this connection is broken, there will be no function

(Hossain, 2018:1-2). Spatial planning is a fine art where integration of sectors and land should create a sustainable long-term structure.

The challenges facing spatial planning and urban land use models is the correction of transportation policies, while avoiding problems that might cause further damage to the environment (Joscelyne, 2015:19-20). In a new era of travel models, activity-based models require more data on the inner workings of households, as well as employment characteristics and finally neighbourhood scale transportation policies. The goal is to create more sustainable transportation modes. The modes can promote healthier lifestyles and support the environment, if planned correctly. The sustainable transportation models mentioned are walking, cycling and public transportation (Wegner, 1995:2-3).

4.2 Population density

The increasing population density of an area is linked to the capacity of the spatial plan and is generally broken down into two main categories, rural and urban areas. The perspective of the population size is considered to be larger in urban areas, owing to the availability of jobs, housing, entertainment and other necessities. The growth of the population can often determine the name of the area of the local community. An example of this is the growth of a village into a town and then into a city (Pacione, 2005:24). The spatial plan may incorporate future strategies to expand the settlement within future prospects, but this has been limited in previous models, seen in the garden city model (Phillips, 1970:6, Parsons & Schuyler, 2003:531). The garden city spatial plan was designed according to the simple concept of designing surrounding towns if the capacity of the existing town was exceeding its capacity. The concept helped to promote transportation modes and to decrease urbanisation and urban sprawl. The capacity of a town/city can be exceeded through both positive and negative growth. Positive growth depends on future planning for the extension of the spatial plan and can be considered a sustainable population growth plan. Negative growth refers to the growth of a city through urban sprawl and the creation of slums.

4.3 Environmental aspects

Spatial planning is separated into various models, which take into account the impact of regional planning as well as housing and market developments. The most recent model in spatial planning is the environmental impact model. The environmental model is then broken up into various subdivided models, namely weather forecasting models, climate models, air dispersion models, chemical reaction models, rainfall-runoff models, groundwater models, soil erosion models, biological ecosystem models, energy system models and noise propagation models (Wegener, 2000:2). These models play a crucial role in dealing with the environmental impact and through individual assessment of these models a conclusion can be formulated on how to decrease the environmental impact through the use of spatial planning.

Spatial planning models should be able to predict both the future economic and environmental impact on an area. Land use is highly important in the spatial development of a society, hence transportation policies should be carefully evaluated and analysed to create the most efficient link between transport and land use. This will take into consideration the area in which it will be implemented and the amount of emissions released into the area to regulate air quality and environmental impact (Wegener, 2000:7).

Spatial planning of transportation modes classifies the geographical placement of transportation systems in order to apply mobility in the economic, social and environmental spheres. This all falls into the category of energy expenditure and the impact it may have on the environment. Commuting is an essential spatial aspect of service delivery and the growth of an area.

The environment has always played a massive role in the spatial planning of transportation. Other factors that play a role in the spatial placement of transportation modes and decisions on which transportation unit will be more efficient are physical distance, topography, hydrology, climate and natural hazards, according to Rodrigue et al. (2006:208).

The environment has always been considered a key priority in spatial planning, because human needs and integration of settlements may have a devastating impact on it. Various deliberations about the urban form have started to illustrate that environmental considerations need to be taken into account in human settlements. This not only indicates that the environment is considered, but that in spatial planning the integration of various factors are conservative up to a certain point (Joscelyne, 2015:20; Yamagata et al., 2016:7).

One of the many challenges faced by spatial planners is the incorporation of policies within land distribution. This has to provide various forms of freight as well as passenger transportation in an attempt to decrease the number of cars and other emission-releasing transportation systems. One area of concern is the transport of freight and passengers, which can be determined by the travel time and distance from work. New intermodal transport systems have been identified as a viable and more sustainable alternative than the use of vehicles. Promoting public transportation that is time-aware and other forms of transport, such as walking and cycling, will not only decrease emissions, but also improve the health and quality of life of individuals. This will indirectly promote the environment and improve conservation and protection of natural resources (Yamagata et al., 2016:7-8).

Spatial planning has also been subject to difficulties within zoning systems that may be incompatible in terms of their overall functionality. The limitation of zonal systems has led to numerous methodological difficulties, one of which relates to the “modifiable areal unit problem” as well as spatial interpolation between incompatible zoning systems (Yamagata et al., 2016:8; Goodchild et al., 1993:392-395). The problem with the restriction of zoning systems is the ability to determine the resolution of common problems, for example energy consumption and the flow of air dispersion, noise propagation, surface flow and ground water flow, which hampers protection of the environment. This issue lacks the potential barriers that are needed to avoid being dispersed to surrounding sectors. As a result, the environment may be conserved by a policy within the sector, but cannot be protected from noise, air pollution, surface water flow, river systems that may carry pollutants and other pollutants being carried from other zonal sectors. The placement of certain zones is a major challenge for spatial planners and it should be considered how it may affect the surrounding zones and environment.

Spatial planners often ask to do an environmental impact assessment (EIA) when visiting a site that needs to be spatially developed. This EIA is done by an environmentalist and identifies the indigenous fauna and flora in the area. This often determines the success of the spatial development plan, since if an organism should be on the verge of being endangered or even worse, becoming extinct, the development plans would be terminated (Joscelyne, 2015:20).

4.4 Interaction

The interaction of numerous attributes of a community is crucial in spatial planning and because of various changes in the environment as well as human needs, drastic adaptions have to be made to allow each element to work systematically with others. Spatial planning has been used for sustainable development to ensure functionality for both the urban and natural environments (Manderscheid, 2011:197).

4.4.1 Sectoral interaction

The incorporation of various policies may aid the functioning of the spatial plan, while the spatial framework supports this function. The spatial sectoral elements that need to be considered are (Manderscheid & Richardson, 2010:1797-1798):

- Economic
- Social
- Political
- Structural
- Transportation-related
- Environmental.

4.4.2 Economic

Spatial planning needs to create a sustainable development, creating and supporting its own financial funding. The economic aspect of spatial development is important for self-sustaining developments, as well as the perception of being sustainable over a long period of time. Spatial planning of an area can contribute to the creation of regional competiveness and also relates to inequality and differentiation of space (Manderscheid, 2011:209-210).

The economic element in spatial development is often distinguished by land use and the distribution of land. Sustainable development will be ensured if this is done correctly, but the immediate downfall of the development could result from incorrect implementation. The economic aspect of land has to be taken into account. The CBD is often known as the "heart" of a spatial development, since it continuously distributes wealth to the surrounding spatial development. The CBD is often situated in the centre of a development to achieve accessibility from all directions. The CBD comprises various markets, shops, businesses, educational institutions, social buildings (church, city hall) and various types of entertainment. As a result, more economic competitiveness is created (Pacione, 2005:199; Cilliers, 2010:22; Manderscheid, 2011:205). This forces businesses to use different marketing strategies to attract individuals. The businesses occupying the CBD are also taxed by the government on each item sold and have to pay rent to the land owner, while still considering their livelihood. In the transitional zone/industrial sector, where all medium to heavy industries are situated, manufacturing takes place to create products. The transitional zone is often considered to have low land value, because of the noise and air pollution created by factories, and is consequently commonly inhabited by the lower class in view of affordability (Chaplin & Kaiser, 1979:32).

Spatial planning often divides individuals based on their income capacity. Higher-income earners are based on the outskirts of a spatial plan, because of their capacity to purchase land that has a higher land value. This affects funding for spatial development and markets in the area. The higher-income earners (higher class) often have to travel to the CBD to work. This channels money into the transportation sector, since the distance necessitates travel. Middle-income earners (middle class) are often situated closer to the CBD and industrial sector, where the land value is lower. The public transportation sector in these areas would be operational and funded owing to the distance that has to be travelled and the number of individuals in relation to the distance travelled. Lower-income earners (lower class) are often situated adjacent to the industrial area, where most work in industries and factories. Travel costs would be lower for these individuals, because the distance travelled is shorter and the cheaper alternatives of walking or cycling can normally be considered (Cilliers, 2010:19). Social injustice is often seen in spatial developments; this is not due to the spatial framework, but rather to the economic prospects of the spatial development. The exploitation of lower-income earners is often the problem in spatial developments. Higher-income earners often use this labour force, since it is more affordable, while the lower-income earners often accept little money out of desperation (Manderscheid, 2011:211).

The environment is also considered from an economic perspective, taking into account that the natural environment needs to be conserved. Protection and conservation of the natural environment are crucial for long-term sustainability. To achieve ecological sustainability, the development of the area of land must be fully understood to conserve natural resources (Manderscheid, 2011:205-206). The reason for conserving the environment as an economic factor is firstly its recreational attraction for outsiders and secondly the use of natural resources.

4.4.3 Social

Spatial development takes on various forms because of social considerations. Social injustice is consequently often seen as a result of the segregation of various class hierarchies. As discussed above in relation to the economic aspect, the land value determines the class that would inhibit that specific land. The centre of the spatial development would comprise the CBD, then the transitional zone, which would be the industrial area. The industrial area would attract mostly lower-class occupants, because of its low land value, since pollution is created by the manufacturing of goods. However, their close proximity to their working environment allows them to spend little or nothing on transportation services. The selection of this area of residential land is not by choice, but is enforced by economic circumstances (Manderscheid, 2011:206; Cilliers, 2010:23-24).

The middle class is located further outside the transitional zone development, where land value is lower, but not cheap. This attracts the middle class, because living cost and land value are inexpensive, yet they can live in a noise/pollutant-free environment. This quality of life is related to the social perspective.

4.4.4 Political

Spatial planning and land use have been affected by the political perspective, where power refers to the capacity of an individual or group of people to exert control to yield a desired result, issue commands and influence the behaviour of others (Pacione, 2005:571). Power over individuals can be fear-inflicted or democratically debated. There are different spheres of government that can dictate the outcome of the urban form and spatial plan. The spheres of government may differ from country to country, but similarities can span from an international sphere to a local sphere. The following spheres of government may determine the impact of spatial planning in a political manner:

1. International sphere
2. National sphere
3. Regional sphere
4. Local sphere.

Within this field of spatial division, the focus will be placed on the impact that political power has on the spatial aspect of planning as well as socio-spatial form in a city. Spatial planning of an area is managed by the closest form of government in order to retain power, control, structure and evaluation of the area, so the local government role is predominant. The emphasis of the local government can be placed on basic values that are adopted and fully understood. The local government’s responsibilities in this regard are (Pacione, 2005:571-572):

- The structure of the local government should ensure liberty from the central authority and restrain abuse of central power.
- Public participation is often encouraged as a link between decision-makers and citizens.
- As different spheres share responsibility in the combined government, certain advances by scale of organisation permit local, sensitive provision of public services and functions, which will allow for better efficiency in government.

The local government has the responsibility of promoting certain activities to create an integrated and diverse society (Pacione, 2005:572):

- The first responsibility that must be fulfilled by the local government is to supply public services and maintain the system.

- By law the local government should also implement and act as an agent of central government, to help enforce state legislation.
- Policies and plans should be formulated in the interests of the state and its structures as well as society. Local government must ensure that this is done.
- Financial aid should be found within the locality to deal with other spheres of government.
- The local government must resolve conflicts between competing local interests, in terms of facilities and their placement.
- Land use and building control have to be regulated in terms of environmental conservation and sustainable planning. This regulation of areas is seen mainly in private sector activities and development.

4.4.5 Structure of urban models

The structure of an urban model can affect functionality, economic growth, future development strategy, cooperation with neighbouring towns and productivity. In essence the structure can make or break a development. Numerous urban structures have been designed to fit a specific purpose (Longa, 2011:7; Cilliers, 2010:26; Waugh, 2002:425). The theory of urban models has been based on policies that will allow cooperation. Through the simplification of theory, the following aspects are always considered in sustainable urban models (Longa, 2011:9):

A. Population
B. Employment
C. Housing
D. Land use
E. Transport
F. Travel
G. Industrial and services logistics.

The structure of an urban model is based on policies and guidelines according to the design required for the specific type of model. The urban form can differ in various ways, but through correct implementation of economic, political, social, cultural and environmental aspects, a level of sustainability can be achieved. The guidelines below for the structure of urban models allows for a baseline in the redesigning process (Longa, 2011:8-42):

- **Urban renewal**

Renewal legislation in urban planning dates to 1949, when it was adopted in Californian communities. Urban renewal is defined as a city’s transformation after WW2 or after the 1950s.

The term urban renewal was seen to tackle certain problems, such as housing in North American countries. Slums are a good example of housing problems in third world countries (Longa, 2011:12-14). Renewal of urban models will also have a substantial impact on the degradation of important urban functions. This would create a significant identity in area as well as the metropolitan area. The idea that arises when the word renewal comes to mind is often the demolition of buildings. This is half the image and mainly refers to the partial build-up of the urban district, involving retiring buildings out of commission.

- **Urban redevelopment**

The urban model goes through redevelopment in various forms, when policies that control the development of residential settlements are implemented. These settlements need to be rationalised after rapid development. This can be compared to a negative effect that would cause urbanisation if not addressed correctly and can be identified within private investments as well as public-private partnerships (Longa, 2011:12-16).

- **Urban regeneration**

When it comes to determining the regeneration of urban models, the main consideration is long-lasting resolution of various urban problems and the change that causes these problems. Regeneration is seen as a vague and confusing word within implementation, but can be based on two sectors, which are known as the public and private sectors. These sectors have various implications and affect the urban model in different ways. Regeneration also implies the correct integrated perspective and is ultimately based on cooperation between the sectors. In essence, regeneration highlights the interdisciplinary intervention, which is aimed at removing urban pathologies, which can be seen in economic dynamics and the environmental, social, cultural and political spheres (Longa, 2011:13; Alpopia & Manolea, 2013:182-184).

- **Urban recovery**

The main purpose of the urban recovery principle is to help conserve the urban environment through urban rehabilitation. This refers to the immovable physical aspect of poverty, infrastructure or a specific aspect of it. This relies on the exclusive physical aspect of the built-up property and may have consequences for the components of the urban structure in terms of specifically conversion and maintenance. The difference between recovery and urban renewal is that urban renewal implies the demolition of urban infrastructure to build and employ various other forms of infrastructure. Urban recovery, on the other hand, implies the remodelling of the already established urban infrastructure, while working on change and the functioning of the type of infrastructure. Urban recovery is often confused with renewal, but recovery is aimed at changing the current function to a multi-function facility (Longa, 2011:14-28).

- **Urban revitalisation**

Urban revitalisation is used in specific circumstances as part of a type of strategic plan to identify certain areas of poor or weak value that can be revitalised to strengthen the overall urban design. Revitalisation has been used in many cities in England located within the centre/inner design. The surrounding cities would often be regarded as having mono-function designs and containing natural elements, such as iron, carbon or a cotton industry. Revitalisation is identified as a project strategy to improve the urban structure economically and focuses on financial matters (Longa, 2011:31; Alpopia & Manolea, 2013:181-182).

- **Urban framework**

The urban framework is identified as the setting-up intervention of urban renewal, which is marked as the exact times of construction and specific functions associated within linking new economic and social aspects. This intervention is intended to achieve profitability as well as efficiency, while maintaining good management. Its essence is to identify decaying functions and replace them, while focusing on effectiveness. The urban framework can be seen as a specific aspect of urban renewal or can relate to the particular production process, where private output is one factor. This may relate to properties being sold on the market and can thus benefit from the redistribution of profit while cutting loss (Longa, 2011:33-34).

- **Urban gentrification**

Urban gentrification implies the movement of individuals for a specific purpose. This involves the use of certain parts of a city by some art-orientated or emergent social classes, at the expense of other economically and socially declining classes. This deals with cultural interpretation as the movement of various ethnic groups for different reasons. Different professions could also inhabit certain areas in a class-based society. Low-income earners would occupy older buildings because of the low rent, while other classes may adjust to lower or higher land value (Longa, 2011:35-38; Manderscheid, 2011:211).

- **Urban restructuring**

Urban restructuring has been identified as the end phase to the urban design process. It is particularly evident in Eastern European cities that have experienced rapid social and economic changes. Urban restructuring is regarded as a combination of social, economic and physical interventions. These physical standards focus on the use of urban systems and satisfying new needs. Restructuring involves both macro- and micro-aspects of physical intervention in existing properties. The distribution of interventions is also important, as is the mobilisation of financial resources. In some instances, this can lead to either the demolition of an area or reconstruction of the function of existing urban infrastructure (Longa, 2011:39).

4.4.6 Environment

Spatial planning has become a tool for achieving compact cities and sustainability, but the environment cannot be underrated, in view of the implications of lack of natural resources, increasing diseases caused by transportation modes, extinction of fauna and flora, decrease in the quality of life and finally the destruction of planet earth through incorrect implementation of land use. Scenarios that have been created to identify solutions within the urban form refer to the following (Yamagata et al., 2016:27):

- To make use of advancing technologies, spatial planners should be able to incorporate the results published in theses to preserve the environment.
- Decreasing carbon dioxide emissions should be considered in each and every city.
- Electric cars and public transportation systems have been identified as sustainable modes of transportation that can preserve the environment and move towards more compact cities.
- The accommodation of electric vehicles can decrease heat islands and increase vegetation.
- Spatial planners need to consider the time taken to travel a particular distance, since this could increase or decrease productivity.

Various forms of freight and passenger transportation modes have been created to allow the free flow of economic benefits and to offer a viable form of transport to get passengers to work and back to their settlement in the shortest possible time. This helps increase productivity, but has simultaneously harmed the environment. Numerous policies have been created and tested to develop a more viable and sustainable transportation system. One specific policy has targeted public transportation systems on a neighbourhood scale. Spatial planners have realised that planning for sustainable transportation, for example cycling and walking, needs to become a reality in vehicle-dominated urban forms (Yamagata et al., 2016:7). Consideration of environmental pressures is mainly confined to developing countries, because of urban agglomeration and the management of resources. The population in third world countries (South Africa) grows rapidly, with no consideration of housing and space. This ultimately leads to destruction of the environment or inappropriate intrusion to create space for the majority of the poorer classes (Pacione, 2005:748). This mass movement into the natural environment needs certain infrastructure. This specific infrastructure may consist of pipelines for water and sewage, electricity lines, sanitation facilities, paved roads for accessibility, health care, police services, fire services etc. The amount of infrastructure needed decreases the unit cost within the community and owing to the concentration of community interests and infrastructure, there is limited consideration of environmental pressures.

Spatial planning of mobility is crucial to avoid complications. The initial concept is to offer mobility with the intent of conserving the environment, while providing an efficient transportation service. However, specific environmental elements are placed under pressure in order to implement mobility (Pacione, 2005:546). The environmental elements that face pressure from the spatial planning of mobility are discussed in the subsequent sections (Rodrigue et al., 2006:211-213).

4.4.7 Environmental aspects (hygienic living)

Through environmental pressures placed on the ecosystem in developing countries, various hazards occur in the neighbourhoods (community), in housing and on the land on which it is situated, in the working environment, the city and municipal district. This can branch out into larger environmental hazards and become a regional if not a global problem. Categories are analysed and the initial issues are identified below (Pacione, 2005:749-751):

On a global scale hazards that could damage the environment often originate in three areas, namely the chemical, physical and biological fields. The first aspect that has a massive impact and can cause the progression of hazards on a global scale is the use of non-renewable resources. These can be identified as fossil fuels and other substances used as fuel, for example oil and fuel derived from oil. This can cause massive damage to ecosystems on a global scale (melting of global ice caps) and global warming. The second cause of damage on a global scale is the development of non-renewable transportation modes. This occurs through persistent release of chemicals caused by gas emissions, which causes the emission of stratospheric ozone-depleting chemicals that break down the ozone layer and decrease protection against the rays of the sun. This is a result of the overuse of limited renewable resources. This happens because the rate of resource use is too high, which could be caused by lack of land management on a smaller, regional scale. In a long process of depleting resources, there are global limitations on the amount of soil covered, forests cut down and fresh water stored in order to create sustainability (Rodrigue et al., 2006:81).

4.5 Conclusion

This chapter has come to the conclusion that certain spatial plans can sustain transportation systems through correct implementation. The chapter gave multiple examples of urban models that have promoted or hampered the implementation of transport in the urban form (Hurley, 2014; Clevenger & Andrews, 2017:5). Through the evaluation conducted in this chapter, attention was focused on various aspects of spatial plans, not only the implementation of transportation infrastructure.

The urban form adapted and evolved in a time when transportation systems would have been fairly basic and moderately simple to implement. Modern-day transportation systems have become complex and difficult to implement in a spatial plan. The difficulty of implementing transport systems stems from the need to allow for access to each sector in the urban model. This is closely related to costs and maintenance, which may be based on the distance travelled or time taken within the system. The affordability of the transport system can determine its relevance in the spatial plan, because of the simple fact that if the transport system is too expensive, it may never be used. This would illustrate a waste of space within the development and fail to solve the problem of moving freight and passengers in the working environment. Analysis of the implementation of spatial planning and environmental considerations has established a firm base for the implementation of transportation systems. The post-urban models represented in this chapter illustrate strategies implementing transportation in the urban structure (Pacione, 2005:548-550; Morphhet, 2011:172-173). The components of the urban structure have to be functional and effective.

The urban structural components should be capable of working systematically with one another to improve efficiency and productivity (Phillips, 1970:50; Chaplin & Kaiser, 1979:32; Cilliers, 2010:15). After a full evaluation of the implementation of transportation infrastructure, this chapter concludes that transportation systems are in fact the arteries of the urban model, allowing improved efficiency and economic growth. Without the use of efficient transportation systems, productivity, socio-economic well-being and general functionality would decline rapidly (Cilliers, 2010:27). This illustrates that the correct transport infrastructure should be implemented with caution in a spatial plan. In this chapter various transport modes have proven to be detrimental to the environment, inefficient, counter-productive, expensive, maintenance-intensive and dependent on a source of fuel that is not sustainable (Rodrigue et al., 2006:101-105). The sustainability of an urban model is of high importance, and transportation is a crucial component of such a model. The use of unsustainable transport is a problem that has been postponed instead of receiving the attention it deserves.

CHAPTER 5 TRANSPORTATION SYSTEMS - A REVIEW

5.1 Introduction

This chapter illustrates the spatial implementation of various transportation systems, correlating with the objectives of this research study. The second objective of this research study is to evaluate the theoretical foundation of sustainable transport systems and international best practice. This could be illustrated by identifying key foundations of various spatial structures and how road and rail are implemented in these functional communities. Two main spatial structures and the relevance of their functions will be discussed. The two main spatial structures are monocentric spatial structures and polycentric spatial structures, which are fully illustrated in this chapter in order to understand the theoretical functioning of city structures and transport (Bertaud, 2002:2-5).

5.2 Spatial organisation of transportation

The urban spatial structure can be split into two main categories, which can be regarded as either monocentric or polycentric. These spatial urban structures can either benefit the flow of transportation and accessibility or slowly decay the urban form. This makes the spatial organisation of transportation crucial for the urban structure to function efficiently and correctly (Bertaud, 2002:3; Alqhatani *et al*., 2014:218-219). Monocentric spatial urban structures have been identified to be more restrictive, posing various constraints to accessibility. Polycentric spatial urban structures tend to offer various forms of accessibility to the urban form and tend to decentralise the urban structure. The initial concept of spatial organisation of transportation is to provide in the needs of the built environment, while considering sustainability and the need for diverse accessibility to support an urban model's function, which has been identified in Alonso's bid-rent theory (Pacione, 2005:146). The spatial organisation of transportation is used as a method to promote economic participation and social interaction within communities and to provide a consistent and efficient source of delivery (Alqhatani et al., 2014:219). Better accessibility is of more benefit to people and the community. The accessibility of a spatial form should incorporate various forms of transportation, allowing more accessibility from various angles. The idea of increasing accessibility was to consider various approaches through which accessibility can be measured and implemented efficiently by using different transportation modes. These five approaches would allow for effective spatial planning and organisation of transportation units within a spatial plan (Alqhatani et al., 2014:219):

1. The first approach is based on accessibility metrics, which involves the cost or time of travel, moving towards the opportunity. This is calculated by the sum of impedance.

2. The second approach focuses on origin-destination accessibility and works on the assumed spread as well as the proximity of chosen destinations. This can be identified as an entropy-based approach and a place-ranked approach.
3. The third approach is based on the travel time and is highlighted for its importance; it considers the average travel time in comparison with the opportunity either at the destination or the centre of the city.
4. The fourth approach highlights the initial utility-based approach. This approach would illustrate the cost of moving at the end of the trip.
5. The fifth and last approach focuses on the constraints and how the number of opportunities can be viable under the access travel time budget.

The spatial organisation of the two categories, monocentric and polycentric structures, can ideally illustrate the different impact of each spatial structure, while demonstrating the activity levels and their impact on the urban design. The representation of two scenarios below illustrates the difference in the activity growth and the initial accessibility:

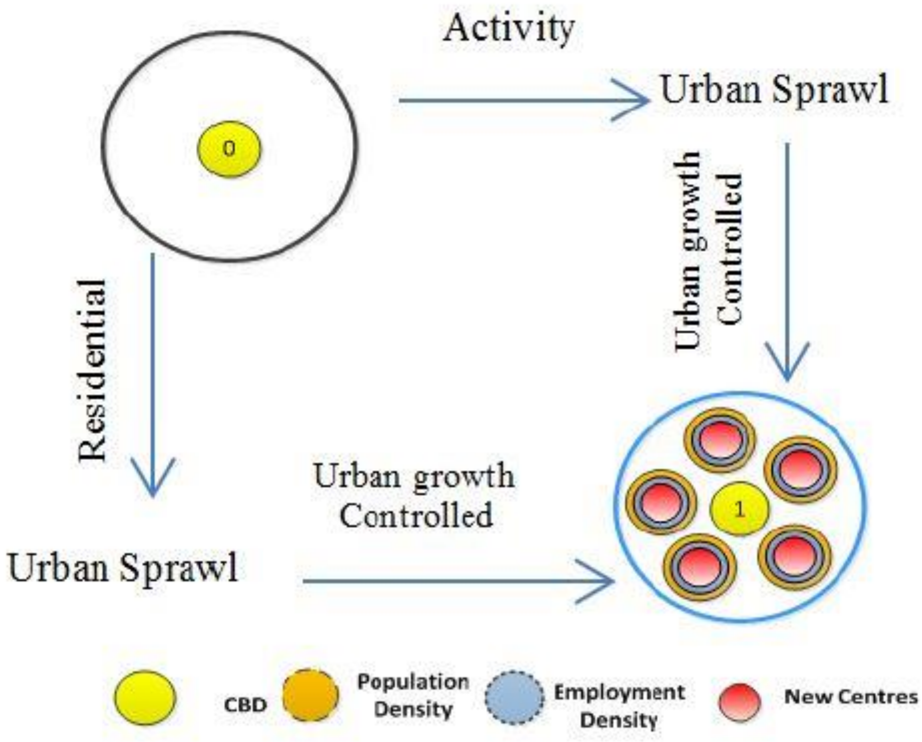

Figure 5-1 Different impact in two scenarios

Source: Alqhatani et al., 2014:220

Figure 5-1 illustrates how new centres are formed from urban sprawl, which is either controlled or uncontrolled, given the factors of employment and population density close to new centres (CBD).

5.2.1 Monocentric spatial structure

The monocentric city that has been widely used in the spatial organisation of towns and cities. It was discussed as an urban model in Chapter 3 (O'Kelly, & Bryan,1996:457-459) and is a primitive design on which various specialists had collaborated. The specialist model of Alonso (1964) in Chapter 3 illustrated the bid-curve model and identified this spatial organisation as specifically effective in using transportation to increase the density of the metropolitan area. The monocentric model was used to derive more evolved urban structures. This slowly decayed as an option in the spatial distribution of cities, for one specific reason, that the CBD was not the only destination for the individuals occupying the area (Bertaud, 2002:3; Pacione, 2005:375).

The monocentric spatial structure was seen as the most basic model and assumed that the economic/social/cultural infrastructure would be situated at the core of each urban development, significantly allocating transportation routes towards the centre in a radial approach to the urban structure (Alqhatani et al., 2014:118). The transportation was used as a tool to concentrate employment and population in the centre of the urban structure. The use of public transportation would be limited to that specific urban structure and not branched out towards surrounding towns (Bertaud, 2002:3; Alqhatani et al., 2014:222).

5.2.2 Polycentric spatial structure

The polycentric spatial structure was designed against the background of the failures of the monocentric city. The polycentric design focused on the use of transportation units, while considering the needs of the community, whereas monocentric spatial design had assumed that all individuals would move towards the core of the settlement. The polycentric design was considered to have more accessibility options, while incorporating various transportation modes.

The process that had to take place to form a polycentric spatial organisation was evolution of the urban structure. The monocentric city was considered to be small and allocated transport to the CBD of the development; as the population expanded, changes had to occur. It was realised that not all transportation should lead towards the CBD and should in fact be dispersed into various clusters of activities that would generate trips spreading out in the built-up area (Bertaud, 2002:2-4). Figure 5-2 below illustrates the spatial distribution of transportation infrastructure between polycentric and monocentric models. The illustration shows that monocentric models are only capable of dealing with transportation to the core destination, while polycentric ones are capable of distributing transport throughout the built-up environment.

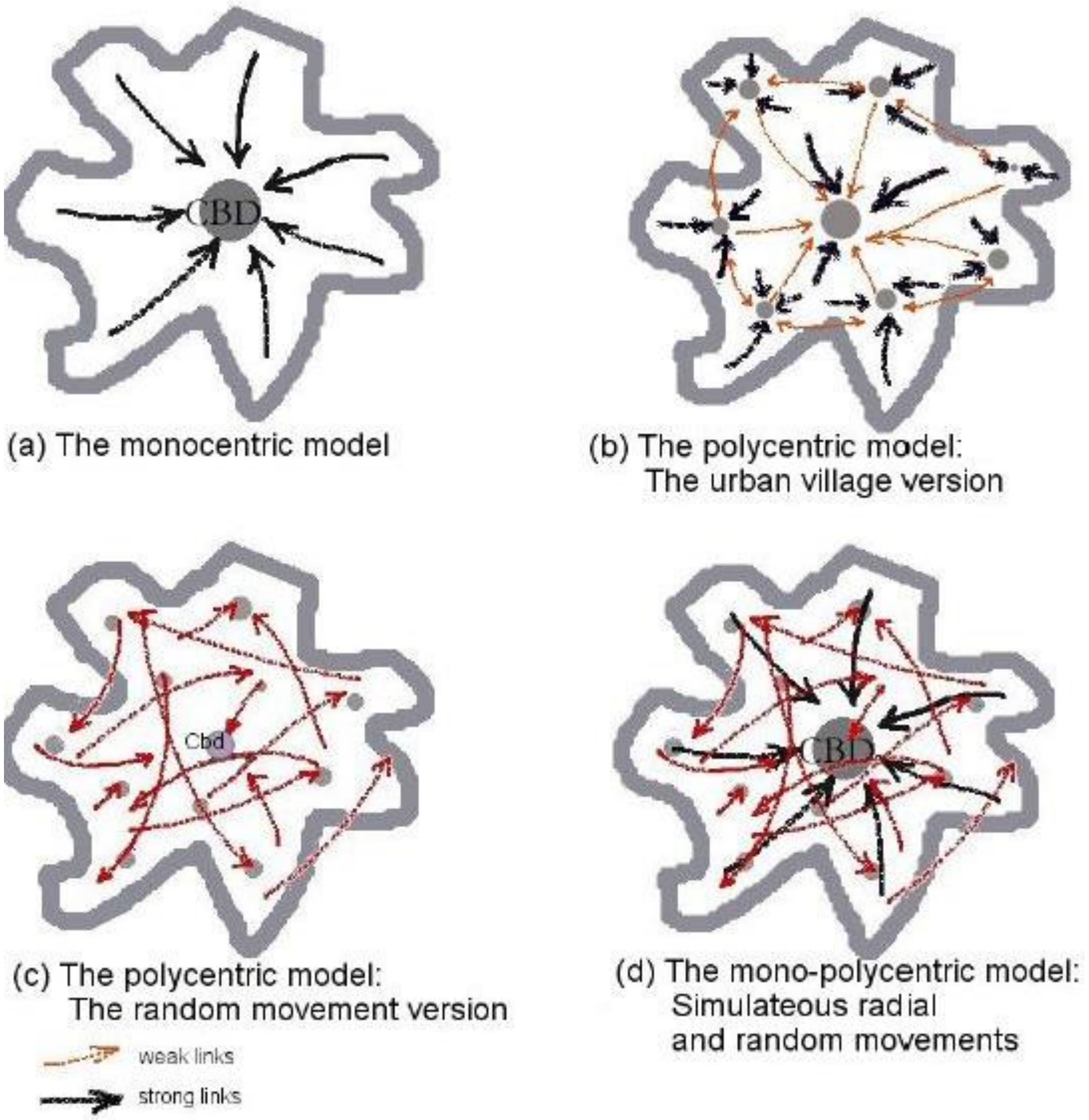

Figure 5-2 Comparative analysis of mono- and polycentric transportation models

Source: Bertaud, 2002:3

The figure above reflects the bridge between transportation and urban form. It illustrates the movement of transportation between various nodes. The most centralised node is in fact the closest and most desired point of interest, in view of its distance from the surrounding nodes. The central node attracts growth from the outer nodes thorough goods, services and business and is the most centralised area to satisfy common needs.

5.3 Networks

The term networks is used throughout transportation systems. It refers to the framework used for various routes over a large spatial plan regarding various transport nodes, which form part of a larger network. These routes can be referred to as tangible routes, for example rails and roads. These can also be seen as less tangible routes in other transportation systems, such as the routes in maritime sea corridors and by air in air transport nodes (Rodrigue et al., 2006:47).

Networks in transportation systems have often been found to be a more practical approach to mobility under the influence of economic factors. The implementation of networks is often not considered in transportation systems, despite the need for transport and lack of spatial planning. This concept concerns access, flow and general time of travel to an area, region or city CBD. The location of these networks is known to be permanent tracks (rails, roads) or the networks operate from fixed points at scheduled times (airline, ship) of travel and these cannot be resituated without disrupting the flow of mobility. Networks can be categorised into two main forms of spatial transportation networks (Rodrigue et al., 2006:48).

Centripetal networks are transportation systems that favour a limited number of locations and function through the use of a main node, known as a hub. Such a network is based on the joining of various surrounding locations to one main location. This network has been identified as a transportation system structure that favours the use of air transportation. It greatly increases the concentration of economic growth at a specific location (hub), which allows for more effective economic growth. The network currently known as the "hub-and-spoke" network illustrates the dynamics of a type of centripetal network.

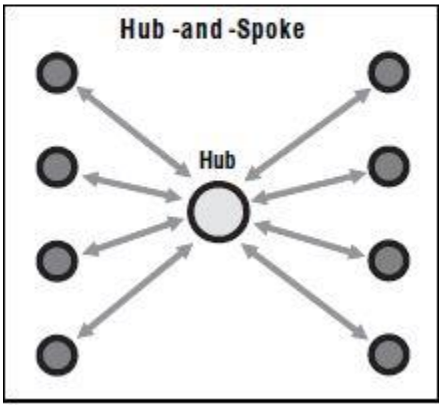

Figure 5-3 Hub and spoke network (centripetal networks)

Source: Rodrigue et al., 2006:48

Centrifugal networks do not have a localisation advantage, since the distribution of the network can incorporate various nodes.

5.4 Transportation flows

Flow is defined as the amount of traffic that takes place in the network. This relates directly to the function of increasing demand and the capacity of the links that support this transport system. The assumption of flow is that it is the friction of space between various modes of transportation and considered to be one of the most significant factors affecting transportation systems. The flow of a transport system can directly affect the productivity and economic growth of a community (Rodrigue et al., 2006:6). Flow can either break a community down or greatly benefit it, regardless of the types of transportation systems implemented and the intermodal collaboration (Pacione, 2005:247). There have been three particular issues with the concept of flow (explained above in systems), namely (Rodrigue et al., 2006:39-40):

1. Value
2. Volume
3. Scale.

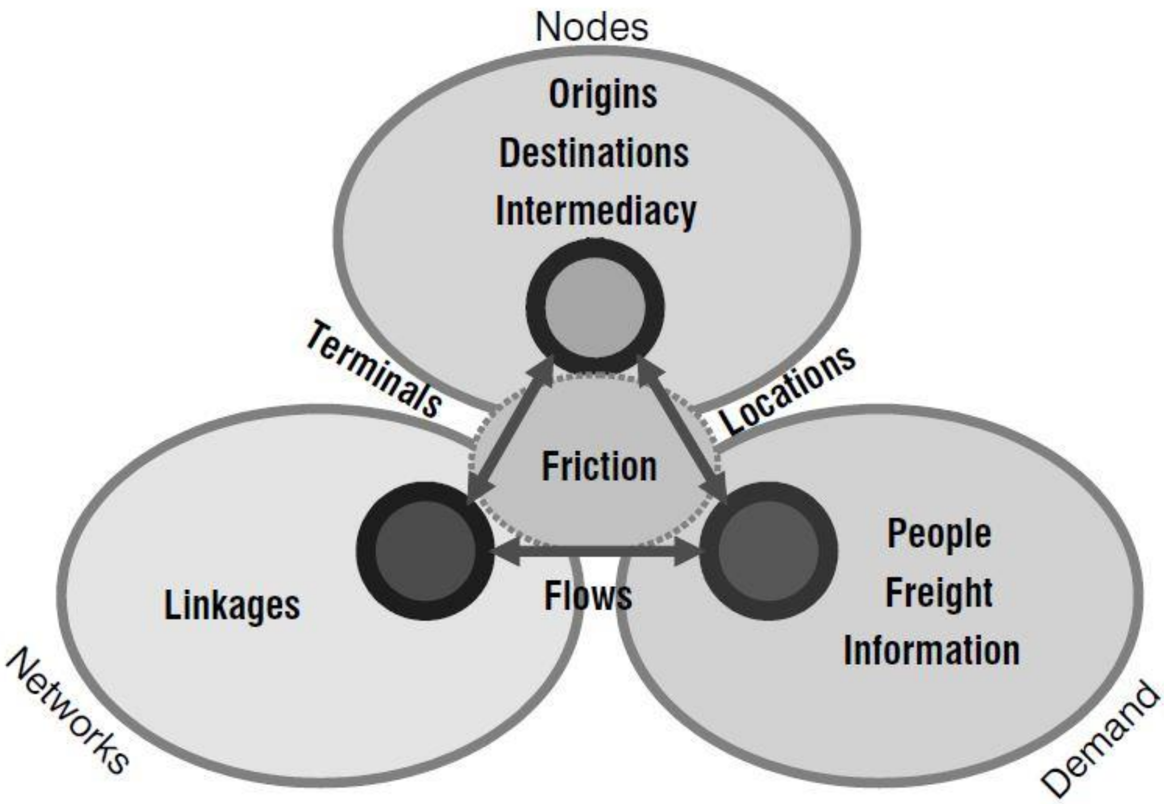

Figure 5-4 Transportation factors with the interlinkage of flow

Source: Rodrigue et al., 2006:6

The distribution of freight and passengers is determined by the main factor of flow, which increases the distribution while allowing for an increase in productivity. This activity of transportation is often considered to be the relationship represented through the space and time taken in transportation systems. The factor of flow within freight transportation is illustrated through the traditional arrangement of goods, which includes manufacturing and distribution. The process of the flow of freight is relatively direct and involves the transporting of raw materials to the manufacturer, which are then distributed to all wholesalers/shops and finally reach the final consumer. Delays in any section of the process may occur, leading to a lower rate of distribution. The idea of flow in the distribution of goods and services is to minimise costs through an increase in distribution (sales), but is limited to the efficiency of the transportation system. As discussed above, certain transportation units are limited in the volume carried as well as the speed of distribution. The association of various freight flows has resulted in freight being carried in lower volumes at a higher frequency. This illustrates that speed is the determining factor in freight transportation. These specific flows have also been determined as a factor in modal adaptation, where various modes of transportation play a role in the transportation of a single product (Rodrigue et al., 2006:162).

5.5 Transportation modes

The components of transportation fall under the concept of transportability, which is defined as the ease of movement of passengers, freight or information. This correlates directly with the cost of travel and is derived from the specific goods or passengers that must be transported, while considering the distance as well as the time. Three main attributes are consistently related to the components of transportation, namely fragility (how fragile and sensitive the object of travel might be), perishability (indication of most consumable products with specific expiry dates) and price (this entails both transport cost and the cost of the product), which differ between items. Ultimately there is evidence that transportation advances the productivity of activities and releases various constraints (Rodrigue et al., 2006:2; Cilliers, 2010:9). To determine the full value of transportation and the various components that play a specific role in the flow of transport, two different demands will be discussed to illustrate the importance of spatial planning in transportation (Rodrigue et al., 2006:2-4): The first is the directly derived demand, which refers to movement that would directly affect economic activities. Without this specific type of demand, no economic activities will occur. The best example of this is seen in work-related activity and involves commuting to and from the place of work. The concept is that one area would supply work (residences) while another area would demand the labour for potential work outcomes (workplace). This concept is known as the supply and demand chain that initiates economic growth. The transportation of freight has a different approach, which is nevertheless highly important. All products are developed through the use of raw materials and without the delivery of these raw components, products cannot be created or distributed to various sectors of the community. The perceived travel of freight can be identified as a crucial section of the supply chain. The transportation systems that are mainly involved in this supply process are rail transport, trucks and other road infrastructure modes and lastly container ships (Meijers & Burger, 2009:1-6).

The second type of demand initiated within the transportation systems is indirectly derived demand, which considers the movements created by other specific movements. The best example to illustrate this type of demand is the energy source used to fuel the transportation system. This concerns the various fuels consumed by the various modes of travel and allows the transportation system to function efficiently. This relates to the extraction of specific fuels and the movement to areas in need of that fuel (petrol stations), which is identified as transportation between zones. This specific form of demand can be described by one specific name that illustrates the whole process, namely “warehousing”. This is the label used to identify the process of indirectly derived demand and is seen to be a non-movement of a freight element, even though the factor of transport is involved.

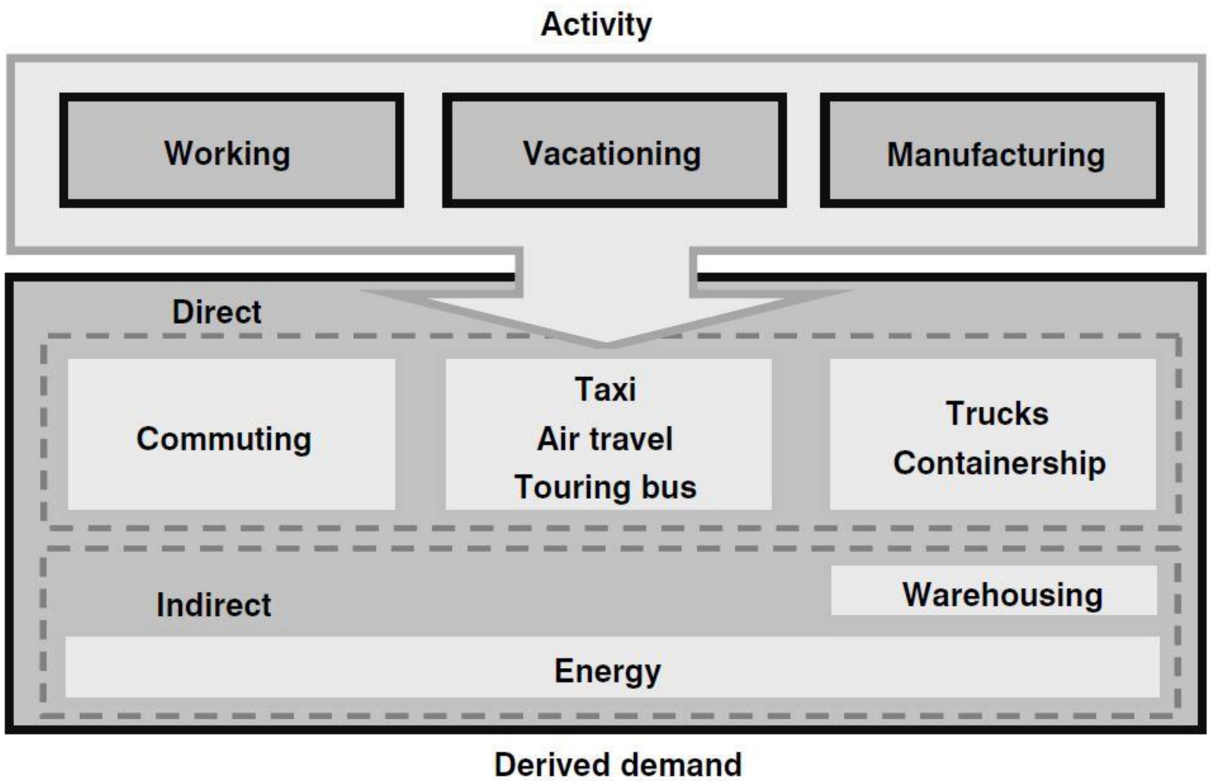

Figure 5-5 The derived demand of transportation systems

Source: Rodrigue et al., 2006:2

5.5.1 Road transportation

Road transportation is regarded as the most frequently used form of transportation, which is dominant over any other mode. Transportation located on road infrastructure entail automobiles, buses, trucks, bicycles and various other modes of transportation. The road infrastructure that is needed is highly expensive over the long term, owing to the need for maintenance and its perishability (Pacione, 2005:791-792). The cost of road infrastructure involves divergent costs. These costs can range from building a gravel road to a multilane expressway, not even considering the costs of safety, traffic lights, barriers and other structural designs, such as bridges. Road transportation can be beneficial by overcoming topographical obstacles (mountains), for example slopes. Vehicles are able to climb these topographical features with minimal problems. In most countries, public transportation systems have been implemented to provide mass mobility, but only first world countries have been able to implement this transportation mode effectively without affecting other traffic, the time of travel, cost of travel and overall spatial plan. The road transportation mode is in fact commonly used and provided by the government as a category of public goods, but in first world countries most people have privately owned vehicles (Dur, & Yigitcanlar, 2015:814; Rodrigue et al., 2006:101-102).

The understanding of road transportation modes is often overestimated in terms of supplying the economy effectively in all ways. This transportation mode has limited abilities when considering the effect on the economy. The limitations often relate to energy consumption, which is not sustainable and involves a non-renewable source of energy. The other limitation is the weight capacity of each vehicle. Some trucks and automobiles do not have the capacity to carry heavy loads and are often constrained by weight restrictions in attempts to increase safety (Rodrigue et al., 2006:102).

Consideration of road transportation modes is advantageous for the community and the economy, since some modes can deal with numerous aspects of transport better than other modes of transportation (Rodrigue et al., 2006:102):

- The capital cost of vehicles is relatively low in comparison to other modes of transportation. This indirectly favours road transport as overall the most suitable transportation system. The fact that the capital cost of vehicles is low makes it an easier initial option to obtain individual vehicles and enter the business field.
- The speed of vehicles is high, which allows for shorter travel time from destination A to B. This is favourable for greater productivity, in view of the effective use of time. It also allows for more effective planning schedules, since the times of departure and arrival are known. The government has imposed speed restrictions for safety purposes.

- The flexibility of route choice is an advantage in regard to road transportation; longer distances can be decreased by choosing alternative routes. Combined with the speed of vehicles, this would shorten travel time.
- The appointed road transportation can effectively be used as door-to-door services in terms of passengers as well as freight. This makes it easier for the consumer to order products and have these delivered to their houses, while they are occupied with other activities, ultimately increasing productivity.
- Multiple trips can be undertaken by cars and trucks. Ease of undertaking multiple trips is regarded as one of the main advantages of road transportation modes. Road transportation therefore dominates the market and allows for a greater number of trips per day, increasing productivity.

5.5.1.1 Rail transportation

The rail transportation mode involves a locomotive that operates on a rail system and can obtain a power source either internally (steam, coal) or externally (rails, electricity lines), but is guided by a supported rail. The capital costs of rail transportation modes are high, involving the construction of rail tracks and provision of the rolling stock. The rail transportation system has a historical background, through investments made by the government or private sector. Expenditure is required before any revenues are realised, which represents an important entry barrier. In comparison to road transportation modes, it is an older innovation, but also serves to delay innovation. This is due to the service life of a minimum of 20 years. According to statistics, railway locomotives have a disadvantage in comparison to road transportation modes, due to their inability to climb gradients and cross other topographical barriers (Rodrigue et al., 2006:102). Expensive engineering solutions are required to overcome this disadvantage in comparison to road transport modes. The engineering solutions mainly point to one highly important aspect of rail modes, known as the gauge. Most locomotives operate under a standard gauge of 1.4351 metres, which commonly refers to the capacity/freight/passengers they can handle effectively. This specific gauge was incorporated in Western Europe and across the whole of Northern America. As a transport mode of freight, it had been considered successful, but in terms of passengers had been seen as inefficient, because individuals had to change rail systems at various points to reach their destination. This caused a delay in travel time as well as an unnecessary increase in the distance travelled. Most first world countries have developed ways to utilise the rail transportation mode to their benefit. One of these is extending the rail system across continents and regions. This can be seen between France and Spain, Eastern and Western Europe, Russia and China (Pacione, 2005:377-378).

One of the main advantages of the rail transport mode is its ability to haul a large capacity of freight as well as passengers over longer distances. Its high speed also ultimately defines the rail transport mode as a high speed-high capacity service (Pacione, 2005:365). Road transport modes have a very limited range, since this specific mode was developed for large capacity, while maintaining speedy delivery. The passenger section of rail transport serves as a bulk mobility system. This system is effective to deal with a large population that originates from a specific destination A and needs to travel to the same area destination B, C, D). Rail transport modes offer little flexibility of destination or route of travel. This transport mode has undergone advances in terms of the speed, comfort, design and engineering solutions from the nineteenth century onwards. Rail transport modes have been implemented in large cities in Europe and Japan, where it is estimated that these modern-day rail systems could reach speeds of up to 515 km/h. The development of fast rail modes has led to speculation on the use of other modes of transportation, in response to the dominant nature of rail systems over medium to short distances (Rodrigue et al., 2006:103).

One of the underlying characteristics of rail systems is that they have been considered an excellent mode of public transportation in addition to being sustainable. The reason for the sustainability of this mode is found in the energy consumption; it needs less fuel per kilometre than any transport mode (Pacione, 2005:376; Rodrigue et al., 2006:103). For this reason, the following countries have implemented rail transport systems throughout their spatial plan:

- Most European countries are linked with rail system transportation
- Japan (high-speed passenger train)
- South Korea (Seoul-Pusan).

5.5.2 Transportation infrastructure

Transportation infrastructure employs various modes. Without the correct infrastructure in a spatial plan, transportation becomes inefficient and may even lead to the unnecessary use of funds (Pacione, 2005:370). Transportation affects productivity directly and the economic growth of a community indirectly. Transportation infrastructure needs to ensure the efficiency and capacity of transport modes and various terminals, which can have a direct impact on transport costs (Rodrigue et al., 2006:45).

Transportation infrastructure is determined by the topography of the area as well as the use of the transportation system. The spatial transportation infrastructure assumes numerous forms to benefit the community. This infrastructure may be used to benefit the economy, cultural beliefs, productivity, the CBD or even travel between work and residences and the efficiency of the transport system. This can affect the accessibility, flow and network of the various transportation systems implemented. Through a geographical analysis of the spatial implementation of transportation modes, three specific transport corridors were highlighted and compared. The three models of transportation corridors and regional spatial structures were designed to play a specific role in the community (Rodrigue et al., 2006:84-85; Pacione, 2005:169):

- Location and accessibility model (A)
- Specialisation and interdependency model (B)
- Distribution/flow model (C).

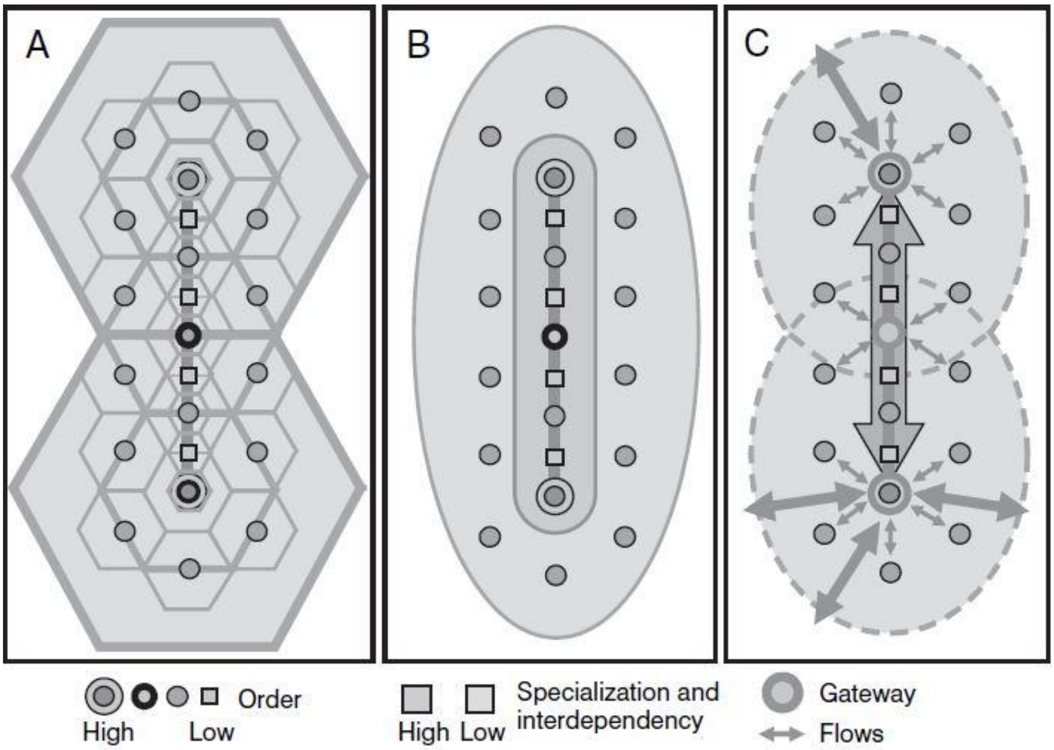

Figure 5-6 Three transportation corridors and regional spatial structures

Source: Rodrigue et al., 2006:84

5.5.2.1 Location and accessibility model (A)

The central place theory concept has been incorporated in this model to achieve independent entities, which will in theory compete against overlapping market areas. This specific model falls under the ideology of a hierarchy of services and other functions. The transportation corridor would link the various hierarchical service nodes to interact with one another in various ways. Transportation costs have been regarded as dominant in this model in order to allow individuals to obtain goods and services without many constraints in terms of transportation modes. This model is built up of various small market areas that are accessible over a transportation corridor. In the figure above, model (A) illustrates the concentration of each market node and the infrastructure of the transportation system (Rodrigue et al., 2006:84).

5.5.2.2 Specialisation and interdependency model (B)

The specialisation and interdependency model illustrates that the levels of interaction in various cities are different and that some require more active transportation systems. This plays a massive role in market accessibility, as well as comparative advantage and regional specialisation. This model best illustrates the design of a megalopolis concept, which had been designed by Gottmann in 1961. The concept of the megalopolis best illustrates the design of large urban corridors used for transportation systems/infrastructure and terminals used for various interactions. The concept is based on an interdependent as well as a specialised approach to sustainability, in view of the focus on and precision of transportation accessibility. Accessibility is a factor that encourages both production and consumption. This model had made one assumption, namely that accessibility given by a corridor reinforces territorial specialisation as well as independency. This illustrates that the model is consequently reliant on regional transportation systems. This assumption is not completely false, but the city will be able to function without a regional corridor. Nevertheless, efficiency will decrease dramatically, which will lower productivity throughout the entire model (Rodrigue et al., 2006:85).

5.5.2.3 Distribution/flow model (C)

This model is the best illustration of a design that incorporates various types of transportation systems, linking global, national and regional systems. The model illustrates a paradigm through three core structural elements that play a role in the parts of a regional corridor (Sato & Chen, 2018:844):

- Gateways regulate the number of passengers as well as freight and information flows. This is implemented throughout the regional corridor to ensure that regulation of these factors is sustainable.
- Transportation corridors have a linear accumulation of transportation systems and infrastructure services regarding the various types of gateways. This helps provide a type of physical capacity of distribution.
- Flows play an important role in the implementation of transportation systems and in fact determine the efficiency of the underlying activities of production, circulation and consumption in the community.

5.5.3 Systems

Spatial planning includes various aspects of mobility in order to create functionality and efficiency. Transportation systems are considered to be the main aspect of mobility and are composed of complex relationships determining demand. Transportation systems are based on various attributes, which are based on the central place theory, while focusing on urban ecology, the environment and human behaviour (Pacione, 2005:169). Transportation systems are dependent on transport costs, reliability, speed, capacity and efficiency. Transportation systems are in fact a complex set of routing and mobility to allow demand for and supply of services to take place. Transportation systems operate in two categories. The first category is the trade of transportation systems, while the second entails the commercial use of transportation over a geographical space (Rodrigue et al., 2006:38-40).

5.5.3.1 Trade transportation systems

The trade transportation system is based on the economic attribute of trade and transaction. This is based on the efficiency and reliability of the transportation system implemented, which requires interdependency, assuming that trade is considered to be a transmission of possession in order to receive a return, in this specific instance money. This involves an exchange or transaction associated with flows of information, finished products, capital and commodities. Trade in transportation systems is relatively complicated in that various conditions have to occur to render this system fully operational (Rodrigue et al., 2006:39-40), i.e. transferability, value, transactional capacity, availability, volume and scale.

5.5.3.2 Commercial transportation systems

The commercialisation of transportation systems has adapted in various ways to become more efficient in the transportation of passengers, capital, information and freight. Transportation services experience forms of market competition, globally and regionally, since transportation is considered to be a commodity, much like other services and goods. This means that transportation is traded, like other goods and services. Some of the core considerations in a transportation system often involve costs and distance. This is often negotiated within a certain degree of public transportation, because transportation is perceived as a service provided to individuals (Pacione, 2005:365). Transportation modes have become a product on the market and easily accessible to the public. This illustrates that transport can be used as a service and a product.

5.6 Urban structure and transport

While urban structure has determined the layout of infrastructure and green spaces, it has also created a large demand for transportation among cities/towns. Most urban models discussed in Chapter 3 have not successfully implemented transportation systems, but have become more aware of how to implement transportation spatially. Transport has nevertheless been considered one of the most important factors in the urban spatial structure. An element that plays a crucial role in satisfying the need for efficient transportation is distance (Chaplin & Kaiser, 1979:32; Cilliers, 2010:15). This can be based on the mobility of freight as well as passengers, while relying on the spatial arrangement of different land uses. Third world cities often suffer from rapid urban expansion as well as sprawl. The issues that have to be considered are that residential areas are being situated further and further away from the CBD, increasing the demand for transportation. This places job opportunities further from residential areas, forcing individuals either to use transportation or form settlements closer to the CBD. This has caused an excessive number of informal economic activities to generate a living in affected areas. Informal economic activities are also encouraged by patterns and routes of travel by transportation systems and have a significant impact on the characteristics of an area. Polarised distribution of income is formulated in third world cities. Traits and characteristics differ tremendously within the urban spatial structure of westernised cities, which would not be able to operate using a radial transportation system. Three specific character traits are evident in land use and transportation systems, when operating in a third world country (Pacione, 2005:789):

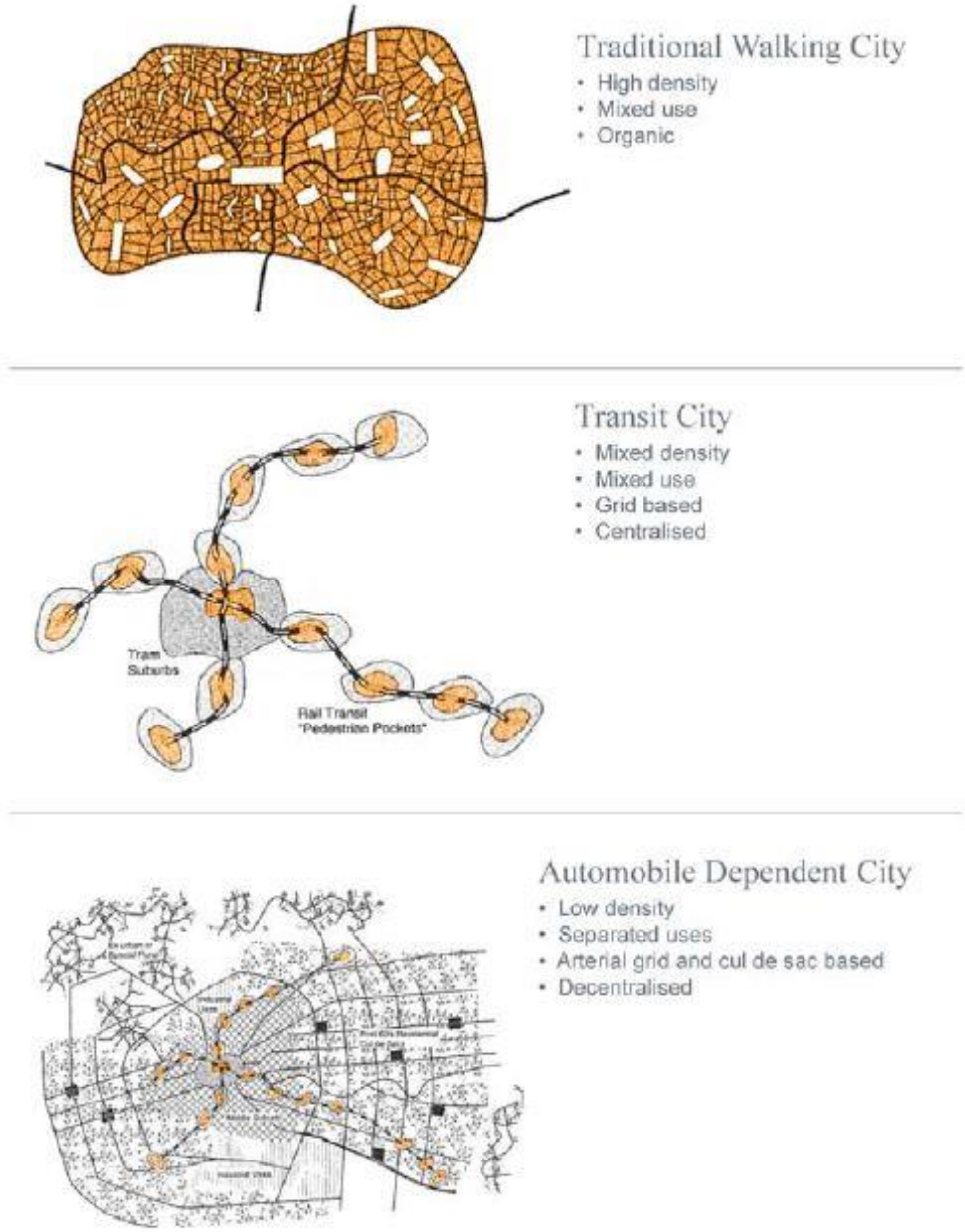

Figure 5-7 The relationship between urban structural form and transportation systems

Source: Pacione, 2005:789

The above figure illustrates the layout of the urban structure form with the implementation of various types of transportation systems in descending order and the effect of this on the spatial structure. The above three illustrations are discussed below (Pacione, 2005:789-791; Rodrigue et al., 2006:177-179):

a) <u>The traditional walking city</u>

Referring to the above figure, transportation involves a traditional way of mobility, namely walking. Cities where this is likely to happen would generally accommodate 100-200 individuals per hectare, which is considered a compact urban form. The pre-industrial urban form is an efficient example of the inclusion of this specific type of mobility, since the urban spatial structure is situated in close proximity to residential areas. The streets in such an urban structure would often be congested and problematic when using motor vehicles, thus making walking the preferable option. The urban structure would be composed of a small administrative core and various functioning segments, which would operate individually (Pacione, 2005:789-790).

b) <u>The transit city</u>

With reference to Figure 5-7, the tracked or transit city is considered to be more complicated in comparison to the traditional walking city. It may contain a larger number of residences spread over a larger area. The type of city has been estimated to contain 70 to 100 individuals per hectare of land (Rodrigue et al., 2006:178). This urban structure was implemented in developed countries, for example America and Europe, in the nineteenth century. The most active transportation systems would have been railways and trams. The reason for these specific transportation systems was the extended range that needed to be covered to allow people to reach their destination. This type of structural form became very popular because of its efficiency in commuting to work and back to residential areas. The cost of travel was relatively low, owing to the masses of individuals moving towards a common destination. The time of travel would have been efficient, since no other transportation system occupied the rail infrastructure, eliminating congestion as a factor (Pacione, 2005:789-791).

c) <u>The automobile-dependent city</u>

With reference to Figure 5-7, this city is characterised by a motor vehicle-orientated transport system, which is situated over a large land area. The occupancy rate is 10 to 20 individuals per hectare, allowing for a larger area of distribution. The motor vehicle is an efficient mode of transportation in view of its convenience in terms of travel, time, cost and route choice (Rodrigue et al., 2006:178-179). This initially freed individuals from tracks and widened residential areas. The negative aspect was increasing distance from traditional urban cores, which would no longer serve as attractive areas. The invention of the motor vehicle transport system decreased walkability in small city centres. The distinctive transit city contains various modes of transportation, often rail systems in the centre and motor vehicles on the outskirts, comprising low-density suburbs, which are ideal for the use of vehicles (Pacione, 2005:791).

The urban spatial structure determines the type of mobility systems needed to function efficiently. The concept determined through the above spatial forms illustrates that compact cities would be more efficient if there were fewer transport systems, ensuring effective mobility. Cities/towns extending over vast areas of land would require transportation systems based on the masses of individuals living in the area. Higher population density would require public transportation systems, allowing for more effective transport costs and lower congestion levels. A lower population density would require more individual transport systems, for example motor vehicles (Pacione, 2005:791). This would offer a more cost-efficient way of travel, based on the individual's timeframe of travel, and lead to less congestion, due to the low population density of the area. One aspect of transportation in this urban form focuses on relationship between space and travel time the commuter has to deal with, illustrating the importance of numerous modes of transportation. The following assumptions could consequently be made (Rodrigue et al., 2006:173-174):

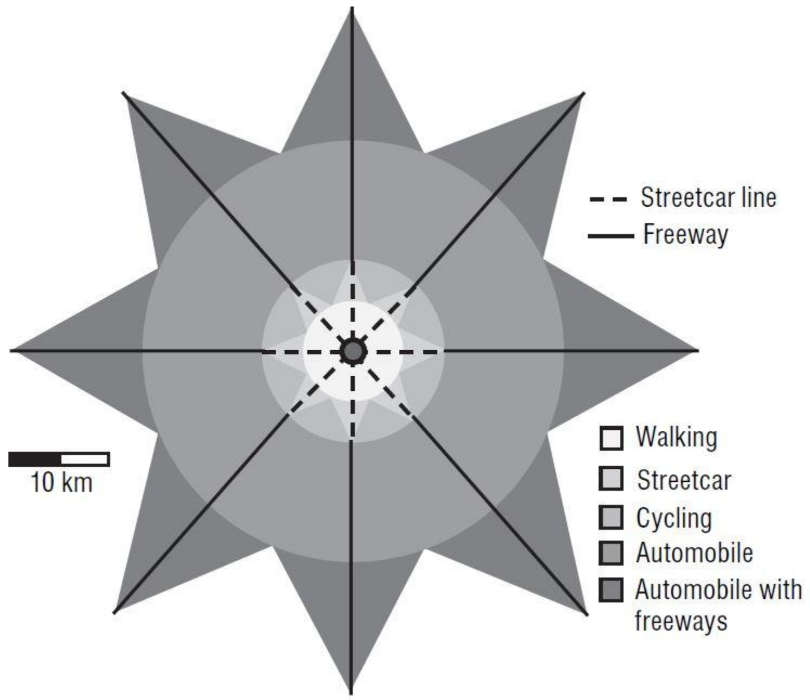

Figure 5-8 Hour commuting time range of travel in transportation systems

Source: Rodrigue et al., 2006:173

- **Walking distance**
  Walking distance is assumed to be the distance a pedestrian is willing to cover in an hour. The assumption is that a pedestrian can cover a distance of 5 km per hour. The focus is then placed on the time and space of travel, the trip from point A to B and back being an estimated 10 km (Rodrigue et al., 2006:174).
- **Street vehicles**
  Street vehicles or street cars can operate at a speed of 15 km per hour along straight lines. This is a faster and more efficient way of travel, but the focus must still be placed on the total time/space taken. This allows for the correct assumptions when implementing an urban spatial structure (Rodrigue et al., 2006:174).

- **Cyclists**

  Cyclists would travel at approximately the same speed as a street car, but have few limitations. The time and space demanded by this mode of transportation may make it more efficient as well as faster, because of the lack of restrictions (Rodrigue et al., 2006:174).
- **Driving**

  When driving is considered, various aspects are relevant: driving where there are no freeways implies limitations (freeways, congestion, traffic lights and stop streets) on the car's speed and the distance of travel. The slower spectrum of a vehicle illustrates that an individual could drive at a speed of 30 km per hour. (Rodrigue et al., 2006:174).
- **Driving on freeways**

  Driving vehicles on a freeway allows for a fast and efficient form of transportation; because of the fixed infrastructure the driving speed can be considered to double. Driving on a freeway can mean that an individual can travel 60 km within an hour (Rodrigue et al., 2006:174).

The rapid expansion of cities and urban areas has created a larger demand for transportation systems, since an increasing number of trips across urban areas are required. Urban spatial structures have responded to these expansions and increases in population by creating an ever expanding supply of transport systems. This happens through the maintenance and upgrading of transportation infrastructure (implementing more lanes to accommodate an increasing number of vehicles), while improving the transport system. There are four major types of urban spatial structures, which are used to accommodate different ways of mobility (Rodrigue et al., 2006:177-179):

d) <u>Type 1 urban spatial structure</u>

This urban spatial structure represents a completely motorised network, which is automobile-dependent and has limited centrality. The land use density has been characterised as low to average, while people use motor vehicles as the main type of transportation between all locations. Motor vehicles are the major transportation system, but not the only system occupying the urban form (Pacione, 2005:791). Public transportation is situated within the urban form, but plays a small role in the transportation of individuals, while sharing the same infrastructure as motor vehicles. The urban structure requires a large network of high-capacity highways, which starts to base the urban form on a single transportation system. This also includes massive parking areas and expensive upgrades on infrastructure (Rodrigue et al., 2006:177-178). The secondary factor has to do with the road coverage of highways and along small centres in towns/suburbs. This is not a sustainable urban structure, because of its lack of diversity in transport systems and failure to consider the impact on the environment, quality of life, productivity and cost. The figure below illustrates the layout of a type 1 urban spatial structure.

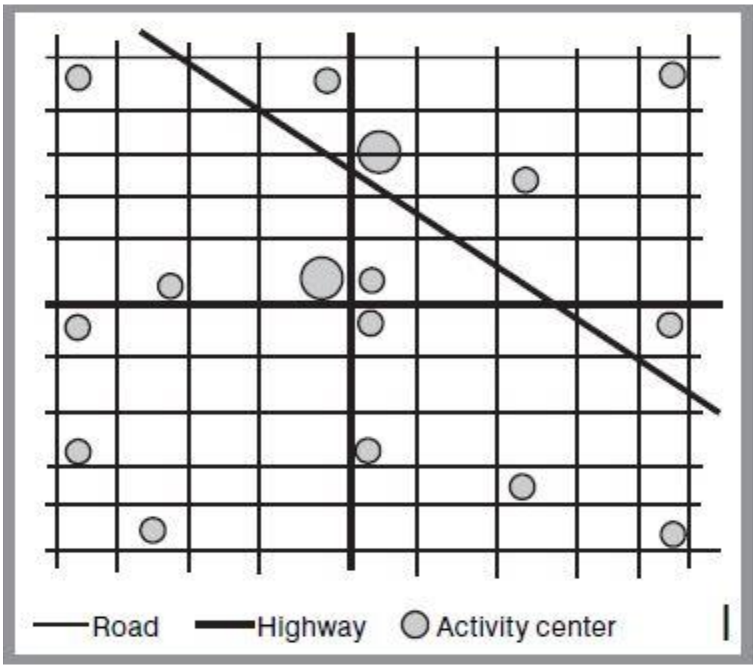

Figure 5-9 Type 1 urban spatial structure

Source: Rodrigue et al., 2006:178

e) <u>Type 2 urban spatial structure</u>

The urban spatial structure found in the form of a type 2 development is regarded as having a weak centre and is represented by numerous American cities. The characteristics of these urban forms are average land use densities and a concentric pattern design. The CBD is accessible by motor vehicles, while public transit systems remain unused or minimally used. This urban system, much like the type 1 urban form, finds it particularly hard to implement various transit systems. One of the distinguishable traits is seen when service transportation systems are located among major corridors. The design has various ring roads around the periphery to allow more economic activities around the CBD. The urban spatial design incorporates various radial lines moving towards the centre of the urban form and is seen in older cities, for example Melbourne, Australia (Rodrigue et al., 2006:178). This spatial urban structure is regarded as more sustainable than that of the type 1 urban structure, but shares a lack of variety in transportation systems. This is not necessarily sustainable, for the same reasons as those affecting the type 1 urban form. The figure below illustrates the type 2 layout and its functionality in transportation systems.

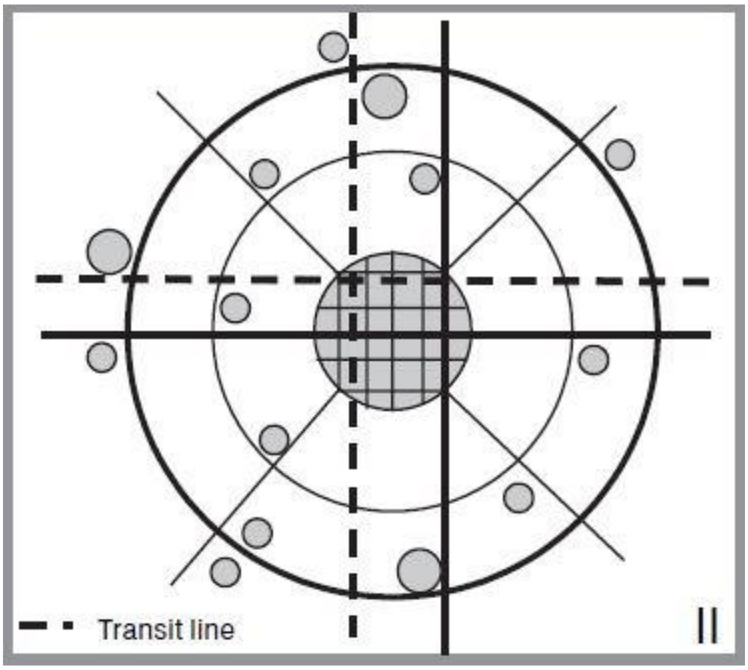

Figure 5-10 Type 2 urban spatial structure

Source: Rodrigue et al., 2006:178

f) <u>Type 3 urban spatial structure</u>

The urban spatial structure is based on a strong centre, because of its high land use density as well as high levels of accessibility to urban transit. The fact that motor vehicles are not the dominant type of transportation system within the urban form illustrates that there is a limited need for highways and parking areas in the central place. The need for public transportation systems is high and their use and profitability remain high (Pacione, 2005:789-791). The productivity of the CBD is based on the efficiency of the public transportation system. The urban design includes a series of radial roads as well as ring roads, to allow for maximum accessibility. The roads also favour secondary centres, because of the expenses (rent) associated with the CBD (Rodrigue et al., 2006:178). The design of the type 3 urban spatial structure is intended to increase mobility through various types of transportation systems, indicating that the spatial layout allows for a multimodal transport service. This spatial structure is entirely based on commercial, financial and productivity levels. The design has been incorporated in the urban spatial design of New York and Paris. The urban spatial structure is sustainable and is self-generating from an economic point of view, allowing for the urban form's independence and growth. The figure below illustrates the urban spatial design and how the incorporation of transportation systems is implemented.

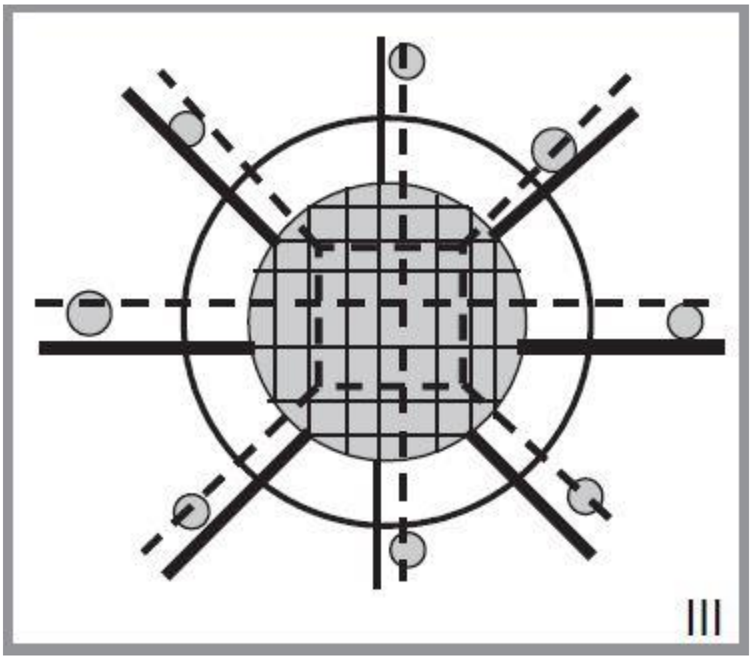

Figure 5-11 Type 3 urban spatial structure

Source: Rodrigue et al., 2006:178

g) Type 4 urban spatial structure

The last and most advanced type of urban spatial structure is developed in terms of mobility. This represents traffic restrictions as well as traffic limitations, effectively limiting traffic through the design of the spatial structure. This design is completely dominated by public transportation and limits motor vehicles (Pacione, 2005:789-790). The design characteristics illustrate high land use density (compactness) and the system is ideally designed to remove SOVs from the urban central space. The motivation for the limitation of motor vehicles is the preservation of the historical character of the infrastructure, while avoiding congestion. The design incorporates a series of narrow roads leading towards the centre of the development, known as the “funnel effect”, allowing the management of small numbers of transportation units entering the CBD. Figure 5-12 illustrates the Type 4 urban spatial structure (Rodrigue et al., 2006:178-179). Individual motor vehicle use is not limited on the periphery and between suburbs, but remains a secondary transport system in comparison to underground trains, railways and buses. This urban spatial structure can be found in cities with a history of public transit. The design is based on a socio-economic approach and is of high importance. This urban spatial design is seen in London, Hong Kong and Stockholm. The urban structure is highly sustainable, self-generating, independent, preservation-conscious and environmentally conscious, as well as socially and culturally incorporated. The figure below illustrates the urban design and its restrictive conditions on SOVs, while promoting public transportation.

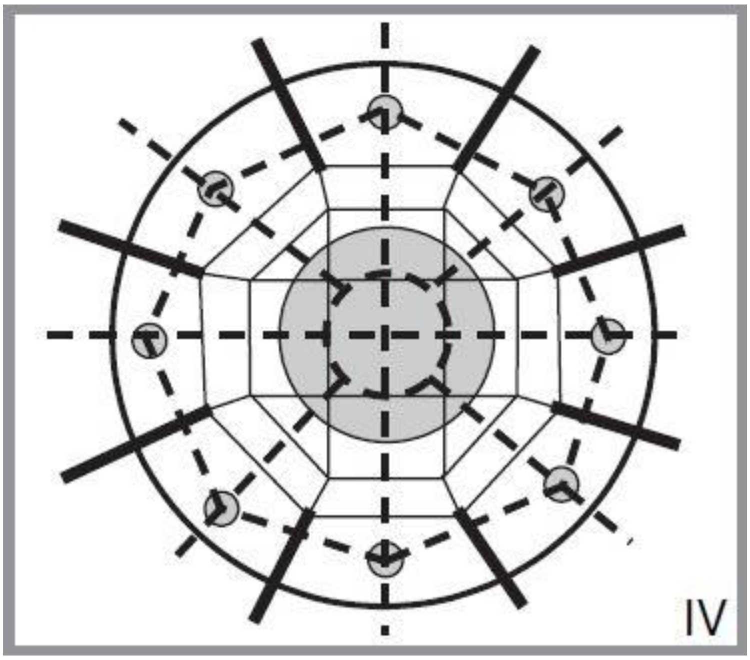

Figure 5-12 Type 4 urban spatial structure

Source: Rodrigue et al., 2006:178

5.7 Challenges in transport planning

The spatial allocation of a specific location to settlement, as well as its mobility systems and associated environmental aspects, should be considered. The aspects discussed below have repeatedly been evident throughout the history of transportation of freight and passengers (Rodrigue et al., 2006:88; Cilliers, 2010:28; Pacione, 2005:787-789):

5.7.1 Land use and transportation planning

The origin of poor land use and poor implementation of transportation systems is lack of appropriate legislation and policies. Spatial development forms part of this challenge and unless spatial plans are suitable, a stagnating urban form could result. The province of the Eastern Cape has noticeably experienced this spatial challenge, which stresses the need for sustainable functionality of urban structures. It has been noted that in the Eastern Cape province, planning of transportation is poor and the opposing demands of settlements are not satisfied. This has resulted in urban sprawl due to the lack of planned areas and great distances from work, forcing individuals to migrate closer to working areas, thus causing urban sprawl. There is a continued shortage of experience/skilled workers to solve this problem. A conference to deal with the problem highlighted a specific aspect, illustrating the importance of this spatial challenge: “Thus the land use/transportation planning task should become one of defining and evaluating sequences of project activities through time in accordance with the achievement of demand vs supply specified policy parameters. It is further concluded that national policies should take cognisance of geographical problems and socio-economic differences in order to bridge inherited gaps" (Situma, 2002:2-3).

5.7.2 Impact on the environment through the loss of energy

The impact on the environment is considered throughout developments, but future expansion and cooperation among sectors are often considered to be of less interest. Natural resources are a core requirement for each community in order function efficiently, but the use of raw materials may damage the environment. Fossil fuels are a natural resource through which petrol, diesel and oil are created. The use of these products through transportation systems releases toxic gases, which may damage the environment over a short or long period of time. This air pollution can indirectly cause water and general ground pollution through the use of the transportation system. This may indirectly cause noise pollution as well and consequently decrease the quality of life (Rodrigue et al., 2006:88).

5.7.3 Pedestrian structures

The improvement of mobility in transportation infrastructure has led to lack of improvements in pedestrian safety and sidewalks. The mobility of pedestrians along major transportation routes has been stunted by overactive transportation systems that jeopardise safety and render cross-walks hazardous. This may also affect cyclists and may cause serious injury or death of both pedestrians and cyclists (Pacione, 2005:789). The spatial concern regarding the layout of mobility systems should be closely analysed; all aspects of this should be considered to ensure maximum safety and efficiency. The physical design of pedestrian facilities should be accommodated, while considering nearby transportation systems and their effect on the facilities.

5.7.4 Political challenges - legacies and transformation

While spatial planning undergoes large changes in the spatial structure, political pressure is also applied. Politicians fail to formulate the necessary supply and demands, among others by advocating equal use of land for each sector. This hampers economic markets and limits access. This would also decrease or limit transportation planning as well as its efficiency throughout the urban form. The problem, which has had a serious detrimental effect on the spatial structure, is the distribution of land and its uses. This has an impact on transportation as well as land use and is politically driven (Situma, 2002:3-5).

5.7.5 Policy implementation

Policies are created despite policy-makers having minimal knowledge of the area concerned. The issue with policy implementation in a spatial plan commonly arises from either the creation of policy or its subsequent implementation. Policies are created and are either too complex to interpret or too complicated to implement, inevitably causing more problems than before the policy was formulated. The common issue in policy creation is that a criterion has not been established and therefore the correct policy cannot be created. Policy creation follows certain principles in order to be efficient and change the functioning of the spatial plan. The principles are illustrated in the recommendations contained in this document (Walters, 2014:6).

5.7.6 Public transportation inefficiency

Public transportation systems are not considered as sustainable systems and this often leads to the collapse or over-use of a transportation system. Many public transit systems are either under-used or over-used, which either draws the public to other transportation systems or leads people to abandon a transit system. The population of an area decides whether a public transit system is needed when overcrowding in a certain transport system leads to congestion and inefficiency. Transportation systems have not only been used for the mobility of freight and passengers, but also to render a service, but the financial income from this could be very unstable (Robson, Gharehbaghi & Young, 2018:386-389). The components of public transportation are crucial for its effective implementation; if not seen to be more efficient than other transportation modes, it could be rejected by the community.

5.7.7 Traffic congestion and parking facilities

Traffic congestion has been an important consideration in spatial planning and the distribution of various transportation systems to improve efficiency. Congestion has become the main problem in transportation systems and can cause decreasing levels of productivity. Inefficiency can affect the built and natural environment in many ways, as discussed in previous chapters. It has been identified that lack of facilities will inevitably lead to the misuse/over-use of an individual facility, which would have a chain effect in the system. If other facilities are not presented for mobility purposes and distributed in close proximity to communities, this may cause the over-use of an existing facility (i.e. roads – over-use of motor vehicles), causing congestion (Kumarage, 2004:1-4).

5.8 Transport-orientated development

Spatial development in cities has been based on various strategies to allow for sustainable growth. This concept is widespread and linked to many misconceptions in developments and frequent incorrect implementation. The focus is based on mobility and perceived efforts to transport individuals from various residential areas to the rest of the city/town. Through transit-orientated development, various aspects of the urban form should be considered. Consideration of sustainable growth in mobility systems begins with transport-orientated development. The compact city has been identified as a type of smart growth process, which has identified the key components of mobility within that specific urban form, allowing for transportation strategies to manage transport (Wilkinson, 2006:223-224). The aim of these transport strategies is to decrease aggregated travel demand and increase transit ridership, mainly seen in developed North American cities. The problem has been identified in South African transportation systems and should be effectively corrected through implementation, while cities/towns expand.

The smart growth concept of transit-orientated development of transportation systems was associated with a model in the US applied in the late nineteenth century and early 1980s. The US had designed a neighbourhood development model, which was identified as a neo-traditional model through which a neighbourhood transport-orientated concept had originated. The neighbourhood transit-orientated development concept was identified as the following neighbourhood transit-orientated development and metropolitan or city-wide context of TOD (Wilkinson, 2006:224):

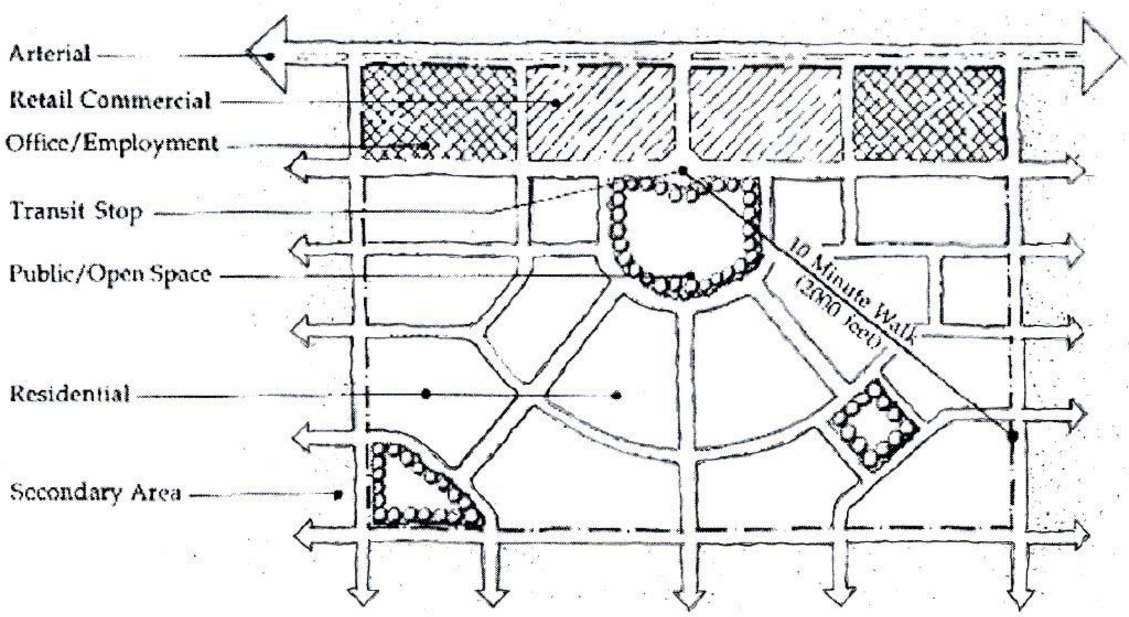

Figure 5-13 Neighbourhood transit-orientated development

Source: Wilkinson, 2006:224

The transit-orientated development neighbourhood layout was designed for the efficient mobility of the nearby community. The basic ideas would formulate a simple design to achieve the generally accepted features discussed. The features would consist of a transit-orientated development, which had been centred on a rail or bus transit system, which would extend to a walking distance of 400 m – 800 m radius (South Australia, 2009:3). The urban design would be developed according to a moderate to high density, known as the 'human scaled development'. The design would have to include a sufficient amount of provision for public and civic spaces. This would be situated in residential areas, located close to retailers, adjacent stations and other local transport systems. The smart growth neighbourhood design has been implemented in a grid layout (open) to create accessibility through numerous routes (Wilkinson, 2006:224). This cannot be conceived within a cul-de-sac, loop layout which would lead to single road network congestion with limited access to other routes. The neighbourhood transit development has been implemented employing the concept of pedestrians and cyclists (South Australia, 2009:2-4). This infrastructure is highly important for the movement of pedestrians among neighbourhood blocks or destinations in close proximity.

5.9 Metropolitan/city transit-orientated development

The metropolitan transit-orientated development has been based on a similar concept as the neighbourhood TOD, but owing to its larger scale of implementation and range of land uses it has to incorporate more principles (South Australia, 2009:2). The benefit of the transit-orientated system is that it allows for the effective functioning of each land use system. This would be a similarity between the neighbourhood scale and the metropolitan scale. This has been based on the 'New Urbanist' movement and allows for the free exercise of property rights. Smart growth has been identified as a strategy to remain sustainable, while allowing for future growth. The beneficial aspects discussed below have been assessed in the metropolitan TOD area (Wilkinson, 2006:224-225). The figure below is a representation of a metropolitan TOD area and how it would be implemented, indicating the beneficial traits:

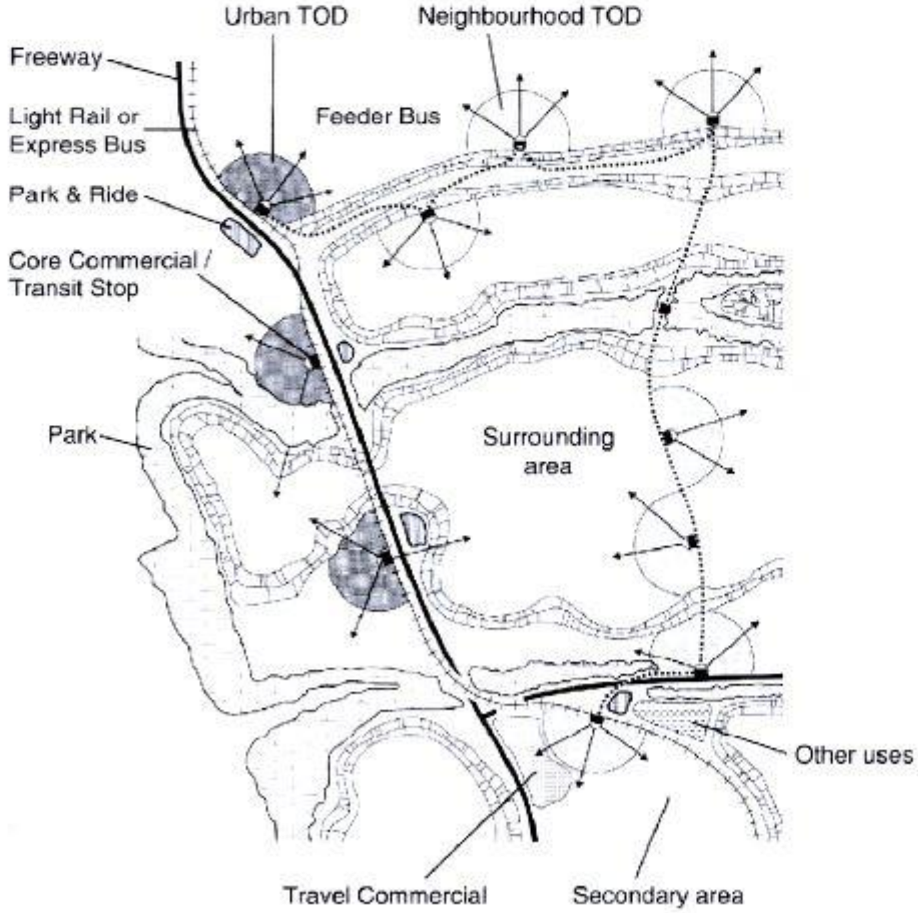

Figure 5-14 Metropolitan/city transit-orientated development

Source: Wilkinson, 2006:225

The first important aspect of TOD in metropolitan areas is that it enhances the accessibility of the area from the neighbourhoods as well as the CBD. The fact that transport systems have been planned efficiently also allows for an increase in land use and land value/rentals. This would increase in both residential and commercial property markets. While transit-orientated developments become successful, there will be reduced per capita motor vehicle travel, which then manifests in lower wide aggregate vehicle-kilometres travelled. The decrease in vehicles on roads will have a positive chain effect, which then lowers overall road congestion and travel time and helps preserve the environment, since minimal emissions are released (South Australia, 2009:3-4). The second aspect of metropolitan TOD is that through the illumination of vehicles in certain sectors, individuals are more likely to use public transportation services, improving ridership levels as well as operating costs. The public transportation services increase both the efficiency and mobility of TOD neighbourhoods (Wilkinson, 2006:225). The reason for this advantage is that vehicles are banned from areas where public transport enjoys full access. This would be regarded as a massive transportation disadvantage if SOVs should be used.

Transit-orientated developments are movements towards sustainable urban forms, which can be achieved through correct spatial planning, but should stay conscious of mobility and the environment. The first aspect that has identified itself as a highly effective way of implementing urban spatial structures is densifying the population and CBD. This would help distinguish the type of transportation needed and allow for public transportation systems to be used more widely. The identified aspects for sustainable TOD are indicated in Figure 5-15 (Wilkinson, 2006:223-225; South Australia, 2009:1-3):

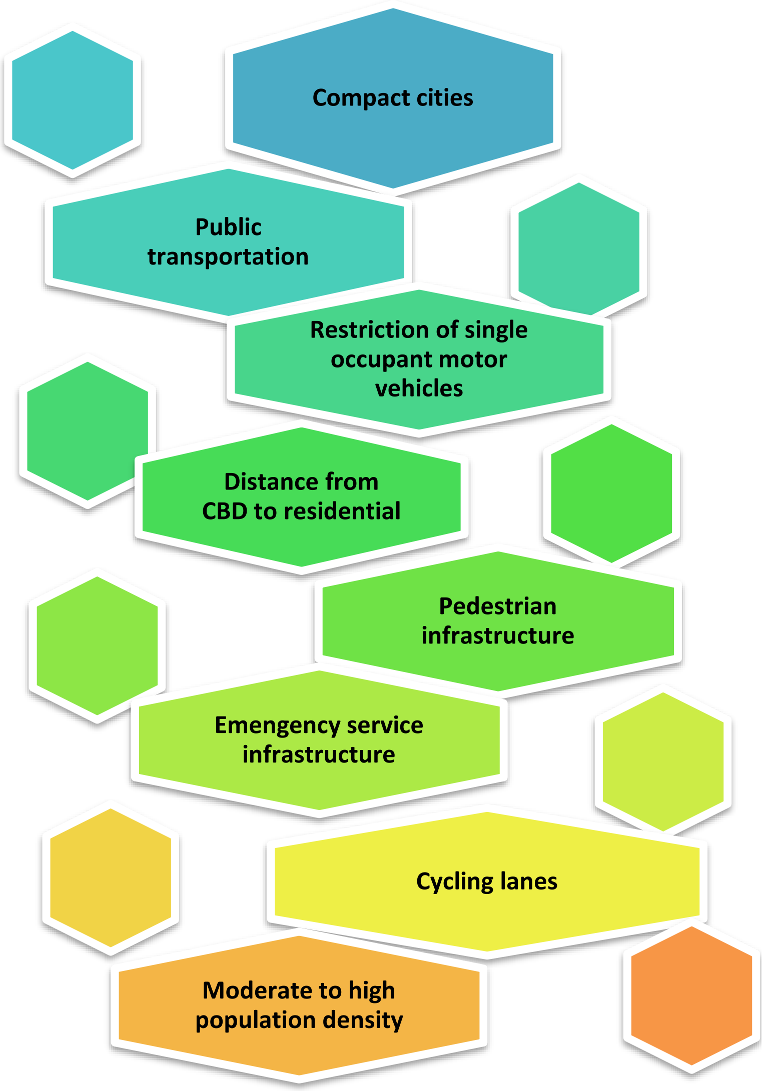

Figure 5-15 Sustainable aspects to consider for transport-orientated developments

Source: Own creation

The conclusion is therefore that the implementation of transit-orientated developments is in fact a forward movement towards sustainable infrastructure if the above aspects are considered in the spatial development of an area.

5.10 Conclusion

To conclude this chapter, the urban spatial structure determines the type of transportation needed to be sufficient. Spatial planning of a specific urban design should incorporate the concept of the type of multimodal transport service implemented. Throughout the dissertation, a series of issues related to pollution, congestion, safety, inefficiency, low productivity, decrease in quality of life and lack of environmental preservation was considered. All the above negative impacts of transport modes should be considered before designing the urban form (Pacione, 2005:787-789; Rodrigue et al., 2006:174-179; Cilliers, 2010:28).

The solution is illustrated in the paragraphs above: sustainability and the incorporation of transit systems would be effective if cities/towns/suburbs could be designed on a high-density foundation. This would allow for the incorporation of public transportation systems, walkability and environmental conservation, since minimal use of space occurs in the built-up area (Pacione, 2005:789-790). The above paragraph also states the specific types of urban spatial structures and how transportation would either improve or decrease efficiency (Rodrigue et al., 2006:178-179). All this relates to the restriction of SOVs moving towards the CBD. The restriction would also trigger a decrease in parking areas (built-up area) and in expensive transport infrastructure (roads) and allow for sustainable transportation systems to be incorporated, for example cycling. This would have a chain effect and increase pedestrian infrastructure, because of the close proximity to the workplace. Public transportation would be more efficient, because traffic congestion would be eliminated (decrease in SOVs) and a cost/time effective type of mobility would be enabled. This would increase productivity and allow economic growth to take place.

The conclusion can be reached that spatial plans should focus on the terrestrial surroundings and analyse what is needed for the current development, while incorporating the five assumptions on mobility in the urban form. This will give a perspective on how the urban spatial structure should be designed and what the purpose of transport systems is.

CHAPTER 6 INTERNATIONAL PERSPECTIVE

6.1 Introduction

This chapter illustrates various international case studies, while incorporating legislation and policy. This will also deal with part of objective 2 with regard to illustrating what has been considered. The case studies analysed relate to Australia and Denmark (Denmark Consolidated Act, No 813 of 2007). The case studies will evaluate specific cities in each country in order to create a spatial criterion on how transportation systems can be spatially integrated. The spatial criteria should help to create a spatial framework with policies that would support the different functioning and efficiency. Denmark is used to determine the principles required to formulate a sustainable transportation system using various modes of transportation (Tharan, 2004:15). This determines the use of a multimodal transportation system as well as the restrictions placed on motor vehicles. Denmark is highly effective in terms of the integration of public transportation and pedestrian-friendly infrastructure. A case study of Australia helps to determine the principles of efficiency in transportation systems. Australia has focused on the aspect of efficiency, implying that motor vehicles are not limited to specific areas, and public transportation and other modes of transportation (pedestrian walkways, bicycle lanes) have been implemented effectively (South Australia, 2013:22-30). Developed countries have stipulated multiple sectors of growth through the correct spatial integration of transportation systems. Developing countries (South Africa, Pakistan) are limited to growth and lack efficiency, productivity and functioning. These countries lack policy implementation, which decreases the potential functioning of the settlement.

6.2 International best practice

The best international practice is a vague topic of interpretation. Spatial planning does not have a specific criterion for every development. Spatial planning of an area is dependent on the topography, population density, surrounding land use, poverty and other factors that depend on the area. The beginning process of spatial planning is based on the creation of effective policy and implementation. The international best practice for a policy criterion is illustrated according to the Public Policy Web (2001) in creating efficient policies (Walters, 2014:6). This has been illustrated in the dissertation. The urban land use model that has proven to be highly effective and sustainable is known as the garden city (Clevenger & Andrews, 2017:5; Hurley, 2014). The garden city model is not a final spatial representation with a set spatial plan, but in fact is successful owing to its principles, which are implemented. The principles of a garden city are commonly:

1. Environment

2. Radial spatial structure
3. Sustainable transportation systems (bicycles, public transportation and pedestrians)
4. Distance between residential area and CBD area
5. The compact city design
6. Accessibility
7. Recreational parks
8. Efficient land use management.

The above principles have been identified in developed countries (Australia and Denmark), and in cities in developed countries. This can be demonstrated in Annexures A, C and D.

6.2.1 United Nations Human Settlement Programme

The United Nations Human Settlement Programme (UN-Habitat) is an international series of guidelines created to formulate the sustainable principles needed as a basis for spatial development. This international book of guidelines has been devoted to the sustainability of both the environment and the needs of humankind. The final objectives of these guidelines were to (UN-Habitat, 2015:1-3):

- Create a link to other international guidelines in order to achieve sustainable urban development;
- Create a universal framework to guide urban policy reforms;
- Raise urban and territorial dimensions of development agendas of national, regional and local governments for functionality of urban forms; and
- Record worldwide principles and combine them to improve local experiences and adopt diverse planning approaches.

The scope of this international guideline policy can be implemented through three levels, which are seen at a multiscale level. The guidelines promote key urban and territorial planning principles, which play a role on various levels (UN-Habitat, 2015:2-3):

6.2.1.1 Global level (multinational policy)

Supranational and transboundary strategies are regarded as multinational regional strategies that could help with investments in global issues (climate change) and energy efficiency. This multiscale guideline could enable integrated expansion of various urban areas in different regions. The purpose is to increase sustainability through sustainable management of natural resource strategies (UN-Habitat, 2015:1-2).

6.2.1.2 National level

The focus of the guideline on national level is to provide economic benefit. This would support the development of existing economic poles, while promoting the growth of numerous other economic poles. This would also promote the planning and implementation of large infrastructure in order to support and balance the development of settlements (cities/towns) in the region, which would have the advantage of increasing economic potential by increasing urban corridors and protecting river basins (UN-Habitat, 2015:2).

6.2.1.3 Regional and metropolitan level

The regional and metropolitan level guideline supports development by promoting regional economies of scale through agglomeration. Increasing the productivity and prosperity of an economy would directly strengthen the urban-rural linkage. This would ease adaptation to climate change impacts and help in preparing for natural disasters. The essence of the guideline is to address social and spatial disparities, while promoting territorial cohesion and complementarities. The city-level development guideline prioritises the city's development strategies as well as the integrated development plans. This places the focus on investment decisions and interaction between different urban areas. Both the built and natural environments have to provide in the needs of the community without compromising the natural environment. The dependability of this guideline is based on the correct distribution of land (land use), known as land-use management. Proper land use management strategies would help protect the environment and consider the sensitivity of areas. The regulation of various markets would help limit the various forms of land use to the built environment, despite the expansion of the city. Urban extension and various infill plans would help to minimise transport and service delivery costs. Through the urban renewal process and upgrading, plans would serve to increase residential as well as economic densities. This would promote the establishment of more socially integrated communities. These considerations on metropolitan level focus on the integration of land and its uses (UN-Habitat, 2015:2-3).

6.2.1.4 Local level

The neighbourhood development level is where the development of streets and public spaces occurs. This level of the guideline is considered to be the smallest point of implementation. It focuses on the improvement of urban quality, protection of the environment and local resources, social cohesion and social inclusion. This guideline allows for public participation through the involvement of the local community. This helps to improve public spaces and services and possibly improve spatial integration in the long term. Neighbourhood-level implementation of the guideline is intended to improve connectivity, human security, local democracy, resilience and social accountability (UN-Habitat, 2015:2-3).

6.2.2 International guidelines on urban and territorial planning

International guidelines on urban and territorial planning have yielded the following approaches to the creation of sustainable communities (UN-Habitat, 2015:13-22):

6.2.2.1 Urban and territorial planning and social development

The aim of this specific guideline to is achieve adequate standards of living and working conditions for all. This strategy is aimed at creating future sustainable societies, which will ensure equitable distribution of costs, opportunities and benefits in urban development. This will help to create social inclusion. The second principle driving this guideline is essential investments made in the future growth of the urban environment. This would not only bring about improved quality of life, but also help initiate respect for various cultural heritages globally. This guideline also seeks to reduce commuting time between living, work and service areas. The proposals illustrate that by promoting mixed land use, safety, comfortability, efficiency and affordability, a reliable transportation system could be implemented. These principles are initiated through various spheres of government (UN-Habitat, 2015:14-16).

6.2.2.2 Urban and territorial planning and sustained economic growth

The economic perspective of territorial and spatial planning is driven by two principles. The first principle illustrates urban and territorial planning as a catalyst to sustaining inclusive economic growth in the community. The purpose of this principle is to create a general framework for new economic opportunities, which regulates both land and housing. This is based on service delivery as well as infrastructure. The second principle is based on decision-making processes through which certain powerful decisions should be made on how to sustain economic growth, environmental sustainability and social development. This principle focuses on connectivity at all territorial levels (UN-Habitat, 2015:17). The national sphere of government is based on certain guidelines to allow for sustainable settlements. This sphere plans and supports the development of polycentric urban regions by clustering industries, services and other institutions to concentrate economic growth. It supports inter-municipal cooperation to ensure optimum mobilisation and the sustainable use of natural resources. This level also formulates various methods of communication, thus optimising connectivity through a technology policy framework. The local sphere focuses on creating favourable conditions to develop efficient mass transit of both freight and passengers. This focuses on the minimising of individual vehicle use in order to increase urban efficiency in the mobility sector. This should be affordable as well as energy-efficient to obtain a sustainable settlement. The second important aspect of mobility is the maintenance of the transport infrastructure. This should supply adequate space for streets, safety, efficient street networks and maximum connectivity, while encouraging non-motorised transport. Through these strategies of mobility, travel time should decrease, as well as the cost of service provision. The goal is to implement a sustainable public transportation system accessible to each individual within the settlement. This will directly and indirectly enhance economic productivity, while facilitating local economic development (UN-Habitat, 2015:18-19).

6.2.2.3 Urban and territorial planning and the environment

Urban and territorial planning reflects on the environment in terms of creating a spatial framework to protect and manage the built environment as well as the natural environment of cities/towns. This includes the management of biodiversity, land use and natural resources. The purpose is to ensure integration. Urban and territorial planning protects nature and contributes to its integration into towns and cities to create sustainable developments. Moreover, urban and territorial planning could indirectly increase human security by strengthening the environment and socio-economic resilience. This sustainable adaptation would enhance mitigation and adaption to climate change. These guidelines, on national government level, set standards and regulations for the protection of water, air, green open spaces, ecosystems, biodiversity hotspots and other natural resources. Such guidelines ensure that urban and regional plans address the need to implement sustainable energy services, keeping in mind the concept of clean energy consumption and a reduction in the use of fossil fuels. This encourages the use of various clean energy resources, while focusing on efficiency in buildings, industries and incorporation of multimodal transport services. The guideline aims to establish a compact city design to optimise economic potential, while reducing urban sprawl and initiating a progressive densification strategy, and to optimise land use in urban spaces and reduce the cost of transportation infrastructure, while decreasing the demand for transport. This will lower the carbon footprint of urban areas, allowing for effective strategies to increase sustainability and decrease climate change. The local government (authorities) would implement this guideline to set up a low carbon urban form with specific development patterns in order to improve energy efficiency and increase access. This would create a base for using renewable energy sources and incorporating these in the urban form (UN-Habitat, 2015:26-27).

6.2.3 Sustainable Development Goals

The United Nations' Sustainable Development Goals (SDG) are common goals related to a common interest in creating a better future. There are 17 goals to build on the success of the already developed Millennium Development Goals (MDG), including new areas such as climate change, economic inequality, innovation, sustainable consumption, peace and justice, which are regarded as priorities for a better future. It is hoped that the 17 goals listed below will be achieved by 2030 (UNDP, 2017:16-59):

Figure 6-1 Balance within SDGs

Source: Own creation

Spatial planning has also been promoting SGDs by improving various urban forms to create a better quality of life for communities. This allows for proper planning of pipelines and for access to clean water and adequate disposal of human waste, improving sanitation (UNDP, 2017:16-59).

6.2.4 European Union Commission

The European Union (EU) Commission implements the ideals of the SGDs as well as the New Urban Agenda to provide a foundation for legislation and policies. This provides a base for spatial planning and governance while adjusting the urban form to conform to a sustainable strategy (European Union, 2018:1-2).

The term spatial planning does not have a specific definition, which means that it is based on more than a single definition. The EU has given two definitions in its efforts to define spatial planning (European Union, 2018:2):

- It has been defined as the methods used mainly by the public sector to influence the distribution of activities in a specific space. This aims to segregate sectors of land for more rational territorial organisations of land uses and create linkages between them to form effective functionality in spatial development. This has been interpreted to balance the demands of socio-economic goals, development, environmental conservation and transportation.
- The second definition states that spatial planning embraces measures to co-ordinate various sectoral policies in order to achieve better distribution of land and more even distribution of economic development between regions. This would prevent market forces from evading large areas of land and help conserve the environment through proper use.

The EU coordinates planning in three different spheres, which all operate to ensure the sustainability of spatial planning. The spheres are recognised as the following (European Union, 2018:3):

1. National level
2. Sub-national level
3. Local level.

6.2.5 Environmental policy and legislation

There are multiple laws on the protection and conservation of the environment to ensure sustainability while providing in all the needs of the community. The following legislation has been labelled as significant in environmental conservation (European Union, 2018:6-8):

- **Strategic environmental assessment**

Strategic environmental assessment (SEA) legislation requires an impact assessment before implementing certain plans and programmes; these laws are to be prepared and adopted by national, regional and local authorities. This includes land use plans as well as any other plans regarding the development of the spatial structure. SEA analyses the effects of the development on the immediate natural environment to determine the validity of the development or restrict it. SEA focuses on specific fields, including soil, water, air, flora, fauna, cultural heritage and human wellbeing. This legislation is responsible for setting sustainable guidelines to accomplish sustainable and integrated human developments, through the integration of the built and natural environment (European Union, 2018:6).

- **Environmental impact assessment**

Legislation on EIAs requires an assessment on the impact of specific types of large-scale developments/projects before these are carried out. The projects include motorways, railways, urban developments, industrial developments and other transport infrastructure. The impact assessment includes the effects of these developments on the environment during future implementation. The variables that need to be assessed in the environment are biodiversity, fauna, flora, water, soil, cultural heritage and human health. The difference between SEAs and EIAs is the level of implementation. SEA is implemented in various spheres of authorities from a general preservation perspective, while an EIA is a tool to protect the environment by assessing new areas and determining the impact developments may have on the local environment (European Union, 2018:6).

To conclude the comments on the above legislation, it is noted that it is intended to ensure sustainable spatial development. The effect of such developments can be seen in the implementation of transport systems. Transportation systems have caused major problems, as described in EIA, SEA and other legislation. The problem, as mentioned throughout the dissertation, has been identified as SOVs.

- **European Union transportation policy**

The EU created regulations through a set of guidelines for the development of trans-European transportation networks. These apply to a comprehensive network incorporating various core networks. This implies that different transportation systems are implemented in different segments of the spatial development, which comprise their core. The regulations identify the common interests as well as the requirements for managing the various transport infrastructures. Priorities were determined in the regulations enforced by the EU transport policy. While the EU had full control over spatial systems in the national and sub-national sphere, it had little influence over local/domestic spatial systems. The idea generated by the EU was to expand urban mobility planning by adding local land use planning (European Union, 2018:12).

6.3 CASE STUDIES

6.3.1 Introduction to first world countries

The case studies related to first world countries are sustainable and ranked in the top ten most sustainable countries worldwide. This allows detailed spatial representation of the cities developed in those countries. The cities/towns in developing countries are considered the aim of the comparative study and will be used as a base format. The first developed countries illustrated in the case study are Denmark and Australia. Individual case studies in each discuss what are considered to be some of most efficient transportation systems in the world. The two cities that are examined are Adelaide in Australia and Odense in Denmark. Both have implemented what is known as a light rail transit (LRT) system. The cities are aligned in a hierarchy, since one is less developed than the other. This would facilitate comparison with cities in South Africa, where there are numerous inequalities between cities. The second aspect to consider is the use of transport facilities, even though South African cities have deteriorated because of lack of upgrades. Local transportation systems that have been implemented are bicycles, SOVs, public transportation systems and pedestrian infrastructure. Both South African cities and Denmark have implemented transportation systems in their spatial structure and urban forms, but the levels of efficiency in the two are completely different. The last aspect to note is that all are regarded as secondary cities.

6.3.2 Introduction to Denmark

Understanding of policies determines the level to which a developed country is able to achieve sustainability in spatial planning transportation networks and the functioning of the urban form. The policies help to achieve a successful functioning spatial structure reflecting the foundation on which they were developed. Numerous strategies in each sector of development enable maintenance of the infrastructure.

The economy of Denmark was not always as strong as it is at present; it actually went through a dramatic economic crash after WW2. The service sector was able to repair this economic deficit status by trading and shipping meat and brewery products, followed by the development of many bigger companies in engineering, pharmaceuticals and agricultural machinery. This led to an increase in the tourism and food industries. The country was able to dominate the world’s small and medium-sized markets and became one of the world’s richest countries in 2002 with a gross domestic product (GDP) of $155,3 billion. The sectors that are responsible for the success of Denmark are ranked through the contribution each made. The agricultural sector contributed least, only 3%, towards Denmark's economy, while industries contributed 26% and lastly the largest sector, services, contributed 71%. It is important to realise that efficient services are created through resilient transportation systems planned effectively within spatial planning to enable maximum distribution of services without escalating time and cost. The planning of the spatial design and layout has to be meticulous in order to achieve high efficiency (Tharan, 2004:2)

Combustion engine transportation systems have become a popular transportation system, which are implemented in all countries. Denmark has the benefit that because of its strong economy and vast network of transportation systems it has minimal transport-related problems, yet the country faces severe environmental issues, mainly air pollution from vehicles and power plants. Denmark is a victim of motor vehicles, even though it is a developed country. In 1992, Denmark was the first country to introduce a tax on carbon dioxide (CO2) emission. This highly developed country then started to produce and distribute 20% of its power created by wind turbines rather than power plants. The Kyoto Protocol was also implemented to decrease CO2 emission and stop the release of greenhouse gases (Tharan, 2004:3)

6.3.2.1 Policies in Denmark

6.3.2.1.1 BYPAD bicycle policy

The BYPAD bicycle policy has been implemented in the entire country of Denmark in an effort to create more efficient bicycle transportation and services. The levels of cycling infrastructure in cities differed dramatically and needed change through the improvement of various elements of transportation. This policy is significant because it recognises the principles needed to change vehicle transportation in cities into sustainable, efficient transport. The policy has been particularly relevant in the city of Odense, because of its compact spatial development and the close proximity of various points to the CBD. The policy was implemented to support a redesign in infrastructure, which occurred in the 1970s, when spatial policies changed to reduce car traffic. The design of Odense that made it effective for the implementation of the policy comprised ring roads and a radial network design (Krag, 2004:2-3). The policy was implemented through the use of modules and the objective was to reach smaller aims in a process of achieving the effectiveness of the policy as a whole. The following modules were implemented and rated according to the level of implementation in the city (Krag, 2004:2-3):

- ❖ Focused and pin-pointed user needs. (Implementation efficiency level: 88% effective)
- ❖ A firm sense of leadership. (Implementation efficiency level: 79% effective)
- ❖ Policy on paper before implementation. (Implementation efficiency level: 88% effective)
- ❖ Means and personnel. (Implementation efficiency level: 92% effective)
- ❖ Infrastructure for cyclists and pedestrians. (Implementation efficiency level: 87% effective)
- ❖ Communication and education of the affected community to facilitate the implementation of a new transport system. (Implementation efficiency level: 88% effective)
- ❖ Bicycle transportation systems that focus on specific groups and partnerships. (Implementation efficiency level: 75% effective)
- ❖ The initiation of complementary activities to allow for a sense of freedom and willingness to use the transport infrastructure. (Implementation efficiency level: 63% effective)
- ❖ Focus on evaluation and the effects on the community, while determining efficiency. (Implementation efficiency level: 97% effective)

The above level of effective implementation illustrates that the policy had been successfully implemented and could be viable for future sustainable implementation in other cities. The policy allowed for a better quality spatial plan to foster future development.

6.3.2.1.2 The Planning Act in Denmark, Consolidated Act No 813 of 2007

This Act was implemented to ensure the overall planning and interests of the community with regard to land use. It contributes to conservation of the country's natural resources and environment. This Act was implemented to create sustainability and improve living conditions while conserving wildlife, including vegetation. The Act strives to achieve five specific aims throughout Denmark.

The first aim is appropriate development throughout the whole country. This includes administrative regions and municipalities. This aim has been based on overall planning and economic considerations.

The second aim focuses on creating as well as conserving valuable buildings, settlements, landscapes and urban environments.

The third aim is to maintain open areas to increase and maintain important natural as well as landscape resources. This is vital for a settlement to preserve future resources.

The fourth aim of this Act is to prevent further air, noise, water and soil pollution, which is mainly caused by vehicles or factories.

The fifth and last aim involves the public in the planning process (public participation) as much as possible to allow the community to voice its opinion on development.

The Act's bylaws are intended to help local authorities to establish a sustainable perspective and consequently to create a large number of cities that adopt the same or a similar approach to sustainability, leading to a sustainable country. The sustainable concept portrayed in the Act is not only for future use of resources, but to increase efficiency and socio-economic activity.

6.3.2.2 Transportation in Denmark

Denmark has a unique approach to transportation systems, among others the vision to upgrade rail transit systems. This simplistic idea of a transportation system is referred to as the LRT system, which is a popular type of transportation system in middle-sized European cities. The LRT system is planned to support urban development strategies. It is hoped that it will be possible to implement the LRT project in the larger cities of Copenhagen, Aarhus, Odense, and Aalborg. The problem with the LRT is that it has previously yielded poor socio-economic return owing to traffic congestion, which often caused time delays. Its construction and maintenance were also expensive. The idea of incorporating underground metro systems seemed to be popular, but the required infrastructure was expensive (Nicolaisen et al., 2017 1-2). The large cities in Denmark had a choice between the well-known BRT and LRT systems. Three of the four cities preferred the LRT over the BRT because LRT allows for travel over longer distances, while BRT is a short-distance form of transport. LRT also allows for quality urban space and attractiveness (Tharan, 2004:2-3)

In order to implement the LRT network in cities correctly, the gap between the current policy and the planning and implementation of the transportation system should be eliminated. The approach taken by the Danish authorities was to design an actor network theory, which allows for the LRT system to be planned spatially in the cities from a theoretical point of view. The theoretical implementation will be able to identify if the transportation is viable and if it is possible to implement it physically.

Table 6-1 Proposed implementation of LRT in cities in Denmark

City/ Year/ Inhabitants	Length, stops, travel time	Estimated Costs billion DKK State financial support	Mio. DKK/km	Present value (NNV) (mio. DKK) Internal rate	Estimated no. passengers/day
Aarhus / 2017 / 250,000	12 km/18 stops	LRT: 1.1 DKK State: 0.6 DKK	94	NEG	?
Greater Copenhagen Area / 2023* / 1,800,000	27 km/28 stops	LRT: 3.7 DKK State: 1.7 DKK BRT: 2.4 DKK	132 86	NVV: -2,581 Rate:+2,8 % NVV:+528 Rate: +5,7 %	57.820 passengers/ day (2018) 53.400 passengers/ day (2018)
Odense / 2020 / 170,000	14 km/26 stops	LRT: 1.6/2.3 DKK State: 1.1 DKK BRT: 1.3 DKK	109 88	NVV: -4.157 Rate: neg. NVV: -4.296 Rate: neg.	25.100 passengers/ day (2020) 20.400 passengers/ day (2020)

Source: Nicolaisen et al., 2017:9

The above table illustrates how the LRT transportation system will be implemented in Aarhus, Copenhagen and Odense.

6.3.2.3 Spatial implementation of light rail transit system

The spatial implementation of LRT was considered to adjust transportation units to the large population accommodated in the cities of Aarhus, Copenhagen and Odense. Aarhus is regarded as one of the most important cities in the Denmark and is particularly focused on commuting and sustainable transportation units. Aarhus is also the second largest city in Denmark, which illustrates its high population density. Consideration of transportation systems had to focus on the efficiency and capacity of the system to allow for a fast flowing network in which productivity could be sustained. The conclusive analysis made illustrated that if no alternative transport modes were implemented, the urban form would come under pressure, hence the LRT systems. Copenhagen had a problematic transportation system; road infrastructure had become congested through the use of combustion vehicles, which led the authorities to implement an LRT system. This had positive results for the productivity of the city, which led to the subsequent implementation of bicycle lane infrastructure and a restriction on vehicles. Odense is considered to be one of the least developed cities in Denmark, but it implemented LRT systems to increase productivity and efficiency. The traffic congestion in Odense is great, thus illustrating the effects of poor transportation units on urban forms (Nicolaisen et al., 2017:9-14). The LRT has been regarded as an effective and efficient way of moving large numbers of passengers from one point to another. Denmark decided to implement these systems based on the concept of maximising profit and productivity in the long term. The transportation systems have been extremely successful, which has led to the idea of implementation in cities with large population densities in third world countries. The developing country of Pakistan has already considered LRT as a solution for transportation issues (Masood et al., 2011:260).

6.3.2.4 Odense

Denmark is regarded as one of the most sustainable countries in the world, owing to small elements implemented correctly throughout the spatial plan. The spatial development framework (SDF) has been modified to accommodate various types of transportation systems to increase mobility and productivity. The key goal is to obtain a sustainable country, which is only possible through the improvement of all the cities and towns situated in the country. The goal is to implement the correct infrastructure throughout the topology of Denmark in order to create a functional system. Transportation plays a massive role in the sustainability and economic growth of a country; it is regarded as one of the main factors in spatial development frameworks. The city of Odense is the third largest city in Denmark and has 185 000 inhabitants, of whom a large number are associated with the university (Pucher & Buehler, 2007:33). The topology is ideal for cycling, because of the relatively flat surface.

6.3.2.4.1 Land use in Odense

Odense has efficient services, green spaces, various residential areas and a diverse array of transportation systems. The implementation conserves the environment and provides what the local communities require. This pristine environment not only creates beauty, but increases the quality of life for communities. The clarity of the open green spaces helps individuals to increase their well-being and mental clarity and increase productivity. The spatial structure of Odense is based on pre-determined human behaviour and plays an import role in the development of the city. Figure 6-2 below illustrates the various elements of Odense and how its spatial structure was used for specific land use purposes (Schipperijn., Stigsdotter et al., 2010:25-28).

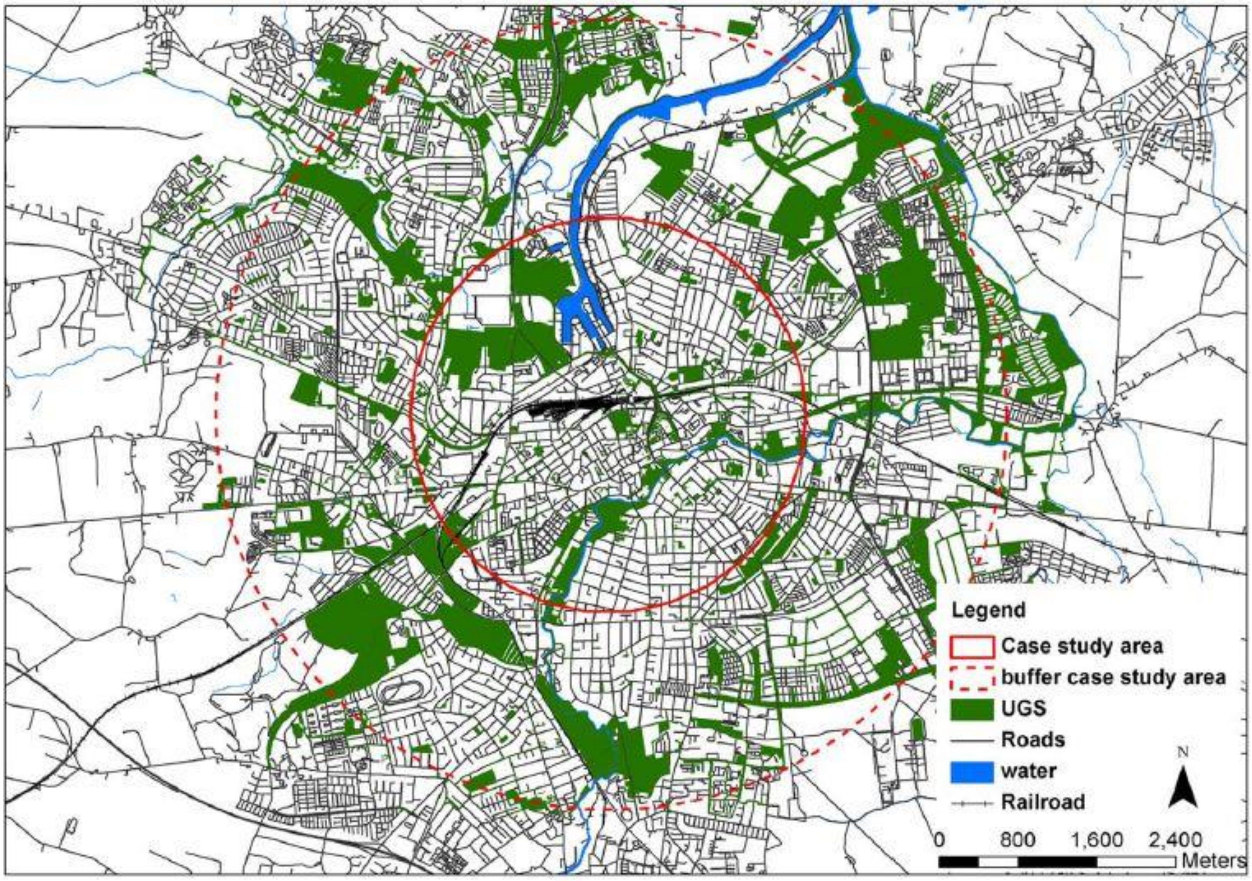

Figure 6-2 Study area and land use elements in Odense

Source: Schipperijn et al., 2010:27

Odense in Denmark has focused on its identity of becoming a “big city”; the development of the LRT infrastructure and transportation system will help support that image. One of the main land use attributes of Odense is the ability to preserve and maintain green open spaces. The statistics illustrate that green space has been incorporated throughout the city, leading to it being perceived as a green city. Land use in Odense encompasses a wide ranges of housing types, from apartment buildings to semi-detached dwellings as well as family houses, ranging from small to large. All the relevant buildings share a green area or have a garden to give them access to open space. The second reason for the development of an LRT project is to connect the surrounding suburbs effectively to help expand the university as well as the university hospital. This specific public transportation system connects all areas of Odense and actually preserves the green area. The theory behind the implementation of LRT systems is reducing traffic and the use of cars, which inevitably preserves the environment and creates effective mobility for the residents of the area. The urban transportation process has been aimed at decreasing traffic on the roads built in the 1960s. The LRT will help give a new vision in terms of urban transportation and eliminate the need for cars. The LRT was designed as a solution for eliminating vehicles, which has been implemented in the city of Aarhus as well. The launching of the new LRT project was associated with restrictions on vehicles in order to direct individuals towards this more efficient transportation process (Nicolaisen et al., 2017:11-12). Odense is the home to a BRT system as well, but even though it is a more economic type of transportation system, it lacks the efficiency that is crucial in public transportation. Odense was considered to be the official bicycle city of Denmark in 1999, when more cycling trips were made in the city than in any other Danish city (Pucher & Buehler, 2007:32-33).

6.3.2.4.2 Spatial layout of transport infrastructure

The spatial layout of transportation facilities is limited to BRT and LRT units; the restriction on motor vehicles and limitations placed on their use require limited infrastructure. Odense is known as the cycling city, because of its efficient use of bicycles as a mode of transportation. This is possible because the distance between the CBD and residential areas is no more than 10 km, making the use of bicycles feasible. The fact that bicycles are used proves that the facilities to operate this transportation system successfully are available. If the distance between the CBD and residential areas is close enough to operate a bicycle system, this suggests that the use of pedestrian lanes would also have been indicated and used (Schipperijn et al., 2010:26-30).

While the implementation of transportation systems in Odense is not illustrated, it has been identified as a city with a multimodal transport system. Figure 6-3 below illustrates intermodal collaboration and functioning in Odense. The idea of this system has been illustrated throughout first world countries, among others in Adelaide, Australia (Andrade et al., 2011:69; Adelaide City Council, 2012:64-66)

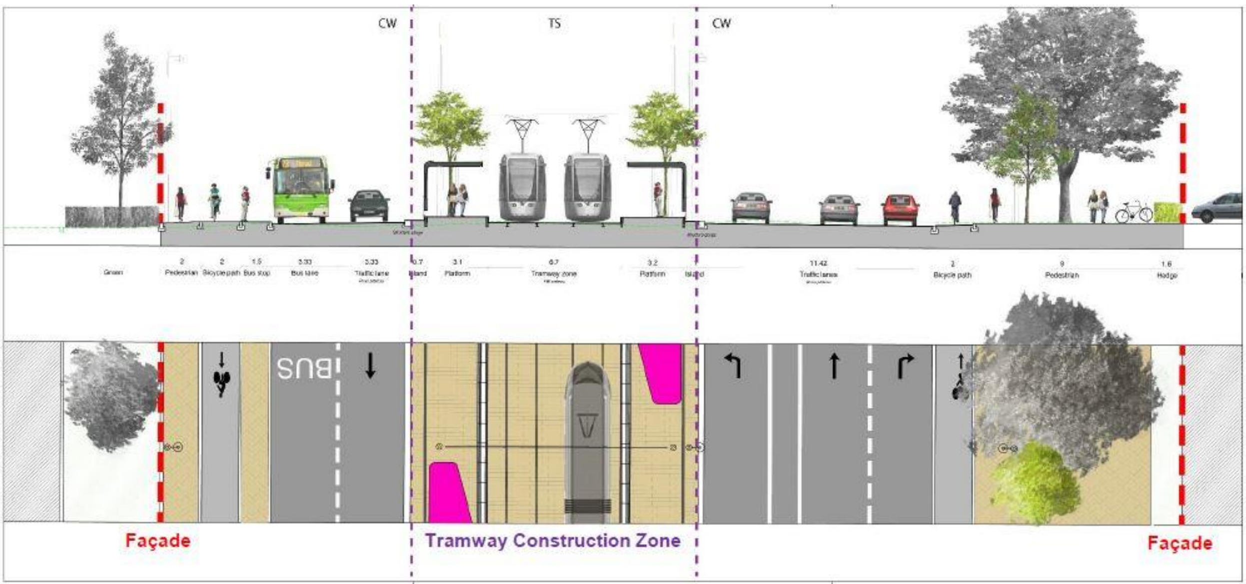

Figure 6-3 Illustration of the spatial layout of the multimodal transport system in Odense. Source: Nicolaisen et al., 2017:12-16

The figure above illustrates how the system would function in a spatial structure and work towards a multimodal transport system. The transportation has been implemented for convenience and efficiency and should be considered in third world countries. This proposed and implemented preliminary design is efficient enough to sustain a community and will increase productivity. The major concern would be the cost of facilities and efficient maintenance.

6.3.2.4.3 Public transportation

Public transportation in Odense is distributed in an array of modes of transportation. The public transportation modes used are the following: LRT systems, taxis, buses and BRT systems. The idea of public transportation in Odense is to reduce the use of vehicles, to create a superior environment for everyone living in the area. Understanding human behaviour helps to determine the needs of individuals, as well as their likes and dislikes. Public transportation is not merely aimed at reducing the number of vehicles, but also at protecting and preserving the prestige environment created through an increase in the number and extent of open spaces (Schipperijn et al., 2010:25-30).

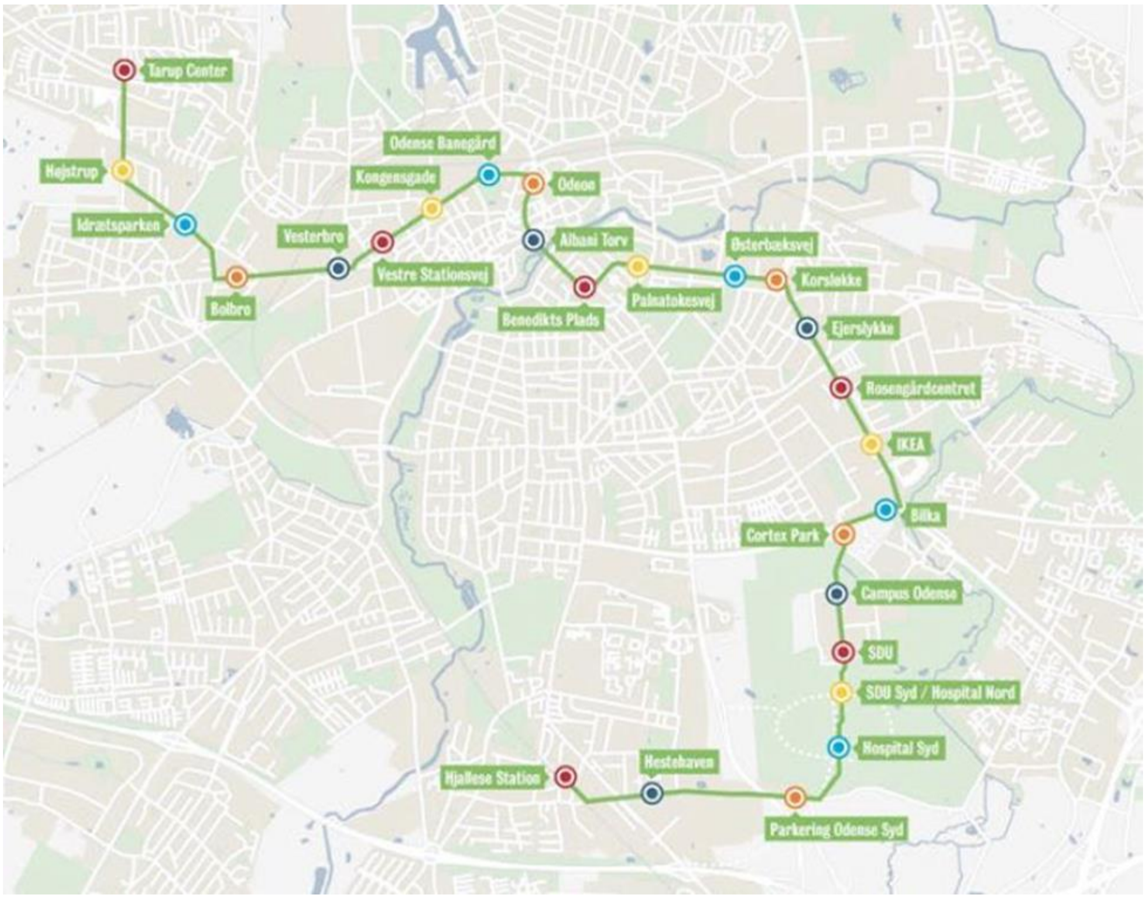

Figure 6-4 Map of LRT spatial development infrastructure in Odense

Source: Nicolaisen et al., 2017:12

Odense grew substantially in the period from 1989 to 2002, when it was estimated to have grown over 80%. The reason for the increase in bicycles is the lack of transportation and the large population needing transportation. Manual key counts ensured that bicycle traffic would be analysed constantly to determine when and if this was being used efficiently (Pucher & Buehler, 2008:33). The bicycle infrastructure has been successful throughout Odense, as determined by using the manual counting stations to analyse the number of cyclists. A policy was implemented to ensure the safety of cyclists and reduce injury, which on the whole has been a success. The policy entails regular maintenance and modernising the facility to allow access to various parts of the city.

Odense had to create a policy platform to develop sufficient transportation systems. The first and most prominent form of transportation identified in Odense is the sustainable use of bicycles. The question that had been asked throughout the implementation process is how cycling can be made safe and convenient. A sustainable transportation system in the form of cycling is similar or identical to various modes employed in the urban form of Adelaide, Australia (Adelaide City Council, 2012:36-38). Odense in Denmark had followed key policies and innovations in promoting safe cycling. The policies were applied not only in the Danish city principle, but also in German and Dutch cities. The key policies and innovations are discussed below (Pucher & Buehler, 2008:510-518; Adelaide City Council, 2012:38).

A. Bicycle parking areas

If bicycle facilities and infrastructure are to be implemented, large parking areas should be made available around the city for bicycles. This would require improving bicycle parking facilities, often through the use of guards, camera surveillance and separate parking for women to allow for a safer environment compared to a multi-gender parking area.

Figure 6-5 Bicycle parking area with pillar

Source: Own creation

B. Intersection modification and priority traffic signals

Bicycle paths need to turn into brightly coloured lanes when crossing an intersection. Green lights for cyclists must be incorporated at each intersection to indicate when it is safe for them to cross. Safety between cyclists and motor vehicles has to be improved by creating advanced cycling lanes, which would help feed cyclists into a position in front of cars in the waiting lanes in order to facilitate fast, efficient and safer transition of cycling lanes for cyclists. To increase efficiency, traffic lights and signals should be synchronised in order to ensure safe cycling speeds when moving in traffic. To allow for shorter distance travel and to decrease travel time, short-cuts can be created for cyclist, which avoid vehicle traffic and incorporate successful T-intersections for cyclists. To create awareness among vehicle drivers, bollards with flashing lights can be used to indicate specific bicycle routes.

C. Traffic laws to accommodate cyclists

Special laws are implemented to ensure the safety of particularly young individuals and elderly cyclists. The enforcement of laws for cyclist is done by the police and courts to ensure the law is legitimate.

D. Traffic calming to reduce speed

The same level of implementation has been accommodated in Adelaide City, where vehicle speed is considered to be an issue. Bicycle streets are narrow, restrict vehicle access and give priority to cyclists over vehicles. Traffic calming in the residential area is considered to be highly significant. Some ways in which this can be achieved are creating 30 km/hr lanes or considering narrow roads, which would decrease vehicle speeds and serve as a deterrent to dangerous driving. Traffic calming is enforced through the use of “home zones”, which fall under the concept of 7 km/hr speed travel to increase the safety of pedestrians and cyclists. This would revolve around cyclists using roads and pedestrians using sidewalks.

E. Traffic education/training and awareness

The implementation of social training tests among cyclists could be considered, which would allow special training for children and ethical conduct when a cyclist uses the road. Cycling training courses for adults and school children would be enforced by the police. Motorists also need training to make drivers aware of cyclists, which should result in fewer accidents between cyclist and vehicles.

F. Cycling systems with separate facilities from other transportation systems

Colour-coded coordinated bicycle lanes, as well as direction signs, help cyclists to move in the direction of the desired destination. It should also be considered to create off-street short-cuts, considered to be a midblock, to allow cyclists through and create a dead-end for vehicles. Well-maintained and fully integrated paths and lanes for cyclists should be provided in specific streets that traverse the region.

G. Coordination and support of public transportation

The opening of bike rental stores at most train stations would encourage cycling. Cyclists should be able to call a bicycle rental service operating a “Call a bike” programme. This would allow individuals to obtain a bicycle in any area of the city through phone calls. The bicycle could be rented and paid for per minute or per day. Bicycle parking facilities at train stations should have high video surveillance, guards, lighting and music, as well as repair and maintenance and other rental facilities. Sufficient bicycle parking must be made available at metro stations, in various suburbs and at other regional train stations.

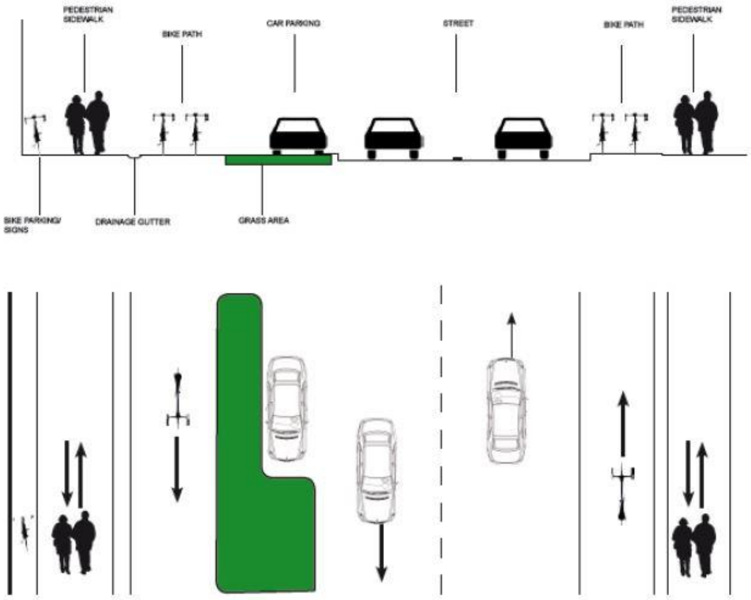

Figure 6-6 Implementation strategy of cyclists and pedestrians in a street layout in Copenhagen

Source: Andrade et al., 2011:69

6.3.2.4.4 Implementation plans

The future implementation plan for Odense is in fact the extension of the tramway. The tramway is to consist of two lines, of which the first has been created and is fully functional. The second line is to extend mobility to areas where this is required and to connect with other areas of interest. This will extend public transportation, thus making vehicles a second option in comparison to the tram. The tramway is known to be an efficient and sustainable option for longer distance mobility.

6.3.3 Introduction to Australia

The first world country of Australia is regarded as one of the most efficient countries in the world. Policies in the country are based on a green sustainable spatial structure, which is supported by various multimodal transportation systems. The transportation systems supporting this structure are separated into two types, private and public. Efficiency is not based on private vehicles and SOVs, but on mass mobility of individuals. The ability to move the majority of residents to CBD areas or a point of interest without the use of SOVs will determine the level of congestion. The more effective public transportation in Australia became, the more it was used by the residents. The transportation modes were based on an LRT system in CBD areas, SOVs around various areas (residential, business district, industrial), bus rapid systems, bicycle lanes, pedestrian lanes and other transportation (aircraft). Australia has preserved the environment, while increasing development and developing transport system infrastructure. Australia is broken up into various suburbs/towns and cities, which are all based on a single spatial structure discussed in Chapter 4 of this research document, known as a polycentric spatial structure. This structure, as illustrated in Chapter 4, does not decay and stagnate like a monocentric spatial structure (Bertaud, 2002:2-4; Pacione, 2005:375), but is based on transportation units as a type of dynamic method to achieve growth and productivity. The polycentric structure is used in Adelaide, Sydney and Melbourne, but the discussion will focus on a specific city of interest, which has incorporated all the traits of sustainability. This spatial structure illustrates the same objectives seen in Howard's garden city design in Chapter 3. The case study of a city in Australia is of Adelaide, which is classified as one of the most liveable cities in the world (Adelaide City Council, 2012:80-81). This is also illustrated in Annexure A of this research paper.

6.3.3.1 Policies in Australia

6.3.3.1.1 Thirty-year Australian transport policy

The first policy is illustrated through the implementation of the 30-year Australian transport policy, which has been implemented to deal with future challenges, both known and unknown ones. The policy has been implemented to ensure sufficient transport infrastructure and facilities in Australia. The goal was not to obtain a transportation system perspective, but rather to improve and create high levels of transportation. The policy assesses the current transportation systems and determine their effectiveness, while identifying possible faults (Potterton, 2012:1-3). The policy was implemented in the 1970s and assessed transport systems in six areas of relevance, which were considered to affect productivity (Potterton, 2012:2-10):

1. Aviation and airports
2. Road networks
3. Road safety
4. Road freight
5. Rail freight
6. Urban public transportation.

6.3.3.1.2 The State of National Urban Policy in Australia

The state of national urban policy is known as the “Smart cities plan”, which was implemented in 2016. The smart cities plan is based on a criterion of three pillars known as:

- Smart investment
- Smart policy
- Smart technology.

The policy was formulated to increase productivity and economic growth and to create a sustainable city. It aimed to promote urban land use and enhance the environment, while maintaining resilience to climate change. This would respond to the population dynamics, prepare the services infrastructure and provide services to the population. The policy augmented municipal finances and created an effective governance system, reflected in the state of national urban policy in Australia (2016:1-3).

6.3.3.1.3 Urban transport strategy

The urban transport strategy established a series of principles to assist with the planning of urban transport systems. The aim was to prioritise the development of infrastructure, while accommodating urban transport systems. The key objectives in this policy were to widen the performance of transportation systems and national outcomes. The main focus in integrated transportation systems was the aspect of land use. The purpose of the policy was to address other transportation systems rather than road infrastructure, which had become dominant throughout Australia. The key focus was sustainable transportation systems (public transportation, pedestrians, light rail and cyclists) rather than the use of SOVs.

The integration of transportation services is crucial for sustainable and smart cities. The concept illustrates that if properly implemented, productivity will increase, access will increase and there will be a decrease in SOVs. This policy illustrates an approach to a first world perspective of cities and attempts to ensure sustainability through the improvement of local transportation systems. The policy is illustrated in the urban transport strategy (2013:1-5).

6.3.3.2 Transportation in Australia

Australia has various modes of transportation that differ between suburbs and cities. The aspect that does not differ is the guidelines that identify how to implement transport modes in the urban form. This is crucial because of its relevance in the functionality of the spatial structure as a whole. Large cities such as Adelaide in Australia have various types of access points for different modes of transportation, as well as changing between various modes (multi-modal system) of transport (NTC, 2016). All of these large cities have certain principles in place to achieve a specific result, namely efficiency. Public transportation involves buses that travel between residential and business district nodes, allowing for an effective transportation system, which is both affordable and efficient. The buses also travel between various cities and undertake intra-regional travel. Buses illustrate a unique quality of multimodal transport, characterised by various bus stops at rail stations and activity nodes. One of the most noticeable attributes of this type of transportation is its ability to transport individuals with their bicycles to various points of interest. Aircraft are used as a public transportation system, and require little infrastructure in order to operate this transport mode. This could be a viable solution to increase the efficiency of transportation without disrupting the spatial structure. Aircraft need little or no infrastructure to function effectively. Such an external transport mode that does not affect the spatial structure or influence the urban form in any negative manner could be described as a sustainable transportation mode. The reason for this is that the infrastructure for aircraft remains static and does not need to expand with the growth of cities, yet the system can effectively transport individuals over long distances. The maintenance of aircraft can be costly, but this is similar to the cost of regular upgrades in other forms of transportation spatial infrastructure. The cost of plane tickets may vary from affordable to expensive, depending on one’s origin and destination. The third public transportation system relates to the rail systems that are spread over the northern territory of Australia. Rail systems cover the entire area of Australia, but mainly the northern territory. This transportation mode is not as efficient as buses and aircraft.

6.3.3.3 Implementation of LRT in Australia

LRT systems are seen as trams, which are used within the urban form. The LRT system is inexpensive and enables commuters to move within the CBD. This type of transportation system is confined to the urban form and does not move between regions and suburbs. The main objective of effective mobility of LRT units is to help individuals move from one side of the business district to the other to increase productivity by decreasing travel time and avoiding congestion. The figure below illustrates the existing tram networks with bus transportation:

Figure 6-7 Existing and proposed tram and rail network throughout the spatial development of Adelaide

Source: Adelaide City Council, 2012:43

The figure above is similar to the bus hierarchy but illustrates the movement of trams and railway networks. This involves existing infrastructure as well as expanded railway infrastructure, which is set to increase before 2022. The purpose of extending the railway infrastructure is to give accessibility and access new sections in the spatial development plan. This would increase the number of passengers and provide better access for individuals further from the original spatial integration of public railway systems (Adelaide City Council, 2012:42-43).

The strategy of integration of extended infrastructure of public transportation considers numerous aspects, which include the maintenance and development of trams/railways as well as buses. The strategies stated in the smart movement plan are illustrated in order to create sustainable cities (Pacione, 2005:365-367; Adelaide City Council, 2012:43-46):

1) Expand public transportation services.

2) Create a tram loop network through a state government initiative.

3) Work with the state government to create mass transit routes in suburbs.

4) Introduce underground city railway systems.

5) Improve accessibility to an interstate rail terminal.

6) Create opportunities for park-and-ride facilities at key transit nodes.

7) Improve integration of public transportation systems, walking and cycling.

8) Improve public transport services in the metropolitan areas.

9) Improve bus priority on key bus streets.

10) Improve tram priorities.

11) Improve waiting facilities at bus and tram stopping points.

12) Allow accessibility to all individuals at various levels of mobility.

13) Introduce low-emission buses.

14) Determine a sufficient number of bus stops.

15) Upgrade Adelaide’s connector bus service.

16) Improve taxi rank waiting facilities.

17) Ensure that taxis are adequate and accommodate a sufficient number of passengers.

18) Improve the taxi information system to the general public.

19) Increase signage for correct navigation of public transportation services.

20) Accommodate the affected population.

The above strategies are separated into sub-categories in which minor detail allows for the correct implementation to achieve results. The process of implementation differs when opposed to a theoretical basis. The theoretical platform would allow one to understand the general concept within the spatial implementation of transport infrastructure. This will change according to the practical implementation, owing to topology, geographical barriers, economic circumstances, site obstacles not displaced on satellite and the general community (Adelaide City Council, 2012:83).

6.3.3.4 Adelaide

The city of Adelaide (Illustrated in annexure A) is situated in south Australia and comprises numerous suburbs around a CBD area. Adelaide is regarded as a city that has been transformed throughout the years, while adapting and extending its spatial structure. The stages of evolution of Adelaide have been determined by the transportation infrastructure and there has been constant development in spatial planning. The first phase Adelaide underwent was considered to be "the walking city" in the 1830s, when vehicles had not yet been recognised as a transport system. The population used to horse-drawn carriages and transport by foot as well as railway. In the 1920s motorisation became recognised as an effective way of mobility. When an increase in motor vehicle ownership started to occur, general provision on spatial infrastructure had to be incorporated. This necessitated a redesign process, which transformed pedestrian streets into motor vehicle roads. The era of "the tram city" was the 1930s, when mobility for a large population had to be provided. Individuals who did not have vehicles would use the public service of trams, a light rail electric transportation system. The tram would operate from specific stations near residential areas and pass through the CBD. The concept was to allow effective mobility from residential areas to the workplace. This increased productivity, decreased travel time (considering as walking), was cost-efficient, increased the possible distance of travel and catered for a large population. The third phase in which Adelaide had evolved spatially was known as "the car city", in the 1960s. The accommodation of the motor vehicle called for a spatial structure change, which involved the removal of the electric tram network to accommodate the infrastructure of the motor vehicle. A section of the tram network was not removed; it still runs between the city and Glenelg. However, the car network then dominated the metropolitan network as the main transportation system in the spatial district (Adelaide City Council, 2012:80-81). The dominant car phase had a negative impact on the city and caused various problems in terms of its expansion. This led to a specific negative stage of growth, called the "deserted city", between 1980 and 2010. This was due to the increasing number of vehicles being operated on limited infrastructure. The spatial structure was inadequate to accommodate the population growth and because little expansion had occurred, the transportation infrastructure started to become highly congested (Pacione, 2005:787). The use of cars and various other vehicles gave the public no alternative transportation options, thus congesting certain transport modes. The population of Adelaide has increased over the years and more sustainable spatial structures have been focused on, while accommodating a multi-modal transport system. The city has become a sustainable model for cities around the world, describing its current spatial structure adaptation as the “vibrant city”, which nevertheless poses challenges. These challenges have been dealt with through a strategy known as the “smart move strategy”, which is currently employed (Adelaide City Council, 2012:81).

6.3.3.4.1 Land use in Adelaide

Figure 6.8 illustrates the various factors currently associated with the city of Adelaide. It illustrates the various land uses and current activities that may take place in the area. Adelaide consists of various suburbs around the CBD area, which should be considered part of the spatial objectives. Through the figure below, some conclusions can be made (Adelaide City Council, 2012:22).

Figure 6-8 Spatial distribution of land use and activities in Adelaide

Source: Adelaide City Council, 2012:22

The future direction

The future direction in the distribution of land use and activities will determine the spatial structure of the layout. This implies better use of land, while considering land value, spatial structure, distribution of the various land uses, the distance between the CBD and residential areas, while lastly adapting strategies for ensuring more sustainable urban form. This will help to increase economic growth and preserve the environment, which includes the spatial integration of various sustainable transportation systems and their accessibility, considering each land use (Adelaide City Council, 2012:23):

1) The role of streets needs to be enhanced, through directing them to and around square built-up areas, making it possible to activate each square's activity. This is because a square can be accessed from various sides.

2) Planning should enhance the roles and use of parkland areas for either development or recreational use.

3) Authorities should create a diversity of places by identifying successful streets (Rundle Street and Gouger Street) and optimising their performance by increasing activity between them.

4) Planning should support as well as enhance new main streets or streets with a large volume of activity in commercial and entertainment opportunities.

5) New places should be created by developing more points of activity. This is known as nodes of activity in close proximity to residential areas.

6.3.3.4.2 Spatial layout of transportation infrastructure

Figure 6-9 showing Adelaide's spatial structure represents the vehicle movement in each sector (colour-coded) and divides the levels of traffic into specific hierarchies. Three main factors are evident from the figure below, namely (Adelaide City Council, 2012:12-13):

1) There are high levels of vehicle traffic on most streets; five main north-south routes are highly congested with an estimated traffic volume of over 20 000 vehicles per day. It may even be considerably higher, in view of the increase in population. This would necessitate two links, one link functioning on level 1 (metropolitan significance), while the level 2 link (regional significance) considers the regional linkage between cities.

2) The road infrastructure on certain roads accumulates large volumes of vehicles (>40 000 vehicles per day). These streets, Jeffcott Street and O'Connell Street, are located in the northern section of Adelaide. Northern Adelaide generally has lower volumes of traffic than southern Adelaide.

3) A study by the department of transportation, energy and infrastructure on the number of vehicles found that 20-30% of the traffic on the streets did not stop anywhere in the city.

Figure 6-9 Different level transport linkages between the spatial structure of Adelaide

Source: Adelaide City Council, 2012:20

The future direction is the term used to indicate attempts to establish more sustainable cities, while trying to maintain the current economic standard and environmental conservation (Adelaide City Council, 2012:21), by:

1) Maintaining low-speed, two-way traffic movement across a grid spatial plan, while maintaining good accessibility and lowering traffic density through dispersion of traffic;

2) Lowering the speed of traffic to enable more environment-appropriate creation of places, both natural green areas and built-up hard spaces;

3) Prioritising pedestrian use, cycling and other public transport systems through the correct spatial infrastructure for specific transport; and

4) Discouraging driving, whether entering or leaving the city district, by improving the facilities for pedestrians, cyclists and various types of public transportation.

6.3.3.4.3 Public transportation

Public transportation in Australia is considered to be essential in the mobility process. The original spatial design of buses was to ensure mobility from residential outskirts to the metropolitan area. The buses would have various stations on the outskirts of the residential district. Figure 6-10 below illustrates the number of buses entering each sector; metropolitan areas receive most buses per day. The spatial implementation of buses function under a certain concept, namely to implement effective mass mobility to the CBD. There are various modern-day conclusions on the use of buses (Adelaide City Council, 2012:26). Buses are regarded as the main public transportation system and accommodate 77% of people using public transportation systems. Public transportation systems using buses offer insufficient information on waiting areas and are furthermore seen as highly unattractive facilities. The bus public transportation systems use various short-distance stops in the CBD. This allows for short-distance travel within the metropolitan area as well as to residential districts. This often increases bus travel time, because of the frequent starting and stopping within a short distance to allow more passengers to access the public transport system. The current problem with bus transportation is that it is not available between key destinations; planning is often based on estimated cover of the location to accommodate every individual rather than focusing on key destinations. This decreases costs per passenger, but does not allow for long-distance travel. Lastly, according to recent surveys, the volume of bus transportation systems is significantly higher in the northern part of Adelaide, compared to the southern part. This may be caused by poor service rendered by bus systems in the southern part or higher activity and productivity in the northern territory.

Figure 6-10 Spatial planning of public transportation between sectors in Adelaide

Source: Adelaide City Council, 2012:26-27

Public transportation services should be regarded as a mobility system that continues to adapt to the population and constantly needs to undergo maintenance. The reason for this perspective is the population growth/decline and density (mainly through growth), which is constantly changing. While bus public transportation is considered the main public transportation system in use, it is imperative to note that the standards of the transportation service are constantly changing. Specific measures have been identified for the future growth of this transport system (Adelaide City Council, 2012:26-27):

1) The first key link to improve the spatial distribution of bus linkages is to divert attention from bus public transport and focus on other public transport services, for example light rail networks. Good maintenance and improvements on the light rail service attract potential passengers.

2) Bus public transport will continue to supply most public transport service trips to the city and residential areas.

3) The networks of bus public transportation should be simplified to improve the practicality of the transport network. This will help cities to focus more strongly on services along key public transport corridors such as King William Street.

4) The focus of bus public transportation systems is on transporting individuals efficiently from the CBD to residential areas. Expanding the spatial infrastructure and creating more routes would help increase the efficiency as well as reliability of the public transportation service.

5) Increasing the frequency of bus services would improve connections and help develop new services to key link destinations.

6) To focus on a sustainable transportation service, the public transportation service of buses should significantly improve and adapt to serve the needs of an ever expanding city. These strategies have been listed in the 30-year plan of greater Adelaide.

6.3.3.4.4 Implementation plans: Spatial development plan for various mobility outcomes

The spatial plan has been separated into numerous mobility systems and has been categorised according to specific outcomes. Each outcome represents the current situation of the mobility system as well as the future goals and lastly the challenges that may be faced through the spatial implementation of the transport infrastructure. The future goals should be implemented by 2022, taking into consideration all relevant factors. The outcomes that are addressed through the implementation of the smart movement strategy are discussed below (Adelaide City Council, 2012:30-66):

A. <u>Implementation of easy walking</u>

The goal was to create a city that is regarded as comfortable and safe, in which walking should be considered to be easy. Pedestrians should be given the right of way over other transportation systems, thus initiating a sense of pedestrian priority. The pedestrian infrastructure should consider the movement of all people, including the disabled. The pedestrian network should be well distributed, allowing for connection between various sectors (Adelaide City Council, 2012:30).

The challenges facing the spatial network and integration of mobility infrastructure for pedestrians should be dealt with taking into consideration all transportation systems. The first aim of the strategy is to reduce the waiting times at traffic signals without disrupting the efficiency of the transportation network. Pedestrians must feel safe and be accommodated in the infrastructure, by day as well as at night. Economic, health and community benefits have to be promoted by creating safe infrastructure for cyclists and pedestrians. This would create the concept of a cycle- and pedestrian-friendly neighbourhood. One main aim has been to improve accessibility for both pedestrians and cyclists to suburbs, parks and CBD areas. A factor of concern is obtaining sufficient funds to implement the infrastructure spatially, allowing cyclists and pedestrians access throughout the city. The building infrastructure plays a role affecting people both inside and outside buildings, by improving the quality and aesthetics of building frontages. At present, only 12.5% of building frontages are implemented (Adelaide City Council, 2012:30). Infrastructure on certain sections of roads, predominantly those used by vehicles, has to be improved to create better visibility of cyclists and pedestrians at night. Figure 6-11 below illustrates the future spatial layout needed to incorporate easy walkability.

Figure 6-11 Future spatial development plan to ensure easy walkability

Source: Adelaide City Council, 2012:35

The strategy presented in the figure above illustrates how the spatial structure will be manipulated to improve infrastructure for pedestrians and cyclists. The following methods will be implemented to improve pedestrian and cycling spatial design (Adelaide City Council, 2012:30-35):

- Give priority to pedestrians on city streets.
- Improve pedestrian connections and ease of navigation.
- Create a better environment for pedestrians.
- Improve pedestrian access to parklands and squares.

B. <u>Implementation of safe cycling</u>

The second outcome is intended to be improved cycling infrastructure. This would help to create a sustainable city by accommodating people having diverse levels of cycling ability, ensuring their safety. While cycling has been considered an efficient way of local transportation, especially short trips, when cycling is incorporated in a spatial plan, it should be implemented with the intent of guaranteeing safe cycling between different suburbs (Adelaide City Council, 2012:36).

Since bicycles have become a popular transportation mode, it has become imperative to promote and encourage the use of this infrastructure to less interested individuals. The increasing amount of infrastructure for cyclists should also ensure sufficient facilities at the destination of the cycle trip. The facilities expected would be showers, clothing storage, lockers and secure areas to park bicycles. The implementation of cycling infrastructure is not only more efficient and less costly, but also provides an opportunity to improve health. However, fear of vehicle traffic had kept people from cycling (Adelaide City Council, 2012:36).

Figure 6-12 below illustrates the design and integration of bicycle lanes, while extending the infrastructure throughout various sectors of the spatial development plan. The spatial implementation of cycling infrastructure was initiated to offer cyclists various benefits. The bicycle network in the figure below was designed to stop or minimise interaction between vehicles and cyclists, provide and ensure good directional signage for cyclist navigation, provide facilities and connected crossing lanes for cyclists and minimise interaction between public transportation systems and cyclists (Adelaide City Council, 2012:38). The spatial development structure integrates separate bicycle lanes, while sharing the paths in parklands with pedestrians. The spatial plan will also be designed in a very effective way; streets shared by vehicles and vehicle traffic will often be low-speed streets, without jeopardising the efficiency of the transportation system (Adelaide City Council, 2012:36-38).

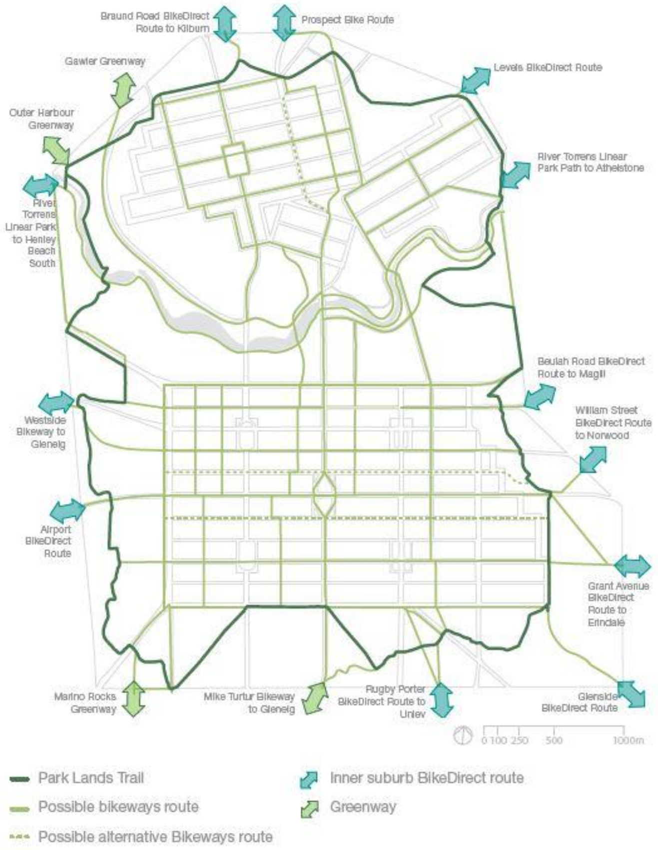

Figure 6-12 The integration of bicycle lane infrastructure into Adelaide's spatial development plan

Source: Adelaide City Council, 2012:38

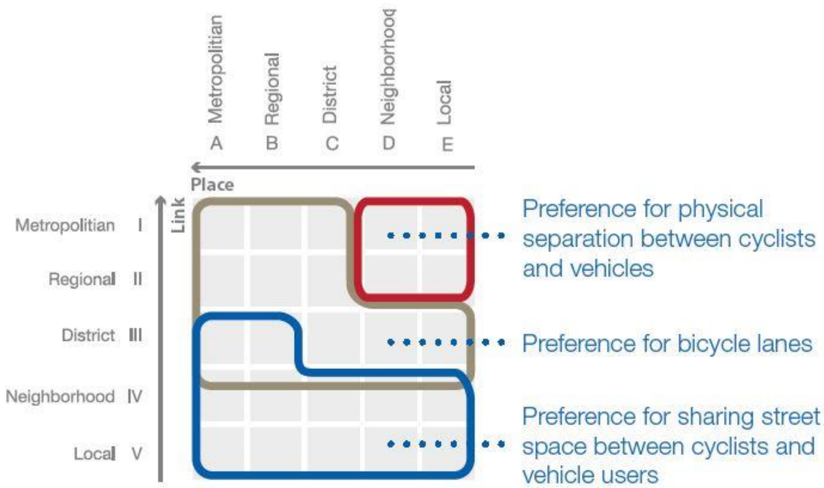

Figure 6-13 Segregation of cyclists in vehicle traffic

Source: Adelaide City Council, 2012:38

The smart move transportation strategy has created various implementable solutions, which may help to maintain and increase the amount of cyclist infrastructure. The general concept of the above spatial plan is to integrate cyclists through the following strategies (Adelaide City Council, 2012:38):

1. Creating various cycling networks throughout the city
2. Accommodating cyclists within each street, increasing accessibility
3. Improving and ensuring cycling facilities as well as crossing lanes/intersections
4. Extending the time limits for peak period bicycle lanes
5. Reducing conflict between parked cars and cyclists
6. Allowing two-way travel of cyclists on a local street.

C. <u>Implementation of quality public transport</u>

The goal of implementing public transportation is not only efficiency of the transportation system, but includes creating sustainable, quality and reliable public transport systems to be implemented through a long-term plan. The spatial integration of public transport could benefit the community by creating effective mobility systems for affordable, reliable and cost-effective travel (Pacione, 2005:368). The city of Adelaide plans to integrate extended spatial infrastructure for bus, tram and train transport, while making any transportation system readily accessible. The advantage of the spatial integration of these transportation systems is that they provide a more effective and safe way to travel around the city at night. This could be considered a general need of individuals who do not have access to their own transport. An array of multi-modal transportation systems can give an individual a choice to decide which may be a faster mobility system in the current circumstances. The most important goal of the smart move strategy is to ensure that public transportation systems provide an easy-use type of mobility, which should be affordable, reliable, and responsive to all customers (Adelaide City Council, 2012:41).

The current challenges that face public transportation in Adelaide are related to the number of buses occupying the streets. The first challenge is identified as seeking basic improvements in public transport systems. It is necessary to manage the efficient movement of buses and trams on city streets correctly, without disregarding other transport users. The impact of buses is regarded as a problem; even though they only represent 12 to 15% of the total trips per day, buses are perceived to cause noise as well as pollution. The connectivity challenge in public transportation systems entails the continual upgrading of existing bus stops, tram stops and railway stations to allow access to people of various mobility levels and age groups. Infrastructure around the city needs to be expanded to attract more passengers. The number of large buses is considered to be a problem, which is due to lack of management (Adelaide City Council, 2012:41). The use of public transportation would enable more effective mobility. This would lower congestion of traffic on road infrastructure, created by cars and other motor vehicles.

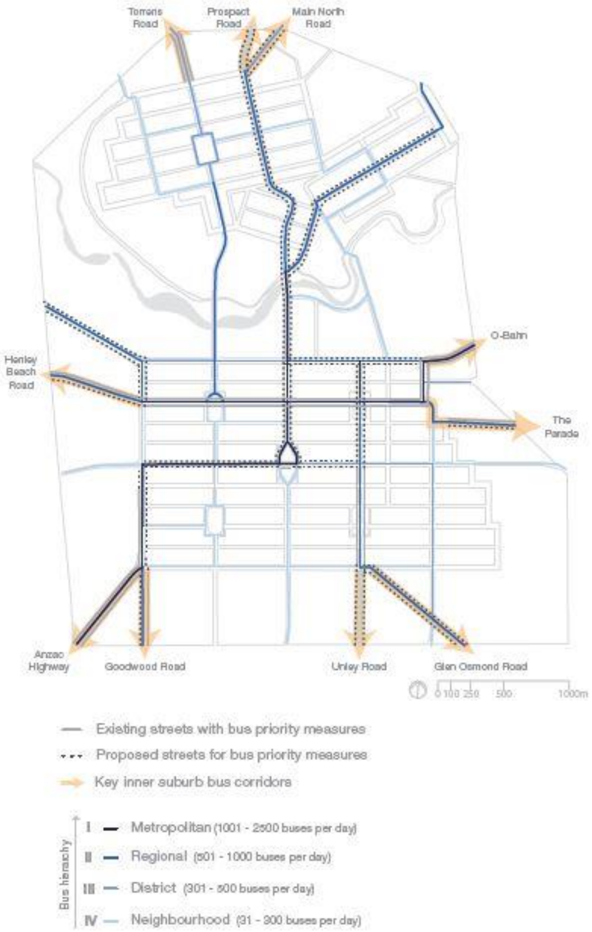

Figure 6-14 Bus hierarchy in the spatial development plan

Source: Adelaide City Council, 2012:44

Figure 6-14 above illustrates the hierarchy of buses and how they have been integrated into the spatial development plan (Pacione, 2005:791). The figure identifies that most buses are used in the metropolitan area and often travel to and from the CBD. This public transportation system has created various inner suburb corridors, which allow for easier travel. The second-highest density areas through which buses move are the regional districts, illustrating that passengers are being moved over long distances. The last sector in which the lowest number of buses is used is the neighbourhoods, which is a positive trait that allows for safer mobility of pedestrians (Adelaide City Council, 2012:44).

D. Implementation of green travel

The goal of implementing green travel in Adelaide involves a process of integration of various modes of transportation systems into the spatial design. The first goal involves a high proportion of low-emission vehicles being used as a general every-day transportation system. The second goal entails accessibility within both residential and business areas to allow individuals to use the available transportation rather than their own vehicles. The last goal is to create efficient public transportation modes that individuals would prefer for their journey to and from the workplace (Adelaide City Council, 2012:47).

The goals can only be reached by addressing the current challenges. The first challenge is to reduce transportation-related emissions, which are typically created by motor vehicles. This occurs in cities with a car-dominant transportation system; it has been determined that 36% of Adelaide's carbon emissions are released through the use of vehicles. Improvements in public transportation, walking and cycling help create awareness and provide opportunities to use alternative modes of travel. The implementation of car share schemes could further share infrastructure with various transport modes (bicycles, public transportation) and improve productivity. This would create a resilient city in terms of oil and petrol costs for vehicles. The last challenge is to encourage a large percentage of individuals to go to work using sustainable transportation modes, which can lower travel costs and offer a significant health benefit (Adelaide City Council, 2012:47).

E. Implementation of efficient services

The implementation of services has two specific goals. The first is to increase the efficiency of freight deliveries, while avoiding some transportation systems. This would help increase productivity between sectors, while decreasing travel cost and time. The second is to create effective waste management strategies, which ultimately support the government's zero waste objective and help to achieve its targets (Adelaide City Council, 2012:51). The main objective is to maintain an efficient level of service delivery and provide adequate facilities to the public.

The challenge regarding this implementation process is to implement and deliver higher standards than expected, while avoiding traditional problems in the public realm. For this implementation to be successful, an increase in the intensity of activities needs to be strategised. This implies creating compact developments and infrastructure throughout the spatial plan. Common interests should be considered to advocate better service methods for stakeholders. The necessary infrastructure has to be developed to manage waste disposal and serve freight collection centres. Sufficient waste disposal infrastructure is required to serve the population and allow for its perceived future growth. Strategies should be implemented for various types of waste and waste disposal, by recycling certain waste materials (glass, paper) (Adelaide City Council, 2012:51).

The strategies to be implemented should apply the right policies, while putting the necessary infrastructure in place. Facilities have to be made available according to the current services' functioning. Through the implementation of the following strategies, efficient services could be rendered successfully and sustainably (Adelaide City Council, 2012:51-53):

1. Allocated space for infrastructure of transportation systems, which gives access to various delivery vehicles
2. Improvement of loading zone management areas, to allow for effective and fast loading and offloading
3. Improvement in knowledge of the current transportation systems and how they could be upgraded
4. Public participation to create management plans for servicing key locations
5. Waste pickup points in various areas around the development
6. Encouraging the use of small, compact vehicles for delivery purposes.

The above are the main strategies formulated to improve efficient services. The consideration is developing small points of sustainability throughout a development, allowing for large-scale strategies to be implemented more effectively. The implementation of efficient services and deliveries should have prioritised, rather than merely accepting average delivery.

F. <u>Implementation of smart parking</u>

While the number of privately owned vehicles increases, rapid adaptation in parking facilities needs to be accommodated in the spatial development of Adelaide. Smart parking has been developed to accommodate numerous vehicles in various sectors of the city. The two main initiatives have been identified as the cost of parking through demand and parking as a non-dominant feature. The cost of parking has been based on the demand of individuals using private cars. This could be manipulated; increasing the cost of parking might eventually push individuals towards the use of a more sustainable transportation system. This would encourage individuals to use pedestrian sidewalks and bicycles as an alternative way of travel (Adelaide City Council, 2012:51-53).

There are various challenges in the implementation of smart parking, involving space, the distance from parking areas, the use of multi-transport modes, preservation of the environment, accessibility of infrastructure, demand for parking spaces, population density and occupants working in a specific building. The challenges faced in the implementation and adaptation phase lead to conflicting public views on transport. Illustrating that pedestrian-friendly cities are more efficient and enable reduced parking and making public transportation more efficient and accessible to everyone, by making it more cost-effective than the use of private vehicles, would encourage individuals to use public transportation. An increase in parking fees and a decrease in parking areas would help increase economic competitiveness and attractiveness. Various council parking stations can be operated on a commercial basis. The aim is to find a balance between parking space and sustainable travel, avoiding the negative effect of satisfying needs incorrectly. The negative effect mentioned is that supplying the public with more parking would actually increase the number of vehicles in the city, hampering sustainable transportation. The effect of sustainable transportation should be to decrease SOVs (cars) and increase the quality of life, efficiency and future development. Pedestrian sidewalks should be widened to decrease space on streets, to allow limited vehicle access per lane (Adelaide City Council, 2012:54).

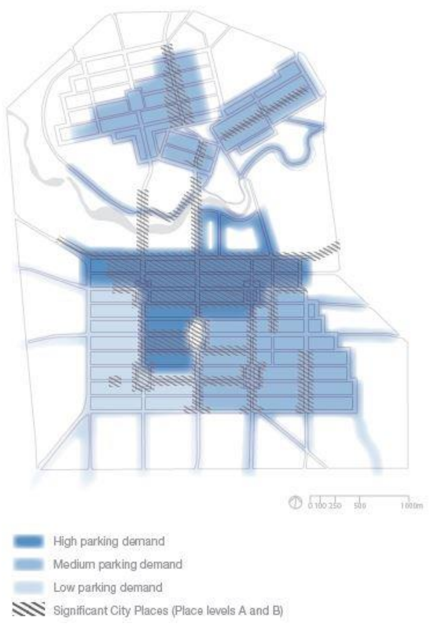

Figure 6-15 Illustration of the parking demand in the spatial plan of Adelaide

Source: Adelaide City Council, 2012:56

The strategy of implementing smart parking is contradictory to the intentions of sustainable parking methods., by increasing vehicle parking, thus encouraging the use of vehicles and occupying much needed space for various types of development. The strategy aims to decrease parking for cars, while increasing pedestrian, cycling and public transport infrastructure, by increasing parking fees and limiting SOVs. This strategy is broken down into smaller implementable strategies in an effort to decrease the use of cars and move towards sustainable transportation. The small sustainable strategies used are (Adelaide City Council, 2012:55-56):

1. To prioritise pedestrian, cycling and general spaces over car park provision;
2. To reduce the visual impact of double-storey car parks;
3. To extend time periodsof traffic lights for buses and cyclists during peak periods;
4. To charge a large fee for on-street parking in areas of high demand;
5. To optimise the price of parking in accordance with the time period parked; and
6. To provide on-street parking for residents and elderly people.

The design of these strategies is to encourage individuals to move towards public transport and sustainable transportation. This would allow for more sustainable growth, with the intention of expanding the spatial plan and becoming self-sustaining.

G. Implementation of traffic calming

Vehicle traffic has always been a major issue in any spatial development plan. The correct implementation of transport and general infrastructure would avoid traffic congestion. The layout of the development would determine alternative routes, allowing for different exits from currently congested routes. Traffic calming is the first goal of a well-connected street grid facility, operating on two-way movement and accommodating all transport systems. The second most prominent aim of this implementation is to lower traffic speeds to create safer and more pleasant throughway traffic. The third and last aim is to allow sustainable transportation systems to grow and adapt within the urban form, allowing large numbers of pedestrians and cyclists to move easily. This would include public transportation systems. Multi-transport systems and distribution of travel between different transport modes lower the chances of congestion (Adelaide City Council, 2012:59).

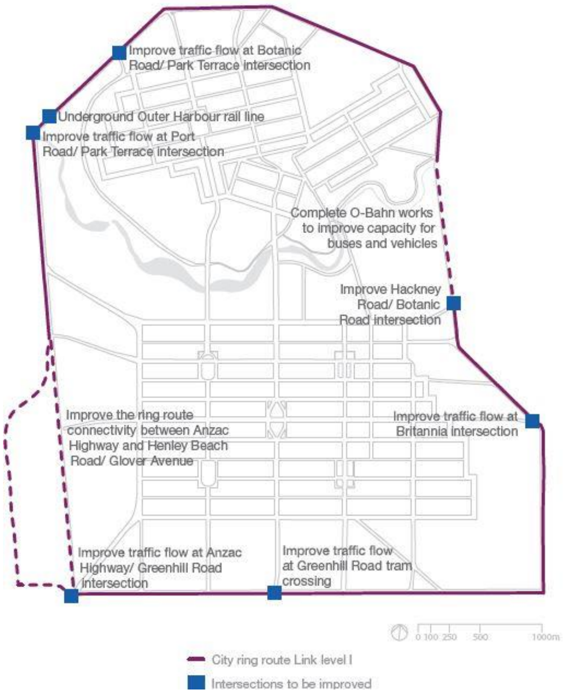

Figure 6-16 The calming of traffic through ring route implementation in Adelaide

Source: Adelaide City Council, 2012:62

- The challenges that are faced when attempting to calm traffic are largely determined by the public. The number of SOVs being used on a day-to-day basis is massive and in most cases is based on personal preference. The first challenge is to improve the city ring route around various parklands. Slower traffic in the city would allow for a calmer traffic environment, safer pedestrian walkways and safer cycling. The slow traffic nevertheless has to be moved in a balanced speed range to ensure that productivity and efficiency do not decrease. More pedestrian walkways and cycling infrastructure will lead to a reduction in traffic speed. Creating mid-block pedestrian crossings on an east-to-west basis, reducing vehicle lane width and allocating the street space to pedestrians would decrease traffic speed. A study has shown that a pedestrian being hit by a car going at a speed of 50 km/h has a fatality risk of 70%; the fatality risk could be decreased to 25-30% if the speed is decreased to 40 km/h. This illustrates that a slight decrease in speed could ultimately save a person’s life. This illustrates the economic benefits of lowering vehicles’ speed; it would not only benefit pedestrians, cyclists and the environment, but also lower fuel usage, which is directly linked to the cost of operating an SOV. Another considerably difficult challenge would be by-passing traffic around urban developments, meaning that vehicles could only be used on the outskirts of developments (Adelaide City Council, 2012:59).

The strategy of implementing traffic calming is technical, owing to its direct relationship with the original layout design. The spatial development layout has to be altered at certain points, allowing for effective implementation (calming traffic) of the end product. The following strategies were implemented in Adelaide to calm traffic (Adelaide City Council, 2012:60-62):

1. The speed of vehicles in streets was reduced, with special attention being paid to residential areas.
2. Specific areas were designed in residential and business districts to lower speeds to 30 km/hr.
3. Parkland speeds were adjusted to 50 km/h.
4. Pedestrian count-down signals were introduced.
5. Specific waiting times for pedestrians were introduced at traffic lights, to allow for safer crossing of pedestrians.
6. Street widths were adjusted, allowing for more room for pedestrian infrastructure, which ultimately decreased vehicle speeds.

The above strategies could help impose traffic calming in general, but should be implemented in each sector, while considering the implementation of other sustainable goals for cities. The improvement of other sustainable measures would have an unintended calming effect on traffic (Adelaide City Council, 2012:60-62).

H. <u>Implementation of great streets</u>

The last and final strategy that Adelaide hoped to implement was the development of great streets. A great street does not refer to only the design and efficiency of the street, but also to its versatility and resilience. A great street is a street that has the capability to be implemented for multi-modal transportation systems or has already been used in that way. The spatial planning of streets to accommodate various land uses and infrastructure is a delicate procedure, in view of its entire impact on surrounding developments. The planning of streets is determined by the factors of density, land use and population. The goal of creating great streets is to allow public participation. A sense of place is created through high-quality streets and public spaces. The most important aspect of street design is seen as a positive or negative impact on the environment. A well-planned street would increase aesthetics without decreasing the quality of the environment (as seen in Annexure A), while the opposite would influence the environment negatively (Adelaide City Council, 2012:63).

The challenges regarding the creation of great streets emanate from various transportation issues and incorrect implementation. The first challenge is to analyse which street would attract large amounts of activity. The current activity of streets is evident from large numbers of heavy vehicle-orientated lanes. This implies that streets are vehicle-prioritised and that other transport modes have not been implemented successfully. The great street has to be redeveloped to prioritise more pedestrian- and cycling-based travel. The most significant challenge is to find a median in the decision making-process, allowing for partially implementing certain aspects without compromising the satisfaction of the community. The implementation of various transportation modes, through the department of planning, transport and infrastructure, will create more open space for managing service delivery and street space (Adelaide City Council, 2012:63).

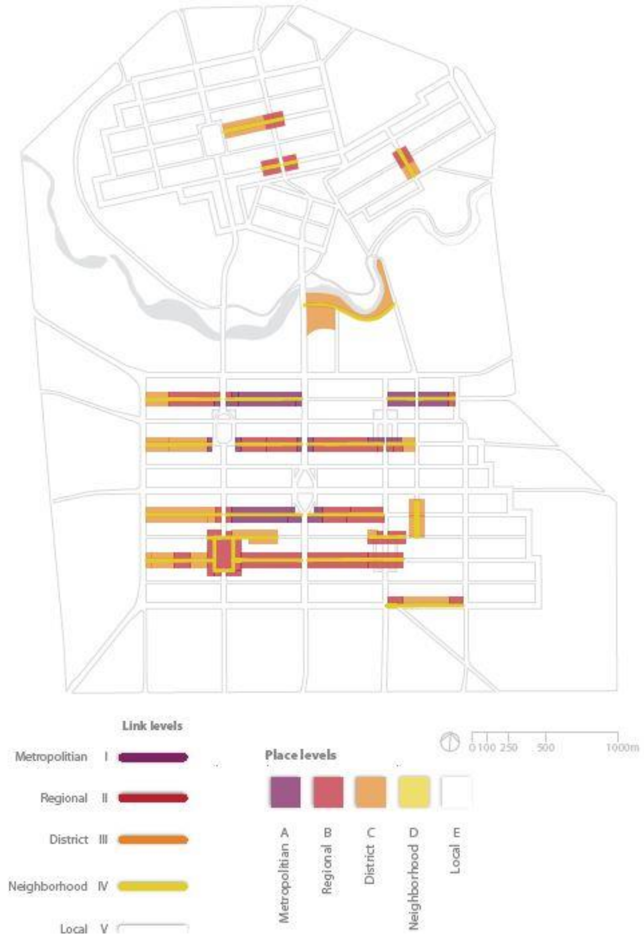

Figure 6-17 Thirty-year future link plan on space and main street priority, while incorporating the environment in the city of Adelaide

Source: Adelaide City Council, 2012:66

The strategy regarding the implementation of great streets is to effect small, significant implementations that would improve the entire urban form, if done correctly and according to a spatial framework. The spatial design of streets is a strategic art of incorporating current needs, while considering future problems. This helps to avoid issues in spatial development in future generations. Adelaide has devised numerous small strategies that would help to create great streets (Adelaide City Council, 2012:64-66).

6.3.3.4.5 Conclusion

The city of Adelaide continues to expand and intends to become more sustainable and maintain it economic status. The above information provided detailed spatial development strategies, plans and implementations of transportation systems. The current situation seems to be efficient, with first-hand experience of the use of transportation systems. The spatial development is regarded as highly efficient and Adelaide is ranked as the fifth most liveable city in the world (Adelaide City Council, 2012:4). The city has a diverse range of cycling infrastructure and hiking/cycling courses devoted to sustainable transportation and leisure. The researcher has had the privilege to visit these areas and experience the transportation systems, while experiencing a dynamic city.

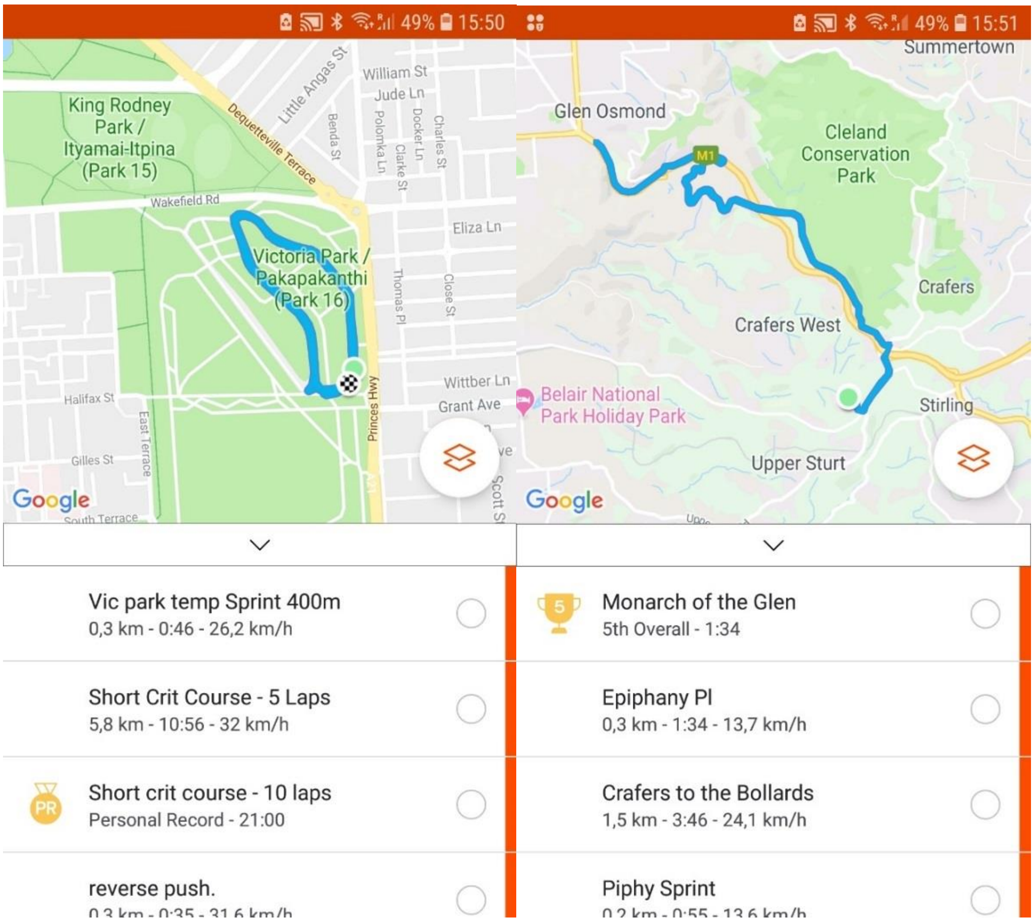

Figure 6-18 Victoria parkland for pedestrians and cyclist (left), Cleland conservation park for cyclist's leisure (right), both including the environment

Source: Own experience -STRAVA Application

The above two figures illustrate the fitness application (STRAVA) and indicate that the environment has been integrated into the sustainable transportation system. Bicycle lanes have been correctly implemented and attract cyclists from around the world to participate in an event known as “The tour down under”. The cycling event is regarded as a mini-tour de France. Adelaide maintains a strong economic foundation and does not lack infrastructure, but constantly considers the integration of the environment. Annexure A illustrates a green boundary around the city centre, incorporating components of the Ebenezer garden city discussed in the third chapter (Phillips, 1970:6; Parsons & Schuyler, 2003:531).

6.3.4 Introduction to third world countries

Third world countries have had a different spatial structure from first world countries, owing to different issues of relevance. First world countries are more inclined to have a sustainable spatial framework, while third world countries are facing poverty, lack of housing, little or no education, lack of jobs and crime. This reflects that in different countries various priorities are formulated in response to the current situation. Efficient spatial planning can decrease most third world countries’ problems, but incorrect implementation may simply worsen the problem.

6.3.5 Introduction to Pakistan

Pakistan is in the process of solving transportation problems, even though large expenditure on urban transportation systems is required. Pakistan is a developing country and has the same problems as South Africa, necessitating the implementation of adequate transportation systems. This also refers to the correct type of multimodal system being implemented in a certain space. An analysis of Pakistan’s spatial structure indicates that traffic and population growth will continue to increase rapidly. This implies that the need for mobility is significant, but is subject to individual land use patterns. The problem of inefficient transportation systems has highlighted three important issues to be considered in Pakistan (Masood *et al.*, 2011:256-257):

1. The importance of governance
2. The individual capacity of each building or infrastructure
3. The importance of urban planning in providing adequate, effective public transportation in Pakistan.

6.3.5.1 Policies in Pakistan

Spatial development policies are lacking in Pakistan. The third world country has focused on issues that are not related to spatial development and planning; it has paid more attention to implementing the MDG (United Nations, 2015:4-65). Pakistan has focused more strongly on economic growth rather than the development of the urban form.

Of interest about Pakistan's policy system is that it is striving to become industrialised. Pakistan is one of the largest economies besides Asia. In promoting growth, it takes cognisance of the incorporation and implementation of various policies. The policies initially helped improve the country's growth, but were halted by the increasingly poor community, which widened interpersonal and inter-regional income gaps. The country has adopted various policies that have been implemented across the world to increase economic growth, but these initiatives have consistently failed, owing to lack of spatial development in residential areas. No new job opportunities were consequently created through this development. The population continuously increases, while job opportunities remain the same or fewer. This illustrates that the poverty gap is becoming larger and the income per capita is dropping, decreasing economic growth. The policies and frameworks adopted from other countries may not be efficient for Pakistan, since each country's policies are implemented to improve specific priorities in that specific country and not necessarily Pakistan (Burki, 2008:23-29). This third world country illustrates the use of incorrect policy creation and implementation mentioned in connection with spatial challenges in previous chapters.

6.3.5.2 Transportation in Pakistan

Transportation systems have become directly linked to productivity and economic growth. This is known as the key to the global economy and has changed the way of trade, employment, health care and family life. It has allowed individuals to travel longer distances to obtain work without mass movement. The problem is specifically the use of SOVs; maintenance and costs tend to exceed the benefits, while the spatial implementation of road infrastructure is highly costly (Masood et al., 2011:257). Transportation systems in all countries have been considered a vital commodity, which is linked to the successful development of businesses, while it also ensures a link between all economic activities. This encourages individuals in a society to use transportation, which can achieve effective use of time spent on travel, ensuring the operation of businesses with minimal travel cost. This is seen as the objective of transportation systems in developing countries.

The concept of transportation in developing countries is understood, but the correct spatial implementation, which is desperately needed, has not happened. The understanding is that a reliable transportation system must grant effective access to the labour force, while generating economic growth. Countries with better and more developed transport infrastructure consequently have more effective transportation systems, and are economically more competitive than countries with poor transportation infrastructure. The enhancement of transportation systems offers better telecommunication systems, industries and businesses. This directly increases economic growth and indirectly improves the general standard of living of the community. The understanding is that transportation is a beneficial sector in a community rather than merely a type of mobility. Even developed countries have realised that transportation is a crucial sector and plays a significant role in economic growth (Masood et al., 2011:257).

6.3.5.3 Transportation issues in Pakistan

Pakistan is a developing country where different aspects have to be considered in addition to the spatial structure of transportation systems. This has led to a number of problems in the transportation systems and the general economy of the country, which have been identified as follows (Masood et al., 2011:258):

- Lack of multi-modal transport systems
- Unnecessary restrictions on transportation systems
- Road safety problems due to a lack of upgrades
- Lack of finances for the public sector
- Environmental pollution
- No or little coordination among transport agencies
- Lack of transport for students
- Lack of transport for females
- Inadequate transportation of professionals in the planning of transport system policies and projects
- Inadequate traffic management techniques
- Proliferation of smaller vehicles
- No private sector transportation system
- Poor maintenance of transport systems
- Inadequate labour laws
- Inadequate institutional arrangements for the planning of proper transportation systems.

While these are not the only problems, the above list represents the problems caused by inefficient transportation systems and lack of knowledge about spatial implementation. The crucial problem in Pakistan is the correct spatial integration of multimodal transportation systems. The aspects that should be addressed in various developing countries in addition to Pakistan are considered to be the following (Masood et al., 2011:257-258):

- Public transport by rail
- Management of transportation systems
- Research and development
- The multi-modal transport structure
- Implementation of policies and maintenance
- Funding
- Integration of transport systems
- Lack of planning amid increased corruption in the public and private sectors
- Lack of safety regulations.

Solutions for improving the transportation issues have been suggested, but have not solved the problems, rather postponed them. The problem with Pakistan relates to development and maintenance in the transportation sector; initially the difficulties were solved through developing more roads. The problem with the development of more road lanes is that they open up space that has to be developed further, in view of the rapid population increase.

6.3.5.4 Implementation of LRT in Pakistan

Pakistan, a developing country, did not implement an LRT transportation system, but implemented a type of passenger railway, which forms part of its transportation network. The development of this railway system was a strategy to decrease the number of motor vehicles. The railway was effective between 1964 and 1970, when a trip was made every half an hour and in total 104 trips were undertaken per day. This deteriorated overt ime owing to insufficient maintenance and upgrades, which would inevitably lead to the downfall of this once effective system. From 1968 to 1978, the following percentages of the various types of transportation modes were used in Pakistan (Heraa, 2013:16-18):

- motor vehicles (ibid.) - 58%
- mini-buses - 95%
- rail - 5%.

The statistics indicate that mini-buses were more effective than the rail system, leading to complete lack of maintenance of the railway system and a massive increase in buses and mini-buses. By the end of 1960, all motor vehicle transportation systems had increased to 45%, including a rapid increase in buses (900) and mini-buses (1800), illustrating the disregard of the railway system. The simple conclusion is that Pakistan focused on BRT units rather than LRT.

The specific systems relate to railways and traffic caused by motor vehicles. The second crucial factor is that the railway system is cost-inefficient and does not have any economic benefit. The railway stations are insufficiently maintained, while the distance travelled is relatively limited, illustrating that more benefit would come from other transport modes over longer distance travel (Masood et al., 2011:258-260).

6.3.5.5 Karachi

6.3.5.5.1 Land use in Karachi

In most developing countries, rapid urbanisation, poverty and increasing population growth have applied pressure to land use and infrastructure; specifically, transportation infrastructure is poorly maintained and upgraded. This results to problems in the social, economic and environmental areas. Karachi is the largest and most economically strong city in Pakistan, but in attempting to maintain this status it does face major obstacles (Heraa, 2013:3-80). Land use in Karachi is inefficient, because of its rapid population and urban sprawl, illustrated in Figure 6-19 below, as well as the various squatter settlements and the distance between the business district and the surrounding settlements.

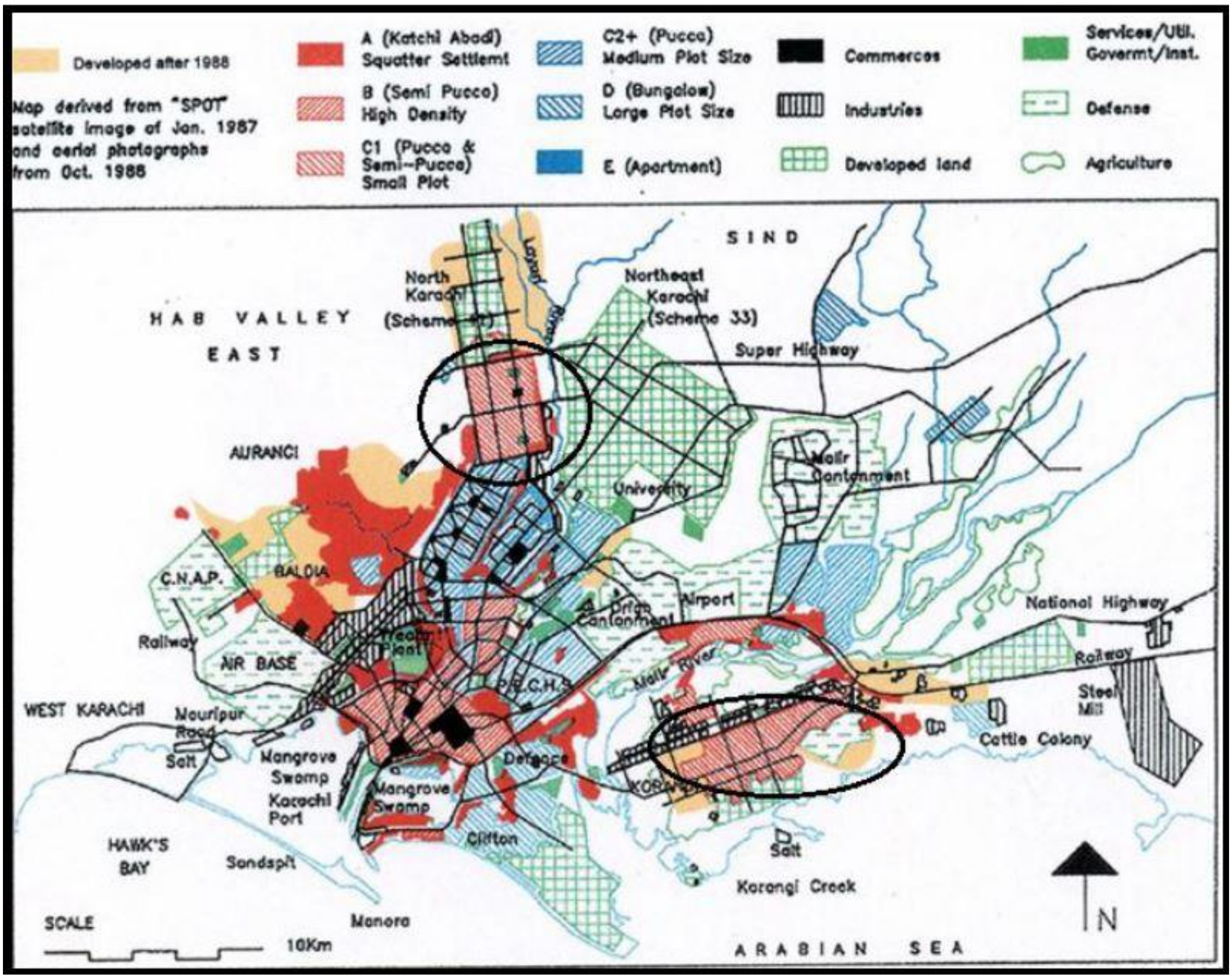

Figure 6-19 Land use in Karachi

Source: Hasan & Mohib, 2003

6.3.5.5.2 Spatial layout of transport infrastructure

The spatial layout of transport infrastructure was incorrectly implemented. Most of the roads are located over water and sewage lines, which means that little maintenance is done. This situation arose from lack of coordination between departments. The problem is that numerous areas were placed under different departments, which led to miscommunication in many fields of implementation. The departments concerned are the following, which are considered to be responsible for different areas in Karachi (Heraa, 2013:12-14):

1. Sindh Road Transport Corporation (Defunct)
2. Karachi Transport Corporation (Defunct)
3. Karachi Urban Transport Company (Founded 2008)
4. Provincial Transport Authority
5. Karachi Public Transport Society (Government of Sindh).

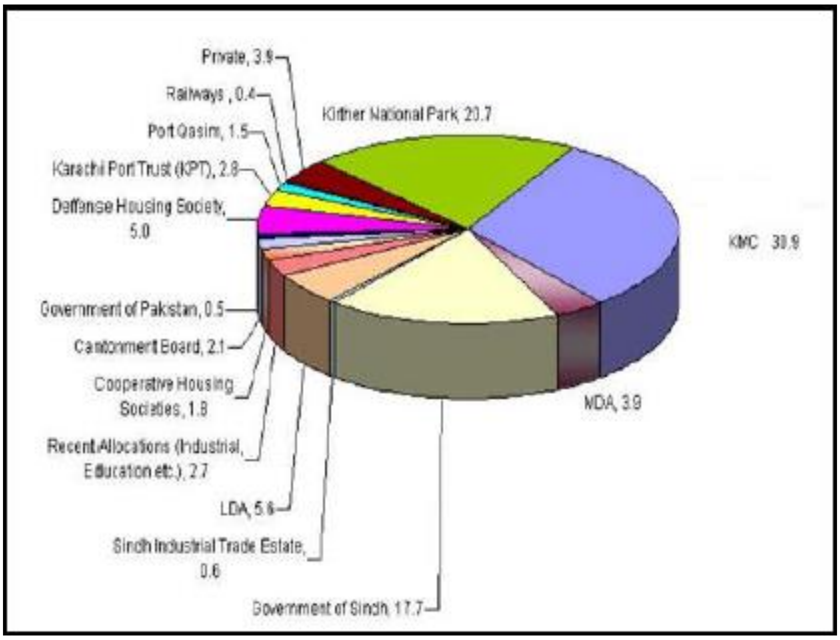

Figure 6-20 Departments and sections of land they control in Karachi

Source: CDGK, 2007

Figure 6-20 illustrates a city being divided by various departments, which would cause a decrease in efficiency, as well as miscommunication. This is an example of miscommunication between different spheres of government.

6.3.5.5.3 Public transportation

Pakistan had shown positive results when implementing the use of public transportation systems and high-density vehicle periphery mobility. The problem began with the implementation of the policies and the principles contained in them. The policy lacked the ability to implement aspects of high importance in the spatial urban structure. These aspects were not implemented because of deficiencies in governance and inadequate urban planning. The policies did not comply with the spatial structure design, which means that the policy could not be implemented with complete confidence (Masood et al., 2011:260).

The above public transportation systems mentioned in relation to the implementation of LRT and BRT systems illustrate that mini-buses offer an effective public transportation system. The statistics have illustrated that mini-buses are used 38% of the time rather than other transportation modes. This indicates that the need for public transportation is in fact urgent, judged from the number of vehicles occupying the roads (Heraa, 2013:19). The pie chart below illustrates the use of alternative vehicles in Karachi:

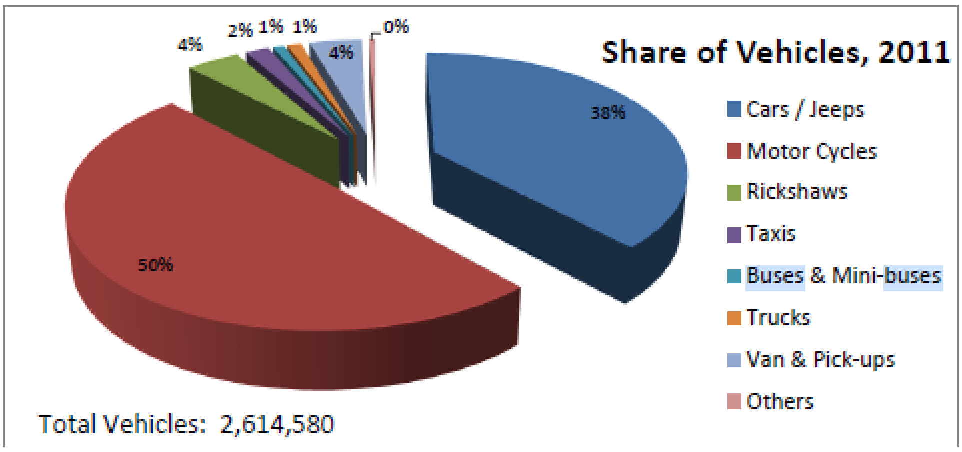

Figure 6-21 Use of transport modes in Karachi in 2011

Source: URC, 2011

6.3.5.5.4 Implementation plans

Pakistan has identified its problem with the spatial implementation of transportation systems and its ineffectiveness in certain transport modes. This has led to alternative transportation infrastructure, which will be more sustainable over a long period.

The above research on Pakistan has already determined the failure of rail implementation, but indicated that effective public transportation had been implemented to decrease the number of SOVs. These specific types of transportation are rickshaws and mini-buses, which are effective in the current circumstances of overpopulation. The implementation of the following strategies would help decrease the use of cars and lower traffic congestion:

A. Traffic demand management

Compiling traffic demand management (TDM) strategies can be good solution to managing the current traffic situation in Karachi. TMD strategies can be implemented depending on the desired objective. One of these objectives is to decrease traffic congestion at peak hours or all day long. This strategy not only decreases traffic congestion, but decreases exhaust emissions and travel time, while increasing travel time reliability and decreasing energy use. This would increase accessibility in response to the decrease in vehicles, making roads more accessible (Heraa, 2013:41).

B. Congestion management

One of the many problems in developing countries is traffic congestion. This is due to rapid population growth and lack of a multimodal system. The congestion management strategy is a specific method used to create speed harmonisation, which decreases car speeds, thus avoiding possible accidents. This management method also uses sensors on various roads to collect and record travel data. This will determine if the road is exceeding its capacity of vehicles and help to create solutions before congestion increases. This management strategy is used in developed countries (Netherlands) to help maintain and manage traffic (Heraa, 2013:41-42).

C. Alternative transportation means

Alternative transportation means using sustainable transportation modes, such as cycling and walking. This is enabled by developing more infrastructure devoted to the use of cyclists and pedestrians. Upgrading and maintenance of the infrastructure are seen as providing a more efficient type of mobility through dealing with current problems, i.e. traffic congestion. These solutions offer more accessible routes and pathways to points of interest. This not only decreases congestion and the use of motor vehicles, but also improves the quality of life by offering a healthier choice of transportation. This strategy offers the implementation of green motor bikes, which is a motor vehicle powered by electricity and general human effort (Heraa, 2013:41-42).

6.3.6 Introduction to South Africa

South Africa has numerous cities and towns, but all are not equal and they vary in economic growth. The city of Cape Town will be used to illustrate the most economically strong city, since it is internationally well-known, which supports South Africa in respect of imports and exports. South Africa comprises various provinces in which several cities are located. Cape Town supports South Africa not only through imports and exports, but also through tourism. Some of these cities have implemented various types of transportation modes, but cannot compare to first world countries in any way regarding efficiency and spatial implementation of transportation. The cities of Cape Town and George (addressed in local case studies) have developed new, sustainable transportation initiatives. This is intended to manage the rapidly increasing population and to expand infrastructure into the surrounding spatial area. Moreover, consistent maintenance and upgrades are needed to maintain efficiency. Regular maintenance and upgrades have not occurred in Cape Town and George, which affects their spatial form. The number of cars occupying the roads have congested the most dominant road infrastructure, thus decreasing productivity and indirectly decreasing economic growth.

6.3.6.1 Policies in South Africa

The approach to the implementation of transportation infrastructure through policy and spatial planning has developed a single focus. This single focus has not been implemented correctly (Mitchell, 2009:336-337; Walters, 2014:4). South Africa's policies have been based on the improvement of public transportation systems, which have focused specifically on improving road infrastructure. Multimodal implementation and upgrading of transport systems have been neglected. The problem with the spatial implementation process of transportation systems does not originate from the actual implementation, but from the policy itself. The figure below illustrates a funding scheme for improving transportation systems:

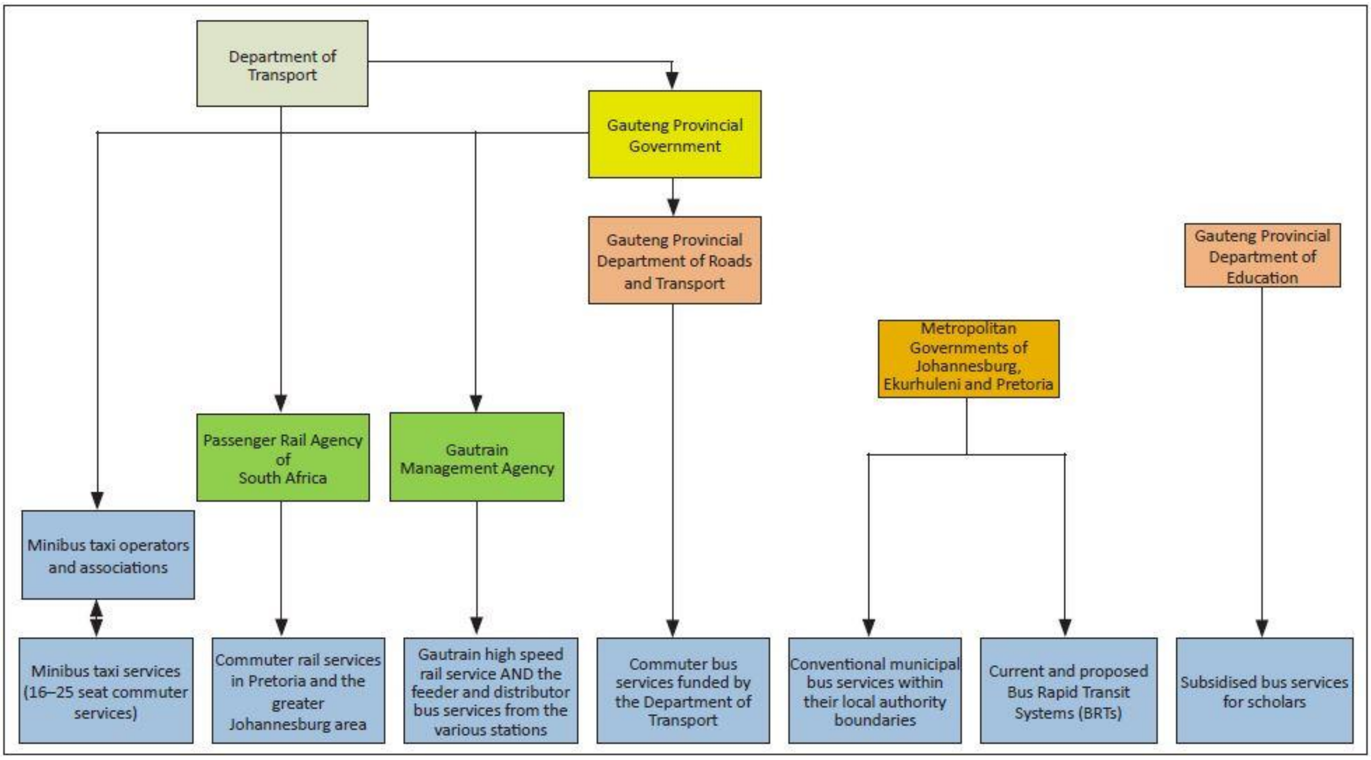

Figure 6-22 Funding of public transportation in South Africa

Source: Walters, 2014:7

However, if the foundation is not correctly implemented, the physical process can be neither sustainable nor successfully implemented; the policy should be the first point of analysis. By monitoring of the policy, a report can be compiled on how successful it may be in the long or short term.

6.3.6.1.1 National Transport Master Plan 2050

The National Transport Master Plan 2050 (NATMAP) is a legislative framework that aims to develop long-term, multi-modal sustainable transportation systems as well as developments and facilities for service delivery/interchangeable terminals. It is hoped that this master plan can be implemented and fully functional by 2050 in order to create self-reliant cities/towns. This will demand socio-economic growth in all three spheres of government (district, provincial and national) through any sectorally integrated spatial development plan. This framework will also coordinate implementation time frames, while accommodating the agenda of the whole country in order to implement effective and efficient spatial development corridors throughout regions before 2050. The NATMAP framework is to be initiated through a project that assesses current issues and identifies problems through the examination of spatial structure (Situma, 2007:388; Schoeman, 2013:1-5):

- The strategy is to be used for various land use and spatial development models in order to sustain investments throughout the development, through the use of multimodal urban/rural developments.
- Cost-effective models need to be developed to integrate the public and private sector through the connection of regional/local corridors for economic development.
- The framework should be based on a vision, goals and objectives in order to create efficient national development corridors, which will stimulate economic growth.
- The development of cost-efficient institutional frameworks in a model is required to ensure effective investments, implementation, maintenance, operations, planning and monitoring of the functionality of the model.
- Integrated growth and development strategies need to be compiled for each national/regional corridor to stimulate economic growth.
- Implementation of multimodal transport infrastructure facilities and the spatial development plan would include use of the surrounding land.
- Various projects for economic growth or potential growth have to be planned.
- An action agenda is required on which various stakeholders can base development strategies, while integrating the development plan.

The project objectives of NATMAP entail vital transportation solutions to be implemented by the planning authorities in the early stages of development. The national plan allows for these goals to be implemented in the interest of improving the socio-economic development plan. Criteria for the transportation goals need to be established in order to improve the following aspects or implementation objectives (Situma, 2007:394; Schoeman, 2013:8-9):

1. Improve development of future infrastructure facilities.
2. Implement rail plan strategies.
3. Maximise use of existing infrastructure facilities.
4. Develop an up-to-date, accurate central land use plan/transportation system.
5. Develop maritime transportation implementation strategies.
6. Develop public passenger transportation implementation strategies.
7. Compile environmental impact standards.
8. Formulate land use strategies to improve transportation cost-effectiveness.
9. Do road infrastructure planning.
10. Consider the contribution of transportation systems towards national GDP.
11. Compile civil aviation implementation plans and strategies.

6.3.6.1.2 Guidelines for human settlement planning and design

The Guidelines for human settlement planning and design, deals with the geometric design, placement of districts, nodes, functionality and overall compatibility of the community in South Africa. The Guidelines for human settlement planning and design has layered the foundation of spatial guidelines in order to establish a well-balanced community. The guidelines in terms of spatial development in mobility are found in Chapter 7, that restricts and controls the placement of transportation systems. Most importantly, these guidelines regulate the two most important aspects of transportation planning, namely transport systems management and traffic calming.

Intensifying the use of space through compact spatial planning will also allow for more sustainable use of public transportation. The growth of the area will become more economically sustainable owing to the concentration of activity and mobility. The principle of reinforcement is consistently mentioned in the development of settlements. Through correct spatial planning, transportation can attract growth and even create growth through the use of activity corridors (Adam et al., 2000:7).

Public transportation should be integrated spatially into every community, but should abide by certain guidelines to maximise its functionality and mobility. The following guidelines should be incorporated in public transportation systems:

- Create public transport stops that provide adequate shelter against the elements.
- Provide areas for resting, waiting or eating in terms of spatial allocation.
- Provide a separate waiting area for different transportation modes.
- Provide street furniture for civilians.

Source: Adam et al., 2000:42

South African policies

The policy has been successful, owing to improvement in five areas, which recorded a considerable increase in efficiency. The policy was implemented successfully, owing to the following factors that had played a massive role in improving transportation units (Potterton, 2012:12-14):

- The creation and acceptance of a goal, as well as rationale for national action
- The policy's resilience and persistence
- Effective government leadership, which had played a large role.

The national perspective was initiated through the White Paper on National Transport Policy (1996). This included numerous strategic objectives for land passenger transportation. The objectives were designed to improve transportation systems. The policy was based on problems in South African transportation systems. The main issue identified was that public transportation systems were inefficient and were consequently rejected by the community, creating problems with funding and subsidies for public transport (Schoeman, 2013:4-8). Table 6-2 below illustrates the policies and legislation by NATMAP, implemented with a spatial development plan to achieve sustainability.

Table 6-2 Transportation core policies including legislative framework

Policy framework	Legislative framework
White Paper on National Transport Policy (1996)	Urban Transport Act (Act 78 of 1977)
Moving South Africa (Vision 2020) (1999)	Road Transport Act (Act 74 of 1977)
White Paper on Spatial Planning and Land Use Management (2001)	Development Facilitation Act (Act 67 of 1995)
National Spatial Development Perspective (2003)	National Road Traffic Act (Act 93 of 1996)
Rural Transport Strategy for South Africa (2003)	Constitution of the Republic of South Africa (Act 108 of 1996)
National Spatial Development Perspective (2006)	National Transport Interim Arrangements Act (Act 45 of 1998)
Accelerated and Shared Growth-South Africa (ASGISA) (2006)	Cross Border Road Transport Act (Act 4 of 1998)
Draft minimum requirements for the preparation of integrated transport plans (ITP) (2007)	Transport Appeal Tribunal Act (At 39 of 1998)
National Land Transport Strategic Framework (2006-2011) (2002) (Draft)	Road Traffic Act (Act 29 of 1989)
Rural Transport Strategy for South Africa (2003).	Municipal Structures Act (Act 117 of 1998)
Sustainable Human Settlement Planning (2009); Human Settlement Atlas (2009)	National Land Transport Transition Act (Act 22 of 2000)
National Housing Code, 2009.	Municipal Systems Act, (Act 32 of 2000)
National Growth Plan (2009)	National Land Transport Act (Act 5 of 2009)
National Transport Master Plan 2050 (NATMAP 2050) (2011)	R. 1208 National Land Transport Act (5/2009): National Land Transport Regulations.
National Planning Commission (NPC) Diagnostic Report (2011)	R. 877 National Land Transport Act (5/2009): National Land Transport Regulations on Contracting for Public Transport Services.
National Planning Commission (NPC): National Development Plan for 2030 (2011)	Spatial Planning and Land Use Management Bill (2012)

Source: Schoeman, 2013:6

The outcome of the White Paper policy was carefully assessed in order to implement sufficient transport strategies and policies in South Africa. The National Land Transport Transition Act (2000) has been implemented to monitor the performance of public transportation systems in respect of performance indicators to maintain the system. The National Land Transport Strategic Framework led to the formulation of a draft development plan, which focuses on strategic transportation forces and development. The last legislation of interest played a particularly large role in transportation systems. The National Land Transport Act (No 5 of 2009) was implemented with the intention of providing supporting regulations. While supporting transportation systems, it became evident that there was potential in the legislation, establishing it as a catalyst for transportation systems in South Africa (Schoeman, 2013:4-7).

The provincial government sphere is responsible for various pieces of legislation to guide land transportation planning, provincial economic growth and development strategies. This entails provincial spatial development frameworks, provincial land transport frameworks and environmental policies and strategies. The main provincial perspective is to initiate a guideline on how transportation systems should be implemented to improve economic growth. This would facilitate the development implementations of large projects or a large scope of work and programmes (Schoeman, 2013:7; Situma, 2007:395).

The municipal sphere is regarded as the most localised government for a small compact area. Similar instruments are implemented to guide transportation development and spatial planning. This area is focused on small framework strategies, which are implemented over a period of five years in order to achieve maximum effect. The frameworks implemented are known as integrated development plans (IDP), integrated transport plans, SDFs, environmental management frameworks (EMF) and strategic environmental assessments used to monitor the environment. These help manage the spatial development of an area to achieve effective economic growth and long-term transportation sustainability (Schoeman, 2013:7-8). Figure 6-23 below illustrates the inter-policy process at work in the municipal sphere and the collaboration between the various plans. This represents the framework for transportation and development plans in the municipal district.

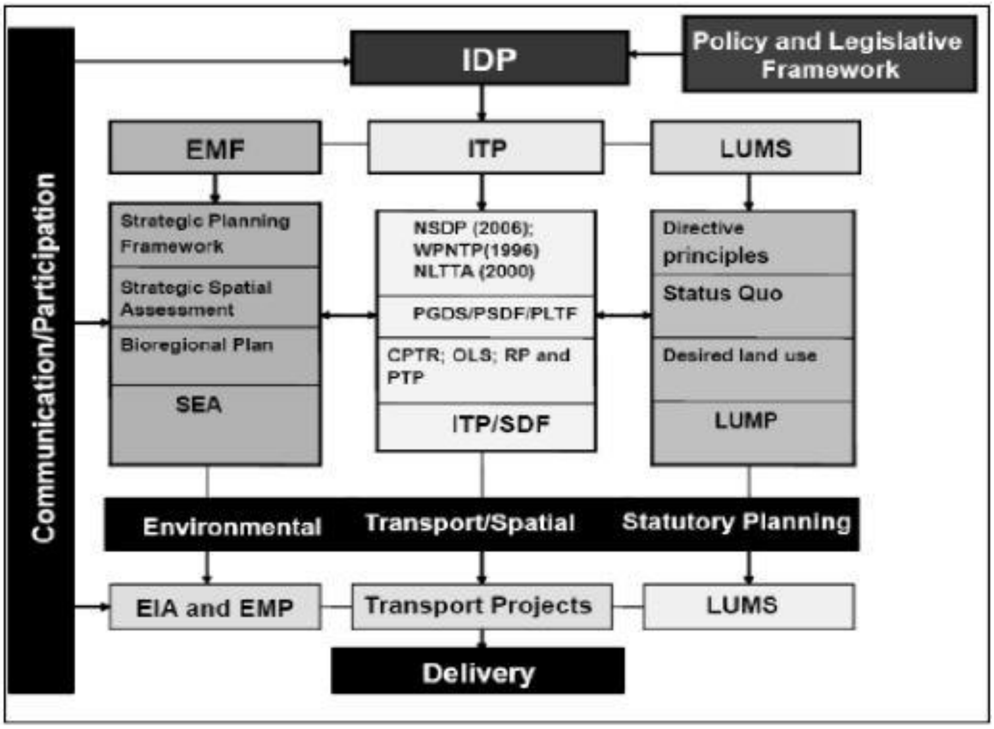

Figure 6-23 Integration of frameworks and policies for the implementation of developments and transportation planning systems

Source: Schoeman, 2013:8

To conclude, the impact of the NATMAP on various areas in terms of land use and the implementation of integrated transportation systems was immense. This provided a base for investment-responsive policies to trigger an increase in national economic growth. The framework provided provincial master plans to use the resources in areas and implement unique spatial developments. The benefit of this framework could be seen after a five-year implementation process, after which, if any adjustments needed to be made to the framework, it could be done efficiently. If the policy had a negative impact, it could be removed after a five-year period, with little damage done to the community, while if a positive effect should occur, the framework could be reinitiated (Situma, 2007:397).

The implementation of NATMAP in South Africa had a positive impact; huge progress has been made over the past 18 years in the transformation of transportation policies and other legislative frameworks implemented. There have been integration and alignment on national level, while growth in development was managed. However, transportation sustainability may remain a distant progression objective (Schoeman, 2013:13).

6.3.6.1.3 Spatial Planning and Land Use Management Act, 16 of 2013, guidelines

Land use management schemes are implemented through the municipality in a local area, under the IDP or SDF, in order to distribute land correctly. The land use scheme was created to distribute the correct portion of land for a specific activity. This is illustrated in a local area, but is guided by legislation known as the Spatial Planning and Land Use Management Act, 16 of 2013 (SPLUMA).

The SPLUMA was based on specific guidelines, to ensure the efficiency of specific land uses. The Act has specific objectives, which need to result from implementation. The first objective is to ensure sustainable and efficient use of land to maximise the potential of an area. The second objective is to create a foundation through standards and norms in terms of development. The spatial planning of land uses should be incorporated in order to promote social and economic sectors. It is also hoped that the Act will maintain a level of cooperation between different spheres of government and equality of the application in spatial planning. The penultimate objective is to implement land use management schemes effectively in SDFs and IDPs (South Africa, 2013:12). This Act is based on five principles of development, namely:

I. Principle 1 - Spatial justice

II. Principle 2 - The principle that incorporates spatial sustainability through spatial planning

III. Principle 3 - Efficiency

IV. Principle 4 - Spatial resilience within a spatial plan, followed by a series of flexible spatial policies and land use management systems. This would accommodate numerous sustainable communities, which are most possibly suffering from economic as well as environmental shocks.

V. Principle 5 - Implementation of good administration.

6.3.6.1.4 National Development Plan

The National Development Plan is accommodated within each country to achieve future goals. The main goal of interest is the eradication of inequality and poverty in South Africa by 2030. The past years of South Africa have created a hard and problematic foundation, which was due to the apartheid era (South Africa, 1994:24). Apart from the numerous small goals that need to be achieved in South Africa, the national development goals aim to (Luke & Heyns, 2013:2-3; South Africa, 1994:61):

1. Improve the economy and increase employment opportunities;
2. Improve the economic infrastructure;
3. Increase environmental sustainability and resilience;
4. Build safer communities; and
5. Redesign and transform different human settlements.

The spatial planning and development of the economy occur through productivity, while indirectly increasing economic growth. The policy focuses on spatial development objectives, but does not cater for the implications of changing the spatial development and accommodating factors in a spatial development.

6.3.6.2 Transportation in South Africa

The developing country of South Africa does not have a sustainable spatial development framework allowing for the effective implementation of transportation systems. The forms of transportation currently implemented in the spatial plan involve the overuse of vehicles, while lacking public transportation and spatial infrastructure. The fact that it is a developing country means that other priorities often enjoy precedence, for example poverty. This causes a massive problem, since funding is used for other priorities, rather than improving infrastructure and increasing job opportunities (Luke & Heyns, 2013:2-6). South African cities have been neglected in certain regions, which only leads to the stagnation of a town or city. These cities and towns rely on transportation systems to establish a financial foundation. These systems have been considered activity corridors, which are formed around frequently occupied transport systems. This allows businesses to form in the vicinity of possible economic areas where a certain level of trade could take place. The consequence is that various routes within transportation systems are developed, while the older transport routes are deserted.

This has happened in the study area and transportation systems that cannot function correctly have consequently been implemented. South African experience proves that if transportation systems are implemented incorrectly, this causes more problems than it solves. BRT systems were implemented in Cape Town, Johannesburg and subsequently in George. South Africa believed that the system would work as a public transportation system. The problem began with the reason why the transportation systems were implemented in the first place. The main issue of concern is that the BRT systems were created to give the illusion of a first world city when the 19th soccer world cup tournament was held in South Africa.

6.3.6.3 Implementation of LRT in South Africa

LRT systems have been implemented in South Africa, but only recently in Cape Town. The LRT system is known as the Metrorail and transports individuals around Cape Town. The Metrorail is highly effective in terms of mobility and extremely efficient. The cost of this LRT system is affordable, but the issue is complicated by its spatial implementation and reach of areas. The Metrorail is limited to a few boarding and stopping points and its maintenance cost is very high. The LRT system has been implemented only recently, but a less effective alternative type of transportation, known as BRT systems, had been implemented earlier. The BRT system was implemented in two major cities (Cape Town, Johannesburg) of South Africa, but not in any other cities. The BRT system in Johannesburg is less effective than in Cape Town, but the guidelines and principles have remained the same, although the land concentration differs. The BRT infrastructure failed to link its infrastructure to various sections. Considering the distance and time of travel, it has become ineffective in respect of time and does not deliver services as planned. The ideology of this type of transportation was to relieve traffic congestion created by masses of vehicles on the road, while creating an effective and affordable public transportation service.

6.4 Conclusion

This chapter addressed various spatial structures in both first world and third world countries to obtain an international best practice perspective. It evaluated various spatial and transportation aspects that make first world countries efficient and third world countries less efficient. The spatial implementation of transportation systems and the various modes and infrastructure implemented determine the level of efficiency and the way in which multimodal systems interact with the various sectors and land uses. The chapter refers to Denmark and Australia as first world countries and illustrates the various modes of transportation implemented. This shows correlation if not close similarity in respect of type of transportation systems used and how these had been implemented in the spatial structure.

In discussing Adelaide in Australia, it became evident that first world countries have implemented various policies and forms of transportation infrastructure to achieve multimodal functionality in the spatial structure. This is evident in Odense in Denmark, another first world country that displays similar traits with regard to multimodal transportation systems. Both first world countries have implemented bicycles, LRT, BRT, pedestrian infrastructure and motor vehicles (Schipperijn et al., 2010:26-30; Adelaide City Council, 2012:12-66; Nicolaisen et al., 2017:12-16). Third world countries (South Africa and Pakistan) had not implemented this transport infrastructure. This was the case in both Pakistan and South Africa (Masood et al., 2011:257; Luke & Heyns, 2013:2-6) prior to recent advances in transportation systems, as illustrated in George (Go George - BRT) and Cape Town (Metrorail).

This chapter identified the successful implementation of transportation systems in the urban structure, as well as the shortfalls in third world implementation. This concludes the second objective in evaluating the theoretical foundation of sustainable transport systems and international best practice.

CHAPTER 7 LOCAL CASE STUDIES

7.1 Introduction

This chapter addresses the local case studies, illustrating similarity in spatial structure, land use, transportation and the implementation of transport infrastructure. The local case studies addressed in this chapter are located in the same third world country (South Africa) as the demarcated study area. This will illustrate the proposed constraints on other towns/cities in the country, but will also determine possible solutions to the implementation of local transportation systems. This illustrates a possible strategy for development, based on the local similarities illustrated in the country. The local case studies that will be addressed involve Cape Town and George, situated in the Western Cape of South Africa.

7.2 The City of Cape Town

The city of Cape Town has various spatial traits that allow it to be superior in its spatial implementation of transportation modes. The spatial structure of Cape Town refers to its location, one of the many factors when determining spatial development (Pacione, 2005:787-789; Rodrigue et al., 2006:88). This has been illustrated in Chapter 4 of this research document. The examination of Cape Town is based on the density of the development; Cape Town is in close proximity to many areas/land uses, because of the limited land it had to develop on. This created a compact city, which led to the efficiency of the transportation system (Wilkinson, 2006:223-225). The compact city has been associated with transit-orientated development, because of its level of efficiency in various land uses. Cape Town was not designed to be highly productive, but rather to be an international water transport hub. This meant that it could obtain and exchange various goods and services with other countries by boat, yet it was primarily known for its world-famous harbour. Figure 7-1 below illustrates Cape Town and its compact design, which developed in response to the limited space available to develop.

7.2.1 Land use in Cape Town

Cape Town can be regarded as one of the most efficient cities in South Africa; owing to harbours and trade, the city has grown to adapt to the constant demand and supply of goods. The aspect of Cape Town that has made it efficient is its spatial structure, illustrated in Figure 7-1 below. It identifies a densely compact spatial design, which illustrates a similar perspective to Johannesburg. The growth of the city is limited by the coastline on either side, which contains the city. It therefore has to seek alternative ways of growth. This situation inevitably causes local businesses, markets, services and communities to be situated closely together. The ideology of this type of spatial structure allows for quick access and exit from various land uses. The figure below illustrates all land uses and transportation systems in the city.

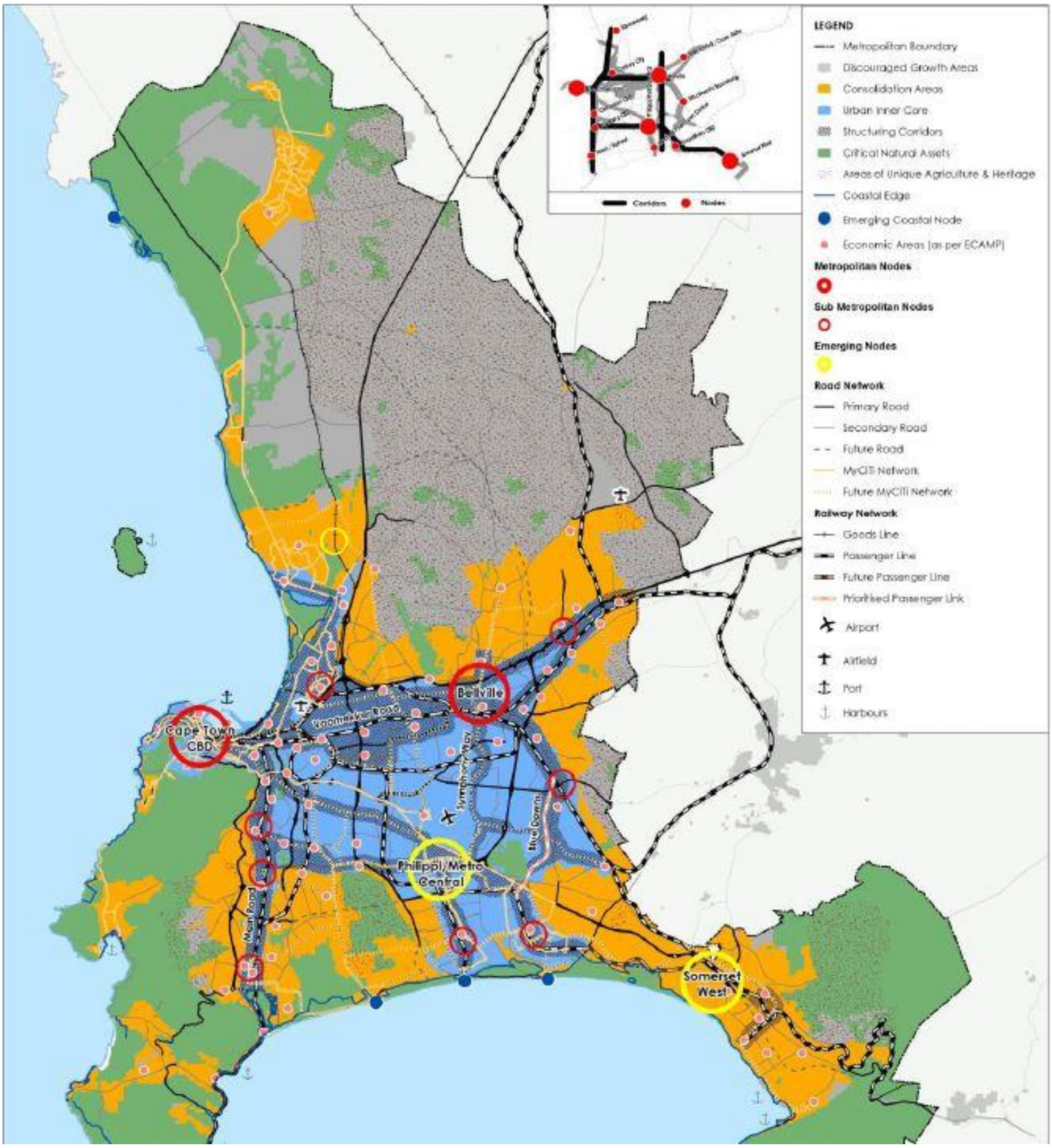

Figure 7-1 Land use development in Cape Town

Source: TDA, City of Cape Town, 2018:71

The above land use development of Cape Town illustrates both transportation modes and the spatial implementation of the specific nodes. The relevance of this land use figure is the connectivity of various land uses, owing to the multiple types of mobility. This allows for various modes of transport of goods and services, as well as connectivity between communities. The vast array of transportation modes helps to provide various options of mobility for passengers and freight, allowing for an efficient system. The above figure illustrates the effectiveness of multimodal transportation in Cape Town, as well as the spatial implementation of transport in a compact city. Figure 7-2 below illustrates the spatial structures' compact design, which is due to limited space between land and coastline, but plays a significant role in generating economic growth.

7.2.2 Spatial layout of transport infrastructure

Referring to the figure to illustrate in land use in Cape Town (7.1.1), it is clear that transportation systems in Cape Town are of various types, including land, air and sea transport. The significant aspect illustrated in the land use models, explained in Chapter 3, is the implementation of the urban fabrics model. This shows the incorporation of transportation modes as in the urban fabrics model (3.12) (walking, transit and automobile), illustrating the incorporation of the applied principles (Thomson & Newman, 2018:218-219). The relevant transportation systems in this case study are illustrated on land. The road network of Cape Town has three principal arterials that connect Cape Town to the rest of South Africa, namely the N1, N2 and N7. The N1 road network is connected to the city centre of Cape Town and reaches towards the northern suburbs. This road is South Africa's most used mobility road in comparison to other high-density mobility arterials. The N2 also begins in the city centre of Cape Town and moves eastwards towards Somerset West. This road is highly regarded, because of its connection to the Cape Town International Airport, illustrating the use of multimodal collaboration.

The lower arterial roads, used for regional and district mobility, are the M3, M5, M7 and R300. These arterials are regarded as highly important for the distribution of goods, services and mobility of passengers between regions and districts. The M3 road connects the upper part of the city centre to the southern suburbs. The M5 runs from north to south to connect Millerton in the northern suburbs to Muizenberg in the southern suburbs. The M7 creates a north-south link through the Cape Flats and ends at False Bay, which is a highly populated area (TDA, 2018:31-32).

The spatial structure was effectively implemented, considering travel time, cost of maintenance, cost of transportation and distance of travel. It was believed that the BRT system would increase economic growth, alleviate poverty, help restructure the apartheid city structure, increase sustainability and allow for good governance (Allen, 2013:2-3). The problem with the BRT system was that it was a new implementation many individuals were not accustomed to using. They tended to resort to the transportation system they had initially been using, because of its convenience. The second aspect of importance is that the city of Cape Town district does have a compact structural plan, making it effective to access various areas. The community resorts to using private vehicles, for the sake of convenience. The BRT stations are not particularly safe places to wait for the transit system; these have often been the sites of multiple cases of robbery and violent confrontations (Jobothaboj, 2018:1). The use of SOVs has become a problem and the need for a local transportation unit is high. The problem with this is the activity corridors on previous routes, which will no longer be profitable or get little income from the traffic flowing through. The best example of a similar situation, which is not well known, is Parys. This small town was built on an activity corridor for individuals travelling from the North West province towards the Gauteng province. The problem occurred with the development of the new road infrastructure (N12) route, which was more efficient, but removed Parys from the designated travellers' route, which inevitably decreased its income. This could have destroyed this small town and caused a decrease in jobs and increase in poverty on a large scale. This illustrates the importance of the implementation of transport routes and how spatial planning in the correct direction could enhance the economic growth of surrounding towns and cities.

7.2.3 Public transportation

While observing road transportation infrastructure as an asset when using SOVs, it could be considered as public transport infrastructure. The M4 is a perfect example of a high-mobility road for public transportation. This lower arterial serves as transport infrastructure to minibus taxis, the Golden Arrow Bus Service (GABS), and a planned MyCiTi service (Phase 2A). In Cape Town public transportation takes the form of various public modal systems that use road infrastructure. These public transportation systems are (TDA, 2018:32-34):

- Minibus taxis
- GABS
- MyCiTi service
- Railway system.

Figure 7-2 below illustrates the current and future infrastructure for roads and railways. These specific types of infrastructure relate to both public and private transportation modes and are highly significant, owing to their multi-use nature.

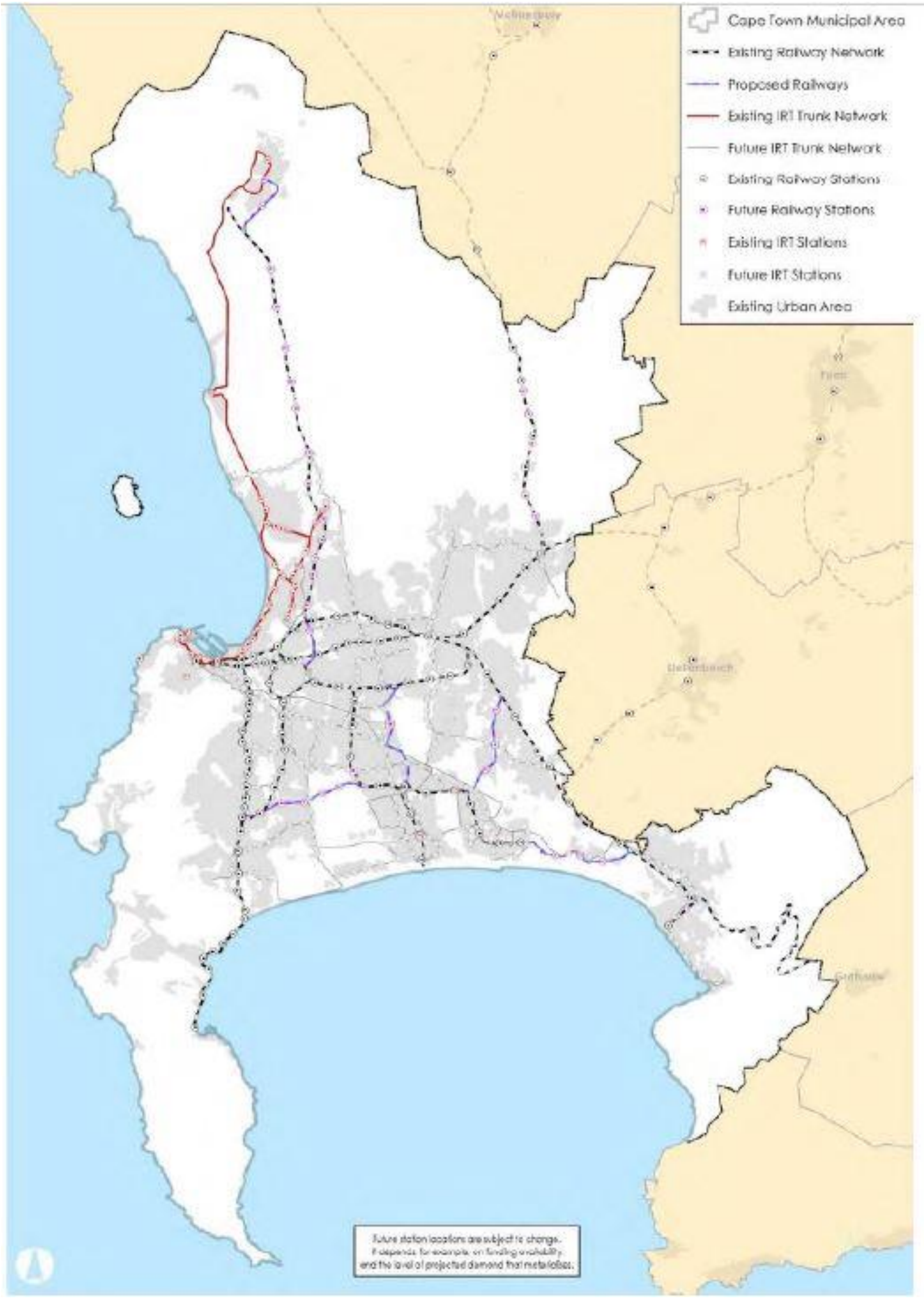

Figure 7-2 Public transportation network in Cape Town

Source: TDA, 2018:144

The minibus taxi transportation system is an informal public transportation system, which has become the most frequently operated public transportation system in South Africa, including Cape Town. It makes use of 120 official public transport facilities, of which 63 are within public transport interchanges, and 57 are stand-alone. In addition, the system includes 65 unofficial public transport facilities. This can be considered an efficient transportation system, which could unfortunately be affected by congestion. Negative characteristics that could hamper the efficiency of minibus taxis are the flexibility and lack of official timetables for the minibus taxi system. Evaluating the efficiency of the fleet is a unique challenge. Public transportation has access to other bus systems, for example the contracted bus, known as the GABS. Sibanye provides contracted bus services in the Cape Town area. Known as the GABS, these are not as successful as the minibuses taxi system, but are considered highly reliable in terms of time management.

The MyCiti transport service, also known as the MyCiti BRT system, has been divided into two phases (TDA, 2018:32-33): Phase 1 of the MyCiti consists of the service that serves the West Coast along the R27 between Atlantis in the north, to the CBD and surrounding areas, moving further south to Hout Bay. Additional routes include a route along the N2, which runs from the Civic Centre to the Cape Town International Airport, as well as Khayelitsha and Mitchells Plain. Plans for Phase 2A entail the extension of the service from Khayelitsha and Mitchells Plain through Philippi to Wynberg and Claremont. A contracted bus system known as the GABS or Sibanya, which is the company responsible for the allocated bus transportation, is also operational in the area. The contracted bus system is active in the Cape Town area. GABS encompasses 30 public transport facilities, of which 21 are located in public transport interchanges (TDA, 2018:32).

The minibus taxi system is an informal public transportation system. This is a common public transportation system seen throughout South African cities and supplies the informal sectors with public transportation, but does not accommodate the whole community. The minibus taxi system makes use of 120 official transportation facilities, of which 63 are in public transport interchanges, 57 are stand-alone and in addition around 65 operate from unofficial public transport facilities. In Cape Town 11 of these public transport systems facilities are situated at public transport interchanges. The efficiency of this public transportation system is undetermined by its lack of timetables and the number of individuals carried per trip. Its efficiency could also be influenced by local traffic congestion and distance of travel. It will remain a future challenge to calculate the efficiency of this public transportation system

The rail system in Cape Town is a public transportation system, which consists of nine radial routes originating from the city. The network of rails uses 118 stations. The five main passenger routes are situated on the southern suburbs line and around the Cape Flats line, the central line, the Malmesbury-Worcester line and the northern line. The Malmesbury and Worcester lines only receive a minimum train service per day. The number of trains required to support this rail network is considered to be 88 operational train sets. The current status of this rail network is that in 2017 only 59 sets were available; 52 of the 59 were considered to be running short. The railways are believed to have requirement capacity problems and should also consider the lack of upgrades and the age of this transportation system, which exceeds 40 years. These issues have massive implications for the functionality and efficiency of the system. The broader factors, which are unpredictable and cannot be determined, are vandalism and theft of components of the railway infrastructure (railway line) and facilities. All these factors were determined in Cape Town; it was found that the system's efficiency and use had decreased by more than 30% (TDA, 2018:32-33).

7.2.4 Implementation plans

The implementation plans of Cape Town comprise a number of strategies to increase the efficiency and functionality of the city as a whole. The spatial targeting of these development initiatives is performance-related regarding integrated city development. The strategies applicable to this study document are the Integrated Public Transport Network (IPTN), TOD strategic framework and integrated zone (IZ) planning and investment strategies for Voortrekker Road, Metro South-East and Blue Downs corridor (TDA, 2018:194). The Main Road corridor is a highly significant mobility route, in view of its connection to Cape Town CBD. Future implementation plans would help increase the city's growth and support its economic status. The city has identified three corridor-scale IZs for development initiative projects for transportation networks.

The corridor-scale IZs are based on various principles, which promote economic growth and efficiency. The first of these is the creation of various opportunities for affordable public transportation and restructuring the urban form. This correlates with TOD principles. The second is the capacity to link concentrations of economic opportunity and mono-use settlement patterns to create more opportunities to increase diversity and intensify land use. The last is to develop improvements to infrastructure and related catalytic urban development projects that may take place to accomplish future expansion. The three main corridor-scale IZs are the following:

1. Metro south-east IZ
2. Voortrekker Road corridor IZ
3. Blue Downs IZ.

Metro South-East integration zone

The illustration below identifies the Metro south-east corridor, which plays an important role in transportation towards the airport, south-eastern metropolitan area and Philippi area.

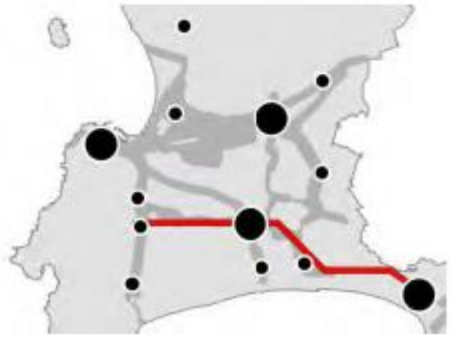

Figure 7-3 West-east/southern corridor

Source: TDA, 2018:246

The Metro south-east IZ surrounds Philippi, Khayelitsha and Gugulethu. The zone contains some of the most marginalised communities (Kosovo), where the number of households and the current population are both high. These are large informal settlements where affordable and efficient public transportation systems are needed. The main objective of the Metro south-east integration zone is to link Mitchells Plain and Khayelitsha spatially to the Cape Town CBD. Doing this will require the use of the existing and proposed public transportation linkages and infrastructure. This in theory would support a more diverse land use pattern and maximise the catalytic benefits of the Athlone power station and Philippi future priority projects (TDA, 2018:250).

Voortrekker Road Corridor integration zone

Figure 7-4 below illustrates the corridor that needs to be strengthened; it links Cape Town CBD to the city of Belville CBD. The illustration below identifies the direction of the corridor and thus the direction of mobility across Cape Town.

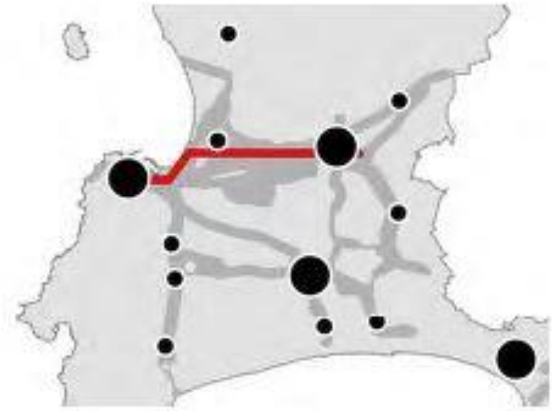

Figure 7-4 Voortrekker Road corridor

Source: TDA, 2018:244

The Voortrekker Road corridor IZ contains the key business districts of Bellville, Maitland, Parow, Goodwood and Salt River, as well as diverse regional health and tertiary educational infrastructure. This integrated zone is anchored to the CBD, which is the same as the Metro south-east IZ. In comparison to the Metro south-east IZ, the Voortrekker Road corridor IZ does not have the same socio-economic profile. The Voortrekker Road Corridor IZ has been affected negatively by urban decay and is in dire need of structured management approaches to support and generate investment, by re-investing in the development of the corridor. The opportunity has been identified in the land use of the area and transit investments and intensified development will benefit the various land uses. The purpose of increasing development is to serve the communities' residential and commercial needs. The availability of affordable rental stock and the increase in its supply are recognised and have been identified as some of the key levers towards integration and the renewal or redevelopment of the corridor (TDA, 2018:250).

Blue Downs integration zone

Blue Downs integration corridor consists of a double rail link, of around 9km between Nolungile station within Khayelitsha and the Kuils River station. This has expanded and incorporates three new stations, namely Mfuleni, Blue Downs and Wimbledon. This corridor is consisting of both road and rail transit.

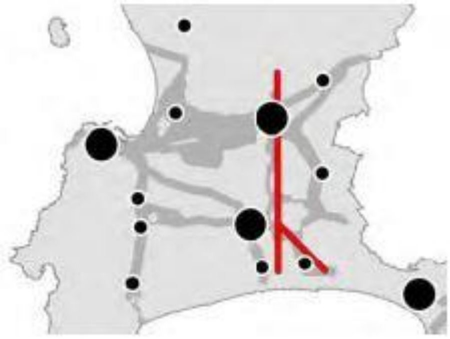

Figure 7-5 Blue Downs Road corridor

Source: TDA, 2018:248

The above figure illustrates the movement of the corridor, as well as the path it follows through Cape Town. This illustrates a North- South movement and is highly significant within Northern and Southern areas of Cape Town.

Main Road corridor

The Main Road corridor is significant, because of its multiple connections to the various sub-metropolitan roads. The connections link it to Claremont CBD, Wynberg CBD and the Tokai/Retreat nodes. The corridor is expected to extend to all the southern suburbs, thus creating an important southern corridor. This corridor will even extend further south than any other road and reach Simon’s Town, situated along the railway line.

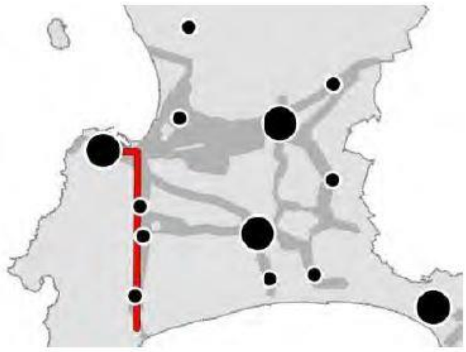

Figure 7-6 Main Road corridor

Source: TDA, 2018:245

The purpose of developing this corridor is both land use and transportation initiatives, which determine future possibilities of economic growth and connectivity through efficient land use. This will be determined by the linkages to land use areas; without the correct link to these areas, development will not be possible. The main road corridor signifies growth and creation of an activity corridor. The corridor operates as a mixed land use area. This incorporates a long stretch of mixed land use districts that encompass businesses/retail as well as a surrounding residential area. This is a pattern characterised by single-use zones, ideally located between single mixed land use activity nodes (industrial, CBD, agriculture), where east to west roads intersect the main road and rail system. The north-south corridor represents a fair activity corridor that provides multiple job opportunities and residential areas derived from the various land uses. When it comes to bulk contribution services and distribution, the northern portion is well accommodated and efficiently supplied. This provides multiple opportunities for high-density, mixed use development and efficiency. The southern portion of the corridor is still in the developing stages, but shares similar traits with the northern portion (TDA, 2018:245). The northern portion of Cape Town is supported by two main corridors, namely the main road and the M3 freeway.

The implementation plans of Cape Town are based on mobility and the diversity and distribution of land use. The existing transportation infrastructure consists of railway lines and numerous stations. The main road of Cape Town, as mentioned above, is the M3 freeway and there are other road-based public transportation systems, as discussed in this chapter.

The planned initiatives of transportation are based on a central section of corridors, which will be supported by the planned IPTN truck routes located between the various land uses and residential areas. The Metro south-east of the city (from Khayelitsha and Mitchells Plan) will attract developers of various land use properties, which will inevitably create job opportunities and growth. This will create an economic foundation that will help support Wynberg and

Claremont through mobility and distribution of services. There are also two IPTN planned west-east routes linking Westlake in the southern portion of the corridor to Bellville, in essence as a metropolitan employment node. The corridor will link Westlake/Retreat to the Strand and Gordon's Bay.

7.3 George Local Municipality

The city of George is located in the Western Cape province in South Africa. This city is a popular holiday destination, owing to its close proximity to the coastline. George is a rapidly growing city, like Cape Town in the Western Cape province. The case study of Cape Town has been referred to in the beginning of this chapter. George is a green city, where open space and green infrastructure play an important role in the development of the city. George shares similar traits with Howard's garden city design illustrated in Chapter 3 (Hurley, 2014; Clevenger & Andrews, 2017:5). The traits are significant, since it is the capital city of the Garden Route, which stretches 300 kilometres down the Western Cape coastline. The city is a commercial hub and a haven for wildlife as well as individuals.

7.3.1 Land use in George

George has a simple land use pattern based on a concentric circle design, such as Burgess's concentric ring model (Waugh, 2002:420). This model is referred to in Chapter 3. George displays a combined spatial structure design representing both Howard's and Burgess's spatial land use models. In this design the CBD is in the centre of the spatial structure. This layout would typically situate residences on the outside of the spatial structure, which typically starts with a lower-class residential area within the CBD/industrial area and radiates outwards. The further away from the city centre, the more land value increases, implying that only individuals who are able to afford the land could possibly live there. This means that middle- to higher-class residents would situate themselves further from the city centre. Figure 7-7 below illustrates the various land use elements spatially demarcated in George. Annexure G illustrates the spatial structure of George and its surrounding towns and cities (GAPP Architects & Urban Designers, 2018:8-10). The area of land use incorporates most common uses of towns and cities (residential, commercial, industrial, business), but places emphasis on preservation of the natural environment and heritage areas.

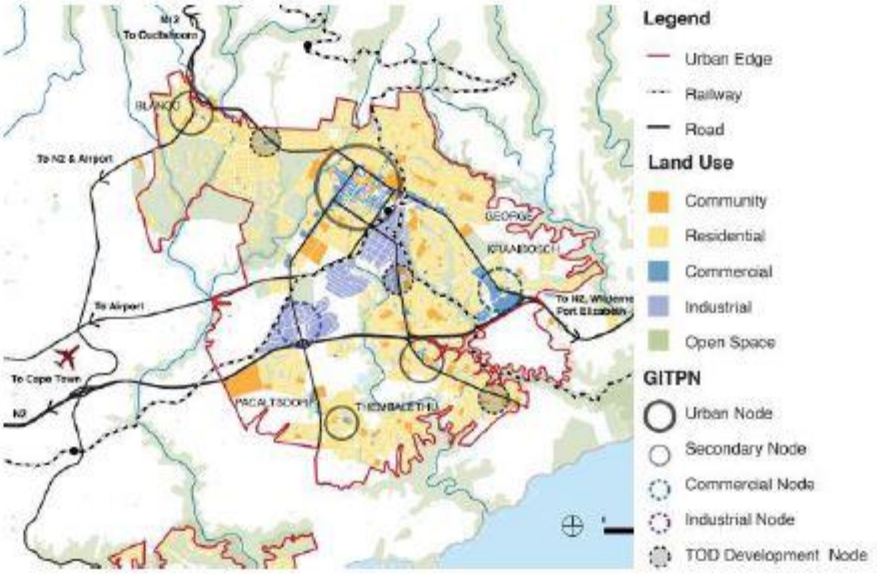

Figure 7-7 Land use development in George

Source: SDF, 2018:27

The land use has been determined by the linkage created in transportation, where communities are orientated around CBDs and radiate outwards. The above illustrated figure of George's land use layout shows the various nodes: primary, secondary, industrial, commercial, and lastly the transport-orientated development node. The design of the city is a clear spatial layout type of polycentric spatial structure (Bertaud, 2002:2-4). The first aspect that illustrates this design is the one major primary node, which is prominent in these polycentric spatial designs. The second aspect that is prominently displayed is its development, radiating outwards, illustrating growth and avoiding stagnation. The third most common trait in this city design is transportation, specifically transport-orientated developments, based on a polycentric spatial structure.

7.3.2 Spatial layout of transport infrastructure

The spatial layout of transportation infrastructure has been best illustrated throughout the SDF of George (2019), illustrating future extensions and growth towards the surrounding area. The SDF illustrates the future development initiatives and current proposed areas of growth. Figure 7-8 below illustrates the existing and future road extensions, as well as the city's development initiatives regarding residences and commercialised areas (GAPP Architects & Urban Designers, 2018:24-38).

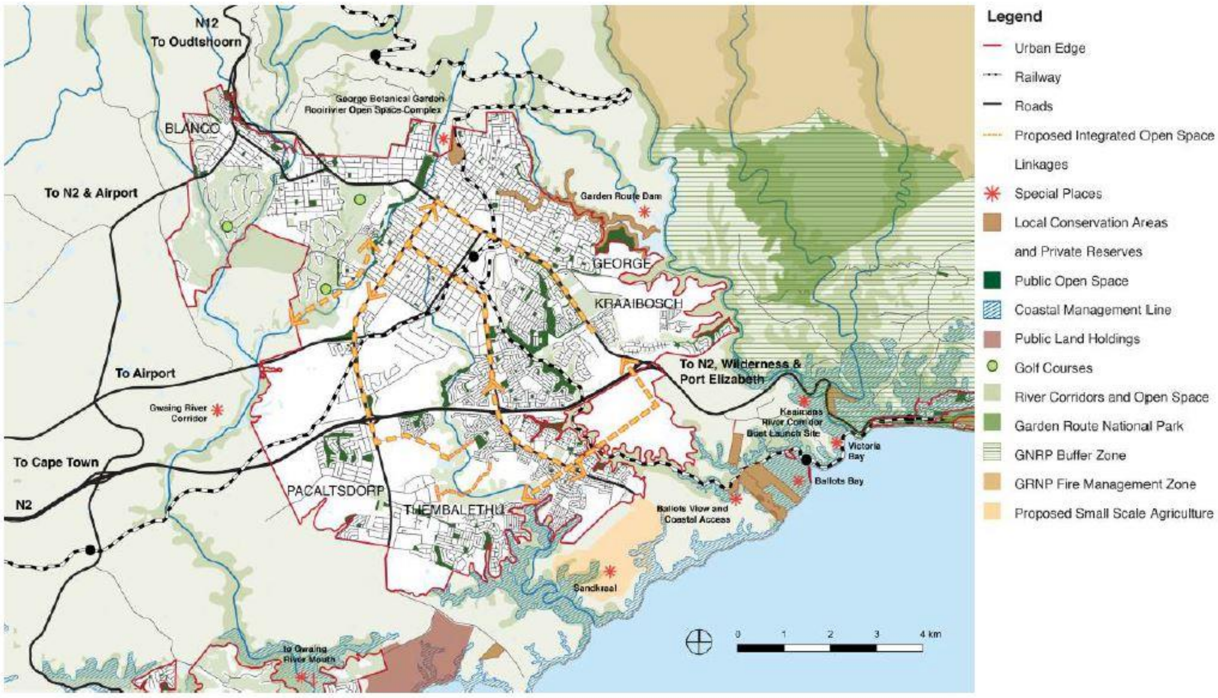

Figure 7-8 Spatial implementation of transport infrastructure including non-motorised transport

Source: GAPP Architects & Urban Designers, 2018:51

The above figure illustrates existing transportation infrastructure. This figure illustrates that there are numerous modes of transportation. The spatial implementation of these modes is crucial and is recognised within the SDF. This spatial structure illustrates two major arterial roads entering the spatial structure, while two principal arterial roads (N2 freeway and western by-pass) move through George. Where freeways and arterials meet, an activity node is created, owing to the concentration of traffic in a specific point. This often generates development. While observing the high-end mobility roads, it has become clear where the primary urban node is situated, in view of another particular transport mode (railway), which creates a point of interest. The railway radiates outwards from the primary urban node to the north, west and east. This railway line is in close proximity to all the nodes created in George, which illustrates that transportation correctly implemented in a spatial structure can create economic growth and increase efficiency (GAPP Architects & Urban Designers, 2018:36-37).

7.3.3 Public transportation

Public transportation has become vital for all cities, including George, owing to uncontrollable factors (population) that make mass mobility not only preferable, but crucial. The concept behind public transportation is to move large numbers of individuals to a specific point of interest in an affordable and efficient manner. This will be linked to other mobility options for individuals who cannot be dropped off at their point of focus, but can use pedestrian sidewalks and bicycles to cover the remaining distance. The figure below illustrates the spatial layout of transportation systems in George, focusing on a motorised and non-motorised approach. George has not implemented LRT, but has implemented a public transport project known as “Go George”, which uses buses and mini-buses for public transportation. This is ideal in view of the road infrastructure existing in that area that is used by three modes of transportation (SOVs, public transport and bicycles) (Djurhuus et al., 2015).

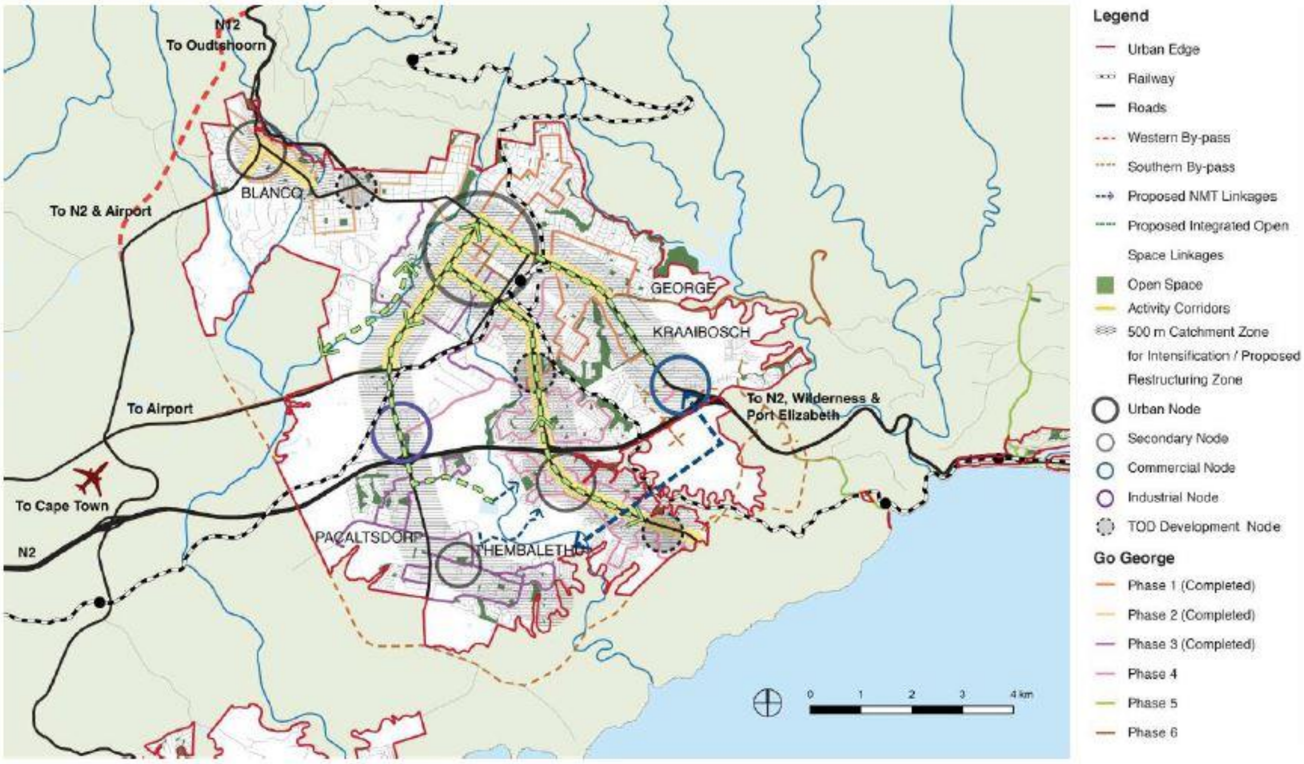

Figure 7-9 Implementation of future plans “Go George”

Source: GAPP Architects & Urban Designers, 2018:61

The above figure not only illustrates the existing transportation infrastructure, but also the implementation of a new public transport system, known as “Go George”. George currently has transport modes, but for future use has started considering non-motorised transport (NMT) as well as its division into phases of development. NMT will be implemented within the activity nodes as illustrated in the above figure. This will strengthen pedestrian walkways and ultimately improve the quality of streets. While the “Go George” public transportation system is still under way, it is important to consider aspects that communities can use before the system is fully operational (GAPP Architects & Urban Designers, 2018:38).

George uses mini-buses and buses for public transportation, which helps to improve NMT by providing efficient and affordable public transportation. The public transportation system is similar to Cape Town’s BRT units. Table 7-1 illustrates the various nodes and activity corridors being used or proposed for public transportation.

Table 7-1 Future transportation implementation between activity nodes

Public Transport/ Activity Corridors	Priority Nodes
George CBD – Pacaltsdorp on York Road/ Beach Road	George CBD
	Western/ Gwayang Industrial
	Pacaltsdorp CBD
George CBD – Thembalethu on Nelson Mandela Boulevard / Sandkraal Road	Nelson Mandela Boulevard / Conville / George Industrial Area intersection
	Thembalethu CBD
	Nelson Mandela Boulevard/ Sandkraal Road & 26th Avenue intersection
George CBD – Garden Route Mall on Courtenay Street / Knysna Road	Eastern Commercial
George CBD - Blanco CBD on George Road	Blanco CBD

Source: SDF, 2018:37

The above table illustrates an important aspect that should not be ignored: all roads and transport infrastructure move towards the CBD, which demonstrates potential economic growth in the centre of the city. This means that there is a common point of interest to which all transport leads.

7.3.4 Implementation plans

The implementation plans have been illustrated in the above proposed figures for roads. This has also been illustrated in the above table, which considers various aspects of public transportation in different nodes. Figure 7-10 illustrates the current distribution of transportation systems and the planning of various routes regarding public transport:

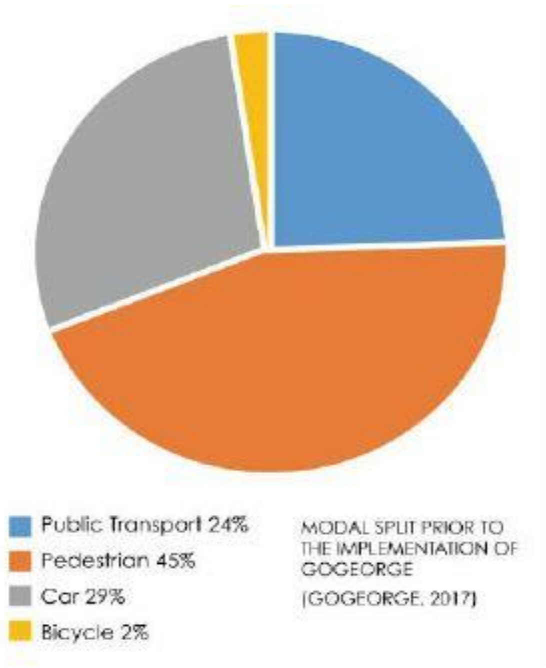

Figure 7-10 Implementation of future plans for transportation

Source: SDF, 2018:38

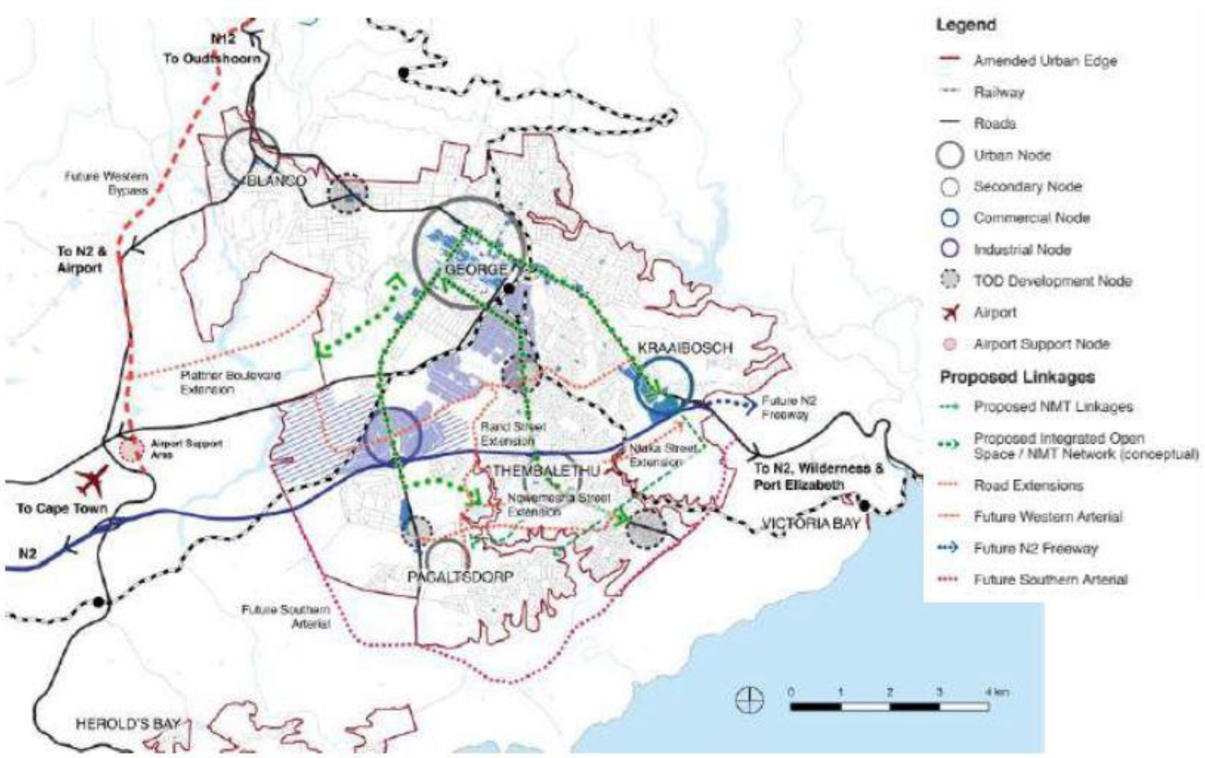

Figure 7-11 Implementation of future plans for roads and NMT linkages

Source: SDF, 2018:61

The figure displayed in the spatial layout of transport infrastructure also illustrates the proposed implementation of various arterial roads, which are classified as class 1, 2 or 3. These roads serve a specific function, which is to provide mobility in and around the city. There are various main road implementation proposals, namely:

- Future western arterial road
- Future southern arterial road
- N2 freeway road
- Class 3 arterial roads around CBD district.

7.4 Study area: Potchefstroom, South Africa

7.4.1 Spatial context

This section deals with the study area in which planning will be theoretically implemented in order to create more efficient spatial implementation of transportation networks. The area in which it will be implemented theoretically is the city of Potchefstroom, North West province in South Africa. The area is relatively small in comparison to George, but is developing quite fast, owing to the increasing activity at the North West university, new houses, increasing job opportunities, proximity to mines and very centralised position close to various provinces.

The study area chosen to undergo analysis and change is Potchefstroom. This city struggles with traffic because of the volume of vehicles occupying the road infrastructure. The spatial plan of Potchefstroom is represented in Annexure B.

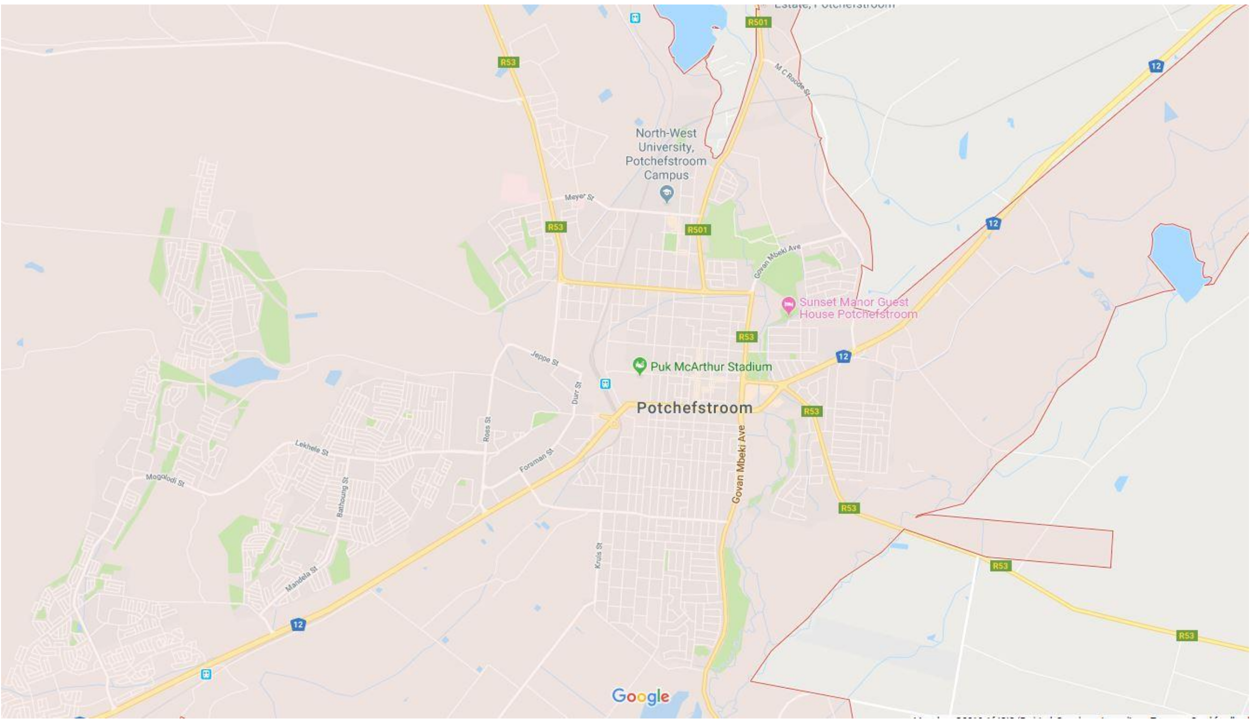

Figure 7-12 Spatial layout of Potchefstroom

Source: Google Maps, 2019

Potchefstroom is a small city located in the North West province and is regarded as a secondary city. This small city is ideal for the spatial implementation of sustainable transportation, in view of its compact spatial area and the distance from the CBD. The city is located in an inland section of South Africa and is surrounded by larger cities, namely Johannesburg, Pretoria, Klerksdorp and Rustenburg. These cities are all connected to the N12, excluding Rustenburg, but connect to various regional routes distributed across the country. This is one of the major highway routes in South Africa.

7.4.2 Analysis of Potchefstroom in terms of spatial structuring elements

The analysed spatial structural elements illustrated in the two developed countries and one developing country identify many mistakes in the spatial implementation of transportation systems in Potchefstroom. The structural elements have been represented in developed secondary cities in both Australia (Bertaud, 2002:2-4; Pacione, 2005:375) and Denmark (Tharan, 2004:2). It is interesting that the spatial development of these developed countries is identical and they even share similar policies of implementation (Pucher & Buehler, 2008:510-518; Adelaide City Council, 2012:38). Both developed countries indicate that the environment should be integrated within the spatial plan. A comparative table will help analyse the spatial structural elements in order to identify the efficient design of a sustainable city layout. This can then be applied in the implementation of sustainable transportation systems throughout the spatial structure of Potchefstroom.

The analyses of the two developed cities should provide a similar foundation in terms of spatial planning. The patterns of spatial layout may differ, but the placement of infrastructure is similar. The developments form spatial structural networks that diverge in each sector, allowing for functionality, increasing productivity, efficiency and inevitably a sustainable spatial structure. The spatial structural elements compared and analysed are the following (Pucher & Buehler, 2008:510-518; Adelaide City Council, 2012:36-63):

- Spatial pattern
- CBD
- Industrial zones
- Residential areas
- Environment
- Transportation system infrastructure
- Road infrastructure
- Rail infrastructure
- Bicycle infrastructure
- Pedestrian infrastructure
- Policies.

Table 7- 2 Comparative analysis of first world spatial structures to Potchefstroom

Comparative analysis of first world spatial structures and Potchefstroom			
Elements of implementation	**Adelaide, Australia**	**Odense, Denmark**	**Potchefstroom, South Africa**
Annexure	**Annexure A**	**Annexure C**	**Annexure B**
Country status	Developed	Developed	Developing
Layout design pattern	Grid pattern (Annexure A)	Radial pattern (Annexure C)	Irregular pattern (Annexure B)
Road infrastructure	Implemented Spatial integration within: 1. Between suburbs 2. Minimal allowance in residential areas 3. Implemented on the outskirts of the development 4. Integrated cycling lanes, tram light rail infrastructure, bus lanes and pedestrian crossings	Implemented Spatial integration within: 1. Between suburbs 2. Minimal allowance in residential areas 3. Implemented on the outskirts of the development 4. Integrated cycling lanes, tram light rail infrastructure, bus lanes and pedestrian crossings	Implemented Spatial integration within: 1. Residential areas 2. Business district 3. Recreational areas 4. Industrial areas 5. Environment 6. Vehicles allowed on every road Car-dominated city ❖ General use: 1. Vehicle movement to workplace and residential

	❖ General use: 1. Vehicle movement on the outskirts of suburbs. 2. Minimal vehicles allowed in residential areas. 3. No vehicles allowed in parks and recreational areas. 4. Narrow roads. 5. Available parking areas	❖ General use: 1. Movement between suburbs. 2. Movement on the outskirts of developments. 3. Vehicle restrictions in residential areas 4. Roads closed off for vehicles 5. Available parking areas	areas 2. Vehicle movement within and on outskirts of development. 3. Main form of transportation
Light rail infrastructure	Implemented (Adelaide City Council, 2012:26-27) Spatial integration within: 1. Business district 2. Environment ❖ General use: 1. Short-distance movement within the CBD area	Implemented (Nicolaisen et al., 2017:11-12) Spatial integration within: 1. Between cities/suburbs 2. Through residential area 3. Environment 4. Between CBDs ❖ General use:	Not implemented

		1. Long travel around the city	
Bicycle infrastructure	Implemented (Adelaide City Council, 2012:36-38) Spatial integration within: 1. Residential areas 2. Business district 3. Industrial areas 4. Recreational parks 5. Environment General use:	Implemented (Pucher & Buehler, 2008:510-518) Spatial integration within: 1. Residential areas 2. Business district 3. Industrial areas 4. Recreational parks 5. Environment General use:	Not implemented
Pedestrian infrastructure	Implemented (Adelaide City Council, 2012:30) General use:	Implemented (Pucher & Buehler, 2008:510-518 General use:	Implemented in sections of the city. General use:
Environment	Integrated within the residential and business district General use:	Integrated within the residential and business district General use:	Has not been integrated within the city
Lower class residential area	Implemented Lower-class residential areas are	Implemented Lower-class residential areas are	Unintentionally implemented Found on the outskirts of industrial

	rare and are considered to occupy small areas.	rare and are considered to occupy small areas.	and abandoned land. Not implemented after actual planning, but created through urban sprawl.
Middle-class residential area	Implemented	Implemented	Implemented
Higher-class residential area	Implemented	Implemented	Implemented
CBD	Implemented	Implemented	Implemented
Industrial area	Implemented	Implemented	Implemented
Social and cultural areas	Implemented	Implemented	Implemented
Recreational parks	Implemented	Implemented	Implemented Not safe

Source: Own creation: 2019

Table 7- 3 Comparative analysis of third world spatial structures and Potchefstroom

Comparative analysis of third world spatial structures to Potchefstroom				
Elements of implementation	**Karachi, Pakistan** **(Heraa, 2013:3-80; Masood et al., 2011:260)**	**Cape Town, South Africa**	**George, South Africa**	**Potchefstroom, South Africa**
Annexure	**Annexure E**	**Annexure F**	**Annexure G**	**Annexure B**
Country status	Developing	Developing	Developing	Developing
Layout design pattern	Irregular pattern, monocentric design (Alqhatani et al., 2014:118)	Radial pattern, polycentric design (Bertaud, 2002:3)	Centre city grid/Irregular, polycentric design (Bertaud, 2002:3)	Irregular/grid pattern, monocentric design (Alqhatani et al., 2014:118)
Road infrastructure	Implemented ➢ Road infrastructure is used throughout developments, but not all are paved. ➢ Used for bicycles, cars, motorbikes, walkability	Implemented The largest harbour for imports and exports, roads used in Cape Town: Cape Town has three class 1 roads namely: ➢ N1: moves directly	Implemented New proposed class 2 and 3 roads: ➢ Implemented between all land uses ➢ Widening of N2 freeway	Implemented Spatial integration within: 1. Residential areas 2. Business district 3. Recreational areas 4. Industrial areas 5. Environment 6. Vehicles allowed on

	➢ No segregation between transportation on roads ➢ Public bus transportation ➢ Used for the dominant transportation mode, motor-vehicle orientated	through the whole of South Africa and is the most frequently used freeway for mobility, which makes it highly significant. ➢ N7: moves northwards along the coastline. ➢ N2: moves north-east along the coastline ➢ Metropolitan and class 3 roads are used in Cape Town for efficient mobility between regions. ➢ There are numerous class 4 and 5 roads (residential,	➢ All roads lead to the CBD of George. ➢ Car-dominant, until implementation of public transport service (Go George) ➢ New public road infrastructure ➢ Implementation of NMT ❖ General use: 1. Vehicle movement to and from CBD area 2. Public transportation 3. Movement between regions or large areas.	every road Car-dominated city ❖ General use: 1. Vehicle movement to workplace and residential areas 2. Vehicle movement within and on outskirts of development. 3. Main form of transportation

		business, industrial and commercial land uses) ➢ Public transportation uses and similar initiatives regarding SOVs ➢ Future implementation plans for road infrastructure to strengthen corridors (chapter 7)		
Light rail infrastructure	Implemented, but inefficient. As illustrated (6.3.5.2), the rail system had been implemented: ➢ Due to advancements in	Implemented (Metrorail, Western Cape) As illustrated (7.1.3), there is a public transportation rail system known as Metrorail.	Not implemented	Not implemented

	road infrastructure, Individuals moved to road transportation, abandoning the rail network			
BRT	Implemented BRT have been implemented in Karachi (6.3.5.2.3): ➢ Considered to be the second most effective public transportation system ➢ 38% of the population use this mode of transportation ➢ The use of buses and mini-buses.	Implemented BRT systems have been implemented in Cape Town (7.1.3): ➢ MyCiTi bus service and various other services are used for public transportation and are highly effective. ➢ Future plans to expand the network to increase sustainability.	Implemented BRT systems have been implemented in George (7.2.3): ➢ The "Go George" project implements BRT services. ➢ There are six phases of implementation, of which three have been completed. ➢ Used for public transportation and is currently operational in	Not implemented

		➢ MyCiTi BRT	certain sectors, but on completion of all six phases, the whole of George will be operational.	
Bicycle infrastructure	Not Implemented	Not implemented	Not implemented	Not implemented
Pedestrian infrastructure	Implemented Refer to (6.3.5.2): Pedestrian implementation has been through sidewalks, but system is inefficient, owing to dominant road network infrastructure	Implemented Pedestrian infrastructure has been implemented (7.1), in road infrastructure, facilities such as walkways and waiting facilities for taxis/buses as well as trains.	Implemented Proposed for future implementation and sustainability by NMT planning (7.2.3).	Implemented in sections of the city. General use: ➢ Walkways ➢ Road crossings
Environment	Implemented	Implemented	Implemented	Has not been integrated within the city
Lower-class residential area	Implemented	Implemented	Implemented	Unintentionally implemented Found on the outskirts of industrial and abandoned land.

				Not implemented after actual planning, but created through urban sprawl.
Middle-class residential area	Implemented	Implemented	Implemented	Implemented
Higher-class residential area	Implemented	Implemented	Implemented	Implemented
CBD	Implemented	Implemented	Implemented	Implemented
Industrial area	Implemented	Implemented	Implemented	Implemented
Social and cultural areas	Implemented	Implemented	Implemented	Implemented
Recreational parks	Implemented	Implemented	Implemented	Implemented Not safe

Source: Own creation

Table 7-4 Analysis in terms of existing transportation system

	Transportation system infrastructure (SPATIALLY IMPLEMENTED)	Adelaide, Australia (Adelaide City Council, 2012:59-81)	Odense, Denmark (Pucher & Buehler, 2008:510-518; Adelaide City Council, 2012:38)	Karachi, Pakistan (Heraa, 2013:3-80; Masood et al., 2011:260)	Potchefstroom, South Africa (Allen, 2013:2-3)
1	Cars	Implemented	Implemented	Implemented	Implemented
2	Taxis	Implemented	Implemented	Implemented	Implemented
3	Buses	Implemented	Implemented	Implemented	X
4	Light rail	Implemented	Implemented		X
5	Pedestrian sidewalks	Implemented	Implemented	Implemented	Certain areas
6	Bicycle lanes	Implemented	Implemented	X	X
7	Car parking	Implemented	Implemented	Implemented	Implemented
8	Bus parking/stops	Implemented	Implemented	Implemented	X
9	Bicycle parking	Implemented	Implemented	Implemented	X
10	Taxi parking	Implemented	Implemented	Implemented	Implemented
11	Pedestrian facilities (bathrooms)	Implemented	Implemented	Implemented	Certain areas
12	Multi-modal transition parking	Implemented	Implemented	x	X

Source: Own creation

7.5 Conclusion

The above table illustrates that towns and cities in first world country are more efficient, because of their multimodal transportation systems that have been correctly implemented in the spatial structure. This illustrates that to transform the spatial structure into a sustainable urban system, South Africa should incorporate these principles instead of continuing the development of road infrastructure. This would sustain the environment, improve the quality of life, increase efficiency, create economic growth and ultimately create the city of tomorrow.

The above analysis indicates that there are numerous aspects of transportation that are significant if a city is to operate efficiently. These transportation systems use of efficient public transportation services, which are highly affordable and effective in use. The time travelled and cost of travel are viable to obtain the necessary goods and services. This has been proven by the four case studies of cities. Potchefstroom is the demarcated study area and is compared to other third world country towns, which include local towns/cities in South Africa. A comparison between these cities shows that not only does Potchefstroom lack various forms of public transport modes/sustainable transport (cycling) infrastructure, but that it does not have the same or a similar spatial structure. The other local third world cities and towns share one common characteristic of the spatial structure in Potchefstroom, since all are considered to have a compact design. This may not be the case with Karachi, Pakistan, but policy implementation and future development plans illustrate that Karachi has identified its spatial structure as a faulty design and is taking action to solve this problem. Potchefstroom cannot even be compared to first world country transportation systems in the urban structure. The reason for the above statement is that cities and towns in first world countries have implemented numerous public transportation systems (trams, LRT, BRT, mini-buses, taxis), as well as other modes of sustainable transportation (cycling, walkability) (Pacione, 2005:365-380; Adelaide City Council, 2012:43-66). Potchefstroom has not implemented any new transportation infrastructure regarding mobility and efficiency. This small city has only one public transport mode, which is not viable for everyone, is explicitly used for the lower-class residents (taxis) and is not safe.

In comparing Potchefstroom to the other case studies, it has become evident that it lacks the correct spatial structure and neglects public transportation for the entire community. The common thought pattern is that such a transport system cannot be achieved in a third world country. If this is true, then why was it possible to implement public transportation and sustainable transportation in both George and Cape Town, Western Cape? Cape Town was able to implement LRT (Metrorail) BRT (MyCiti) and mini-buses, and sustainable transportation was considered as well. The sustainable forms of transportation considered and implemented in Cape Town are cycling and pedestrian walkways. Cape Town’s spatial structure is of compact design, facilitating its success in the implementation of transportation systems.

The ideal implementation is not demonstrated by Cape Town, but by Adelaide and Odense, where it emanates from their emphasis on efficiency. Adelaide has followed very simple principles of implementation of transport in a spatial structure, as illustrated in chapter 5, resulting in perfect multimodal system functions in and around the city. Odense displayed similar traits, proving that these principles are effective in implementing transport in a spatial structure (Andrade et al., 2011:69; Adelaide City Council, 2012:64-66). This shows that the principles implemented are efficient and effective if used correctly. The same principles can be implemented in a third world country, as illustrated in Karachi, which has applied the same principles as the two first world countries that were discussed. Karachi has taken the same principles and applied them throughout the city, but these will take a significant time to become effective, because of faulty and incorrect planning from the beginning in the spatial structure (Heraa, 2013:16-18). This is why it is crucial to identify faults in implementation in Potchefstroom before the city encounters the same problems as Karachi.

CHAPTER 8 SYNTHESIS AND RECOMMENDATIONS

8.1 Synthesis

The research in this dissertation was based on the spatial implementation of local transportation systems, but illustrated more than merely spatial planning. The research illustrated that local transportation modes are highly significant when planned effectively within the system. The research document had to identify different urban models that had been implemented in past planning initiatives. Each of these models acquired certain character traits that were either strengths or weaknesses in the urban design. Through the analysis of 16 of these urban models, certain strengths were determined, as well as various weaknesses. The above research, identified specific spatial implementations, which would change the functioning of cities. Analysis of various urban models was done in Chapter 3 to interpret sustainable spatial structure.

The perspective of this explanatory synthesis is that cities and towns would need to adopt the principles of garden cities. The principles of the garden city do not always refer to its spatial design, as is evident in Adelaide and Odense (Hurley, 2014; Clevenger & Andrews, 2017:5), but the traits become highly significant in the process of ensuring sustainability. This garden city (refer to 3.3) spatial structure is designed in concentric rings, which are surrounded by a “green belt” of agricultural land. This perspective is to limit cities’ growth to avoid urban sprawl. This urban model is illustrated very clearly in Australian cities (Annexure A, D), among others (6.3.3.4) Adelaide. The city displays the principles of a garden city (3.3): the CBD is surrounded by a distorted circle of greenery, but urban growth extends past the boundary of natural greenery. The garden city has been implemented effectively in Canberra (not a case study), which is the capital of Australia. Canberra is the best illustration of what is known as the national triangle, consisting of the Parliament house, the seat of government and the defence headquarters at Russels, while Adelaide employs the principles of a garden city (greenbelt, sustainable transport, walkability, green spaces and concentric ring design). The garden city design used in Australian cities (Canberra) is known as the Walter Burley Griffins garden city design. Adelaide and Canberra illustrate an elite urban structure that dates back to one of the first urban models ever created. The garden city model is an elite urban structure model that promotes sustainability and efficient transportation. The synthesis illustrates that towns and cities should implement bicycle as well as pedestrian lanes with minimal vehicles. This would create effective mobility in a sustainable form. A discussion of Adelaide, Australia in Chapter 6 (6.3.3.4) pointed out that numerous strategies had been implemented to improve the sustainability of mobility. The object of sustainable implementation of transportation systems is to deal with global warming. This has been included in both Australia’s (Kyoto Protocol) and

Denmark’s policies (6.3.2). This identifies common ground where first world countries can work towards being more sustainable. Third world countries, specifically South Africa (6.3.6), have not incorporated this policy and have not compiled sustainable planning of urban structures either. South Africa uses motor vehicles as its most dominant mode of transportation and does not have sufficient public transportation. Minibus taxis have been incorporated into the transportation mode system, but are mainly used by lower income groups. In George and Cape Town, minibus transportation systems have not been allocated to a specific class and are affordable to all. Cape Town has its own BRT system known as (7.1.3) the MyCiTi bus service, as well as the GABS. Cape Town has an allocated rail system, which is used for public transportation. The main benefit in Cape Town is that it was able to implement multiple modes of transportation efficiently in the urban structure. The urban structure is often affected by transportation infrastructure, where activity nodes form between joining freeways and mobility roads or where a class 1/2 road passes through a common point of interest. This will build on an existing node or create an activity node. This is illustrated in all major cities, especially Cape Town, which has three class 1 roads (National roads - N1, N2, N7) entering and exiting the city, which allows for growth and economic benefits.

Adelaide in Australia has a slightly different approach, but has the same perspective on growth. Adelaide (6.3.3.4) has incorporated multiple transportation modes and works on a multimodal transportation system. Adelaide uses the same design as the garden city urban model (3.3) through its incorporation of the green belt and preservation of the environment. This also applies to the circular design of the concentric ring model (3.4): the CBD is situated in the centre, while a transitional zone and various classes of residential areas radiate outwards. The functioning of Adelaide is not due to its land uses, but to the cooperative and mobility network between them. Adelaide has various modes of transportation systems, ranging from cars, buses, trains and LRTs to bicycle and pedestrian infrastructure, with backup facilities. Transportation in Adelaide is versatile (bicycle racks on public buses - bicycle to bus), owing to its change in modes of transportation, which is efficient. The incorporation of numerous public transportation systems (BRT, LRT [trams], taxis, mini-buses) allows for a decrease in SOVs and is beneficial to the Kyoto Protocol policy implemented to decrease the ecological footprint. While Adelaide has implemented policies to help improve the urban structure and preserve the environment, it is noticeable that most first world countries are incorporating the same concept. Odense, Denmark (6.3.2.4) has also included the Kyoto Protocol (6.3.2) for the same reasons that have noticeably improved Adelaide. Odense has a famous LRT system, which was developed in various phases. The LRT seeks to join three cities in Denmark, namely Odense, Aarhus and Copenhagen, to increase economic growth. This public transportation system is to be used as long-distance public transportation, eliminating the use of motor vehicles. Another interesting transportation system implemented was bicycle infrastructure, much like Adelaide, Australia. Odense is known as the “cycling city”, where facilities are available to store bicycles and to shower, maintaining hygiene. This promotes a healthy lifestyle for the entire community and moves towards a more sustainable future. Odense has closed certain roads and streets to vehicles, but allows pedestrians and bicycles. Odense illustrates the urban model design of the concentric ring model (3.4), but because of the complexity of this design, it has used a modified concentric ring model (3.9), which accommodates transportation within the urban structure more effectively. The spatial organisation of Odense is based on a monocentric spatial structure (5.2.1), since it has a singular centre directly in the centre of the city. The network clearly illustrated is a typical centripetal network (5.3), with one main hub in the centre with numerous smaller hubs around it, generating wealth for the main hub. This network works effectively in terms of transportation, as illustrated by networks (5.3) and the design of Odense in Annexure C.

While focusing on third world cities addressed in the case studies, relatively simple faults were found in both the urban structure and the implementation of transportation. When examining Cape Town (7.1), it became clear that some cities have implemented more efficient transportation systems in their urban structures than others. Cape Town is a well-established city, which is known world-wide for its harbour for imports and exports around the world. Cape Town implemented more efficient transportation than Karachi (6.3.5.2), addressing public transportation differently by increasing its application (7.1.3) through a multimodal concept. Cape Town implemented numerous bus services (MyCiTi, GABS and minibus taxis), as well as an LRT known as the Metrorail. Karachi used to have a rail system, but it stagnated owing to lack of passengers. It has a bus service, which has proven to be less efficient than motor vehicles. This means that motor vehicles are used more often than public transportation, which in essence means that the public transportation system implemented is not efficient enough. Examining Annexure E reveals that Karachi lacks a significant factor that Cape Town has implemented. Cape Town (Annexure F) has a compact urban structure, which allows it to generate more economic growth, owing to the close proximity of activity nodes. This also refers to the spatial structure and land use in Cape Town (7.1.1) and Karachi (6.3.5.2.4); both cities are located on a peninsula along the coastline, with similar land use and layout. The implementation of the spatial structure is completely different; hence Cape Town is able to generate more economic growth. This is partially due to how transportation is implemented within the urban structure.

Potchefstroom (7.3) is the spatially demarcated area on which this research document has focused throughout all the above research and study of theories on achieving a sustainable city. Potchefstroom has grown rapidly in the past ten years. Development and land use have escalated in response to policies (SPLUMA: 6.3.6.1.4) and an increase in student residents. Potchefstroom is home to the North West University, which is regarded as one of the best educational institutions in the province. The university attracts numerous students, who have to consider issues of residence, lifestyle, safety, exercise and entertainment. Being separated from their parents (support structure) may influence these young adolescents' behaviour, which is highly important to consider and has been identified in the (3.13) Marchetti constant. This states that behaviour and psychological background have to be taken into account when planning the urban model and the transportation required. Marchetti (3.13) states that urban structures should be planned to accommodate all people in a city (far and near) and to move them from point A to point B in less than 30 minutes. This implies reasonable transportation systems to function in that time, because the time taken by an individual walking compared to a person using a motor vehicle would obviously be different. In view of this, Potchefstroom should focus on the urban fabrics model (3.12), which considers not just a transportation system, but rather the collaboration of walking, rail and (motor vehicle) automobiles. This is a model that works in cities and can serve to regenerate a city into becoming sustainable. Similar to the Marchetti constant, the urban fabrics model is illustrated in concentric rings, which determine the diameter distance for each mode of transport to be efficient. The Marchetti constant focuses on the exact distance in radius from the centre of the CBD. These two models correlate with the concentric ring model (3.4) and modified concentric ring model (3.9) in design, but not in concept. The design of the concentric ring model is based on land use, not on transportation modes, which is what is demonstrated in the Marchetti and urban fabrics model. This correlates with Potchefstroom's needs in terms of urban structure, land use and transportation.

One aspect that plays a significant role is policies, which are often overlooked and considered to be optional. This is vital for any urban structure and correlates with the ability to establish effective functionality. The influence and implementation of a policy are crucial and any policy should be clearly understood before implementation. Policies in first world countries tend to function more effectively because of their relevant goals. In Adelaide, strict policy implementation was crucial to avoid deterioration of the environment, which implies a more NMT (6.3.3.1) approach through sustainable transportation. Denmark approached policies from the same perspective as Australia, in which quality of life and preservation of the environment are highly significant. Denmark's policies illustrate the use of sustainable transportation methods, which is similar to what happens in Australia. Denmark has implemented the BYPAD bicycle policy (6.3.2.1), which is devoted to cyclists and corresponds to sustainable mobility. Australia implemented a policy on sustainable mobility, which resulted in the implementation of various (6.3.3) transportation modes. The point of relevance is that urban structures have a common interest in implementation and sustainability. This has been identified as best practice in developments, where the common interest of spatial structures has been implemented in a policy to obtain a certain perspective of spatial structures. This is known as international best practice (6.2), correlates with all developments and has the best interests of communities at heart. International best practice is dependent on four policies/guidelines for sustainable developments, which are discussed below (6.2):

The United Nations Human Settlement Programme was drafted to create a link to other international guidelines to achieve sustainable urban development. A universal framework would ultimately be developed to guide urban policy reforms, to improve urban and territorial dimensions of development agendas and link national, regional and local governments to achieve functionality in urban forms. This will implement worldwide principles and combine them to improve local experiences and adopt diverse planning approaches to create a sustainable and functional spatial structure. This is a development guideline seen in all first world countries, as illustrated in the above discussion of Denmark (6.3.2) and Australia (6.3.3), regarding preservation of the environment and use of NMT. This has not been implemented in third world countries, because of financial constraints and ineffective policy implementation, as illustrated in the case study (6.3.4; 6.3.5; 6.3.6).

SGDs are not regarded as spatial development goals per se, but the correct implementation of urban structures could help develop these goals and sustain them. SGDs are implemented to benefit the community occupying spatial structures. This focuses on improving the quality of life and the environment in which people live, which are identified in the two first world country case studies, illustrated in the above discussion (Denmark, Australia) on sustainable living. Preservation of natural resources is implemented in policies and transportation systems to decrease damage to the environment. In third world countries, particularly South Africa, implementation has not reached a point of sustainability; policies rather aim to suit the needs of the current circumstances. George and Cape Town (7.1.2; 7.1.3; 7.1) in the Western Cape have started to implement sustainable transport infrastructure in order to reach SGDs.

Certain challenges have to be dealt (5.7) with in order to accommodate sustainable cities, of which one is sustainable transportation. As discussed throughout this research document, transportation networks and flows (5.3; 5.4) are crucial for efficiency, productivity and accessibility. These components have been implemented especially in certain developments to ensure spatial sustainability. The layout that is relevant to the implementation of transportation systems is known as TOD (5.8), which specifically addresses layout. The research identified that all developed countries would implement and integrate the environment within the city (4.3). The planning of environmental space differs when situating an open space as an environmental haven after the planning of built-up areas. It is crucial to plan environmental areas, rather than implementing unused space as an environmental sector. The point of interest, illustrated in the spatial structure of developed countries, was identified as the effective distance of travel between the residential area and the business district. The second problem with the implementation of transportation modes relates to the lack of public transportation systems in South Africa. Public transportation has been recognised by developed countries as cheap and affordable, which addresses the requirements in terms of travel time and cost. Adelaide, Canberra (not a case study) and Odense illustrate this implementation in their own spatial design, while developing countries, for example Pakistan, are implementing the same principles (Masood et al., 2011:258-260). The above research found that effective policy creation satisfies simple criteria, which have not been applied in most policies in South Africa. This illustrates that starting on an unstable base for spatial planning would only lead to a continuation of the problem in the future. The spatial implementation of cities and towns in South Africa has not reached its maximum potential owing to the initial process of formulating policies. The process would often begin with a project plan and after the implementation of half the project, would be dismantled because of its problematic foundation. This would lead to significant waste of money and further future problems. The sustainability of a city is not based on its spatial design, but this plays a massive role in achieving self-sustainability.

8.1.1 Objective 1 - To evaluate the theoretical foundation of spatial planning tools and their impact on sustainable transport systems

Objective 1 was partially addressed when a firm foundation was created through the understanding of the various models implemented and the tools used to implement these models. Each urban model addressed had either adopted its own interpretation of transportation systems or was based on a previous model. Some urban models (garden city model (3.3), concentric ring model (3.4), modified concentric ring model (3.9)) apply a circular design in various sectors, while others are based on land use. A correlation is identified where the circular design of concentric circles has been developed for either certain transportation modes or for land use. Two models can be identified as a match or a suitable combination. The first is the urban fabrics model, which represents concentric rings as radial benchmarks for efficient transportation modes. The second, the concentric ring model (3.4), illustrates the various land use zones radiating from the core (CBD) to the higher-class residential areas on the fringe of the development. These two models could be considered “lock and key” developments in which sustainable development can be maintained by correcting and integrating a multimodal transportation system. Garden city principles can apply to this “lock and key” model to increase sustainability and potentially preserve the environment more effectively, since the garden city model has the same or a similar concentric ring design. This means that the principles may possibly work in the layout. The third model that can be incorporated in these models is the Marchetti constant (3.13), which illustrates the concentric ring design with the correct distance and mode of transportation needed to travel efficiently over a distance. This model stipulates a time period of 30 minutes or less for a large number of individuals to reach a common point of interest using any transportation mode. Some models (apartheid city model (3.14)) were not designed for efficiency or sustainability, but rather as a political tool to control the community or segregate areas.

The theoretical foundation of urban models has illustrated various problems in the spatial structure, as addressed in Chapter 4. Increasing population density (4.1) and environmental aspects (4.2) play a role in the sustainable implementation of transportation systems. Another important aspect discussed in Chapter 4 is the integration of various sectors and their functionality in relation to one another. This has been related to the interaction (4.3) of numerous sectors, including the economic, social, political and environmental fields, without deteriorating the environment. This is chiefly why transportation in the urban structure needs to be sustainable to avoid deterioration of future natural resources, living conditions and the urban structure.

Chapters 3 and 4 identified various tools used to create the foundation for sustainable transportation in the urban structure; some models were implemented for efficiency and productivity, while others where used as a tool for political segregation. Each model identified various tools to ensure sustainability, but could lack certain tools; where one model lacked a certain tool for implementation, another might provide a solution. The “lock and key” phrase illustrates the ability to incorporate two models; this unlocks a more sustainable urban model, as mentioned in the above objective.

8.1.2 Objective 2 - To evaluate the theoretical foundation of sustainable transport systems and international best practice

The second objective was to evaluate the theoretical foundation of sustainable transport systems and international best practice. This interprets the spatial structure and the spatial organisation implementation of different transportation systems. This conforms to two major spatial structures, namely monocentric and polycentric spatial structures, as discussed in chapter 5.2, which describes urban structures with one or more core or CBDs. This illustrates that within monocentric structures (one core), transportation would centralise to a single CBD area and over time go through a period of stagnation because of the growing city. Polycentric spatial structures (two or more cores) would implement multimodal systems to move between the numerous CBDs and would be least likely to stagnate. This is determined by the network and flows of each transportation system or multimodal system that has been implemented and should consider the surrounding community. The more effective the transportation network is implemented, the better the flow of mobility around the spatial structure, increasing accessibility to areas and productivity.

The components of transportation (5.5), referring to the available infrastructure and available systems, also play a role in how mobility is effectively distributed throughout the spatial structure. If there is only one dominant transportation system or limited infrastructure, the transportation system will become congested or some systems may be neglected and stagnate if they are not as efficient as other transportation systems in the area. Road infrastructure has become particularly dominant in all spatial structures, owing to the range of transportation systems it can accommodate: various motor vehicles, bicycles, public transport and even pedestrian pathways. This allows the transport infrastructure to become dominant, but mainly motor vehicles will be used if this is not implemented correctly. This illustrates numerous challenges (5.7), which depend on how the system is spatially implemented according to land use and whether it is policy-based. This can have an impact on the environment in various ways, among others by causing pollution and deterioration of natural resources. SOV-dominant roads imply that public transportation had not been implemented effectively. This forces individuals to move towards singular use of cars, causing congestion over the long term. This renders the spatial structure slow and inefficient, leading to deteriorating productivity and a chain reaction in economic growth. Chapter 5 (5.8) discusses a tool that could help sustain developments and help manage transportation systems, known as TOD, which includes a specific design (Wilkinson, 2006:224) that allows it to manage the spatial structure and its development. The TOD model is similar to the modified concentric ring model (Waugh, 2002;423), which illustrates that modern-day models are being created from past models.

International best practice involves the most sustainable policies and implementation methods used to deal with common problems in the spatial structure. International guidelines give direction on the final goals (eliminate poverty, provide shelter etc.) embodied in the MDGs, SDGs and United Nations Human Settlement Programme. The original objective of spatial structures needs to be addressed. This requires international analysis of first and third world countries. While addressing first world countries (6.3.1-6.3.3) (Adelaide, Australia and Odense, Denmark), it became clear that transportation had been implemented in multimodal systems. Both Denmark and Australia implemented public transportation systems as well as bicycle infrastructure. This was accompanied by various pedestrian walkways and infrastructure accommodating sustainable transportation. Both these first world countries implemented LRT and BRT systems effectively. However, third world countries are identified as inefficient, owing to deficiencies in their available transportation systems. The analysis of third world countries (Pakistan and South Africa) (6.3.5-6.3.6) indicates that transport in these countries is based on road infrastructure. Both countries lack sufficient public transportation and sustainable implementation of multimodal systems. They use bicycles and pedestrian walkways with little or no infrastructure, which causes conflict between transportation systems and is highly inefficient.

An interesting fact observed in these third world countries is that SOVs were the dominant mode of transportation. This caused congestion and in Karachi led to the deterioration of the railway system, due to little or no use. In first world countries, public transportation has not been neglected and a spatial foundation and infrastructure are planned to create the most effective mobility system possible.

8.1.3 Objective 3 - To provide solutions to improve the efficiency of local transportation modes in developing countries at local (precinct) level

In Chapters 7 and 8, possible solutions were identified, using identified methods of implementation. In referring to local case studies (7.1 and 7.2), it has become evident that even though transportation systems are inadequate, some systems have been implemented in South Africa relating to sustainable spatial structure. The discussion of the previous objective showed that third world countries use SOVs more often than public transportation systems. As illustrated in Chapter 7, Cape Town and George in the Western Cape have implemented different public transportation units in efforts to improve sustainability. While Cape Town implemented the Metrorail (LRT) and BRT, George had a similar objective with BRT units. This illustrates that not only can these systems be implemented in third world countries, but they can be considered a sustainable solution to preserving the spatial structure and possibly preserving it. This would include better functionality between sectors and more effective mobility to sustain the prospects of increasing economic growth.

Through this analysis, a proposed preliminary design in chapter 8 was presented to give an idea of the various transportation modes and how these could be implemented in the city of Potchefstroom. This illustrates the possibility of implementing a multimodal system and how it may function. Various recommendations were given on improving infrastructure or implementing infrastructure. The objective has not only been met, but has been illustrated as a working model (8.3), which is based on a geographical system and can be implemented theoretically and practically (8.3.1).

8.2 Recommendations

The recommendations relate to all forms of implementation to create a stable foundation throughout the spatial structure. The recommendations will follow a specific criterion, as illustrated below:

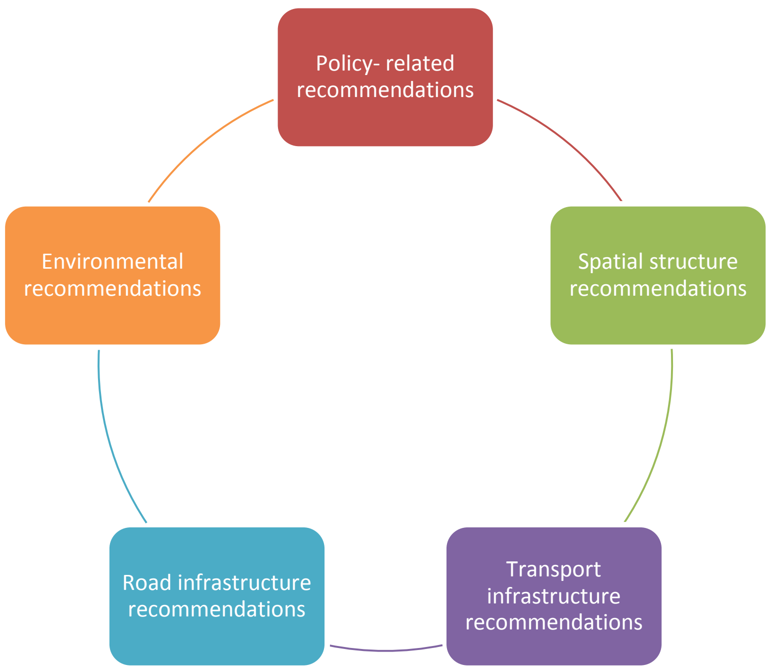

Figure 8-1 Recommendations for Potchefstroom

Source: Own creation

8.2.1 Policy recommendations

Policy recommendations on the sustainability of Potchefstroom and many other cities with a similar spatial layout and issues associated with lack of local multi-modal transportation systems are made according to certain criteria. Policies have been compiled despite lack of knowledge displayed by political groups. This leads to policy failure before the policy has even been implemented, which causes more problems during the implementation process. Criteria for a successful policy implementation have been compiled by The Public Policy Web (2001):

- The policy should be clear, simple and theoretically implementable.
- Leadership, which is both skilled and experienced, should be committed to the policy.
- The operational goals must be clear and feasible to allow for general understanding in all groups.
- The period of time for the policy, as well as the budget, should be adhered to and carefully analysed in order to achieve the goals of the policy. Funds should be set aside for process evaluation.

Policies should all be implemented with the intention of improving the community in the long term. If short-term policies are implemented, validation of improving a specific sector needs to be identified. The focus is on improving public facilities and economic growth to maintain or conserve the environment.

8.2.2 Recommendations on spatial structure

The spatial structure of a city cannot be rebuilt or redeveloped, but it can be used to create various points of interest and help accommodate the population. The city's spatial structure determines the efficiency of an area. The problem with the concept of expanding the city is generally misunderstood, which leads to generating development on the periphery of the city and radiating outwards. The problem with this is that the further residential settlements are from the CBD, the more transportation infrastructure is needed and the more travel time and cost increase. This becomes a problem, because environmental areas become built-up settlements, which decreases natural resources, destroys fauna and flora and may even cause the extinction of species.

Recommendations on the spatial structure have been derived from highly successful and sustainable cities. These cities have become efficient and functional by generating self-sustaining wealth through development. The first and most important requirement is to create compact cities. This helps with the flow of goods and services, while generating high productivity in the workforce, since individuals are able to move from residential areas to work efficiently. Correcting Potchefstroom's spatial structure should be achieved by redeveloping buildings for other land uses. This will open up areas within the city for future development, while implementing effective and efficient transportation systems. One of the main problems with the spatial structure of cities is that it is extremely difficult to redevelop, while limiting other components (transportation), as has been seen in Johannesburg, as well as George and Cape Town. In Potchefstroom, it would therefore be important to:

- Focus on planned environmental conservation areas;
- Create shorter distances between residential areas and the business district. Pathways should be segregated for non-motorised transportation;
- Implement public transportation systems (BRT, LRT, mini-buses);
- Implement circles, which allow better traffic flow for automobiles;
- Create job opportunities through the development of various transport infrastructures; and
- Encourage the use of public transportation through affordability and efficiency.

8.2.3 Transportation infrastructure recommendations

8.2.3.1 Pedestrian infrastructure

The implementation of pedestrian infrastructure should be regarded as of high importance, since it is the only way in which pedestrians are able to be mobile in the spatial plan. Potchefstroom does have pedestrian sidewalks, but these are regarded as insufficient because they are limited to residential areas and smaller areas in the CBD. Because implementation is insufficient, the following is recommended:

- ❖ Increase walkways throughout the city, including parks, CBD areas, residential areas and workplaces.
- ❖ Improve accessibility for pedestrians.
- ❖ Increase safety through railing and other restrictions to vehicle access.
- ❖ Improve cooperation of cyclists and pedestrians in certain areas to share transportation infrastructure.
- ❖ Implement crossing lanes and signage to illustrate where pedestrians are, while indicating where they going.
- ❖ Improve safety for pedestrians through lighting. This will involve the installation of street lights.

Potchefstroom would be able to implement these minor spatial changes to create sustainable pedestrian infrastructure. The areas of implementation should be predominantly residential areas, CBD areas and areas functioning with minimal or little external help. An example of an area functioning with minimal or no help is known as “Die Bult”, which accommodates the local students in close proximity to the university (North West University, Potchefstroom Campus), which has been illustrated in Annexure B. The implementation of pedestrian lanes should include lighting to facilitate various times of travel and to increase safety and visibility, especially in recreational parks. Maintenance of pedestrian infrastructure has been lacking in Potchefstroom and should be monitored, in view of the deterioration of infrastructure. Pedestrians should enjoy easy access to CBD areas and other squares of activity. The infrastructure should include street furniture and vegetation in order to decrease stress, while enhancing a peaceful atmosphere.

8.2.3.2 Bicycle infrastructure

Cycling is the most sustainable form of transport illustrated in all case studies and has shown significant results through increasing efficiency in local transportation systems. This mode of transportation is recognised internationally for its benefits and efficiency in the correct spatial structure implementation. Adelaide in Australia and Odense in Denmark have successfully implemented this sustainable transportation system. The following recommendations are made, based on its simplicity and its relevance to the city if implemented correctly:

- ❖ The very first requirement is to implement cycling lanes in the residential areas and CBD. Further implementation can take place later, after the spatial infrastructure has been placed.

- Once the above point has been implemented, cycling lanes should be constructed in the spatial network around the city, with links to each sector.
- Accessibility for cyclists should be ensured among city blocks and residential areas.
- Cycling lanes should be implemented in every street on the spatial structure.
- Facilities for bicycles should be provided, for example crossing lanes and intersections.
- Cycling hubs should be incorporated into the spatial plan, which would provide various facilities and bicycle parking, as well as small shops.
- Training courses should be offered for cyclists in various age groups.
- Shower and bathroom facilities for cyclists should be provided, to encourage the use of bicycle facilities.
- Secure bicycle parking facilities should be erected closer to the CBD than vehicle parking.
- Connecting bicycle lanes between residential areas and industrial areas are required, since it is an affordable type of transportation system for middle- and lower-class residents.
- Lighting should be installed along cycling lanes to indicate where cyclists could be, as well as making them visible.
- Security cameras have to be installed within a 500 m radius to reduce crime.
- Implementation of various forms of signage for cyclists' direction and awareness for vehicles is necessary.
- Bicycle parking facilities should be provided at other modes of transportation, to allow a change in mobility.
- Vehicles' speed should be reduced through traffic calming and by planting trees alongside the road, which is a natural barrier to reduce traffic speed and increase aesthetics.

The use of bicycles in Potchefstroom would make a significant difference and help create sustainability. This type of transportation infrastructure is inexpensive compared to LRT, bus transit and car transit, besides being more efficient than walking. The reason for the significance of cycling lanes is the number of cyclists on vehicle and pedestrian infrastructure, which indicates that there is a need for this spatial implementation. Moreover, vehicles have become a dominant transportation system and owing to increased use of SOVs, there is insufficient infrastructure, causing congestion and inefficiency. Odense in Denmark, which is considered one of the most liveable cities in the world, has a similar population to Potchefstroom and has implemented cycling lanes. Adelaide is larger than Potchefstroom, but does not have the same population density, yet the CBD is significantly smaller and Adelaide has become the second most liveable city in the world. The point illustrated in the above case studies is that the implementation of bicycle lanes will make the city more sustainable.

8.2.3.3 Light rail infrastructure

The implementation of LRT systems would help increase efficiency in the CBD of Potchefstroom. The implementation of a type of LRT would include tram transportation systems and would be implemented between the residential areas and the CBD. This would optimise the time and cost of travel to work, while causing no transportation congestion issues. The LRT system would be efficient if implemented over a short distance. The spatial structure would have to accommodate a series of transportation systems to use the tram at various drop-off/pick-up points (stations), which would have accommodation for parking of other transport modes. Trams and other LRT systems have been incorporated in developed countries, as well as in cities regarded as sustainable. Adelaide in Australia has adopted the concept of LRT, which is only implemented in the CBD, allowing for movement across the business district. This has been proven to be efficient both financially and in terms of travel time. Odense in Denmark has adopted the concept of LRT and continues to grow successfully. The difference between Odense and Adelaide is the spatial planning of the light rail network; while Odense focused on long-distance travel, Adelaide focused on close-proximity travel. This illustrates that whether LRT is incorporated for long or short distances, it will create a positive flow of transportation. Potchefstroom has not considered the implementation of an LRT system for passengers, but continues to maintain road infrastructure. One of the main problems with the LRT system to be implemented is lack of funding. The implementation of the LRT system is essential for maximum efficiency. It would involve the following steps:

- Establish the areas of implementation and create a spatial development framework to allow for a preview of how the LRT will be implemented.
- Expand the network across the CBD, but consider future expansion.
- Create opportunities at the LRT stations to use other transport modes, such as bicycles.
- Improve the integration of public transport systems (bus-LRT; bicycle-LRT)
- Create tram priorities.
- Create stations at various points to increase access to the LRT system.
- Establish waiting facilities in these stations.
- Create signage to allow a correct sense of direction towards the access points of the LRT system.

The above points are listed to form a spatial foundation for the LRT to function efficiently and if implemented correctly, would allow further implementations. The city would grow and transportation systems would be continuously maintained, matching ongoing spatial growth. This would allow for underground implementation of LRT systems to create a compact city.

8.2.3.4 Public bus infrastructure

Public bus facilities have been implemented in many countries, even South Africa, but the correct spatial implementation will determine how sustainable it will be. Potchefstroom has not implemented short-distance bus transportation systems, which have been implemented in two other cities in South Africa, illustrating that the concept may be known, but has not been implemented. The bus transportation system implemented in Cape Town, the BRT, did not prove effective when implemented in Johannesburg. The BRT system has proven to be successful in Cape Town, because of its spatial design and structure. Cape Town, though a large South African city, was able to achieve this because of its compact spatial layout. Developed countries have implemented public bus transportation in each of their cities. Odense and Adelaide have both successfully implemented bus transportation systems. The following implementation procedures are advised to implement this transportation system spatially:

- The creation of a viable policy for public bus transportation systems
- A significant spatial plan according to which bus transportation systems should be implemented
- The implementation of facilities (shaded benches for waiting) at various points of access
- The spatial planning of parking (cars, bicycles and motorcycles) for various other modes of transportation
- Signage to indicate direction of bus stations, which would create awareness
- After the above has been successfully implemented, consideration of underground public bus infrastructure
- Maintenance and extension of the spatial plans when possible to reach different areas of the city.

8.2.4 Road infrastructure and spatial components

The road infrastructure of Potchefstroom lacks the maintenance required to sustain the increased demand in vehicles, which would generally lead to congestion on the various intersections in the city. Various intersections experience high volumes of traffic during early mornings (7:30-9:00) and late afternoons (16:00-18:00), which may cause a decrease in productivity. The relevant intersections are in Chief Albert Luthuli Street, Walter Sisulu Lane and Govan Mbeki Avenue, as well as Meyer Street. The applicable roads are used as main routes to individuals' work areas. The number of students entering the university and individuals driving to and from their workplaces causes congestion. The recommendation is to implement circles in an attempt to cause free-flowing traffic instead of using of stop streets. This would alleviate traffic congestion and has been used in larger cities as an affordable solution to traffic congestion. The use of circles is internationally recognised and implemented in sustainable cities. The recommendation also suggests more free-flow traffic rather than robots and other traffic stop signs.

8.2.5 Environmental considerations

The layout of Potchefstroom is based on a spatial structure that has no regard for the planning of environmental areas, as shown in Annexure B. Potchefstroom has been based on a built infrastructure plan, according to which the areas left unoccupied after development would be considered environmentally based areas. This reflects the lack of regard for environmental conservation and integration in this small city. The disregard for the environment has caused a significant decrease in the aesthetics of the city, as well as decreasing the general sense of place. The objective is to increase the comfort of the residents, which should increase productivity. Happy individuals are more likely to have a better work ethic than unhappy ones. The environment has been considered one of the main aspects to be taken into account in developed cities, where attempts are made to conserve and protect natural areas. This is illustrated in Annexures A, C and D, which emphasise the importance of the environment. These also show how the environment could be used as a barrier in transportation systems and considered a tool in spatial planning. The difference in environmental integration is immense in comparison to Annexure B (Potchefstroom), which displays lack of awareness of the natural environment. The following points were derived from the comparative analysis of cities and it is concluded that these should be implemented in Potchefstroom:

- Purposeful implementation of environmental areas
- Implementation of environmental barriers between transportation systems
- Establishment of greenery along sidewalks
- Implementation of recreational parks with bicycle and pedestrian infrastructure.

8.3 Preliminary design of transportation infrastructure for Potchefstroom

When creating a preliminary design for Potchefstroom, various aspects should be considered. Preliminary designs are created by civil engineers to indicate a direction of implementation as well as a general perspective on the costs of the proposed infrastructure. The design has been created mainly to determine if local transportation systems can be implemented in the urban spatial structure and whether they could function effectively. The preliminary design considers certain criteria related to where the activity nodes, activity corridors, residential areas, business districts and other land use zones are situated. The criteria are as follows:

Figure 8-2 Summary of recommendations

Source: Own creation

The scope of this preliminary design is to implement multiple modes of transportation systems sustainably throughout the spatial structure of Potchefstroom. The preliminary design takes cognisance of the newly enabled SPLUMA legislation, as well as other current legislation and infrastructure. The preliminary design calculates the relevant transportation infrastructure and considers the existing transport systems. For the draft spatial layout of transportation modes throughout Potchefstroom, refer to Annexure H.

The preliminary model illustrated in Annexure H illustrates potentially sustainable implementation of transportation in the spatial structure of Potchefstroom. This has been developed by quantum geographical information system (GIS), which imposes the inputs of precise placement of cadastre data as well as the implementation of created vector data. The draft model gives broad understanding of the existing transportation system and its activity nodes. The data created for this model refer to the following:

1. LRT
2. BRT
3. Bicycle lanes
4. Facilities (bus stops)
5. Activity nodes

6. Arterial roads
7. Secondary roads.

This is to illustrate the idea of implementation under correction and create a transport master plan. Transportation should be regarded as a long-term issue. With the continual development of roads, future development will deteriorate. Deterioration of infrastructure, the environment, quality of life, safety initiatives, efficiency and productivity will occur in a chain effect on economic growth. Figure 8-3 below illustrates the process of planning the various transportation modes in the spatial structure of Potchefstroom.

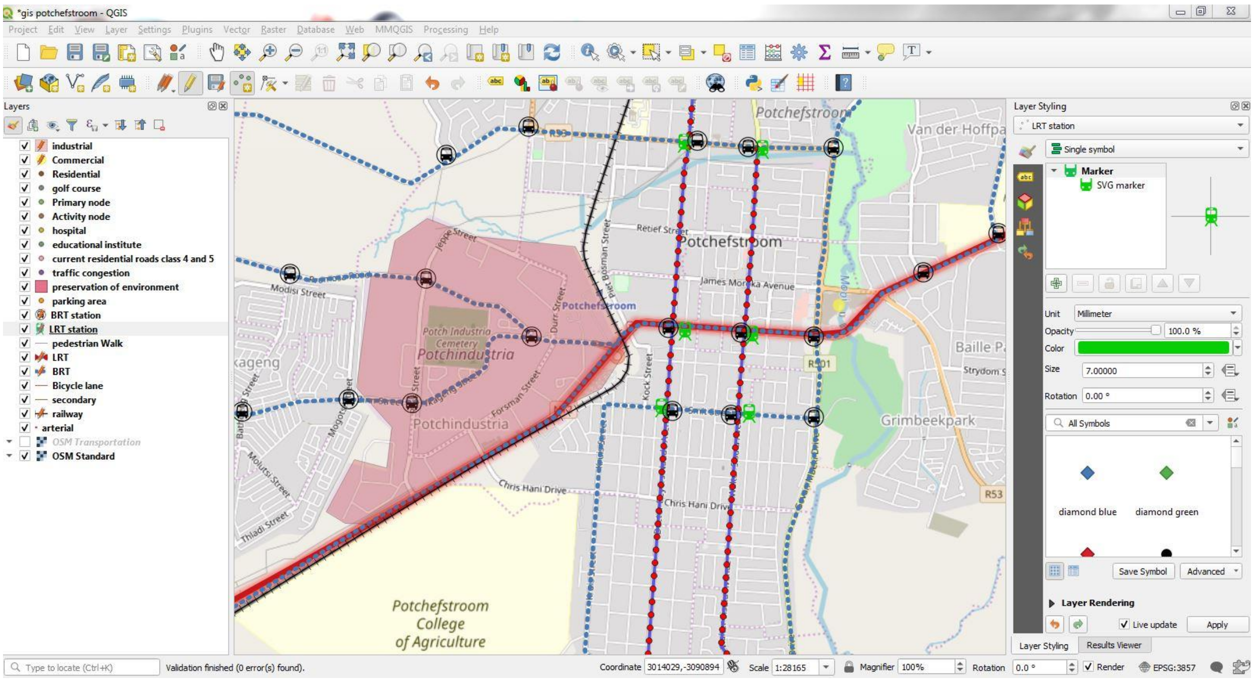

Figure 8-3 Quantum GIS program for draft implementation of transportation modes

Source: Own creation

The preliminary design will illustrate the use of bicycle and pedestrian lanes in residential areas, identified in Adelaide, Australia. Vehicles will be limited to residential areas, illustrated in the above road classification. Light rail will be used in the central city for short-distance movement. This will help individuals move from one area to the next in the city. BRT will be used for longer-distance travels between residential areas and the business district; bus stops could be erected at various points. The arterial roads will illustrate where traffic is entering the city in large volumes, as well as where possible nodes can be created. This model is flexible and can be altered and programmed for future transport planning initiatives.

While looking at Potchefstroom's EMF and Strategic Environmental Management Plan, the matters discussed below were identified relating to the future development prospects/initiatives of the city (NWDACERD, 2010:44-50):

8.3.1 Spatial development patterns and planning

- The integration of intermodal transport facilities
- Strengthening activity nodes around the N12
- Linking the CBD through the most efficient corridor of development and business nodes in close proximity to the N12.
- Opportunity for infill in the CBD and to the north of the developed area.

The model that has been proposed identifies all points of development and strengthens activity nodes, but also considers the idea of implementing public transportation. This addresses the local community in the area of Potchefstroom and identifies future development initiatives for this city. This encourages awareness of future prospects for sustainable developments and addresses the Marchetti constant (3.13) principle of allowing 30 minutes or less for a large number of individuals to reach a certain area. The proposed implementation of public transportation not only decreases travel time, but also the efficiency of travel between goods and services addressed in Christaller's model of hexagons (not mentioned in this research document). The second model it addresses is the urban fabrics model (3.12), which complies to three main urban fabrics components (walking city, transit city, automobile city) and has been implemented in the proposed transport modes. While Potchefstroom had implemented walkways and taxis, the concept of efficiency was lacking, because of the distance that had to be travelled from the residential area to the commercial/business or industrial area. Taxis, as mentioned in the above analysis of Potchefstroom, support lower income groups and areas and the service is highly inconsistent, because of the lack of facilities and stops. This type of mobility is also affected by traffic congestion and is often the cause of such congestion, due to random stops on roads to pick up passengers. Walking had previously been implemented in the urban fabrics model, but was inefficiently implemented in the urban structure. The reason for making that statement is the analysis and layout of Potchefstroom (Annexure B), illustrating that residential areas are concentrated in areas distant from the CBD. This leaves individuals with the option between automobiles (if affordable), bicycles (no bicycle infrastructure) and walking (highly inefficient), which does not support productivity or efficiency. The proposed transportation implementation correlates to principles applied in Odense, Denmark and Adelaide, Australia, where the tram (LRT) is used for short-range travel, increasing walkability,

8.3.2 Implementation of public transportation

The illustration of Potchefstroom below is a model designed on a quantum GIS, where using an exact coordinate referencing system can illustrate the exact location of each transport implementation.

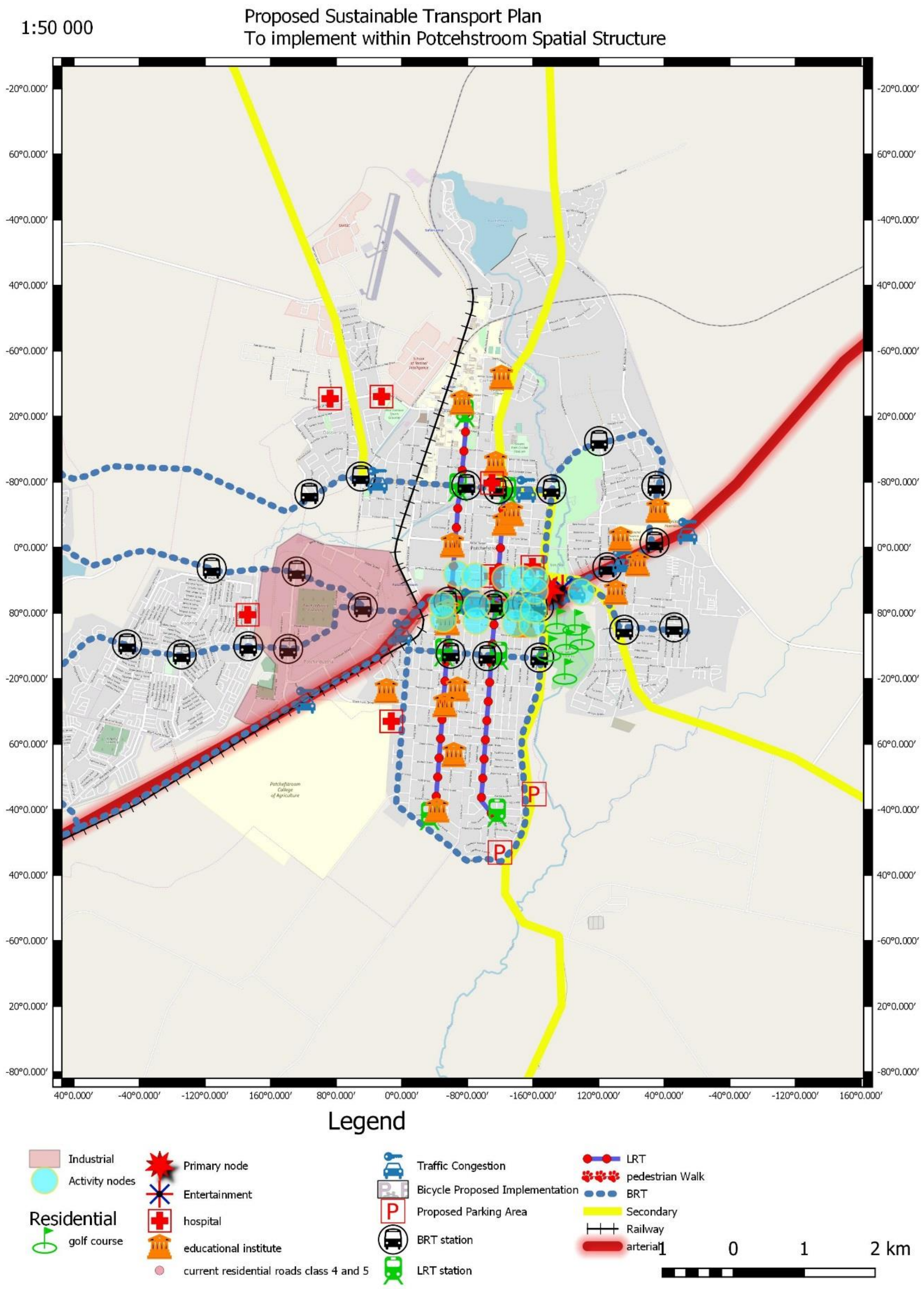

Figure 8-4 Proposed LRT and BRT in Potchefstroom

Source: Own creation

The above map represents the existing transportation structures with proposed LRT modes and BRT. This also illustrates the main arterials roads, which correspond with the placement of activity nodes. The idea behind the implementation of BRT and LRT modes was to impose that this theoretical document, based on theories (chapter 3) and past case studies (chapter 6 and 7), which identifies a practical spatial implementation initiatives and past faults. Consideration of implementing public transportation includes its effectiveness and accessibility. Most transportation systems mentioned would stagnate in an automobile-dominant city, because of increased congestion and numerous problems discussed (chapter 4) in this research document.

This preliminary design imitates the theory applied in Adelaides (6.3.3.4.3) and Odense (6.3.2.4.3) and the implementation of their transportation systems and seeks to identify possible opportunities in Potchefstroom, to move a step forward in the development of sustainable cities.

8.3.3 Implementation of pedestrian and cycling infrastructure

The figures below illustrate a working model of the implementation of pedestrian and cycling infrastructure in Potchefstroom. The model illustrates that cycling and pedestrian infrastructure should be implemented in residential areas, while considering access to commercial and business areas. This model illustrates all urban fabrics components discussed in chapter 3, and it considers the Marchetti constant stipulating 30 minutes of travel time or less. The model identifies various BRT and LRT stations, which are in walkable/cycling range, allowing for multimodal transport systems. The implementation of pedestrian and cycling infrastructure is proposed to help avoid complications between two different modes of mobility.

Pedestrians and cyclists are able to move between various modes of transportation systems using various options, based on the distance of travel and the costs applicable. This model simulates a first world country perspective and indicates how multi-modal transportation is implemented. This has been addressed (6.3.1; 6.3.2; 6.3.3) in the previous chapters and has been included as a recommendation in Chapter 8. This is due to the understanding that implementation of a system in a first world country can be imported into a third world country (South Africa). This has been identified in previous case studies (7.1; 7.2) of Cape Town and George in the Western cape. The preliminary design has been based on various aspects of first world countries, as addressed in Adelaide and Odense (6.3.3.4.2; 6.3.2.4) in Chapter 6. This helped to identify particular problems and lack of implementation illustrated in the comparison table (7.4), which reflected the state of implementation in Potchefstroom.

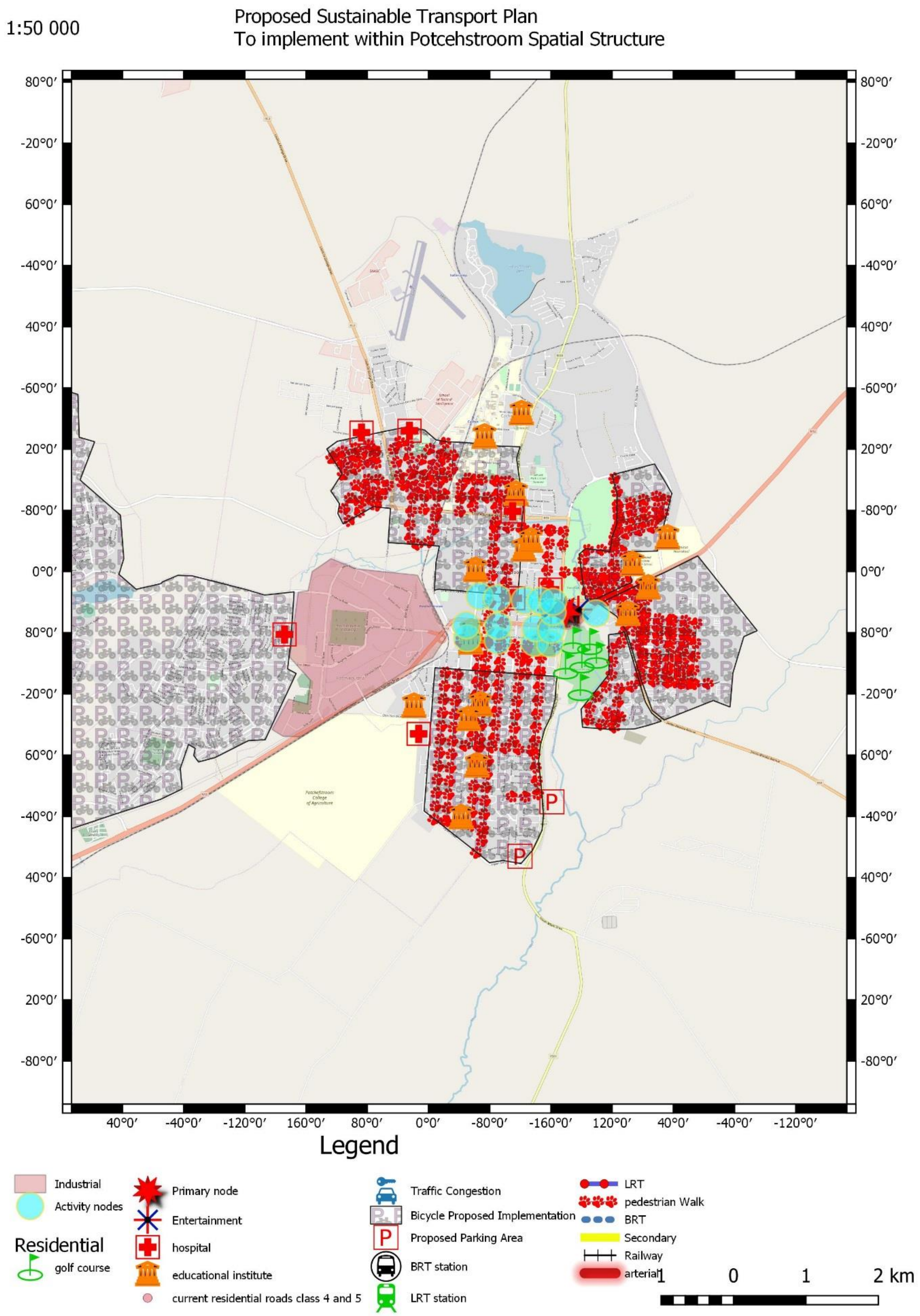

Figure 8-5 Proposed cycling and pedestrian infrastructure in Potchefstroom

Source: Own creation

The above quantum GIS illustrates the practical implementation of cycling and pedestrian routes. In Annexure H, multimodal cooperation is demonstrated at the various BRT and LRT stations identified. All the pedestrian and cycling infrastructure illustrated above identifies the distance covered as not exceeding 6 km. This makes it easy to travel by bicycle and it is even possible to walk that distance.

8.4 Conclusion

The fact that spatial planning has been adapted in various towns and cities to accommodate the surrounding communities illustrates that the urban form can change. The type of implementation is significant to future sustainability. The ideology of developed countries is different from that of developing countries, but both seek the end result of sustainability. Potchefstroom has not established any type of public transportation and suffers from congestion and lack of facilities. The research identified that the above factors alone could not create a sustainable spatial plan, but integration and correct policy implementation could. This document addresses the most significant aspects of sustainable transportation systems and formulates a preliminary design for implementing this multimodal system in Potchefstroom.

To conclude the above research and illustrate the spatial implementation of transportation systems in the city of Potchefstroom, the comparative research illustrated in this dissertation indicates that the implementation of the above recommendations is in fact possible. While addressing all three objectives throughout the document, it can be concluded that this is not only theoretically based, but can possibly be a practical solution that can be implemented for long-term sustainability. The development of a variety of transportation infrastructure would help redevelop the city of Potchefstroom into a more sustainable city. The problems that have been identified in the spatial design of Potchefstroom are that it is an irregular design and have been focused on redeveloping the apartheid city. The focus of the design has been incorrectly visualised, since the correction of a previous design is highly expensive and requires full redevelopment of the city. This would be catastrophic, considering the years required for the implementation to function and generate a livelihood for the community. This would entail numerous individuals losing their jobs and create a highly inefficient system.

The implementation of the various local transportation systems and infrastructure would change the urban form, while creating jobs through the development of various infrastructures as well as job opportunities when these are fully functional. This would result in a change from the apartheid model, while improving the economy. Other factors are of some significance, for example the environment. Focus on the spatial structure of transportation systems in Potchefstroom would indirectly improve the environment, economic growth, the spatial structure of the city, efficiency, productivity, dynamics, traffic calming, decrease in car use and an increase in the use of sustainable transportation systems. The research illustrates that the developed countries discussed, Denmark and Australia, experience great efficiency through the use of public transportation, bicycles, pedestrians and cars. This arises from the policies these developed countries have implemented.

8.5 Limitations of research

This research study was confined to a certain criterion, which implied limitations. The following limitations where experienced in this research dissertation:

- Data for case studies are not always comparable, which limits the case studies evaluated in this study.
- Data availability in South Africa is limited and only metro’s focus on TOD.
- Pollution not taken into consideration from utilising public transport (diesel buses/ electric transport modes) in a developing country like South Africa.

This concludes the research document, which reported research and offered recommendations on providing a more sustainable platform for the implementation of local transportation systems in Potchefstroom in order to create a sustainable city.

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ANNEXURE A (ADELAIDE)

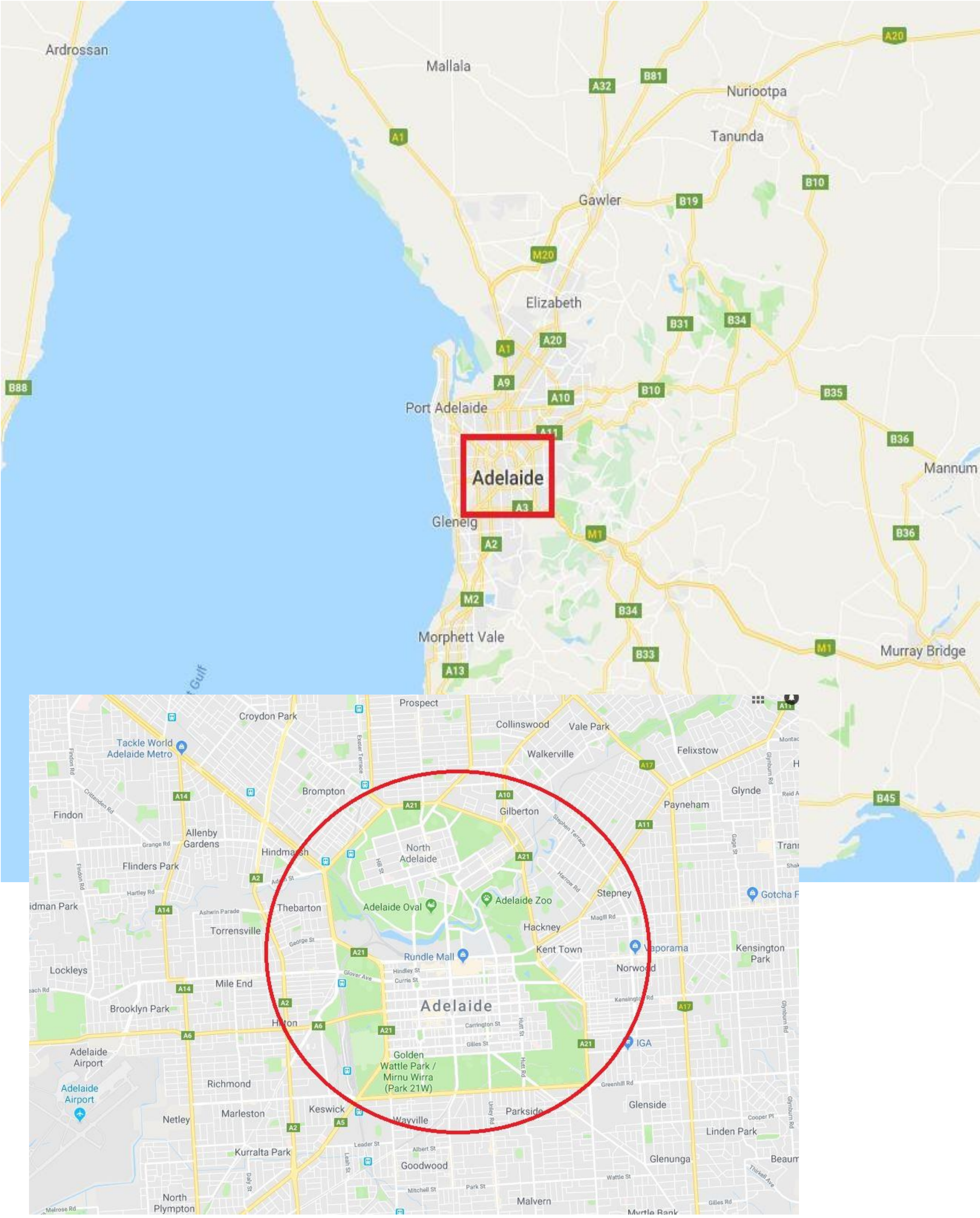


Figure: Adelaide CBD

Source: (Google Maps, 2019)

ANNEXURE B (POTCHEFSTROOM)

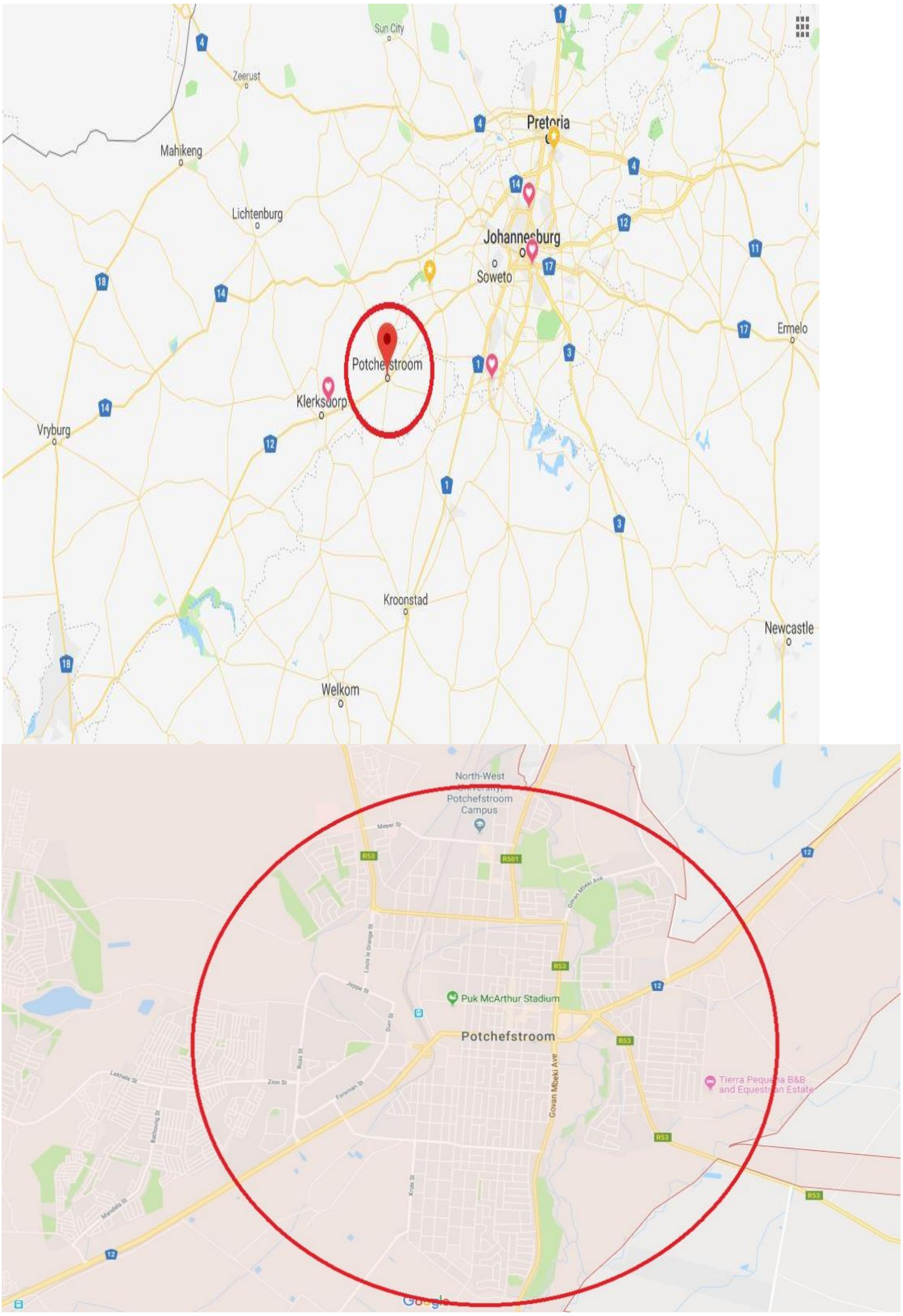


Figure: Potchefstroom

Source: (Google Maps, 2019)

ANNEXURE C (ODENSE)

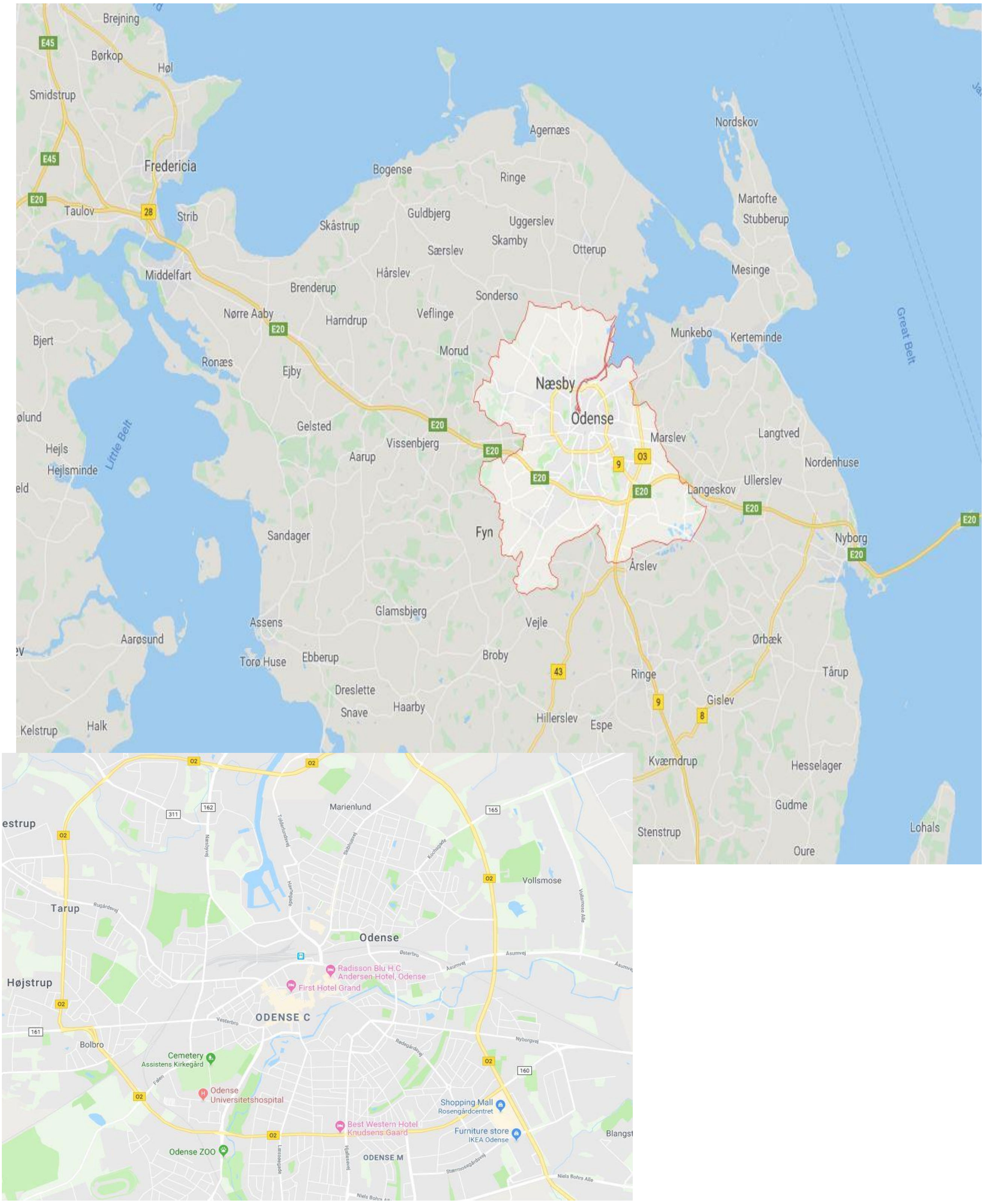


Figure: Odense, Denmark

Source: (Google Maps, 2019)

ANNEXURE D (CANBERRA)

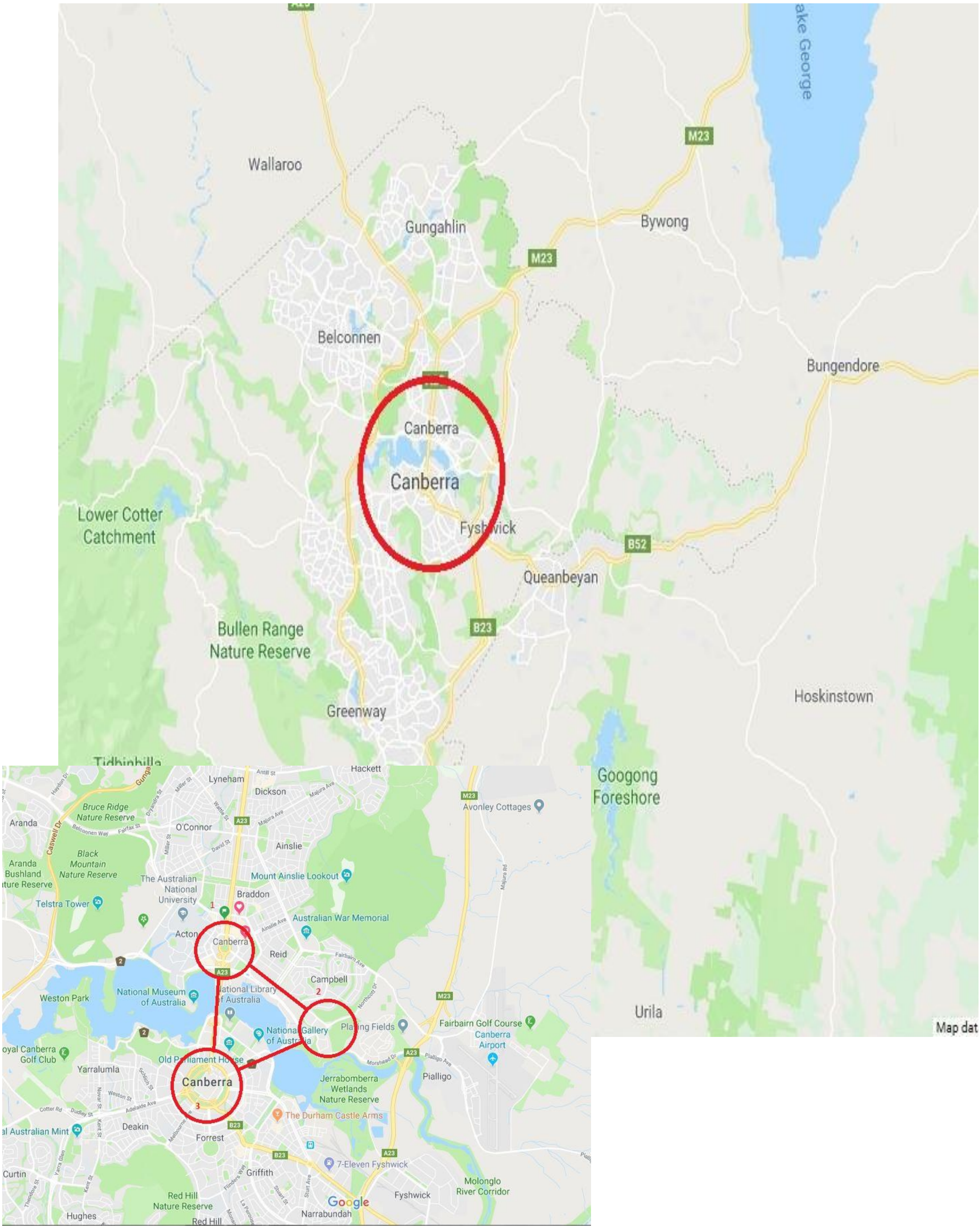


Figure: Canberra, Australia

Source: (Google Maps, 2019)

ANNEXURE E (KARACHI)

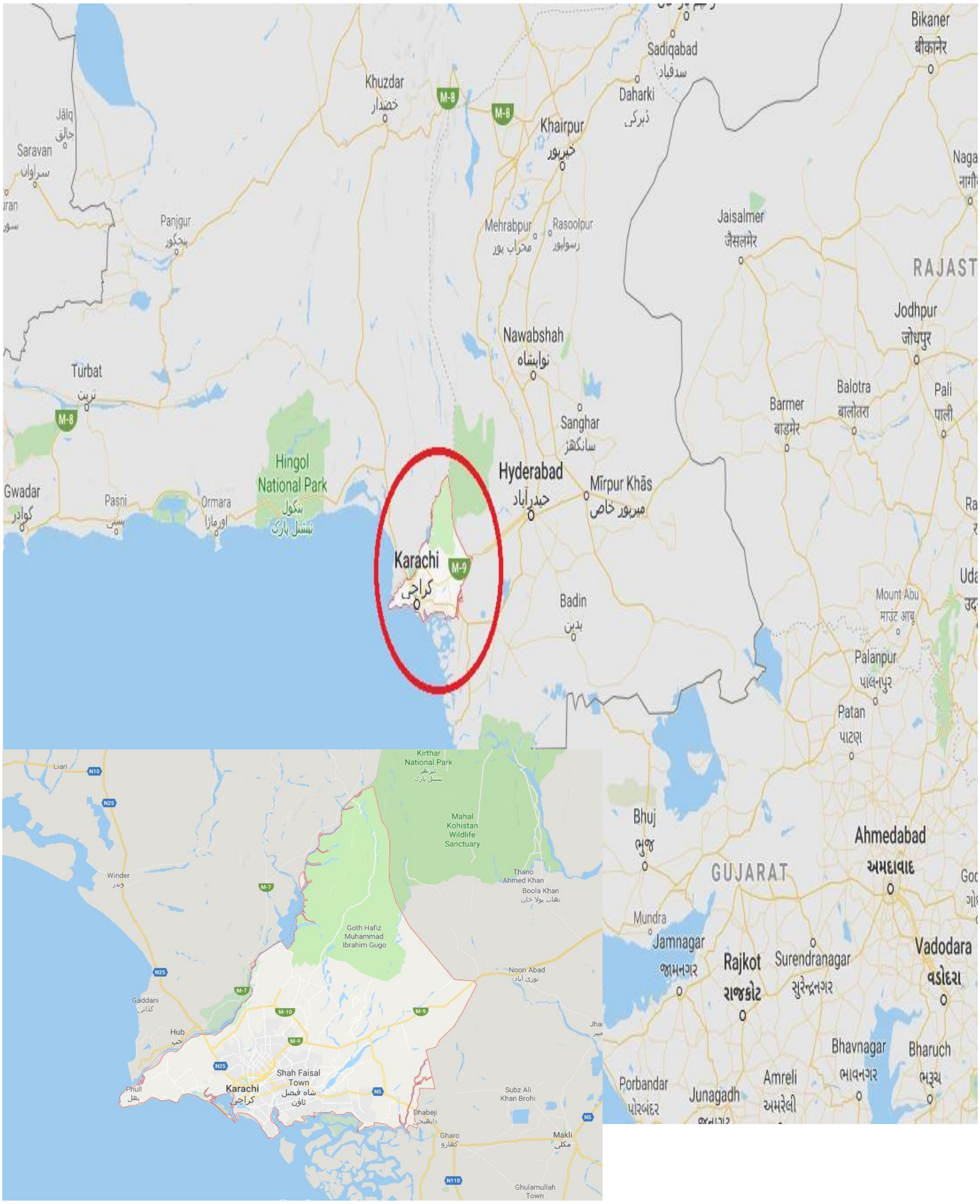


Figure: Karachi, Pakistan

Source: (Google Maps, 2019)

ANNEXURE F (CAPE TOWN)

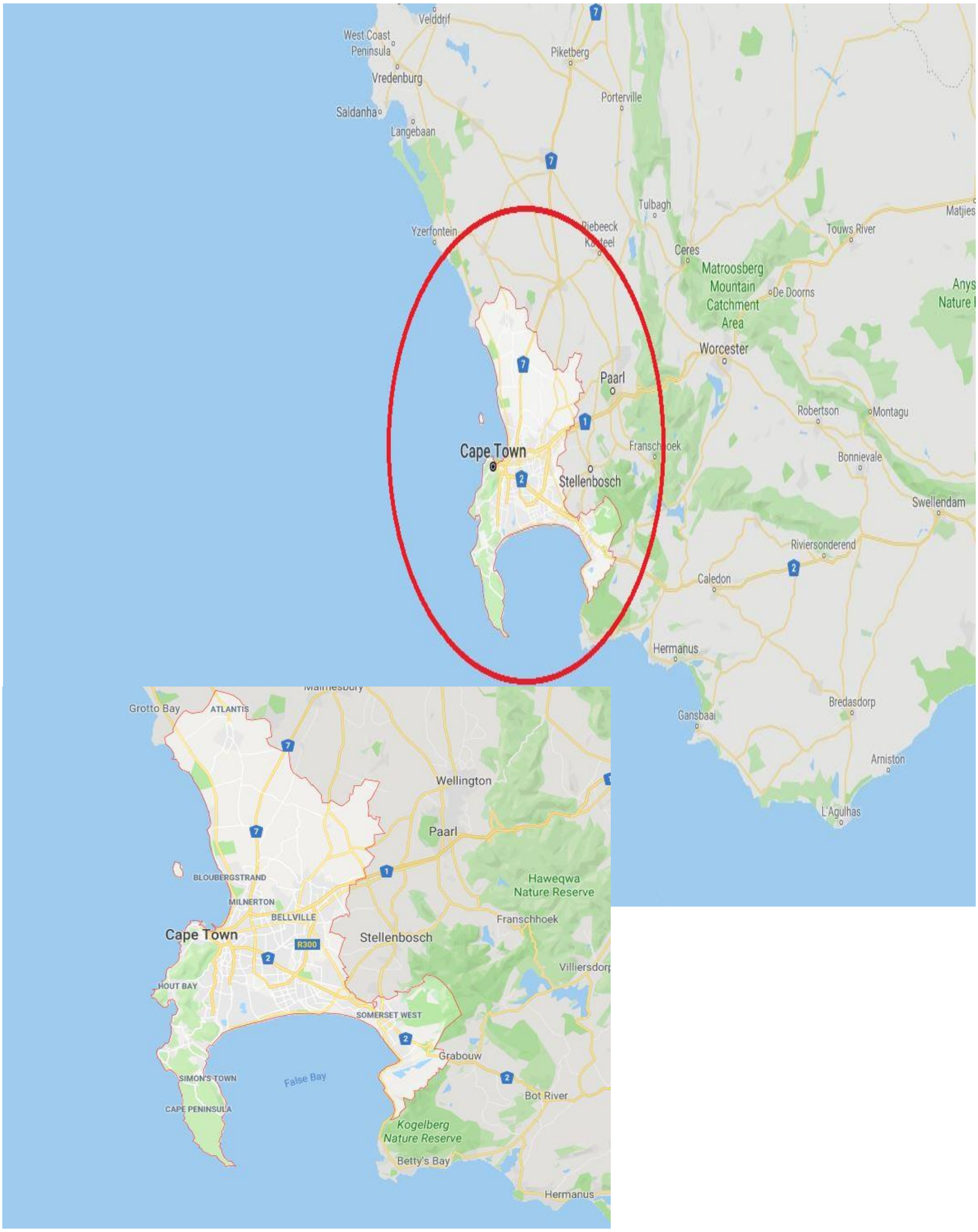


Figure: Cape Town

Source: (Google, 2019)

ANNEXURE G (GEORGE)

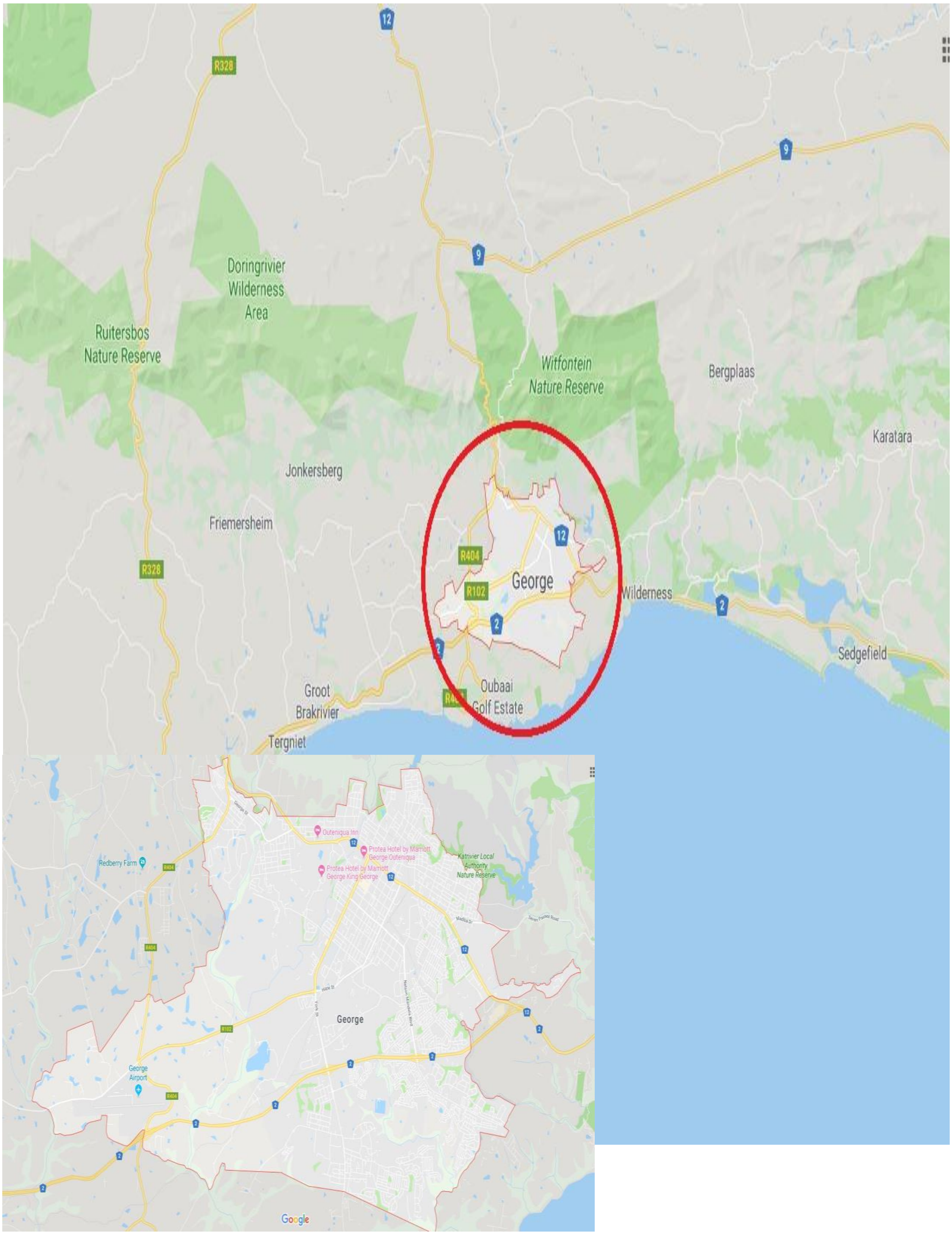
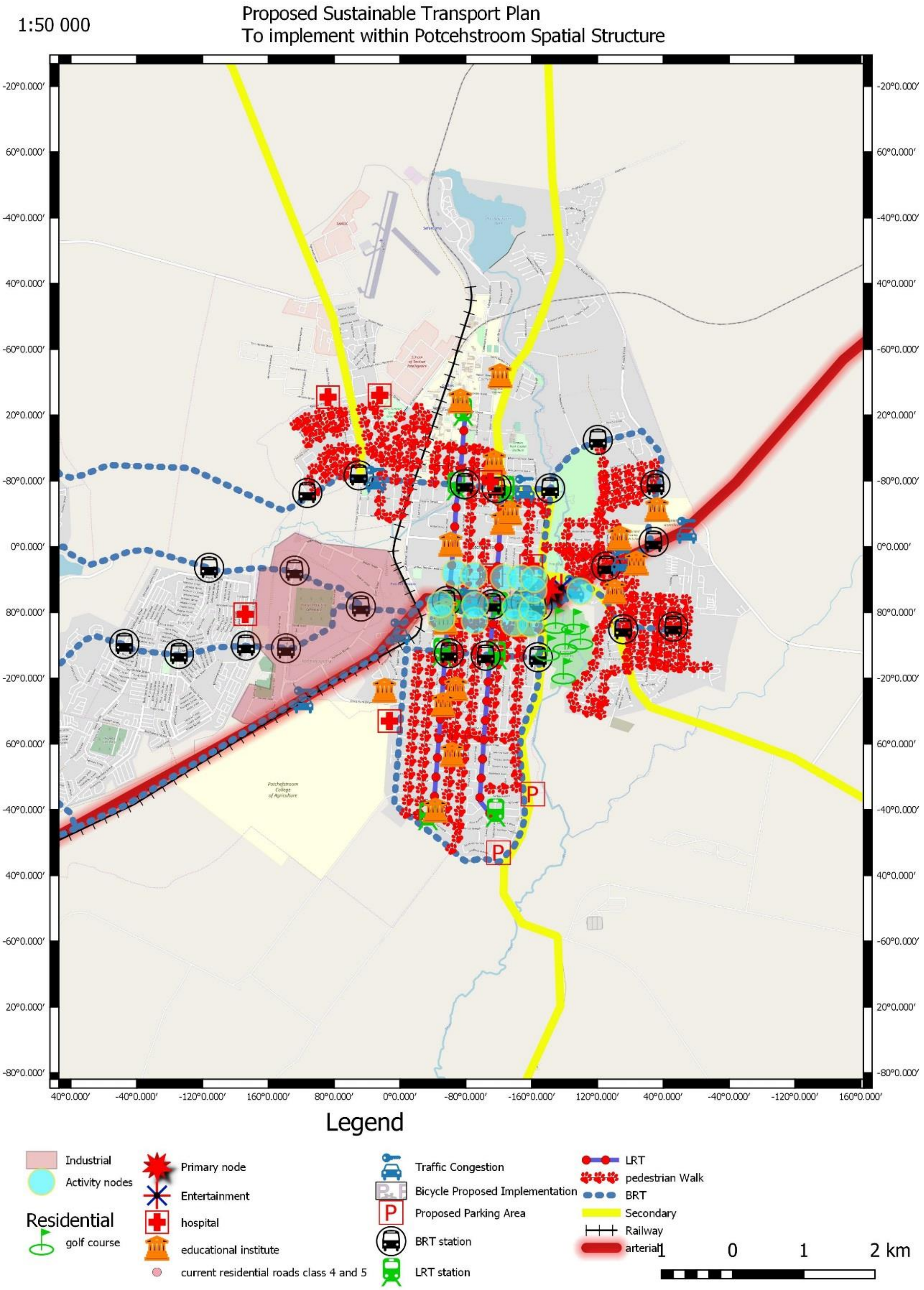


Figure: George, South Africa

Source: (Google Maps, 2019)

ANNEXURE H (PRELIMINARY DESIGN OF TRANSPORTATION NETWORKS IN POTCHEFSTROOM)



Source: Own creation