A more efficient spatial planning approach towards transport networks determined by the urban structure

RR Cullinan

orcid.org 0000-0003-2170-5504

Thesis accepted in fulfilment of the requirements for the degree *Doctor of Philosophy in Science with Urban and Regional Planning* at the North-West University

Promotor: Prof JE Drewes

Co-promotor: Prof M van Aswegen

Graduation: July 2025

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 Prof. 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, and just for 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 seeing the positive side while motivating me in terms of sport. Arguments between us are few and far between; one sure thing 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 transportation systems have been restricted to limited transportation planning (Chapter 4) infrastructure under various urban spatial structures (Chapter 3). This study is the first in South Africa to address transportation systems and implementation within an urban structure, to improve efficiency and connectivity. Limitations on TP have affected numerous components of the urban SS due to the limited modal options and planning thereof. Transportation modes aim to increase efficiency and move towards sustainable cities. However, public transportation has been disregarded as a significant factor in cities, leading to motor vehicle-dominated cities; opposingly, transportation infrastructure has been largely planned under a single urban SS, which can prove problematic. This causes congestion, inefficiency, decreased productivity, increased travel costs, increased travel time, decreased economic growth, numerous safety hazards, lack of sustainable transportation and environmental damage. The problem is evident in the lack of transportation systems being implemented according to the urban SS and the resultant co-dependency on TP. This creates mass inefficiency, which is highly problematic for the urban SS.

The spatial implementation of transportation infrastructure is significant for mobility between the central business district (CBD) (places of employment) and residential areas. This is visible in the study area, as South African cities lack effective spatial planning for transportation systems and neglect aspects of the urban SSs. South Africa, as a developing country, is focused on spatial planning of road infrastructure, while lacking pedestrian walkways in various areas of development. Numerous cities within the country are planned according to the same TP perspective but have different urban SSs. South Africa not only lacks TP according to the varying urban SSs but does not include public transportation services in most instances and has resorted to using motor vehicles as the last option to achieve mobility in most cities. This has become problematic since the urban SS lacks appropriate infrastructure and TP which uniquely correlates to each urban SS. Each urban SS has different attributes; thus, one cannot be utilised across the board in all other urban SSs.

This study aimed to identify guidelines for several identified urban SSs that could be spatially and practically implemented in the urban structure. The literature research aimed to identify various urban and spatial models that have been used worldwide and, more specifically, in South Africa. Transportation models were assessed to combine both the urban structure and TP. The principles of each SS and the aims and objectives of the design, thus creating a foundation for the various transport models to be incorporated within the urban structure; this involved different principles for implementation. The study’s objectives were all addressed. The empirical research approach was based on a comparative analysis of the implementation of transportation systems within the urban SS of developed countries (as best-practice case studies) and the principles for successful implementation. The comparison between the transport implementation was determined through a comprehensive empirical review of international countries versus cities within South Africa. The comparative analysis approach attempted to identify various spatial implementations, tools, policies, land use and political aspects successfully implemented in a sustainable city. This created various guidelines for TP within each unique urban SS.

The study addressed all research components to efficiently implement transportation systems within various urban structures and provided a series of guidelines. The recommendations included efficient implementation strategies and components towards the various urban structures and different transportation systems addressed within the study. The recommendations consisted of an urban model with a theoretical implementation (Cullinan Urban Model, or 'CUrM') of all the components of transportation networks implemented within the study. The comprehensive urban model illustrated an understanding towards improving and implementing transportation networks within an urban structure through the research illustrated. The theoretical implementation of the urban model derived various guidelines towards TP and SS planning.

In conclusion, a more efficient spatial planning approach towards transport networks could be determined by the urban structure. The guidelines contributed in this study illustrated possible future planning approaches and methods of implementation. The CUrM is, therefore, considered a theoretical urban model based on the developed guidelines and can be used as a template for future TP approaches to improve transportation efficiency.

Keywords: *Sustainable, Transportation, Spatial structure, Urban model, Transport infrastructure, Transport planning*

OPSOMMING

Die ruimtelike beplanning en implementering van vervoerstelsels is beperk tot vervoerbeplanning (see TP) infrastruktuur onder verskeie stedelike ruimtelike strukture (see SS'e). Hierdie studie is die eerste in Suid-Afrika wat vervoerstelsels en implementering binne 'n stedelike struktuur aanspreek om doeltreffendheid en konnektiwiteit te verbeter. Beperkings op TP het talle komponente wat die stedelike SS beïnvloed as gevolg van die beperkte modale opsies en beplanning daarvan. Vervoermodusse het ten doel om doeltreffendheid te verhoog en na volhoubare stede te beweeg. Openbare vervoer is egter verontagsaam as 'n beduidende faktor in stede, wat lei tot stede wat deur motorvoertuie oorheers word, terwyl vervoerinfrastruktuur grootliks onder 'n enkele stedelike SS beplan is, wat problematies kan blyk te wees. Dit veroorsaak opeenhoping, ondoeltreffendheid, verlaagde produktiwiteit, verhoogde reiskoste, verhoogde reistyd, verminderde ekonomiese groei, talle veiligheidsgevare, gebrek aan volhoubare vervoer en omgewingskade. Die probleem is duidelik in die gebrek aan vervoerstelsels wat volgens die stedelike SS geïmplementeer word en die gevolglike mede-afhanklikheid van TP. Dit skep massa-ondoeltreffendheid, wat hoogs problematies is vir die stedelike SS.

Die ruimtelike implementering van vervoerinfrastruktuur is betekenisvol vir mobiliteit tussen die sentrale sakekerne (SBD) (werkplekke) en woongebiede. Dit is sigbaar in die studiegebied, aangesien Suid-Afrikaanse stede nie effektiewe ruimtelike beplanning vir vervoerstelsels het nie en aspekte van die stedelike SS'e verwaarloos. Suid-Afrika, as 'n ontwikkelende land, is gefokus op ruimtelike beplanning van padinfrastruktuur, terwyl dit nie voetgangers paadjies in verskeie gebiede van ontwikkeling het nie. Talle stede in die land word volgens dieselfde TP-perspektief beplan, maar het verskillende stedelike SS'e. Suid-Afrika het nie net 'n gebrek aan TP volgens die verskillende stedelike SS'e nie, maar sluit in die meeste gevalle nie openbare vervoerdienste in nie en maak gebruik van motorvoertuie as die laaste opsie om mobiliteit in die meeste stede te bereik. Dit is problematies aangesien die stedelike SS nie geskikte infrastruktuur en TP het nie, wat uniek korreleer met elke stedelike SS. Elke stedelike SS het verskillende eienskappe; dus kan een nie oor die algemeen in alle ander stedelike SS'e gebruik word nie.

Hierdie studie het ten doel gehad om riglyne vir verskeie geïdentifiseerde stedelike SS'e te identifiseer wat ruimtelik en prakties in die stedelike struktuur geïmplementeer kan word. Die literatuur navorsing het ten doel gehad om verskeie stedelike en ruimtelike modelle te identifiseer wat wêreldwyd en, meer spesifiek, in Suid-Afrika gebruik is. Vervoer modelle is geassesseer om beide die stedelike struktuur en TP te kombineer. Die beginsels van elke SS en die doelwitte en oogmerke van die ontwerp, skep dus 'n grondslag vir die verskillende vervoer modelle om binne

die stedelike struktuur geïnkorporeer te word; dit het verskillende beginsels vir implementering behels.

Die studie se doelwitte is almal aangespreek. Die empiriese navorsing benadering was gebaseer op 'n vergelykende ontleding van die implementering van vervoerstelsels binne die stedelike SS van ontwikkelde lande (as beste-praktyk gevallestudies) en die beginsels vir suksesvolle implementering. Die vergelyking tussen die vervoer implementering is bepaal deur 'n omvattende empiriese oorsig van internasionale lande en stede binne Suid-Afrika. Die vergelykende analise-benadering het gepoog om verskeie ruimtelike implementerings, instrumente, beleide, grondgebruik en politieke aspekte wat suksesvol geïmplementeer is in 'n volhoubare stad te identifiseer. Dit het verskeie riglyne vir TP geskep binne elke unieke stedelike SS.

Die studie het alle navorsing komponente aangespreek om vervoerstelsels doeltreffend binne verskeie stedelike strukture te implementeer en 'n reeks riglyne verskaf. Die aanbevelings het doeltreffende implementering strategieë en komponente ingesluit vir die verskillende stedelike strukture en verskillende vervoerstelsels wat in die studie aangespreek is. Die aanbevelings het bestaan uit 'n stedelike model met 'n teoretiese implementering (Cullinan Urban Model, of 'CUrM') van al die komponente van vervoer netwerke wat binne die studie geïmplementeer is. Die omvattende stedelike model het 'n begrip geïllustreer vir die verbetering en implementering van vervoer netwerke binne 'n stedelike struktuur deur die navorsing wat gedoen is. Die teoretiese implementering van die stedelike model het verskeie riglyne vir TP- en SS-beplanning afgelei.

Ten slotte, 'n meer doeltreffende ruimtelike beplannings benadering ten opsigte van vervoer netwerke kan deur die stedelike struktuur bepaal word. Die riglyne wat in hierdie studie bygedra is, het moontlike toekomstige beplannings benaderings en -metodes van implementering geïllustreer. Die CUrM word dus beskou as 'n teoretiese stedelike model gebaseer op die ontwikkelde riglyne en kan gebruik word as 'n voorbeeld vir toekomstige TP-benaderings om vervoer doeltreffendheid te verbeter.

Sleutelwoorde: Volhoubaar, Vervoer, Ruimtelike struktuur, Stedelike model, Vervoerinfrastruktuur, Vervoerbeplanning

TABLE OF CONTENTS

PREFACE I

ABSTRACT II

OPSOMMING IV

LIST OF TABLES XV

LIST OF FIGURES........ XVI

LIST OF ACRONYMS........ XX

CHAPTER 1 INTRODUCTION........ 1

1.1 RESEARCH CONTEXT **1**

1.2 RESEARCH PROBLEM **3**

1.3 RESEARCH AIMS AND OBJECTIVES **4**

1.4 HYPOTHESIS **4**

1.5 CHAPTER DIVISION........ **4**

1.5.1 Chapter 2 (Research analysis): Research methodology........ 5

1.5.2 Chapter 3: Urban structures - A review 6

1.5.3 Chapter 4: Transportation Planning (see TP) - A review 7

1.5.4 Chapter 5: Integration of urban structures and transportation networks 8

1.5.5 Chapter 6: Case study approach to urban structures and implemented transportation systems 9

1.5.6 Chapter 7: Synthesis and Recommendations 10

CHAPTER 2 RESEARCH METHODOLOGY 11

2.1 INTRODUCTION........ **11**

2.2 RESEARCH PARADIGM........ **13**

2.3 RESEARCH APPROACH........ **14**

2.4 RESEARCH PURPOSE **16**

2.5 RESEARCH DESIGN........ **16**

2.6 CONCLUSION **19**

CHAPTER 3 URBAN STRUCTURES: A REVIEW ... 20
3.1 INTRODUCTION ... **20**
3.2 URBAN MODELS ... **20**
3.2.1 The garden city model ... 20
3.2.1.1 Land use ... 23
3.2.1.2 Mobility ... 24
3.2.2 The concentric ring model ... 26
3.2.2.1 Land use ... 27
3.2.2.2 Discussion ... 30
3.2.2.3 Mobility ... 31
3.2.3 The multi-nuclei model ... 34
3.2.3.1 Land use ... 35
3.2.3.2 Mobility ... 40
3.2.4 The urban structure model ... 40
3.2.4.1 Land use ... 41
3.2.4.2 Mobility ... 43
3.2.5 The urban realms model ... 44
3.2.5.1 Land use ... 44
3.2.5.2 Mobility ... 45
3.2.6 The twenty-first-century (21st-century) city model ... 45
3.2.6.1 Land use ... 46
3.2.6.2 Mobility ... 48
3.2.7 The urban fabrics model ... 50
3.2.7.1 Land use ... 52
3.2.7.2 Mobility ... 54
3.2.8 The apartheid city model ... 58
3.2.8.1 Land use ... 60
3.2.8.2 Mobility ... 61

3.2.9 The Marchetti Constant model 62

3.2.9.1 Land use 63

3.2.9.2 Mobility 64

3.2.10 The theory of agricultural land-use model 66

3.2.10.1 Land use 68

3.2.10.2 Mobility 73

3.3 URBAN TRANSPORTATION NETWORKS **74**

3.4 CONCLUSION **75**

CHAPTER 4 TRANSPORTATION PLANNING: A REVIEW 77

4.1. INTRODUCTION **77**

4.2 TRANSPORTATION NETWORKS **77**

4.2.1 Connectivity structure 78

4.2.2 Spatial organisation of transportation 79

4.2.2.1 Monocentric spatial structures 81

4.2.2.2 Polycentric spatial structures 83

4.3 TRANSPORTATION FLOWS **84**

4.4 TRANSPORTATION PLANNING MODELS **87**

4.4.1 Travel demand models 91

4.4.1.1 Network structure 92

4.4.2 Trip and parking generation models 94

4.4.2.1 Network structure 95

4.4.3 Walking and bicycling models 99

4.4.3.1 Network structure 100

4.4.4 Economic evaluation models 104

4.4.4.1 Network structure 104

4.4.5 Integrated transportation and land-use planning (ITLUP) models 105

4.4.5.1 Network structure 106

4.5 CONCLUSION **109**

CHAPTER 5 INTEGRATION OF URBAN STRUCTURES AND TRANSPORTATION NETWORKS 112

5.1 INTRODUCTION **112**

5.2 URBAN STRUCTURE PLANNING **113**

5.3 TRANSPORT NETWORK PLANNING **118**

5.4 INTERACTION OF LAND USE **121**

5.4.1 Economic interaction 122

5.4.2 Social interaction 124

5.4.3 Political interaction 125

5.4.4 Environmental interaction 126

5.4.4.1 Chemical 126

5.4.4.2 Physical 127

5.4.4.3 Biological 127

5.4.5 Community health 127

5.5 TRANSPORTATION COMPONENTS **129**

5.5.1 Mobility and connectivity 129

5.5.2 Location and accessibility model (A) 133

5.5.3 Specialisation and interdependency model (B) 135

5.5.4 Distribution/flow model (C) 136

5.5.5 Transportation infrastructure 138

5.5.5.1 Walkability 139

5.5.5.2 Road transportation 140

5.5.5.3 Rail transportation 142

5.5.6 Transportation systems 145

5.6 URBAN SS AND TRANSPORT **145**

5.7 CHALLENGES IN TRANSPORTATION PLANNING **149**

5.7.1 Land use and TP 150

5.7.2 Impact on the environment 151

5.7.3 Pedestrian structures 151
5.7.4 Political challenges 152
5.7.5 Policy implementation 153
5.7.6 Public transportation 153
5.7.7 Traffic congestion and parking facilities 154
5.7.8 Population density 155
5.7.9 Maintenance 156
5.7.10 Financial restraints 157
5.8 TRANSIT-ORIENTATED DEVELOPMENT (TOD) **.. 158**
5.9 INTERNATIONAL BEST PRACTICE **.. 161**
5.10 CONCLUSION **.. 162**
CHAPTER 6 CASE STUDY APPROACH TO URBAN STRUCTURES AND IMPLEMENTED TRANSPORTATION SYSTEM 164
6.1 INTRODUCTION **.. 164**
6.2 CANBERRA (THE GARDEN CITY MODEL) **.. 165**
6.2.1 Land use 166
6.2.2 Transportation networks 168
6.2.4 Spatial policy 171
6.2.4.1 Spatial plan 171
6.2.4.2 Urban Open Space Policy 171
6.2.4.3 Housing Choices Policy 171
6.2.4.4 Integrated Transportation Strategy 172
6.2.4.5 Active travel strategy 172
6.2.4.6 Public Transport Expansion Plan 172
6.3 CHICAGO (THE CONCENTRIC RING MODEL) **.. 173**
6.3.1 Land use 173
6.3.2 Transportation networks 175
6.3.3 Spatial policy 179

6.3.3.1 Chicago Zoning Ordinance *179*

6.3.3.2 Chicago Transit Authority (CTA) *179*

6.3.3.3 Pedestrian and bicycle plans *179*

6.3.3.4 Chicago Complete Streets Policy *179*

6.3.3.5 Transportation demand management (TDM) ordinances *179*

6.3.3.6 Chicago Department of Transportation (CDOT) Policies *180*

6.4 LOS ANGELES (MULTI-NUCLEI MODEL) **180**

6.4.1 Land use 181

6.4.2 Transportation networks 183

6.4.3 Spatial policy 185

6.4.3.1 Overarching scheme *185*

6.4.3.2 Zoning ordinances *186*

6.4.3.3 Transit-oriented development (TOD) *186*

6.4.3.4 Ecological advancement *187*

6.4.3.5 Public transport *187*

6.4.3.6 The Policy for Complete Streets *187*

6.4.3.7 Parking regulations *188*

6.5 ERBIL (THE URBAN STRUCTURE MODEL) **188**

6.5.1 Land use 189

6.5.2 Transportation networks 191

6.5.3 Spatial policy 193

6.5.3.1 Residential single plots policy *193*

6.5.3.2 Adaptation of policies *193*

6.5.3.3 Transit-oriented development (TOD) *193*

6.5.3.4 Zoning and land use regulations policy *194*

6.5.3.5 Complete roadways policy *194*

6.5.3.6 Effective Parking Management Practises Policy *194*

6.6 SAN FRANCISCO (SF) (THE URBAN REALMS MODEL) **194**

6.6.1 Land use 195
6.6.2 Transportation networks 197
6.6.3 Spatial policy 199
6.6.3.1 Transit-First Policy 200
6.6.3.2 Transportation-oriented development (TOD) 200
6.6.3.3 Complete Roadway Policy 201
6.6.3.4 Pedestrian policies 201
6.6.3.5 Affordable housing policies 202
6.6.3.6 Environmental sustainability 202
6.7 LAGOS (THE 21ST-CENTURY CITY MODEL) **202**
6.7.1 Land use 203
6.7.2 Transportation networks 206
6.7.3 Spatial policy 210
6.7.3.1 Lagos State Law on Urban and Regional Planning and Development 210
6.7.3.2 Lagos State Transport Reform Law 210
6.7.3.3 Lagos State Bus Reform Initiative (BRI) 211
6.8 BARCELONA (THE URBAN FABRICS MODEL) **211**
6.8.1 Land use 212
6.8.2 Transportation networks 215
6.8.3 Spatial policy 218
6.8.3.1 The Superblock Policy 219
6.8.3.2 Bicycle Lane Network Expansion and Incorporation Policy 219
6.8.3.3 Green Spaces and Public Realm Enhancements Policy 219
6.8.3.3 Urban development and zoning laws 220
6.8.3.4 Integrated Public Transport Policy 220
6.9 ROME (THE MARCHETTI CONSTANT MODEL) **221**
6.9.1 Land use 221
6.9.2 Transportation networks 224

6.9.3 Spatial policy 228
6.9.3.1 Zoning ordinances *229*
6.9.3.2 Preservation of historic sites *229*
6.9.3.3 Transportation policy *229*
6.9.3.4 Environmental policy *230*
6.9.3.5 Improvement of public transportation policy *230*
6.10 ANTIGO (THE THEORY OF AGRICULTURAL LAND-USE MODEL) **230**
6.10.1 Land use 231
6.10.2 Transportation networks 234
6.10.3 Spatial policy 236
6.10.3.1 Zoning regulations *237*
6.10.3.2 Comprehensive planning *237*
6.10.3.3 Agricultural preservation policies *237*
6.10.3.4 Activity corridors development *238*
6.10.3.5 Sustainability initiatives *238*
6.11 CAPE TOWN (CPT) (APARTHEID CITY MODEL) **239**
6.11.1 Land use 239
6.11.2 Transportation networks 242
6.11.3 Spatial policy 246
6.11.3.1 Municipal by-laws *246*
6.11.3.2 Land Use Management Scheme (LUMS) *246*
6.11.3.3 Bulk contributions policy (BCP) *246*
6.12 DISCUSSION **247**
6.13 CONCLUSION **255**
CHAPTER 7 SYNTHESIS AND RECOMMENDATIONS 258
7.1 INTRODUCTION **258**
7.2 SYNTHESIS **258**
7.3 RECOMMENDATIONS **267**

7.4 GUIDELINES FOR TRANSPORTATION PLANNING (TP) **274**

7.4.1 Guideline TP1: To promote public transportation 276

7.4.2 Guideline TP2: To improve active transportation and pedestrian infrastructure 277

7.4.3 Guideline TP3: To reduce the number of automobiles on the road 278

7.4.4 Guideline TP4: To incorporate sustainable transportation infrastructure 279

7.4.5 Guideline TP5: To incorporate intelligent transportation systems 279

7.4.6 Guideline TP6: To base transportation on the income group and capacity 280

7.5 GUIDELINES FOR SPATIAL STRUCTURES (SS) **282**

7.5.1 Guideline SS1: To prioritise mixed land-use development 282

7.5.2 Guideline SS2: To incorporate green spaces 284

7.5.3 Guideline SS3: To implement smart growth principles 284

7.5.4 Guideline SS4: To utilise sustainable practices 285

7.5.5 Guideline SS5: To plan for resilience 286

7.6 PRACTICAL IMPLEMENTATION OF THE CURM MODEL **287**

7.6.1 Step 1: Identify arterial roads 289

7.6.2 Step 2: Increase accessibility to public transportation systems 290

7.6.3 Step 3: Implementation of policy 291

7.7 CONCLUSION **294**

7.7.1 Study limitations 295

7.7.2 Areas of future research 295

BIBLIOGRAPHY 296

ANNEXURES 325

LIST OF TABLES

Table 6- 1 Delineation of unique traits of the case studies 248

Table 7- 1 Proposed guidelines for TP and SS implementation 275

LIST OF FIGURES

Figure 1 - 1 Research approach and paradigm 6

Figure 1 - 2 Urban models.. 7

Figure 1 - 3 TP models.. 8

Figure 2 - 1 Research onion 12

Figure 2 - 2 Relationship between research designs and methodological paradigms 15

Figure 2 - 3 Research paradigms and the pragmatic approach 18

Figure 3 - 1 Garden city model 21

Figure 3 - 2 The garden city land use layout.. 23

Figure 3 - 3 Garden city model transportation system 25

Figure 3 - 4 Concentric zone model.. 28

Figure 3 - 5 Mobility of concentric ring model 31

Figure 3 - 6 Transportation systems' evolution in concentric ring land use 32

Figure 3 - 7 Multi-nuclei model 36

Figure 3 - 8 Multi-nuclei model and distribution of land use 37

Figure 3 - 9 Urban structure model.. 41

Figure 3 - 10 Modified concentric ring model of urban land use... 43

Figure 3 - 11 Urban realm model... 44

Figure 3 - 12 The 21st-century city model.. 46

Figure 3 - 13 Mobility of the 21st-century city model.. 49

Figure 3 - 14 The urban fabrics model... 50

Figure 3 - 15 Combination of transportation and land use within the urban fabrics model........ 53

Figure 3 - 16 Urban fabrics model mobility 54

Figure 3 - 17 Breakdown of the urban fabrics model 55

Figure 3 - 18 Modernised apartheid city model... 59

Figure 3 - 19 The apartheid city model 61

Figure 3 - 20 The apartheid city model: Implementation of transportation 62

Figure 3 - 21 Anthropological invariants in travel behaviour 63

Figure 3 - 22 Bid-curve model (Alonso’s model) 68

Figure 3 - 23 Distance from Urban Structure core and land value 69

Figure 3 - 24 Land use based on land value 71

Figure 4 - 1 Connectivity of activity points within an urban structure 79

Figure 4 - 2 Urban SSs integrated into the spatial organisation of transportation 81

Figure 4 - 3 Monocentric and mono-polycentric SSs 82

Figure 4 - 4 Polycentric SS 84

Figure 4 - 5 Transportation factors with the interlinkage of flow 86

Figure 4 - 6 Central place theory 89

Figure 4 - 7 Christaller transportation connectivity modes 90

Figure 4 - 8 Example of a travel demand model 92

Figure 4 - 9 Process of travel demand and interaction of components 93

Figure 4 - 10 Trip generation and parking models’ flow of road traffic 96

Figure 4 - 11 Institute of Transportation Engineers’ vehicle trip rate formulae 97

Figure 4 - 12 Hour commuting time range of travel in transportation systems 101

Figure 4 - 13 Implementation strategy of cyclists and pedestrians in a street layout 102

Figure 4 - 14 TELUM process 107

Figure 5 - 1 Conceptual framework for TP 119

Figure 5 - 2 Factors influencing the health policy of urban structures 128

Figure 5 - 3 Components of an urban transit system 131

Figure 5 - 4 The derived demand for commodities transportation systems 133

Figure 5 - 5 Location and accessibility model (A) 134

Figure 5 - 6 Specialisation and interdependency model (B) 136

Figure 5 - 7 Distribution/flow model (C) 137

Figure 5 - 8 Capacity of travel and economic growth 143

Figure 5 - 9 Test development model for a city in the UK 147

Figure 5 - 10 Types of Urban Forms 148

Figure 5 - 11 Neighbourhood TOD 160

Figure 6 - 1 Criteria of transportation efficiency 164

Figure 6 - 2 Canberra city centre 168

Figure 6 - 3 Canberra Road and zones 169

Figure 6 - 4 Chicago land use zoning map 174

Figure 6 - 5 The implemented transportation systems within Chicago 178

Figure 6 - 6 Land use in CoLA 182

Figure 6 - 7 The implemented transportation systems within LA 184

Figure 6 - 8 Master plan for Erbil cities land use 190

Figure 6 - 9 The implemented transportation systems within Erbil 192

Figure 6 - 10 Land use zoning within SF 196

Figure 6 - 11 Transportation systems within SF 199

Figure 6 - 12 Land uses within Lagos 206

Figure 6 - 13 Transportation systems within Lagos 209

Figure 6 - 14 Land use within Barcelona 214

Figure 6 - 15 Transportation systems within Barcelona 218

Figure 6 - 16 Land use within Rome 224

Figure 6 - 17 Transportation systems within Rome 228

Figure 6 - 18 Land use of Wisconsin, USA 234

Figure 6 - 19 Land use development throughout CPT 241

Figure 6 - 20 Public transportation network in CPT 245
Figure 7- 1 Proposed urban model 268
Figure 7- 2 The land use and transportation systems within the CUrM 270
Figure 7- 3 The land use within the CUrM 270
Figure 7- 4 The transportation systems within the CUrM 272
Figure 7- 5 The public transportation systems within the CUrM 276
Figure 7- 6 The pedestrian infrastructure within the CUrM 278
Figure 7- 7 The lower-income/middle-income and higher-income hierarchy within the CUrM 281
Figure 7- 8: The expanding CBD within the CUrM 283
Figure 7- 9 The smart growth strategy of the CUrM 285
Figure 7- 10 Practical implementation of the CUrM Part 1 288
Figure 7- 11 Practical implementation of the CUrM Part 2 289
Figure 7- 12 Practical application of CUrM on existing SS 293
Figure A- 1: Canberra 325
Figure A- 2: Chicago 326
Figure A- 3: Los Angeles 327
Figure A- 4: Erbil 328
Figure A- 5: San Francisco 329
Figure A- 6: Lagos 330
Figure A- 7: Barcelona 331
Figure A- 8: Rome 332
Figure A- 9: Antigo 333
Figure A- 10: Cape Town 334

LIST OF ACRONYMS

AADTD	Annual Average Daily Trip
ACT	Australian Capital Territory
ANU	Australian National University
BART	Bay Area Rapid Transit
BCP	Bulk contributions policy
BRI	Bus Reform Initiative
BRT	Bus Rapid Transit
CBD	Central Business District
CDOT	Chicago Department of Transportation
CoLA	City of Los Angeles
COTO	Committee of Transport Officials
CPT	City of Cape Town
CTA	Chicago Transit Authority
CUrM	Cullinan Urban Model
DASH	Downtown Area Short Hop
E80	Strength component of road infrastructure, used by civil engineers
EHD	Extra Heavy Duty
EIA	Environmental Impact Assessment
FQD	Traffic factor to convert AADT to an impact trip rate
GABS	Golden Arrow Bus Services
GDP	Gross Domestic Product

GHG	Greenhouse Gas
GIS	Geographic Information System
GPS	Global Positioning System
GRIP	Global Roads Inventory Project
IDP	Integrated Development Plans
IT	Information Technology
ITLUP	Integrated Transportation and Land-use Planning
km	Kilometres
LA	Los Angeles
LAMC	Los Angeles Municipal Code
Metro	Los Angeles County Metropolitan Transportation Authority
LPI	Logistics Performance Index
LRMT	Lagos Rail Mass Transit
LRT	Light Rail Transit
LRV	Light Rail Vehicle
LUMS	Land Use Management Scheme
NGO	Non-Governmental Organisation
NMT	Non-Motorised Transport
SDF	Spatial Development Framework
SF	San Francisco
SFMTA	San Francisco Municipal Transportation Agency
SOV	Single-Occupant Vehicle

SPLUMA	Spatial Planning and Land Use Development Act 16 of 2013
SS	Spatial Structure
TDM	Transport Demand Model
TELUM	Transportation Economic and Land Use Model
TMH	Technical Methods for Highways
TOD	Transit-Oriented Development
TP	Transportation Planning
TRH	Technical Recommendations for Highways
UC	University of Canberra
UK	United Kingdom
UN	United Nations
USA	United States of America
VMT	Vehicle Miles Travelled
WRS	World Road Statistics
WWII	Second World War
ZAR	South African Rands

CHAPTER 1 INTRODUCTION

1.1 RESEARCH CONTEXT

The interplay between transportation systems and urban structures forms a foundational pillar in urban and regional planning. Urban structure refers specifically to the internal organization of a city, including the spatial distribution of population, land uses (residential, commercial, industrial), economic activities, and infrastructure within urban boundaries. As cities evolve, the dynamics of transportation planning become increasingly complex, driven by the multifaceted interactions between land use patterns, socio-economic activities, population growth, technological innovation, and environmental considerations. Transportation planning is a systematic, multi-disciplinary process used to design, evaluate, and implement strategies for the development, operation, and management of transportation systems to meet the mobility needs of people and goods in an efficient, safe, and sustainable manner. Transportation systems not only facilitate spatial mobility and accessibility but also serves as a structuring force that shapes urban form. A transportation system refers to the integrated network of infrastructure, modes, services, technologies, and institutional frameworks that enable the movement of people, goods, and information across spatial and temporal dimensions. This influences land development trajectories, and determines the efficiency and equity of urban systems. This study aims to identify guidelines for implementing transportation solutions based on the spatial structure (hereafter SS) of various urban structures. A spatial structure refers to the overall arrangement and distribution of physical space including land uses, transport networks, and environmental features within a geographic area. This will form part of efficient spatial planning techniques through which transportation can be introduced locally, nationally, and internationally, with minimal impact on the immediate environment whilst improving the functionality of the urban structure. The study also aims to identify specific guidelines and principles for implementing transportation systems according to specific urban SSs. The significance of a study aimed at implementing guidelines to improve transportation efficiency within a spatial structure, which lies in its potential to inform evidence-based planning and policy-making. It contributes to the academic discourse by integrating land-use dynamics with transportation networks to enhance systemic performance and sustainability. The study addresses critical challenges in urban form, accessibility, and mobility, thereby supporting equitable and resilient urban development. Accessibility refers to the ease with which people can reach desired services, activities, and destinations from a given location, using available transportation and land use systems.

The study offers a methodological framework for evaluating spatial configurations that optimize connectivity and reduce inefficiencies. The guidelines will provide a sustainable approach towards functionality and implementation within local, national, and international communities. The case study of cities will illustrate a comparative study to identify the efficient and non-efficient transportation networks and methods of implementation, modes of transportation, and urban structure.

Spatial planning has devised many approaches to the mobility of freight and passengers in various countries but should include transportation planning (Chapter 4) for specific urban structures. Various urban structures are implemented with different topography, transportation systems, population, and land uses, among others. Transportation systems cannot be implemented on a single criterion when all urban structures differ based on multiple components. The study will, therefore, illustrate that urban structures may share similarities within the implementation of transportation systems but also that different components should be addressed individually. Thus, transportation systems should be carefully implemented according to the urban structure to improve the efficiency and connectivity of different land uses. The transport geography is especially important to the spatial layout of communities and their transportation systems. Transportation geography determines the layout of transportation networks, which connect all land uses within an urban structure. The spatial layout of transportation networks should be planned effectively to improve the efficiency of transportation systems. This would increase connectivity of land uses and general daily mobility between workplaces and residences. Mobility refers to the ability of people, goods, and services to move freely and efficiently within and between geographic spaces.

Transport geography is defined as the geography of transportation systems, which is a sub-discipline of geography and is concerned with the movement of people and information. According to Rodrigue *et al.* (2006:5), transport geography seeks to link spatial constraints and attributes with the origin, destination, extent, nature, and purpose of movements. Spatial planning should, therefore, be used in coordination with economic, social, political, and environmental impact factors to increase the efficiency of mobility. This is significant because the efficiency of transportation systems improves productivity, while congestion and aspects decreasing transportation systems consume time and decrease productivity. This has been illustrated within the central place theory model, based on supply and demand (Jamoliddinov & Dsilva, 2019:13-16). Therefore, the research reported in this dissertation addresses the spatial planning of transportation modes. Transportation modes refer to the distinct categories or types of transport systems used to move people or goods from one location to another. It seeks to decrease negative environmental effects by carefully allocating various transportation modes to facilitate movement within an SS effectively.

The spatial planning of transportation infrastructure is crucial for a city or town’s efficiency and ability to link nodes of significance. A sustainable spatial layout comprises numerous intricate functions, with a need for a local, sustainable transportation system (Phillips, 1970:50; Chaplin & Kaiser, 1979:32; Cilliers, 2010:15; Cullinan, 2019:58-61). Sustainable transportation is a long-term investment which can promote a more efficient and healthier lifestyle, with minimal environmental implications (Tharan, 2004:15; Heraa, 2013:41-42; Cullinan, 2019:125-165). This can improve mobility and create efficient mobility in all aspects, as demonstrated in South Africa, Denmark, Australia, and Spain, among others (Cullinan, 2019:100-167). The implementation of transportation is based on various factors, all deliberated from the existing or planned urban models. A city's urban structures determine the spatial planning of transportation and can either increase or decrease the functionality of transportation systems. Transportation systems are implemented through a strategy that uses 'transportation models' and the 'current urban structure'. This does not refer to a specific implementation strategy between the two planning methods but rather a generic concept of implementation. The generic implementation of transportation systems refers to general connectivity between land uses by common modes of transportation systems, for example, single-occupant [motor] vehicles (SOVs) but not specific spatial planning implementation strategies.

To incorporate efficient or sustainable transportation, guidelines need to be developed to illustrate a specific structure of transportation systems. To determine these guidelines a comprehensive analysis of various international case studies needs to be determined, to serve as international best-practice case studies. The case studies will illustrate the practical implementation of the selected urban models in illustrating the potential advantages and disadvantages of the urban structure. The comparative analysis will illustrate the required guidelines that could be illustrated and implemented into South Africa's prevailing urban structure, namely the twin-city (apartheid) urban structure, to increase efficiency and sustainability.

1.2 RESEARCH PROBLEM

There is a lack of spatial planning that is integrated with transportation systems. TP has been comprised of numerous models, which are present within spatial planning. However, some urban models lack guidelines for the implementation of transportation systems. Various specific urban models have been delegated to a generic planning of transportation systems. This has decreased productivity due to poor maintenance and planning of transportation infrastructure (Peixoto Neto *et al.*, 2008:133-141; Carroli, 2012:1-3; Cullinan, 2019:70-84; Boussauw, 2023:8-11).

The lack of focus on spatial planning for public transport has limited local transportation diversity, owing to the accommodation of only a single type of transportation (motor vehicles). This inevitably increases the use of private vehicles due to limited mobility infrastructure, which in turn causes long-term environmental damage. The associated health and safety implications also create problems for pedestrians and cyclists (Rodrigue *et al.*, 2006:101-102; Dur & Yigitcanlar, 2015:814; Cullinan, 2019:70-86). These issues are caused by the spatial planning of transportation systems, where transportation has not been planned according to the urban structure and does not function as efficiently as it should within the urban model. There are few guidelines present when implementing transportation according to the urban model (Wilkinson, 2006:223-224). In addition, various cities and urban models do not abide by a specific transportation system structure (Cape Town, South Africa; Antigo, America; and Lagos, Nigeria). This has become evident through the lack of efficiency within transportation systems and constant congestion within numerous cities. With an ever-growing population, a more coordinated implementation of transportation that accounts for the urban structure would increase efficiency.

1.3 RESEARCH AIMS AND OBJECTIVES

This study has one main research aim. The aim is to investigate the implementation of different transportation systems within various urban models by identifying the efficient methods of implementing transportation. This will provide guidelines for all urban structures, which will support a more sustainable transport network.

To achieve this research aim, several research objectives have been created. These include:

1. To review existing transportation guidelines and systems which would potentially improve efficiency within cities;
2. To determine how sustainable transportation systems function within different urban structures;
3. To improve the efficiency of transportation modes within each urban structure by identifying guidelines for each type;
4. To identify how urban spatial planning policy in a developing country can enhance efficient transportation systems based on the established guidelines; and
5. To have a more efficient spatial planning approach towards transport networks determined by the urban structure.

1.4 HYPOTHESIS

This study has one hypothesis, namely:

> *H1: The urban structure mainly determines the efficiency of an urban transportation system.*

1.5 CHAPTER DIVISION

This thesis is divided into several chapters which follow this, the introductory chapter. Their structure and a summary of their content are discussed below.

1.5.1 Chapter 2 (Research analysis): Research methodology

This study hopes to determine guidelines on how to implement transportation systems based on the urban structure. This should illustrate previously implemented urban structures and specific implementation used based on land use connectivity and efficiency. The objectives and aims will be used to create guidelines for transportation implementation while improving efficiency. The study will, therefore, focus on various components affecting transportation systems and urban structures to determine a specific approach toward improving transportation efficiency. Thus, the study will follow a pragmatic approach to collect the relevant data, using both qualitative and quantitative methods (known as mixed-methods research).

The study will also make use of the pragmatic paradigm. This is a research philosophy which helps the author focus on the usefulness of a source of data and determines how it can be effectively used throughout the study (Du Toit & Mouton, 2011:1-4). Based on this paradigm, the pragmatic approach then systematically uses a process which considers six facets, namely: i) research content; ii) research aim; iii) research purpose; iv) methodological paradigm; v) methodological approach, and vi) source of data (Du Toit & Mouton, 2011:131).

The pragmatic approach will assist the researcher in identifying primary sources of data, through which case study and field data will ultimately be collected for the comparative analysis (Du Toit & Mouton, 2011:131). The thesis is based on a comparative analysis, which focuses on facts of past spatial planning models and determines if local transportation systems were imperative in the development of sustainable cities.

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 the hypothesis, which aids in determining various implementable models, principles, guidelines, policies and potential ideas throughout the study. This also aids in identifying possible challenges and problems that become evident through mobility and spatial implementation (Du Toit & Mouton, 2011:132). The structure of Chapter 2 is described in the Figure 1-1 below.

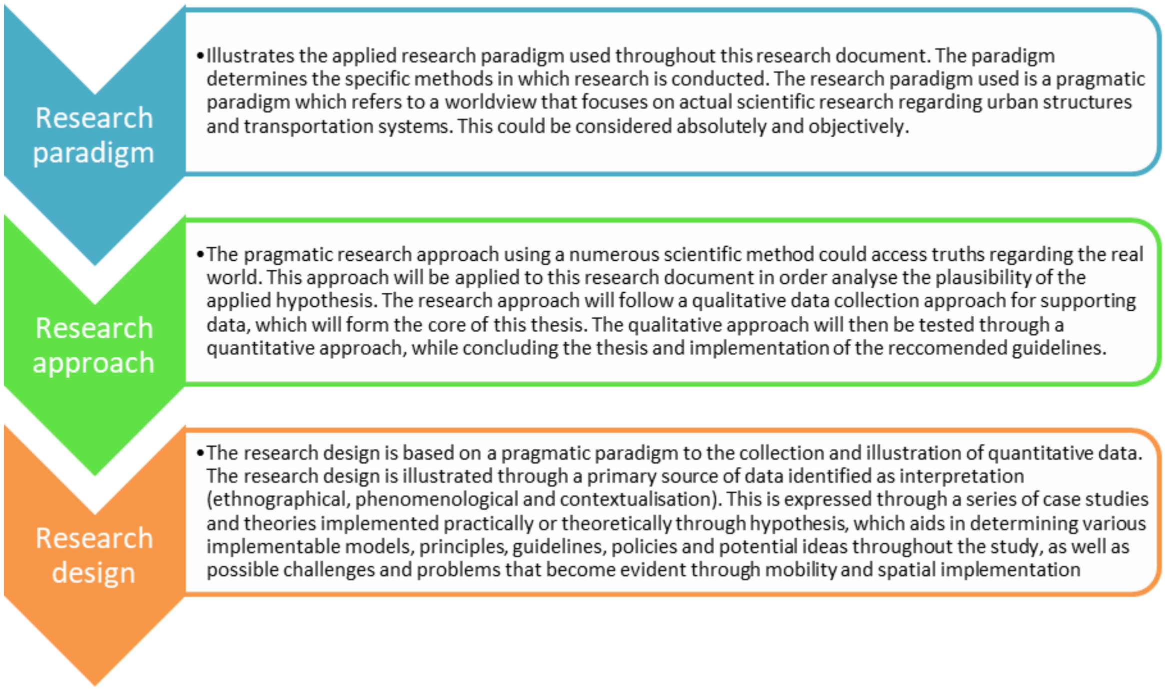


Figure 1 - 1 Research approach and paradigm

Source: Author's own (2024)

1.5.2 Chapter 3: Urban structures - A review

This chapter will firstly identify the various urban structures, and secondly, analyse each according to their advantages and disadvantages regarding the functionality of the urban structures' transportation systems. This chapter is intended (in part) to achieve **Research Objective 2** (To determine how sustainable transportation systems function within different urban structures), by illustrating the SS of each urban model. The following transportation systems will be evaluated according to efficiency, time of travel, passenger capacity, distance of travel and financial feasibility (maintenance). The focus is to identify efficient methods of implementing transportation systems while considering urban structure and environmental sustainability. This is addressed in the implemented transportation systems (Wegner, 1995:2-3; Pacione, 2005:789-790; Rodrigue *et al*., 2006:178-179), namely SOVs; bus rapid transit (BRT); rail (tram/train); bicycle; walking; taxis, and Uber.

This chapter will illustrate the various SSs of both transportation networks and urban models and create a foundation for the study's two-pronged focus (see Figure 1-2). This will assist in determining whether the SS would be compatible with the applied transportation network or if it hinders the mobility of land use and affects the efficiency of the urban model.

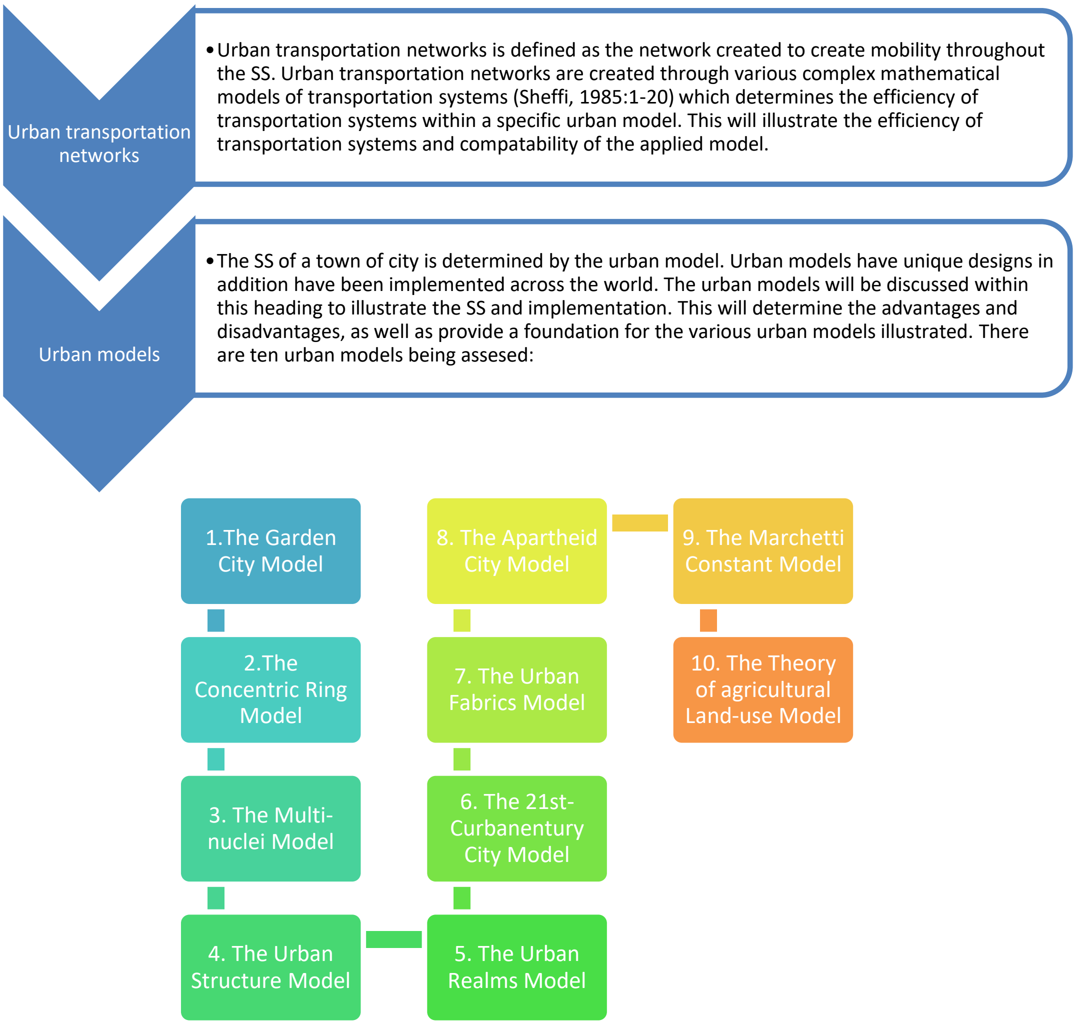


Figure 1 - 2 Urban models

Source: Author's own (2024)

The analysis of the above models will illustrate the SS as well as the efficient or inefficient transportation systems implemented. This chapter identifies the various urban models and their urban structure, while the following chapter will address transportation frameworks and the efficiency of each.

1.5.3 Chapter 4: Transportation Planning (see TP) - A review

This chapter will illustrate possible challenges within spatial planning of transportation as well as possible factors which prove difficult to overcome within spatial planning of transportation. The chapter will address **Research Objective 1** (To review existing transportation guidelines and systems which would potentially improve efficiency within cities) through the various TP models. These factors will each be evaluated according to the implementation of transportation. The Figure 1-3 below illustrates the various components of transportation models to be assessed in this study.

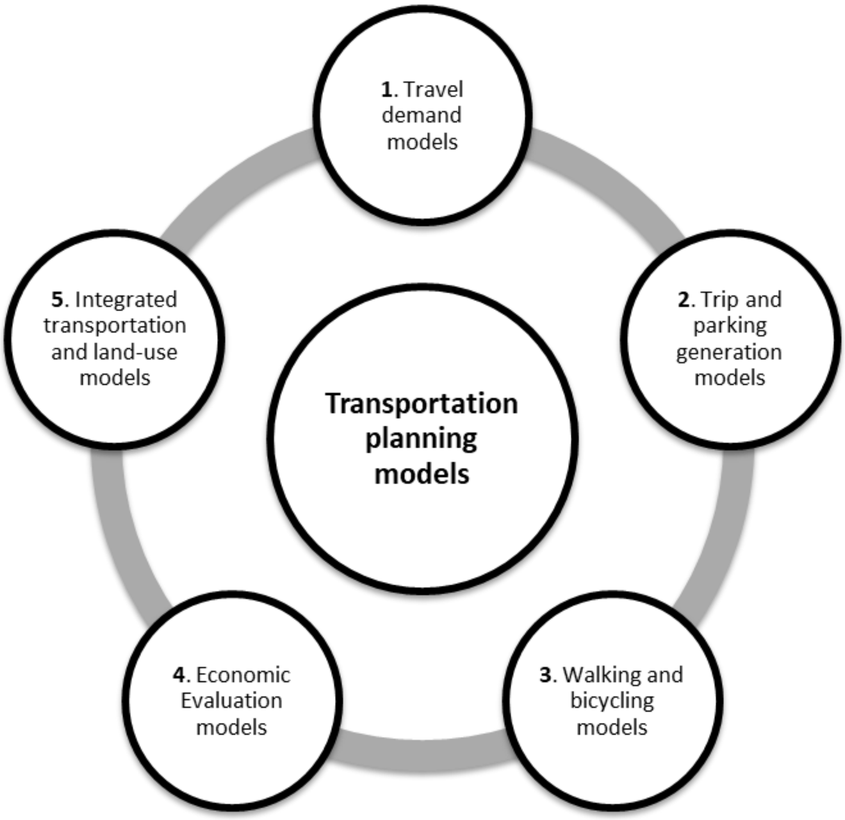


Figure 1 - 3 TP models

Source: Author's own (2024)

The above transportation models illustrate the various frameworks in which transportation is planned. The models illustrate various frameworks which create the foundation of transportation implementation throughout the urban structure and determine the efficiency of mobility within the urban model.

1.5.4 Chapter 5: Integration of urban structures and transportation networks

This chapter will focus on the future efficiency of transportation implementation through various transportation models. This will improve the overall sustainability and efficiency of transportation systems within the urban structure. The transportation models will be analysed to identify the proposed transportation guidelines and recommended implementation methods and approaches. The chapter will address **Research Objective 3** (To improve the efficiency of transportation modes within each urban structure by identifying guidelines for each type). The chapter will be divided into various sustainable (but not necessarily implementable at present) implementation methods. The various transportation models will illustrate implementation methods as well as several comprehensive approaches based on all the components of the urban structure and the perceived outcome of implementation (goals) (Robson *et al.*, 2018:386-389). Transportation systems (public transportation, electric vehicles, walking and bicycles) require all components to be incorporated to create efficient mobility. The last section of the literature review refers to international best practices (cf. 5.9), which will be determined through the comparative analysis.

The chapter illustrates challenging components (cf. 5.8) to TP at different levels of implementation (cf. 5.2.1), through general criteria of urban structure planning (cf. 5.2) and transportation network planning (cf. 5.3). The interaction (cf. 5.4) of implementing transportation systems within an urban structure needs to be addressed to improve efficiency and mobility. The interaction will affect different sectors of the urban structure, which addresses the connection between transportation and sectoral interaction (cf. 5.5). The chapter focuses on various transportation networks (cf. 5.6), which may improve the efficiency of transportation and impact the external and internal aspects of the urban structure. This determines the spatial organisation of transportation systems (cf. 5.6.2) which can either improve connectivity or detriment efficiency. The flow (cf. 4.2) of transportation is crucial and can be detrimental to congestion and lack of connectivity between land uses. The challenges (cf. 5.10) of implementing transportation systems within the urban structure may differ based on the type of spatial layout; however, the principles of TP addressed in Chapter 4 will illustrate a theoretical approach. Previous models of implementation can identify possible methods and approaches towards transit-orientated developments (TODs) (cf. 5.8) to improve transportation efficiency and interaction within the urban structure.

Chapter 5 also illustrates the possibility of combining TP models (Chapter 4) with the urban structures within the urban models assessed in Chapter 3 (Shaw & Xin, 2003:105; Cullinan, 2019:16-48) while considering all possible outcomes through the above-illustrated chapters. This involves considering other factors within the urban structure and possible approaches to creating a more efficient transportation system (Wegner, 1995:6-7; Shaw & Xin, 2003:104). It is critical to delineate these developments to illustrate the implementation principles, policies and guidelines for implementing transportation within the urban model. The guidelines illustrated in transportation-orientated models would assist in formulating the final guidelines for the implementation of transport systems within the various urban models (C40 cities, 2022:5-15).

1.5.5 Chapter 6: Case study approach to urban structures and implemented transportation systems

The empirical approach, as mentioned within the methods of investigation, will follow a pragmatic approach through mixed-methods research. The chapter will determine the various guidelines required to implement transportation systems to support **Research Objective 4** (To identify how urban spatial planning policy in a developing country can enhance efficient transportation systems based on the established guidelines) or act as a foundation to illustrate the foundation of efficiency within the implemented guidelines. Several models will be assessed for the case studies, including the garden city model (Canberra), and the concentric ring model (City of Chicago), among others.

The case studies will illustrate the various approaches based on their country, topography, transportation systems, urban structure and economic status (developing or developed). The case studies will help identify challenges and effective ways of implementing transportation to improve efficiency. Based on a case study analysis, the international and national best practices will be determined by existing developments and urban models. The case studies addressed in Chapter 6 will be evaluated to create a table on specific components and approaches towards the implementation of transportation systems.

This chapter will include the delineation of all the significant aspects of improving TP within the urban structure on a practical framework. The chapter can be considered as a summary of all the significant aspects of the above case study analysis (cf. 6.2-6.11); it will help identify the components used within the urban structure and assist with the creation of guidelines to possibly improve the efficiency of transportation systems. This will illustrate the practicality of policy and spatial planning principles to assess and identify the possible advantages and disadvantages, as well as solutions, towards TP.

1.5.6 Chapter 7: Synthesis and Recommendations

The ultimate goal of this study is to follow a systematic pragmatic approach by identifying the TP traits of each model illustrated in the paper. Chapters have been combined to formulate a conclusive outcome for the research.

The synthesis illustrates a summary of each chapter, illustrating the relevance of the recommendations. The chapter demonstrates the use of an urban model known as the “Cullinan urban model” (CUrM hereafter) to illustrate the implementation of the proposed guidelines based on the research that will be performed. The chapter will address **Research Objective 5** (To have a more efficient spatial planning approach towards transport networks determined by the urban structure:). The information illustrated within the literature study, as well as the case studies, illustrates the functionality of transportation systems. The CUrM will demonstrate several practical guidelines for TP implementation as well as several urban structure planning guidelines, to improve current transport efficiency.

CHAPTER 2 RESEARCH METHODOLOGY

2.1 INTRODUCTION

The thesis addresses the efficiency of transportation systems within an urban structure. The problem statement suggests that, due to the increase in SOVs and population growth, transportation systems have decreased in efficiency causing congestion and other challenges that restrict mobility. The thesis also addresses the challenges to TP; if addressed, it is hoped that transportation efficiency will increase within all urban structures. Research suggests that the use of generic TP models may not accommodate the various types of urban structures. The thesis, therefore, will use a mixed-method approach (both qualitative and quantitative) to address this problem. The qualitative approach represents the core of the thesis, with the use of various experiences and phenomena based on past studies regarding implementation. The qualitative approach addresses past studies and information to form a fundamental base for the thesis, illustrating background information based on urban structures as well as transportation systems. The data will then reflect a case study analysis with practical implementations for several urban models (cf. 3.3) regarding the possible efficiency of transportation systems.

The quantitative data are addressed within the case study analysis (Chapter 6), which uses 10 case studies to determine similar or duplicate implementation principles. This will follow a testing process based on similar implementation strategies to improve transportation systems within the urban structure. The chapter illustrates the foundation of the research methodology and how the thesis will be structured through the pragmatic philosophy while using a deductive approach to theory development. The guidelines should illustrate possible land use, spatial planning guidelines and possible transportation guidelines.

This longitudinal research will illustrate a core foundation of theory and observation based on previous studies, which will use grounded theories and hypotheses. Due to the case studies, the data are collected over multiple points in time, illustrating several hypotheses that shift and change over time. The below Figure 2-1 illustrates the structure of the study by providing a background to the research methodology.

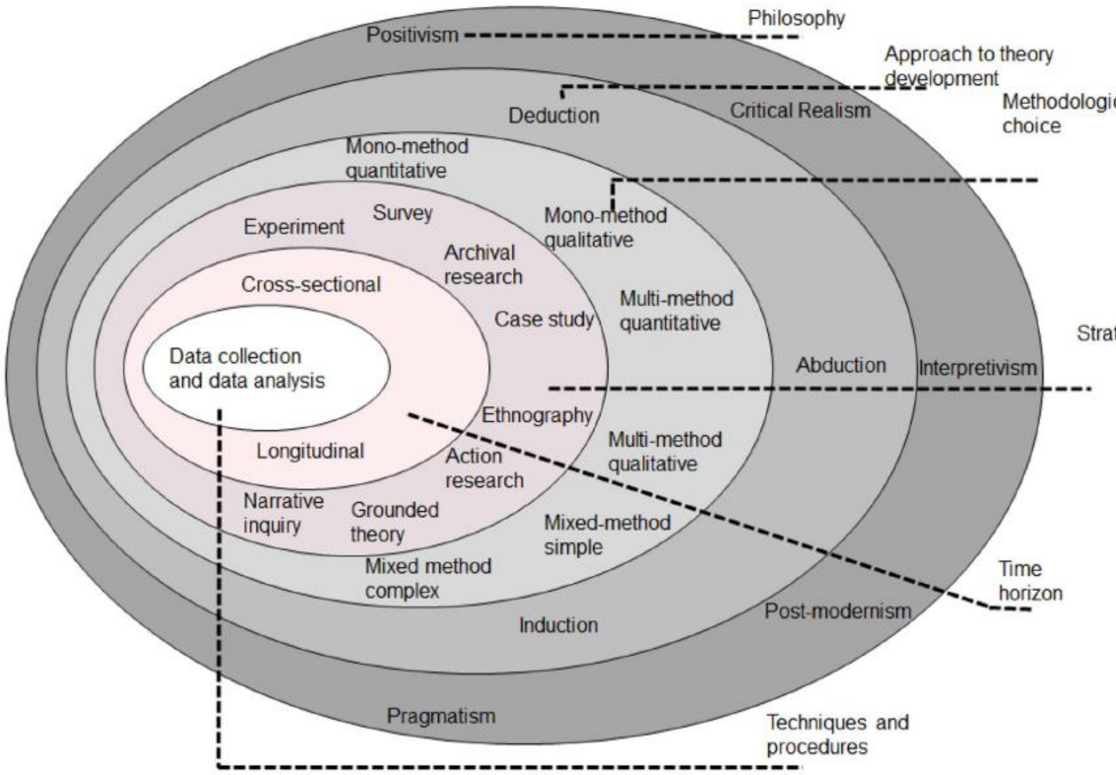


Figure 2 - 1 Research onion

Source: Saunders et al. (2019:108)

The core foundation of the pragmatic, mixed-methods study will be based on qualitative data collection illustrating past urban models, hypotheses and transportation models. This will illustrate the various urban models and transportation systems planned throughout various timelines to determine possible implementation strategies based on the urban structure and TP models. The data collected will focus on past, present and current implementation strategies and planning components. The study will address all components of transportation systems and urban structures throughout the study while illustrating significant challenges and possible solutions towards improving transportation efficiency throughout the urban structure. The research will follow a practical approach towards urban structures and the implementation of efficient transportation systems through the use of case studies.

The interplay of theory and method through mixed-method research is shown through the collection, analysis and subsequent testing of the data found in the case studies (Seuring *et al.*, 2020:5-6). The case studies will illustrate the various practical components implemented within the urban structure and the possible efficiency of transportation models. The use of quantitative data will be applied through the testing of the models within the case studies, illustrating the possible practical components towards implementing urban structures and improving transportation efficiency. The practical components assessed will be used to create policy guidelines to improve transportation efficiency and urban structure planning, which will be illustrated in a proposed urban model (CUrM) to demonstrate practical implementation.

2.2 RESEARCH PARADIGM

The research paradigm revolved around social research in the built environment. This study considered the systematic process of examining the implementation of efficient mobility and its impact on surrounding areas. Spatial planning is immensely important and is at the core of transportation systems that enhance the efficiency of the built environment through correct spatial implementation (Bertaud, 2002:3; Talpur *et al.*, 2012:1-3; Alqhatani *et al.*, 2014:218-219; Cullinan, 2019:62-63;). The research, therefore, considered a social research design that has led to the successful implementation of transportation system plans within the urban model; it also delved into how incorrect planning can hinder mobility in the structure.

The methodological paradigm of research (in this case, pragmatic) approached a data source and determined how it could effectively be used throughout the study (Du Toit & Mouton, 2011:1-4). As mentioned, based on this paradigm, the pragmatic approach systematically used a process which considered six facets, namely: i) research content; ii) research aim; iii) research purpose; iv) methodological paradigm; v) methodological approach, and vi) source of data (Du Toit & Mouton, 2011:131). (Du Toit & Mouton, 2011:131). The spatial content regarding the spatial planning perspective was identified through various articles to assess specific implementation points. Transportation systems and their spatial planning are akin to the human body – whilst everybody is controlled by electrical impulses that tell the body how to move, each body is unique; so too, are urban models (Hossain, 2018:1-2). The common features of an urban model are better understood as transport routes being the nervous system and the mode of transport being the electrical impulses sent to the 'brain'. Thus, 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 or limited control (Hossain, 2018:1-3; Cullinan, 2019:12).

This research aimed (cf. 1.3) to identify possible implementable TP models throughout the spatial form by employing effective strategies, principles and guidelines. The research purpose (cf. 1.5) was to improve the efficiency of mobility systems around and in the SS, which could 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 SOVs. The pragmatic approach assisted the researcher in identifying primary sources of data, through which case study and field data were ultimately collected for the comparative analysis (Du Toit & Mouton, 2011:131). The thesis was based on a comparative analysis, which focused on past spatial planning models to determine if local transportation systems were imperative in the development of sustainable cities. The same concept was shown in spatial planning of transportation systems, where limited access to certain areas of development and decreasing mobility in the areas could cause a decrease in economic development and lower quality of life (Rodrigue *et al.*, 2006:88) and harm to the environment, bringing development to a standstill (Pacione, 2005:787-789; Rodrigue *et al.*, 2006:174-179; Cilliers, 2010:28; Cullinan, 2019:91).

This pragmatic paradigm used a theoretical approach to qualitative data. This data could be classified as either primary or secondary data. This thesis followed a chronological approach throughout (Du Toit & Mouton, 2011:20).

2.3 RESEARCH APPROACH

This thesis had an interpretive, explanatory, descriptive research purpose. The methodological paradigm illustrated a mixed-method approach which involves the use of both qualitative and quantitative research. To begin, qualitative data were collected as primary and secondary core logic. The qualitative approach was used to illustrate the various hypotheses, concepts and experiences. The qualitative approach formed the base of this thesis to demonstrate the theoretical testing performed within the quantitative research approach. The quantitative research approach illustrated the testing of the above qualitative approach to form a theoretical hypothesis. The data underwent a theoretical testing process, which was demonstrated within the quantitative approach. The primary source of data was based on interpretation (ethnographical phenomenological and contextualisation), considered to be a hybrid approach to a theoretical study. The secondary source of data was identified through interpretation (hermeneutical) data (Du Toit & Mouton, 2011:20; Mol *et al.*, 2017:111-112). The thesis was based on a deductive research approach; thus, it focused on past spatial planning models to determine if local transportation systems were imperative in the development of sustainable cities, as stated (McDonagh, 1997:3).

The methodological paradigm included a chronological literature review (Du Toit & Mouton, 2011:132), in which international case studies were examined through a process of detecting similarities between various city transportation spatial plans. This involved a desktop analysis of international case studies regarding various cities' specific SS traits, allowing the researcher to identify elements of sustainable design. The elements or similarities in the developed countries were used in the recommendations to adapt the spatial design to a functional spatial plan. The research approach, methodological paradigm, and research design are interrelated components that collectively shape the structure and execution of the research study. The relationship is essential for ensuring coherence and rigor in the research process. The research approach also aimed to analyse the policy implementation and land use of areas. By identifying the perceived problems in developing cities, a solution could be implemented through the integration of various policies and spatial design, thus creating a sustainable city. Figure 2-2 illustrates the various research designs and methodological paradigms between the two research dimensions in this paper.

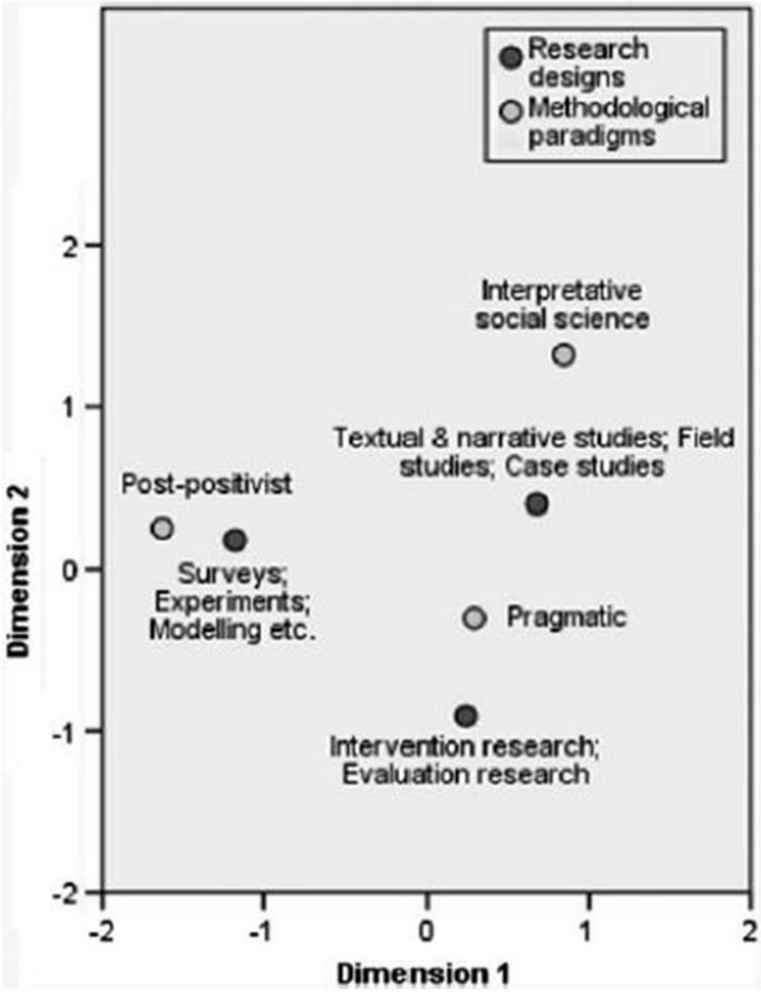


Figure 2 - 2 Relationship between research designs and methodological paradigms

Source: Du Toit & Mouton (2011:134)

The primary data, which was collected through interpretation (ethnographical, phenomenological and contextualisation), was expressed within various case studies and theories. This was implemented practically to develop a hypothesis, which aided in determining various implementable models, principles, guidelines, policies and potential ideas throughout the study (Wang, 2024:1-12). Some possible challenges and problems became evident when investigating mobility and spatial implementation (Du Toit & Mouton, 2011:132).

2.4 RESEARCH PURPOSE

The purpose of the research was to collect both qualitative and quantitative data. This data illustrated several urban structures to determine various guidelines which could improve the efficiency of transportation systems within an urban structure. The research purpose refers to the central aim or intent that guides a study. It articulates why the research is being conducted and what it seeks to achieve. This includes identifying the problem or issue being addressed, the scope of inquiry, and the expected contribution to knowledge, policy, or practice.

The study applied the pragmatic approach to a mixed-method study to discover these guidelines, as they could provide possible implementation strategies for both TP and SS. The data demonstrated possible problems and solutions towards urban structure planning and transportation systems. The qualitative data was applied through the use as the base point or core of the study based on previously implemented urban structures through hypothetical-, theory- and case studies. The quantitative data was shown through the comparative analysis compiled in Chapter 6, demonstrating the practical implementation of the qualitative data. The comparative analysis was used to test possible principles, urban structures, transportation systems and possible challenges. The mixed-method illustration described the applied knowledge and theoretical implementation of TP and SS.

This research sought to provide possible guidelines for all urban structures to efficiently implement transportation systems. The guidelines demonstrated the applied research and objectives throughout the study.

2.5 RESEARCH DESIGN

This study's research design followed a pragmatic paradigm using the mixed-method approach for the collection and illustration of qualitative data. Several case studies were performed (using qualitative data) to gather primary data which in turn aided in creating a model (using quantitative data) that considers all the implementable models, principles, guidelines, policies and potential advantages found throughout the study, as well as possible challenges and problems that became evident relating to mobility and spatial implementation (Du Toit & Mouton, 2011:132). Thus, the quantitative data was illustrated in the testing of urban models and transportation systems to determine the validity of possible guidelines to improve transportation efficiency. Figure 2-3 below illustrates the various approaches to methodological paradigms and various data sources used in the study. The research design illustrates the use of case studies within Chapter 6 and are applied within a pragmatic research paradigm using a mixed-method approach. This demonstrates a qualitative data collection and illustration due to the paradigm's emphasis on practicality, contextual relevance, and methodological pluralism. The pragmatic paradigm is not committed to any single system of philosophy or reality, instead valuing what works in a given context to address complex research questions. The mixed-method sampling approach is demonstrated through concurrent sampling (Creswell, 2009:17-18). The sampling technique is based on the qualitative study and derived from the various urban models illustrated in Chapter 3 (urban models). The qualitative study approached the theoretical implementation and illustrates the practical approach of implementation in Chapter 6 (urban model- case studies). This delineates the use of case studies to illustrate a real-world implementation. The quantitative data methodology is applied through the comparative analysis of the above case studies in testing the guidelines and approaches used within each applied case study in order to depict efficient and non-efficient planning guidelines.

The research design is illustrated through a desktop approach of both quantitative and qualitative data (mixed-method). The applied data demonstrates the use of the qualitative approach through the use of captured characteristics, concepts, perceptions, opinions, and experiences. This is illustrated through the use of hypothesis, observation, and case studies. The quantitative data is illustrated through the testing of the case studies in order to depict guidelines.

Research context & Research aim	Research purpose	Methodological paradigm	Methodological approach	Source of data	Core logic	Research designs
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

Figure 2 - 3 Research paradigms and the pragmatic approach

Source: Du Toit & Mouton (2011:132)

The above figure illustrates the applied research design, namely a methodological approach through both qualitative and quantitative data (mixed-method), to provide a hybrid source of data. This produced a core logic based on intervention as well as evaluation. Thus, the research was assessed through evaluation and intervention to provide a practical and theoretical solution to improving the efficiency of transportation systems. The above figure demonstrates the various research designs in order to illustrate the approach within the thesis. The research design applies qualitative data through the use of textual and narrative studies, as well as case studies. The research design includes the use of quantitative data through the use of modelling, simulation, mapping, and visualisation. This demonstrates the use of invention and evaluation of core logic which refers to a hybrid source of data collection.

2.6 CONCLUSION

This chapter illustrated the research methodology applied to the thesis with a comprehensive analysis of methods, paradigms and approaches towards the study. The chapter described the use of a mixed-method approach to illustrate previous theories and hypotheses through the study's achieved and implemented theories. The research discussed comprehensive background knowledge through the use of a pragmatic approach. This was illustrated through the applied methodological paradigm. The study sought to identify possible TP guidelines as well as urban structure guidelines to present a contribution towards improving transportation efficiency within the urban structure. The guidelines were based on practical implementation through a comparative analysis of case studies. The guidelines illustrate implementation strategies which could be used for any/all urban structures to improve the efficiency of transportation systems within the urban structure.

CHAPTER 3 URBAN STRUCTURES: A REVIEW

3.1 INTRODUCTION

Urban models are considered spatial design guidelines whereby a community could be planned to achieve maximum efficiency, economic growth, environmental sustainability and other priorities considered by the urban planner and dictated by the community's needs (Shaw & Xin, 2003:105). **This chapter is intended to achieve Research Objective 2 (To determine how sustainable transportation systems function within different urban structures)**. This chapter forms the foundation for urban structure and components which affect the urban model.

Many different urban models can be compared to determine both advantages and disadvantages. Therefore, the integration of urban models and TP has become crucial in terms of efficiency, sustainability and transportation systems. The built environment is under immense stress due to inefficient transportation systems and the effects of spatial planning of urban models (Wegner, 1995:1-2). Transport policies and environmental provisions are often only the beginning of poor spatial planning, reflecting a lack of awareness of future implications towards efficiency (Delucchi, 2009:448-459; Cullinan, 2019:16-18; Salimbene & Wiggins, 2020:59-63). The main concern is the impact on the efficiency of community mobility when TP fails to consider the urban model (Suzuki *et al.*, 2013:35-37). The urban models discussed in this study is based on a series of theories and their implementation. This chapter will discuss various urban models based on their urban structure, land use, transportation systems and functionality of implementation.

3.2 URBAN MODELS

This section discusses 10 urban models currently being used in both developed and developing countries. They include the i) garden city; ii) concentric ring; iii) multi-nuclei; iv) urban structure; v) urban realms; vi) twenty-first-century city (or 21st-century); vii) urban fabrics; viii) apartheid city; ix) Marchetti Constant, and x) theory of agricultural land-use models. The section will illustrate each urban model will be articulated against land use and mobility.

3.2.1 The garden city model

Urban models have taken on various forms of adaptation (such as in Welwyn, Canberra, Radburn, and Letchworth) in pursuit of a sustainable future. However, previous urban models that have failed do not seem to play a significant role in spatial planning (Nabil, 2021:4-6); rather, they act as a reminder of mistakes. Importantly, each model represents a specific approach to the urban structure, for example, economic growth, environmental preservation, efficient mobility and sustainability (Gataric *et al.*, 2019:34-41).

The garden city model focused on within this chapter is based on Ebenezer Howard`s model, which was implemented as London's urban model and has been modified (originally known as Abercrombie's Greater London Plan) (Pacione, 2005:256-257). The green city model, as presented by Howard in 1889, has proven to be highly sustainable (Phillips, 1970:15; Hurley, 2014; Clevenger & Andrews, 2017:5; Cullinan, 2019:18-19). 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. Howard's model reflected future traits without prior knowledge of modernisation; they managed to identify the changing elements at the time and developed this model to illustrate a true, sustainable urban model, as shown in the Figure 3-1 below (Phillips, 1970:6-8; Parsons & Schuyler, 2003:530-532; Cullinan, 2019:19-20).

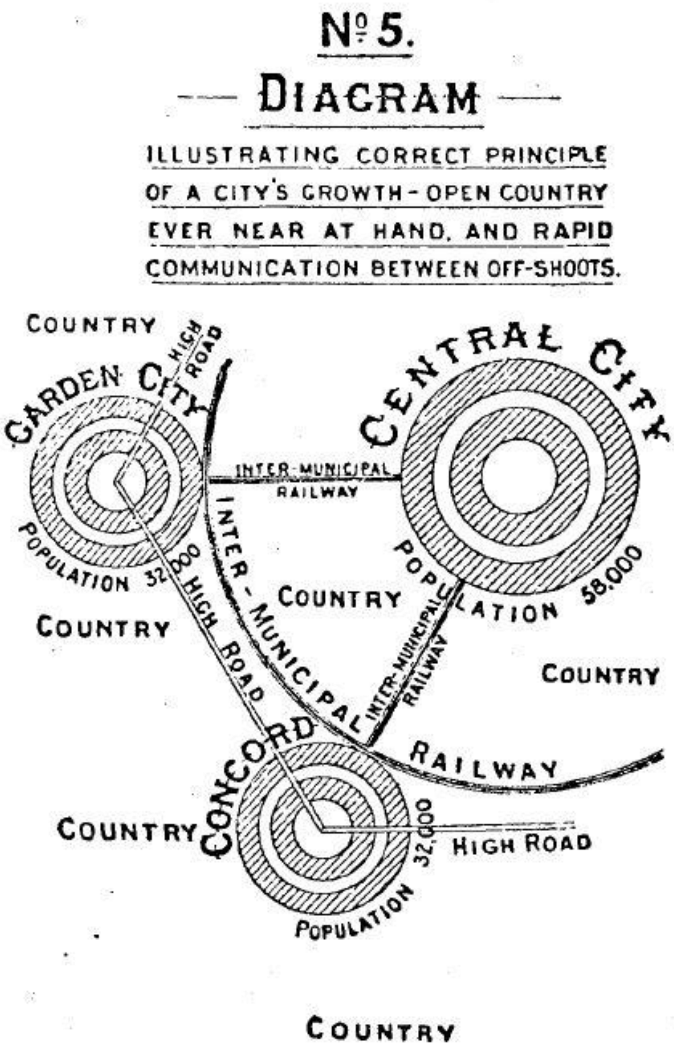


Figure 3 - 1 Garden city model

Source: Phillips (1970:50)

The garden city was a major component of spatial planning, which concentrated on the organisation of the city and its land uses. Previous conversations centred on both the advantages and disadvantages of this land use plan. Some of the world's most ecological and liveable towns, such as Adelaide and Canberra in Australia, have adopted the garden city idea (Cullinan, 2019:118-138). Every effective spatial development adapted to contemporary city models has demonstrated these principles (Prajapati & Paneria, 2021:21-24). Various garden city urban models have been implemented on various continents (Nabil, 2021:5).

Howard built their vision for the model around three ideas, namely identifying the issue, coming up with a solution, and how this would be accomplished. Considering the nineteenth-century (19^{th}-century) issues of overcrowding, poverty, crime, high death rate, congestion, land distribution, urban sprawl, and land ownership, Howard sought to find a solution using urban planning and land usage (Nabil, 2021:4-6). Howard sought to disperse London’s population northward by creating garden cities. The model’s design took into account several important factors, including transportation infrastructure. Howard intended to employ a small-scale exemplary model to accomplish their goal of nationalising rural, undeveloped land for the development of new towns (Phillips, 1970:15). Public transit was included in the garden city plan to improve efficiency and freight and individual mobility. Howard dubbed this the "garden city of tomorrow" to promote sustainable urban growth. In creating the garden city, Howard revolutionised four ideas, namely (Phillips, 1970:6, Parsons & Schuyler, 2003:531; Patel, 2017:13):

- Limited acreage must be set aside for a particular purpose for possible users;
- An improved physical environment must be built in an urban area, which includes better housing and transportation, more parks and open spaces, and more hygienic amenities, all while maintaining the environment – this includes a wide diversity of flora and fauna;
- Communities and little, economically viable towns will guarantee a higher standard of living. Given the availability of open space, this frequently consists of new, low-density settlements; and
- Compact cities must be built to generate sizable activity hubs. Due to confined activity and centralised nodes, this will essentially boost the mobility and efficiency of transport systems.

This plan served as the foundation for upcoming town planning and modernisation occurred without suggestions for integration into the garden city due to presumptions (Phillips, 1970:6–8, Parsons & Schuyler, 2003:531) that human nature and behaviour, the economy, and social values would all stay the same or barely change. This gave rise to the theory that societal shifts could impact design in the future. The ultimate supposition was that there would be no discernible change in the connection between humans and the natural world, with a greater emphasis on environmental sustainability. These presumptions were used to build the garden city, but they lacked guidelines for population expansion, excessive use of natural resources, and land use planning after the city had grown to its limit (Pacione, 2005:24; Cullinan, 2019:50).

3.2.1.1 Land use

The garden city illustrates the land use in Figure 3-2 and identifies various zones. Howard's ideology was based on greenery and sustainability, hence the *garden* city. The concept comprises a green central business district (CBD) and radiates outwards with arterial roads and local road webbing to provide access into neighbourhoods and other land use areas. The industrial areas are situated on the outskirts of the model to prevent air and noise pollution and a decrease in land use value to the internal residential areas of the model. Radial network planning acts as an irregular grid that provides access to the urban model. The interesting factor associated with this model is the large greenbelt which surrounds the urban model to prevent urban sprawl from occurring. The model had been designed to prevent growth and act as a single activity node that compacts transportation and land use – known as compact cities. Through centralising and limiting growth, it acts as a self-sustaining urban model, where goods as well as services circulate within this node.

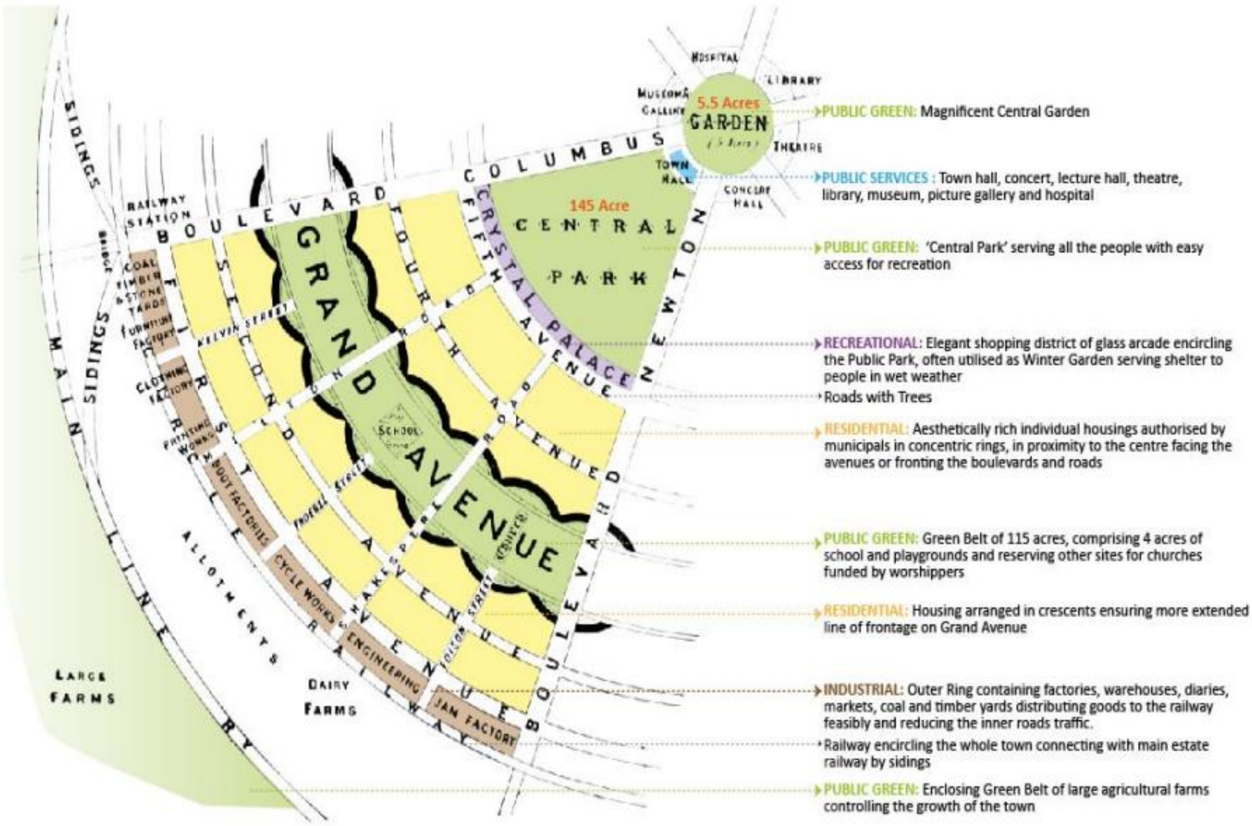


Figure 3 - 2 The garden city land use layout

Source: Nabila (2021:3)

The spatial planning context included the natural environment, which was used to obtain natural resources through eco-cities. This is based on the principle that garden cities should improve economic development, social ecology, bioregionalism and sustainable development.

The land use of the garden city is seen through various concentric zones linked to transportation infrastructure and several types of mobility. To understand and determine the functionality of the urban model, land use should be identified, and the implementation should be done to understand the flow of the network between sectors and the efficiency of the flow. Howard`s city was based on several principles (Pacione, 2005:226-230):

- Each garden city would be limited to 32 000 people in population size;
- The garden city would be large enough to create sufficient jobs and ultimately become self-supporting;
- There will be a diversity of activities and social institutions for communities;
- The garden city would be spacious and open;
- The land will be owned by the local municipality and rented/ leased out to private concerns to avoid any increases in land value to the community as a whole, to keep living costs low and affordable;
- The method of growth that would occur is known as colonisation; and
- The garden city would have a distinct attribute known as a green belt, which would be used for recreational space, agriculture and most importantly to limit the physical growth of the city.

The above principles illustrate consideration towards land, population as well as aesthetics. The first garden city did not follow the basic principles of a garden city and was not considered to be as functional as the modern-day improved garden cities (Phillips, 1970:6; Parsons & Schuyler, 2003:531; Cullinan, 2019:18-19). The first attempts to create a garden city were made at Radburn (Nabil, 2021:5) by the New York-based Regional Planning Association of America, which functioned between 1923 and 1933. Whilst Radburn never honoured three of the basic garden-city principles (the green belt, the provision of industry, municipal ownership and control), it remains one of the United States of America's (USA) most significant experiments in comprehensive urban planning (Pacione, 2005:226).

3.2.1.2 Mobility

The garden city model reflects a multimodal transportation system. The transportation system implemented illustrates that road infrastructure dominates the urban structure (Phillips, 1970:50; Waugh, 2002:423; Cullinan, 2019:18-20; Nabil, 2021:5). SOVs and road-based transportation are prominent in the previous land use figure (see Figure 3-2). The modern-era concept of transportation systems is influenced by increased transportation infrastructure. The increase in road infrastructure has increased the use of SOVs due to the lack of multimodal transportation options provided (Rodrigue *et al.*, 2006:101-102; Dur & Yigitcanlar, 2015:814). The garden city model illustrates the implementation of road infrastructure among other transportation modes but also focuses on aesthetics.

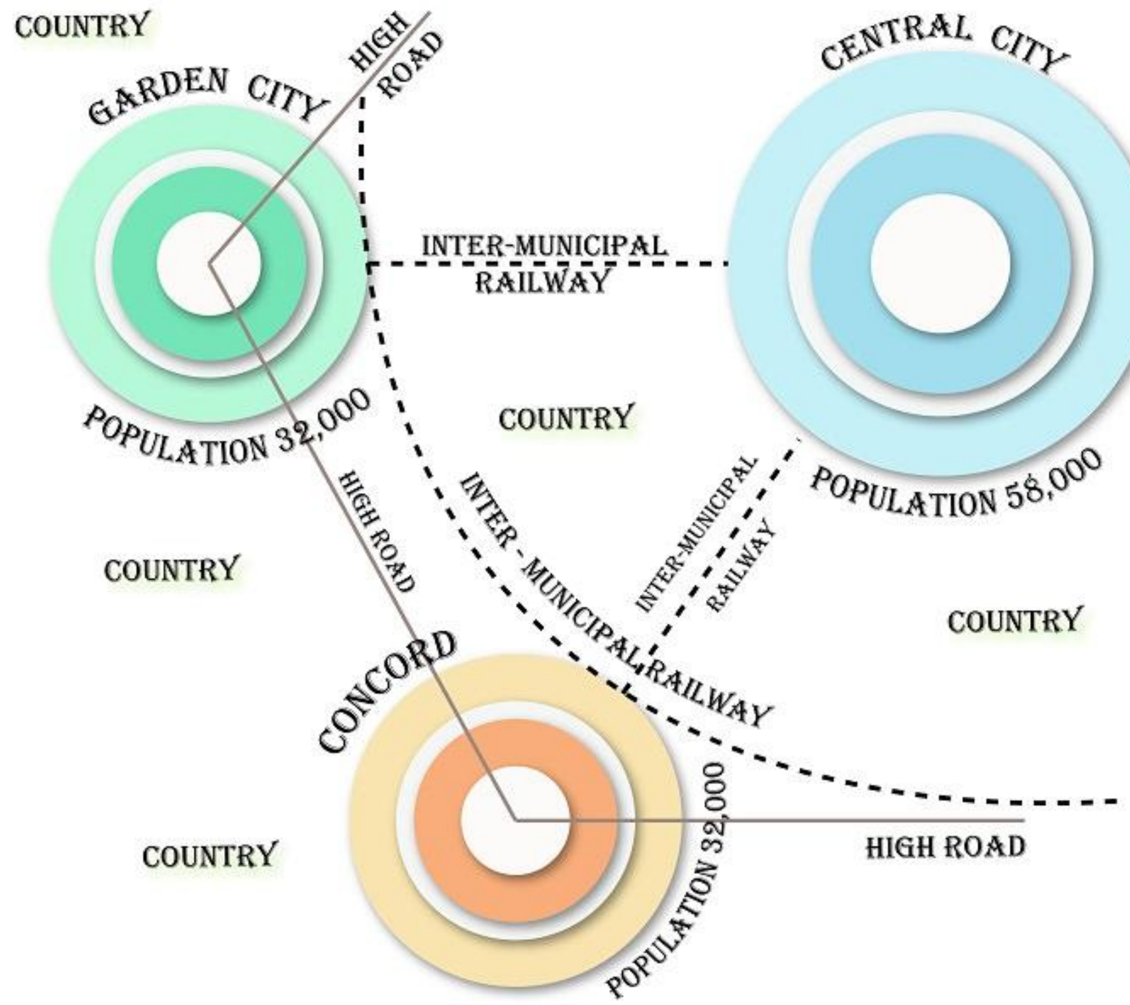


Figure 3 - 3 Garden city model transportation system

Source: Planning Tank (2020) and Phillips (1970:50)

The garden city's approach towards mobility followed a multimodal sequence, as illustrated in the above Figure 3-3. The urban model would delegate various transportation modes throughout the model based on the needs of the community (Nabil, 2021:2-4). Road infrastructure and highways were delegated to the urban model's outskirts and used for long, interregional travel. Road infrastructure is illustrated throughout the garden city model in Figure 3-3, spaced out to provide sufficient space for land use and greenery (Xu *et al.*, 2012:20-21). The model illustrates that the community frequently used vehicles and other road mobility. The point of interest illustrates that land had been conserved in this process, as illustrated in Figure 3-2. The garden city also used other modes of transportation, such as rail, as illustrated in Figure 3-3. Rail infrastructure was delegated within the urban model and had been specifically planned from the outer part of the model to the core CBD area (Phillips, 1970:49-51). The rail system was used to provide goods and services to the core CBD area and surrounding industries from the implemented green belt area. The green belt, as noted, was used as agricultural land and would require transportation to the internal factories and industries to manufacture goods for the residing community (Patel, 2017:13; Cullinan, 2019:190). This indicates that the rail infrastructure and mobility system had been used to carry freight from the agricultural area to the internal factories and from this point to the CBD to sell goods to the community. This requires the mobility system to be efficient in providing the community with essential needs (Gataric *et al.*, 2019:35-36).

The garden city included sustainable transportation, for example, walking and cycling (Gataric *et al.*, 2019:39). Howard used this sustainable transportation to incorporate the concept of the garden city (Hurley, 2014; Clevenger & Andrews, 2017:5). The city would incorporate pavements for pedestrians and cyclists to appreciate the green design of the city and to reach their destination. The residential areas are allocated in the middle of the urban model (see Figure 3-1), which illustrates that walking and cycling would be possible if moving towards the agricultural green belt or the factories and industries around the CBD area (Nabila, 2021:3). This concept has been illustrated in the Marchetti Constant model, illustrating a five-kilometre (5km) distance between the residential area and place of work (this model is discussed later) (Marchetti, 1994:77; Cullinan, 2019:40). Howard had foreseen distance as a possible problem within mobility systems and had provided various alternatives which the community could utilise.

3.2.2 The concentric ring model

The early stages of this urban land-use model were presented by Ernest Burgess in 1923. The theory illustrated behind the land-use model was that numerous concentric rings would lead the city's growth further outward from the centre ring. Burgess's theory was created from Von Thunen's previous urban structures (O'Kelly & Bryan, 1996:457-467; Rodrigue, 2013:114-115). The design was initially created to implement rural land use and values a century before Burgess. The model was created to illustrate the concept of a medieval village, which does not consider technological advances (McDonagh, 1997:1-2).

According to Burgess, the city constantly grew because of population pressures – a highly unpredictable and uncontrollable issue when planning urban models and structures. This would trigger a dual process of central agglomeration and commercial decentralisation; that is, spatial competition attracted new activities to the centre of the city but also repelled other activities to the fringe area (Rodrigue, 2013:115). As activities themselves were located on the fringe, the fringe itself was pushed farther out from the city. The area of the city continually grew outwards as activities that lost out in CBD competition were relocated to the shifting periphery (Rodrigue, 2013:113-115). In Burgess' theory, the city would eventually take on the form of a highly concentrated CBD that would dominate the region and be the site for the highest competitive land prices, while the surrounding area would comprise four distinct concentric rings. These include a zone in transition; a zone of workingmen's houses; a residential zone, and a commuter zone (Gottdiener *et al.*, 2016:84-85).

The concentric ring model illustrates the distribution of social groups and land use within urban areas, which is illustrated within the apartheid model implemented in South Africa (discussed later). The concentric ring model was created through Burgess's observation of the distance from the CBD and the wealth of the inhabited area. This illustrates that wealthier families would be situated on the outer part of the urban structure while the poor and middle class would live closer to the CBD and industrial areas (Chaplin & Kaiser, 1979:32; Cilliers, 2010:15). The simple explanation has to do with mobility and distance from the workplace. The wealthier individuals were able to afford transportation services or SOV to travel to and from the CBD, while the poor and middle class would use public transportation services, bicycles and walking to attend work each day (Rodrigue, 2013:115-117).

3.2.2.1 Land use

The central ring is known as the central district or CBD, which consists of high-rent uses often occupied by office buildings, department stores and other retailers. This illustrates the central activity node within the model based on the figure below (see Figure 3-4) and Burgess's assumptions, as previously illustrated. The 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 to create a central economic activity node. 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 (White, 1987:236-240; Pacione, 2005:148-149; Cilliers, 2010:15-16). The Burgess urban land-use model began to adapt and in time each concentric ring developed its specific uses, while also being given specific labels (Pacione, 2005:187-193). 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 which would accommodate various retail establishments (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 (Pacione, 2005:191-192; Cilliers, 2010:15; Cullinan:2019:21-23). The concentric rings then verge outwards, allowing 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.

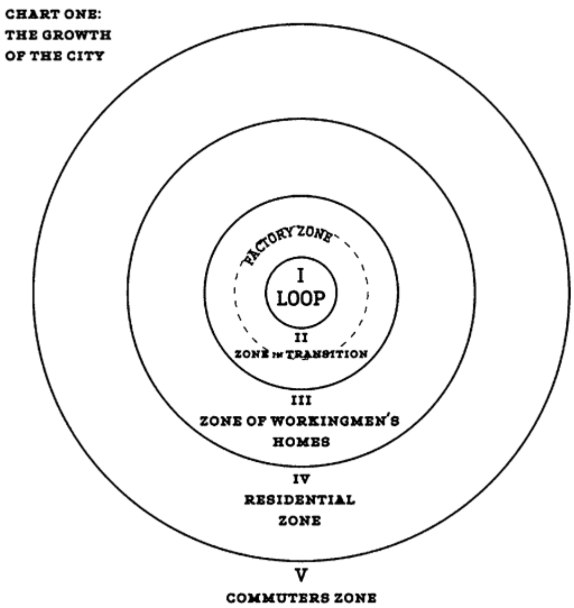


Figure 3 - 4 Concentric zone model

Source: Adhvaryu (2010:125)

Burgess's concentric zone model had been adapted and as a result was composed of five concentric rings, which separate different land uses, but are not restrained by a green belt as illustrated in the garden city model (cf. 3.2.1). The urban structure of the Burgess urban model has been illustrated and emphasised within the above paragraphs and is summarised in the subsections below (Chaplin & Kaiser, 1979:32; Cilliers, 2010:15).

- ***Zone 1 - Central Business District (CBD)***

This comprises the innermost ring containing the shops and offices. It is used to attract the residing community to a central activity node to improve economic growth and efficiency. It is the main entertainment area and has the highest activity level in the city. Based on Burgess's assumptions, this is where the most economic growth would take place.

- ***Zone 2 - Transitional zone***

The transitional zone is considered to be an area of work for lower-class individuals due to stagnation and constant pollution from the factories and old buildings occupying the area. Land value is considered to be low and most affordable within the concentric ring urban model. 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. The area offers proximity to the workplace for factory workers and the lower class due to the affordability of rentals as well as little to no mobility costs from transportation systems. The use of bicycles and walkability allow for quick, efficient and low-cost mobility, which is considered to be ideal for poorer living classes.

- ***Zone 3 - Lower-class housing***

This is occupied by individuals who have ‘escaped’ the transitional zone but are considered to be poor. As they live close to the CBD and transitional zone, their travel costs are lower. This is a high-density area with low land value. The individuals are considered lower-class residents and can afford the minimal costs of mobility and transportation systems. The land value within this area is considered to be higher than within the transitional area (Zone 2) but is still affordable. The difference between the transitional zone and the lower-class residence zone is the distance from the factories located within the transitional zone. The individuals acquiring the lower-class zone can afford to use public transportation to get to and from the workplace. The land value is considered to be low due to the pollution from the transitional zone thanks in large part to the manufacturing of products within factories.

- ***Zone 4 Medium-class housing***

This is a housing zone where land value is higher than in the previous zones, with private residences as well as apartments. This concentric ring is home to the more white-collar families. The area will consist of townhouses and private property. Land value is higher within this concentric zone in comparison to the transitional zone and lower-class residential zone. The land is situated a long proximity from the transition area which is acquired by factories and pollution is blocked by the lower class residential concentric ring, which would act as a barrier. Individuals in the area can afford to utilise the implemented transportation systems or public transportation to go to and from work.

- ***Zone 5 Higher-class housing***

This area has the highest land value, and lowest density and is distant from the transitional zone and CBD. This concentric ring would be considered the ideal living concentric ring but is determined by the land value and affordability of the occupant or buyer. The families and individuals occupying the area would not consider transportation as a major factor and could effectively afford any transportation system based on choice or preference.

3.2.2.2 Discussion

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 or 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 (Pacione, 2005:189-191). 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 (Waugh, 2002:420; Cilliers, 2010:14-15). 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 (Cullinan, 2019:21-23). This had proven to be false based on previous assumptions.

An additional problem raised in terms of geographical features is that these would often prevent the radial development of urban settlements because of the influence and impact on surrounding towns/cities. The 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 were created and this would affect the patterns and growth of other surrounding urban areas (McDonagh, 1997:3).

3.2.2.3 Mobility

The concentric ring model's mobility system is considered a pre-twentieth-century (20th-century) transportation system dated back to 1925 (McDonagh, 1997:1-2). The model illustrates the movement between concentric rings and land use. The implementation of transportation systems can be delegated to distance travel, whereby some transportation systems can travel further than others. The correct implementation of transportation systems can create mobility between different land uses, based on distance travelled. The current transportation systems shown in the Figure 3-5 below illustrate the maximum distance each of those transportation systems can travel effectively. This is also present in the Marchetti urban model, which demonstrates mobility and effective travel over a specific distance from the centre of the urban structure CBD (Marchetti, 1994:77; Cullinan, 2019:40-41). This will determine the efficiency and functionality of the urban model and the importance of the implemented transportation system at the time. The below Figure 3-5 illustrates this predated mobility system and the movement of the residents.

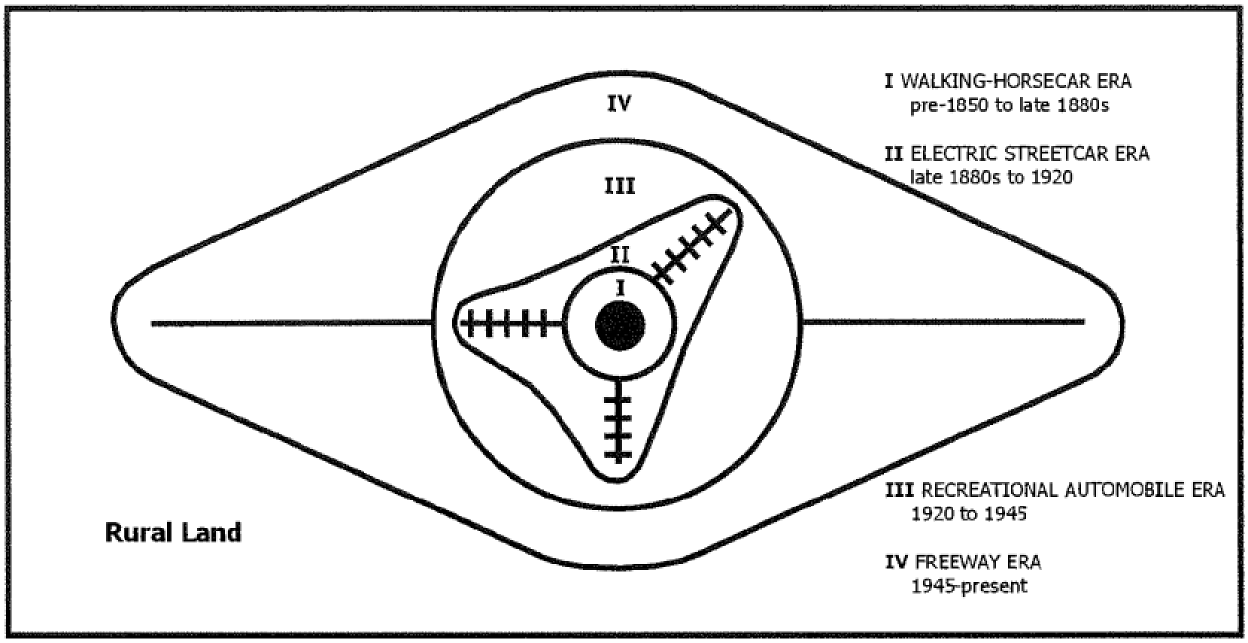


Figure 3 - 5 Mobility of concentric ring model

Source: Adams (1970:56)

The above Figure 3-5 illustrates the implementation of transportation within the concentric ring model and movement between concentric rings. The land use of this urban model has been specified in the above subsection and can be seen in the Figure 3-6 below.

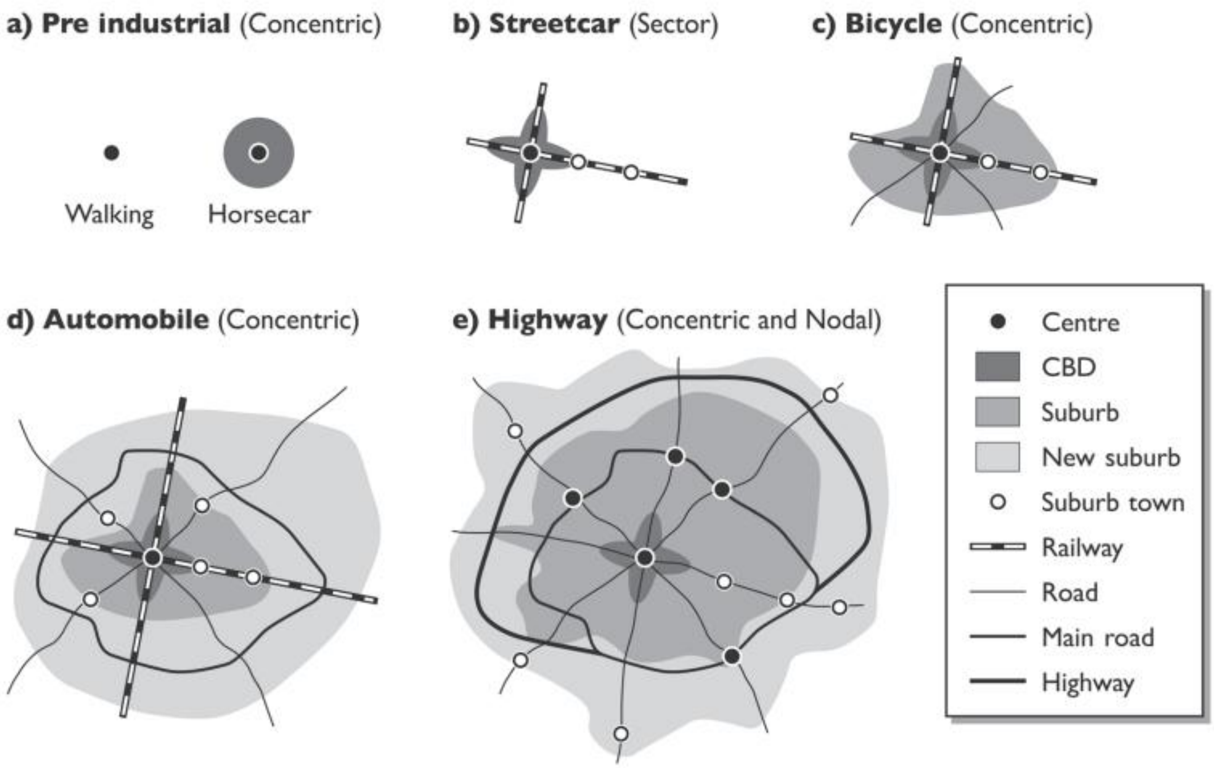


Figure 3 - 6 Transportation systems' evolution in concentric ring land use

Source: Rodrigue (2013:115)

The Figure 3-6 above illustrates the various transportation systems used within the concentric ring model's evolutionary transportation development system. The pre-industrial transportation model as illustrated in Figure 3-6, illustrates the original urban structure of the concentric ring model. These transportation systems predate the creation of the existing model but illustrate the concentric rings and movement thereof. Based on the figure (see Figure 3-6), the predated transportation systems implemented can be discussed below.

- ***Walkability or bicycles***

The movement between (concentric) Zones 1 and 2 illustrates no implemented transportation systems, which determines that other transport or mobility systems have been implemented based on the proximity of the concentric rings. Thus, mobility could be achieved through walkability or bicycles. This simple transportation system would be efficient in moving between Zones 1 and 2 (Marchetti, 1994:77; Rodrigue, 2013:108).

- ***Walking horse carts***

Horse carts were used as transportation modes between Zones 2 and 3. The zone illustration above illustrates that Zone 2 is considered to be the transitional zone and Zone 3 is considered to be the lower-class residential area for the poorer-class residents. The use of horse carts and possibly walkability illustrates that transportation systems were considered to be affordable for those residents. Zone 2 was determined to be used as a manufacturing zone, which illustrates that the transportation systems were used to move to and from the workplace (Cilliers, 2010:14-15; Cullinan, 2019:21-22). This specific transportation mode predated 20th-century transportation systems but specifically illustrates the purpose of these concentric rings (Pacione, 2005:76-77).

- ***Electric streetcar***

The electric streetcar, known as a tram, was used from Zone 3 to the end of Zone 4. The light rail transit (LRT) system was used as a public transportation service for the community to move to and from work. This type of transportation system would require a fee to utilise it and would vary depending on the local authority or municipality. The concept of the tram was to increase the mobility of individuals between the CBD and residential areas, while distance restrictions may have impacted this transportation system (Rodrigue *et al.*, 2006:178; Thomson & Newman, 2018:222). The LRT (a tram) had been used in the concentric ring model by both the lower and middle classes to go to and from central places of interest (Marchetti, 1994:77; Cullinan, 2019:37-38). This transportation system has been considered to be efficient and has been implemented in most developed countries (Pacione, 2005:360-361).

- ***Recreational automobile***

Recreational automobiles are considered to be a mode of road transportation. The recreational automobile is considered to be a SOV and a luxury transportation mode. This mode of transportation can be used throughout the concentric ring model and can access all land use (Cullinan, 2019:38-39). This mode of transportation had only been implemented in the late 19th-century and required road infrastructure to operate (Pacione, 2005:361). The road infrastructure would require land use to acquire access to multiple land uses. This mode of transportation had been considered as efficient. The reason behind its efficiency was due to the ability to be utilised at any time required, long-distance travel, time taken on travel, cost of travel and availability of infrastructure (Thomson & Newman, 2018:222).

- ***Freeway or major road network***

The freeway and major road network are considered to be an infrastructure for extending road transportation around and to other urban structures. The freeway infrastructure had been designed to uphold high volumes of traffic while maintaining a high speed to increase mobility and decrease travel time (Cullinan, 2019:80-81). The freeway offered individuals the choice of travel distance and time travelled to achieve each daily or monthly objective (Pacione, 2005:361). The motor vehicle, or SOV, had been recently invented and designed to function on road infrastructure (Rodrigue *et al.*, 2006:174). This type of transportation system is costly to maintain and operate, which means that few were able to obtain this luxury and were confined to public transportation.

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 competing satellite urban centres on the distribution of land uses (Cullinan, 2019:22-23). 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 (Cilliers, 2010:15) because of the problems caused by traffic volumes. This would also attract lower-income occupiers, who could use public transportation near their homes, similar to the concentric rings model. This theory tends to alleviate the problem but does underestimate its impact on the area (Pacione, 2005:189-193).

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 (Adams, 1970:56; refer to Figure 3-5). Traffic congestion in larger cities is often caused by the incorrect implementation of urban land use design that does not adapt to general requirements. While travel costs may not be of serious concern to higher-class earners, travel and commuting are still time-consuming, thus decreasing productivity (Cullinan, 2019:23). This affects general economic growth over time, which is detrimental to the urban model (McDonagh, 1997:3).

3.2.3 The multi-nuclei model

Through the analysis of the concentric zoning (cf. 3.2.2) and sector urban land-use models, Harris and Ullman found that many parts of the model's perception and design were left out, potentially leading to future issues (Pacione, 2005:193-194). Their conceptual design was grounded in a practical application of the urban land use design model, encompassing the variables that could impact the function of the urban design. Enhancing functionality and efficiency throughout land use had been the primary goals. Harris and Ullman compared their urban model to Burgess and Hoyt's models; this was more intricate, but it would also provide greater insight into how urban planning generally works. Harris and Ullman's model is thought to be the third and final classic urban model regarding the spatial planning of cities (Johnson, 1967:170; Herbert, 1972:72). The garden city (cf. 3.2.1) and concentric ring (cf. 3.2.2) models yielded a single core CBD region; this new concept included many CBD sections. Thus, in 1945, the multi-nuclei model was developed as the first urban land-use model (Wegner, 1995:4).

The multi-nuclei urban land use structure was used for large cities and was considered to be an enlargement of Hoyt’s design (Cullinan, 2019:24-26), as it was more centralised and efficient for the 20th century. 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 (Pacione, 2005:193-194). The model focused on transportation systems and hierarchy; it presented an equilibrium between land use and the purpose thereof. The nuclei (CBD) would develop a type of hierarchy, through which an equal rank would have been established through the types of land use.

3.2.3.1 Land use

The multi-nuclei model's land use had different assumptions compared to the garden city (cf. 3.2.1) and concentric ring models (cf. 3.2.2). One of the main reasons it was regarded as a multi-nuclei model was 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).

The model's spatial layout, time and distance became an issue, forcing the CBD to take on new functions. The issue first arose at the outbreak of the Second World War (WWII), as the importance of motor vehicles increased and the extensive growth of transport networks and the building of new roadways became necessary. The CBD experienced urban congestion as a result. It was discovered that public transit systems might reduce traffic congestion, which would greatly strengthen the CBD (Wegner, 1995:4).

Burgess and Hoyt's theories served as the foundation for the multi-nuclei model's presumptions. The resulting model's realisation was interpreted as follows (Herbert, 1972:72; Chapin & Kaiser, 1979:36; Waugh, 2002;423; Pacione, 2005:145; Cullinan, 2019:25-27):

- Within the urban landform, nuclei serve as growth points and have distinct primary functions (city);
- Each nucleus eventually grows outward and unites to form a single, sizable urban landform centre;
- The urban structures and designs of modern cities are far more intricate than those of the straightforward models created by Burgess and Hoyt;
- Several separate nuclei rather than a single nucleus are the sources from which cities and towns develop; and
- If the city becomes too densely populated, certain functions might be divided up into several nuclei.

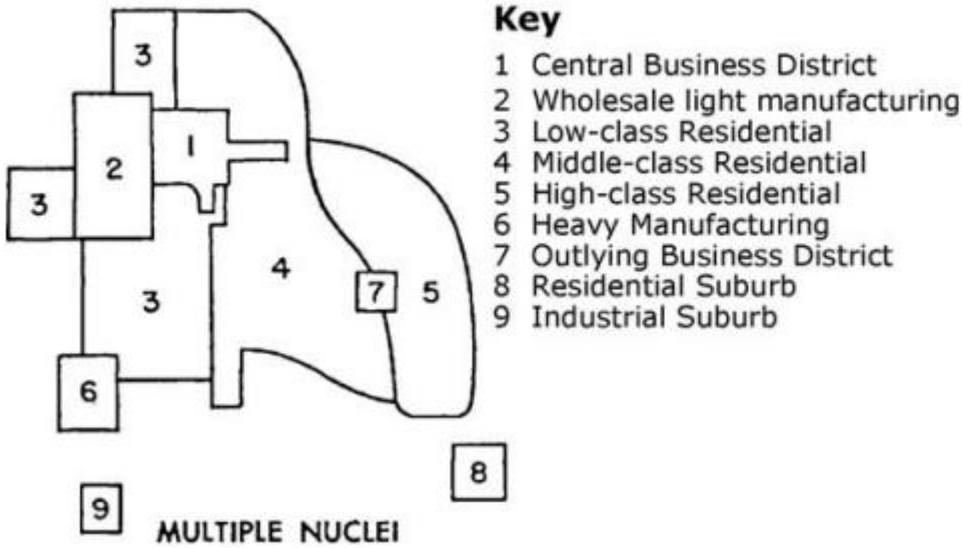


Figure 3 - 7 Multi-nuclei model

Source: Adhvaryu (2010:126)

According to Harris and Ullman, not every city can be ranked using the same criteria because different cities may have different social, cultural, and industrial conditions. This establishes the city's structure and might not allow for the right land uses in the right places (Pacione, 2005:145). The urban land-use model developed by Harris and Ullman served a useful function in that it addressed the requirement for maximum accessibility to the centre for decentralisation and, more crucially, to protect land value through the separation of land use (Chapin & Kaiser, 1979:37). Nodes will grow on the edges and spread outward as a centre of interest. The multi-nuclei model's conceptual design is depicted in the Figure 3-8 below. The model shows an alternative urban structure to the concentric ring (cf. 3.2.2) or garden city (cf. 3.2.1) models:

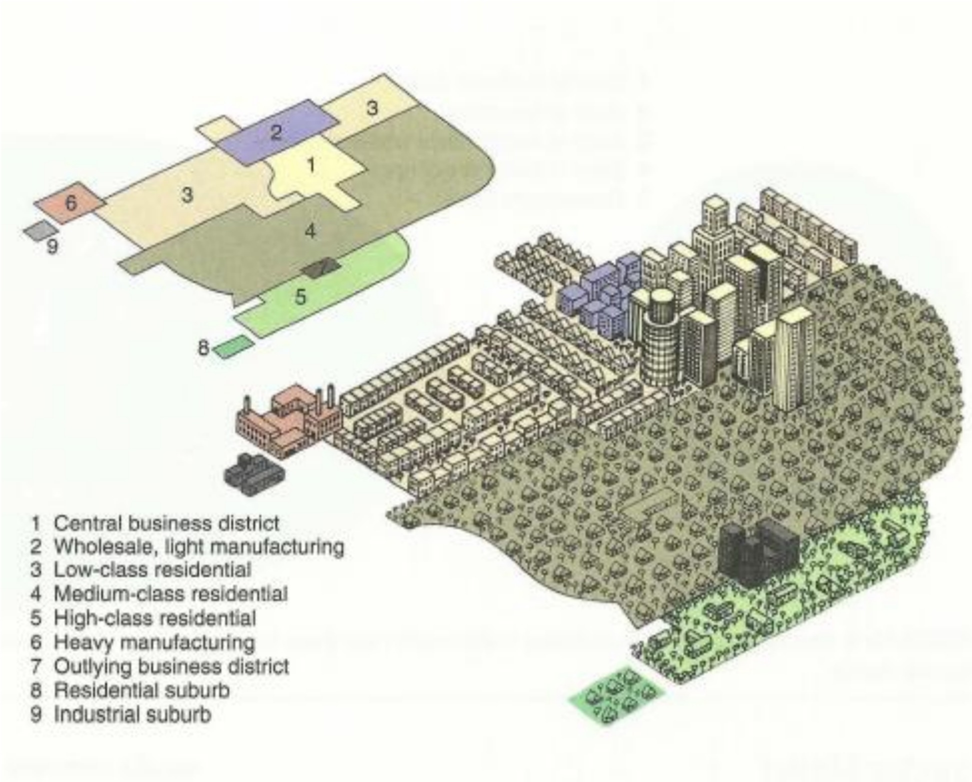


Figure 3 - 8 Multi-nuclei model and distribution of land use

Source: Planning Tank (2020)

The above Figure 3-8 illustrates the implementation of land use within the multi-nuclei model. The land use had been divided into nine sections which differs from the conventional six sections within the concentric ring model (cf. 3.2.2). The model had been designed to operate from various nuclei (CBD/industrial) allowing for increased economic activities and job opportunities. The distribution of various sectors illustrates several CBD areas and numerous industrial areas. The industrial sector was divided into various manufacturing categories (heavy, medium and light) to conserve land use and its market value. The nine land use sections are discussed in the subsections below.

- ***Central business district (CBD)***

The CBD still existed as the primary nucleus, however, multiple small business districts were developed and distributed around the metropolitan area, hence the multi-nuclei model. Most of the undeveloped new areas competed with the CBD for traditional businesses such as banks, real estate, and insurance companies. These separate nuclei became specialised and differentiated, reducing the pull of the CBD.

- ***Light industrial area***

These businesses were more consumer-oriented and based on the demand and supply concept within all cities, which were situated near residential areas. Manufacturing goods that need small amounts of raw materials and space developed in this area. This manufacturing process was not as detrimental to land value as the other manufacturing categories. The businesses that offered wholesale goods like clothes, furniture and consumer electronics were found in this node or CBD area.

- ***Low-income residential area***

Residential neighbourhoods had various class statuses and emerged in a nearly random fashion, creating "pockets" of housing for both the rich and poor alongside large zones of lower-middle-class housing. There is a sort of randomness to multi-nuclei cities, making the landscape less legible for those not familiar with the city, unlike the concentric ring (as discussed before) cities that are easy to read by outsiders who have been to other similar cities.

The lower-class residential areas had specific mobility corridors known as industrial corridors for the lower- or working-class residential zones. The assumption of people who live here tend to be factory workers and live in low-income housing. The lower-class housing area was considered affordable or cheap due to its proximity to industry where pollution, traffic, railroads, and environmental hazards made living conditions poor. Those living in this sector did so to reduce commuting costs to work. Those living on the "other side of the tracks," may have experienced discrimination due to the various hierarchies of class. This has been determined from other urban models, for example, the apartheid urban model implemented in South Africa (Davies, 1981:59-72).

- ***Medium-income residential area***

The middle-class residential area had been assumed to work the majority of the time within the CBD, and due to its proximity to and from the CBD, it would have been seen as affordable. The land value was higher due to its distance from industrial zones, which minimised all types of pollution.

This middle-class residential area was considered more desirable because it was located further from industry and pollution. People who work in the CBD had access to good transportation lines, making their commute easier. The middle-class sector was the largest residential area.

- ***High-income residential area***

Hoyt's model also identified an elite zone, for the few upper-class individuals who lived in the city. For example, Michigan Avenue was an elite district in Chicago (Johnson, 1967:167; Waugh, 2002;423;). High-class residential sectors tended to be quiet and clean with less traffic than others. The land value was high. There was also a corridor that extended from the CBD to the edge of the city, where you could find prime real estate.

In many cities, the high-class district is often on the west side, where prevailing winds enter the city and are upwind from industrial zones (which are dirty and smelly). It was unlikely that high-class residential housing would be found near factories or lower-class housing areas. In this way, Hoyt's model suggests a distinct physical separation between the wealthy and the poor (Johnson, 1967:169; Herbert, 1972; Waugh, 2002:422; Pacione, 2005:147).

- ***Heavy industrial area***

This node was occupied by factories that produced heavy materials such as chemicals, steel, and industrial machinery. Mining and oil refining industries could also be found in this node. The zone was situated far from middle-class and higher-class residences due to the pollution produced by these factories. Thus, it was located on the brim of the lower-class residences to increase mobility efficiency while considering the cost of transportation systems for the low-class individuals, who had been assumed to work within the industrial zone.

- ***Outlying business district (CBD – Number 2)***

This district competed with the CBD for residents living in nearby middle and high-class neighbourhoods offering similar services and products. The zone was considered to be an additional activity node for residents. The activity node was used as a secondary point to obtain goods and services, with various types of businesses found such as malls, airports, colleges and community businesses.

- ***Residential suburb***

These suburbs were usually single-family homes on a small plot of land on the city's outskirts. They tended to be laid out on roads with cul-de-sacs instead of following the traditional grid pattern. These types of residential areas were considered to be separate from the model but due to the main core (CBD), the residential area would proceed to obtain their goods and services from the urban model.

- ***Industrial suburb***

This was a community created and zoned for industrial sources on the city's outskirts. Industrial districts in these new cities, unfettered by the need to access rail or water corridors, instead relied on truck freight to receive supplies and to ship products, allowing them to occur anywhere (zoning laws permitting). Since industrial zones create pollution, they were located away from residential areas.

3.2.3.2 Mobility

The mobility of the multi-nuclei model is based on the Chicago design implemented in the USA. The mobility was based on a grid street pattern, which was common in early planner designs (Rifaat *et al.*, 2012:336-339). The mobility of the grid street pattern was based on the use of motor vehicle transportation and the implementation of multiple streets intersecting one another. The grid pattern mobility system was illustrated to have various criticisms towards its design, including safety considerations. The mobility of this urban model had also been considered to be efficient due to its access to various land uses and various alternating routes (Wilkinson, 2006:223-225). The mobility systems implemented within this urban model had been predominantly based on motor vehicles and road transportation, which would commonly cause traffic congestion (Charles, 1964:96-97).

The movement from the traditional grid system was illustrated through fragmented parallel patterns since the 1950s, revealing the diminishing value of pedestrian access and the growing focus on automobiles. The warped parallel pattern comprised curvy streets in long, narrow blocks, T-intersections and L-corners. Relative to the fragmented parallel pattern, it restricted the visual length of the street. This illustrated that visibility for most SOVs was compromised. Therefore, an automobile subdivision became more pronounced in this pattern, with significant reductions in intersections, street lengths, blocks and access points (Watanabe, 2015:112-114).

3.2.4 The urban structure model

Mann's urban structure model, which was created by combining the urban models of Burgess (concentric ring model; 3.2.2) and Hoyt (sector model - which is not included in the examined urban models) was the first contemporary model to be altered (Cilliers, 2010:16). In 1965, three industrial towns in the United Kingdom (UK) adopted the urban land use concept (Sheffield, Nottingham and Huddersfield). Mann incorporated the sector component from Hoyt's urban model and the concentric rings (cf. 3.2.2) from Burgess's model (Johnson, 1967:169; Herbert, 1972:320; Waugh, 2002:422; Pacione, 2005:147). While still permitting certain towns access to the CBD, their model considered wind effects and air pollution from industry and cars, which would affect how functional the urban design would be (Johnson, 1967:167; Waugh, 2002:423).

3.2.4.1 Land use

Mann's urban structure model contained specific elements that would serve as the model's foundation and explain how they would impact the way cities functioned. With the same notion as the multi-nuclei model, the urban model depicts a concentric ring structure akin to that of Burgess' concentric ring (cf. 3.2.2) model, as seen in the Figure 3-9 below.

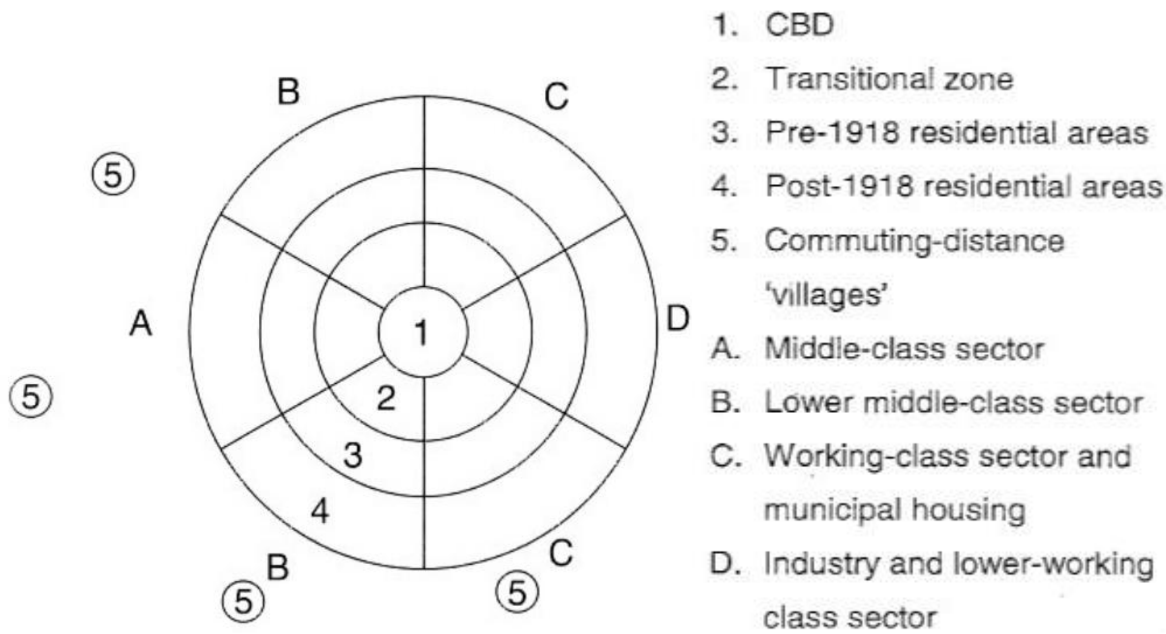


Figure 3 - 9 Urban structure model

Source: González & Medina (2004:73)

The idea was to develop several activity nodes rather than just one CBD and to decentralise land usage. Mann compiled significant design elements and condensed them into five key themes that highlight the significance of the urban design framework, as discussed in the subsections below (Waugh, 2002:422; Pacione, 2005:147).

- ***High-income residential area***

Higher-class housing would be situated away from the business district and industries due to noise and pollution nearby. The land value would consequently be higher and the environment more pleasant. The concept of higher-class residences far from industrial areas was prominent, as determined through the previously evaluated models.

- ***Middle-income residential area***

The middle-class residential areas were situated at the same distance from the industrial area. However, land value and transportation systems were affordable.

- ***Heavy industrial area***

Heavy industries would be situated along the main lines of communication. In addition, major transportation routes were moved away from higher-class neighbourhoods.

- ***Central Business District (CBD)***

The CBD was centred away from the transitional zone and was not concentric to the CBD. Therefore, the zone could accommodate higher-class residential areas.

- ***Low-class residential area***

Lower-class housing would be situated close to industrial/business areas, owing to its low land value, high density and proximity to work, thus lowering travel costs as well as the initial rental cost. This area was known as the “zone of older housing”.

- ***Urban sprawl and slums***

Slum clearance and gentrification are phenomena through which low-cost, physically deteriorated neighbourhoods undergo physical renovation or redevelopment, which increases property value. This leads to the development of large council estates and forces working-class groups to the periphery of the city. The local government implemented this strategy to eliminate slums and stop the stagnation of the urban environment.

The model had been replicated and approved to focus on the specific aim of this urban model, namely to replicate the Burgess model whilst adjusting the urban structure by taking the contemporary dimensions of urbanisation into account. 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.

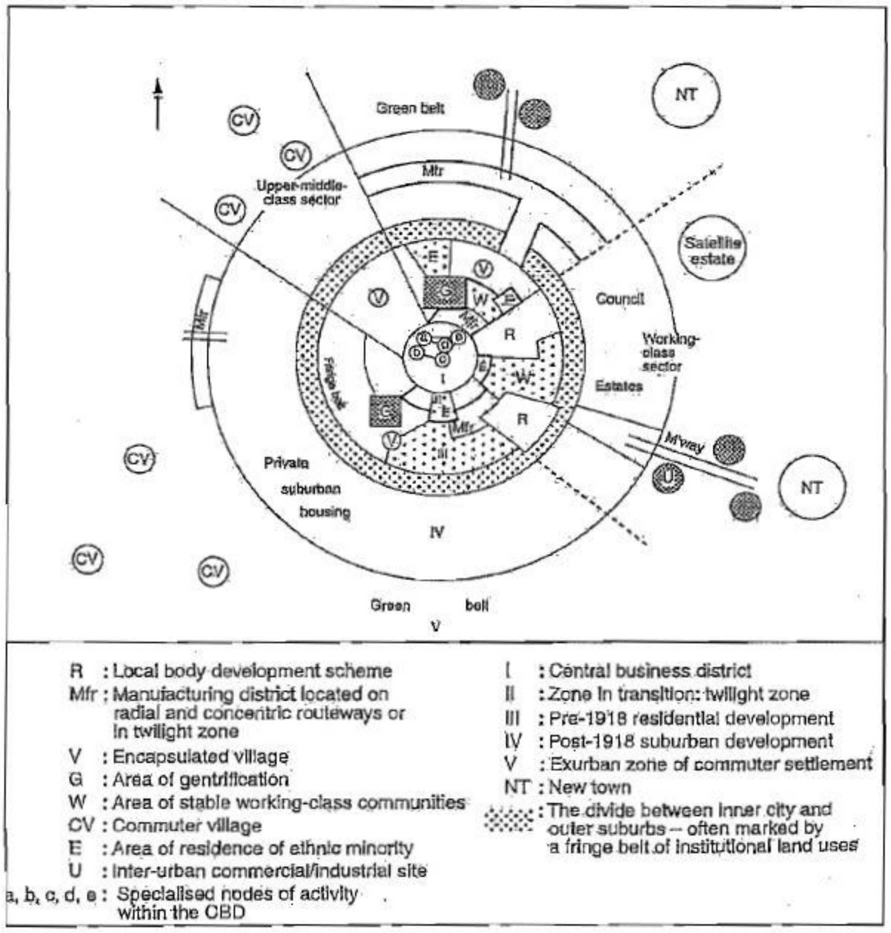


Figure 3 - 10 Modified concentric ring model of urban land use

Source: Waugh (2002:423)

In 1983, the urban model depicted in the above Figure 3-10 was introduced. The satellite estates, new towns, and council estates were also depicted in the model (Pacione, 2005:147). The UK adopted this strategy, which minimised the number of government dwellings and slums. The urban structure model illustrated similar traits to the concentric ring model (cf. 3.2.2) but differed through segregation parallel within the concentric rings. The concept of land value and CBD remained the same and, through urban growth, was assumed to radiate outwards from the core of the urban structure.

3.2.4.2 Mobility

The mobility of the urban structure model is based on the combination of two urban models, namely the concentric ring model (cf. 3.2.2) and the sector model. The mobility illustrates that there are various movements from the inside to the outskirts of the model and vice versa. Mobility is divided into multiple modes of transportation, which are implemented through the hierarchy of class groups. This has been illustrated in the above models and is not considered to be uncommon.

3.2.5 The urban realms model

All modernised urban land use structure models are derived from earlier models, where errors were found and corrected to produce an urban model with few issues. The more archaic urban land-use model (known as the multi-nuclei model) served as the basis for Vance's urban realms model. Hence, it is not an exception to the aforementioned assertion. According to the model, Vance concentrated on independent regions while historic downtown areas received more attention. The name "urban realm" comes from Vance's model, which also addressed urban growth and frequently referred to newly developed urban regions (Vance, 1964:78; Cilliers, 2010:20; Cullinan, 2019:30-31;).

3.2.5.1 Land use

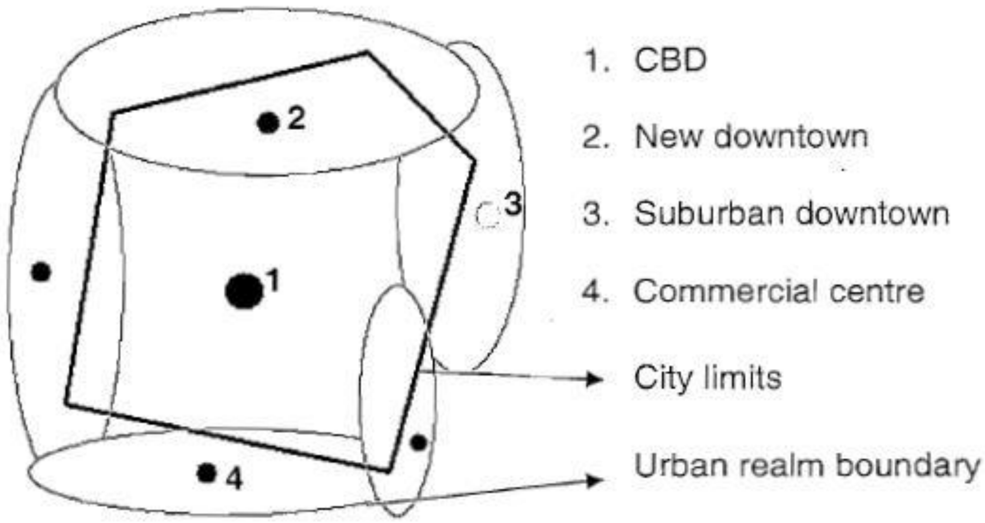


Figure 3 - 11 Urban realm model

Source: Vance (1964)

The urban realms model had been a response towards improving the multi-nuclei model. As a geographer, Vance proposed the urban realms model in 1964. The model suggested that cities are made up of small "realms", which means kingdoms, that are self-sufficient urban areas with main, independent points. The model was based on how these particular components functioned, and the urban structure of the urban model was determined by five criteria (Pacione, 2005:196-198; Lang & Nelson, 2007:6; Cullinan, 2019:30-32):

- Topographical conditions;
- The current metropolis's size;
- Interaction and accessibility between domains;
- Each realm's economic activities; and

- Each realm's accessibility.

As a result of Vance's hypothesis, the five criteria enabled the urban realms to attain horizontal expansion and self-shape. To meet the cultural demands of the urban realms, structures and corporate offices were included, along with cultural and entertainment venues (Pacione, 2005:199; Cullinan, 2019:30-31).

3.2.5.2 Mobility

The urban realms model illustrates various spatial components of a modern metropolis. The concept is that each realm is separate and is used for a segregated and different purpose; however, all the realms are linked together to form one large city. Each realm is a smaller city but forms one large metropolis when linked together (Pacione, 2005:197-200).

There have been several urban models throughout history, whereby the urban realms model is considered the final predated urban model (San Francisco [SF] Bay area, Atlanta, Georgia, the City of Los Angeles [CoLA], Chicago and Istanbul). Transportation and accessibility to the conventional CBD became impractical as cities expanded. Additionally, to support the limited resources of all expanding urban regions, work had to be available in surrounding bands, resulting in job displacement (Heikkila, 2007:84-86). That employment was generated by the outer shift in manufacturing and wholesale, as well as in retail and office work (Vance, 1990). The technical advances in the cities become more spread out due to the increasing use of road infrastructure and abundance of motor vehicles. The suburban areas would have functions in the CBD but were not considered significant (Karakuyu, 2008:1-3).

The purpose of the urban realms model is to create functions in the CBD which can be moved to the suburbs, therefore diminishing the importance of the CBD. The urban realms model can simply be illustrated as several different realms acting and functioning independently but still working in unity as a whole city. This model describes some of the characteristics of urban growth because, as an automobile-dependent model, urban growth would not be an issue; therefore, it can keep expanding. The suburbs would become so big that they would have exurbs and would then make up another urban realm.

3.2.6 The twenty-first-century (21^{st}-century) city model

The 21^{st}-century model was based on (but presented as a revision of) the concentric zone model in 1987 (cf. 3.2.2) (White, 1987:236-242). The proposed aim of White's model was the incorporation of certain modern traits that had been important for the urban land use structure. These traits included industrial development, social interaction, suburban residential areas, decentralisation of businesses as well as industries, and 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).

3.2.6.1 Land use

White's model of the 21st-century city was created using several concepts, as 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 transitional zone or stagnation zone. 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.

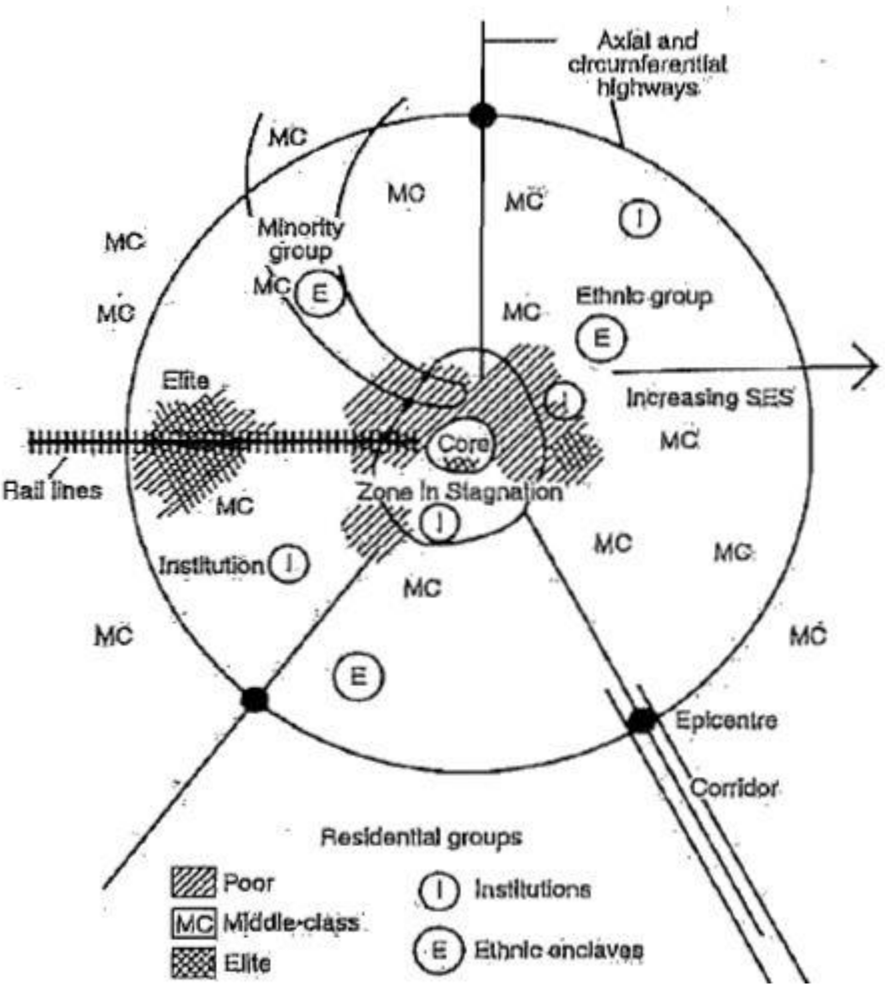


Figure 3 - 12 The 21st-century city model

Source: White (1987)

The concentric ring model (cf. 3.2.2) contained the CBD. This element would remain the focal point of the actual metropolis. The purpose of the CBD remained unchanged. Despite its functions becoming more complicated through years of adaption, it still consisted of houses, financial institutions, corporate head departments and government buildings. According to White, a few large department stores could retain their flagship developments downtown. Still, the majority of retail stores moved with the rest of the affluent population towards the suburban regions in hopes of keeping close to customers (Pacione, 2005:149).

From Burgess's assumptions, White identified that the CBD would eventually attract investors that would expand the CBD into the transitional zone. However, White felt 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, thus he called for drastic measures to deal with slum clearance and highway construction. This led to the relocation of transport routes and warehouses to residential suburban areas. The older industrial cities in the USA have considered revitalising the areas 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 Burgess's model.

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 (zone of stagnation). White also identified that the surrounding area would reflect people's status in the community and 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 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, and offered an immaculate view of nature that 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. It was characterised by its socially diverse activities and had two important traits, namely (White, 1987:236-240):

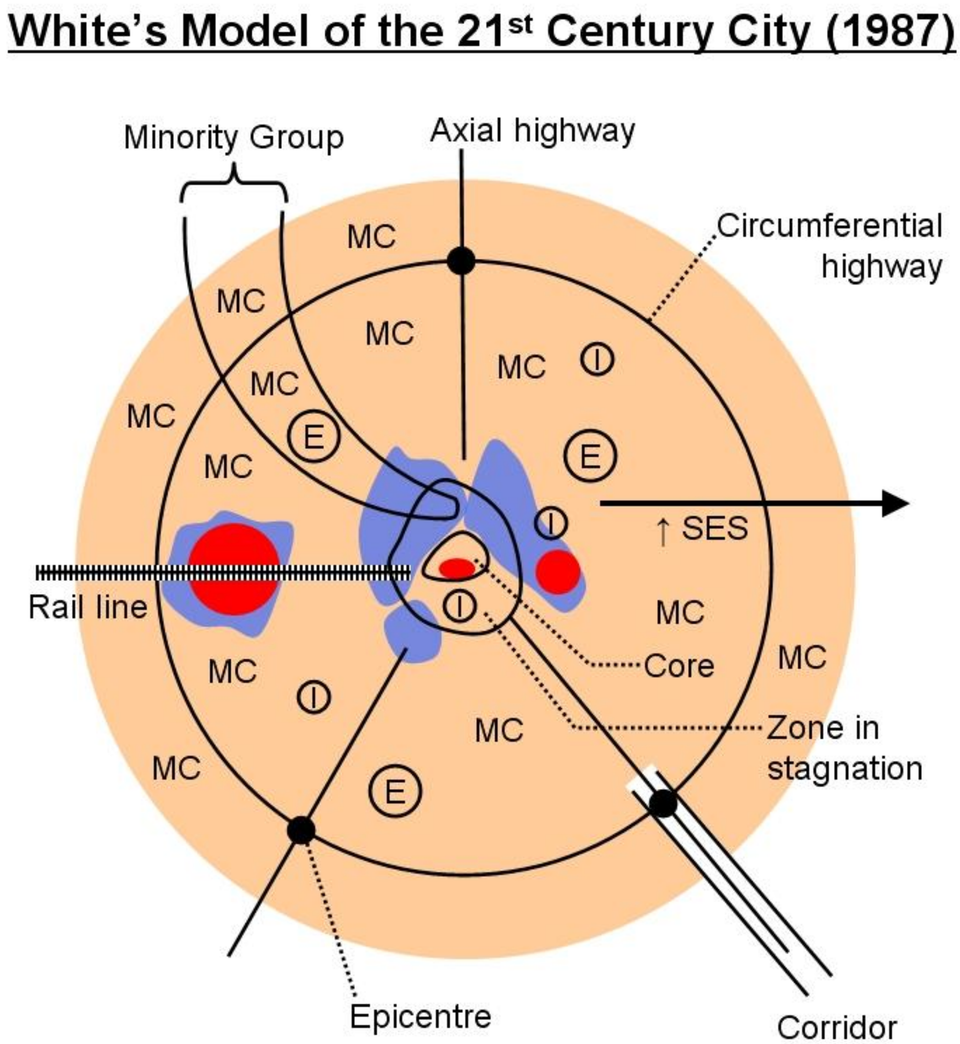
- It was considered to be the interior section of the model, where many families originally settled before going through the transition of moving to other dwellings. This attracted the interest of a majority of African Americans middle-class workers. In this process, many African Americans would move to suburban areas and live relatively dispersed among other races; and

- The outer division would consist of families with younger children and spacious areas and segregated housing. This would be detached housing with gardens and would generally lead to the 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 how future development may have to take place (Pacione, 2005:148-149).

3.2.6.2 Mobility

The evolution of urban design structures in the 21^{st}-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 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. Figure 3-13 illustrates the abbreviations regarding land use and connectivity.



*E: Ethnic enclave; I: Institution (such as a university, research and development centre or business park, hospital); **RES:** Residential area; **MC (RES):** Middle class (orange areas); **RES** (Blue area) Blue indicates areas of poor housing; **RES** (Red area) indicates areas occupied by the city's higher class.*

Figure 3 - 13 Mobility of the 21st-century city model

Source: PlanetTech (2020)

Various land uses are shown in the Figure 3-13 above, with abbreviations provided below the image (Pacione, 2005:200-202). The Figure 3-13 illustrates that there are several mobility systems connecting land use and travel within the urban model. These transportation systems are, in fact, highways and road transportation systems connecting land towards the central core (CBD) to form a central activity node (White, 1987; Pacione, 2005:200-201).

The residential areas are situated around the CBD area and connected through road transportation as well as rail. The Figure 3-13 above illustrates that both higher-class individuals and lower-class residential areas are connected by rail. The middle-class residential areas are accessible to all types of transportation systems and make up the majority of the urban structure around the central node. The lower-class individuals are closely situated in the transitional area where they are assumed to continue working. This allows for easy and accessible mobility systems. The higher-class individuals can utilise costly transportation systems and are not limited by travel.

3.2.7 The urban fabrics model

The term ‘urban fabrics model’ describes how sustainable cities are understood and implemented through the usage of urban metabolisms. The urban fabrics model focuses on a paradigm whereby urban areas and cities are considered living things that go through a variety of metabolic processes (input and output). As creatures vary, so too do cities and urban configurations. The urban fabric model takes into account three distinct city components that form the foundation of any metropolis and are associated with various metabolic systems. These three areas of a city are known as the walking, transit, and car urban fabrics, and they all need different kinds of infrastructure to be included in the urban structure (Thomson & Newman, 2018:218-219). The urban fabrics model shows similarities with the Marchetti Constant model (Marchetti, 1994:77), which demonstrates an intermodal connection – it will be assessed later in this chapter. The urban fabrics model and divided mobility sections, which are thought of as distinct species inside a single metabolism, are depicted in the Figure 3-14 below (Thomson, 2016:37-42; Cullinan, 2019:34-36).

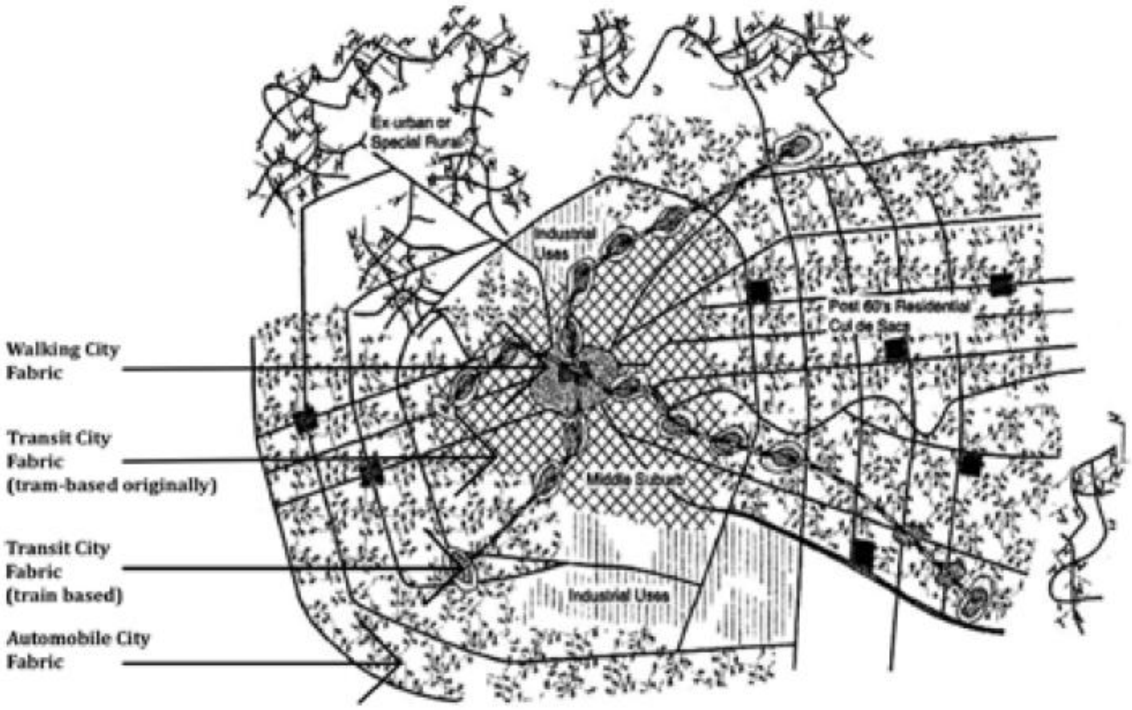


Figure 3 - 14 The urban fabrics model

Source: Newman et al. (2016:431)

The utilisation of natural resources and the creation of open space are examples of the input and output metabolic processes mentioned above. This could be considered a damaging element of the natural world (Cullinan, 2019:35-37). The model follows an ecologically extractive process, and may also be used to understand how sustainable cities are implemented. This methodology finds answers that can be put into practice as well as ways to improve cities. The urban fabrics model recognises that various urban fabrics (components of the city/town) have different urban metabolisms (Pacione, 2005:830-832; Toros, 2010:1-7). The urban fabric model is viewed from the standpoint of change rather than as a fixed model that is limited to use with particular models. Its main goal is to restore the biosphere to its pre-damaged state if any damage is caused by that particular urban structure (Thomson, 2016:1-47).

Urbanisation has led to an increase in the human population, which requires the formation and expansion of urban structures that gradually cover the surrounding area. This gradual cover causes a loss of natural resources. The rate at which natural resources may be exhausted with the constantly increasing population growth (Pacione, 2005:376-378; Cullinan, 2019:35) determines the design of urban structures, and landscape architecture could be an effective approach, according to the urban fabrics concept. This model exemplifies the typical 'Anthropocene' (Thomson & Newman, 2016:1-10), in which the human population shapes the environment and climate. The beneficial and negative effects of the Anthropocene can be felt in the environment; however, in this day and age, the negative effects are noticeable based on population density and number (Thomson, 2016:1-47). This has many more detrimental repercussions in addition to the waste and pollution which is typified by the rapid growth of the human population. The urban fabrics model takes into account the "regenerative cities" concept, which is applied to the entire urban system and is created by landscape architects (Thomson & Newman, 2018:220-221). The ecological infrastructure system of cities is discussed in this urban model regarding urban metabolism. This aids in identifying cities and the economic growth opportunities they may present. The three components of regenerative cities are explained as (Pacione, 2005:824-825; Thomson, 2016:35-40; Cullinan, 2019:36-37):

- Using environmental ethics as a means of restoring the natural systems that cities depend on while also improving the environment;
- The urban model being based on renewable energy systems; and
- Encouraging individuals and communities to take part in this change process through new lifestyle options and economic opportunities, which not only increase efficiency but also improve quality of life.

The idea of sustainable development, and the aforementioned elements serve, as the cornerstone of a regenerative city (Pacione, 2005:824-830; Manderscheid, 2011:209-210). The future should be taken into consideration to enable cities to develop capital for future generations instead of using the remaining natural resources to gain net income. Instead of spending money that has no future in the urban framework, this is seen as an investment in future growth. This lends credence to the sustainable city concept of the urban fabrics model. To prolong future growth, one should grow natural capital rather than economic capital (Pacione, 2005:832-842; Cullinan, 2019:36-37).

The urban fabrics model has been implemented in Australia, which uses techniques to reduce ecological footprints. Australia has a large ecological footprint and can be compared as three times larger than the average for the world. The model is seen as a solution having real-world applications rather than merely a theoretical application. The ability of the urban fabrics model to comprehend human conduct and adapt it by patterns and human predictability sets it apart from other models discussed in this chapter (Bertaud, 2002:2-4; Pacione, 2005:375). Reducing waste and pollution can lead to an increase in sustainability, as demonstrated by the urban fabrics concept. The steps in the process include using more public transportation, reducing the number of cars per person, recycling, and expanding the usage of renewable energy (Pacione, 2005:789-790; Thomson & Newman, 2018:221-222).

3.2.7.1 Land use

The land use of the urban fabrics model illustrates the same concept illustrated in the garden city model (cf. 3.2.1) and the concentric ring model (cf. 3.2.2); however, it links and connects mobility differently to increase it within the urban fabrics model. The land use of the urban fabrics model has not been identified specifically but illustrates its function. The Figure 3-15 below illustrates the implementation of land use within the urban model, as well as the dominant transportation system implemented.

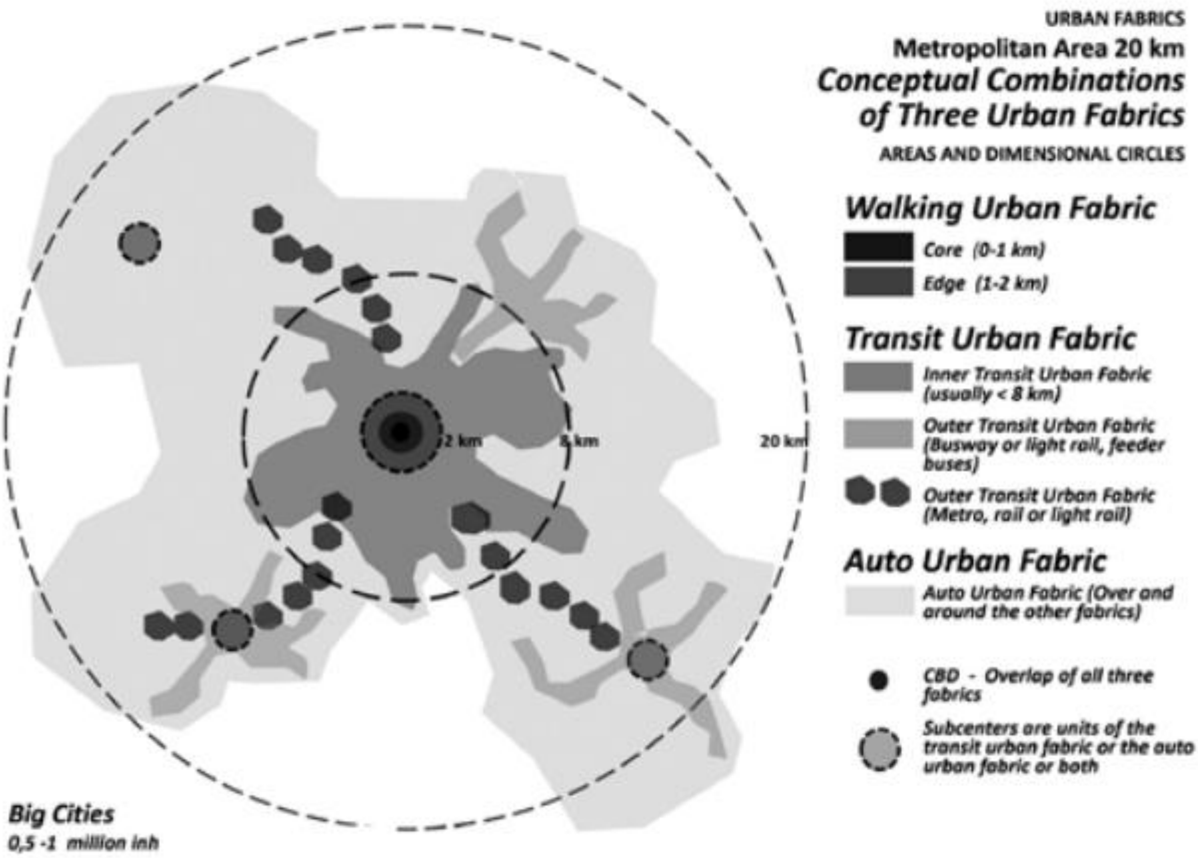


Figure 3 - 15 Combination of transportation and land use within the urban fabrics model

Source: Kosonen (2013:2015)

The land use of the urban fabrics model is similar to that of the concentric ring. The CBD is situated in the centre of the urban model illustrated above, as it is within the concentric ring (cf. 3.2.2) model and garden city (cf. 3.2.1) model.

The second ring illustrates the edge, known as the transitional zone as determined in the concentric ring model (see Figure 3-4), which is occupied by industries and factories. This land is considered to be cheap, due to the ever-decreasing land value as a result of factory pollution. This zone may occupy lower-class residences due to the cheap living costs and affordable transportation (walkability, bicycles) as determined within the urban fabrics model (Thomson & Newman, 2018:216-219). The third zone would illustrate the residential area for middle-class residents (Newman *et al.*, 2016:431). This area will have multimodal transportation systems to provide various options for middle-income residential areas. This zone would often have public transportation to accommodate the masses of individuals travelling to a certain point of interest. The urban fabrics model includes tram transportation to facilitate the movement from residential to the workplace. The final ring on the outskirts of the urban structure includes the higher-class residential areas, whereby the main transportation system used is automobiles and road infrastructure. The land use value is high and unpolluted.

Land use has been delegated to specific transportation systems that are predominantly used within the sector or various sectors; this determines the functioning of the urban structure and its efficiency. The urban fabrics model will illustrate the various transportation modes within the following subsection to understand the inner workings of this unique model.

3.2.7.2 Mobility

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 3-16 below illustrates the design of the urban fabric model while considering the three main aspects, namely transit, automobiles and walkability (Thomson & Newman, 2018:218-219):

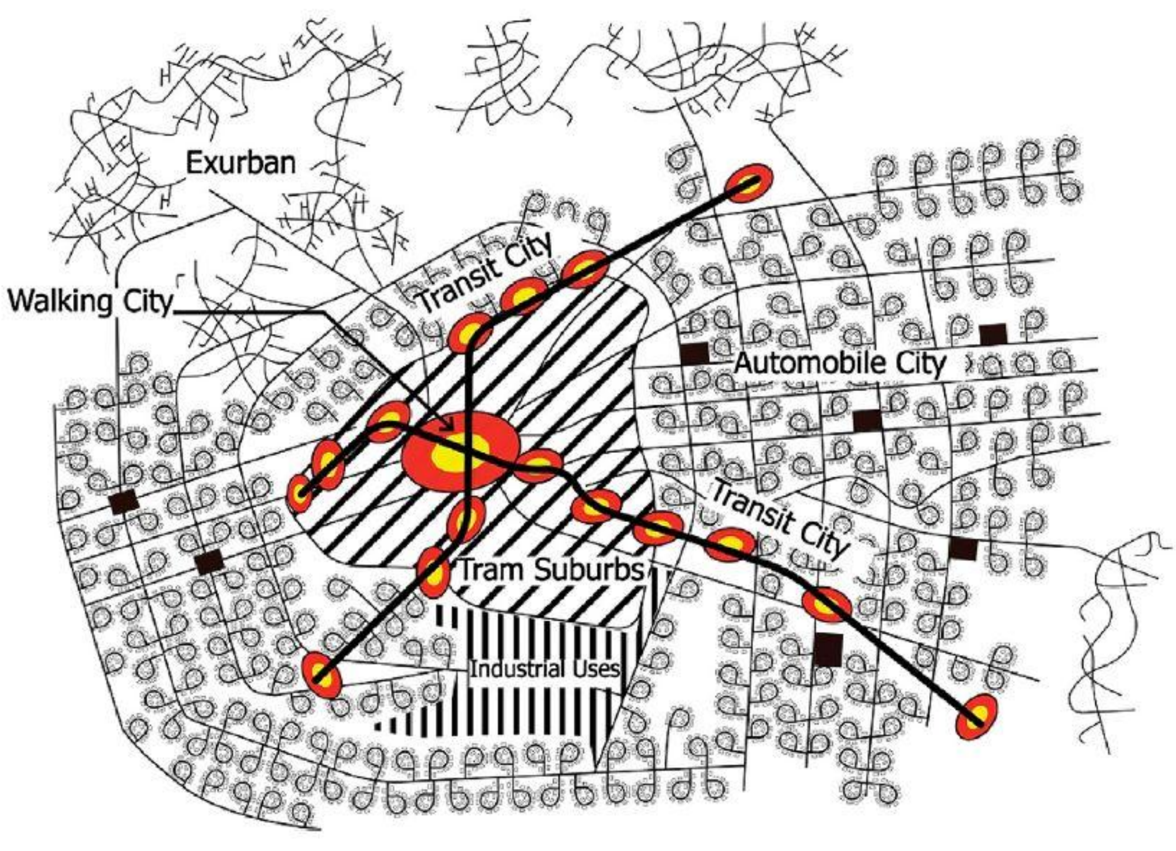


Figure 3 - 16 Urban fabrics model mobility

Source: Thomson & Newman (2018:219)

The Figure 3-16 represents a model with 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 and deterioration of natural environment). The model presented in the Figure 3-16 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.

The urban structure of the urban fabrics model, illustrated in Figure 3-16, can be compared to Howard's garden city urban structure (cf. 3.2.1) based on the use of circles and nodes (Phillips, 1970:50). The nodes comprise various concentric rings, which then illustrate the principles represented in the concentric ring model (cf. 3.2.2) and modified concentric ring model (Adhvaryu, 2010:125). The concentric ring model illustrates the use of various rings symbolising various sectors of an urban structure; however, the urban fabrics model illustrates an area segregating a particular mobility system. This means that various sectors could correlate with different mobility systems (Waugh, 2002;423; Cullinan, 2019:37-39).

The urban fabrics model theory elucidates how transport networks shape the design and function of cities. This idea was developed from previous models showing how transport shapes urban areas' structure and functions. As per the Figure 3-17 below, there are three kinds of urban fabric types used to create the urban fabrics model.

Figure 3 - 17 Breakdown of the urban fabrics model

Source: Newman et al. (2016:432)

The structure seen above is comprised of three transportation systems (walkability, transit and automobiles), which ultimately create the entire urban fabrics model. The transportation systems implemented can be identified as TOD. The breakdown of the urban fabrics model can be identified through the transport systems discussed below (Pacione, 2005:830-832; Toros, 2010:1-7; Newman *et al.*, 2016:431; Cullinan, 2019:34-39).

- ***The walking city***

The earliest city topology has the most basic layout and mode of transportation - walking, which was primarily utilised in the 1850s. It was determined that there were just two forms of mobility available at the time, and it is considered to be a predated urban structure. Animal-powered transportation was the alternative mode of transportation; it was effective over larger distances (town-to-town travel), but not so effective for shorter ones. Even though walking was seen as a slower form of transportation (3-4km per hour [/h]), people used it as a method of mobility within the urban framework. When mobility distances in the urban structure exceeded 3-4km, walking also imposed some restrictions. This concept has been illustrated in the Marchetti Constant urban model, which will be assessed later (cf. 3.2.9). Pedestrian mobility would offer specific benefits to the walking city and would include the following (Pacione, 2005:789-790; Thomson & Newman, 2018:221-222):

- Enhancing life quality (health);
- Minimal or non-existent pollution;
- Easy to use and efficient for short trips;
- Minimal or non-existent upkeep;
- Utilised by people of various ages;
- Preserve the environment; and
- Easy to maintain and has simple infrastructure.

The necessity to travel between cities, the growing population, and the requirement for effective mobility to move large amounts of freight and boost production made the walking city short-lived. As a result of long-distance travel, the walking city gradually gave way to a transit city (Cullinan, 2019:36-38).

- ***The transit city***

The transit city had an effective urban structure that allowed for the efficient flow of people and goods and was not limited to short-term trips. When it was first established (between 1850 and 1950), the goal of the transit city was to connect cities (Pacione, 2005:377-378; Cullinan, 2019:71-72). The transit city has been limited to two primary modes of transportation, namely transportation *between* and *within* urban structures. Trams were considered to be a form of short-distance transportation (5-10km) that allowed people to move quickly and in large groups within the urban framework. The second transit system was based on trains, which also used rail infrastructure. The system was effective because trains could move large groups and goods across 40km of cities efficiently. The rail-operated transport systems could travel farther than by walking or using animal-power transportation systems. On average, they would travel between cities at speeds of 80km/h (Rodrigue *et al.*, 2006:178; Thomson & Newman, 2018:222). Infrastructure was crucial inside the transit city but not considered within the walkable city's urban fabric. The usage of trains and trams supported development corridors and provided an efficient method of transport; however, they required a lot more maintenance than the walkable city. The fact that the transit city's advantages outweighed its drawbacks was viewed as a progressive development in the field of transportation. As such, the introduction of the use of SOVs within urban fabrics was sparked by trains and trams. This led to the development of the automotive city in the 1950s (Newman *et al.* 2016:436-437; Cullinan, 2019:70-71).

- ***The automobile city***

The automobile city made it possible for development to take a flexible strategy that was centred on the needs of each individual rather than being restricted to rail or the interests of large numbers of people. This made it possible to travel around suburbs and urban structures more flexibly. This, mobility supported both long and short-distance travel, making the vehicle city an automatically superior mode of transportation (Wegner, 1995:4; Cullinan, 2019:76-84). Roads and parking facilities would be expanded to increase the capacity of cars used in place of public transportation (Rodrigue *et al.*, 2006:101-102; Dur & Yigitcanlar, 2015:814). This resulted from the personalisation of mobility, in which each person's schedule was determined but could be flexible regarding travel time (King, 2020:18-26). The challenges identified in the automobile city are widely distributed. The transportation option improves accessibility and efficiency relative to another, it will be utilised more frequently while other forms of transit come to a standstill (regular maintenance/damaged infrastructure or inaccessibility). SOVs will control the urban fabric of the transportation system in the automotive metropolis (Thomson & Newman, 2018:222).

The automobile is one of the most popular and efficient forms of transportation. The automotive city has grown more convenient for the individual but does not incorporate many other means of transportation. This becomes problematic due to several reasons that contribute to congestion, which in turn causes a chain reaction that lowers efficiency and production (Rodrigue *et al.*, 2006:178-179). There are three common urban fabrics that have been identified by the urban fabrics model; however, the point of attention is not established until a certain level of comprehension of human behaviour and mental processes is attained (McDonagh, 1997:3; Pacione, 2005:169).

3.2.8 The apartheid city model

Many South African cities adopted the apartheid city model with the goal of racial and political segregation. The model aimed to leverage land use to separate different racial groups (Cilliers, 2010:23-24). The apartheid city model uses racial segregation to depict the political hierarchy represented by class groupings in the concentric ring, urban structure, garden, and other models. The design had more of a political execution strategy, and the model represents the distribution and segregation of land usage to assign areas of property to different races.

The apartheid city model, in general, placed a strong emphasis on outward growth towards the city's edges. This urban design model aspect has been perceived as resembling the sector model (Pacione, 2005:193-194; Cullinan, 2019:25), thus exposing the fundamental idea behind this urban plan. The apartheid city model, which was popular in the years leading up to apartheid, is summed up as the government's enforcement of racial group segregation to prevent social interaction between them country’s minority groups and White citizens (Davies, 1981; 59-72). Hoyt's model served as the foundation for the apartheid model, which bears structural similarities (Chapin & Kaiser, 1979:35; Simon; 1989; 191). The planning of the apartheid model focused on segregation, whereas most urban models focused on sustainability.

In considering the apartheid city model, Simon (1989) modified the model in hopes of eliminating its faults and allowing for better functioning of the urban model. 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”; thus
- This allowed all races to conduct business regardless of the colour of their skin.

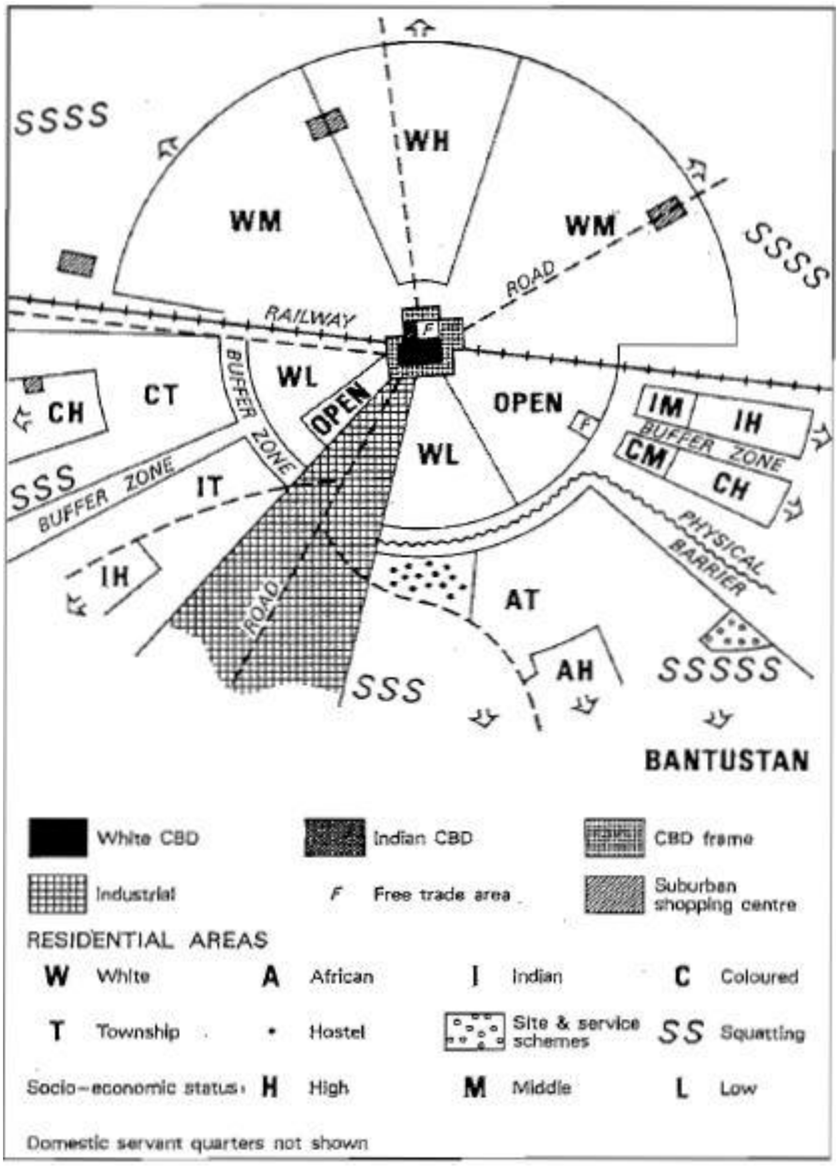


Figure 3 - 18 Modernised apartheid city model

Source: Simon (1989:193)

The modernised apartheid model had an impact on the earlier apartheid model. This was 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 through decentralisation; and
- Due to 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 have continuously changed and perfected their functions by changing their structures. The Hoyt model was still primitive but the concept had been maintained and illustrated in the Davis apartheid model. Both models were based on the concept of core-to-periphery growth and reflected the evolutionary base of the Davis apartheid model (Chapin & Kaiser, 1979:35; Waugh, 2002:422). 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 trade with other countries. This forced South Africa into different structures, 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 have 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.

3.2.8.1 Land use

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:

- Black 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 Black 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; and
- The White residences (higher-, middle- and lower-income) were situated around the White CBD.

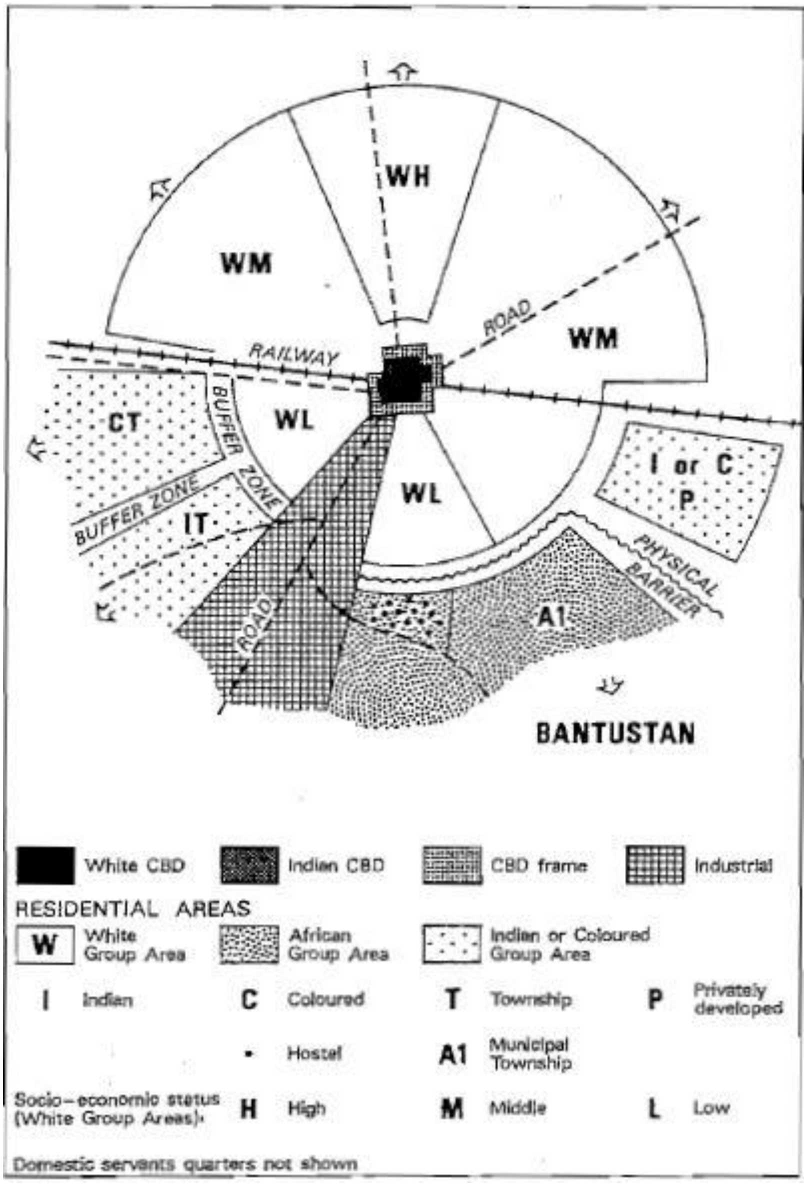


Figure 3 - 19 The apartheid city model

Source: Simon (1989:192)

The model was formed through strong political ideologies, which led to the forceful removal of residents and their allocation to specific areas according to the model. This model removed the basic rights enforced by the now-implemented Constitution of the Republic of South Africa, 1996 (the Constitution), which explains why it is mostly frowned upon when discussed.

3.2.8.2 Mobility

The apartheid city model illustrates similar mobility strategies and implementation of transportation systems in other models. These include the garden city (cf. 3.2.1); concentric ring (cf. 3.2.2); urban structure (cf. 3.2.4), and the sector models (Chapin & Kaiser, 1979:35). The apartheid model represents an implemented sector urban model. Mobility radiates outwards from the centre of the model, illustrating the similarity to the other models analysed. The Figure 3-20 below demonstrates the implementation of transportation.

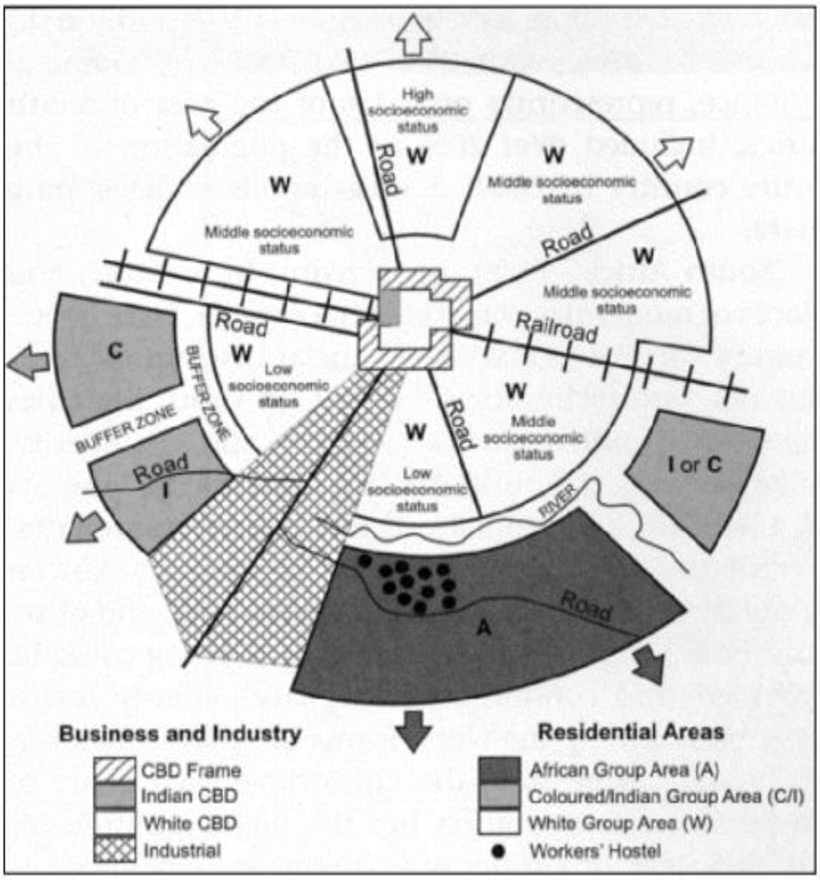


Figure 3 - 20 The apartheid city model: Implementation of transportation

Source: Davies (1981:61)

The above Figure 3-20 illustrates the transportation systems implemented within the apartheid model. The Figure 3-20 shows the railway moving through the CBD to the outskirts of the urban model. The implemented transportation system above provides a visual example of the implementation of roads, connecting various land uses, with the radial street pattern showing similarities between the garden city (cf. 3.2.1) model (Phillips, 1970:50) and the sector model (Waugh, 2002:422). Mobility was created to allow all individuals to reach the CBD. A buffer zone was imposed between the residential areas and the CBD area.

3.2.9 The Marchetti Constant model

The Marchetti Constant model is based on human behaviour, which is implemented within the urban structure due to the significance of the anthropological variants determining human movement. The anthropological invariants of travel behaviour form the foundation of the Marchetti Constant model (Marchetti, 1994:77). The model shows how much time is spent travelling using different means of transportation, as well as how instincts rather than economic motivations typically govern personal travel. The model understands humans' innate need to claim territory, elude predators, and seek refuge by looking at the species from a psychological point of view. The concept takes a behavioural approach, focusing on the animalistic, broken-down person who tries to fulfil their basic needs to survive. This relates to the urban fabrics model (cf. 3.2.7) mentioned above, in which people typically select the more practical choice for transit. The Marchetti Constant model focuses on the same concept as the urban fabrics model (cf. 3.2.7) illustrated. The Marchetti Constant model's depiction of anthropological invariants in travel behaviour is shown below; subsection also relays the distance travelled in each method of transportation (Marchetti, 1994:75–77; Cullinan, 2019:39-41).

3.2.9.1 Land use

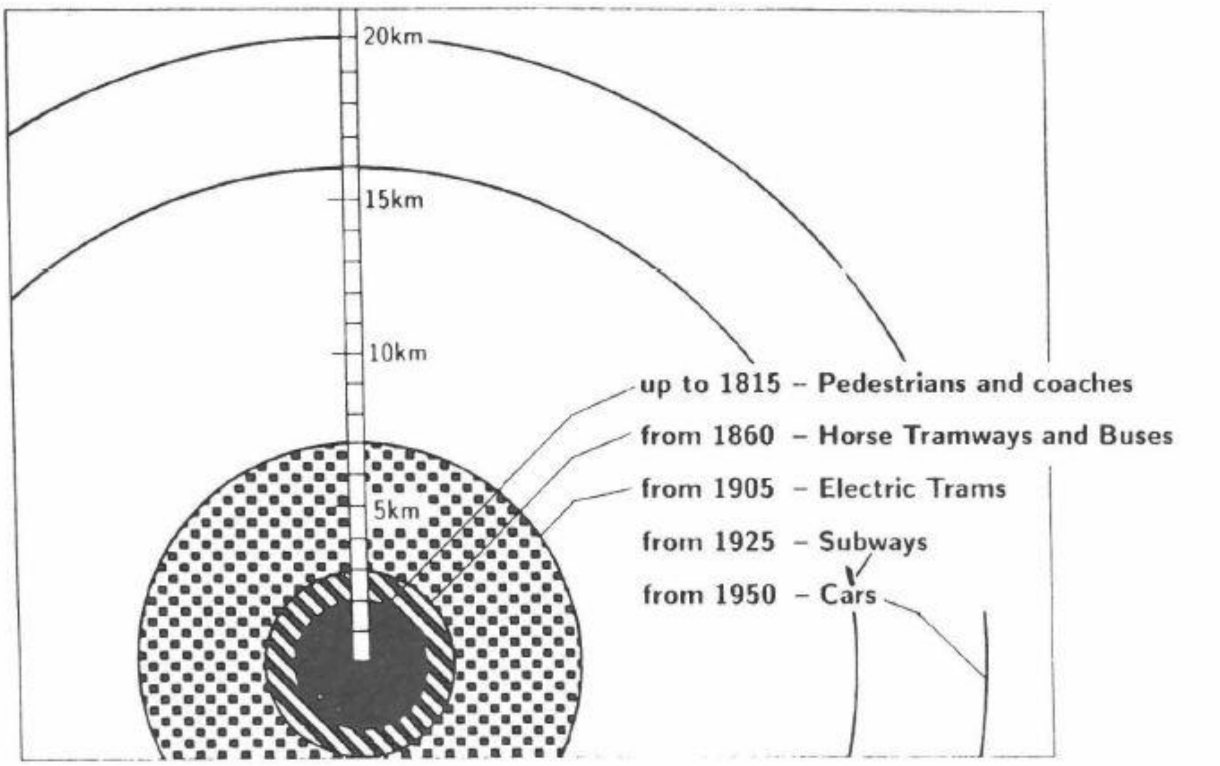


Figure 3 - 21 Anthropological invariants in travel behaviour

Source: Marchetti (1994:77)

The Figure 3-21 shows the various distances considered between various sectors. The model's urban structure is very similar if not the same as the garden city model (cf. 3.2.1); it is the same as the concentric ring theory (cf. 3.2.2). The urban fabrics model (cf. 3.2.7), which illustrates the concentric rings of various modes of transport, is based on a larger scale than Marchetti's model. Thus, the implementation of the same urban structure with different methods of transport implementation is shown.

In addition to showing how different distances relate to different forms of transportation within the urban structure, the Figure 3-21 above also shows how the city has grown and added new modes of transportation to fit its size and structure. The idea was to build little cities in the end; Berlin is used to illustrate the design above. The concentric ring model (Waugh, 2002:420; Cilliers, 2010:15) indicates that the CBD is only 2.5km from the transitional zone (cf. 3.2.2), which is the rationale behind the walkable mobility system and the implementation distance; however, this model concentrates on 5km as the maximum walking distance. According to the Marchetti Constant model, the location that the greatest number of people can go to in less than half an hour is the city's centre or core. The Marchetti Constant model demonstrates the following ideas (Marchetti, 1994:76–78; Thomson & Newman, 2018:219; Cullinan, 2019:40-41):

- Walking can cover a maximum distance of 5km;
- The distance between the transitional zone and the CBD's centre is 2.5km;
- Transportation can reach up to 20km^2 according to the way the urban structure is designed;
- The principles cover the physical dimensions of the urban structure as well as the political, economic, and population zones; and
- The point of significance (city centre) is considered to be the area that the greatest number of people can get to in less than half an hour.

The Marchetti Constant model was interested in adopting transport based on distance travelled. This establishes the type and level of efficiency of transportation that is required. The Marchetti Constant model includes people from higher, middle, and lower socioeconomic classes, each of whom is assigned to a particular method of transportation (Chaplin & Kaiser, 1979:32; Cilliers, 2010:15). This aligns with the concentric ring model (cf. 3.2.2) as well as the garden city model (cf. 3.2.1), highlighting different land use areas.

3.2.9.2 Mobility

The above introduction illustrates the concept of the Marchetti Constant model. Research has determined that, on average, commutes to work, whether one walks, cycles, drives or takes a bus or train, would take approximately 30 minutes. Civil engineers and mobility experts refer to this as ‘the Marchetti Constant’; it is the average time spent commuting from one’s home to one’s office or vice versa (Marchetti, 1994:75-76). The Marchetti Constant model is based on an anthropology approach, whereby human behaviour is a variant within planning and should be considered as the main aspect. In a work entitled *Anthropological Invariants in Travel Behaviour*, published in 1994, Italian physicist Cesare Marchetti posited that although urban planning and transport modes may differ vastly, individuals seem to gradually adjust their lives according to their options and availability within the surrounding environment, as well as the location of their homes and offices. This, therefore, determines that the average daily time spent travelling remains constant (Ausubel & Marchetti, 2001:20-22; Cullinan, 2019:40-41).

Marchetti explained that the total average time spent travelling between home and office does not exceed one hour. Planning should consist of various transportation models that decrease time travelled across all societies. Marchetti calculated that early humans travelling on foot at about 5km/hr would move over a radius of 2.5km and verified this hypothesis by observing individuals travelling on foot in villages in rural areas of Greece (Marchetti, 1994:77; Cullinan, 2019:40). Yacov Zahavi's 'cost of travel' concept relates to Marchetti's work, as they also noticed that people seem to spend the same time travelling (Zahavi, 2021:1-4).

Commuting time is not only often frowned upon as lost time but correlates to inefficiency due to a decrease in work time (Zahavi, 2021:1-4). Travel time can also directly correlate to health issues brought on by obesity (convenience and lack of exercise) and higher blood pressure (Lasi *et al.*, 2020:30-32). The Rockefeller University research team developed a study on driverless cars and hyperloops to illustrate how Marchetti's Constant may be affected by new emerging forms of transport, such as smart, traffic-defeating, self-driving cars, extremely fast trains and even 800-km/hour hyperloops (Ausubel *et al.,* 2000:149-151). The various models indicate that Marchetti's Constant will continue to hold no matter how fast and efficient our new modes of transport become. What will probably change is that we may decide to live even farther away from our workplaces, for example, to travel by sea, out in the countryside, or even in a different state; however, the average commute time is not expected to change. Research done on how Marchetti's Constant may have been impacted by historic elements showed that the average "commute time" of Ancient Romans was probably about half an hour on foot (Ausubel., Marchetti & Meyer, 2000:142-144; Ausubel & Marchetti, 2001:20-21). The same time is spent on public transport (or car) by commuters in this modern-day era.

Commuting has had a large impact on modern life. It has allowed cities to grow to previously impractical sizes, and it has led to the proliferation of suburbs. Many large cities or conurbations are surrounded by commuter belts, now known as metropolitan areas. The prototypical commuter lives in one of these areas and travels to work or school in the city daily (Cullinan, 2019:39-41).

The propensity for human travel has never exceeded 30 minutes, yet the main question is *how much more can our cities expand*? Larger cities such as London and New York, in which average travel times are respectively between 36 and 41 minutes due to congestion and population influx, are already pushing the limit described by Marchetti's Constant. In fact, in many densely populated cities around the world, 30 minutes on public transport systems are not sufficient to cover much more than 10km (Marchetti, 1994:76-78; Thomson & Newman, 2018:219; Cullinan, 2019:41;). The Marchetti Constant model has illustrated great planning principles for urban models and transportation but it must be determined whether growth and expansion were considered in the process.

Whether we are, therefore, unlikely to see the rise of megalopolises has been asked. Marchetti claims that this depends on the speed of transport systems. Faster transport will allow individuals to move farther away from their workplaces. However, one must determine how congestion will decrease if the speed of transportation increases (Ausubel, Marchetti & Meyer, 2000:149-151). The implemented urban models, for example, in SF, Los Angeles (LA), New York, and Washington, generally use hyperloop segments (currently the fastest envisioned mode of civilian transport). These are currently being planned over distances that will take 30 minutes to cover (Zahavi, 2021:1).

The Marchetti Constant provides significant mobility principles that had been incorporated from ancient times and progressively implemented in the modern-day era, which significantly impacted mobility and further study of transportation variants. Marchetti also focused on the human behaviour aspect, whereby individuals would have a certain pattern of daily routines and adapt to their current surroundings (Marchetti, 1994:75-77; Ausubel, Marchetti & Meyer, 2000:137-138; Cullinan, 2019:39). This is a vital element to planning because various models do not incorporate the individual's perspective and focus on practicality but not efficiency.

3.2.10 The theory of agricultural land-use model

The theory of agricultural land-use model is based on land value and subsequent property purchase, as demonstrated by the urban land-use model (O'Kelly & Bryan, 1996:457–459). This means that, rather than being determined by usefulness, the land is sold to the person who can make the greatest bid (Waugh, 2002:425). Von Thunen's rural land-use model, an earlier model that is not discussed in this paper, provides the greatest illustration of this idea, since the value of the land may vary by location. The CBD has the highest land value since it is easily accessible and has limited area; higher economic wealth may also play a role. Thus, the model proposes that land would become more affordable the further it was from the CBD (Jamoliddinov & Dsilva, 2019:16). This resulted from the construction of residential settlement zones farther away from noise barriers and enterprises. Cost increases have also affected land that had been easier to access (Mashabela, 2023:218-222). Although this seems to be extremely paradoxical, it makes sense in the context of financial power. According to Cullinan (2019:45-48), the model's spatial design of transport units shows that land next to transport routes is likely to have a greater 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, which would 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 their importance in economic growth, accessibility, development, increasing urban sprawl, and transport of passengers and freight (O'Kelly & Bryan,1996:459-460).

Urban structures are continuously evolving in response to new developments. The land value urban land-use model served as the foundation for Alonso's theory of land value. This approach established the distinction between land value and land use. Alonso's approach featured seven steps (or considerations) and a convoluted twist (Pacione, 2005:146; Cilliers, 2010:26-28; Cullinan, 2019:46):

1. According to Alonso, the first step of the procedure is when the model goes into the market to bid on or purchase land, taking the distance from the city centre into account;
2. There is just one CBD with no zoning limitations, based on the same assumptions as Burgess and using the same model;
3. It is considered that purchasers are aware of the land's worth and the accessibility of transportation (Waugh, 2002:392). This presupposes that the buyer will possess the necessary funds and be entirely capable of paying for the three primary items (land, transportation, and further composite goods). There may be misconceptions regarding the cost of land that is farther from the city centre being lower while the cost of transportation increases because of the fluctuation in goods and services;
4. According to Alonso, the bid-rent theory that underpins the urban model takes into account two crucial components. The first is the development of a bid-theory curve, which indicates if the price of the land and associated factors (distance, transportation, and composite commodities) will be sustainable or cost-effective;
5. The objective is to separate different price ranges and decide how affordable each set may be. The bid curve would look at external criteria to ultimately decide the most advantageous location and land;
6. The bid curve is specific to each person, to produce the best outcomes. People put up bids for land, with the winning bidder receiving the land's title deed; and
7. This bid-curve idea would then shape the urban structure and the premise.

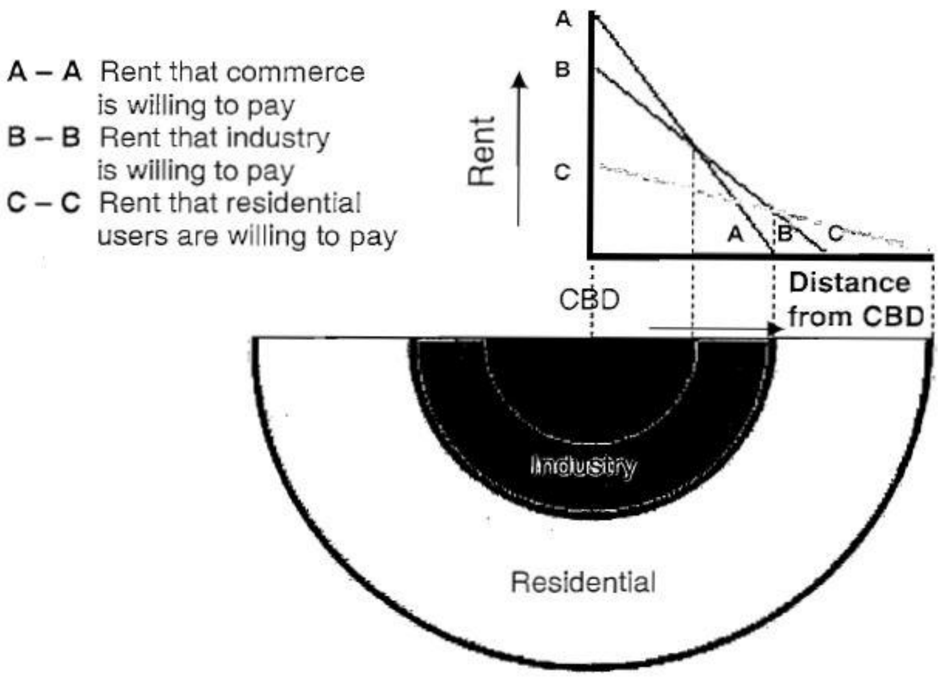


Figure 3 - 22 Bid-curve model (Alonso's model)

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 Figure 3-22 shows the affordability of transportation and the distance needed to travel each day. Lower-class individuals would be more likely to stay near 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.

3.2.10.1 Land use

There are four rings of agricultural activity surrounding the city (Cilliers, 2010:27; Cullinan, 2019:47; Mashabela, 2023:222). The model shows similarity towards the garden city model (cf. 3.2.1) as well as the concentric ring model (cf. 3.2.2). The first ring around the CBD describes dairying and intensive farming occurring in the ring closest to the city centre (Waugh, 2002:425). The purpose of this concentric ring was to transport vegetables, fruit, milk and other dairy products to market quickly (Cilliers, 2010:26-28). The factor of refrigeration was not available in that era and ox wagons were used for transportation. The second concentric ring describes the milling of timber and firewood which would be produced for fuel and building materials. The urban model was implemented before industrialisation and wood was a very important fuel for heating and cooking. Wood is very heavy and was difficult to transport so it was located as close to the city as possible. The third zone consists of extensive fields of crops, for example, grains for bread. Since grains last longer than dairy products and are much lighter than fuel, reducing transport costs, they could be located further from the city. The final ring surrounding the central city is considered to be ranching, this would involve the breeding of domestic livestock. The livestock could be raised far from the city because they were self-transporting. The livestock would walk to the central city for sale or butchering. The area beyond the fourth ring is wilderness and was used for expansion when the population exceeded its current urban structure (Cullinan, 2019:47).

Modern location economics began with Von Thunen (1826), who focused on the value of land use and increasing its value through various aspects of transportation, economic benefit and connectivity (Mashabela, 2023:221-222). They were the first to develop a basic analytical model of the relationships between markets, production, and distance. The purpose was to focus on the agricultural landscape. Von Thunen observed that the land use structure around German villages in the early 19th century was remarkably similar; thus, they postulated that relative costs of transporting different agricultural commodities to the central market determined the agricultural land use around a city. The most productive activities would compete for the closest land to the market and activities. The least productive activities would have been located further away from the CBD (Waugh, 2002:425; Pacione, 2005:195).

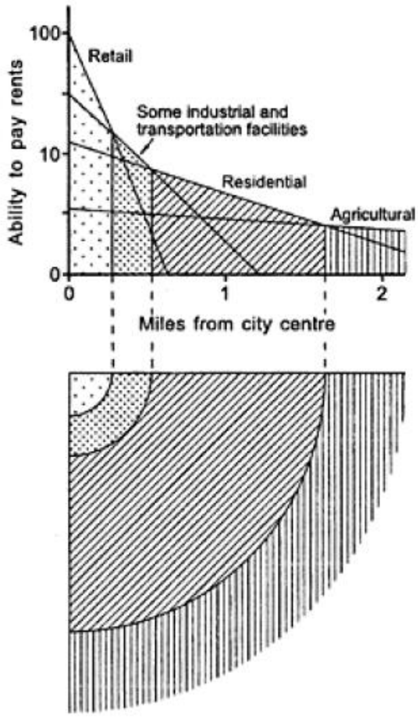


Figure 3 - 23 Distance from Urban Structure core and land value

Source: Pacione (2005:195)

The model had a set of two basic assumptions which reflect agricultural conditions within the Figure 3-23 above. These were:

- Isolation: There was one isolated market in an isolated state having no interactions (trade) with the outside. The assumption was that the output is for the local market with ubiquitous land characteristics (the land surrounding the market is entirely flat and its fertility is uniform); and
- Transportation: It was assumed that there were no significant transport infrastructures, such as major roads or rivers, and that farmers transported their products to the market using horses and carts. Transportation costs were dependent on the type of commodity being transported to the market and the distance involved.

The land value and cost concerning land use had been delegated to the highest bidder. The above Figure 3-23 illustrates (bid-curve model) that certain industries were able to afford certain land use properties while others would settle for lower land value costs (rent) away from the CBD. The Figure 3-23 illustrates three points of land value and costs at which the individual had been willing to pay (Waugh, 2002:425):

- Commercial land use: The cost at which businesses were willing to pay to occupy the land use;
- Industrial land use: The cost at which industries and factories were willing to pay to occupy the land use; and
- Residential land use: The cost at which residents were willing to pay to occupy the land use.

Land value and costs were illustrated on a graph to describe the medium that individuals were willing to pay. The average cost shows land value, which would decrease and increase with effective transportation. The model illustrates concentric rings as does Burgess's model but differs in land use and land value. The concentric ring model (cf. 3.2.2) shows that land value is lower towards the centre and more expensive in the outskirts of the model. The below Figure 3-24 describes the delegation of land use based on land value.

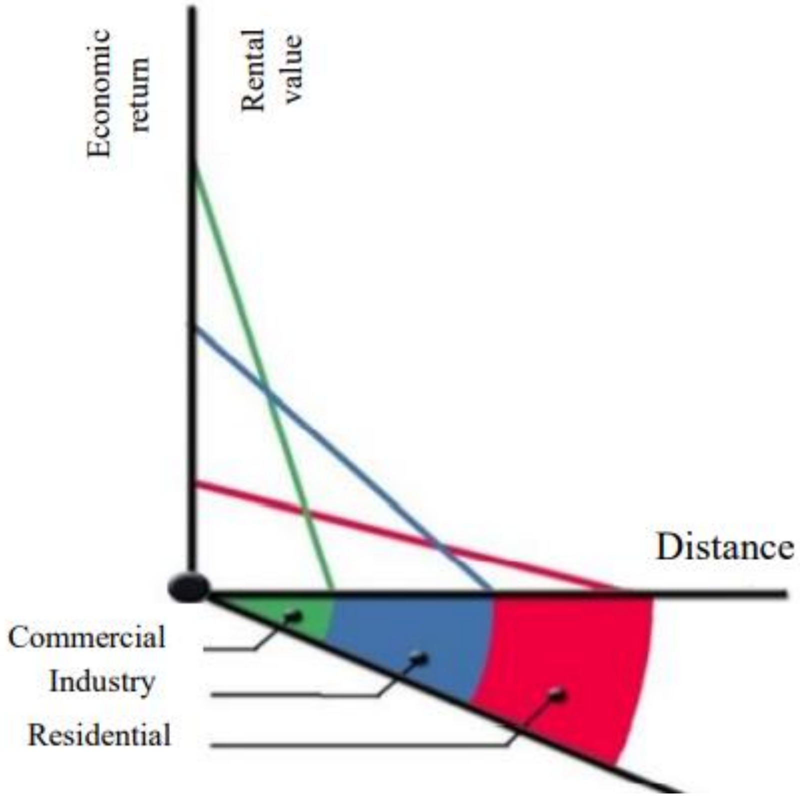


Figure 3 - 24 Land use based on land value

Source: El-Barmelgy et al. (2014:93)

The Figure 3-24 above is a graph used in this land use value model to illustrate the economic benefit of the various land uses (El-Barmelgy *et al.*, 2014:92-94). The graph demonstrates that commercial land used provides the most economic benefit within the urban structure, while residential demonstrates the least economic benefit towards land use value. The aspect which plays a significant role is the distance from the CBD. In contrast, most of the above models illustrate the CBD as an important activity node to generate economic benefit (concentric ring model (cf. 3.2.2), garden city (cf. 3.2.1)). The other models show various activity nodes or CBD areas to increase economic benefit throughout the urban structure (multi-nuclei model, urban realms model). The primary function of land use had been to increase land use value as well as economic benefit. There were land use categories and aspects which may have decreased land value performed within the model (El-Barmelgy *et al.*, 2014:92-98). These are described in the subsections below.

- ***Residential land use***

The land was used for residential use due to the following:

- The soil and subsoil conditions were adequate for development but not for agriculture;
- The groundwater level was not high and would not damage infrastructure;

- It provided a safety aspect from runoff or surface floods;
- It protected the surrounding ecosystem from topographic accident hazards;
- It was near available utilities and protection services; and
- It was situated far from industries meaning fewer local hazards and nuisances, such as accident hazards, noise, vibration, noise, smoke, dust, disease hazards and moral hazards.

- ***Commercial land use***

Land was used for commercial use, due to the following:

- The flat land or topology, which was preferably not more than 5% so as not to cost much when settled;
- The possibility of choosing the right location for shops was in the heart of the city, or neighbourhoods or on its outskirts;
- The sites contacted main streets and transportation directly - both for receipt of the goods for shops or for delivering goods to customers; and
- There were large parking areas to accommodate large populations.

- ***Educational uses***

Land was used for educational purposes, due to the following:

- The land use was within proximity to the area allowing accessibility from houses;
- There were safety precautions regarding roads, meaning only local roads in the area with crossings prevented children from crossing any major streets;
- The land use was considered to be quiet to avoid any distractions;
- The land use had large open areas suitable for playgrounds;
- The area was higher than the water level and provided a flat and dry site; and
- The educational site for schools had to be far away from the noise, factories, and railway stations.

- ***Medical land use***

Land was used for medical use, due to the following:

- The infrastructure that needed to be built had sufficient space;
- The neighbouring land use was situated near the medical area in case of an emergency; and
- The transportation network allowed for fast-flowing and efficient traffic flow for ambulances and emergencies.

- ***Cultural land use***

Land was used for cultural use, due to the following:

- Provided adequate accessibility from neighbourhoods;
- The library had to be near parks and open areas in a quiet environment; and
- Large parking areas were needed to accommodate the population.

- ***Social land use***

Land was used as a social centre. This was different from one neighbourhood to another but these centres were set up, nonetheless.

The delegation of land use was similar but varied depending on the residential area and cost of transportation. This has also been illustrated in different implementation aspects throughout the previously analysed models.

3.2.10.2 Mobility

The model compares the relationships between production cost, market price and transport cost of an agricultural commodity. This had been determined by a formula used to ascertain current land value. The formula used within this urban land-use model is expressed as follows:

R = Y(p-c) – Yfm

- **R**= Rent per unit of land;
- **Y**= Yield per unit of land;
- **p**= market price per unit of yield;
- **c**= Average production costs per unit of yield;
- **m**= Distance from the market (in km or miles); and
- **f**= Freight rate per unit of yield and unit of distance.

The mobility within the theory of agricultural land-use model demonstrates the main focus on mobility to supply demand and increase economic benefit within the agricultural sector as it had mainly focused on agricultural uses. All agricultural land was used to maximise their productivity (rent), which had been dependent upon their location from the market (CBD). The role of a farmer was to increase or maximise profits (market price) while deducting the transport and production costs. The most productive activities (gardening or milk production) or activities with high transport costs (firewood) were located near the market. The Figure 3-24 above provides an overview of Von Thunen’s agricultural land-use model with the basic assumptions being applied (isolation, ubiquity, transportation). It can be divided into two parts:

- The pure isolated state over an isotropic plain (left). In this case, land uses took the form of perfect concentric circles; and
- The potential impacts of modified or amended transportation costs and the presence of a competing centre.

The relationships between agricultural land use and market distance are very difficult to establish in the contemporary context. However, the model illustrates the competitiveness of various markets in increasing land value.

3.3 URBAN TRANSPORTATION NETWORKS

Urban transportation networks are various mathematical models of transportation systems (Sheffi, 1985:1-20) which determine the efficiency of transportation systems within a specific urban model. The mobility and efficiency of transportation systems are determined by the statistical and mathematical approach of civil engineers (Nowakowski, 2004:113-130). Travel behaviour has already changed considerably as lifestyles changed during the past two decades, and it will continue to change in the future (Kane & Behrens, 2002:1-7). To cope with this change, the current urban transportation systems must be reshaped to better support future urban mobility as well as the sustainable development of our society, economy and environment (Manderscheid & Richardson, 2010:1797-1798).

The amount of travel taking place within an urban model at a given moment on any street, intersection or transit line in an urban area is the result of many individuals' decisions. Individuals choose if and when to take a trip for some purpose, and which mode of transportation to use. This is determined by the individual's designated location to travel to and from a specific point. These decisions depend, in part, on how congested the transportation system is and where the congested points are (Kane & Behrens, 2002:4-6). Congestion at any point of the transportation system, however, depends on the amount of travel through that point (Suzuki *et al.*, 2013:30-31). There are several urban models (cf. 3.2) with unique SSs which makes this implementation process difficult even through the use of calculations. There are three main problems when implementing an urban transportation system (Sheffi, 1985:1-20):

- The transportation infrastructure and services, including streets, intersections, and transit lines;
- The transportation system's operating and control policies; and
- The demand for travel, including the activity and land use patterns.

Another approach towards the urban transportation network is the implementation of urban public transportation systems. An urban public transport network can be viewed as a complex system of the urban transport system and socio-economic environment (Jia *et al.*, 2019:1-3). The urban public transportation network improves the urban transit network, which increases mobility for all surrounding communities (Wegner, 1995:4; Suzuki *et al.*, 2013:35; Cullinan, 2019:26-27).

3.4 CONCLUSION

The urban models addressed illustrated comprehensive principles of implementation within urban structures. The various urban models (cf. 3.2) analysed illustrated a specific purpose for implementation and cannot be compared to one another based on implementation - since they all have various reasons for their specific implementation. The garden city model (cf. 3.2.1) illustrated a sustainable concept concerning the implementation of transportation and the environment. The garden city model had various rings radiating outwards from the core CBD area; while the same concept has been used within the concentric ring model (cf. 3.2.2), it differs due to the different land use planning approaches. The concentric ring model had various land uses and distances from the CBD but considered class hierarchy to improve the efficiency of lower-income groups and their mobility. The concentric ring model (cf. 3.2.2) had one nucleus (core). In contrast, other models such as the multi-nuclei model and the urban realms model demonstrated multiple nuclei to improve economic benefit. The models also illustrated land use planning of class hierarchy such as planning of the lower income group close to factories and industries. This area (transitional area) was illustrated in the multi-nuclei and concentric ring models. The concentric ring model was used to construct the urban structure model, which is a combination of the sector model as well as the concentric ring model (Waugh, 2002:422). Land use was segregated through concentric rings in combination with sectors, while land use of class hierarchy had been considered; it shared similar traits with the core being used as the CBD (nuclei) area. The implementation of the urban structure model influenced the design and development of the apartheid city model implemented in South Africa and used a different type of hierarchy (race hierarchy) to segregate races. The 21st-century city model also illustrated a less complex land use management perspective than the concentric ring model (cf. 3.2.2) and was created for UK cities. The common use for the core being centralised in the above-mentioned models was to compact and attract economic benefit to a single point within the urban model.

The multi-nuclei model showed various cores of activity nodes, such as epicentres, which created numerous centres of economic growth. This was assisted through the incorporation of transportation systems and activity corridors. Transportation systems were crucial to increasing economic benefit, as illustrated in the urban fabrics model (cf. 3.2.7) and Marchetti Constant model (cf. 3.2.9), whereas the urban fabrics model used multiple modes of transportation which bound together to form the urban model. The Marchetti Constant model focuses on the efficiency of the transportation systems as well as time, cost and distance of travel to align various transportation systems to create an effective multimodal transportation system. The mobility of individuals to a concentrated point (activity nodes) within the urban structure increased economic benefit and potential land use, which was the main focus of the theory of agricultural land-use model (cf. 3.2.10). The model (cf. 3.2.10) illustrated that the highest land value was situated within the core and decreased as it radiated outwards.

The models expressed various delegations of land use and hierarchy as well as specific methods of transportation implemented based on the urban structure. Thus, each model had specific aspects to their design to benefit a unique need. The urban model design had various advantages and disadvantages but may not have been created for the possible disadvantages. Therefore, specific principles should be abided by to create a unique outcome. These principles can be applied to create an urban model which uplifts the majority of the urban structure's aspects (environment, economics, and land use, among others) to form a sustainable urban model or guidelines which can be incorporated.

This chapter demonstrated relevance towards **Research Objective 2** (cf. 1.3) by illustrating various urban models (cf. 3.2). The research objective has been addressed with the chapter by showing the different urban structures and their SS. This demonstrates the implementation or layout of transportation systems within the different urban models. This described the various types of urban structures requiring different transportation systems or TP strategies. The following chapter will evaluate several types of transportation models to identify character traits which may enhance the efficiency of transportation systems within an urban structure. There are various types of transportation modes and implementation, as there are urban models (as seen in this chapter).

CHAPTER 4 TRANSPORTATION PLANNING: A REVIEW

4.1. INTRODUCTION

The study seeks to identify possible traits of implementation of transportation systems with relevance towards types of transportation modes, as well as efficiency of implementation. The chapter will illustrate the various spatial implementations of transportation systems. The spatial organisation of transportation systems will illustrate the various networks and flows of transportation systems. The chapter will address **Research Objective 1 (To review existing transportation guidelines and systems which would potentially improve efficiency within cities).** The different transportation models (see TP) will be evaluated in this chapter under a set of criteria deemed significant towards this study and may exclude other types of transportation systems. This may be a limitation, as the chapter only reflects on the relevant models; however, there are multiple types of TP models implemented worldwide. The chapter will assess TPs based on its network structure.

The above criteria will support the objectives proposed for the chapter, as well as illustrate possible methods of implementing transportation models to improve the efficiency of transportation systems within the urban structure. These systems will be reviewed according to their transportation networks' (cf. 4.2) flow, connectivity and efficiency. Efficient transportation systems can be based on network and TP components, therefore implementing a specific system must have improved practical components. These components can include connectivity, as the connectivity of land uses based on the transportation system can impact flow (cf. 4.3) and may cause inefficiencies. The spatial organisation of transportation (cf. 4.2.2) can be based on two SSs, namely monocentric (cf. 4.2.2.1) and polycentric (cf. 4.2.2.2). The monocentric SS (Phillips, 1970:49-51) describes limited accessibility towards land use, but the polycentric SS demonstrates multiple accessible networks and flows (Bertaud, 2002:3).

This chapter will illustrate the implementation of the transportation models to determine possible guidelines towards improving transportation efficiency. The chapter will do so by evaluating TP models' implemented transportation networks, their flows and their spatial organisation.

4.2 TRANSPORTATION NETWORKS

The movement of people, products, and services across different SSs is more efficient through transport networks. A transportation network is a structured system of nodes (points) and links (connections) that facilitates the movement of people, goods, and services across geographic space. It represents the physical and functional arrangement of transportation infrastructure (roads, railways, air routes, waterways) and transit lines designed to enable connectivity and accessibility between various locations. These networks facilitate effective and coordinated travel and distribution, including roads, railroads, air routes, sea routes, and public transportation systems. Transportation networks are considered to be a vital component of economic activity, connecting urban and rural areas (Arora & Pandey, 2011:2-3).

4.2.1 Connectivity structure

SS networks are determined by the type of mobility or transportation system implemented, such as the type of connectivity between land uses and the efficiency of mobility. The network can be a type of multimodal transportation system with various transportation components that work simultaneously. The urban structure has various networks, however, in this study, relevance will be focused on urban structure and SS. The network in predated spatial planning had focused on the land use structure, but not connectivity. The present-day notion has three criteria for networks based on spatial planning approaches (Van Schaick, 2008:17-20):

- The first criterion is the area's topography. Unique topography requires a unique spatial planning network to create direct connections between points. The idea of ubiquity characterises the topology of a network. This may require a unique urban model (cf. 3.2) or SS to connect land use and provide efficient mobility. The topography of an area can greatly affects the network required due to natural barriers that may be present. This requires a unique transportation system to improve efficiency and connectivity;
- The second criterion is known as the kinetic criterion. This refers to the efficiency of transportation or mobility, while instantaneousness refers to the homogeneity of speed and the importance of rapid transportation and flows. This considers time losses or interruptions and defines networks' movement or kinetic aspect. This is often seen in over-congested transportation networks or slow transportation modes; and
- The third criterion is known as the adaptive criterion. The word network includes the notion of multiple choices concerning connections, both in space and in time. This is not explored in the paper but it is important to note. These connections may require permanent support and a fixed infrastructure. On the other hand, ideally, the network must be able to adapt itself to new user requirements constantly.

The network of an urban structure is comprised of various components. The significant components within the urban structure are transportation and land use connectivity. Individual mobility is a significant factor that can affect productivity efficiency and economic benefit. The illustration below demonstrates the simple connectivity of points in an urban structure.

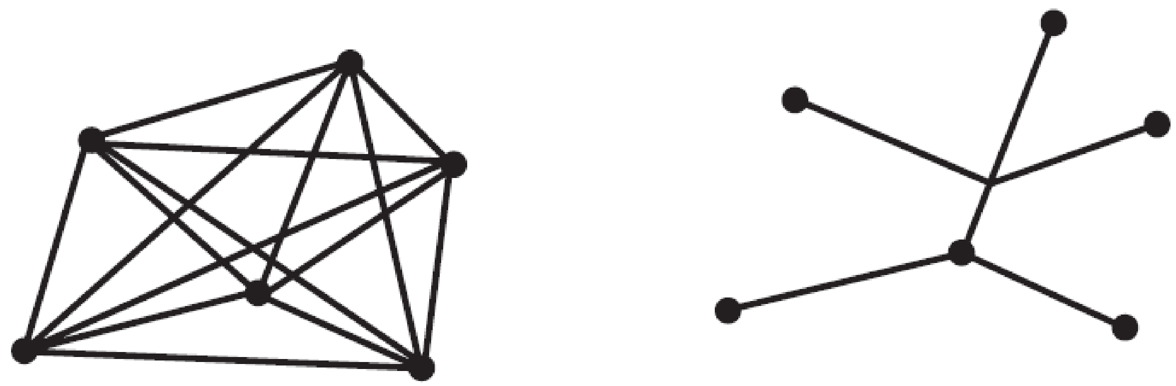


Figure 4 - 1 Connectivity of activity points within an urban structure

Source: Van Schaick (2008:44)

The simple connectivity diagram above illustrates the mobility and access of mobility towards each activity node. The diagram on the right demonstrates a simplistic connectivity structure between activity nodes; it shows one-way access between nodes and that if mobility structure is compromised through congestion or any other reason, efficiency is decreased. The diagram on the left demonstrates the same activity node structure but differs in accessibility between nodes; it has multiple accesses and mobility between activity nodes. This will increase efficiency between activity nodes due to the numerous mobility accesses provided.

From the Figure 4-1, the simplicity of transportation may not offer an effective mobility system. Therefore, the use of various access or multimodal transportation systems can increase efficiency and productivity. This would depend on the size of the urban structure as well as the surrounding urban structures to provide efficient movement of both goods and people.

4.2.2 Spatial organisation of transportation

The spatial organisation of transportation refers to the implementation of transportation within the urban structure. It dictates where and what transportation will be implemented within the area to create an efficient flow of mobility, which, in turn, increases economic benefits. The connectivity of land uses increases productivity and indirectly increases land value. The spatial organisation of transportation is based on the urban structure, which can be categorised into two main structures (monocentric [4.2.2.1] and polycentric structures [4.2.2.2]). The monocentric structure focuses on a specific transportation system, while the polycentric structure focuses on multiple transportation systems to create accessibility and increase mobility flow. The two main structures are equally efficient but would be determined by the SS (Bertaud, 2002:3; Alqhatani *et al.*, 2014:218-219).

The implementation of the monocentric urban SSs has been identified as more restrictive, posing various constraints to accessibility, due to the singular aspect of transportation. Implementing a polycentric urban SS would increase various forms of accessibility to the urban structure. This will decentralise the urban structure, due to the various forms of mobility, multiple transportation modes, and various city centres (CBD). The two urban SSs will be illustrated in the subsections below. The initial concept of the spatial organisation of transportation is to provide for 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-curve 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. The increase in accessibility is of more benefit to people and the residing community. The accessibility of a spatial form should incorporate various forms of transportation, allowing more accessibility from various angles.

The spatial organisation of transportation has been based on five approaches that would allow for effective spatial planning and organisation of transportation units within a spatial plan and urban structure (Alqhatani *et al.*, 2014:219). The first approach refers to the accessibility factor, which involves both cost and time taken to travel. This is calculated through a sum of impedance. The second approach focuses on the origin and destination of travel. This requires different transportation based on various factors. A calculation, known as either the entropy-based approach or a place-ranked approach, is used to determine the best and most efficient way to travel. The third approach would determine the average travel time based on the opportunity at the destination within the urban structure. The fourth approach would determine the cost of mobility at the end of the trip. This would involve various transportation services or time taken between points of interest and is known as the utility-based approach. The fifth approach focuses on the various constraints of mobility, for example, congestion, cost of travel and type of transportation mode. This is determined as the opportunities available based on the access to travel and cost predetermined by an individual's budget.

The spatial organisation of transportation can be illustrated in a simple diagram illustrating the flow of transportation of mobility between urban structures. There are various factors which cannot be controlled (urban sprawl) but can be used to increase population density and centralise growth. Increasing activity between city centres or CBDs would increase the population around the area and ultimately with the increase of supply and demand would create new city centres to sustain the surrounding population. This can create two different scenarios, where one urban structure would stagnate through urban sprawl, while the other scenario illustrates urban growth in a positive manner (new city centres, increasing job opportunities and increasing population density). The representation of the two scenarios below illustrates the difference in the activity growth and the initial accessibility.

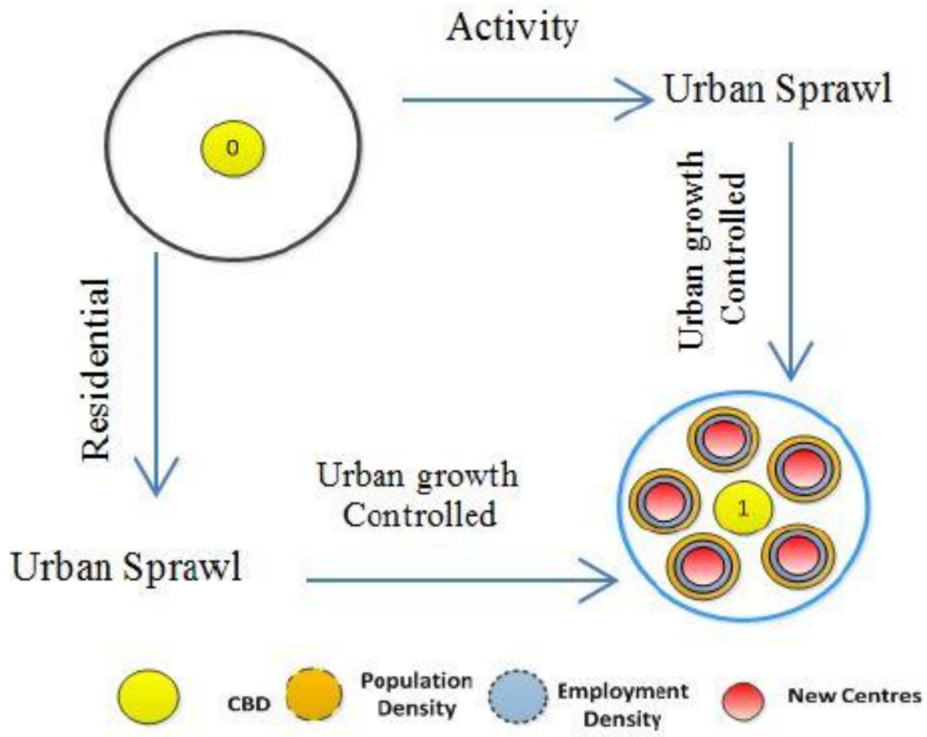


Figure 4 - 2 Urban SSs integrated into the spatial organisation of transportation

Source: Alqhatani et al. (2014:220)

The above Figure 4-2 shows two scenarios of urban structures and the development of the urban form. One scenario illustrates stagnation, which can occur through urban sprawl, while the other illustrates the concentration of urban sprawl and mobility. The second scenario concentrates urban sprawl to create population density and indirectly increase city centres and development. This would be determined through mobility within the urban structure and its ability to expand the population. Through the expansion of the urban structure, supply and demand will increase due to the increasing population.

4.2.2.1 Monocentric spatial structures

The spatial organisation of transportation through a monocentric SS has been implemented in predated city models, such as the garden city model (cf. 3.2.1) (Pacione, 2005:226-230). The garden city model illustrates the correct implementation of transportation systems and mobility. The reason this can be determined as a successful implementation of the monocentric SS is due to the restrictive greenbelt, which does not allow the city to expand. This would ultimately require a new node to be created outside of the greenbelt, which limits urban sprawl. This can also be considered a mono-polycentric model, illustrating one main city centre (CBD) (Phillips, 1970:50).

The urban structure as an individual can be identified as a monocentric SS, as all components and land uses are connected to the CBD. This can also be identified within the concentric rings model (cf. 3.2.2) and other predated urban models. Another illustration of a monocentric SS is discussed as an urban model (cf. 3.2.1) and is considered to be a primitive design on which various specialists have collaborated (Waugh, 2002:425). The theory of Alonso's (1964) agricultural land-use model describes the bid-curve model and identifies this spatial organisation as specifically effective in using transportation to increase the density of the metropolitan area. This refers to the above-illustrated scenarios, wherein centralisation of the population creates the economic benefit of the SS.

The monocentric model (cf. 4.2.2.1) was used to derive more evolved urban structures. The SS model directed all activity towards the singular sector of the urban structure. This may have been successful in predated models but as technological advances and new transportation systems arose, economic benefit became a more prominent objective. The monocentric SS would slowly be decayed as an option in the spatial distribution of cities, for one specific reason - the mobility of individuals would not just be delegated towards the CBD and was not the only destination for the individuals occupying the area (Bertaud, 2002:3; Pacione, 2005:375). The more efficient monocentric SS through advancements would be considered the mono-polycentric model. This is considered to be a hybrid SS model that illustrates the movement from the outer city towards the CBD but it uses multiple city centres and improves accessibility as well as connectivity. The monocentric and mono-polycentric model is illustrated in the Figure 4-3 below.

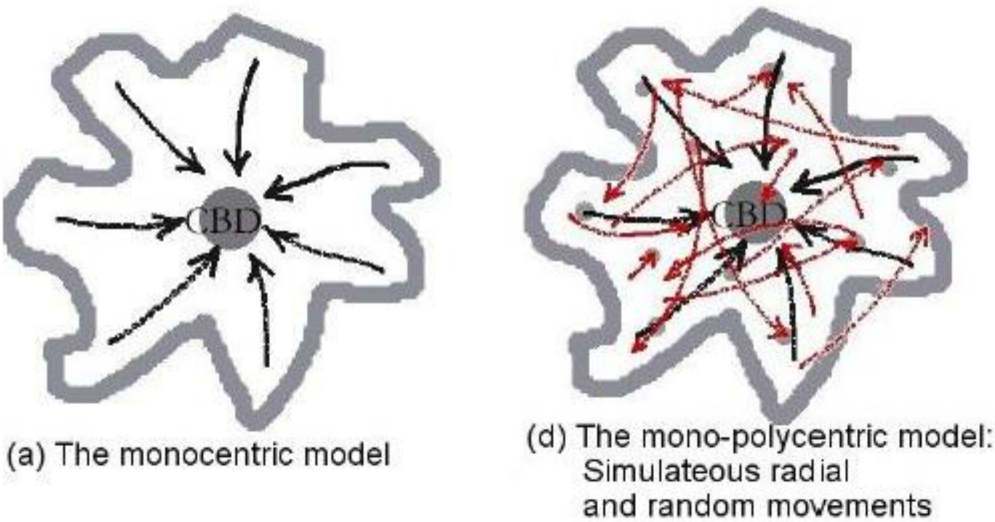


Figure 4 - 3 Monocentric and mono-polycentric SSs

Source: Bertaud (2002:3)

From the above, the monocentric and mono-polycentric spatial models can be examined. The monocentric SS was seen as the most basic model, where all land uses are directed towards the city centre. This is based on assumptions about the economic, social, and cultural infrastructure that would be situated at the core of each urban development. The monocentric SS would allocate transportation routes towards the centre in a radial approach to the urban structure (Alqhatani *et al.*, 2014:118). The predated urban model (cf. 3.2.1) is presumed to require transportation to be 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). The mono-polycentric SS, as illustrated, would have a similar concept, but multiple cores and more points of accessibility. This would allow for multiple access points to land use and would benefit through secondary cores (CBDs) connecting to a main CBD area. The multiple points of connectivity would make it viable for various modes of transportation to create multimodal transportation systems. This would ultimately increase efficiency and economic benefit, which in modern-day models is one of the main objectives.

4.2.2.2 Polycentric spatial structures

The polycentric SS was designed against the background of the failures of the monocentric (cf. 4.2.2.1) city. It was designed to provide multiple access points to several city cores. This would involve various transportation modes, including multimodal transportation. The polycentric design focused on the use of transportation units while considering the needs of the community, whereas the monocentric SS (cf. 4.2.2.1) assumed that all individuals would move towards the core of the settlement.

The polycentric SS had been based on the assumption that it would provide multiple access points and adequate transportation modes between cores. The assumption of multiple access could prove problematic if not implemented strategically. An example of the polycentric model can be illustrated within Chapter 3, as the urban fabrics model. The urban fabrics model (cf. 3.2.7) illustrates multiple city cores and several access points. The core of the SS would be accessible through various transportation nodes (Newman *et al.*, 2016:431).

The processes of the monocentric (cf. 4.2.2.1) SS and polycentric SS differ due to the movement of individuals. The process that had to take place to form a polycentric spatial organisation was considered an evolution of the urban structure. This evolution has been mentioned in the monocentric spatial model, which illustrates a predated SS through the examples provided of the concentric ring model (cf. 3.2.2), garden city (cf. 3.2.1) and Alonso's model (cf. 3.2.10). The monocentric (cf. 4.2.2.1) city was considered to be small and allocated transport to the CBD of the development. The expansion of the urban structure would be due to urban sprawl, which would ultimately create stagnation of the urban structure if supply and demand had not been met. It was realised that not all transportation should lead towards the CBD and should be dispersed into various clusters of activities that would generate trips spreading out in the built-up area (Bertaud, 2002:2-4). The below diagram illustrates the spatial distribution of transportation infrastructure of polycentric models. The Figure 4-4 illustrates the distribution of transportation systems with multiple cores and access points:

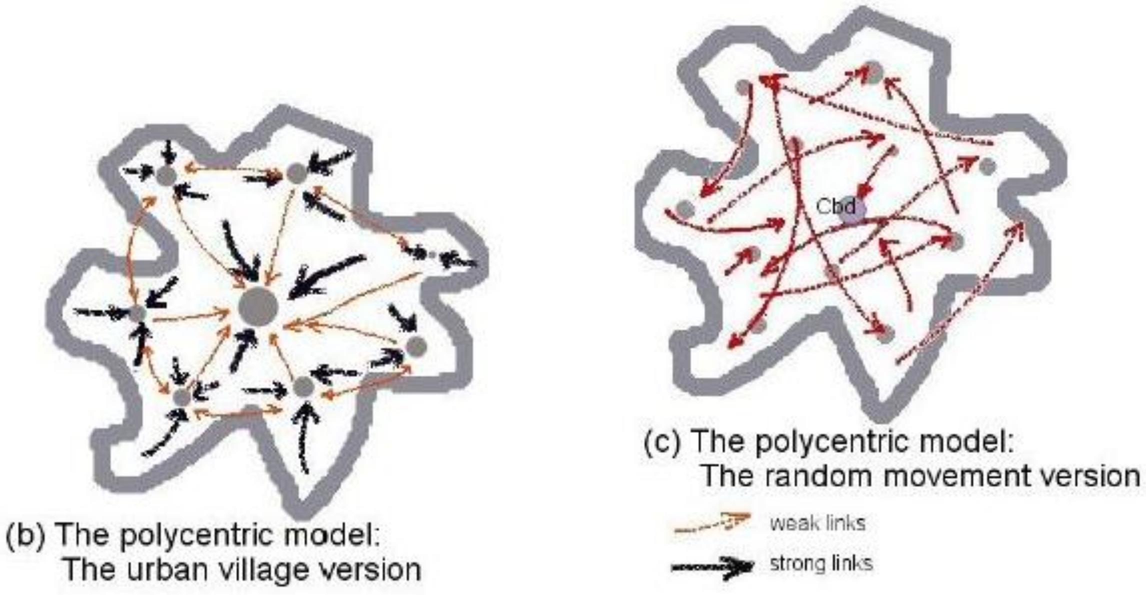


Figure 4 - 4 Polycentric SS

Source: Bertaud (2002:3)

The above Figure 4-4 illustrates the polycentric SS within the spatial organisation of transportation (cf. 4.2.2). The illustration represents the flow of movement between the various city cores. The mobility between cores can be considered to be random or structured but provides several points of access. The central node attracts growth from the outer node's thorough goods, services and business and is the most centralised area to satisfy common needs. The distance between cores can vary, which allows for different transportation modes and implementation. The nodes would be connected to a primary node, while the secondary nodes surround the primary core. The movement can be strong with regard to mobility or weak between secondary nodes. The polycentric (Figure 4-4) differs from the monocentric (Figure 4-3) based on connectivity and mobility as illustrated above, whereas the polycentric model is based on a more modern-day mobility approach.

4.3 TRANSPORTATION FLOWS

The flow of mobility is a crucial factor within urban structures and is predetermined through the use of calculations created by civil engineers. The connectivity structure (cf. 4.2.1) of the SS will determine the various transportation flows within the urban structure. Transportation flow has predominantly been based on the flow of motor-vehicle traffic, due to the increase in motor-vehicle infrastructure within urban structures around the world. The calculations in the next section (cf. 4.4) are used to predict traffic based on estimated vehicle data previously recorded. The flow of transportation has been illustrated within the trip and parking generation model (RSA, 2013:2-3). The calculations may differ between countries but the future prediction of traffic flow remains the same based on data.

The purpose of transportation flow is to increase the efficiency and sustainability of mobility systems. This is to increase economic benefit throughout the urban structure. The transportation model based on traffic flow can be identified as a traffic flow propagation model (Maerivoet & De Moor, 2008:15-19). These models differ based on the urban structure and type of transportation used. The models differ based on the level of aggregation and can be classified under the propagation models into the following four categories:

- The **macroscopic propagation model** illustrates the highest level of aggregation, and the lowest level of detail and is based on continuum mechanics, typically entailing fluid-dynamic models;
- The **mesoscopic propagation model** illustrates a high level of aggregation and a low level of detail and is based on a gas-kinetic analogy in which the driver behaviour is explicitly considered;
- The **microscopic propagation model** illustrates a low level of aggregation and a high level of detail, which is based on models that describe the detailed interactions between vehicles in a traffic stream or flow of traffic; and
- The **sub-microscopic propagation model** illustrates the lowest level of aggregation and the highest level of detail. This is considered to portray microscopic models but extended with detailed descriptions of a vehicle's inner workings.

The propagation models all calculate the flow of traffic on different levels. Each model has numerous calculations used to acquire data to project a future estimate for traffic flow (Maerivoet & De Moor, 2008:16-36).

The flow of traffic is determined by the amount of traffic that takes place in the network. The purpose of traffic flow is to determine efficiency and increase the time of mobility to increase demand and the capacity of the links that support the transport system. There are various assumptions about transportation flow, which is predominantly motor vehicles and road transportation. The assumption of transportation flow is the friction of space between various modes of transportation and is considered to be one of the most significant factors affecting transportation systems. Transportation can be affected by multiple factors, depending on the type of transportation used. It is presumed that transportation congestion can indirectly affect communities and surrounding urban structures positively or negatively based on the flow

(Rodrigue *et al.*, 2006:6), since flow can either break a community down or greatly benefit it, regardless of the types of transportation systems implemented or the intermodal collaboration (Pacione, 2005:247). There are three particular issues regarding flow (explained above in systems), namely (Rodrigue *et al.*, 2006:39-40):

- Value;
- Volume; and
- Scale.

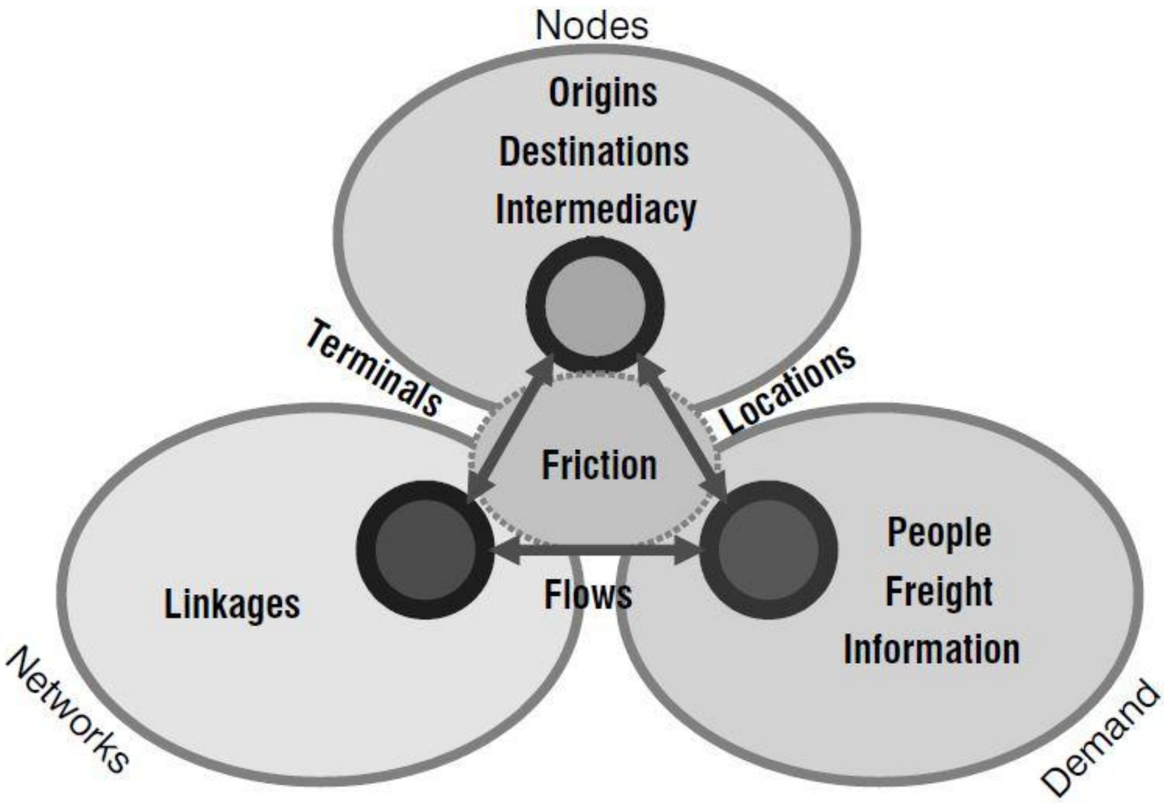


Figure 4 - 5 Transportation factors with the interlinkage of flow

Source: Rodrigue et al. (2006:6)

The Figure 4-5 above illustrates various factors which play a role in transportation flow. The mobility of both individuals and freight can be affected through the factor of friction. The flow of transportation can deteriorate if friction and congestion increase, due to a population increase through the factor of more individuals using a singular transportation system. This is illustrated in both Chapter 3 (cf. 3.2) urban models (Marchetti Constant model - 3.2.9) (Marchetti, 1994:77) and this chapter (Mackett, 1998:91-94) which illustrates future forecasts of increasing traffic volume.

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 is then distributed to all wholesalers/shops and finally reaches the final consumer. Delays in any section of the process may occur, leading to a lower rate of distribution. Flow in the distribution of goods and services is used to minimise costs through an increase in distribution (sales) but is limited to the efficiency of the transportation system. 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).

4.4 TRANSPORTATION PLANNING MODELS

The determination and planning of transportation have been based on critical analyses and connectivity of land use through the complex use of TP models. The comparative analysis of the various models will help to identify efficient approaches to TP as well as effective implementation of transport networks within an urban structure.

TP models are used to determine the connectivity of transportation systems and facilitate travel demands for the residing community as well as regional mobility. Transportation modelling is used to develop information to help make decisions for the current community or individuals to determine the future development and management of transportation systems, especially in urban structures. There are four stages to transportation modelling (Ahmed, 2012:22-38). The first stage is **trip generation** (Tsekeris & Tsekeris, 2011:84), which determines the time cost and distance of the transportation system. The second stage is **trip distribution**, which determines the number of individuals travelling and possible routes and pick-up and drop-off points based on the activity nodes. The third stage determines the **modal split**, which establishes the various types of transit systems required and the infrastructure needed. The fourth and last stage in transportation modelling is the **trip assignment**, based on assigning traffic to a transportation network, such as roads and streets or a transit network. This is derived by assigning traffic to available transit or roadway routes using a mathematical algorithm. The algorithm would determine the amount of traffic as a function of time, volume, capacity or impedance factor. The transit routes are determined by the choice of routes in the development of TP based on certain parameters such as travel time, distance, cost, comfort, and safety (Tsekeris & Tsekeris, 2011:84-85). Depending on the future development strategy of the urban structure, a specific travel demand modelling is created to improve the efficiency and sustainability of the spatial distribution of travel. Modelling of travel demand is a procedure for predicting what travel decisions people would like, to generalise the travel cost of each alternative.

The transportation models differ in various aspects to approach and achieve various needs for transit and mobility. The various approaches used by the transportation models have different initiatives and goals to achieve. The previously evaluated urban models (cf. 3.2) illustrate different methods of incorporating transportation systems within the urban structure. The majority of urban models (cf. 3.2) demonstrate the connectivity between land uses and could be efficient or unfunctional depending on the type of urban structure.

The following section will illustrate the types of TP models (cf. 4.4) to demonstrate the importance of transportation systems within the urban structure. The link between transportation systems and urban models is demonstrated through Christaller's central place theory. This illustrates the significance towards efficient transportation systems and how they will improve the mobility of goods and services (Jamoliddinov & Dsilva, 2019:15). The central place theory represents the connection between TP models and urban models (Chapter 3), as an example towards the integration of mobility and connectivity to improve the efficiency of the urban structure. The model below illustrates the aspects of the central place theory.

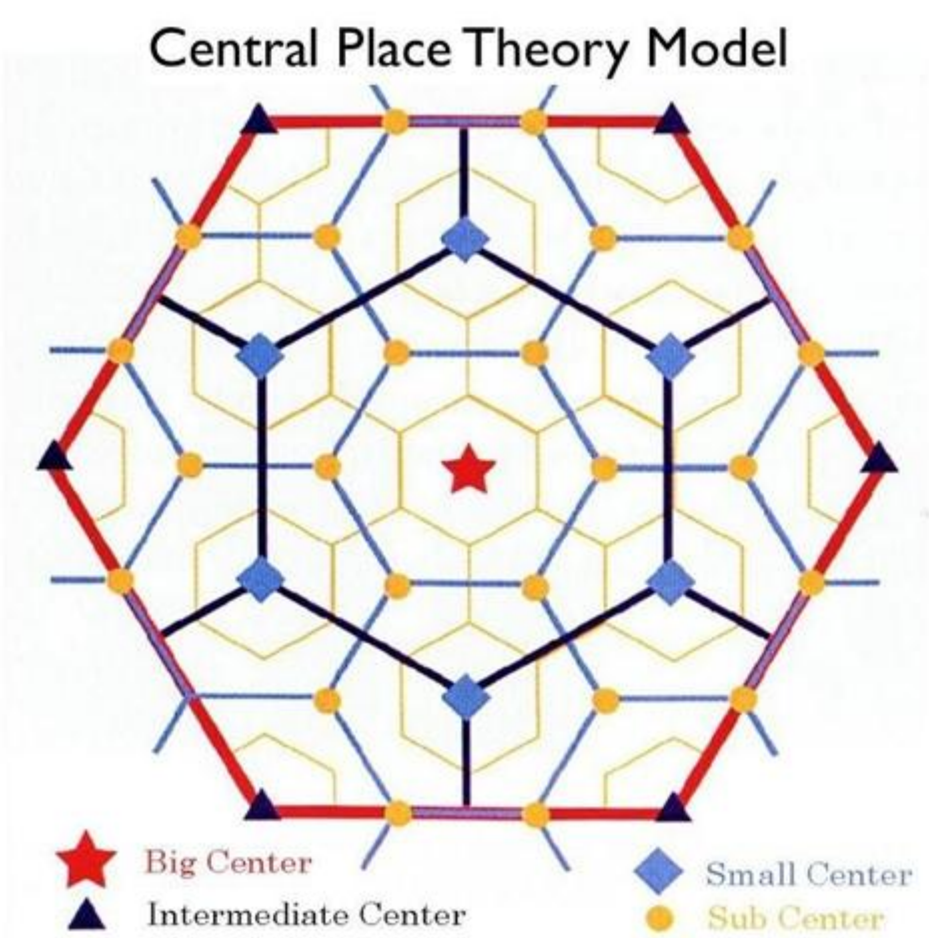


Figure 4 - 6 Central place theory

Source: Lasisi (2019:189)

The model illustrates the central place theory created by Christaller (Chapter 4). The main focus, as mentioned, is to connect various urban structures throughout the region to efficiently distribute goods and services. The urban structures have been governed according to a hierarchy. Large urban structures would distribute the majority of the goods and services which were unobtainable in smaller cities and towns. The economic evaluation of this model focuses on improving goods and services delivery and increasing economic benefit through transportation systems (Pacione, 2005:165-170).

The economic evaluation model requires long-range travel, as represented in the figure of the central place theory (see Figure 4-6). The model requires road, air and sea mobility to distribute goods and services throughout the region to maximise profit and economic benefit (Jamoliddinov & Dsilva, 2019:16-18). The main focus of transportation is delegated to road and rail transportation. The use of motor vehicles and trains would maximise each trip due to the amount of cargo carried or individuals. These types of transportation are considered to be long-range transportation. This is illustrated in the above Figure 3-21 of the Marchetti Constant model (cf.

3.2.9), illustrating distance and time travelled (Marchetti, 1994:75-77). Transportation and connectivity have been illustrated within the central place theory. The Figure 4-7 below illustrates the connectivity of the above-mentioned transportation system.

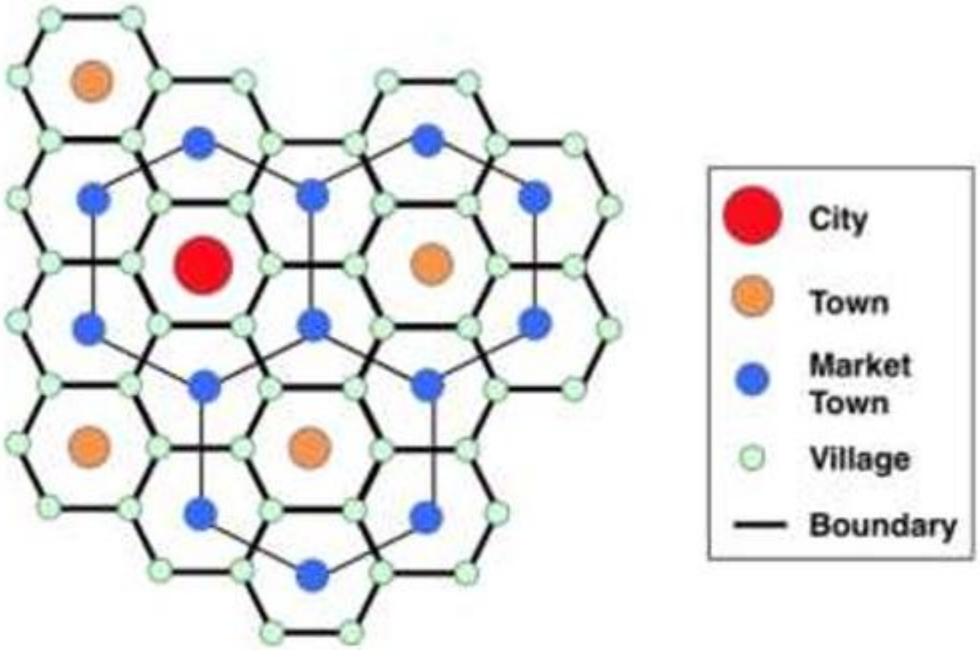


Figure 4 - 7 Christaller transportation connectivity modes

Source: Jamoliddinov & Dsilva (2019:17)

From the above, the connectivity of railway and road modes of transportation can be seen. The main line of connectivity illustrates the use of rail transportation with various railroad stations. The secondary lines show the use of roads or short-distance rail transportation systems. The economic evaluation model may differ in various urban structures, however, the concept of connecting various CBD areas to maximise profits and efficiency has remained the same (De Rus, 2020:12). The concept is to attract individuals from the residential areas to the CBD district to centralise economic benefit.

The central place theory illustrates the implementation of transportation systems within an urban structure. The urban models (cf. 3.2) previously addressed demonstrate the urban structure, while this chapter (Chapter 4) illustrates several types of transportation models. The following subsections will address the relevant TP models to determine the network structure, types of mobility, advantages and possible disadvantages. The transportation models assessed may improve the understanding of connectivity and implementation of transportation systems, which in turn may improve efficiency.

4.4.1 Travel demand models

Travel demand models evaluate traffic and are known as traffic models. These models were designed to evaluate traffic on the number of individuals travelling under specific circumstances and choices based on the cost of transportation, transportation services and land use. The models would determine or predict the transportation volumes, impact on the community or environment and usage. The models had originally been used for road transportation and the efficiency of mobility. The models are based on a four-step model (Mackett, 1998:91-93; Tsekeris & Tsekeris, 2011:84-87; Ahmed, 2012:22-38).

The first phase follows what is known as the trip generation (Tsekeris & Tsekeris, 2011:84-86). This predicts the total trips that start and end in a particular area. This phase is based on factors such as each zone's land use patterns, number of residents and jobs, demographics, transportation system features and distance between two zones. This would determine the efficiency of the transportation system within the area. The second phase would focus on what is known as trip distribution (Ahmed, 2012:25). Through the understanding of trip distribution, trips are determined and distributed between pairs of zones, based on the distance between those zones. The third phase focuses on mode share or multimodal distribution. This is determined through the trips allocated among the available travel modes (multiple modes of transit, such as train, vehicle or BRT). The fourth and last phase is known as the route assignment. This determines the trips which are assigned to specific facilities included in the highway and transit transportation networks based on the community and its needs (Mackett, 1998:91-94).

These phases help to determine baseline conditions and trends used by the community, as well as all types of mobility within the urban structure. The phases are used throughout the planning of transportation services to determine transportation demand. This forms a specific travel survey and census data to predict the mobility of the community (such as work, shopping or other). Initially, this would improve the transportation network and prevent congestion of certain road transportation systems (Gundlegard *et al.*, 2016:3-10). The models often incorporate several types of bias, favouring automobile transport over other modes and undervaluing Transport Demand Model (TDM) strategies (Ahmed, 2012:20). The models were evaluated through surveys and are considered to be based on tendencies that exclude non-motorised travel. This undervalues non-motorised transportation (NMT) improvements for achieving TP objectives (Mackett, 1998:93-94). The Figure 4-8 below illustrates the four phases and implementation of the travel demand models.

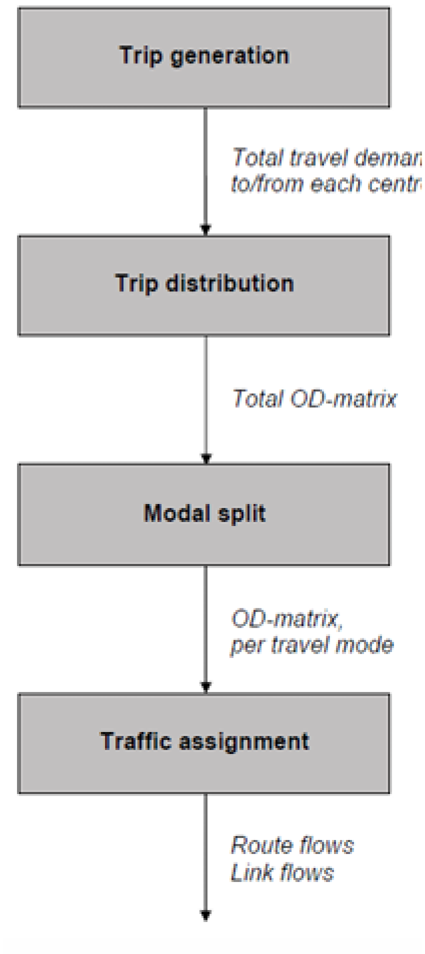


Figure 4 - 8 Example of a travel demand model

Source: Ali & Eliasson (2018:2)

The process shown in the Figure 4-8 above is followed by the process of forecasting travel demand at a local level. It is divided into four stages, which can be regarded as equivalent to the following simple questions (Mackett, 1998:92):

- Shall I travel?;
- Where shall I go to?;
- Which form of transport shall I use?; and
- Which route shall I take?

4.4.1.1 Network structure

The above questions identify the proposed implementation based on the required outcome. This would then formulate a larger network which incorporates the use of various modes of transportation and land use. The process is illustrated in the Figure 4-9 below.

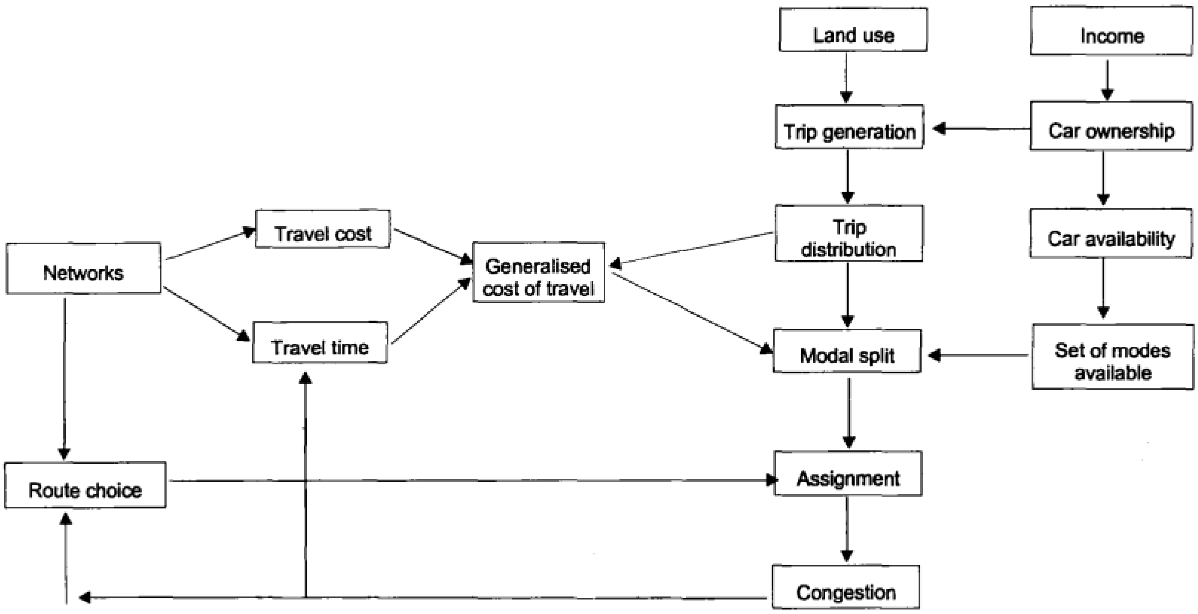


Figure 4 - 9 Process of travel demand and interaction of components

Source: Mackett (1998:92)

Figure 4-9 shows that the travel demand network had been based on two main factors (travel cost and travel time). This is a similar framework to Christaller`s central place theory (King, 2020:18-26), whereby the movement of goods and services had been based on similar principles. The travel demand models are used based on road transportation (Mackett, 1998:93-96). This refers to the use of motor vehicles, whereas the travel demand had been based on the cost of fuel, km travelled and the number of car ownerships. The commercial motor vehicles that were used were included in a similar calculation to predict the traffic forecast of the urban structure (Mackett, 1998:93-96; Tsekeris & Tsekeris, 2011:88-91). The possible benefits of the travel demand models are illustrated by its purpose of implementation. The travel demand models are based on providing affordable costs for transportation based on the urban structure:

- To focus on economic sustainability for the surrounding community;
- To provide affordable costs of transportation;
- To focus on the movement of goods and services; and
- To focus on a multimodal split.

The general concept is based on the economic benefit of the urban structure. This would often use motorised transportation due to the provided calculation which requires the variable of trip generation as well as the cost of travel, which cannot be calculated in NMT. The disadvantages of the travel demand models are evident because it is only associated with motorised transportation. The focus on efficient mobility, cost of mobility and distance travelled have caused probable issues in sustainability. The below points illustrate the various disadvantages identified (Kane & Behrens, 2002:1-6):

- Focuses on motorised transportation and does not implement sustainable NMT methods;
- Focuses too much on the efficiency of motorised transportation, but can cause congestion;
- Does not illustrate environmental strategies of implementation and due to the motorised vehicle concept, can deteriorate the environment over time;
- Transportation network not specifically illustrated; and
- The cost of transportation will increase with a growing population.

The disadvantages illustrate that there is little to no consideration towards the environment. The travel demand models may focus on multimodal transportation but completely disregard NMT because the transportation models are focused on economic benefit and not sustainability.

4.4.2 Trip and parking generation models

The trip and parking generation models illustrate reports that can be summarised as information from numerous site surveys for road transportation which measure the number of vehicle trips and vehicles parked in various land use types (Ewing *et al.*, 2017:20). The models predict information used to determine the impacts that future developments will have on local traffic volumes and the number of parking spaces required (Regidor, 2006:1-8). The models are used to determine future developments and the increase of road transportation. They formulate a resulting value which may influence planning decisions in various ways, including the transportation impact cost, efficiency and minimum parking requirements for new developments, which may be implemented in the future (Ewing *et al.*, 2017:112-113).

Surveys are used within these models to determine road transportation requirements. These surveys are performed in automobile-oriented urban structures to implement on-site parking since those tend to be the easiest sites to measure (Ewing *et al.*, 2017:41-43). This is a complex process due to the various factors (geographic, demographic and management) that affect trip and parking generation. However, it rarely indicates the types and incomes of people who live or work at a site (this will differ depending on middle-class, lower-class and higher class), mobility service proximity, efficiency and quality, local walkability, whether parking is free or requires a fee (Tsekeris & Tsekeris, 2011:88), as well as whether the site has transportation or parking management programs (Regidor, 2006:10). There are various trip and parking generation guidelines which differ according to the area of implementation.

The trip and parking generation values may vary and tend to be much higher than would occur in more accessible, multimodal areas. The models provide little guidance for evaluating the impacts and benefits of smart growth, transportation and parking management strategies (Ewing *et al.*, 2017:3-8). Several recent studies have examined ways to better predict how smart growth locations and demand management programs can affect trip and parking generation (Lee *et al.* 2012). The network structure has been based on assumptions derived from traffic data intervals. The trip and parking generation model has been determined by the types of trips performed. The transportation models are based on road transportation and vehicles. South Africa has implemented transportation guidelines to improve trip and parking generation. The guidelines are implemented through the Committee of Transport Officials (COTO). The guidelines are illustrated through manuals which vary and specify certain aspects of transportation systems (Technical Methods for Highways [TMH], Technical Recommendations for Highways [TRH]). For example, the *TMH 17* defines the following types of trips (RSA, 2013:11-13) based on sub-categories, such as primary trips; pass-by trips; diverted trips, and transferred trips. Primary trips consist of the complete road network implemented, working simultaneously with the other types of trips and considering new segments of the road network. Pass-by trips are determined by all trips on adjacent roads to developments; they are determined by direct access to the development. Pass-by trips consist of vehicles that would access developments on the way from the origin to the primary destination; these trips would not be deducted from the trip generation, because the primary destination would remain the same and only the trip distribution would be affected. Diverted trips are considered to be similar to pass-by trips but differ because other road networks would accumulate traffic to access developments; thus, diverted trips tend to continue to the primary destination and route origin after visiting the developments (Mogakabe *et al.*, 2018:1-10). The last trip sub-category refers to transferred trips, which are determined by the present road network which could visit similar developments near the proposed development and have the potential of transferring or switching their destination to the proposed development. These trips differ from diverted and pass-by trips because they are wholly transferred from one development to another.

The above trips would all affect the trip generation but will vary in terms of affecting the primary destination. The type of trips may only affect the trip distribution and accumulate on different roads accessing developments. This is determined by the individuals while using the transportation mode; however, through predictability and parameters, civil engineers can determine the traffic volume based on data previously logged.

4.4.2.1 Network structure

Trip and parking generation transportation models are tools used for urban planning and traffic engineering that estimate the number of vehicle trips and parking demand created by different land uses in a given area. The models include significant transportation systems such as road networks for automotive traffic, public transit systems (such as buses, subways, and trams), pedestrian walkways, and, in some cases, bicycle infrastructure (Gundlegard *et al.*, 2016:1-10). They assess how various types of land developments (residential, commercial, industrial, and recreational) influence travel patterns, peak-hour traffic, and parking requirements. Planners can anticipate probable congestion points and parking needs by analysing these elements, resulting in more effective resource allocation and improved traffic management. The trip and parking generation models analyse the trips and use of road infrastructure (Mackett, 1998:93-94; Tsekeris & Tsekeris, 2011:88-91).

The above analysis of the transportation models illustrates only the use of roads and road capacity, while not illustrating multimodal transportation. The manual which illustrates trip generation provides parameters towards the construction of roads and is not specific towards other transportation modes. The manual illustrates that it does not include any data on pedestrian or cyclist trip generation developments. The formula in Figure 4-10 has been used in the South African manual for trip generation and flow of traffic. A civil engineer would use calculations regarding trip generation and parking to further understand the flow of transportation (cf. 4.3).

$$Q_T = \frac{N_L \cdot Q_L}{2 \cdot F_{D1}}$$

Where:

Q_T = Service flow rate of the road (veh per hour)

N_L = Number of lanes on the road (e.g. 4 for a 4-lane road)

Q_L = Service flow rate per lane (veh per hour per lane)

F_{D1}, F_{D2} = Background traffic directional split $F_{D1}:F_{D2}$ with $F_{D1} > F_{D2}$

Figure 4 - 10 Trip generation and parking models' flow of road traffic

Source: RSA (2013:2-3)

The above calculation has been used with parameters provided from various areas within an urban structure to calculate the service flow of road traffic. These parameters are measured through traffic count and predictive trip data. This illustrates that the use of mobility has been calculated through road transportation with this specific transportation model.

The trip generation of an urban structure uses a specific calculation to determine the average trip rate. Several variables are used within the formulae to calculate the average trip generation of an urban structure determined by the South African manual. They may differ according to other countries but they include (RSA, 2013:10-15, Clifton *et al.* 2015:12-13):

- The first variable is known as the AADTD (the Annual Average Daily Trip generation rate), which is determined per unit of size. This is determined through the estimated total ingoing and outbound traffic generated by one size unit of the development over a year period which is divided by the number of days in a year;

- The traffic factor is calculated through the FQD (peak factor parameter per land use) which is used to convert the AADTD to an equivalent impact hourly flow rate per development within the urban structure. The parameters for the peak factor are found within the manuals for trip generation based on the country and development;
- The Hourly Trip Rate (FQD x AADTD) needs to be calculated by multiplying the AADTD by the factor FQD. This will determine the rate used by the engineering service contribution;
- The other factor includes the percentage of heavy vehicles occupying the road transport infrastructure to determine an accurate AADTD generation rate; and
- The strength component of the road infrastructure is determined by the number of E80 axles per heavy vehicle (this is the strength component of road infrastructure, used by civil engineers), also known as extra heavy duty (EHD) which is used for establishing the engineering service contribution. This takes into consideration the size adjustment factor used in AADTD to determine the development and capacity of vehicles entering and leaving the land use.

The trip generation rate calculation may differ according to the transportation manual provided for other countries. In South Africa, the manual provided by the Institute of Transportation Engineers illustrates the following method of calculation:

Vehicle trips per 1000 sq. ft.

$$Vehicle\ Trip\ Rate_{study} = \frac{(P_{IN} + P_{OUT})_{Obs}(\%AUTO)_{Survey}}{VEH\ OCC_{Survey}} \times \frac{1}{1000\ Sq.\ Ft.\ Area}$$

Where: P_{IN} = Person count entering the establishment (observed),
P_{OUT} = Person count exiting the establishment (observed),
$\%AUTO$= automobile mode share (from the visitor survey), and
$VEH\ OCC$ = Average vehicle occupancy (from the visitor survey)

Figure 4 - 11 Institute of Transportation Engineers' vehicle trip rate formulae

Source: Clifton et al. (2015:13)

The transportation models have several factors for which trip generation can be calculated. Trip generation parameters differ according to the location within the urban structure and region. The components of which trip generation is calculated are based on the following (RSA, 2013:10-16):

- Peak-hour trip generation rates;
- Heavy goods transport;

- Vehicle ownership and transit availability;
- Mixed-use development;
- Combination of reduction factors; and
- Peak-hour spreading.

These components are used to calculate the trip generation through which more comprehensive calculations are used to calculate the trip length. The trip length would be determined by the distance needed to be travelled from the origin to the destination. This would be determined and differ due to the type of land uses accessed by the ongoing traffic.

The trip and parking generation models illustrate the significance towards sufficient parking of motor vehicles based on land use and trip generation. The parking aspect of these models has been determined using parking studies and analysis, whereby parameters have been provided depending on the specific land use within the urban structure. Parking studies undertaken were able to calculate the parking accumulation which can be obtained from in- and outbound traffic counts or a count of parked motor vehicles. The studies would establish the amount of parking needed for developments considering the following components (RSA, 2013:77):

- In/out vehicle count;
- In/out pedestrian count; and
- In/out on-street count.

These components would be used in a trip survey to determine the parking required per development/land use. The advantages of the trip and parking generation models include the accommodation of future planning of developments as well as the required parking for the increasing population. The population will increase, which means more SOVs, thus more parking is required. The advantages of the trip and parking generation models are illustrated as (Ahmed, 2012:39; Ewing *et al.*, 2017:71; Mogakabe *et al.*, 2018:1-3):

- Focuses to accommodate for future parking and land use;
- Considers all aspects of travel including pedestrians;
- Focuses on efficiency and future planning;
- Focuses on the expansion of the urban structure; and
- Accommodates increasing SOV and efficiency.

The advantages of the travel and parking generation models are based on the future planning of parking as well as land use. This is to accommodate future development through the use of estimated variables and calculations. The trip and parking generation transportation models may have various difficulties concerning implementation. The disadvantages are presented as the lack of mobility modes used in calculating the future planning of each predicted development. Future developments and land use can be unpredictable due to population growth. Additional disadvantages of the trip and parking generation models are as follows (Regidor, 2006:9-11; Ewing *et al.*, 2017:25-34):

- The models do not illustrate the use of LRT;
- The models do not represent the use of BRT;
- The calculation used to determine future planning concerning parking may be flawed due to the "estimate variables" used;
- Future development can be impacted by different factors which have not been approached or addressed;
- The cost of future developments can change based on political factors and currency, which cannot be calculated; and
- The use of heavy vehicles and transit may damage the current road infrastructure, which has not been considered.

The disadvantages of these models are generally presented due to the lack of constants used within the calculation. The calculation uses averages to determine the possible future development of parking spaces and trip generation, which means it is an estimate (Ewing *et al.*, 2017:1-2). The factors that can affect these models are not illustrated within the calculation but can cause dramatic changes to development. One of the biggest impacts towards the transportation models is demonstrated through political implementation (policies, guidelines, budgets) which cannot be calculated and can differ between regions and countries.

4.4.3 Walking and bicycling models

The walking and bicycle models have several different ways of implementation. The various models share a common approach to implementation and have been developed to predict how transport and land use changes (increasing sidewalks and walkways as well as creating a compact and mixed development) affect walking and cycling activity (Frank *et al.* 2009:8-10; Clifton *et al.* 2015:25-27). The problem developed within these models illustrates a lack of distance; they are limited in the range of factors they consider as well as the types of travel they predict.

The implementation of sidewalks and cycling lanes would drastically improve sustainability; however, as mentioned, this is limited to a specific distance. The implementation of these transport modes would decrease emissions produced by motor vehicles and promote a healthier quality of life (Frank *et al.*, 2009:4-5; Veisten *et al.*, 2011:1-9). The aspect not determined is the efficiency of these transportation systems when implemented with the correct planning and provisions. The pedestrian and cycling models have been segregated into various sections and can be identified as the following implementation and protocols (Peltier, 2011:1-7):

- Section A (Design and planning): Involves the design controls which are significant to the design of pedestrian and bicycle facilities. The controls would include accommodating the needs of pedestrians and cyclists, safety concerns and basic aspects of the pedestrians and cyclists;
- Section B (Crossing): Involves the implementation of pedestrian and bicycle crossings at midblock locations or road junctions to improve safety for pedestrians. It has been identified that pedestrians and cyclists are at their most vulnerable when crossing roads and streets. The crossings draw motor users' attention for improved safety;
- Section C (Infrastructure): Involves providing infrastructure for pedestrians and bicycles. This includes sidewalks, walkways, bicycle lanes and bicycle roads, which are very important facilities for improving road safety;
- Section D (Facilities): Involves the inclusion of pedestrian and cyclist amenities to provide support facilities that can improve the experience of walking and cycling. This includes aspects such as road lighting and traffic calming;
- Section E (Restriction): This involves segregation of pedestrian and bicycle lanes where priority is given to pedestrians and cyclists, while vehicular traffic is discouraged; and
- Section F (Incorporation): The final section involves the incorporation and planning process illustrating considerations aimed at ensuring the successful provision of pedestrian and bicycle facilities.

The above sections and the implementation of the pedestrian and cycling models illustrate a process of planning followed by incorporation. The guidelines illustrate a set process of including pedestrians and cyclists. This will assist in improving the mobility and efficiency of transportation networks based on a sustainable non-vehicle approach.

4.4.3.1 Network structure

The network structure of the pedestrian and cycling models may differ based on the urban structure. The process of planning should allow pedestrians and cyclists to reach the CBD and residential area while considering safety. The pedestrian and cycling models are not considered to be for long-range mobility modes, which identifies that distance is a factor within the transportation mode. This has been illustrated in the Marchetti Constant model (cf. 3.2.9) illustrating types of mobility and travel efficiency. The Marchetti Constant model illustrates pedestrian and cycling mobility to be efficient between certain distances, focusing on efficiency through time spent travelling. This is crucial for travel and focuses on the five aspects of travel (Marchetti, 1994:76-78; Thomson & Newman, 2018:219; Cullinan, 2019:40-41):

- Maximum distance on foot (walking) is considered to be 5km (cf. 3.2.1, 3.2.2, 3.2.4, 3.2.10);

- There are 2.5km between the CBD and the transitional zone (cf. 3.2.1, 3.2.2);
- The urban structure is such that transportation can reach areas as far as 20km^2 (cf. 3.2.10);
- The principles apply to the political, economic and population zones and the physical size of the urban structure; and
- The centre of the city is defined as the point that the largest number of people can reach in less than 30 minutes to create concentrated economic benefits.

The Marchetti Constant (cf. 3.2.9) is one of the few models that considers pedestrians and cyclists. Pedestrian and cycling models differ in implementation based on the urban structure which may be due to various aspects, such as climate, topography, available infrastructure and so on. This may be efficient based on the urban structure's needs. The models regard short-range mobility modes, as shown in the Figure 4-12 below.

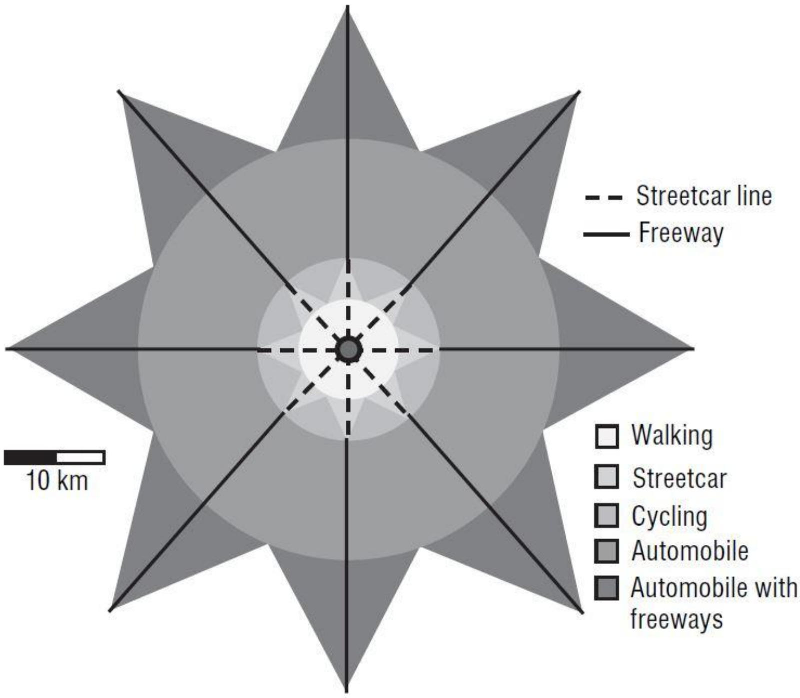


Figure 4 - 12 Hour commuting time range of travel in transportation systems

Source: Rodrigue et al. (2006:173)

The above image illustrates the hours spent commuting for the various transportation systems, showing the time and distance taken while travelling, identifying pedestrian and cycling transportation modes as short-range (a distance between 5km to 10km) (Rodrigue *et al.*, 2006:174). The types of mobility used within the models are cycling and walkability. The mode of transportation requires a perceived effort to operate the transportation system, unlike motor vehicles and trams. Figure 4-13 shows the general implementation of pedestrian and cycling models.

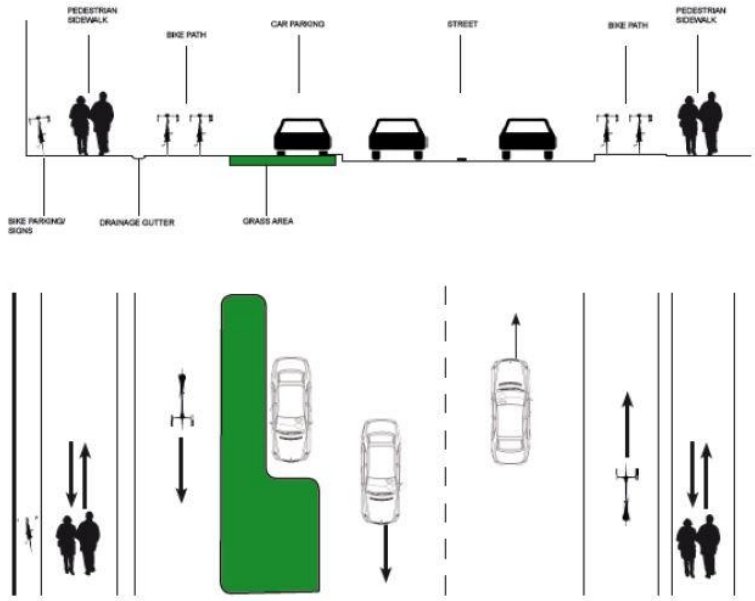


Figure 4 - 13 Implementation strategy of cyclists and pedestrians in a street layout

Source: Andrade et al. (2011:69)

As seen above, the implementation of pedestrians and cyclists within the urban structure delegates infrastructure towards the outside of road transportation. This allows for the transportation models to remain unaffected by other transportation congestion and traffic. The main concern with the pedestrian and cycling model is, in fact, safety. This has been mentioned within the above sections on implementation. According to Peltier (2011:1-7), pedestrian infrastructure can improve or increase economic benefits as its implementation could improve job creation as well as employment. This is relevant for developing countries with a low gross domestic product (GDP). The implementation of pedestrian infrastructure not only refers to the simple additional lane for cyclists and pedestrians but also refers to the implementation of additional facilities required to improve the safety and efficiency of mobility. The above Figure 4-13 is a simple illustration of the functionality and planning of transportation infrastructure in comparison to walkability and cycling uses. According to Litman *et al.* (2009), transportation requires community participation and the inclusion of other facilities to improve pedestrian safety. This refers to special walkways, crosswalks, and access to disabled individuals, among others (Litman *et al.*, 2009:1-17). The advantages associated with walking and bicycling models illustrate a type of sustainable transportation mode. The concept of these transportation models is to reduce emissions released through motorised vehicles, improve the quality of life for the community, conserve the environment and improve community health (Wegner, 1995:2-3; Litman *et al.*, 2009:1-9; Peltier, 2011:9; Cullinan, 2019:192). The models illustrate a sustainable future if infrastructure is improved for walkability and cycling (Yamagata *et al.*, 2016:7-8). The bullets below provide the possible advantages of the walking and bicycling transportation models:

- Improve sustainable transportation through the reduction of emissions from motor vehicles;
- Improve quality of life, through a reduction in types of pollution as well as through exercise;
- Improve air quality by reducing motor vehicle use - less emissions released and noise created;
- Improve the surrounding ecosystem through a reduction in ecological footprint from the human population;
- Little maintenance for transportation infrastructure, which is more cost-efficient; and
- Improve the mental health of the community through exercise.

The advantages of the walking and bicycling models are illustrated and can be implemented within other modes of transportation. The models demonstrate a path towards sustainable planning based on the advantages but may be limited due to certain factors within the urban structure. The disadvantages of the walking and bicycling transportation models are dependent on distance, time travelled and cargo carried. The models cannot be used as a single type of mobility throughout an urban structure as they cannot replace motor vehicles based on efficiency and time travelled. The models can only transport one or more people per trip and are exposed to the environment (Tight *et al.*, 2011:30-33; Cullinan, 2019:210-212). In addition:

- The models are restricted to a short range of travel and are not as efficient as motor vehicles;
- The mode of transportation is limited to fewer passengers per trip;
- The infrastructure may not be available in developing countries and is not accommodated as a transportation mode with its own infrastructure;
- The models may struggle with safety, given that vehicle transportation is dominant in most urban structures and can be hazardous;
- This mode of transportation is exposed to all weather conditions and may prove problematic in certain weather conditions;
- The time travelled is considered to be longer in zero congestion conditions in comparison to other transportation modes; and
- The cargo carried on this type of transportation is little to none, due to the limited space or carrying ability.

The disadvantages of the walking and bicycling models are based on economic benefit, cargo carried, time of travel, safety and vulnerability. The models are still considered to be a sustainable type of transportation but must operate in a multimodal transport system. The mode is used for short-range travel and preservation of the surrounding environment. The concept of implementation is focused on health, while most transportation modes are used for efficiency.

4.4.4 Economic evaluation models

Economic models are used to evaluate and compare the value of the implemented or planned transportation system, as well as its proposed improvements. This would refer to aspects such as the benefit of widening a road/highway or improving public transit service as well as implementing TOD (Wilkinson, 2006:224; Cullinan, 2019:60-61; Sebastian & Sangeeth, 2021:3-5). The main attribute of economic evaluation models is to compare various categories of benefits with the costs of these proposed strategies, to increase economic benefit. This would also be determined by the transportation modes implemented and the efficiency thereof (De Rus, 2020:83-87). The models were originally developed to evaluate roadway improvement and transportation options. They were based on vehicles and roadways, with the general assumption that total vehicle mileage was constant. Economic evaluation models follow numerous statistical and analytical methods to determine if any economic benefit would be achieved through the type of transportation method applied. The models follow general principles of economic evaluation to interpret what individuals are willing to pay to obtain a good or service (Bates, 2003:1-3). The models can be identified through Christaller's model of central place theory which focuses on the aspects of economic surplus in the proposed implementation of public transportation which not only decreases travel time but also the efficiency of travel between goods and services addressed in Christaller's model of hexagons (Jamoliddinov & Dsilva, 2019:15; King, 2020:18-26).

4.4.4.1 Network structure

The network of the economic evaluation models may differ according to the urban structure. The models illustrate the general aspects of the central place theory (King, 2020:25). The other urban model (cf. 3.2) that can illustrate similarities towards these transportation models, is the theory of agricultural land-use model (cf. 3.2.10). The models illustrated aspects of the distribution of goods and services through the hexagon regional structure. The advantages of the economic evaluation models demonstrate certain design character traits which may be seen as an advantage within spatial planning and transportation implementation. The advantages of the economic evaluation models are as follows (Pacione, 2005:169; King, 2020:25):

- They display a consistent and efficient method of mobility towards the mass distribution of goods and services;
- They are implemented with long-range transportation modes, which benefits mobility over distances; and
- They illustrate motor vehicles as a main use of transportation and can be efficient transportation based on the majority of urban structures which use motor vehicles as transportation modes.

The economic evaluation models had been based on improving the economic circumstances of urban structures as well as regional connectivity and distribution of goods and services, which had been a similar implementation to Christaller's central place theory. The disadvantages of the economic evaluation models are due to the consistent focus on economic activities and benefits thereof. The focus on improving efficiency, as well as the distribution of supply and demand, has caused other factors of the models to be neglected or discarded. According to Pacione (2005:169-170), there are possible limitations towards the economic evaluation models. The issues analysed within this model are as follows (Pacione, 2005:169-170; Jamoliddinov & Dsilva, 2019:16-18):

- The focus on road transportation modes may cause congestion, due to the number of individuals using motor vehicles as a mode of transportation;
- The infrastructure implemented can prove to be very costly and maintenance can be complicated as well as a lengthy process;
- The cost of travel is affected by outside factors (currency, resources available, individuals occupying the transportation system);
- Public transportation has not been considered a viable source of transportation and can prove to be problematic in the long term with an increase in population; and
- The constant focus on economic benefit can cause stagnation in other sectors, for example, the quality of life for the resided community.

The economic evaluation models may experience other long-term problems, which can be caused by the lack of implementation. The economic evaluation models can be beneficial in terms of economic benefit, but lack of focus may cause other problems.

4.4.5 Integrated transportation and land-use planning (ITLUP) models

The integrated transportation and land-use planning (ITLUP) models were designed to improve land use and connectivity through the use of transportation to improve the efficiency of transportation, as well as the cost of land use. The focus on improving transportation modelling as a future aspect of TP and implementation has led to the implementation of ITLUP models (Duthie *et al.*, 2007:3-8).

These models are designed to predict how transportation improvements will affect land use patterns, for example, the location and type of development that will occur if a highway or transit service is improved (Waldeck *et al.*, 2020:235-237). They are often integrated with TP models as indicated above. These are considered the best tools for evaluating transportation policies and programs because they can measure accessibility rather than just mobility. The transportation models can be considered complex and expensive to implement. This will make the models more difficult to apply, particularly for evaluating individual, small-scale projects. Some models predict how particular land use factors, such as density and mix, affect travel behaviour, and their impacts on congestion and pollution emissions (Sebastian & Sangeeth, 2021:1-5). The smart growth area planning tool synthesises households and firms in a region and determines their travel demand characteristics based on the aspects of their built environment and transportation policies affecting their travel behaviour.

Some models evaluate accessibility based on the number of services and activities (such as jobs) that can be reached within a given period by various travel modes (Levine *et al.,* 2012). The ITLUP models have been delegated to three generations, namely (Duthie *et al.*, 2007:9; Sebastian & Sangeeth, 2021:5):

- First-generation or aggregate spatial interaction-based models: Based on aggregate data and the principles of gravitation and entropy maximisation;
- Second generation: Multinomial logit models based on the principle of utility-maximisation; and
- Third generation: Based on micro-data and activities travel patterns.

The generations separate the various changes within the model based on the period it may have been implemented. The models have a specific behavioural core they work on based on the implemented aspects of transportation and land integration (Duthie *et al.*, 2007:16; Cullinan, 2019:84-85).

4.4.5.1 Network structure

This transportation models are used to predict how transportation systems may impact land use in the future. The focus of the models' networks may differ based on the various urban structures. These networks consist of two sectors working together simultaneously to create sustainability and growth. The network structure of these transportation models was not designed but only applied through guidelines and principles. These models have been applied through 12 applications within the USA (Miller *et al.*, 1998) using equations determined by Transportation Economic and Land Use Model (TELUM). TELUM uses ITLUP equations to illustrate future predictions within the location. The equations determine the growth of residential and non-residential development for up to 30 years; thus they are used to make future predictions based on the analysis of the current year and a lag year within residential and non-residential development. They help to interpret estimates towards the current development and how it may expand (Waldeck *et al.*, 2020:228-237); however, the equations are based on the current area and land use to improve transportation systems and changes in land use (Duthie *et al.*, 2007:3-6). This will determine if the current transportation system is efficient and can accommodate the surrounding community. The ITLUP models have been illustrated in the below Figure 4-14 to simplify the process.

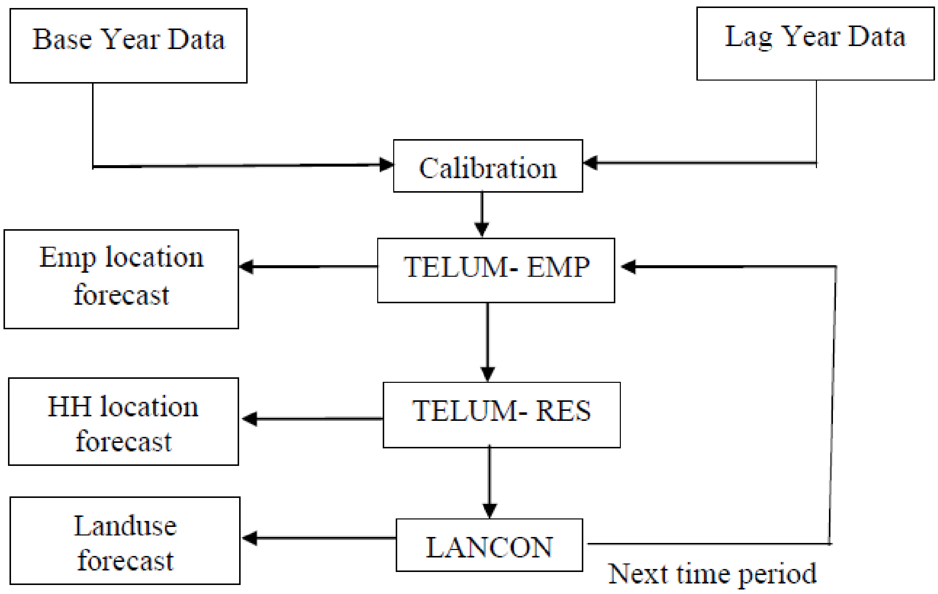


Figure 4 - 14 TELUM process

Source: Duthie et al. (2007:5)

The Figure 4-14 shows process of predicting future developments and transportation. They have been determined within the transportation models to estimate possible growth. The three models are explained in detail below, alongside their relevance to the methods of prediction (Duthie *et al.*, 2007:5-8):

- TELUM-EMP;
- TELUM-RES; and
- LANCON.

The three models determine specific aspects of future developments. The models use different approaches which are visible throughout the analysis. They will not be evaluated further as they are not relevant to this study's objectives. However, it is important to note that the types of mobility within the models can vary due to a focus on connectivity between land use and transportation modes. The integrated and land-use models illustrate the term 'land use transport feedback cycle', which appositely captures the casual relationships and impacts that characterise this common approach. This demonstrates the implementation of transportation to connect land use. The factors which play a large role in the integrated and land-use models are as follows (Spandou, 2010:8-10):

- The distribution of land uses over the urban structure which had been determined by the locations of human activities such as living, working and leisure;
- The distribution of human activities in space requires spatial interactions and may vary between sectors within each sectoral interaction. This refers to the number of trips in the

transport system to overcome the distance between the locations of activities, to promote efficient transportation modes;

- The distribution and type of infrastructure in the transport system, which can be within a multimodal system to create opportunities for spatial interactions and can be measured as accessibility; and
- The accessibility of land uses, as the distribution of accessibility in space co-determines location decisions. This will result in changes in the land use system.

The ITLUP models can vary in types of mobility and may be subjected to efficiency, population and urban structure. The urban models (cf. 3.2) illustrate that long distances can separate certain models and sectors while others may be within a walkable range. The models may use transportation through a multimodal spectrum but can also follow a vehicle-dominated transportation system. This may create problems within the efficiency spectrum if large masses travel through SOVs (Cullinan, 2019:78-83). The models have been designed to create accessibility, sustainability and connectivity between land uses which can vary through different methods of transportation (Sebastian & Sangeeth, 2021:1-8). The models can incorporate trams, BRTs, LRTs, vehicles, walkability and cycling (cf. 4.4.3) if efficiency and accessibility are improved (Pacione, 2005:791). To summarise, mobility modes are not specific and can differ based on accessibility and efficiency. The ITLUP models have provided important aspects which may assist in the planning of transportation and land use. The models illustrate various advantages, namely (Waldeck *et al.*, 2020:227; Sebastian & Sangeeth, 2021:1-5):

- The focus is on the efficiency of transportation modes and not specific transportation systems;
- The component of employment and mobility between residential areas and business districts;
- The calculations consider area covered, area available, land use sectors and vacant land, which assists with future development plans as well as TP; and
- Can improve land development and employment within the community.

The above factors determine the various advantages of the ITLUP models. The ITLUP models can assist in the future development and planning of urban structures for a more efficient transportation system (Cullinan, 2019:88-89; Wilkinson, 2006:225). The problem is the lack of consideration towards other sectors of the urban structure. The components that were not focused on within the models include:

- The lack of planning in regards to the environment and detriment which may cause the deterioration of the natural environment;

- The calculations use estimates based on previous data provided and are not specific. This can be used as a guideline;
- The limitations of connectivity with urban structures and their various topographies;
- The lack of implementation towards sustainable transportation infrastructure; and
- The lack of equality is illustrated by the segregation of residence through income groups.

The ITLUP models have demonstrated certain shortfalls within the planning of connectivity between land uses but can be used as a guideline and not a definite implementation strategy. The models have illustrated significant components of planning within urban structures. This refers to the connectivity and efficiency of travel within mobility. The models have shortfalls within some sectors but can be used as a good reference towards the development of future urban space while employing transportation systems to maintain the fictionality within. The models demonstrate methods that are used to improve economic benefits. This has been illustrated in the above economic evaluation (cf. 4.4.4) TP models as well as the travel demand (cf. 4.4.1), trip and parking generation (cf. 4.4.2) TP models. There is a similarity within each model present within the ITLUP models, namely the efficiency of mobility.

4.5 CONCLUSION

The transportation models above illustrated the various planning strategies towards the implementation of transportation modes. All TP models act as a base towards mobility and connectivity within the urban structure to improve efficiency and productivity.

The chapter illustrated the two significant types of networks (cf. 4.2.2) towards TP models (cf. 4.4). These types of networks would form two different types of networks, which make up the spatial organisation of transportation (cf. 4.2.2). The two structures of these networks can be illustrated as monocentric (cf. 4.2.2.1) and polycentric (cf. 4.2.2.2) SSs. Monocentric SSs (cf. 4.2.2.1) illustrated that the organisation of transportation systems would flow (cf. 4.2.2) directly towards the CBD area and would not interlink with surrounding nodes. Polycentric SSs (cf. 4.2.2.2) illustrated that the organisation of transportation systems would flow (cf. 4.3) directly towards the CBD area and would interlink with surrounding nodes. The models all illustrate an economic factor to improve economic benefit. The economic benefits as well as the efficiency of transportation systems within an urban model (cf. 3.2) are directly as well as indirectly connected to the flow of transportation systems (cf. 4.3). The flow of transportation systems would either increase or decrease productivity within the urban model based on congestion and other challenges within the decreasing flow of transportation systems (cf. 4.3).

The previous chapter presented the urban models (cf. 3.2) which represent the planning of land use. The following chapter assesses the TP models (cf. 4.4) in line with the research objectives (cf. 1.3). The chapter achieve **Research Objective 1** through the following discussion. The current chapter discussed the connectivity between the different land uses and possible implementation strategies towards ITLUP (cf. 4.4.5), which determines the functionality of the urban structure as well as the efficiency of the transportation systems illustrated. The spatial planning was presented through Christaller's central place theory (Chapter 4). The travel demand models (cf. 4.4.1) showed improving supply and demand and the importance of transportation systems for the distribution of these necessities and wants. The internal factors which may decrease or increase efficiency were determined through the trip and parking generation TP models (cf. 4.4.2), which analysed the amount or capacity that can be travelled through one trip. The parking aspect of these models had to focus on available parking spaces to accommodate more individuals within the business district to increase sales. The walking and bicycling models (cf. 4.4.3) illustrated the incorporation of pedestrian infrastructure for walkways and bicycle lanes. The comprehensive transportation models did not only represent the incorporation of pedestrian transportation infrastructure but also other significant components (walkways, disability access, and crossings, among others), which would improve sustainability according to Peltier (2011). The economic evaluation TP models (cf. 4.4.4) have been created for this factor, which as the name suggests focus on the economic aspect of an urban structure. The economic evaluation models are demonstrated in two different urban models, namely the central place theory (Chapter 4) and the theory of the agricultural land-use model (cf. 3.2.10). The models mentioned demonstrated methods of improving economic benefit, but not quality of life or environment except for the walking and bicycling models (cf. 4.4.3). The final transportation models considered within Chapter 4 are the ITLUP models (cf. 4.4.5), which demonstrate the implementation of transportation systems to increase accessibility towards land. This can be considered as a TOD, which will be discussed in the following chapters (cf. 5.8). The models had been created to forecast future sales strategies and used estimates to calculate the future forecast. This leaves gaps within the calculation for economic crashes and other unexpected events. The main disadvantage is determined by the type of transportation used. Both models involved the use of motor vehicles and not sustainable transportation. This can prove to be problematic in the future through the rapid increase of technological advancements.

The focus on economic benefit (cf. 4.4.1, 4.4.4) and increasing profits has shown a gap in the community's quality of life. The walking and bicycling models (cf. 4.4.3) illustrated the implementation of cycling and walking lanes. The benefit was focused on the community and not on profits, while the models could improve quality of life as they limit distance travelled. This is where the ITLUP models (cf. 4.4.5) could be initiated, as they describe the connectivity between land uses and also focus on economic benefit and efficiency (cf. 4.4.4) to improve the quality of life for the community with the correct implementation of transport. The models did not illustrate a specific type of transportation but focused on efficiency and distribution, which means sustainable transportation can be implemented. The concept of cost of transportation may remain a concern but can be decreased through public transportation. The implementation of any model should be considered with accurate data before implementation to provide the optimal transportation system for each unique urban structure.

In conclusion, this chapter discussed the various aspects and components implemented within TP. The chapter created the foundation towards the implementation of transportation models to improve efficiency. The next chapter will focus on combining the urban models (cf. 3.2) and the TP models (cf. 4.4). This will illustrate the possible functionality between the two within the urban structure to improve the efficiency of transportation systems and connectivity.

CHAPTER 5 INTEGRATION OF URBAN STRUCTURES AND TRANSPORTATION NETWORKS

5.1 INTRODUCTION

The integration of urban structures and transportation networks had been based on efficiency, mobility, distance and economic aspects, such as the cost of mobility. There is no set standard for a specific guideline to produce a sustainable layout but may all differ based on the topography, energy source, environment, climate and status of the country (Bertaud, 2002:3; Pacione, 2005:789; Peltier, 2011:1-7; Alqhatani *et al.*, 2014:218-219; Cullinan, 2019:62-76; Jamoliddinov & Dsilva, 2019:12-18). The components of transportation systems play a role when implemented within the urban structure and can determine possible links or hubs for connectivity and mobility. The urban structure differs based on the topography, demographics and socio-economic status, illustrating that different materials are required to implement the infrastructure of the proposed transportation system. This may be seen in green areas or the surrounding natural ecosystem, which can be used for greenery and to decrease heat islands.

The chapter will address **Research Objective 3 (To improve the efficiency of transportation modes within each urban structure by identifying guidelines for each type).** The chapter will illustrate multiple examples of challenges, types of transportation flows (cf. 4.3), and factors that can affect the urban structure as well as transportation systems. The chapter illustrates the inclusion of chapter 3 (research objective 2) and chapter 4 (research objective 1). This will also address all the components which can render an urban structure inefficient or less sustainable. The focus will be on understanding the interaction of the urban structure and the particular components which affect its efficiency and mobility between land uses. The chapter illustrates the incorporation of both **Research Objective 1 (To review existing transportation guidelines and systems which would potentially improve efficiency within cities)** and **Research Objective 2 (To determine how sustainable transportation systems function within different urban structures)** in order to illustrate the intricate planning components of SS planning and TP.

The chapter presents the combination of urban models (cf. 3.2) and TP models (cf. 4.4) to create an efficient and functional urban structure. The chapter also illustrates the theoretical implementation of urban models (cf. 3.2) and TP models (cf. 4.4), to determine the possible components which should be considered. This also addresses the possible sections and transportation components required to efficiently implement transportation systems into the urban structure. Finally, the chapter seeks to identify the possible challenges within TP and land use connectivity. Thus, the chapter addresses two research objectives to determine possible transportation guidelines to improve efficiency within the urban structure.

5.2 URBAN STRUCTURE PLANNING

This section illustrates the different components of an urban structure as well as the functionality of these components in an efficient system. The chapter will focus on how transportation systems can be integrated within the urban structure land uses and improve functionality as well as increase efficiency. The integration of transport systems with or without pre-existing infrastructure will be discussed under the concepts of sustainability, efficiency, and other components. Many factors must be taken into account, which will be addressed in this chapter. The implementation of transportation systems inside metropolitan structures requires a comprehensive transportation plan, which illustrates the possible connectivity between land uses and the efficiency of mobility. The following significant components have been illustrated for the implementation of transportation systems within the urban structure (Cervero, 2001:1652-1653; Tzeng & Huang, 2011:4; Lucas, 2012:4-5; Banister & Hickman, 2013:4-6):

- **Integrated planning and design:** To improve the efficiency of existing transport systems, which fit the requirements of the city and its residents. This includes implementing transportation systems that could be integrated with urban planning by taking economic activity, population density, and land usage into account (cf. 4.4.5);
- **Sustainability and environmental impact:** The correct implementation of transportation systems will lower emissions and boost energy efficiency. The integration of efficient transport systems should place a higher priority on sustainability to decrease the environmental impact and promote public transportation (cf. 4.4.3);
- **Equity and accessibility:** To improve accessibility to all demographic groups (cf. 3.2.8) to increase mobility by utilising the transportation networks (cf. 4.2). This involves offering all locals convenient and reasonably priced options;
- **Multimodal integration:** The urban structure planning process requires several modes of transportation to provide various options towards the resided community, to give users a more accessible and efficient experience. This involves the implementation of efficient urban transportation systems (cf. 4.4.5) including several forms of transportation (such as buses, trains, and bicycles). Infrastructure and scheduling coordination are required to operate public transportation services effectively;
- **Safety and security:** To increase safety and security, which involves possible conflict between modes of transportation. This is to ensure the security of transport systems and put safety measures into place, which are essential for safeguarding users and preserving system dependability; and
- **Public feedback and engagement:** Incorporating public feedback and engaging the public in the design and implementation phases helps guarantee that the transport system

satisfies community requirements and preferences. This has been illustrated from a human behaviour aspect and is demonstrated within the Marchetti Constant model (cf. 3.2.9).

The urban structure planning process is an intricate network of factors, which function simultaneously to create a sustainable urban structure. The urban structure requires mobility to transport various goods/services and conduct other forms of business (cf. 4.4.1). The integration of efficient transportation services is significant as it will improve the socio-economic status of an urban structure (cf. 4.4.4). This refers to the integration of efficient transportation systems and how it may improve other components within the urban structure. The urban structure planning process must consider several components, as discussed below (Larsson, 2007:106; Lucas, 2012:3-5; Hasanien, 2022:606-608).

The urban structure is comprised of various **land use zones** (Hasanien, 2022:607) as illustrated within the urban models (cf. 3.2). The types of land use that can be present within the urban structure are (Chaplin & Kaiser, 1979:32; Cilliers, 2010:15; Cullinan, 2019:92-93):

- Business;
- Mixed-use;
- Residential;
- Commercial;
- Industrial zones;
- Parks and open spaces;
- Agricultural; and
- Environment.

The land uses are governed by municipal authority with delegates specific land use rights as per land use zoning. The implementation of these land uses is based on various environmental factors. The significant component of land use is connectivity through the implementation of transportation services. The connectivity between different land uses will determine the functionality of the urban structure. The transportation service should be efficiently planned to avoid congestion and increase mobility between land uses to directly improve economic benefit (cf. 4.4.4). The type of transportation service implemented will determine if there are various options for efficient mobility, while a single transportation mode can cause congestion if the population expands.

The **implementation of transportation systems** within the urban structure has been determined through the layout of land use based on the urban models (cf. 3.2) and the type of TP model (cf. 4.4) used to improve functionality. The types of transportation systems implemented within the urban structure may differ based on various factors, such as:

- Urban structure;
- Topography;
- Demographics;
- Developed or developing country;
- Financial status;
- Socio-economic status;
- Political influence;
- Policy;
- Environmental preservation/ conservation; and
- Global initiatives.

The above-mentioned factors can influence the implementation of transportation systems. The case study analysis within Chapter 6 will illustrate various cities within different countries and provide various factors within the urban structure that influence the implementation of transportation systems. The implementation of urban structures (discussed below) illustrates a brief review of the types of land use within urban structures based on urban models (cf. 3.2) to delineate how transportation is connected within the urban land use structure and how it can influence urban structure planning (McDonagh, 1995:1-19).

The urban structure comprises various land uses, including transportation land uses, to connect or access the above-mentioned land use zones. The system that makes travelling inside and between locations easier is known as the transportation infrastructure/transportation land use, which includes servitudes. This can be illustrated through three different types of transportation land uses:

- **Streets and roads land use:** This land use category is predominantly illustrated throughout the urban structure. This is focused on land use which is used to implement transportation infrastructure to improve mobility. This category includes municipal, arterial, and highways (Pacione, 2005:789-791; Cullinan, 2019:200-205; Nabila, 2021:3). This includes public transport networks including trams, trains, buses and ferries and has been illustrated within Chapter 3, demonstrating the implementation of transportation services (cf. 3.2.1-3.2.10). The implementation of transportation infrastructure may be determined by different TP models (cf. 4.4). According to the Global Roads Inventory Project (GRIP) and the World Road Statistics (WRS), the total coverage of road infrastructure is estimated at 32 million km of roads between the years 2005-2014 (Meijer *et al.*, 2018:7-8);
- **Bicycle and pedestrian paths land use:** The land use for the implementation of pedestrian mobility is considerably less than that of motorised transport infrastructure. The use of pedestrian infrastructure is used for short-distance mobility (Marchetti, 1994:77;

Pacione, 2005:789-790; Thomson & Newman, 2018:221-222; Cullinan, 2019:37) and is confined to areas with applied non-motorised land use. The land used for pedestrian mobility can often be seen as mixed land-use, commonly incorporating mobility within an area of environmental sustainability as it does not share the destructive nature of motorised transportation systems (Pacione, 2005:365-366); and

- **Parking facilities land use:** The parking facilities and land use for motorised vehicles are simply illustrated as parking lots and structures for both public and private parking (Manville & Shoup, 2005:233-235). This has been illustrated in the TP model (cf. 4.4.2). The land used within the urban structure is for the storage of modes of transportation (Cullinan, 2019:80). The land use is commonly seen within CBD areas as well as areas commonly attracting numerous individuals (institutional land uses, religious land uses, parks and recreational areas, among others). This illustrates that some transportation systems require more than infrastructure to operate efficiently (Pacione, 2005:366-375). The previous paragraph illustrates that there are more than 32 million km (based on between the years 2005-2014) of road infrastructure. Thus, the amount of parking infrastructure has increased based on the increase in road infrastructure (Meijer *et al.*, 2018:7-9).

The urban structure is based on various types of land use, which includes open spaces and are considered places set aside for social, recreational, and neighbourhood activity (Pacione, 2005:485-486). The open spaces land use is derived as a separate part of nature and is considered as a place of peace for the resided community. Open spaces land use is generally used for recreation in the outdoors and is known as parks and green spaces. Squares and plazas are urban open areas created for parties and festivals within communities (Yang *et al.*, 2019:5). Civic centres are places where community services and public administration are located. The true "Green lung" in the high-density areas of urban centres is the open space designated for leisure, or green area (parks). In addition to improving the local microclimate, beautifying the landscape, removing pollutants from the air, preventing noise pollution as well as averting disasters, it is an essential landscape structure that gives pedestrians in urban areas places to go for recreation, amusement, and communication (Yang *et al.*, 2019:1-2). The open space land use can be illustrated in the urban model's section (cf. 3.2.1; 3.2.2; 3.2.4; 3.2.6; 3.2.7). The improvement of the urban structure is illustrated through the implementation of sustainable infrastructure, including environmentally green areas (Situma, 2002:2-3; Cullinan, 2019:84-85).

The land use of urban structure planning requires a system and service delivery portion of land that are necessary to sustain regular urban life are utilities and services. The services and systems illustrated are found in servitudes, which are preserved spaces alongside roads and property lines to provide water, electricity, human waste disposal (sewers), waste disposal and access to properties (Pacione, 2005:735). The first service is regarding water supply and sewage systems, which are considered waste management and clean water provisioning systems. The energy infrastructure refers to the networks that distribute gas and electricity. The waste management system refers to the infrastructure and procedures used to gather, recycle, and get rid of waste. The telecommunication networks used for phone, Internet, and other communication services are known as telecommunications.

The CBD is designated towards economic activities. This refers to places and infrastructure that promote economic expansion. The business districts are areas where company headquarters, financial institutions, and offices are concentrated (Manville & Shoup, 2005:241; Cullinan, 2019:63-65). The examples of land use are illustrated through the implementation of retail corridors, markets, and shopping centres. The connectivity of transportation systems between residential areas and transition areas has been implemented through TP models (cf. 4.4) to increase socio-economic benefit (cf. 4.4.1, 4.4.3, 4.4.5). This has been illustrated in the urban model's chapter and is illustrated through several models (cf. 3.2.1-3.2.10). The CBD area is surrounded by industrial land use, also known as the transitional area (Chaplin & Kaiser, 1979:32). The transitional area is used for the manufacturing of goods and services for the CBD area. The connectivity between land use may differ with transportation modes but the concept remains the same as it is determined by the urban structure within the urban models (cf. 3.2).

The residential neighbourhoods, as illustrated in Chapter 3, are used for accommodation of the resided communities. The residential areas may differ between income groups or racial groups (cf. 3.2.8) and are predetermined through land use value (cf. 3.2.10), as well as the distance from the workplace (CBD). The land use of the residential area is illustrated in the urban models (cf. 3.2), while lower income groups will be situated near or in the transitional zone and higher income groups further away. This is determined through urban structure planning and transportation mode (cf. 4.4.1-4.4.5) connectivity and affordability.

The urban structure is also comprised of institutional land use, based on the area and size of the urban structure. This is to improve access to education and increase the functionality of the workforce. Institutional land use is required to educate youth to create an efficient and improved transition into the workplace. The other form of institutional land use is used for public access, which includes libraries, museums and cultural history (Hodgson, 2006:3). The institutional land use component is smaller than the residential, agricultural, and business land use components. The urban structure planning of institutional land use is based on various factors and requires phases of implementation (Bukhari, 2010:1-14). This land can also be used for the residential population's care facilities which preserve public safety and health (emergency and health services). This can refer to clinics and hospitals as well as other medical facilities for health care and medical treatment. The land use refers to government-owned land, which can be used for schools, public safety and emergency response services provided by police and fire stations.

The land use illustrated within urban structure planning which is highly significant refers to agricultural land use as well as environmental conservation. The agricultural land use is used for the production and distribution of natural resources for the community (cf. 3.2.10). Most often, the resources would be distributed to the transitional area (cf. 3.2.2). This would manufacture the raw natural resources for community consumption through the travel demand transportation (cf. 4.4.1) model concept (cf. 4.4.1). This will increase the supply chain based on the needs and wants of the community. The conservation of environmental land use is to preserve ecosystems and over expansion of human development. The urban structure could be located within a critical biodiversity area and preventing the extinction of certain fauna and flora is crucial for human settlement (Manderscheid, 2011:205-206; Yamagata *et al.*, 2016:27; Cullinan, 2019:50-60).

The planning of urban structures far extends the above-illustrated land use based on different urban models (cf. 3.2) as well as TP models (cf. 4.4). There are several other land uses which can be illustrated within the urban structure, which are irrelevant regarding this thesis. The above-mentioned land use is based on frequently implemented land use within an urban structure.

5.3 TRANSPORT NETWORK PLANNING

Transportation network planning is considered to be a comprehensive process which involves several components and various methods of implementation based on the urban structure (Meyer, 2016:1-1142). According to Meyer, planning a transport system can be a very technical process that frequently uses computer models (cf. 4.4) and other advanced tools to mimic the intricate relationships between the performance of the transport system.

Transportation planners frequently engage with a broad spectrum of stakeholders and members of the public, making it a process that is focused on building public relations (Cullinan, 2019:84-86). Any particular decision's politics can likewise entangle TP (Situma, 2002:3-5). Transportation systems should be effectively planned to improve the efficiency of mobility. This includes connection between different land uses as well as mobility between each one. The implementation of a transportation system can be based on a singular transportation system's operation in the same/different areas of the urban structure or different transportation systems working simultaneously with one another; this is known as a multimodal transportation system (Meyer, 2016:84). This has been identified in TODs (cf. 5.8) and is addressed in the upcoming chapters of this study (Wilkinson, 2006:224). Transportation network planning would differ based on the urban structure and is illustrated in the previous urban models (cf. 3.2) chapter as well as the several types of transportation models illustrated. The fundamentals of transportation systems are shown in the below Figure 5-1.

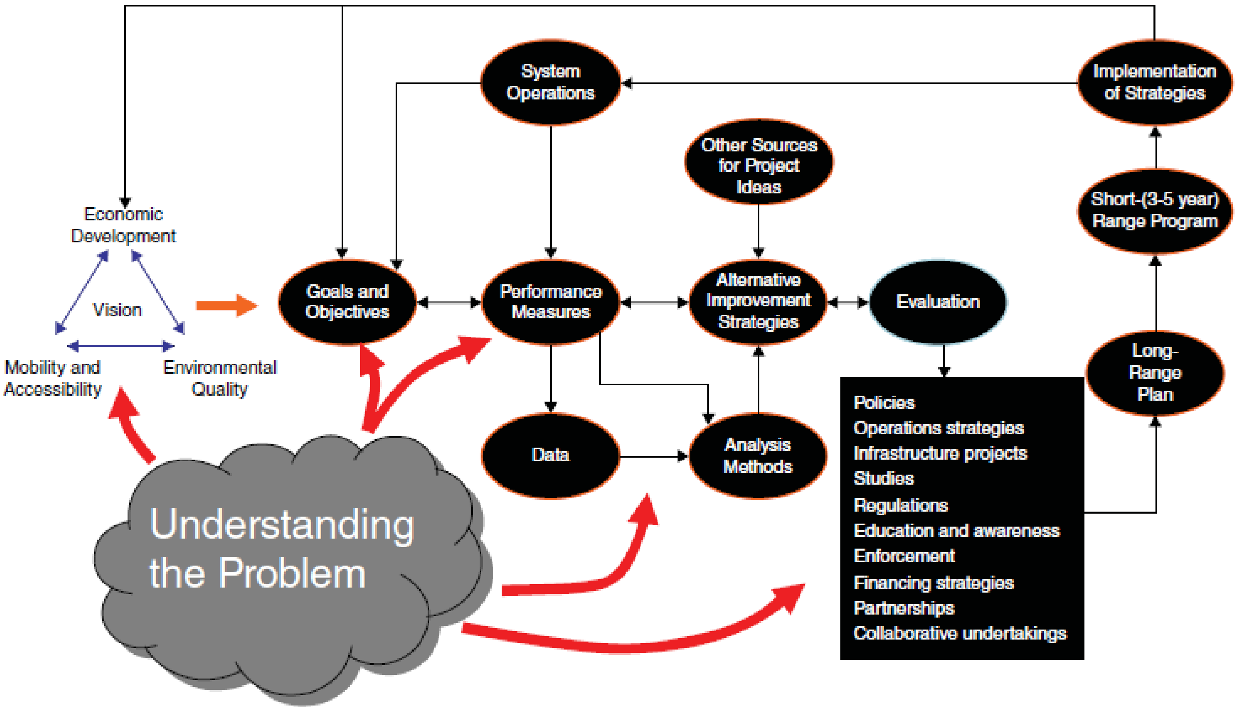


Figure 5 - 1 Conceptual framework for TP

Source: Meyer (2016:3)

The above conceptual framework for network TP refers to three main components, namely economic development, mobility and accessibility and environmental quality. The first two components are considered to be significant to all urban structures, while the third component can be considered as a sustainable concept towards co-habilitating an area with little to no effect on the environment (Meyer, 2016:100; Cullinan, 2019:88).

Transportation network planning has several major steps to improve and implement transportation systems within an urban structure. There are multiple TP methods based on the various models illustrated in Chapter 4 (Mackett, 1998:90-95; Lee *et al.* 2012). The method of implementation illustrated will be on a broad spectrum of TP and not a specific transportation model. The general categories addressed when planning transportation networks are described below (Mackett, 1998:93-96; Meyer, 2016:3-8).

The first step is to comprehend the economic, land use, and sociodemographic environment in which a transportation system functions. The next step is to become conscious of the issues, difficulties, chances, and shortcomings related to the operation of the transport system in this particular context of a state, province, region or community. This is the beginning of the process regarding data collection.

The next step refers to the focus area in which transportation modes will be planned. This means that creating a study area or community vision is the next stage. The interplay between the intended states of social justice/community quality of life, environmental quality, and economic prosperity is reflected in the elements of the vision. This will be addressed in the following section (cf. 5.4). This stage is to understand the current conditions of how the urban structure operates and how implementing transportation systems improves the current urban structure.

The following step illustrates a more comprehensive approach towards TP by gaining more detailed information on the meaning of the vision in the next phase. What level of performance is expected from the transport system? Which aspects of community life stand to gain the most from improved transport? This more detailed description of a community's future is typically achieved by setting goals and objectives that provide the planning process with general direction. This has been illustrated within the models discussing travel demand (cf. 4.4.1) by identifying the solutions through various questions.

The following step refers to what is required from the urban structure and the objectives towards the implementation of transportation systems. This will focus on system performance measures that can also be identified as a result of goals and objectives. In the realm of transportation, using metrics to track the effectiveness of the system and the development of plans and strategies for transportation is relatively new. This will improve mobility by addressing the challenges as illustrated in the first step and how to improve the efficiency of the transportation system (Pacione, 2005:787-789; Rodrigue *et al.*, 2006:88; Cilliers, 2010:28; Meyer, 2016:320-321; Cullinan, 2019:84-86).

The penultimate step will focus on collecting and analysing data. This can refer to past data based on trip generation, which has been illustrated in the chapter on TP models (cf. 4.4). The significant focus of this section is understanding the issues and future difficulties that the transit system and the neighbourhood are likely to face depending on the next stage of the planning process. The main goal of this study method is to understand a transportation system's operation and how modifications to its components will affect its performance. Determining the system's performance state is a major component of the analysis process. This involves finding alternate plans or initiatives that satisfy the study's goals is another aspect of analysis.

The last step involves the final evaluation in the procedure for combining the data generated by the analysis step. The evaluation process involves a set of characteristics which will provide a model of the area and allow for improvements, by identifying the current conditions. The characteristics, based on a general TP model (cf. 4.4), are as follows :

- Focus on the choices that decision-makers must make;
- Discuss how alternatives' effects relate to your aims and objectives;

- Ascertain the effects that transport ideas have on various groups;
- Pay attention to when project impacts are most likely to happen;
- When it comes to regional TP, compile data in a way that enables planners to evaluate the possible outcomes of various options at different intensities;
- Examine each alternative's implementation needs;
- Evaluate the plan recommendations' financial viability; and
- Give timely, easily understood information about the pros and cons of choices for those who make decisions.

The above characteristics are used to identify an approach towards the implementation process, which is the practical side of TP. Assessment criteria that represent significant decision-making concerns are used to gauge the cost-effectiveness of various alternatives or strategies. This is one of the most popular approaches to guarantee that the evaluation process's outcomes are directly related to decision-making. These standards give planners and engineers crucial direction for the kinds of data and analytical instruments to be utilised to produce the required information.

5.4 INTERACTION OF LAND USE

The interaction of TP and urban structures determines the efficiency and connectivity between the various land uses. The interaction is crucial for an urban structure to become more efficient in creating economic benefits, increased productivity, and happier communities. The interaction of an urban structure can happen at various levels and in different sectors, for example (Manderscheid & Richardson, 2010:1797-1798):

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

Urban and regional planning is not just passed on for the planning of cities and towns but also to improve efficiency of all aspects; this creates sustainable functionality of all components in a city. The above-mentioned aspects illustrate the various categories of planning and increasing interaction, which can later be broken down into various other sub-categories which require a more specific illustration towards functionality. While many attributes focus on the efficiency and connectivity of an urban structure, functionality is generally the most significant factor. The above-mentioned sectoral factors have been illustrated in both TP models (cf. 4.4) as well as urban models (cf. 3.2). The interaction of the different sectoral models is based on urban structure planning (cf. 5.2) and the implementation of land use. The sectoral interaction has various aspects and levels it can operate on; however, only the most significant aspects will be focused on within the study to improve efficiency. In this study, sectoral interaction will focus on the connectivity of the economic, social, political, environmental and community realms and how the structure of urban models may affect the efficiency thereof. The economic interaction within spatial planning of urban structures is needed for the continuous flow of economic benefit; this creates sustainable growth in the urban structure. The economic aspect had been incorporated for self-sustaining growth of developments and flow of financial stability. This would create competitiveness between urban structures and ultimately competition between regions, which provides opportunity as well as differentiation of space in various aspects (Manderscheid, 2011:209-210).

5.4.1 Economic interaction

The economic interaction aspect within spatial planning can be divided into numerous land use aspects and zoning of land. The connectivity between these various land uses determines the efficiency of economic benefit as well as the increase or decrease thereof. The purpose is to create economic sustainability, which would be determined by the implemented urban structure as well as the implemented policies. The economic aspect of land use has been taken into account, as the cost of land may vary. The land use distribution of an urban structure is crucial, as mentioned, to the connectivity and efficiency that determine the economic benefit. To determine economic benefit, most urban structures have been designed with certain sectors, to improve connectivity and mobility. This has been discussed within Chapter 3, illustrating that urban structure models have various layers, namely (Simon, 1989:193; Waugh, 2002:420; Nabila, 2021:3):

- CBD;
- Industrial;
- Residential;
- Environmental; and
- Agricultural.

The urban structure may differ based on the topography, while some would have different sections which segregate mobility as illustrated in the urban fabrics model (Newman *et al.*, 2016:431). This would play a specific role in economic interaction but is considered an indirect impact. While transportation, as mentioned above, is used to create connectivity and efficiency, the focus should be placed on land use, as this plays a role in the distribution and manufacturing of the product. The CBD of an urban structure is considered to be the "heart" of the urban structure and a focal point where products can be distributed to the surrounding community (Eldeen, 2013: 917-918). The strategies used to increase economic surplus within the CBD have been based on both TP models (cf. 4.4) to increase access and mobility based on the various income groups residing within the urban structure (Jamoliddinov & Dsilva, 2019:15). This has been identified in most urban models (cf. 3.2), where lower class income groups are situated close to transitional areas (cf. 3.2.2). This can be considered as social injustice is often seen in spatial developments as illustrated within the apartheid model (cf. 3.2.8) (Simon, 1989:192-195). This is not due to the spatial framework but rather to the economic prospects of the spatial development. This is also present in numerous urban models (cf. 3.2), which had been planned to accommodate lower-class income groups, nearby or within the transitional areas (Cilliers, 2010:19; Cullinan, 2019:22-47); this would prevent lowering higher cost land value. This is also a strategy to sell higher-value land use to individuals who can afford to purchase it. This illustrates an economic perspective towards land use, which outlines the spatial injustice in urban models (Chaplin & Kaiser, 1979:32; Cilliers, 2010:15).

The middle-class income group (middle class) are often situated closer to the CBD and industrial sector, where the land value is lower than the outskirt areas but more expensive than the properties situated around and within the transitional zone (Cullinan, 2019:53). The middle-class income group can purchase affordable land but consider other living costs as mentioned within the lower-class income group (cf. 3.2.2). The cost of transportation is still considered within this income group and illustrates the use of public transportation. This is evident when focusing on the Marchetti Constant model, illustrating the distance travelled between sectors and types of transportation used (Marchetti, 1994:77). The economic aspect focuses both on land use, cost of travel and distance from the CBD. The middle-class income sector is operational and funded owing to the distance that has to be travelled and the number of individuals concerning the distance travelled.

The higher income group can afford higher land values (cf. 3.2), due to their financial capacity to obtain higher-cost properties which are situated on the outskirts of a spatial plan. 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 (cf. 4.4). The higher income group can afford to utilise any mode of transportation (including SOVs) while commuting; this is often similar between various income groups. The focus would be to travel between residential areas and the CBD.

The above economic aspects are all possible through the basic incorporation of an agricultural foundation. This is the primary aspect of all spatial developments and provides for the basic need for food. This is crucial within any urban structure and is illustrated in all the above-mentioned urban models (cf. 3.2), from simple models (cf. 3.2.1, 3.2.2) to the garden city (Pacione, 2005:226-230; Raven *et al.,* 2018:151-157). This may have not been illustrated within modern-day models, because urban models primarily focus on the urban structure and not areas between urban structures. Current urban structures have implemented farms and agricultural areas between urban structures because the land is vacant and can be used to cultivate a mass food supply for the surrounding communities. These areas would use the urban structures (towns/cities/villages) as central nodes to acquire machinery for plantation. The product of agriculture becomes an economic aspect through the use of manufacturing. The manufactured product may be used for other methods of food creation (ingredients for bread) and will be sold to stores and shops in the CBD. This will then be sold to the community as a basic necessity, and so on.

This illustrates numerous transactions of economic benefit, which have been illustrated in various sectors of connectivity. Land used for its specific purpose does not necessarily mean efficiency (cf. 4.4.1, 4.4.4). The purpose of these economic aspects may have a successful production and creation rate but does not create connectivity. This is significant in understanding that land use can be used at its optimal potential but without transportation and mobility, the land use may not be sustainable.

5.4.2 Social interaction

The social interaction within the urban structure may differ between various urban models (cf. 3.2). The social interaction within the urban structure takes various forms, one of which involves the collaboration of communities. This can be illustrated through various functions and events that may take place within the CBD. One of the most common places for social interaction in communities is churches. This helps the community to familiarise themselves with one another and could also increase business interactions between individuals seen as trustworthy.

The negative aspect of social interactions is demonstrated in the various models illustrated above, which are based on the segregation of hierarchy. The urban models (cf. 3.2) illustrate various class groups, racial groups and financial status groups. The social considerations have illustrated a segregation of various groups. This would determine where they would live, what property they could afford and with whom they would socially interact. This has been determined through the applied spatial development plan (Cilliers, 2010:23-24; Manderscheid, 2011:206; Rad & Ngah, 2013:184-186); this is also known as social injustice. The various groups were segregated from society or often situated on low land value properties if seen as lower class, racially different or poor (cf. 3.2.8). The area they would be situated in is often areas close to their work area. This is illustrated in the garden city model (cf. 3.2.1), the concentric ring model (cf. 3.2.2), and the apartheid model (cf. 3.2.8). The 21st-century city model (cf. 3.2.6) also illustrates signs of segregation and hierarchy (White, 1987:236-240; Pacione, 2005:148-149). The above-mentioned models in the urban model chapter (cf. 3.2) all demonstrate some type of social segregation. The selection of this area of residential land is not by choice but is enforced by economic (cf. 5.4.1) circumstances (Cilliers, 2010:23-24; Manderscheid, 2011:206).

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 costs 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. The higher-class individuals would often be situated on the outskirts of urban structures as mentioned with expensive land value, which could only be obtained by what is known as the 'elites'. This land would often be considered the most valuable area by the standard of living or quality of life (Chaplin & Kaiser, 1979:32; Cilliers, 2010:15).

The social interaction aspect exhibits various forms of social injustice, which is a hierarchy that may have various aspects towards the types of hierarchy (race, financial, work status). The social interaction illustrated that social aspects may be lacking in some urban models (cf. 3.2), while it is crucial to include public participation and social interaction. This would improve connectivity which in essence will improve productivity and efficiency.

5.4.3 Political interaction

The political interaction between sectors has a significant impact on spatial planning. This political perspective had been implemented through the aspect of power. Whilst an individual may have limited experience or knowledge about the anticipated implementation outcome, the power has been provided to them through various methods of election depending on the appointed political parties. '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. Different spheres of government can dictate the outcome of the urban form and spatial plan. The spheres of government may differ depending on the country but visible similarities can span from international, national, regional and local spheres (Van Wyk, 2012:288-305; Cullinan, 2019:55). The spheres mentioned are all responsible for specific needs within their designated areas. In the spatial division, the focus will be placed on the impact that political power has on the spatial aspect of planning as well as the socio-spatial form of a city. Spatial planning of an area is managed by the closest form of government to retain power, control, structure and evaluation of the area, therefore the local government role is predominant. The spheres of government work in a similar concept to urban models (cf. 3.2) and hierarchy - while one group can alter or change implementation within a region, the other group are only able to determine their designated area (Pattaroni *et al.*, 2022:1-18).

Spatial planning is analysed on a larger sphere, such as national and regional, but implemented under a local government sphere (Van Wyk, 2012:302-305). This may cause problems in association with planning and implementation. The spatial planning design does not illustrate a specific method of implementation from a political perspective but illustrates the desired outcome of what may be required of the implementation. The implementation of the spatial plan is provided to the local sphere which would resort to other implementation methods based on the resources, knowledge and experience in planning, political aspects and appointed specialists. The political perspective often refers to the local sphere due to the implementation aspect. The emphasis of the local government sphere can be placed on basic values that are adopted and fully understood. The local government's obligations in this regard are seen through the simple analysis of providing and regulating development within the allocated area to sustain growth (Pacione, 2005:571-572). The other main initiative is to conserve and protect areas as well as renew areas through urban renewal, urban regeneration, urban revitalisation and urban sustainability without deteriorating the surrounding environment and its resources. Ultimately, the political interaction and perspective is to manage and provide financial aid for required developments.

5.4.4 Environmental interaction

The environmental interaction within an urban structure plays various roles within the sectoral interaction. As mentioned, it is an important aspect within the structure of urban models (cf. 3.2). The implementation of environmental preservation and conservation has been based on the country's status as well as the community's needs. Environmental pressures are placed on the ecosystem in developing countries through various hazards that occur in neighbourhoods (community), in housing and on the land on which it is situated, in the working environment, the city and municipal district (Yamagata *et al.*, 2016:27). Local authorities must accommodate the needs of the community and the future development initiatives; while the environmental aspect within these guidelines as well as policies may be illustrated, implementation may be different. The environment is often placed below the community's needs - this can be problematic over the long term regarding the development process, which can result in urban restructuring. This can branch out into larger environmental hazards and become a regional if not a global problem. The following subsections analyse the various categories and initial issues regarding deterioration (Pacione, 2005:749-751; Cullinan, 2019:59-60).

5.4.4.1 Chemical

Chemical deterioration has an impact on the surrounding environment and if released into a water supply (river) can be detrimental to the entire region. This can be hazardous not only to areas within the region but can progress to a global scale. Chemical deterioration can be identified through the use of fertilisers and most commonly through the use of fossil fuels, such as oil (Rodrigue *et al.*, 2006:88).

5.4.4.2 Physical

The physical deterioration of an environment is seen as the overuse of resources and inadequate waste disposal. The physical deterioration of an environment can be identified as the overuse of natural resources, which is illustrated through deforestation causing immense erosion of the surrounding environment (Rodrigue *et al.*, 2006:81). This can cause areas to lack food for various fauna and indigenous species of plants. The lack of vegetation will increase water runoff (flooding) and further deteriorate the environment through erosion. This deteriorates the quality of the soil for agricultural use, which leads to a lack of food for human consumption.

5.4.4.3 Biological

The biological impact on the environment is caused or triggered by the environment, due to human activity. The best example is illustrated in global warming, where gasses start to deplete the ozone layer, causing the polar ice caps to melt. This causes drastic changes to the environment through climate change – this, in effect, causes the destruction of ecosystems including forests and other environments. This can cause the extinction of some fauna and flora, which would cause a decrease in resources for human settlements over time (Rodrigue *et al.*, 2006:81).

5.4.5 Community health

The community health aspect may be affected by all the above-mentioned interactions. Community health may differ between regions and countries, based on their status (developing versus developed). This determines a country's priorities (Cullinan, 2019:100-156). Community health has numerous factors which can either deteriorate or improve the community's health (Chang *et al.*, 2022:47-49). The factors can begin as micro-factors and extend outwards to macro-factors. The micro-factors of community health can be identified as four factors and categorised as 'health and equity':

- Public health;
- Individual health;
- Physical health; and
- Mental health.

These micro-factors to community health can be expanded to four other factors (known as mid-factors) and are categorised as 'environment':

- Socio-cultural (cf. 5.4.2);
- Economic (cf. 5.4.1);
- Physical;

- Built;

The macro-factors affecting community health can be identified as five factors and are categorised as 'values':

- Democracy;
- Equity;
- Sustainable development;
- Comprehensive approach to health; and
- Ethical use of evidence.

These factors work in a chronological system, where macro-factors can improve the community's health and micro-factors can decrease the quality of the community's health if they function ineffectively (Pacione, 2005:749-751; Chang *et al.*, 2022:53-55). The below Figure 5-2 illustrates the community health system and micro-, mid- and macro-factor systems used to determine the community's health.

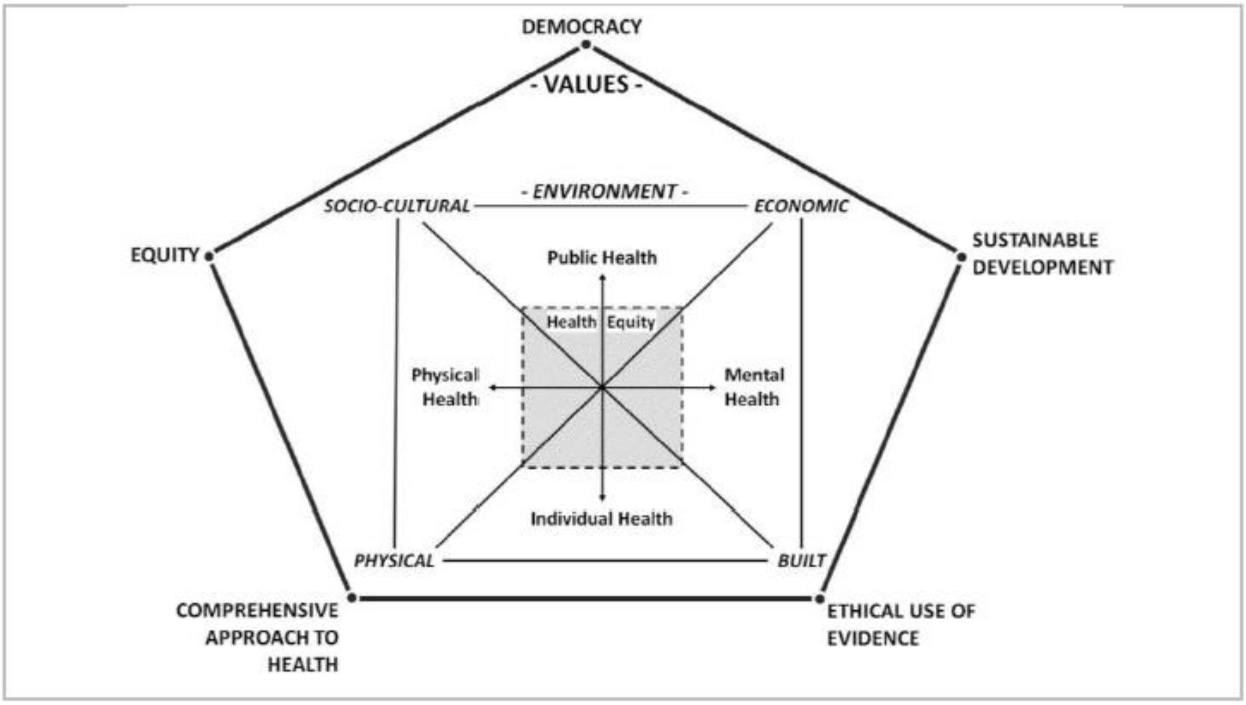


Figure 5 - 2 Factors influencing the health policy of urban structures

Source: Spandau et al. (2010:6)

The above Figure 5-2 shows the components required to improve community health. These micro-components would influence the mid- and macro-components if the majority of micro-components have been addressed while macro-components can influence all the components lower down the chain if effectively implemented (Rodrigue *et al.*, 2006:88; Spandou *et al.,* 2010:7-8).

5.5 TRANSPORTATION COMPONENTS

The implementation of transportation components illustrates different ideologies based on the level of implementation. This section discusses the largest spectrum of planning through spatial planning of transportation systems, which illustrates the spatial planning concept of linking nodes and transportation systems on a larger scale of location, distribution and types of transportation systems. The concept of transportation components on a large scale is demonstrated through possible linkages (cf. 5.5.2) and efficiency (cf. 5.5.4) of transportation based on the type of transportation system (cf. 5.5.3). The components of transportation systems based on the local level illustrate the practical components of the different transportation systems, which are known as transportation infrastructure (cf. 5.5.5). The section will also explore possible implementation strategies and components to efficiently create an efficient transportation system (cf. 5.5.6).

5.5.1 Mobility and connectivity

Effective implementation requires various transportation components to operate on an efficient basis. The implementation of transportation components is crucial for mobility in and around urban structures. The components of transportation fall under the concept of transportability, which is defined as the ease of movement of passengers, freight or information. The components of transportation specifically referred to within this study are the mobility of freight and passengers.

This determines the cost of travel and transportation of goods and services based on the demand of the residing community. This will directly affect the cost of travel based on the distance travelled and refers to the central place theory model concepts (King, 2020:20-26). Transportation components are affected by factors, for example, distance travelled, cost of transportation, capacity of mobility and speed of transportation used. This will affect the three attributes illustrated in transportation components. The mobility of freight may differ based on the goods or services provided. The delivery and transportation of goods have been illustrated in three main attributes, namely (Rodrigue *et al.*, 2006:1-3; Cilliers, 2010:7-10):

- **The fragility of the object or product:** This is determined by how fragile and sensitive the object of travel might be. Special considerations for transportation are required to deliver the product in the same condition as it was received;
- **The perishability of the product:** This determines how long the product may be used or the time frame it can be consumed in before decay takes place. This is indicated on most consumable products with specific expiry dates; and
- **The price of the product or service:** This may dictate the consumer's need or want for the product. This entails both transport cost and the cost of the product, as well as the consumer's demand based on time of travel.

Ultimately, there is evidence that transportation advances the productivity of activities and releases various constraints. The value of transportation is based on various components, which can range from cost of infrastructure, cost of maintenance, cost of travel, speed of travel, capacity of transportation system, availability of transportation system, flow of transportation system (cf. 4.3), time taken on travelling and safety of transportation system.

The concept of mobility in regards to connectivity of components is based on the transportation system implemented. This can be considered as an effective and efficient transportation system which can be used sustainably or a transportation system which is ineffective and inefficient due to speed of travel, congestion or cost of travel. The components of transportation are considered to be points of connectivity that create a viable transportation system, which is optimal for the resided community. The lack of components of transportation can be considered as a lack of connectivity based on accessibility to different land uses and regions.

Another aspect of transportation components can refer to the various components used within the infrastructure of transportation systems. This is identified within implemented multimodal transportation systems (Cullinan, 2019:90-91). The connectivity of different transportation modes can impact the efficiency of transportation and either increase productivity or dramatically decrease it based on effective spatial planning strategies (cf. 5.8). The multimodal transportation system can be considered as various modes of transportation seen as components of a more efficient transportation network. This refers to the correct placement and implementation of transportation infrastructure to increase the flow of transportation (cf. 4.3), as referred to in the previous subsection. The below Figure 5-3 illustrates the connectivity of different transportation modes and functional transportation networks (cf. 4.2). This also includes the connectivity of different activity nodes or SSs, which can be seen as different land use on smaller-scale networks within an urban structure (Rodrigue *et al.*, 2006:187).

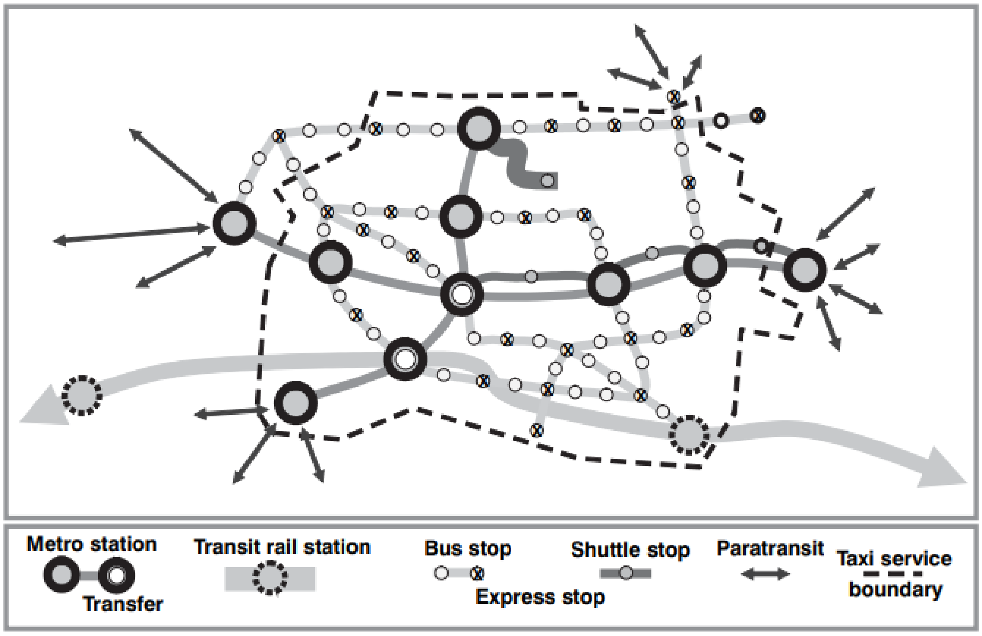


Figure 5 - 3 Components of an urban transit system

Source: Rodrigue et al. (2006:187)

The above Figure 5-3 shows a multimodal transportation system with various modes of transportation connected within a greater transportation network. This illustrates connectivity through connections between transportation modes, which requires various stops for individuals to enter and exit the transportation mode based on the distance, cost and time of travel required to reach their destination. 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 (cf. 4.3), two different demands will be discussed below to demonstrate the importance of spatial planning in transportation (Rodrigue *et al.*, 2006:2-4).

The first aspect is directly connected to the demand of the community and economic activities (cf. 5.4.1) which take place in an urban structure. The concept of demand is that the more commodities are required, the greater the demand will become. Without this specific type of demand, no economic activities will occur. In a mobility and transportation aspect, the best example that can be provided is determined through a work-related perspective, which involves commuting between the CBD and the place of residence. The concept is that one area would supply work (residences) while another area would demand the labour for potential work outcomes (workplace). This particular concept is derived from what is known as the supply and demand chain in economics, which determines that the higher the demand for commodities, the more supply is required. This has significance for the urban structure, as it increases economic benefits and productivity whilst maintaining the supply and demand of products. The perceived travel of freight can be identified as a crucial section of the supply chain. The transportation systems that are generally involved in this supply process are rail transport, trucks, other road infrastructure modes and lastly container ships (Meijers & Burger, 2009:1-6).

The second aspect is indirectly connected to demand and can refer to the mobility of goods and services regarding efficiency and speed of travel. This has been illustrated in the central place theory model and referred to throughout this study. The movement of transportation systems is considered to indirectly affect other movements within the urban structure to increase economic benefit. The best example of this type of demand is the energy source used to fuel the transportation system. The fuel of transportation depends on the mode of transportation, which determines the efficiency of travel. 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.

The two aspects above represent the mobility of freight to increase economic benefit. This refers to the flow and distribution of goods as well as services, which is considered to be a crucial aspect of mobility and can be detrimental to an urban structure if not considered within the spatial planning aspect. This is directly related to the urban models (cf. 3.2) discussed in Chapter 3. The models illustrate specific land use planning, which refers to the connectivity of land and the mode of transportation used to allow mobility to take place between these land uses. The SS determines the difference between the connectivity of land uses and mobility within. This has been shown in the above analysis and comparison of urban models (cf. 3.2). The planning of transportation and transportation models illustrates specific planning strategies for demand and supply chains, as shown in Chapter 4's (cf. 4.4.1, 4.4.4) travel demand (Mackett, 1998:91-94) and economic evaluation models (Bates, 2003:1-3). The below Figure 5-4 illustrates the structure of transportation based on the perceived demand for commodities within urban structures.

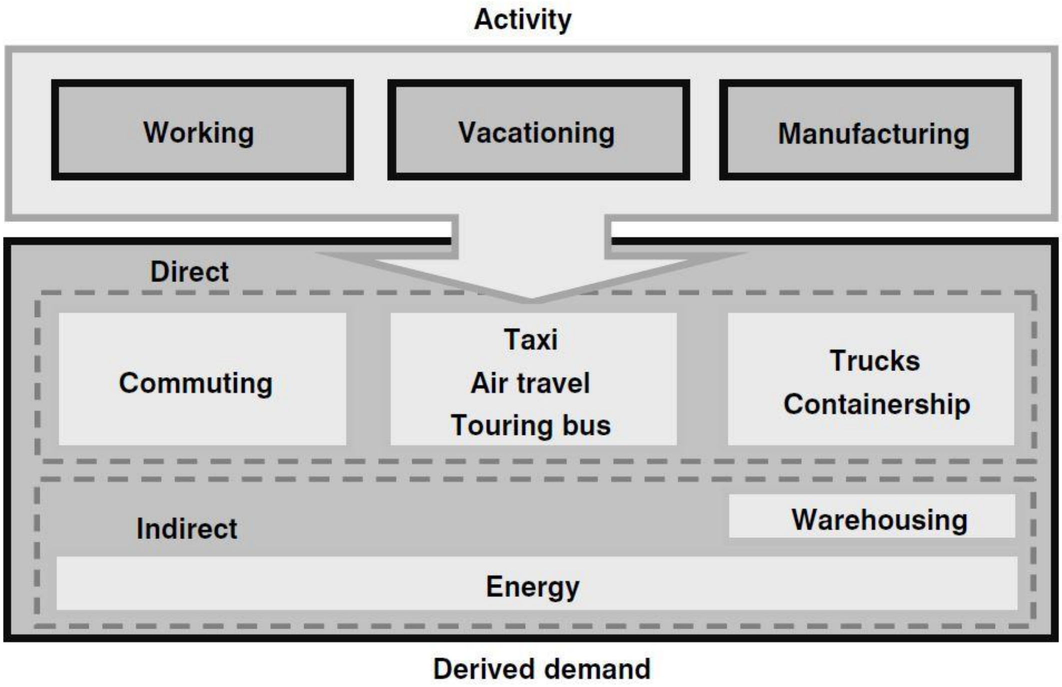


Figure 5 - 4 The derived demand for commodities transportation systems

Source: Rodrigue et al. (2006:2)

Figure 5-4 describes the transportation system through various direct and indirect connectivity points. Thus, there are numerous components required for mobility to become more efficient. The purpose is to illustrate that if one component is not efficient, this may affect the entire transportation system and stunt mobility. This means that all components should be efficient in transporting freight or individuals from one area to another.

The concept of mobility is based on three models which control the planning of infrastructure, mobility, destination, capacity, speed of travel and transport mode used. The three models are:

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

The above models of transportation are determined through calculations, as determined in Chapter 4. The calculations use the previous data acquired to create a model based on the population, growth pattern, trips and cost of travel. The general understanding of the above concept is explained in the subsections below.

5.5.2 Location and accessibility model (A)

The location and accessibility model refers to the area of residence and assumed area of mobility, which may likely be the CBD, transitional zone or agricultural areas (Waugh, 2002:420) based on the needs of the individual. The concept of this transportation component has been identified as the central place theory concept that has been incorporated into this model to achieve independent entities, which will in theory compete against overlapping market areas.

The central place theory concept is based on the ideology of different hierarchies as identified within Chapter 3 (concentric ring and garden city models) as well as the different demands for commodities. This transportation aspect is based on the assumption of a common central place to which all residing communities intend to travel. Through this assumption, major corridors are used to link all hierarchies and different land uses to accommodate mobility. The concept is to create an efficient transportation mode, which would have the capability to transport a large number of individuals from one area to the assumed destination. The transportation system would have to consider various components, such as time of travel, cost of travel, capacity of transportation system and distance of travel. The transportation corridor would have accommodated pickup and drop-off points to provide accessibility to other land uses. Transportation costs have been regarded as dominant in this model 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 5-5 below, model (A) illustrates the concentration of each market node and the infrastructure of the transportation system (Rodrigue *et al.*, 2006:84).

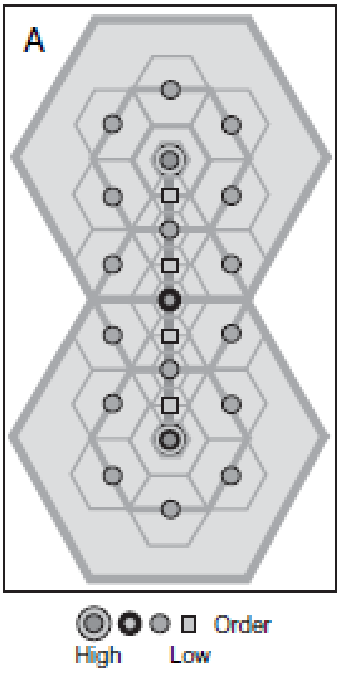


Figure 5 - 5 Location and accessibility model (A)

Source: Rodrigue et al. (2006:84)

The above Figure 5-5 demonstrates the central place theory, where one large mobility corridor is used to connect activity nodes, which are accessible to other nodes within the urban structure.

The hexagon connectivity within the figure connects lower-order activity nodes to the higher-order connectivity nodes to increase productivity throughout the urban model (cf. 3.2).

5.5.3 Specialisation and interdependency model (B)

The specialisation and interdependency model determines the level of interaction in the surrounding urban structures (towns, cities). To achieve vigorous activity levels, it is required to have active transportation systems, whether they be singular transportation modes or multimodal transportation systems. This will assist in achieving regional specialisation and comparative advantage by providing accessibility towards numerous land use types. This model best illustrates the design of a megalopolis concept, which was designed by Gottmann in the early 1960s (Gottman et al., 2002: 83-96). The Gottmann model illustrates the interaction and connectivity in large urban structures. These urban structures are known as megalopolis or metropolis. The urban structure is considered to be larger than that of other cities and towns; thus, the concept of the megalopolis best illustrates the design of large urban corridors used for transportation systems/infrastructure and terminals used for various interactions. This concept is based on interaction as well as specialised approaches towards sustainability. The model focuses on providing sustainable transportation, which in most circumstances refers to multimodal transportation systems to provide accessibility between land uses and other urban structures. The accessibility factor functions as an efficient method of transporting freight between land uses and acts as a stimulant towards economic growth and benefit (cf. 5.4.1). This ultimately encourages both supply and demand with the increasing consumption of the consumer in large urban structures. The transportation modes are precisely planned and are coordinated with one another to effectively transport freight and individuals.

This model had made one assumption, namely that accessibility given by a corridor reinforces territorial specialisation as well as independence. This illustrates that the model is consequently reliant on regional transportation systems. This assumption is not completely false, however, 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). The Figure 5-6 below depicts the specialisation and interdependency model and its specific method of connectivity.

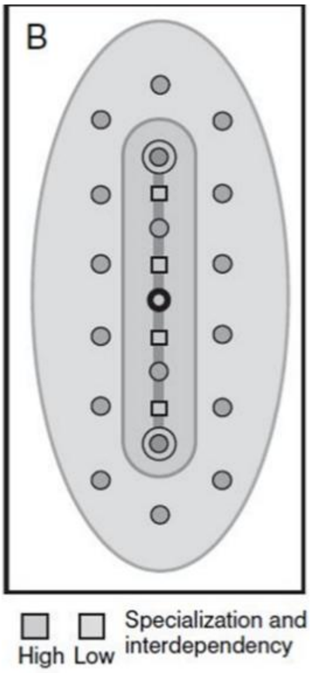


Figure 5 - 6 Specialisation and interdependency model (B)

Source: Rodrigue et al. (2006:84)

The above Figure 5-6 illustrates the use of major terminals within the centre which act as activity nodes and secondary nodes which surround the main transportation mode. The connectivity within the centre is considered to be specialised as well as efficient due to the central place theory and concept of the Marchetti Constant model.

5.5.4 Distribution/flow model (C)

The above model focuses on the implementation of multimodal transportation systems. The purpose of this current model is to implement various types of transportation modes to form a major transportation system. This transportation system acts as a link to activity nodes that are situated locally, regionally, nationally, and internationally. The model provides a paradigm through three core structural elements, which 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 for distribution; and

- 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.

The model illustrates the use of large corridors, used to improve the flow of traffic within transportation systems. The flow within this model depicts specific transportation modes used for both long-range and short-range travel. This improves connectivity on a local and national level of transportation. This is illustrated in Chapter 3 (Marchetti Constant) determining types of transportation modes based on distance of travel and human behaviour. The large corridors used to increase the flow of traffic are shown in the Figure 5-7 below (Phillips, 1970:50).

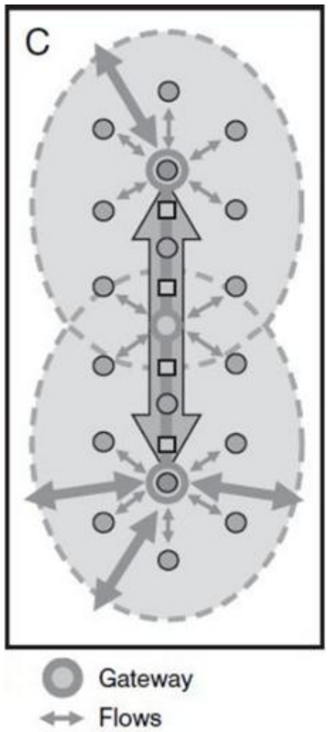


Figure 5 - 7 Distribution/flow model (C)

Source: Rodrigue et al. (2006:84)

The above Figure 5-7 illustrates the large corridors used for high-volume transportation. This will allow individuals to travel and reduce congestion as well as increase connectivity. The model shares the similarity of main activity nodes situated in the centre of the model but differs in the connectivity towards the outer secondary nodes.

The transportation components are complex within an urban structure due to the number of factors that need to be considered before implementation. There are two main categories/components implemented within infrastructure, known as hard and soft infrastructure (Skorobogatova & Kuzmina-Merlino, 2016:320-322). Hard infrastructure refers to the physical network that keeps an industrialised nation smoothly functional. Hard infrastructure is classified as the governing authority's capital assets; it considers various components which play a role in the transportation network. These components are described as utilities, transport vehicles, telecommunication systems, roads, highways, railways, subways, traffic lights and streetlights, dams, walls and culverts, drainage systems, airports and bus terminals, and bridges. Soft infrastructure refers to two different factors described as physical and non-physical factors. Physical factors represent the physical assets, such as buildings, networks and other equipment used to maintain the infrastructure. The non-physical factors are governing rules and regulations implemented by the governing authority. This considers the financial system and the organisational structure. In essence, the soft infrastructure embodies the system of service delivery. The mobility of individuals and freight may differ in components required. Therefore, the infrastructure and facilities may also change based on the need for transportation. As discussed in the above paragraphs, the mobility of freight is known as logistics transportation and will require several components, namely (Skorobogatova & Kuzmina-Merlino, 2016:320-322):

- Warehousing infrastructure, including buildings and premises, storage yards, and warehouse equipment;
- The so-called handling infrastructure, including internal transport, auxiliary equipment for commodity handling;
- Transport infrastructure (roads or rails, for example);
- Transport packaging infrastructure (marked/not marked with a code); and
- Information technology (IT) system infrastructure, including hardware, software, orga-technical means, and equipment to provide telecommunication purposes.

The above components of infrastructure are imperative to increase transportation network performance concerning freight and mobility thereof. In developed countries, the transportation of freight is based on a system to either improve, identify or increase efficiency. The system is known as the Logistics Performance Index (LPI) (Skorobogatova & Kuzmina-Merlino, 2016:323-325).

5.5.5 Transportation infrastructure

Spatial planning of an urban structure is based on the connectivity of transportation, where transportation infrastructure is required for optimal mobility and connectivity. Transportation structure differs between modes of transportation and is required to operate under certain policies and guidelines which vary between countries. The concept of transportation infrastructure is not always delegated to one transportation mode but can be utilised by multiple transportation systems (BRT can utilise road infrastructure besides the use of SOVs, bicycles can utilise roads). This would still require a type of transportation mode to be guided through a series of guidelines and precautions (RSA, 2003:17-18). With the incorrect infrastructure in a spatial plan, transportation becomes inefficient and may even lead to the unnecessary use of funds (Pacione, 2005:370).

It has been assumed that transportation and mobility may impact economic growth within a country or community. Transportation modes are assumed to be efficient and productive but various factors may affect the efficiency of transportation, as mentioned in Chapter 4. These factors can be illustrated as the following and would fall under specific challenges within TP:

- Congestion;
- Topography;
- Population; and
- Economic circumstances of a country.

The above challenges may differ between transportation modes, for example, cycling may be hindered by safety and regulations guiding the cyclist or distance of travel, while road transportation can be based on options of transportation mode and capacity of travel. An urban structure would require various options of mobility to increase the capacity of travel as well as distance. This would ultimately require various drop-off and pick-up stations connecting the various transportation modes. Transportation infrastructure must ensure the efficiency and capacity of transport modes and various terminals, which can have a direct impact on transport costs (Rodrigue *et al.*, 2006:44-47). This is required to maintain and increase the flow of mobility and can be detrimental to efficient mobility if not implemented in a greater transportation system. This can ultimately affect the accessibility, flow (cf. 4.3) and network (cf. 4.2) of the various transportation systems implemented. There were three specific transport corridors highlighted and compared during a geographical analysis of the spatial implementation of transportation modes. The three models of transportation corridors and regional SSs were designed to play a specific role in the community (Pacione, 2005:169; Rodrigue *et al.*, 2006:84-85). Transportation infrastructure may differ between urban structures and land use but under close observation, there are transportation modes that are implemented regardless of the urban structure. The type of transportation infrastructure (not including infrastructure implemented within an urban structure and not referring to international travel - air travel, ocean travel) is:

- Walkability;
- Road infrastructure; and
- Rail infrastructure.

5.5.5.1 Walkability

The walkability of the urban structure is based on the ability to provide safe and accessible infrastructure. This mobility mode requires sidewalks, crossings, traffic lights, streetlights and safety guidelines to protect vulnerable pedestrians from harm. The concept of walkability and implementation of walkability is based on the assumed parameters calculated within the walking and bicycling (cf. 4.4.3) TP models illustrated in Chapter 4. This type of mobility is limited to distance, speed of travel and capacity, but is a sustainable mode of transport. The mode of transportation will be used for short travel and requires various parameters and guidelines to implement effectively (Frank *et al.* 2009:9-10; Clifton *et al.* 2015:24-28). Walkability has been illustrated to be effective for mobility over short-distance travel and provides other benefits which can be considered important to health (cf. 5.4.5) and productivity.

Walkability and cycling are always incorporated within an urban structure, whether it is for recreational use or a type of mobility system. The challenge is to incorporate the infrastructure through unique guidelines to the specific urban structure. The guidelines are not always consistent and would be provided at a national and provincial level, which is not specifically based on the topography of the resided urban structures (Frank *et al.* 2009:7-10; Clifton *et al.* 2015:25-29). This provides a healthier method of mobility and in fact, can improve the community's quality of life and sense of well-being (Frank *et al.* 2009:3-6).

5.5.5.2 Road transportation

The most recognised type of transportation infrastructure in the world is road transportation. Road infrastructure has been calculated on a worldwide database, estimating 32 million km (cf. 5.2) of road infrastructure coverage (Meijer *et al.,* 2018:4). This transportation structure is used for a variety of transportation modes which includes automobiles, buses, bicycles, trucks, and other cultural or transportation modes requiring flat surfaces. 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 general cost of roads in South Africa is based per km and guided under the National Treasury Act. This may differ in other countries but based on a South African perspective, roads would cost ZAR3.5 million (South African Rands) per km (RSA, 2011:166). The cost of road infrastructure is not the only cost required to implement road transportation. Various components towards implementation involve 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.

Importantly, road transportation can be beneficial by overcoming topographical obstacles (mountains), for example, slopes. The assumption is that road infrastructure and the transportation modes used within this infrastructure can overcome minor topographical features with minimal problems. In most countries, public transportation systems have been implemented to provide mass mobility but only developed 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. This has been illustrated in the central place theory and directly refers to the cost and effectiveness of transportation. The road transportation mode is commonly used and provided by the government as a category of public goods, but in developed countries, most people have privately owned vehicles (Rodrigue *et al.*, 2006:101-102; Dur & Yigitcanlar, 2015:814).

The purpose of road transportation is for the mobility of goods and services as well as individuals to designated areas of economic activity (CBD, residential and industrial). This would create or increase the economic (cf. 5.4.1) benefit of the area. The criticisms of road transportation are that it may be limited 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. This is because most road-orientated transportation modes are operated through the use of fossil fuels (oil, petrol, diesel). The other limitation is the weight capacity of each vehicle. Some trucks and automobiles cannot carry heavy loads and are often constrained by weight restrictions in attempts to increase safety (Rodrigue *et al.*, 2006:102).

The implementation of road infrastructure can be advantageous for the economic growth of an urban structure. This can benefit the community through various aspects of mobility and increase productivity. The transportation of freight could be efficient based on the current condition of the road infrastructure and congestion status. The geography of transportation states that road infrastructure could be a viable source of transportation based on the following points (Rodrigue *et al.*, 2006:101-102):

- 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, given 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 another advantage; 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; and

- Multiple trips can be undertaken by cars and trucks. The 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.

The above points illustrate the relevance of road transportation and can be summarised as an effective mode of transportation without congestion. The capital cost of vehicles is low and the flexibility of routes is predominant. This type of transportation is not confined to a single route and can alternate, which allows it to increase productivity based on numerous routes of travel and multiple methods of transportation provided. This also allows individuals to travel to specific destinations as a single individual.

5.5.5.3 Rail transportation

The last type of mobility is identified as rail transportation which is delegated between a few types of transportation modes (train, tram, BRT, LRT). Rail transportation is confined to a specific route, which has designated stations for drop-off and pickup of freight and individuals. This transportation mode requires a rail system and a power supply to operate the locomotive. The older models would operate on steam or coal. The technological advancements focus on an external power source, for example, electricity on a guided rail system. 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 government or private sector investments. 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.

The rail system has advantages as well as disadvantages based on the comparison between road transportation and rail. The road transportation mode can better cross various land topographies, while rail transportation systems lack the capabilities to climb steep gradients (Rodrigue *et al.*, 2006:100-102). Rail transportation however has a better capacity than most road transportation modes and can increase the capacity of mobility between activity nodes. This is a large factor concerning transportation and helps to increase the mobility of both individuals and large amounts of freight. This is illustrated in the below Figure 5-8, demonstrating the demand and capacity of travel.

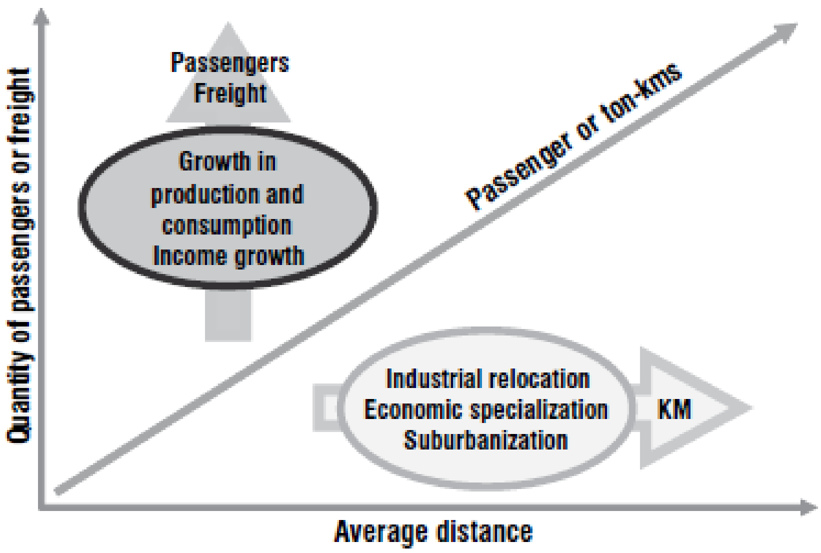


Figure 5 - 8 Capacity of travel and economic growth

Source: Rodrigue et al. (2006:56)

The above Figure 5-8 shows that the higher the mobility capacity, the more productivity growth is identified based on the passenger or ton per km. Trains' primary asset is their ability to haul large quantities of goods and significant numbers of people over long distances. Once the cars have been assembled or the passengers have boarded, trains can offer high-speed and high-capacity service.

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; however, in terms of passengers it 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 developed countries have created 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, as mentioned. Its higher speed 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 in dealing with a large population that originates from a specific Destination A and needs to travel to the same area - Destinations B, C and D). Rail transport modes offer little flexibility in destination or route of travel. This transport mode has undergone advances in terms of speed, comfort, design and engineering solutions from the 19th century onwards. The comparison between road and rail infrastructure may differ based on various advantages as well as disadvantages. The advantages and disadvantages of rail infrastructure are presented in three simple points:

- The cost of rail transportation is described as a cost-effective transportation system as well as an efficient mode of transportation. It can move large quantities of goods over long distances without the need for as many drivers or fuel as trucks, which can be financially beneficial;
- Rail infrastructure is considered to be environmentally friendly in comparison to other modes of transportation, such as trucks, which contribute to air pollution and greenhouse gas (GHG) emissions. A study determined that rail transportation emits less GHGs per ton-mile than truck transportation (Kreutzberger et al., 2003: 6-8); and
- Rail transportation has also been determined to be more reliable than other modes of transportation, such as trucks, which can be delayed by traffic, weather, or accidents. This would fundamentally be based on the transportation of freight, based on a study published in the *Geography of Transportation Systems* (Rodrigue et al., 2006:107-122) that found that rail transportation is more reliable than road transportation.

Rail infrastructure has significant points illustrating its relevance as an efficient and cost-effective transportation mode. The other factors point towards the disadvantages of rail infrastructure and its possible limitations:

- There is a limitation towards flexibility and its fixed routes and schedules, which can prohibit its ability to respond to changing demand or unforeseen events. However, other transportation systems (road) can cause delays due to congestion or lack of access;
- Rail transportation systems require other infrastructure to operate efficiently within the environmental topography (as mentioned above), this determines that rail infrastructure is dependent on infrastructure, such as tracks, bridges, and tunnels, which can be vulnerable to damage from weather, accidents, or other events; and
- The last disadvantage has been identified from the economical perspective, illustrating the initial investment and high cost of rail infrastructure which requires a significant initial investment – this can be a barrier to entry for new companies or industries.

Rail infrastructure has illustrated crucial points towards sustainable mobility while mentioning its ability to travel with a high capacity and cost-effective objective. The lack of other mobility systems does not render the rail transportation system sufficient but can increase productivity through its transport capacity. The rail system is an expensive system which requires various other types of infrastructure to operate sustainably.

5.5.6 Transportation systems

The concept of systems within urban planning refers to the mobility infrastructure and connectivity of land use within an urban structure. Spatial planning includes various aspects of mobility 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 a complex set of routing and mobility that allow demand for and supply of services to take place. Transportation systems operate in two categories, namely the trade of transportation systems and the commercial use of transportation over a geographical space (Rodrigue *et al.*, 2006:38-40).

5.6 URBAN SS AND TRANSPORT

The urban structure comprises various components (cf. 5.5), of which transportation systems are one of the most crucial components to connect various land uses efficiently. There is a misconception surrounding transportation systems and urban SS - that they are the same. This could not be further from the truth and will be illustrated in the below discussion.

The two systems work in synergy with one another to achieve a specific goal. The transportation system and urban SS are seen to be worlds apart regarding their functionality and objectives. The previous chapter sought to identify the function of each of these systems and to illustrate each of their objectives and roles within spatial planning (Roussauw, 2023:1-8). Urban SSs and transportation systems are critical elements that shape the functionality, accessibility, and liveability of urban structures. In the UK, there is a mutual benefit between urban structures and transportation networks (cf. 4.2). This illustrates an intricate dynamic that could positively or negatively influence social (cf. 5.4.2), economic (cf. 5.4.1), and environmental (cf. 5.4.4) outcomes. The research illustrates the two systems that identify key principles within the implementation of land use and transportation systems. The purpose of this section is to identify the link between urban SSs and transportation systems to improve the efficiency of transportation and the long-term sustainability of transportation systems (Williams, 2005:4-5). The implementation of transportation systems within the urban SS has various layouts (cf. 3.2). In addition, the concept of urban morphology may be influenced by various factors.

The incorporation of transportation within a specific type of urban SS would determine the efficiency of functionality within the urban structure. When economists realised that transportation could be considered as a tool to increase and decrease economic benefits, it became evident that a development model should be designed. Development professionals, economists and researchers began to create an urban development model in the 1980s and 1990s. This development model would be illustrated as the beginning of what is known as integrated land-use transportation models (cf. 4.4.5). The integrated land-use transportation models would be further evaluated by transport planners and town planners to increase trip generation and distribution of mobility (Acheampong & Silva, 2015:11-38). The urban models (cf. 3.2) are limited based on the amount of detail required to forecast transportation systems. Transport planners would create various models based on connecting a simplistic urban structure. The urban structure would be based on previous models to provide possible variables used to predict future forecasting. The variables would be based on changes towards the urban structure, population, density and the trips required from residential areas to workplaces. The forecast would also focus on the land use zones (cf. 3.2) to identify the area of daily travel. These geographical zones would effectively make changes to the transport network (cf. 4.1). The transportation planners would focus on the availability of the various modes of transport that connect the different zones (Lundqvist & Mattson, 2001).

The concept of urban SS refers to the physical urban structure. This would include the implementation of residential, commercial, business, green areas and industrial zones. The implementation of these urban SSs dates back to UK cities (cf. 3.2.1). The urban SS started to take form with the knowledge of TP. The focus had been on the compact urban structure, which would create more densely populated areas. This would assist transportation planners to identify fewer areas which required mobility and link general areas of high density to increase the functionality and mobility within the urban structure. This could be identified in London (cf. 3.2.1) and Birmingham, as well as the sprawling suburban areas of cities such as Manchester and Leeds. The urban fabric model (cf. 3.2.7) reflects varying historical changes, planning policies, and socio-economic conditions. The below illustration of the urban structure demonstrates the integration of transportation systems within a proposed urban structure (Boussauw, 2023:10).

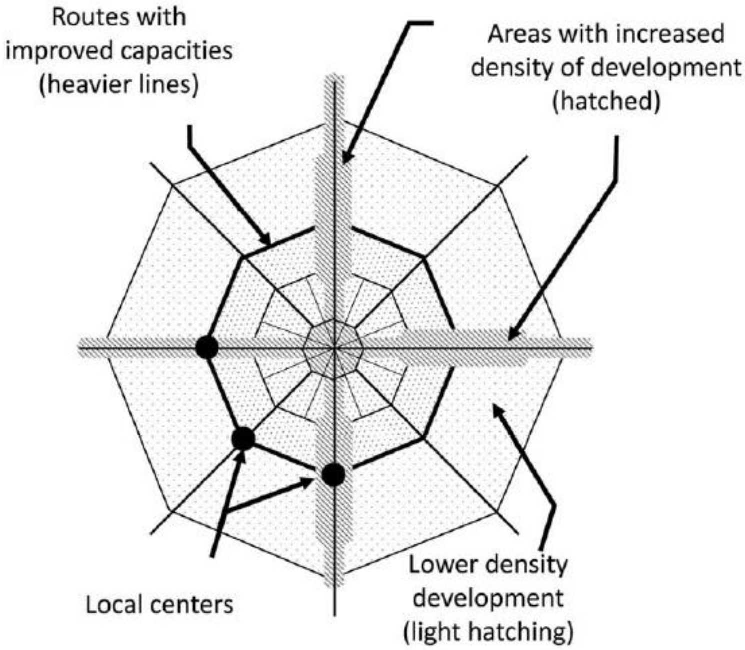


Figure 5 - 9 Test development model for a city in the UK

Source: Rickaby et al. (1992:190)

The above development model has been presented based on the incorporation of transportation systems and reducing urban expansion. The proposed development model would prevent urban sprawl and would create a compact urban structure. The above model illustrated a negative relationship between SOVs and urban structure. The urban structure would also demonstrate a negative demand towards car dependency transportation systems (Boussauw, 2023:10). The layout of the urban structure was demonstrated to have mixed-land use, and was dense with decreased congestion and decreased demand in SOV. The development model would illustrate traits of promoting public transportation and increasing pedestrian and cycling mobility (Ewing & Cervero, 2010:265–294).

The urban form is considered to be a general shape of an urban model (cf. 3.2), while the urban structure is considered to be the intricate layout within the urban model. The above model showed crucial components towards implementation through theoretical analysis. To better understand the integration of transportation systems and urban SSs, a critical analysis should be made through both the types of urban forms and transportation principles. There are several types of urban forms which dictate the (theoretical) implementation of transportation systems within the urban SS, as shown in the Figure 5-10 below.

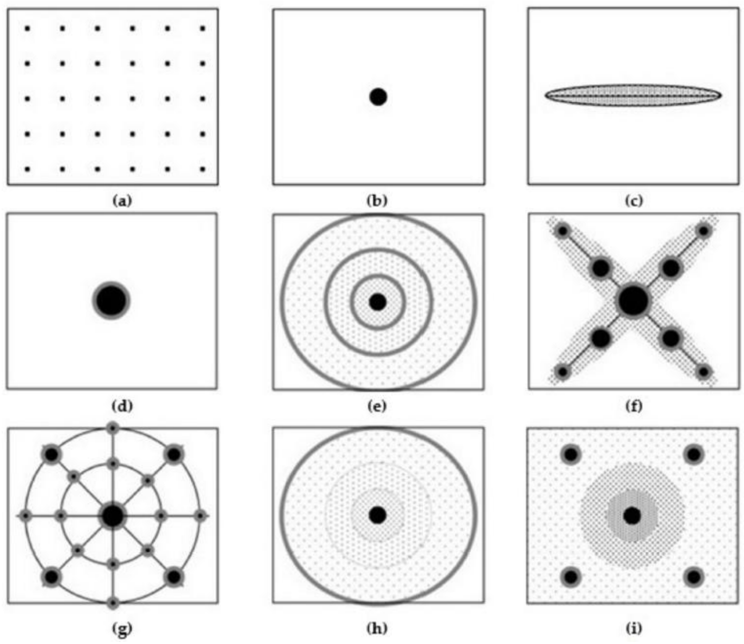


Figure 5 - 10 Types of Urban Forms

Batsuuri et al., 2020:2

The above urban forms have various unique urban structures which incorporate transportation in different strategies to achieve a specific objective. These can be described (Schiller *et al.*, 2010:7-78: Cullinan, 2019:198-213; Batsuuri *et al.*, 2020:2-3):

a) The areal urban structure;
b) The point urban structure;
c) The linear urban structure;
d) The compact urban structure;
e) The dispersed urban structure;
f) The corridor urban structure;
g) The multi-nucleated urban structure;
h) The fringe urban structure; and
i) The ultra-urban structure.

The urban form used would determine the urban SS implemented within the urban model (cf. 3.2). This chapter's main goals are to quantify the urban form and implementation of transportation systems based on various concepts. The current section's purpose would be to compare possible theories and effects of various urban concepts based on land use efficiency and form. A combination of compact, polycentric (cf. 4.2.2.2), and monocentric SS (cf. 4.2.2.1) perspectives is effective, based on a study of Ulaanbaatar (Mongolia); this showed a possible reduction in urban sprawl and should be used for future development (Batsuuri *et al.*, 2020:1-5). The urban form represents a general and broad spectrum of the design and shape of an urban structure.

Transportation systems do not have various forms but do have different structures and modes of transportation with principles of implementation (Vashisth *et al.*, 2018:1598-1602):

- To promote car-free developments;
- To develop TODs;
- To promote clean vehicles;
- To promote pedestrians and cyclists;
- To optimise the road network;
- To develop public spaces in city centres;
- To improve parking management for sustainable transportation; and
- To implement traffic calming strategies.

The above sustainable principles of transportation implementation each have specific strategies. The principles are based on a futuristic solution towards improving transportation efficiency and sustainability within the urban structure.

The urban structure and transportation perspective is based on two different systems that are considered “worlds apart” (Boussauw, 2023:1-14). The integration of sustainable transportation solutions within urban SSs is crucial to enhance the efficiency of urban structures. The challenges of transportation systems (cf. 5.7) will be addressed in the following sub-sections to distinguish possible problems with land use planning as well as strategies to reduce congestion, lower emissions, and improve accessibility. The purpose would be to increase the efficiency of transportation systems based on the urban structure. The urban structure continues to evolve while prioritising sustainable transportation and urban planning. The correct implementation of both urban land uses and transportation systems will be crucial in creating vibrant, efficient, and resilient communities for future generations.

5.7 CHALLENGES IN TRANSPORTATION PLANNING

The challenges regarding transportation systems within urban structures may differ between countries based on legislation, policy implementation, objectives and socio-economic needs. The challenges illustrate possible shortfalls in implementation and guideline creation. The location of the urban structure would determine the possible challenges presented, whether socio-economic, environmental, mobility, resources, modes of transportation or other challenges not illustrated. The challenges discussed in the subsections below have repeatedly been evident throughout the history of the transportation of freight and passengers (Pacione, 2005:787-789; Rodrigue *et al.*, 2006:88; Cilliers, 2010:28). However, not all may apply depending on location.

5.7.1 Land use and TP

TP within an urban structure is considered to be a critical component of urban structures and has a significant impact on land use. This determines the mobility between land uses and the efficiency thereof (Cervero & Kockelman, 1997:199-204). The mobility between land use impacts the supply and demand chain.

Cervero and Kockelman (1997) illustrate the relationship between transportation and land use in urban structures (cf. 5.6). They state that transportation infrastructure (cf. 5.5.5) influences land use decisions, and urban planners should focus on increasing the density, diversity, and design of transportation infrastructure to promote sustainable land use. This would allow for more public transportation services to be viable in accommodating the masses in residential areas. The purpose is to increase the availability of public transportation and promote walkable neighbourhoods; this can reduce dependence on automobiles and encourage more sustainable land use patterns.

The focus on transportation and land use interactions (cf. 5.4) in urban areas has determined key factors which may cause issues within the urban structure. The key issues that influence the relationship between transportation and land use are illustrated as:

- The role of transportation in shaping urban form;
- The impact of transportation on land use patterns; and
- The challenges associated with designing transportation infrastructure (cf. 5.5.5) to support sustainable land use.

These challenges can predominantly affect the functioning of an urban structure and not just the mobility between land uses. The country and legislation provided determine general needs; for example, China has an increasingly high population and little land use to accommodate the density. The objectives of the country are to incorporate sustainable land use and TP. This is critical in addressing the environmental (cf. 5.4.4) and social (cf. 5.4.2) challenges facing urban areas in China. This requires a detailed analysis of the policy and planning frameworks that have been developed to promote sustainable land use and transportation in China, highlighting the importance of integrating land use and TP to achieve sustainable urban development.

Poor land use and poor implementation of transportation systems may also be due to a lack of appropriate legislation and policies. Spatial planning requires planning strategies to combat this challenge and unless spatial plans are suitable, possible stagnating urban structure could result. The lack of transportation modes under viable cost and time of travel have caused populations to shift closer to areas of work to limit the cost of travel. The density of the population can only be maintained until it is exceeded, which then causes urban sprawl. The land use/TP task should become one of defining and evaluating the sequence of project activities, such as the time needed for achievement versus demand and supply as per policy parameters. Therefore, the issue can be said to be caused by insufficient transportation systems (Cervero & Kockelman, 1997:199-205). It is further concluded that national policies should take cognisance of geographical problems and socio-economic differences to bridge inherent gaps (Situma, 2002:2-3).

5.7.2 Impact on the environment

The impact on the environment may differ depending on the urban structure. The urban structure would also depend on various factors, as illustrated in the previous subsections (cf. 4.4). Developing countries often focus on other challenges, not on environmental impact. This can cause depletion of natural resources to supplement the needs of the community rather than to prioritise other factors. This will cause an immense impact on the environment, which is usually considered throughout developments, but future expansion and cooperation among sectors are often considered to be of less interest. The urban models (cf. 3.2) have illustrated that the connection which is most prominent between transportation and the impact on the environment is the fuel source required. The fuel source required by transportation systems is commonly known as fossil fuels which are a natural resource through which petrol, diesel and oil are created. The use of these products through transportation systems releases GHGs, which may damage the environment over time. Transportation systems require these natural resources to operate efficiently and as mentioned within all the urban models (cf. 3.2) within Chapter 3, all have incorporated and even been dominated by the use of motor vehicles. This can cause air pollution, and can indirectly cause water and general ground pollution as well as noise pollution which all consequently decrease the quality of life (Rodrigue *et al.*, 2006:79-89).

The urban models (cf. 3.2) not only illustrate the incorporation of these motor-vehicle transportation modes but TP models (cf. 4.4) in Chapter 4 illustrate the use of motor-vehicles to improve mobility and efficiency. However, these models do not stipulate that environmental concerns are high-up on the priority list. This single-minded focus on efficiency leads to a lack of sustainable methods for preserving natural resources (Mackett, 1998:93-96).

5.7.3 Pedestrian structures

The advancements in mobility and transportation systems have led to an increase in mobility and efficiency thereof; however, through all advancements, simplicity is lacking within certain spatial planning aspects. This has led to a deterioration of pedestrian structures due to stagnation and a lack of repairs and maintenance to maintain the urban structure. These aspects have been illustrated in the different developed and developing countries. Developed countries would prioritise the upkeep of pedestrian structures to maintain a sustainable urban structure. Developing countries focus on basic needs and do not prioritise pedestrian structures - as a result, one transportation infrastructure (cf. 5.5.5) would act as infrastructure for multiple different transportation modes (road, walking, cycling, and motor vehicles, among others). This will lead to a lack of improvements in pedestrian safety and sidewalks, which will then deteriorate further. The improvement of pedestrian structures would ultimately differ based on the country, as illustrated in Chapter 4 demonstrating the various TP models. Certain models illustrated relevance towards the improvement of pedestrian structures (cf. 4.4.3 - walking and bicycling models). Thus, planning for pedestrian structures is considered but is based on the demand of the country (Marchetti, 1994:76-79; Thomson & Newman, 2018:217-220).

The improvement of transportation systems illustrates that the mobility of pedestrians along major transportation routes has been stunted by overactive transportation systems that jeopardise safety and render crosswalks hazardous. This may also affect cyclists and may cause serious injury or death to 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. The improvement of transportation systems should consider both motor vehicles and pedestrian structures as well as the upkeep of both within a set parameter to avoid possible deterioration of walkways, cycling lanes, and crossings and to increase safety.

5.7.4 Political challenges

Political pressure is applied to spatial planning, resulting in significant changes to the SS. Politicians often promote equal land use for each sector, which fails to create the required supply and demand. This restricts access and hinders the economy's markets. Additionally, this would reduce or restrict the effectiveness of TP across the entire urban form. The distribution of land is an issue which has seriously harmed the SS. This is politically motivated and affects both land use and transportation (Situma, 2002:1-6).

Power dynamics are combined with power relationships among various players, including public authorities, business developers, and community organisations, who frequently have an impact on decisions about spatial design. Powerful individuals may control decision-making processes and sway outcomes to further their agendas at the expense of others (Miraftab, 2004). According to Sanyal (2014), this can result in problems such as gentrification, displacement, and environmental injustice (cf. 5.7.2), all of which can have a long-lasting negative social (cf. 5.4.2) and economic (cf. 5.4.1) impact on communities. Additionally, the institutional and governance structures in place also influence spatial planning. These systems could occasionally be dispersed, with various levels of government and organisations in charge of planning-related tasks (Tewdwr-Jones & Allmendinger, 2013). As a result, there may be difficulties with coordination, disputes between various parties, and a lack of accountability and openness in the decision-making process (Sorensen & Torfing, 2011).

The last aspect illustrated as a potential challenge within spatial planning is public participation. Including communities and stakeholders in the planning process is essential to making sure that decisions are inclusive and take into account local needs and preferences. Public participation, however, can be difficult, especially when there are power disparities between various groups (Moulaert *et al.*, 2013). Additionally, factors such as insufficient information and communication, a lack of resources, and a lack of trust between stakeholders can limit the effectiveness of public participation (Berglund & Johansson, 2017).

5.7.5 Policy implementation

In spatial planning, a common problem regarding policy implementation frequently results from either policy formulation or its application. Policies are developed but they are either difficult to understand or difficult to apply, which inevitably leads to more issues than before the policy was developed. A common problem in formulating policies is the absence of a criterion, which prevents proper policy development. Policy formulation must adhere to a set of rules to be effective and alter how the spatial plan operates. The recommendations in this study serve as examples of these principles (Walters, 2014:5-7).

For policy implementation to be successful, spatial planning needs political backing. Politicians, though, can have competing goals and interests, which can make implementation difficult. This is especially true in democratic systems because goals and policies can change when the administration is changed. Several parties with various mandates, interests, and competencies are frequently involved in spatial planning. Effective coordination between various parties can be difficult to achieve, especially when resources are scarce and competing priorities predominate. To support decision-making, spatial planning requires accurate and current data and information. However, it may be challenging to create effective plans if the data is unreliable, inconsistent, or out of date.

5.7.6 Public transportation

Since many public transportation networks are frequently overused or fail due to collapse, they are not thought of as sustainable systems. Many public transportation networks are either underutilised or over-utilised, which either encourages people to use other modes of transportation or causes them to stop using a particular system. When overcrowding in one form of transportation causes congestion and inefficiency, the population of an area determines whether a public transit system is required. In addition to facilitating the movement of people and goods, transportation networks (cf. 4.2) have also been utilised to provide a service, however, the resulting revenue is potentially unstable (Robson, Gharehbaghi & Young, 2018:381-390).

As such, public transportation is a crucial component of spatial planning since it enables access to jobs, education, healthcare, and other critical services in cities. It also ensures more effectiveness and sustainable mobility. However, several challenges in spatial planning related to public transit must be resolved namely:

- **Inadequate finance**. Many communities struggle to pay for their public transportation systems, which leads to a reduction in services and upkeep. Inadequate funding may result in outmoded infrastructure, ineffective operations, and restricted access to public transit;
- **Limited connectivity.** Public transportation networks in many cities are disjointed and do not offer seamless connectivity across various modes and routes. As a result, there may be gaps in service and fewer people may choose to use public transit;
- **Congestion and delays**: In urban locations with heavy traffic, public transit systems are particularly susceptible to congestion and delays. This may result in less dependable service, longer travel times, and unsatisfied customers;
- **Equity concerns:** To guarantee that everyone has equal access to mobility, public transportation systems must also handle equity concerns. The needs of low-income populations, those who have disabilities, and other oppressed groups are included in this; and
- **Environmental impact:** Public transportation must also take into account how transportation systems affect the environment (cf. 5.7.2). This includes reducing GHG emissions, minimising air and noise pollution, and promoting sustainable transportation options.

Public transportation has been implemented in almost every country in the world. Its efficiency is based on the above-mentioned attributes and its implementation within the urban structure.

5.7.7 Traffic congestion and parking facilities

To increase efficiency, spatial design and the distribution of different transportation systems have both taken traffic congestion into account. The primary issue facing transportation networks (cf. 4.2) today is congestion, which can result in declining productivity levels. As was covered in earlier chapters, there are many ways that inefficiency can impact both the built and natural environments (cf. 5.7.2). Lack of facilities will always result in the abuse or overuse of a single facility, which will have a domino effect on the system. The overuse of an existing facility (such as highways - overuse of motor vehicles) may result in congestion if new facilities are not offered for mobility reasons and distributed close to communities (Kumarage, 2004:1-6).

Planning for traffic congestion presents a variety of difficulties, including detrimental effects on the environment (cf. 5.4.4), public health (cf. 5.4.5), and economic productivity (cf. 5.4.1). The following discussion of some of these difficulties includes references to pertinent investigations carried out by Harvard experts:

- **Economic productivity**: By decreasing the effectiveness of the transportation system and lengthening travel times. This problem is in both developed and developing countries. Developing countries have more traffic congestion, harming economic productivity and raising expenses for both enterprises and commuters. Traffic congestion can be detrimental towards the financial sector, as illustrated in a study by Duranton *et al.* (2011). The US economy suffers over $100 billion in annual lost productivity costs as a result of traffic congestion;
- **Public health:** Traffic congestion can have a detrimental effect on the general public's health (cf. 5.4.5). While extended sitting in traffic can lead to physical inactivity and its related health hazards, such as obesity and diabetes, exposure to air pollution from traffic can raise the risk of respiratory and cardiovascular diseases. According to a study by James *et al.* (2015), traffic congestion raises air pollution levels, which in turn can increase the prevalence of asthma and other respiratory disorders; and
- **Environment:** GHG emissions from traffic congestion play a significant role in climate change and other environmental issues (cf. 5.7.2). Reducing traffic jams through better spatial design can aid in lowering emissions and promoting more environmentally friendly modes of transportation. Reducing traffic congestion in urban areas can significantly reduce GHG emissions and have positive environmental effects (cf. 5.4.4), according to a study by Kahn *et al.* (2007).

Overall, these difficulties highlight the necessity for efficient spatial planning techniques. These would reduce traffic congestion and advance more environmentally friendly and productive transportation systems.

5.7.8 Population density

Population density, in simple terms, refers to the number of individuals living near one another and can be considered as compact living. Several difficulties in spatial planning can arise from population density, including (Jayne & Muyanga, 2012:402-418):

- **Limited space**: As population density rises, there is less room available, which can make it challenging to design for new construction and infrastructure. The higher the population density the more traffic congestion, which makes it more difficult for individuals to move about effectively;

- **Strain on infrastructure:** Existing infrastructure, such as roads, water and sewage systems, and public transit, can become overburdened by a large population in a particular location;
- **Housing affordability:** As population density rises, there may be a shortage of homes available, driving up prices and making some tenants' rents unaffordable;
- **Environmental effects:** A dense population can exacerbate the negative effects of human activities on the environment (cf. 5.7.2), such as air and water pollution, and it can put stress on natural resources; and
- **Social challenges:** High population density can cause societal problems such as overcrowding, an uptick in crime, and a strain on social services.

When building urban areas and deciding on land use, transit, and other infrastructure, spatial planners must consider these and other difficulties. Planning carefully can lessen some of these difficulties and build living, sustainable communities for locals.

5.7.9 Maintenance

The continual management and preservation of built environments, infrastructure, and public spaces are all a part of maintenance in spatial planning. Due to scarce financial resources, upkeep can be a major worry for lower socioeconomic groups. Low-income regions' housing, infrastructure, and public spaces might deteriorate due to neglected upkeep, which affects these neighbourhoods' general liveability and quality of life. There are a few typical problems that practitioners frequently encounter although maintenance obstacles can vary depending on the particular environment and purposes of spatial planning. The following are some significant maintenance issues in spatial planning (Ingemarsdotter et al., 2021: 1-14):

- **Infrastructure upkeep**: Development and maintenance of diverse infrastructure systems, including public spaces, utilities, and roadways, are often a part of spatial planning. It can be very difficult to guarantee the appropriate operation, repair, and ongoing maintenance of key infrastructure components, particularly in metropolitan areas with deteriorating or insufficient infrastructure;
- **Environmental management**: The goal of spatial planning is to balance development, environmental sustainability, and preservation. The issues associated with maintenance in this context include preserving and safeguarding natural ecosystems, regulating the effects of development on the environment, and maintaining green areas. This could entail activities such as trash management, water resource management, erosion mitigation, and tree planting;
- **Land use regulation**: To direct development, spatial planning frequently entails enacting and enforcing land use rules. Monitoring and enforcement actions must be continued to

maintain compliance with these requirements. Violations and unauthorised land use activities must also be addressed. In places where there are few resources available for monitoring and enforcement, this can be very difficult. Engagement and involvement of the local community in decision-making processes are essential for effective spatial planning. On the other hand, the long-term sustainability of community participation can be difficult. It necessitates constant efforts to engage stakeholders in communication, resolve issues and conflicts, and guarantee that community opinion is taken into account when making planning and maintenance choices;

- **Financial and material limitations:** Effective implementation and upkeep of spatial plans depend on adequate financial and material support. Securing and assigning enough resources, however, can be difficult, particularly in areas with tight budgets or competing agendas. Repairs, improvements, and continuous maintenance tasks may necessitate continual financial resources, placing pressure on local finances;
- **Spatial planning should be adaptable and flexible enough to take into account shifting societal, economic, and environmental needs**. When plans are out-of-date or do not take into account changing needs and challenges (cf. 5.7.2), maintenance problems occur. Spatial plans need to be reviewed, updated, and modified regularly to maintain their usefulness and efficacy; and
- **Coordination and collaboration:** Many parties are involved in spatial planning, including governmental institutions, non-profit groups, and private developers. It can be difficult to maintain efficient coordination and collaboration across so many entities, especially when there are competing interests or few available communication routes. To tackle maintenance issues collaboratively, regular communication, information exchange, and coordination procedures are essential.

A comprehensive strategy that incorporates planning, monitoring, maintenance, and ongoing stakeholder participation is needed to address these maintenance difficulties. It also calls for a long-term outlook and dedication to maintaining the resilience and sustainability of spatial designs.

5.7.10 Financial restraints

Financial constraints are the constraints or limitations that lower-class income groups encounter when trying to secure financial support for efforts in spatial planning. These limitations may include a lack of money for infrastructure expansion, difficulty obtaining loans or credit for home renovations, and insufficient funding for community development initiatives (Pacione, 2005:465-467). Due to financial constraints, lower-income groups may find it difficult to improve their living conditions and actively participate in spatial planning procedures. Proactive actions are needed to address these spatial planning issues related to financial constraints. Several tactics consist of:

- **Long-term financial planning**: One way to overcome funding limitations is to create thorough, long-term financial plans that consider the various needs of spatial planning activities. This entails locating potential cash streams, utilising public-private partnerships, and investigating cutting-edge finance techniques;
- **Engagement with stakeholders:** Building consensus among stakeholders and spreading knowledge of the value of spatial planning might aid in securing financial support;
- **Advocacy and stakeholder engagement**: Effective engagement and communication tactics may show how spatial planning improves the economy, environment, and society, increasing its likelihood of receiving financing and support;
- **Prioritisation and resource allocation:** Within their budgetary constraints (cf. 5.7.10), governments (cf. 5.7.4) and organisations should give spatial planning priority. Ample financial resources can be committed to support spatial planning activities by performing cost-benefit assessments, assessing possible returns on investment, and incorporating spatial planning goals into strategic plans;
- **Funding methods:** Exploring external funding alternatives, such as grants, loans, or public-private partnerships, might help supplement the financial resources that are already available. Governments may look to regional, national or international financing sources for infrastructure, urban renewal, or sustainable development initiatives; and
- **Building capacity:** This can help organisations and practitioners of spatial planning get over funding obstacles by enhancing their ability to manage their finances. To efficiently negotiate and secure financial resources for spatial planning efforts, entails preparing professionals with financial planning, budgeting, and project management abilities.

Spatial planning can be better supported, resulting in more sustainable and equitable growth within a specific area. This can only occur by tackling these financial constraint concerns and putting proactive initiatives in place (Rodrigue et al., 2006:82-83).

5.8 TRANSIT-ORIENTATED DEVELOPMENT (TOD)

The TOD illustrates the possible benefits and correct implementation of guidelines to increase transportation efficiency. Urban planning strategies known as TODs focus on integrating land use and TP, to build compact, mixed-use, and pedestrian-friendly communities centred around transit stations. Although TODs have many advantages, implementing them within spatial planning can bring several difficulties. Several of these difficulties include (Wilkinson, 2006:224; Bolleter, & Ramalho, 2020: 13-39):

- **Existing infrastructure**: To address the increasing population and transportation demands, implementing TODs frequently necessitates retrofitting or upgrading existing infrastructure. Due to the expense and complexity required in enhancing or expanding transportation infrastructure (cf. 5.5.5), such as adding additional transit lines or enhancing road networks, this might be difficult;
- **Land availability and ownership:** Finding and acquiring suitable land parcels for TODs might be challenging. The supply of property may be restricted, especially in populated areas, and buying land from many owners can be a difficult and drawn-out procedure. Developers, landowners, and governmental organisations must coordinate and work together to implement TODs;
- **Zoning and regulatory barriers:** Zoning laws and land use restrictions may make TODs difficult to implement in many cities. The creation of compact, mixed-use communities with fewer parking requirements can be hampered by traditional zoning laws that may give preference to single-use construction or have minimum parking requirements. Zoning code revisions and political (cf. 5.4.3) support are frequently required to make the necessary changes to overcome these regulatory obstacles;
- **Investment and financing:** Putting TODs into practice frequently calls for large financial resources. These projects often involve numerous stakeholders and call for a long-term commitment, making financing them difficult. Due to perceived risks or uncertainties regarding market demand, developers may have trouble obtaining funding for TOD projects;
- **Community engagement and resistance**: Local communities may be opposed to TODs. Some locals can be worried about a rise in population density, a rise in traffic or modifications to the neighbourhood’s character. Successful implementation depends on involving the community and properly resolving their concerns. Lack of community support may result in project delays, legal action or scope adjustments;
- **Cooperation between agencies**: The implementation of TODs necessitates careful cooperation between the many government agencies in charge of planning the development of infrastructure, housing, and land use. It can be difficult to coordinate the work of several agencies, each of which has its own priorities and decision-making procedures, and this can cause delays or conflicts; and
- **Market forces and economic viability:** Market demand and economic (cf. 5.4.1) viability are key factors in the success of TODs. Developers may be hesitant to engage in such developments if there is inadequate demand for transit-oriented housing or little market interest. For TODs to be sustained over the long term, it is essential to ensure that they are in line with market realities and to conduct thorough market evaluations.

It is necessary to approach spatial planning in a thorough and integrated manner to address these issues. Strategic collaboration between government organisations, developers, and communities is required, as is a readiness to modify current laws and policies to promote TODs. It frequently takes a long-term vision, political commitment (cf. 5.4.3), and consistent efforts to successfully implement TODs and realise the potential advantages of compact, sustainable, and linked communities. The USA's strategy used in the late 19th and early 20th centuries is linked to the smart growth notion of TOD of transportation networks (cf. 4.2). A genesis of the neighbourhood TOD was found in the USA's community development model, which was recognised as a neo-traditional approach (Wilkinson, 2006:223-229). According to Wilkinson (2006), neighbourhood TOD and metropolitan or city-wide context of TOD was identified as the notion of neighbourhood TOD (Wilkinson, 2006:224), as seen in the Figure 5-11 below.

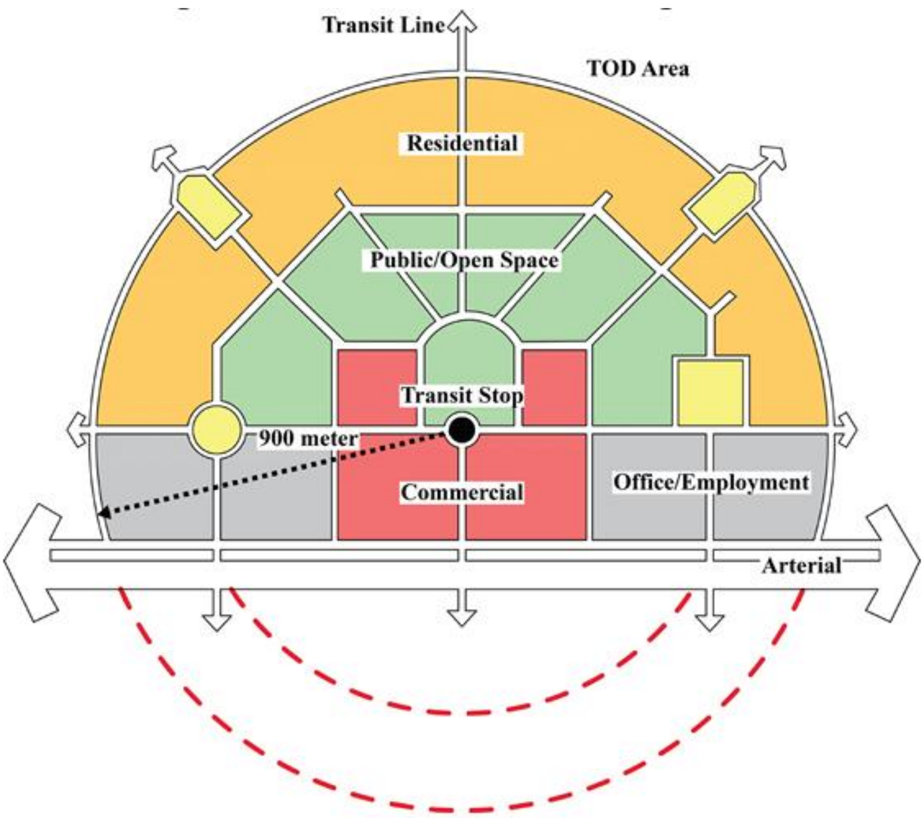


Figure 5 - 11 Neighbourhood TOD

Source: Huang et al. (2020:2)

The smart growth neighbourhood design has been applied in an open grid pattern to promote accessibility through several paths (Wilkinson, 2006:222-225). This cannot be thought of in a loop or cul-de-sac configuration, which would clog the single-road network and make it difficult to reach other routes. The idea of pedestrians and cyclists has been used in the implementation of the neighbourhood TOD (South Australia, 2009:2-6). This infrastructure is essential for people to navigate between nearby locations or neighbourhood blocks. The TOD has been implemented in many developed countries, such as the USA and Australia.

5.9 INTERNATIONAL BEST PRACTICE

Depending on the particular setting and nation, several international best practices for avoiding problems in spatial planning may apply. To handle issues in spatial planning, it is generally advised to follow a few broad techniques and principles. These include (Cervero., et al, 2002:2-60; Banister, 2008: 73-79; Geurs., et al., 2010: 1-18):

- **Adopt an integrated approach to spatial planning**: This approach takes into account a variety of elements, such as land use, transportation, infrastructure, the environment (cf. 5.4.4), social factors (cf. 5.4.2), and economic development. By using a holistic approach, it ensures that all pertinent elements are taken into account and efficiently coordinated;
- **Stakeholder involvement**: Include local communities, corporations, government organisations, and non-governmental organisations (NGOs) among the stakeholders in the planning process. This participation ensures that all viewpoints are considered, fosters consensus, and strengthens the reliability of the planning decisions;
- **Long-term planning**: Develop a long-term vision for the growth of the space that outlines specific goals, objectives, and priorities. This vision should take into account future population increase as well as environmental concerns (cf. 5.7.2), economic trends, and social requirements;
- **Evidence-based planning**: Make decisions on spatial planning based on solid evidence by conducting thorough study and analysis. To comprehend current conditions, forecast future trends, and assess the possible effects of various planning options, use a geographic information system (GIS), remote sensing, and other spatial analysis methods;
- **Flexibility and adaptability**: Be willing to change plans as needed and understand that spatial planning is a continuous process. Adjustments can be made in reaction to shifting conditions, fresh data, and new difficulties because of this flexibility;
- **Sustainable approach:** Promote sustainable development concepts in spatial planning, such as resource conservation, energy efficiency, climate change resilience, and the encouragement of compact, mixed-use development patterns that limit sprawl and encourage walkability;
- **Connectivity between government levels and corporations:** Encourage cooperation and coordination between the many governmental levels, organisations, and industries involved in spatial planning. This comprises vertical coordination between national, regional, and municipal authorities as well as horizontal coordination between various government departments;

- **Public education and awareness**: Inform the public about the value of spatial planning and involve them in the decision-making process. Communities can better understand and support planning initiatives by being informed about the advantages and trade-offs of various planning choices;
- **Use of technological advancements**: Establishing tools for tracking and assessing the effectiveness of spatial plans' execution and results. Regular monitoring makes it possible to recognise and solve problems, track development, make necessary corrections; and
- **Use of international strategies and planning approaches**: Engage in international exchange and learning to share best practices, experiences, and insights from different nations and areas. This can aid in locating creative strategies and answers to typical problems in spatial planning.

It is important to remember that best practices may change based on the context, governing bodies, cultural considerations, and governance arrangements of other nations. Effective spatial planning necessitates adapting these concepts to the individual requirements and conditions of a given region or nation.

5.10 CONCLUSION

The chapter illustrated the integration of various factors which can influence the urban structure as well as its transportation systems. The integration of transport networks (cf. 4.2) and urban architecture has historically been predicated on factors including cost of movement, distance travelled, and efficiency. The efficiency and utility of every element within the urban form have served as the foundation for the development of urban structures and morphology. The various components (cf. 5.5) above have been illustrated and analysed to understand their effect on the efficiency of transportation systems, mobility between land uses and the functionality of the applied urban structure.

Topography and the urban structure would influence the type of infrastructure implemented for mobility within the urban structure. The concept is that developed countries would focus on sustainable transportation and preservation while developing countries would focus on general needs and not on sustainable urban structures. Thus, financial support can increase sustainability and efficiency. The challenges in transportation (cf. 5.7) were listed and remain unresolved in certain developed and developing countries. The difference between the two is that one would provide alternative modes of transportation, while the other has little or no alternative options available. Transportation systems are not only affected in a financial and physical aspect but as illustrated in this chapter, are also constrained to political aspects (cf. 5.4.3) and bound by policies which can also paralyse the system and prevent it from being operational. The chapter was able to achieve **Research Objective 3** by illustrating the current challenges in transportation systems.

This chapter also referred to the various interactions required through transportation systems and various components in order to improve transportation network planning within urban structures (as illustrated in the previous chapters). This will improve urban structure planning based on the implementation of existing urban structures as well as new urban structures within spatial planning. The following chapter will discuss the practical implementation of the above urban models to simulate the functionality, challenges, urban structure, transportation system, and possible guidelines towards implementing efficient transportation systems.

CHAPTER 6 CASE STUDY APPROACH TO URBAN STRUCTURES AND IMPLEMENTED TRANSPORTATION SYSTEM

6.1 INTRODUCTION

This chapter illustrates various international case studies while discussing the practical incorporation of urban models (cf. 3.2). The chapter will comprise various international case studies that have or are similarly structured based on the comparison of the urban models. The chapter addresses **Research Objective 4 (To identify how urban spatial planning policy in a developing country can enhance efficient transportation systems based on the established guidelines)** by illustrating what has been considered while discussing the functionality of transportation systems between land uses and the functionality of the community as a whole. The international case studies incorporated in this chapter are from both developed and developing countries and show the general, practical implementation of transportation systems within urban models (cf. 3.2). The classification of the urban models has been implemented based on previous studies and principles. To implementation of each urban model illustrates a component regarding the spatial planning of urban structures. To evaluate the advantages and disadvantages of each urban model and help determine efficient guidelines to improve the sustainability of each model. The urban models will be analysed according to the below Figure 6-1, assessing six attributes which may affect transportation systems as well as components (cf. 5.5) within the urban structure.

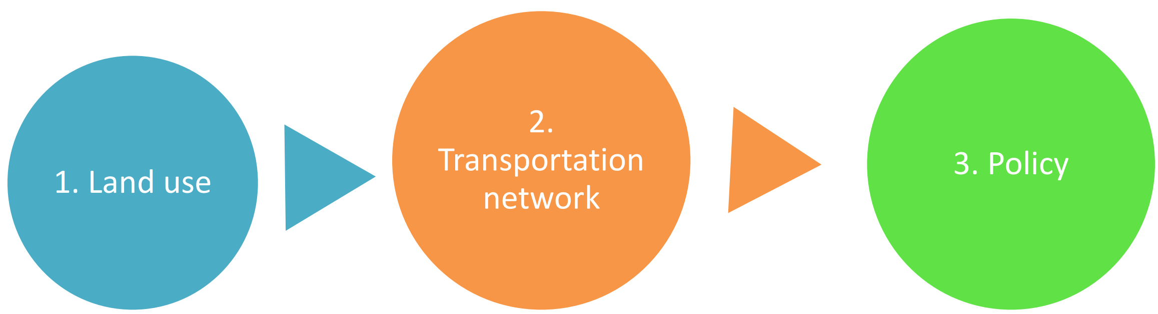


Figure 6 - 1 Criteria of transportation efficiency

Source: Author's own (2024)

The above Figure 6-1 provides a summary of the implementation of transportation systems within the urban structure. It illustrates an underlying criterion for how the efficiency of transportation systems can be improved within the urban structure for future sustainability. This provides a platform for addressing the various case studies and implementation of transportation systems. The case studies have been chosen based on the similarity towards the above-illustrated urban model structure. The case studies represent the practical implementation of the urban models (cf.

3.2), as assessed by the researcher. The case studies will illustrate possible delineation of the urban models to determine possible guidelines for practical implementation.

The nine international and single local case studies which will be applied within this chapter are from several cities situated in different countries. The classifications of urban models and case studies applied are based on previous studies and research. The classification of urban models and case studies are as follows:

- Garden city model: Canberra, Australia;
- Concentric ring model: Chicago, USA;
- Multi-nuclei model: LA, USA;
- Urban structure model: Erbil, Kurdistan;
- Urban realms model: SF, USA;
- 21st-century model Lagos, Nigeria;
- Urban fabrics model: Barcelona, Spain;
- Marchetti Constant model: Rome, Italy;
- Agricultural land-use model: Antigo, USA; and
- The apartheid city model: CPT, South Africa.

A comparative analysis will be done between the above models which will illustrate potential guidelines to strengthen the urban models (cf. 3.2) or determine more sustainable guidelines towards each specific model. The case studies will be analysed using three components, namely:

- Land use of the city;
- Transportation networks (cf. 4.2) implemented within the city; and
- Spatial policy implementation within the city.

This will illustrate the foundation of each urban model's (cf. 3.2) implementation, strengths and weaknesses. It may also provide various methods or solutions regarding the implementation of transportation systems and functionality. The below case study analysis has been illustrated through previous studies and observations:

6.2 CANBERRA (THE GARDEN CITY MODEL)

Canberra's urban structure is an illustration of the garden city model (cf. 3.2.1). The garden city model has been evaluated by the researcher based on Howard's concept and principles of design but may have minor differences due to the terrain and topography of the area. Canberra has deviated slightly from the original garden city model (Gataric et al., 2019:40) illustrated by Howard but still makes use of all its principles which would, therefore, classify it as a garden city (Cullinan, 2019:18-19). Canberra had been designed through the Griffons urban structure model (see Annexure A for the analysis) (Gordon, 2010:4-5).

The subsections below will investigate Canberra's relevance to this study in terms of the urban model's implementation. The garden city (cf. 3.2.1) has demonstrated sustainably, connectivity of land uses and efficiency of transportation systems using a radial street pattern (Phillips, 1970:50) as illustrated in Figure 3-2 (Gordon, 2011:148).

The urban structure of the city is not completely identical to the urban model (cf. 3.2) previously mentioned; however, the principles, layout and connectivity are similar. The analysis below shows Canberra's garden city adjustments in becoming the Griffin model (Nabil, 2021:4-6). The models may vary slightly but still retain the same functionality and principles. The below analysis identifies the similarities between the model and its comparative urban model through a detailed description of each component within the city structure (Gordon, 2011:148-150).

6.2.1 Land use

Canberra is known as Australia's capital city (Kyriakidou, et al, 2015: 260). The city has a wide variety of land uses that support its multiple roles as a centre of politics (cf. 5.7.4), government, and culture (Gordon, 2011:151). The types of land uses within the city can be described (Gataric et al., 2019:34-36) as i) residential regions; ii) commercial and business districts; iii) government and administrative precincts; iv) educational and research institutions; v) recreational and open spaces, and vi) transportation infrastructure (cf. 5.5.5). This can be identified from the previous urban models illustrated in Howard's garden city urban model (cf. 3.2.1). The city's transportation systems are essential for connecting the following land uses as a brief illustration (Walker & Stevens, 2008:8-15; Mensah *et al.*, 2015:205-213; Vernet & Coste, 2017:47-57):

- **Residential land use:** Canberra has developed several residential areas to give the residing community a variety of housing options. These include gated communities, apartment buildings, and suburban neighbourhoods. The residential areas are connected through a network of roads, public transportation and cycling/walking pathways. The residential areas are connected to other land uses and also have access to business districts (CBD), educational institutions and recreational facilities. This connectivity is made easier through the various transportation options;
- **Business and commercial land use**: The commercial and business areas are situated in the city centre, which is illustrated in the garden city model (cf. 3.2.1). The commercial area has various land uses and is open to multiple outlets, workplaces, restaurants and entertainment. The business land use is easily accessible to workers, customers, and tourists. This is due to an efficiently planned transportation system comprised of road networks and public transportation systems, for example, BRT and LRT;

- **Industrial land use:** Canberra has implemented a transitional area near the CBD district for manufacturing. The industrial area is well shielded by green areas, which absorb most of the GHGs released from the factories. The area is located near the CBD to supply the local businesses efficiently with the implemented transportation system to supply the demand of the community (cf. 4.4.1);
- **Educational institution land use:** Canberra has various institutions and research centres, which include the Australian National University (ANU), the University of Canberra (UC) and other high schools and colleges. The transportation systems offer various options for mobility, which include BRT, LRT and designated bicycle and pedestrian pathways. This increases active transportation and is a component of sustainable transportation systems. The various institutions are connected to residential neighbourhoods and other land uses for efficient mobility; and
- **Recreational and open spaces land use:** Canberra is considered to be a garden city (Gataric *et al.*, 2019:34-41), in which one of the most significant principles is green open spaces. The city has multiple parks, nature preserves and recreational places. The green areas that are well-known in the urban structure are Mount Ainslie, Lake Burley Griffin, and Commonwealth Park. Roads, walking trails, and cycling lanes connect to these areas. The city promotes sustainable transportation as well as active transportation. The sustainable transportation systems (walkways and bicycle lanes) are connected to all land uses to increase access. The use of other transportation options including buses and shared bicycles are also available.

The city's transportation systems are essential for connecting these various land uses and maintaining connections. The residents, workers, and visitors all utilise the efficient transportation systems to move between land uses. The urban SS of Canberra is similar in design to Ebenezer's garden city (cf. 3.2.1). The design shown in the Figure 6-2 can be compared to the urban structure in Chapter 3 (Nabila, 2021:3).

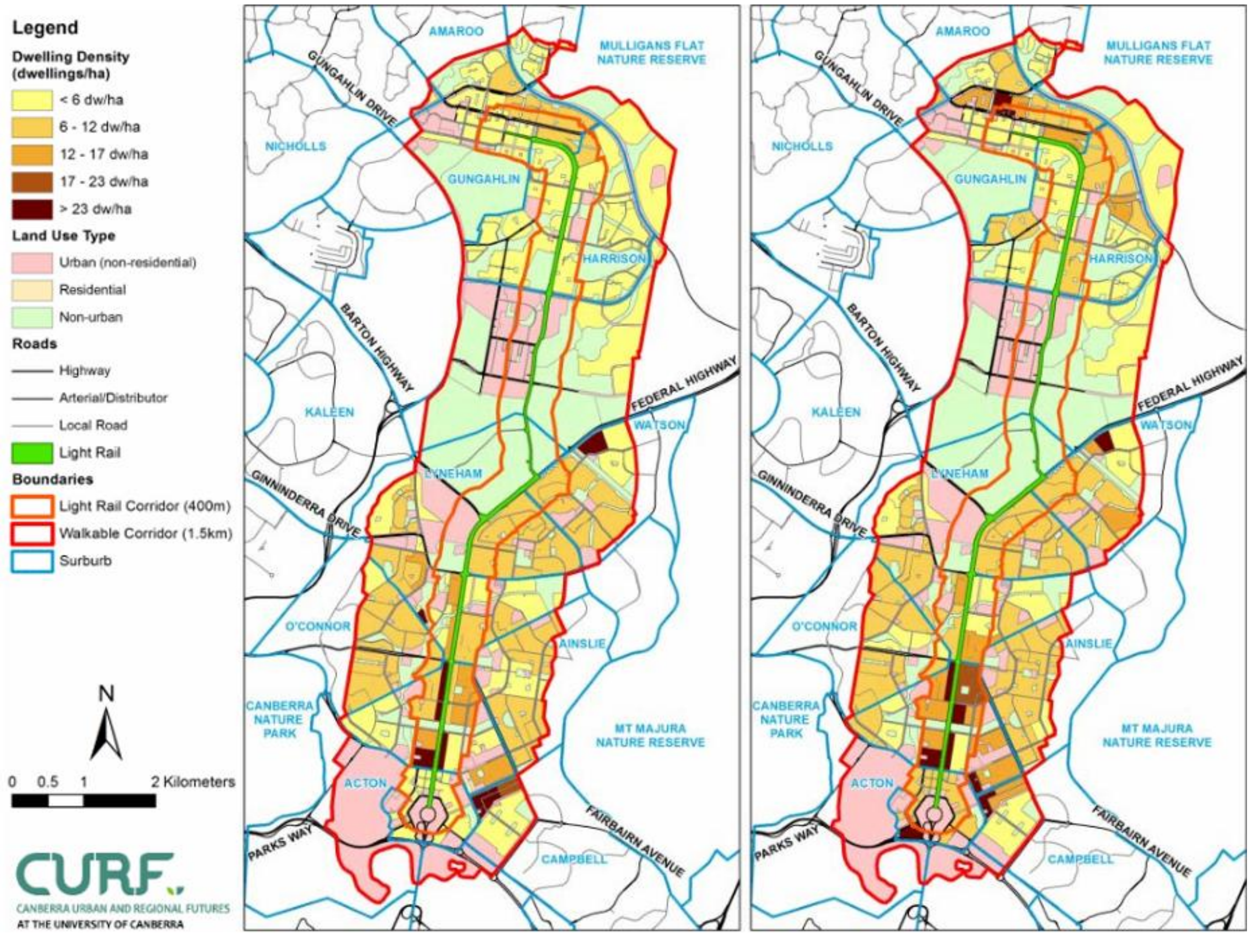


Figure 6 - 2 Canberra city centre

Source: Flannery et al. (2015:59)

The above illustrated urban model shows a similarity to the garden city urban model (cf. 3.2.1). The incorporation of green areas and the promotion of pedestrian infrastructure shows the principles of a garden city, which is based on sustainable development. The urban structure also shows the incorporation of multiple modes of transportation systems (Gordon, 2010:2-3). The layout demonstrates the conservation of the environmental areas, as well as heritage sites. The mobility radiates outwards from the city centre and considers the movement of pedestrians and other transportation systems which interlink with one another to create a multimodal system. The use of public transportation systems has been included and illustrates LRTs, motor-vehicle lanes and BRTs. The urban structure demonstrates a clear understanding towards the implementation of transportation, as well as future development areas to improve efficiency throughout the urban structure (Gordon, 2010:1-19; Vernet & Coste, 2017:56).

6.2.2 Transportation networks

Canberra is considered to have multiple transportation systems implemented within the urban structure, as per its transportation network (cf. 4.2). This includes implementation strategies such as TODs (cf. 5.8). This subsection illustrates a brief analysis of the types of transportation systems used within a developed country, as well as a capital city (Gordon, 2010:3-5). Canberra illustrates a well-structured transportation system, with the incorporation of public transportation systems. The Figure 6-3 below illustrates the road network within Canberra.

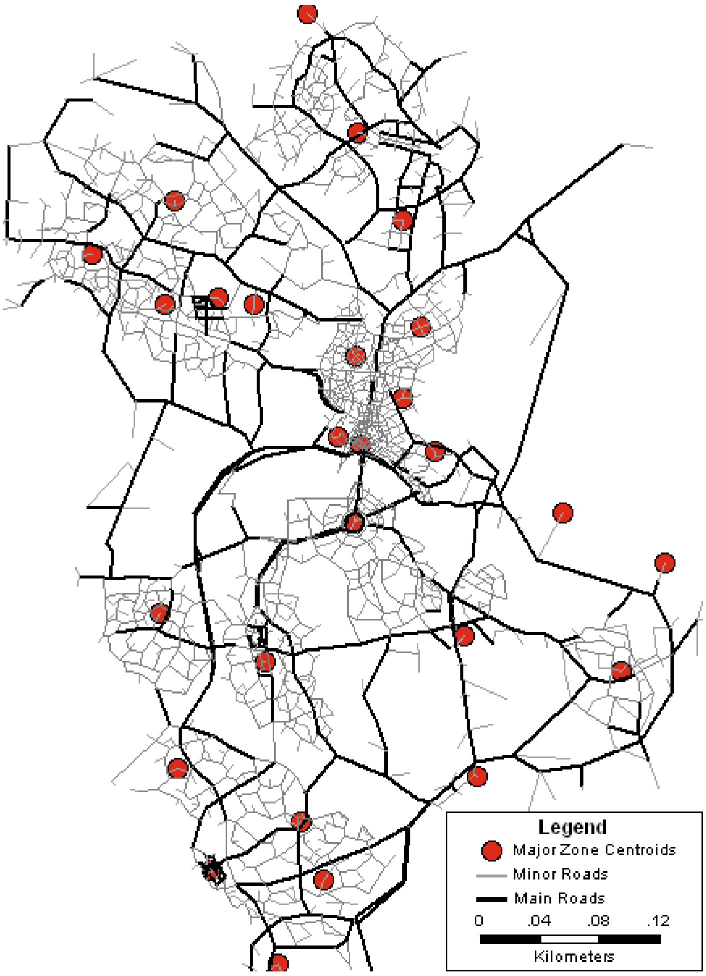


Figure 6 - 3 Canberra Road and zones

Source: Cheung & Blac (2005:3776)

The well-designed transportation infrastructure (cf. 5.5.5) in Canberra, Australia's capital, includes several different means of transit. Canberra's transportation networks are discussed in the subsections below (Cheung & Black, 2005:3780- 3788).

- **Roads and highways transportation system**: Canberra has implemented a comprehensive road system that connects the various land uses of the city. The city has precisely planned a grid of roads to allow access to different transportation modes as well as SOVs (Cheung & Black, 2005:3780- 3784). The city illustrates the use of various roads and road classifications to connect to outward regions (Cheung & Black, 2005:3784), which can be classified as two types of roads, namely minor and major roads;

- **Cycling infrastructure transportation system:** With a vast network of dedicated cycle routes, shared trails, and on-road cycle lanes, Canberra is renowned for its cycling infrastructure. The city has worked to promote cycling as a means of transportation, and both locals and visitors have access to several bike-sharing programs; and
- **Walking paths:** There is a vast network of walking paths and trails around Canberra, especially in the vicinity of parks, lakes, and nature reserves. These routes make it simple for pedestrians to move around the city and take in the scenery. The pedestrian infrastructure provides high-quality walking environments in and around the city. The walkways allow for accessibility to urban intensification areas, such as town, group, and local centres as well as institutional areas. Canberra’s future transportation network promotes liveable neighbourhoods. To guide the city's sustainable transportation, it prioritises walking and bicycling (cf. 4.4.3) in locations backed by the movement and place framework, this effort will also examine global best practices in road intersection design.

The implementation of public transportation services in the capital city of Canberra is a priority as it illustrates the need to improve sustainability and increase the efficiency of transportation modes. The significance of public transportation is linked to the strategy illustrated in the 10-millennium goals to decrease global warming and climate change. This strategy is used to restrict or limit the burning of fossil fuels to decrease emissions. The emissions occur through the use of motor vehicles. The increasing SOVs indicate significant amounts of emissions being released into the atmosphere. The use of large carrier motor vehicles (buses, multiple carrier vehicles) seems to be more viable and sustainable, as well as upholding a certain level of efficiency. This allows individuals to move to areas nearby, with minimal cost. Canberra has implemented an interesting approach to public transportation in hopes of improving the global warming situation. The use of public buses (and BRT) makes up the majority of Canberra’s public transit system. The government is considered responsible for maintaining and upholding the city's public transportation. Canberra's public transportation's standout characteristics include (Gordon, 2010:1-19; Flannery et al., 2015:36-45; ACT Government, 2020:7-27):

- Public buses;
- LRT;
- Pedestrian walkways; and
- BRT.

The majority of the city and its surrounding suburbs are served by Canberra's BRT network. The city has implemented a versatile multimodal system. The use of LRT is also in effect between the north of the city towards the city centre. The LRT transportation system (Metro) is used to transport individuals throughout the urban structure (Cheung & Black, 2005:3773-3776; Gordon, 2010:1-19).

The pedestrian infrastructure has been included in various areas of the city structure. This includes park-and-ride facilities, promoting active transportation for commuters to park their cars and use the facilities. The facilities are necessary for the resided community to avoid the congestion in the city centre (Gordon, 2010:3-4). Canberra provides multiple facilities for pedestrians to walk and cycle to various destinations. The facilities have been implemented throughout Canberra, but due to the type of transportation, the distance of travel is limited. The cost of travel is minimal and increases well-being due to its health benefits (cf. 4.4.3). The transportation infrastructure (cf. 5.5.5) allows for multiple users at one time (LRT, BRT, and walkways) and releases minimal emissions due to the physical aspect. This allows individuals to commute to nearby destinations with minimal damage to the environment (cf. 5.7.2) whilst increasing health benefits (cf. 5.4.5).

6.2.4 Spatial policy

Canberra has several policies governing land use and TP, however, but the main focus of the study is to improve the efficiency and connectivity of land use and transportation modes (cf. 5.7.1). This subsection will discuss the policies implemented to improve transportation efficiency, as well as the use of land within the SS. To produce a more effective and sustainable urban environment, this strategy focuses on combining land use development with TP. The policies discussed below illustrate the implementation of both transportation policies as well as land use policies.

6.2.4.1 Spatial plan

Canberra illustrates within the spatial plan the city's strategy for land use, future development plans and transportation systems, which emphasise the preservation of green spaces, diverse housing options, and sustainable development. To lessen urban sprawl, the spatial plan highlights the significance of compact city planning and urban infill (ACT Government, 2018).

6.2.4.2 Urban Open Space Policy

The goal of the Urban Open Space Policy is to guarantee public access to parks and recreational spaces, thereby promoting biodiversity and community well-being. It places a high priority on creating and maintaining green spaces in metropolitan areas (ACT Government, 2020). The policy is used to preserve green space within the urban structure.

6.2.4.3 Housing Choices Policy

The Housing Choices Policy is based on increasing the range of housing types, which includes affordable housing and mixed-use buildings. The policy has been implemented to accommodate an expanding population. The policy's main objective is to introduce a variety of housing options for the resided community (ACT Government, 2021).

6.2.4.4 Integrated Transportation Strategy

The objective of the Integrated Transportation Strategy is to encourage environmentally friendly means of transport such as walking, bicycling, and public transport. Its goals are to lessen dependency on automobiles and increase accessibility in the city as a whole (ACT Government, 2019). This will include the use of LRT and BRT transportation systems (Flannery et al., 2015:64-65).

6.2.4.5 Active travel strategy

The purpose of an active travel strategy is to promote sustainable infrastructure. By promoting bicycle lanes and pedestrian walkways, the strategy ultimately promotes bicycling and walking. The goal is to make NMT environments more accessible and safer (Flannery et al., 2015:43; ACT Government, 2020).

6.2.4.6 Public Transport Expansion Plan

The plan seeks to increase connectivity and lessen traffic. The additional public transportation systems implemented in the urban structure will increase mobility options, such as the development of public transport options, for example, LRT and BRT. The objective of this strategy is to provide the residing community with access to a dependable and effective public transport system (ACT Government, 2022).

An ITLUP policy (cf. 4.4.5) has been implemented to improve the sustainability of the modes of transportation as well as the efficiency of mobility. By taking transportation infrastructure (cf. 5.5.5) and services into account in conjunction with decisions about where to build residential areas, travel times can be cut whilst encouraging the use of walking, cycling, and public transportation (cf. 4.4.3). This involves TOD as a strategy for promoting dense, mixed-use development around transit hubs (Vernet & Coste, 2017:50-53). The goal of TOD (cf. 5.8) is to encourage higher-density, walkable communities with a mix of residential, commercial, and recreational spaces close to transit stations to decrease reliance on personal vehicles, boost transit use, and develop lively, open communities. The TOD strategy has proven to be an efficient transportation implementation of transportation services and sustainability within spatial planning as illustrated in the previous chapter (cf. 5.8). This illustrates that the strategy can be implemented within the planning field and can increase sustainability of the urban structure and its land uses (Australian Capital Territory [ACT], 2014:9-22).

The policy planning process and strategic measures are used to improve sustainability and economic benefit (cf. 4.4.4). Canberra's city plan has been implemented on a draft map, to align implementation with political policies governing the future development strategy.

6.3 CHICAGO (THE CONCENTRIC RING MODEL)

Chicago is situated in the developed country of the USA (Kyriakidou, et al, 2015: 260). The similarities of this city can be identified within the concentric ring model (cf. 3.2.2), which illustrates the city's design and its current layout. The city illustrates the current connectivity between land uses and Burgess principles regarding the concentric model (Adhvaryu, 2010: 125). Chicago has been illustrated in Annexure B for analysis.

Chicago exemplifies the complex functioning between transportation networks (cf. 4.2) and land development. The large metropolitan centre has created an intricate system of public transportation, railroads, and highways that influence how it is spatially implemented. The transportation infrastructure (cf. 5.5.5) of the city has traditionally shaped the patterns of land use, promoting the growth of both residential and commercial areas. To encourage sustainable development, Chicago's zoning regulations and urban planning initiatives integrate transportation and land use (cf. 5.6). In this framework, the Chicago Transit Authority (CTA) is essential because it offers a wide range of bus and rail services that link different neighbourhoods and lessen dependency on personal automobiles (CTA, 2020). The accessibility of urban areas can expand at larger densities, which leads to more effective urban structures. Chicago has been seen as a significant hub in the national logistics network, its transport networks (cf. 4.2) are essential for both freight movement and commuting (Dunn, 2018:101-115). The relationship between transportation infrastructure (cf. 5.5.5) and land use regulations has a big impact on the city's social fairness, economic dynamism, and sustainability.

6.3.1 Land use

Chicago can be classified under a similar design to the concentric ring model (cf. 3.2.2), where the design of the urban model (cf. 3.2) has been analysed. The land use of Chicago is a combination of residential, commercial, industrial, and public spaces that dominate the city's land use pattern. Following are some essential specifics for each category (Campbell, 1968:103-106; Mills & Simmons, 2001:275-298; Adhvaryu, 2010: 125-126):

- **Residential land use**: Chicago has several different kinds of residential land uses, from single-family houses to high-rise condominiums. The city is made up of thriving neighbourhoods with a variety of housing options and demographics. This has been identified in the previous case study (cf. 6.2);

- **Commercial and business land use (CBD):** The city’s core illustrates the CBD and serves as the city's main business/commercial hub. There are various types of business land uses including office buildings, shopping malls, and cultural organisations. There are numerous commercial areas scattered across the city's neighbourhoods, providing the residing community with goods and services (cf. 6.2);
- **Industrial land use:** The city has several industrial zones located on or near its outskirts. The industrial land is used for factories and industries to manufacture and use as warehouses and distribution centres. This is crucial for the supply and demand of goods and services, which all impact the city’s economic development (cf. 6.2); and
- **Recreational land use:** There are several public places in Chicago, which include parks, leisure areas and waterfront attractions. The areas are known as Grant Park, Millennium Park, and the lakefront walk – they promote active transportation systems (walkability) (cf. 6.2).

The below Figure 6-4 illustrates Chicago’s land use zoning to determine the placement and implementation of land. The city, as mentioned, had been based on the concentric ring model, which clearly illustrates the theoretical implementation of land use.

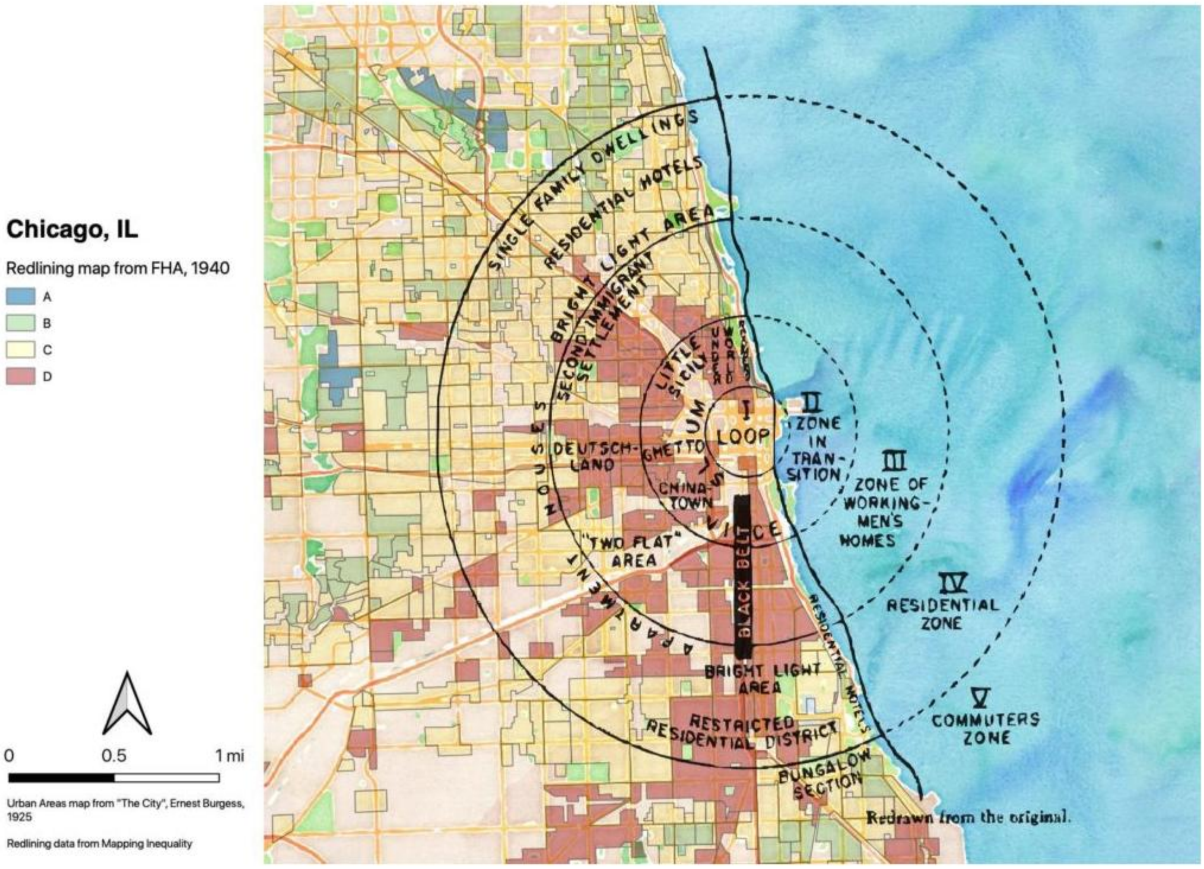


Figure 6 - 4 Chicago land use zoning map

Source: Tom (2020)

Figure 6-4 was obtained by an online system, which provides free access to city data. This is one of Chicago's many innovations towards city planning and monitoring. This illustrates the simplicity it takes to innovate change within the spatial planning spectrum. This also demonstrates that Chicago has a more technologically advanced framework than those within developing countries. The land use of Chicago is connected to a grid-like transportation system which connects all land uses. The city shares the common attributes and traits of an urban structure and is similar to the above case study (cf. 6.2). The differentiation of the city is seen within the efficiency of mobility and connectivity of land use (see Figure 6-4).

6.3.2 Transportation networks

Chicago has implemented various transport networks (cf. 4.2) and systems to enable effective mobility throughout the city. The transportation systems in Chicago are based on TOD (cf. 5.8) (City of Chicago, 2017:36-66). The transportation infrastructure (cf. 5.5.5) ranges from various transportation systems which work in conjunction with one another to create a multimodal transportation system, as discussed in the subsections below (Campbell, 1968:109-115; Du *et al.*, 2015: 1005-1007; City of Chicago, 2017:68-70).

- Road infrastructure: Chicago has incorporated road infrastructure and is centred around an extensive network (cf. 4.1) of arterial streets, expressways and interstates. The design accommodates both resided community and regional traffic. The city's layout contains a grid system of streets, which provides accessibility from various points to the urban core (CBD). To improve traffic flow (cf. 4.3) and navigation, various transportation systems were implemented, and technological advancements were made. Chicago encounters transportation challenges (cf. 5.7), for example, traffic congestion (cf. 5.7.7), ageing infrastructure, and heavy freight traffic. The city's initiatives focus on improving road conditions, reducing congestion, and incorporating more sustainable, multimodal transportation options.

Chicago has an efficient transportation infrastructure (cf. 5.5.5), including a network of main highways and arterial roads. The city has put measures into place to control traffic, increase safety, and improve the effectiveness of transit. The transportation systems discussed below illustrate the mobility systems implemented within Chicago.

- **Pedestrian infrastructure:** Chicago has actively promoted cycling as a form of sustainable transportation. To increase cycling safety and accessibility, the city has expanded its network with bicycle lanes. The city has also adopted bicycle-sharing programmes with rules and regulations to improve mobility and increase safety (Chicago Department of Transportation [CDOT], 2020:33-35). The pedestrian transportation infrastructure in Chicago is facilitated by multiple networks of sidewalks, crosswalks, and dedicated pedestrian paths towards the CBD area. The city’s street grid layout, combined with its extensive public transit system, encourages walking as a common mode of transportation. Chicago also features other pedestrian infrastructure, for example, the Lakefront Trail and the Riverwalk, which offer scenic routes along Lake Michigan or the Chicago River. To improve pedestrian safety and accessibility, the city plans to include street-sustainable strategies to create traffic-calming measures. Chicago supports walkability and helps to reduce car dependency (cf. 5.7.3). The city also offers cycling lanes with bicycle infrastructure, as in the previous case study (cf. 6.2);

- **LRT-Metra:** The Metra is an LRT that provides efficient public transportation to the Chicago metropolitan area. The LRT transportation system connects the CBD with its residential areas and neighbouring regions. The LRT transportation system plays a critical role in reducing traffic congestion by offering reliable, high-capacity transportation and making it an essential part of the region's transit infrastructure. The Metra's integration with other transit options, for example, BRT, enhances regional connectivity through the use of hubs. This will also improve multimodal transportation systems;
- **Pace Bus (BRT):** The Pace Bus is known as a suburban bus division, which serves the Chicago metropolitan area (CBD). It maintains a high operational rate and uses over 200 bus routes, which primarily connect residential communities with key transit hubs, Metra stations, and the transportation network (cf. 4.1). The Pace Bus offers various services, including fixed routes, express buses, and paratransit for riders with disabilities. This public transportation system is known for its affordable fares and wide coverage over the urban structure of Chicago. The Pace Bus also improves regional mobility, while reducing car dependency in areas with no LRT service. The Pace Bus can contribute to the overall efficiency of Chicago's transportation system. This is considered to be a specific type of BRT system;
- **Divvy bicycles**: The Divvy rental bicycle transportation system follows sustainable transportation methods, as well as improves active transport. This bike-sharing system offers an accessible and eco-friendly mode of transportation throughout the city and some nearby suburbs. The transportation is under the authority and maintained by the CDOT. The Divvy bicycle system provides thousands of bicycles and e-bicycles at docking stations located across the city. The users can rent bicycles through a mobile app or Divvy key fob for short trips or commuting, which illustrates technological advancements within transportation systems. The system promotes sustainable urban mobility, reduces traffic congestion, and integrates with public transportation options like BRT and LRT. This transportation system supports Chicago's broader transportation network. There have

been recent expansions and electric bicycle options to further enhance its accessibility and convenience; and

- **Water taxis:** The water taxi transportation system is implemented within Chicago and offers an alternative mode of transportation. The system offers water transportation over the Chicago River and Lake Michigan. This could be highly scenic and would attract tourists. The water taxi is owned by a private company and is not governed by Chicago. The water taxi is used for tourist attractions as mentioned for shoreline sightseeing. The water taxis provide services for both local commuters and tourists with a unique commuting option. These services help alleviate road traffic while offering a pleasant travel experience through the CBD of the city's downtown metropolitan area. This also enhances connectivity between key attractions and neighbourhoods.

Chicago provides a selection of quick and effective ways to navigate around the city. This allows for access to different transportation systems for the resided community. The transportation systems illustrated within Chicago show the radial network from the centre of the urban structure. The city's transportation services serve as sustainable transportation systems, as well as promote pedestrian walkways and cyclists. The city has enhanced transportation systems through technology, as mentioned with the Divvy bicycle services. This is all governed through a series of policies, governing land use and transport. The Figure 6-5 below illustrates the applied transportation systems for Chicago.

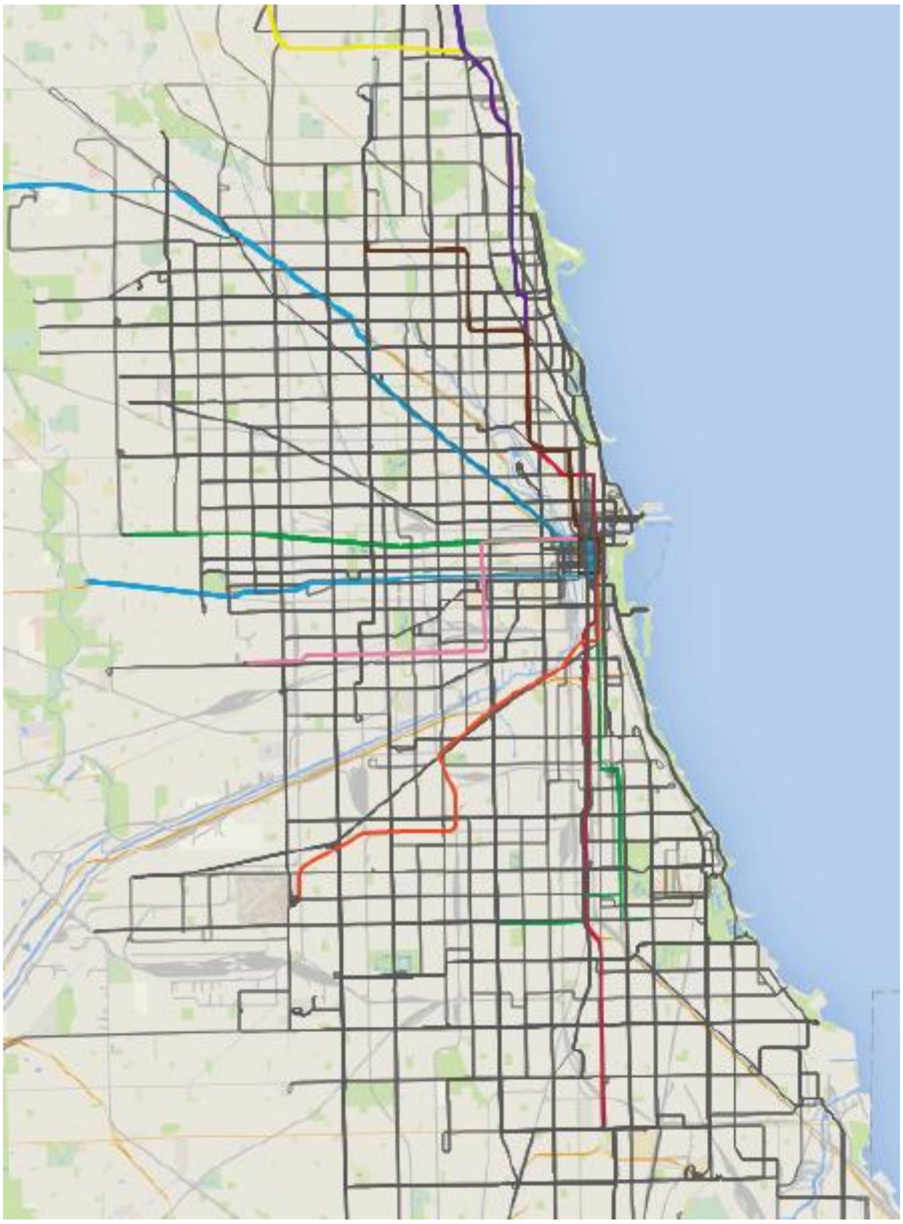


Figure 6 - 5 The implemented transportation systems within Chicago

Source: Verbas & Mahmassani (2015:41)

Figure 6-5 depicts the applied transportation systems within Chicago. The spatial implementation shows a radial transportation network. The transportation system in the above Figure 6-5 also shows:

- A total of eight rail routes;
- The rail pattern;
- The bus pattern; and
- Vehicle trips

6.3.3 Spatial policy

Chicago is governed by multiple policies which regulate the state, city, and local laws. These also govern land use and transportation policy. The policies discussed in the next subsections are an illustration of several of the implemented policies.

6.3.3.1 Chicago Zoning Ordinance

Chicago is designated into various land use zones, which can be illustrated in most countries around the world. The city has various zoning districts; the Chicago Zoning Ordinance controls land use and development (City of Chicago, 2019). The permitted land uses, building setbacks, density, and height restrictions vary according to each district. This can be described as legislation that governs the processes of different land zones and their uses (City of Chicago, 2019, 45).

6.3.3.2 Chicago Transit Authority (CTA)

The CTA is considered to be the governing authority for all public transportation networks (cf. 4.2) within the urban structure. Public transportation uses routes, schedules, rates, accessibility, and safety that are all subject to CTA policy (CTA, 2021). This is highly significant due to the impact that the policy can make on the resided community. If the transit fee were to be too expensive, the community would choose other options for transportation. The maintenance of the infrastructure of this public transportation system can improve safety for passengers, as well as promote the longevity of this public transportation system (CTA, 2022:13-16).

6.3.3.3 Pedestrian and bicycle plans

The city has created pedestrian and bicycle infrastructure, which is governed by the presided policy to promote walking and cycling as a practical and secure mode of transportation (cf. 4.4.3). The type of infrastructure includes enhancing walkways, establishing bicycle lanes, and implementing traffic calming strategies (CDOT, 2020:33-35)

6.3.3.4 Chicago Complete Streets Policy

The Complete Streets Policy had been implemented to develop streets for all transportation systems, which includes drivers, cyclists, pedestrians, and passengers of public transportation. It ensures safety, accessibility and connectivity for all types of transportation. This is considered to support the spatial design and implementation of streets (CDOT, 2020:21-23).

6.3.3.5 Transportation demand management (TDM) ordinances

The transportation demand management (TDM) ordinances govern the implementation of strategies to lower SOV traffic in specific developments, for example, commercial buildings (cf.

4.4.1). This can involve developing bicycle parking spaces, offering transportation passes and encouraging carpooling.

6.3.3.6 Chicago Department of Transportation (CDOT) Policies

The policy (CDOT) enforces regulations for the city's traffic control, infrastructure growth and TP. The focus is to enhance sustainability, mobility and safety across all forms of transportation (CDOT, 2021:14-16; CDOT, 2022:9-11). Chicago is considered to have integrated and diverse transportation modes. This includes LRT, Pace Buses (BRT), Divvy bicycles (rental bicycles), pedestrian infrastructure and water taxis. This intricate transportation system plays a crucial role in supporting the city's land use and urban development. The implemented, efficient transportation systems also enhance accessibility to various neighbourhoods, commercial hubs, and recreational areas, by promoting balanced growth and reducing traffic congestion. The array of transportation options with land use planning allows Chicago to enhance greater connectivity and supports sustainable urban living. This ensures the city remains navigable and accessible for its residents and visitors through technological advancements.

6.4 LOS ANGELES (MULTI-NUCLEI MODEL)

A city with multiple nodes serving as regional hubs for commercial or residential activity within a single larger city is known as a multi-nuclei model (cf. 3.2.3). LA is a classic example of this kind of metropolis with its numerous distinctive neighbourhoods. The term ‘multi-nuclei model’ refers to the creation of nodes or nuclei outside of the CBD. The goal was to create a more intricate but functional urban structure. LA has been illustrated in Annexure C for analysis.

The vast metropolitan geography of LA greatly affects the city's transportation and land use patterns (cf. 5.6). Due to the city's historical growth patterns that have placed a high priority on automotive mobility, suburban expansion has been facilitated by a network of motorways and highways (Glaeser & Kahn, 2004:2484-2486). This car-centric mindset has influenced land use, encouraging residential neighbourhoods with low densities while aggravating traffic congestion (cf. 5.7.7) and environmental problems (cf. 5.7.2). There has been a change in recent years towards more integrated TP, with a focus on active transportation options such as walking and cycling as well as public transportation. The Los Angeles County Metropolitan Transportation Authority (Metro) has begun initiatives to encourage TOD and increase rail and bus services (cf. 5.8).

The city seeks to promote higher-density neighbourhoods and business districts close to transport hubs (Metro, 2020:13-15). This change reflects an increasing understanding of the need to improve accessibility and connectivity throughout the area, addressing issues of social justice and environmental sustainability (Wheeler, 2013:111-113). Land use planning and transportation regulations must continue to be integrated to create a more sustainable and liveable urban environment as LA develops. LA is located within the developed country of USA (Kyriakidou, et al, 2015: 260).

6.4.1 Land use

The land use zones in LA can be described as residential, commercial/CBD, industrial, and recreational. The previous urban models (cf. 3.2) have illustrated similar if not the same land use zones (cf. 6.2, 6.3), which determine the type of land use based on the policy regulations governed by the local authority. As mentioned, LA can be described as the multi-nuclei model (cf. 3.2.3). The urban model illustrates similar traits based on the comparison between Annexure C and the urban model (cf. 3.2.3) (Waugh, 2002:420-424). The assumption is that the urban model has been derived from Burgess and Hoyt's model (cf. 3.2.2) and the applied models had a completely different function. The function of the multi-nuclei model was to accommodate large amounts of individuals from various CBD areas and business districts.

The different land uses were classified into land use zones, which are governed by the local authority. Each land use zone has subcategories of various land uses; these zones assist in organising and planning the spatial layout of a city. LA is separated into several unique land use zones that are each geographically organised in a certain category (Chen, 2009:49-51). The following is a list of some of the major land use zones in LA and how they are spatially organised:

- **Residential land use:** The residential areas are comprised of the community residing within the area, which occupy single-family homes, apartments, and condominiums. The residential land use zones are primarily used for housing, as stipulated in the previous case studies. They are dispersed all around the city (multi-nuclei model), in both rural and urban areas;
- **Business land use:** The business zone is considered to be the retail businesses and other small businesses distributing a product or a service. This allows for office use, retail stores and other small businesses providing a service. This land use zone can be located in the centre of the urban model – in this case, the city has various CBD districts to increase the business and economic benefit of the area. The multi-nuclei model uses several CBD areas to obtain a higher economic (cf. 5.4.1) benefit through assumption;
- **Commercial land use:** The commercial areas are considered to be reserved for business and retail operations. They feature commercial avenues with a variety of businesses, office buildings and shopping malls. The commercial zones are frequently concentrated along main roads and highways as well as activity corridors. This would be used for fuelling stations and other business uses which do not allow manufacturing;

- **Industrial land use:** Manufacturing, warehousing and other industrial operations would take place in this land use zone. The type of manufacturing would be determined if the land use zone would be considered. There are three different types of manufacturing, which are light, medium or heavy industrial areas. The area is known as the transitional area (cf. 3.2.3) (Waugh, 2002:423) and is often found in more rural areas or close to major transit nodes, such as railroads and ports. In LA, industrial districts are frequently concentrated in locations near South LA and the San Fernando Valley. The area also attracts the poor-income class for accommodation in affordable housing; and
- **Parks/open spaces:** The last land use zone refers to parks, open spaces and recreational amenities. The city promotes environmental exposure, active transportation systems and sustainable transportation systems. The land use zone offers outdoor recreation and green spaces. The recreational areas are situated around LA and they frequently contain both bigger parks such as Griffith Park and smaller neighbourhood parks.

The previous case studies illustrate a similar set of land uses. The layout of land uses differs based on the urban structure and the previously illustrated urban model (cf. 3.2.3). The below land use map of LA depicts the implementation principles of the multi-nuclei model.

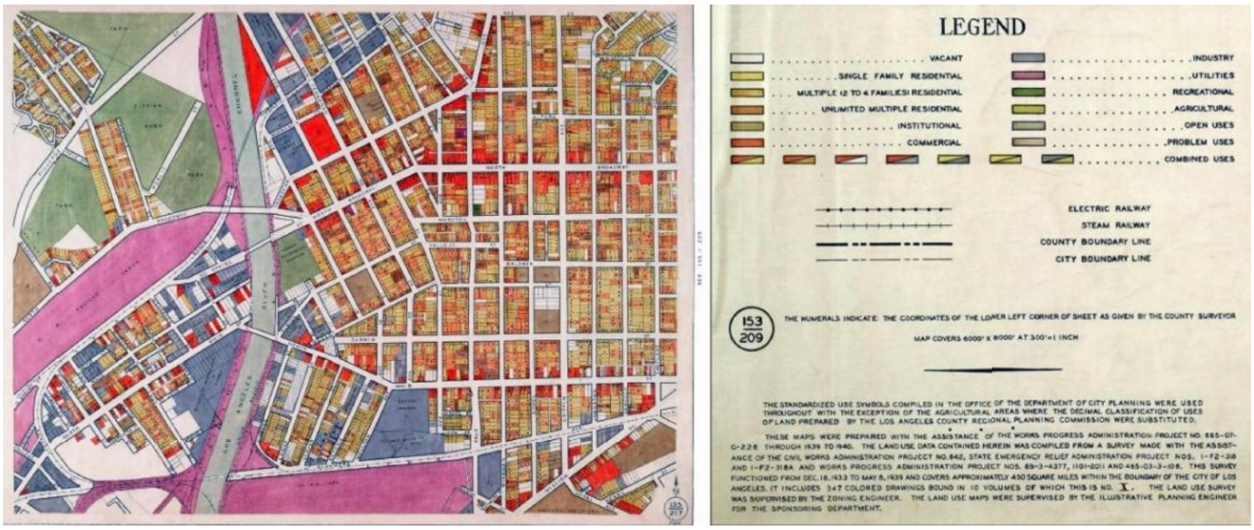


Figure 6 - 6 Land use in CoLA

Source: Pissourios (2023)

The above Figure 6-6 shows the multi-nuclei forming within a mixed land-use area. The nuclei are visible through the red colour coding used by the city's zoning regulations policy. The above land use zoning (cf. 3.2.3) is generic zoning - which is shared by various urban structures. LA is not segregated from these significant components and also functions in synergy with one another.

6.4.2 Transportation networks

The transportation system in LA is extensive and includes a range of modes, for example, public transportation, roads, and active transportation choices. The city is well known for its extensive highway network, which allows for more accessibility for the transportation of goods and services (Glaeser & Kahn, 2004:2483-2486). The car dependency perspective has created transportation challenges (cf. 5.7.2) within LA due to traffic problems and environmental issues (cf. 5.7.2). LA implemented a large, sophisticated network (cf. 4.1) of multimodal transportation systems that consist of many different types of transit in the hopes of increasing efficiency:

- **Road infrastructure:** LA has implemented large road networks for various roadways. The major arterial road is used to travel between regions, as well as travel at large volumes in automobiles. These are known as interstates, and there are other vital transportation arterials linking various areas of the city/region;
- **Pedestrian transport:** LA has incorporated pedestrian infrastructure, for example, walkways and bicycle lanes. This promotes sustainable transportation strategies as well as active transportation for the well-being of the resided community; and
- **Bicycle-sharing:** As mentioned in previous case studies, this refers to a bicycle-sharing programme within LA. This enables communities and visitors to hire bicycles for short-distance travel. This system offers an extra mode of transportation and encourages active mobility, especially for local commutes of a short distance (cf. 6.2, 6.3).

LA will continue to grow while tackling urban issues and improving transportation systems within the multimodal transportation network (cf. 4.1). The city's overall spatial organisation is characterised by a variety of land uses, which include residential, commercial, industrial, and recreational zones that are connected by a sophisticated network of transit systems. (Rosenbloom, 2020:44-46). Several public transport options in LA provide travel between various land uses. The public transportation systems described below demonstrate the implementation of multimodal transportation systems (Katona & Juhasz, 2020:25-32):

- **Metro rail transportation (LRT):** LA has implemented the metro rail system, which operates on both light rail and subway lines. The expo line illustrates the light rail lines, which operate within the urban structure. The LRT system links different land uses. The other rail line connects to the CBD (downtown) LA with various areas of the city;
- **Metro bus (BRT):** In LA, the metro bus system has been implemented and connects different land use zones, for example, residential areas, commercial districts, and CBDs. These transportation lines are an essential means of transit. The entire city is served by the bus network, which offers community services and is considered efficient;

- **The DASH system:** The DASH system which stands for "Downtown Area Short Hop," is a network of shuttle services created to ease local transit in downtown LA. DASH buses provide a practical and cost-effective way to go around the downtown region by connecting several sites of interest and nearby neighbourhoods (Hansen, 2020: 38-40); and
- **Regional commuter rail:** The Metrolink commuter rail system provides services to LA. Commuters can travel between residential areas and downtown employment centres thanks to Metrolink's connections between the city and its neighbouring suburbs and cities. For people who live outside of the city, the commuter rail system offers an alternative to driving and helps to reduce traffic congestion.

The public transit networks in LA connect mobility between various land uses. The implemented transportation systems give locals and visitors options for mobility. The public transportation systems allow access between neighbourhoods, business districts, the city centre (CBD) and other important locations. This helps to reduce reliance on SOVs and ease traffic congestion. The city's initiatives are to continuously expand the Metro rail network as mentioned above. The city offers BRT transportation systems with dedicated bus lanes to better integrate these systems efficiently and increase connectivity. The Figure 6-7 below illustrates the city's transportation network.

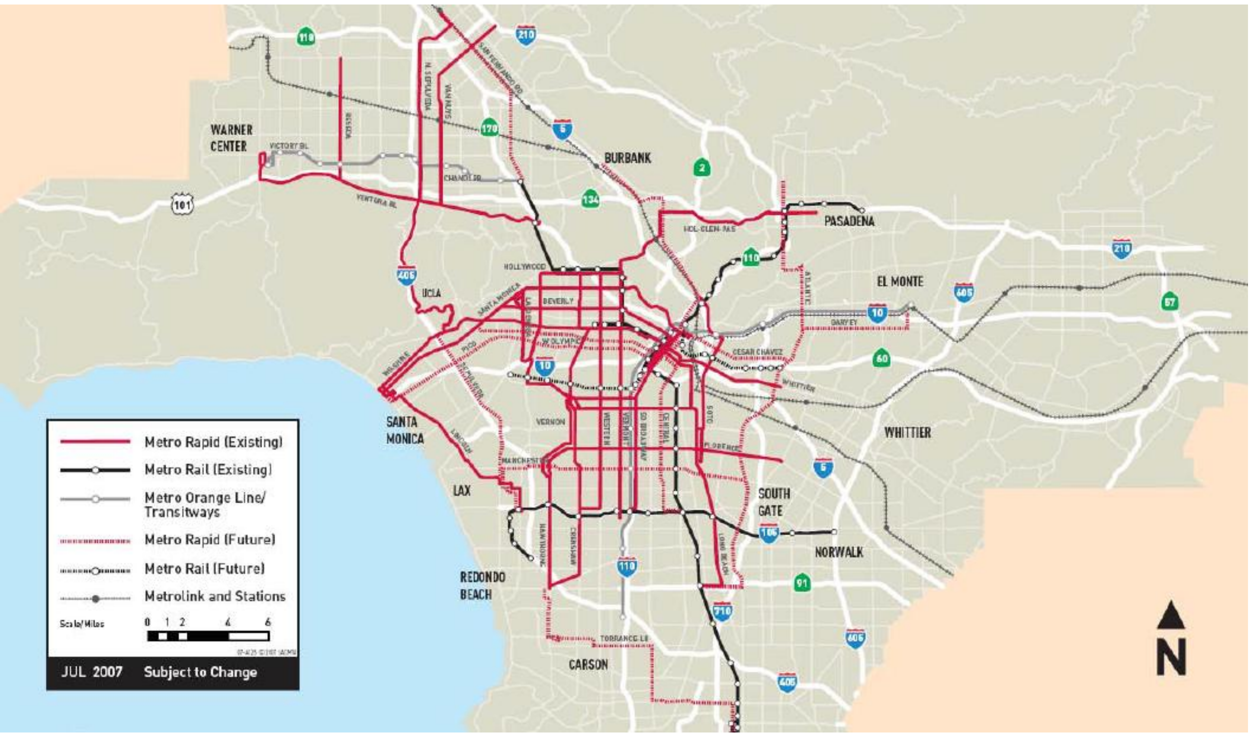


Figure 6 - 7 The implemented transportation systems within LA

Source: Hoffman (2016:53)

The Figure 6-7 depicts the relationship between transportation systems and land use in LA. The transportation infrastructure has been discussed in terms of the city's dependence on automobiles and related challenges (cf. 5.7.7). These include the inefficiency caused by suburban sprawl and low-density development, which increases traffic congestion and environmental degradation (cf. 5.7.2). The discussions in transportation systems often focus on the need for integrated policies that promote public transit, active transportation, and TOD to create a more efficient and sustainable urban fabric. The goal is to enhance connectivity, reduce reliance on cars, and support equitable access to mobility.

6.4.3 Spatial policy

LA has implemented various transportation policies while focusing on improving public transit options and expanding active transportation infrastructure (such as walking and cycling pathways). The objective of the applied policies is to integrate TOD (cf. 5.8) into the urban structure. These approaches aim to reduce car dependence, enhance mobility, and promote a more balanced relationship between land uses and transportation systems. The land use policies are also shifting towards higher-density development near transit hubs, mixed-use zoning, and policies that encourage affordable housing to be co-located with transit services, improving both accessibility and sustainability. The policies implemented in LA are discussed below.

6.4.3.1 Overarching scheme

A general plan for LA acts as a guide for upcoming development. Land use, transit, housing, and environmental sustainability are some of its components. The overarching scheme, referred to as the General Plan (or Master Plan) is an extensive document that covers many topics, including land use, transportation, housing, conservation and so forth and acts as a guide for the development of the city. The plan serves as a long-term roadmap for development and decision-making.

The following are some of the main land use-related components of LA' general plan. The land use element describes how the land is used across the city, designating regions for open space, commercial, industrial, residential, and recreational reasons. It seeks to strike a balance between development and other issues, including the requirements of the community, the economy, and environmental sustainability (CoLA, 2019:21-23). One of the most important aspects of land use planning is taking care of housing demands. With an emphasis on affordability and inclusivity, the General Plan's homes element describes policies and tactics to guarantee a sufficient supply of homes for people of all income levels. The general plan includes the city's TP strategy, such as tactics to increase mobility, lessen traffic, and support non-automotive transportation options like bicycling, walking, and public transportation. The emphasis on TOD (cf. 5.8), which aims to coordinate land use planning with transportation infrastructure (cf. 5.5.5) to promote more environmentally friendly mobility options and lessen reliance on cars, is a crucial aspect of this strategy (Metro, 2020:17-19). The conservation/open space part of the plan pertains to the upholding and improvement of the city's parks, open spaces, and natural resources. It seeks to achieve an equilibrium between the preservation of the environment and urban growth. When planning its land uses, LA takes the economy into account. This section delineates strategies to bolster economic expansion (cf. 5.4.1), employment generation, and business district advancement. The city's physical layout and aesthetics may be covered by this element. It might contain specifications for public areas, streetscapes, and building architecture to produce an appealing and visually harmonious urban setting.

6.4.3.2 Zoning ordinances

Land use is regulated by zoning laws in various areas of the city. This covers usage classifications for commercial, industrial, domestic, and other purposes. The zoning ordinance is identified as land use legislation, which governs land use and development of land. The zoning ordinance represents the policy which categorises land as (CoLA, 2021:1-45):

- Residential;
- Business;
- Commercial;
- Agriculture;
- Industrial; and
- Parks/open spaces.

These have been identified in most if not all urban models, demonstrating a common factor of land use. However, due to different countries, districts, regions and municipalities, policies may differ, which is based on the governing authority (CoLA, 2019:33-35).

6.4.3.3 Transit-oriented development (TOD)

To lessen dependency on automobiles, the city has expressed interest in supporting TOD, mixed-use initiatives and higher-density construction near transport hubs. The TOD has been illustrated in most developed countries' policies (cf. 5.8). The purpose of a TOD is to optimise public transportation accessibility and convenience. The main goal of TODs is to develop thriving, mixed-use neighbourhoods around transit hubs, such as train and bus stations, thereby encouraging locals and companies to use public transport, walk, or bike instead of driving their cars (Wilkinson, 2006:222-225; CoLA, 2021:15).

6.4.3.4 Ecological advancement

Sustainable development is becoming more and more important, with an emphasis on energy efficiency, green building techniques, and environmental preservation. Several policies have been put in place in LA to encourage sustainability and ecological advancement throughout the city. A holistic approach to environmental stewardship is outlined in the Sustainable City Plan, which places special emphasis on objectives such as lowering GHG emissions, developing urban green spaces, and enhancing water management (CoLA, 2019:1-11). This plan acts as a guide for incorporating ecological concepts into the processes of urban development and planning.

The emphasis on green infrastructure, which includes programs to raise tree canopy coverage, boost biodiversity, and improve stormwater management, is a crucial part of the ecological advancement agenda (CoLA, 2020:17-19). The methods for mitigating the effects of climate change, encouraging the use of renewable energy sources, and building community resilience are outlined in the LA Climate Action Plan (CoLA, 2021:24-26). LA's dedication to ecological improvement and sustainable urban development is reflected in its collective policies.

6.4.3.5 Public transport

There is a robust public transit network in LA that includes train and bus services. To offer alternatives to driving a private vehicle, efforts have been made to develop and enhance public transportation infrastructure (cf. 5.5.5). The policy also prioritises strengthening individuals' safety, dependability, and convenience to improve the overall user experience.

The efforts to decrease vehicle miles travelled (VMT) and enhance air quality through increased public transportation alternatives are highlighted in the LA Mobility Plan 2035 (CoLA, 2019:21-23). All of these regulations show how committed LA is to making its public transit system a more sustainable and effective network. The Sustainable Communities Strategy further advances significant regions for public transportation infrastructure investment, encouraging TOD (cf. 5.8) and guaranteeing equitable access to transit services across various communities (CoLA, 2021:29-31).

6.4.3.6 The Policy for Complete Streets

To build safer and more accessible urban spaces, the city has developed a Complete Streets strategy, which aims to design streets that accommodate all users, including cyclists, pedestrians, and users of public transportation. This seeks to provide a more inclusive and accessible transportation network for all users, including cyclists, pedestrians, drivers, and transit users. The city's aim for incorporating Complete Streets' ideas into urban planning and fostering safe and just mobility options throughout neighbourhoods is outlined in the Mobility Plan 2035 (CoLA, 2019:14-16). Important aspects of the Complete Streets program are to implement protected bicycle lanes, better sidewalks, and improved crosswalks, to promote active transportation and lessen dependency on automobiles (CoLA, 2020:27-29). The city highlights the significance of public participation in the planning process to ensure that community opinions are addressed during the development of transit projects (CoLA, 2021:33-35). The ordinance also aims to improve public health (cf. 5.4.2) outcomes through greater physical activity and reduce traffic congestion and GHG emissions, both of which are in line with larger sustainability goals (CoLA, 2019:44-46).

6.4.3.7 Parking regulations

LA's parking laws are included in Chapter I of the Los Angeles Municipal Code (LAMC), which deals with zoning and land use. These rules are meant to control parking availability, lessen traffic, and encourage environmentally (cf. 5.4.4) friendly modes of transportation. To balance the need for accessible parking with the city's objectives for density and TOD, the code sets minimum parking requirements for different types of land uses (CoLA, 2021:11-13). Transportation patterns are shaped in part by parking regulations (cf. 4.4.2). Certain regions might impose regulations on parking spots in newly constructed buildings but others might support less parking to encourage the use of alternate modes of transportation.

The Parking Reform Initiative is one of the initiatives the city has recently put into place to adjust to shifting mobility trends; it aims to simplify parking regulations and encourage the use of shared parking spaces (CoLA, 2020:24-26). This strategy places a strong emphasis on lowering off-street parking restrictions in transit-rich neighbourhoods to promote public transport use and lessen dependency on private automobiles (CoLA, 2021:33-36).

6.5 ERBIL (THE URBAN STRUCTURE MODEL)

Erbil is an urban structure within the country of Iraq; the city is also considered to be a developing country, like many of the cities in South Africa and is closely related to urban structures in, for example, Lagos (cf. 6.7). Erbil has faced notable growth during different periods – after the establishment of Iraq in 1920, and again in 2003 when it witnessed its largest expansion rate (Khoshnaw, 2023:1-3). This, in turn, has influenced the rate of change within the urban structure. This study addresses some of the changes to the city’s urban structure and how its legislation reflects policies that meet several factors such as political (cf. 5.4.3), economic (cf. 5.4.1), social (cf. 5.4.2), cultural, environmental-climate (cf. 5.4.4), and technological (Khoshnaw & Kissfazekas, 2018:11-23). Erbil is a case study based on the urban structure model (cf. 3.2.4). Erbil has been illustrated in Annexure D for further analysis. The city illustrates the transportation systems used in conjunction with land use; this case study is a representation of the functioning and efficiency of transportation systems from a developing country’s perspective.

6.5.1 Land use

Erbil's land use is very similar to the basic urban structure of cities. Erbil illustrates the use of various mixed land-use throughout the urban structure, as per the urban structure model (cf. 3.2.4). A mixed-use approach is frequently used in Erbil's urban land use zoning, which combines residential, commercial, industrial, and institutional spaces. To produce a harmonious and effective urban environment, these zones are carefully planned. Although specific zoning laws may differ, the following is an overview (Nooraldeen, 2015: 418-420; Khoshnaw & Kissfazekas, 2018:11-16; Khoshnaw, 2023:8-9):

- **Residential land use:** These regions, which are set aside for housing, are further broken down into several kinds of residential projects, including single-family houses, apartments, and gated communities. The city seeks to give residents a comfortable place to live;
- **Commercial land use:** These areas are reserved for a variety of commercial uses, including hotels, offices, marketplaces, and shopping malls. Commercial zones are often situated in the city's centre or along important routes to provide easy access.
- **Industrial land use:** These are locations set aside for factories and other industrial and manufacturing facilities, such as storage facilities. They are typically situated further away from residential areas to reduce potential interruptions; and
- **Institutional land use:** These areas are reserved for government, medical, and educational establishments like schools, hospitals, and offices. They are frequently placed in a strategic location to meet the demands of the neighbourhood.

The land use structure of the city is illustrated in the above analysis of the urban structure model. The components of the urban structure may be generic based on the other case study models, however, the design and functionality of these various land uses are very different. The land use structure illustrates a similar representation of the urban structure model (cf. 3.2.4). Figure 6-8 below illustrates the city's master plan created in 2009 (Sabr, 2014:11; Khoshnaw & Kissfazekas, 2018:14).

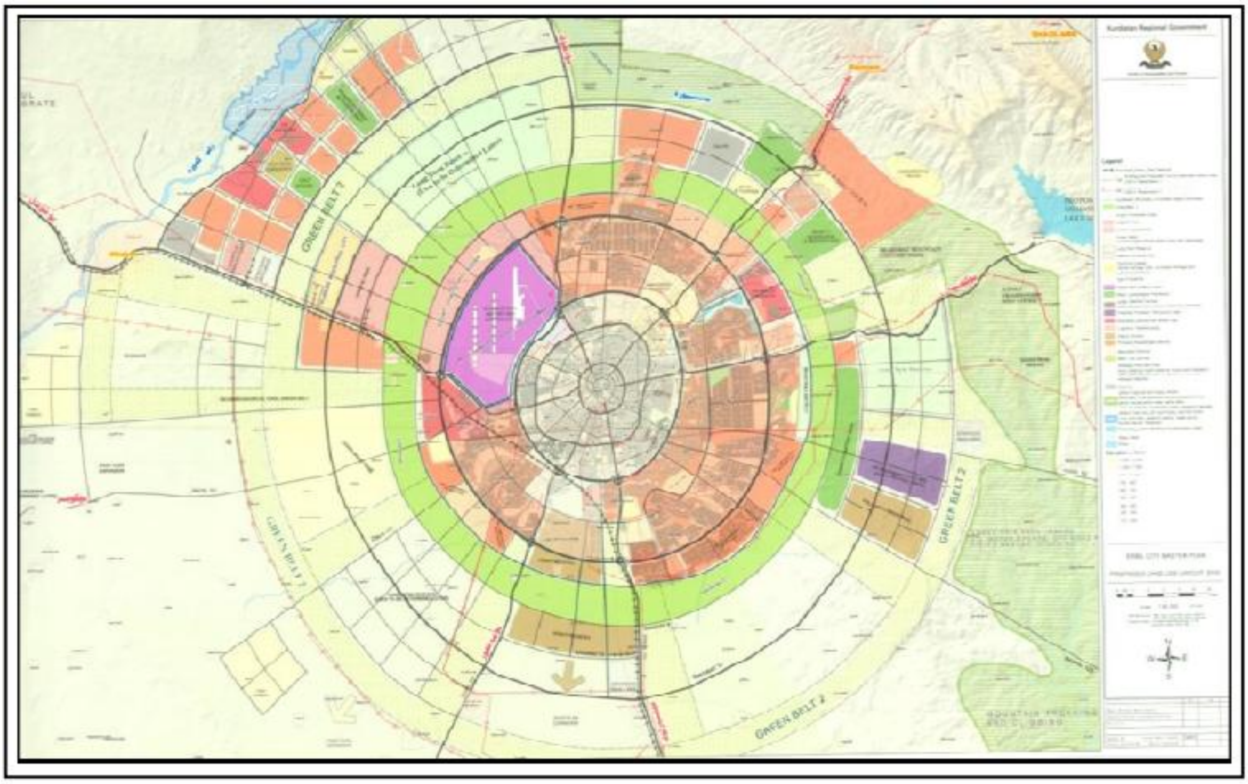


Figure 6 - 8 Master plan for Erbil cities land use

Source: Sabr (2014:11)

The above depicts the urban structure of Erbil city, which can be compared to the urban structure model (cf. 3.2.4). The model had been created in this urban structure to accommodate a large amount of residential housing. The above-illustrated land uses show a similar set of land use zonings as per previous case studies. The land uses and planning thereof are determined by the urban structure as well as the previously illustrated urban model (cf. 3.2.4). The design of this urban structure can be confused with the garden city model (cf. 3.2.1), as well as the concentric ring model (cf. 3.2.2). The above master plan lays out criteria for the development of appropriate community amenities in various districts. The purpose of the master plan comprises commercial, civic, and cultural venues in addition to institutional and governmental buildings, as well as (Khoshnaw & Kissfazekas, 2018:8-20):

- A comprehensive land use budget;
- A phased implementation plan with development rules and estimated expenses; and
- Accommodation of residents with efficiency and open space.

The above describes the same large corridors radiating outwards from the core of the city and branching towards each sector, demonstrating connected and efficient transportation services. The urban structure can be related to the common garden city design which prioritises open space and efficient mobility - one of the common traits is illustrated with a greenbelt concept. As per the

Figure 6-8 above, there is a quarter greenbelt illustrated within the masterplan and this differentiates the garden city from the urban structure model (Nabila, 2021:3-5).

6.5.2 Transportation networks

The transportation services around Erbil have been planned to create efficient and effective mobility for the residing community as well as to supply the demand based on economic principles of fulfilling needs. Transport networks must ensure seamless transportation around the city and connect these various land uses. The transportation system in Erbil is made up of several essential elements, namely (Abdulwahab, 2021: 1-11; Mohammed, 2021:70-82):

- **Major roads and highways:** These link residential, commercial, industrial, and institutional regions together. They make it easier for people and things to move around the city;
- **Public transit:** Erbil's public transit network, which includes buses and taxis, is expanding. These services give city inhabitants access to economical transit while connecting various regions of the city;
- **Pedestrian infrastructure**: Erbil is making investments to upgrade the city's pedestrian infrastructure, which includes crosswalks, pedestrian bridges, and sidewalks. These programmes encourage connectivity between different land uses and walkability, particularly in metropolitan settings; and
- **Infrastructure for cycling:** Erbil is also creating bike lanes and promoting cycling as a green form of transportation. These programmes seek to lessen traffic congestion and offer different modes of mobility.

Overall, Erbil's transport systems are planned to connect the city's diverse land uses effectively, enabling accessibility and convenience of travel for locals, businesses, and tourists alike. The transportation systems in Erbil range from private, public and rail transportation with the inclusion of pedestrian mobility (Khoshnaw, 2023: 1-6). The public transportation systems have been briefly illustrated in the above transportation networks (cf. 4.2) but to identify what specific public transportation system is utilised a further deduction of the transportation systems needs to be identified (Ibrahim, 2016: 50-51). The following public transportation systems are currently used within Erbil:

- **Taxis:** In Erbil, taxis are a popular form of transportation. They are easily located at designated taxi stands or can be called on the street;
- **Shared taxis**: Shared taxis, sometimes referred to as "Kareem" or "van," run along predetermined routes all around the city. The fare is often less expensive than a private taxi because passengers share the vehicle with others travelling in the same direction;
- **Buses:** There are only a few bus routes in Erbil, and they mostly connect to and from nearby towns and cities. The bus service has a poor level of coverage and frequency; and

- **Private vehicles:** The most popular form of transportation in Erbil is private vehicles, such as cars and motorcycles. Both locals and guests frequently use their vehicles or hire private drivers. The use of private vehicles can also be used as public transportation systems due to their capacity, for example, some SOVs can have a capacity between one to six occupants (Khoshnaw, 2023: 3-4).

The above transportation systems can be used for public transportation despite the stereotype surrounding SOVs. The public transportation services in Erbil are vast and have a variety of options for the resided community. The following Figure 6-9 illustrates the implemented transportation systems within Erbil.

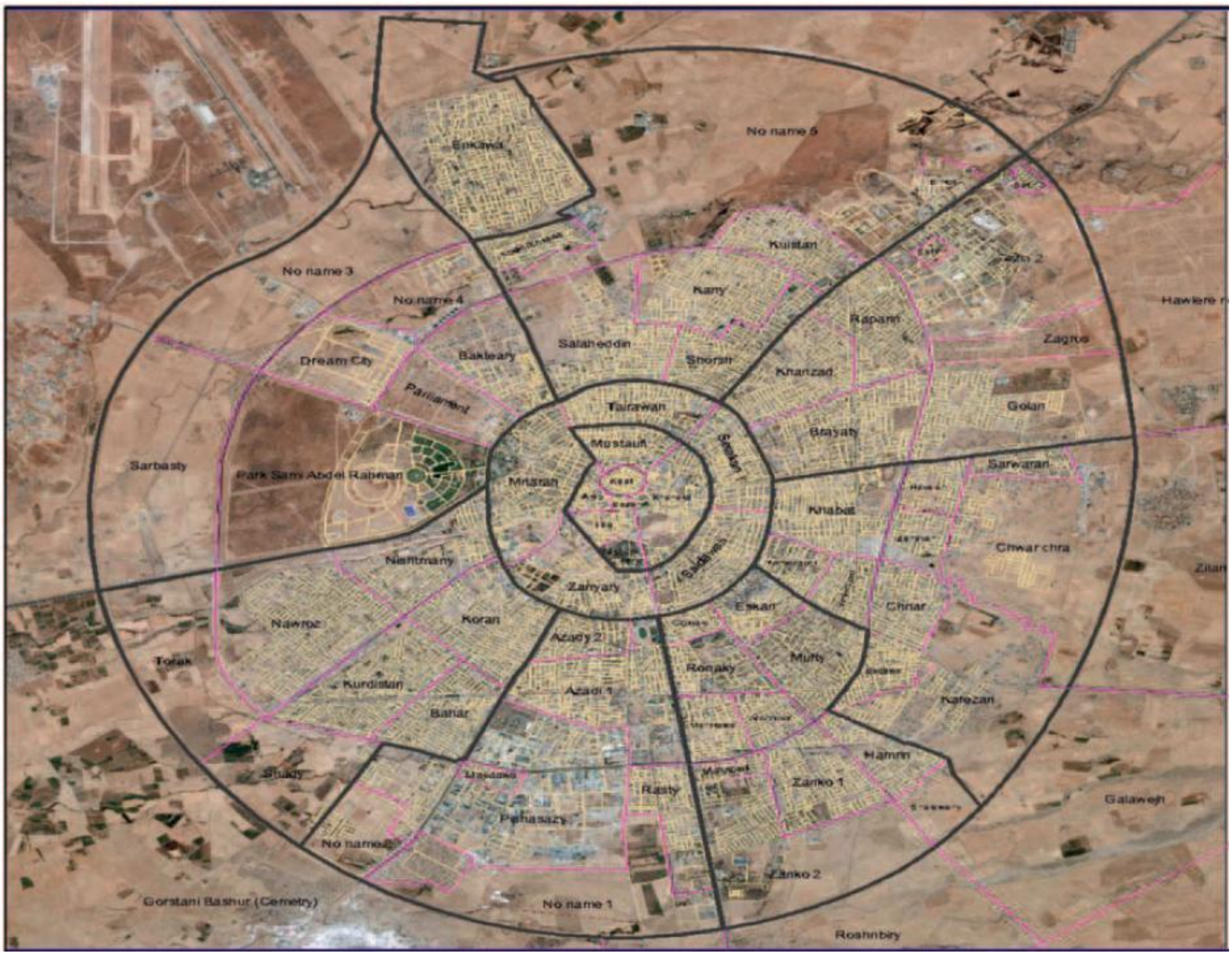


Figure 6 - 9 The implemented transportation systems within Erbil

Source: Aziz et al. (2011:881)

The Figure 6-9 depicts Erbil's street pattern and transportation infrastructure. The transportation systems focus on the centre of the city and radiate outwards from the centre of the development. The city structure and transportation implementation are similar to the case studies of Canberra and Chicago.

6.5.3 Spatial policy

The policy implementation within Erbil is focused on five main legislative backgrounds (from 1920 to 2013). Of the five, only four main types of policies had an impact on the development and evolution of the urban structure (Sabr, 2014:338-339).

6.5.3.1 Residential single plots policy

People are given/allotted residential single plots. There is a policy which states that they may build their own homes on these plots. This would work independently of the building permit laws that towns successively approve. In Erbil, the single plots policy is a component of a larger urban planning framework designed to control residential development in reaction to the city's fast urbanisation and population expansion. To meet the need for affordable housing and support private housing initiatives, this policy permits the allotment of specific plots for residential use. The rules are intended to guarantee planned urban growth and to make it easier for services and infrastructure to be integrated. The government aims to strike a balance between urban liveability, sustainability, and development needs by putting such regulations into effect. Residential campuses built by the government and its public sectors are exempt from municipal regulations. Residential campuses are constructed by NGOs such as Habitat for Humanity and they are exempt from municipal ordinances. Private residential campuses are also exempt from municipal ordinances (Ibrahim, 2016: 51-54).

6.5.3.2 Adaptation of policies

Illegal housing often develops and governments try to regain control of the land use this is known as urban sprawl, which was mentioned throughout the urban model’s chapter (cf. 3.2). Certain policies are implemented to govern transportation systems and land use for a more efficient transportation service. These governing land use and transportation regulations are frequently put into place to direct urban growth, guarantee effective land use, and enhance a city's transportation infrastructure (cf. 5.5.5). The cost of transport and the connectivity between various land use zones can be shaped by these rules (Kurdistan Regional Government, 2021:34-35).

6.5.3.3 Transit-oriented development (TOD)

This strategy encourages compact, mixed-use development while putting a special emphasis on the closeness of residential neighbourhoods to public transportation hubs. TOD (cf. 5.8) lessens reliance on private vehicles, improves connection between land use zones, and can cut the cost of mobility for locals by enticing more people to use public transportation (Ibrahim, 2016: 76-78).

The TOD (cf. 5.8) had been used within previous case studies as illustrated in LA (cf. 6.4), a multi-nuclei model (cf. 3.2.3). Thus, effective TP strategies within both developed and developing countries could be a possible solution.

6.5.3.4 Zoning and land use regulations policy

The land use zoning policy has been illustrated throughout the above case studies. Land use zoning governance is considered to be a commonly used policy within spatial planning. The policies governing zoning and land use decide how and what kinds of development are permitted within an area. The rules can affect the closeness of residential, commercial, and institutional regions, affecting mobility between these zones, by carefully defining land use zones. This will be dependent on the urban structure, as previously mentioned within the above case studies. The proximity of residential neighbourhood areas to workplaces or commercial hubs can cut down on inhabitants' commuting expenses and distances (Ibrahim, 2016: 97-99). Erbil has illustrated a unique approach towards land use zoning. This is illustrated through the compact aspect of urban structures to prevent urban sprawl and preserve green areas.

6.5.3.5 Complete roadways policy

The complete streets regulations seek to provide roadways that are safe and easily accessible to all users, including drivers, bicycles, and pedestrians (cf. 5.7.3). Complete streets policies encourage active transportation and improve connectivity between land-use zones (cf. 5.6) by adding amenities such as sidewalks, bike lanes, crosswalks, and public spaces. This increases mobility options and may lower the cost of automobile ownership and use (Gehl, 2010: 110-113).

6.5.3.6 Effective Parking Management Practises Policy

This policy can have an impact on the price and availability of parking spaces in various land use zones. Implementing tactics such as price structures, time restrictions, and preferred parking for specific users can promote alternate modes of transportation, ease traffic, and have an impact on travel patterns and mobility costs. These are just a few instances of how land use and transport regulations may influence the cost of movement throughout the city. The context, objectives, and implementation tactics picked by the local government and planning authority will determine the specific policies and their effects (Litman, 2020: 41-43).

6.6 SAN FRANCISCO (SF) (THE URBAN REALMS MODEL)

SF is considered to be a replication of the urban realms model (cf. 3.2.5) (Vance,1964:77-80; Cilliers, 2010:19-21). The planning of land use and transportation systems within SF includes providing considerable thought to and coordinating the city's physical growth, transit system, and urban design. It entails making choices and establishing guidelines that influence the expansion and development of the city while assuring effective and environmentally friendly mobility options for both locals and visitors. SF is located within the developed country of USA (Kyriakidou, et al, 2015: 260).

SF is renowned for its distinctive blend of crowded neighbourhoods, multicultural populations, and energetic streetscapes. The city's mountainous terrain and historic characteristics make planning more difficult. Zoning restrictions, land use designations, and development requirements must be established to determine how land should be used, including the distribution of residential, commercial, industrial, and recreational areas. Thus, land use planning would direct future expansion and maintain neighbourhood identity. SF has been illustrated in Annexure E for further analysis.

6.6.1 Land use

The SF General Plan, which offers a thorough framework for the city's growth and development, serves as the basis for the city's land use and zoning regulations. Residential, commercial, industrial, open space and institutional zones are only a few of the different land use categories that the city is divided into, according to the General Plan. This would determine what kinds of activities and developments are permitted in various areas of the city. In SF, some distinct property uses and zoning categories are as follows (Kok *et al.*, 2014:140-141; Grodach, 2022:40-45):

- **Residential land use:** Residential land use is influenced by the zoning regulations policy as seen within the previous case studies. The residential area is comprised of different housing types which are all connected to the public transportation services, which will be addressed in the following section. There are various types of residential housing including those set aside for dwellings, including single-family homes, apartments, and buildings with a mix of uses;
- **Commercial/business land use:** The business/commercial land use within SF has various types of businesses, which have been sub-categorised as illustrated within the residential sector. The CBD is located at a central point and surrounded by residential areas. This illustrates a similar concept to other urban models (cf. 3.2.1, 3.2.2, 3.2.4). The variety of commercial and business uses can be described as retail stores, offices, hotels, and restaurants, which are all permitted in these zones;
- **Industrial land use:** The industrial land use area has been segregated from both residential areas as well as business areas. This is to protect land use value as seen within the theory of agricultural land use model (cf. 3.2.10). The area has various types of industrial uses and is categorised between medium and high industrial uses. The category

includes locations used for production, storage facilities, and distribution hubs. This has been delegated through the land use zoning regulations illustrated in the following section;

- **Open space land use:** The open space area of SF is used for recreational uses. These locations are reserved for societal parks, recreational amenities, and undeveloped natural regions. The city's urban fabric (cf. 3.2.7) includes open space, which is crucial since it offers chances for recreation and the preservation of natural habitats. This type of land use is highly regarded in the garden city model (cf. 3.2.1); and
- **Institutional land use:** The institutional land use area as illustrated in the previous case studies is located near the CBD and includes schools, hospitals, offices of the government, and cultural institutions, which are allowed in these zones.

The general plan of land use is considered to be a standard layout in terms of urban structure planning (cf. 5.2). The land use and zoning would be seen throughout the above case studies as well as the theoretical urban models (cf. 3.2.5). The difference in each model is determined by the functionality of each urban structure as well as the connectivity. This will further the analysis of how policy and legislation may affect transportation and mobility planning. The below illustration of SF's land use layout demonstrates the implementation of the above land use zones.

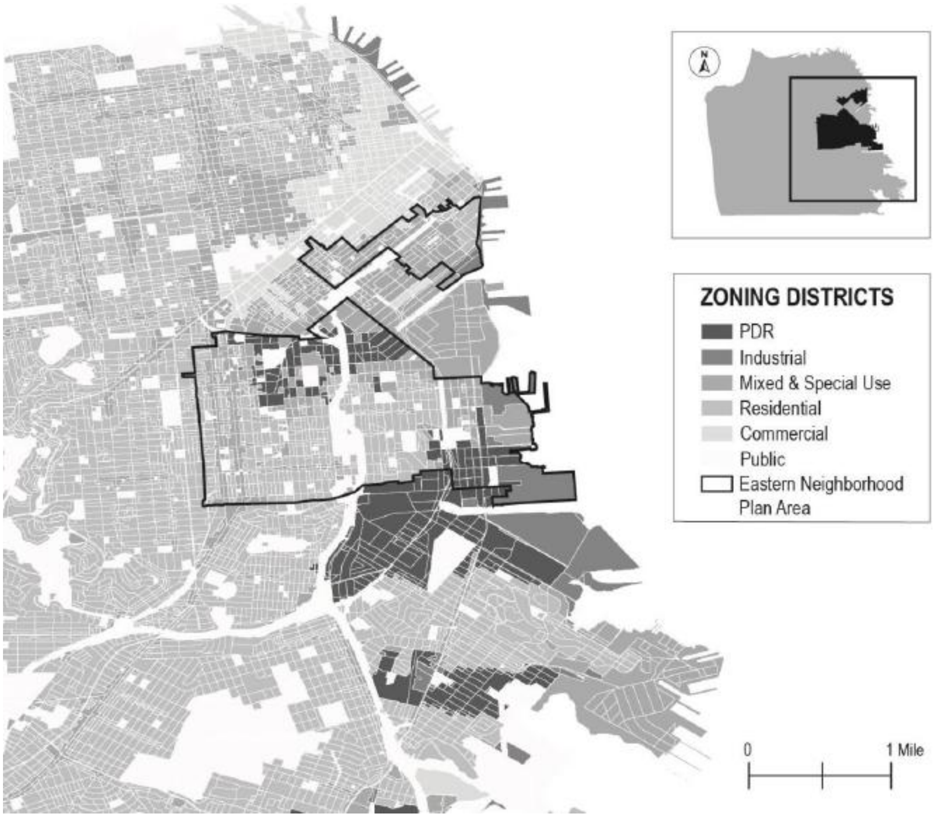


Figure 6 - 10 Land use zoning within SF

Source: Grodach (2022:44)

The above land use zoning Figure 6-10 depicts the implementation of land use. The layout of the urban structure illustrates a compact point within the centre of the urban model, as seen in the urban realms model (cf. 3.2.5). The urban structure and land use zoning principles were applied to the above models (cf. 3.2.1, 3.2.2, 3.2.4). The types of land use are, as mentioned, similar to the above case studies. The land use layout based on the topography is similar to the case study referring to CPT (cf. 6.11).

6.6.2 Transportation networks

SF had implemented transportation systems (cf. 4.4.5) which integrate an array of services to support mobility, environmental sustainability, and economic accessibility. The key components (cf. 5.5) include an extensive public transit network, with the inclusion of pedestrian infrastructure which is governed by the municipal authority. The public transportation system is comprised of BRT, LRT, cable cars, and streetcars. The many land uses of SF are connected in large part by transportation modes. The city features a large network of roads, bike lanes, and pedestrian facilities in addition to public transportation options. Transport links the various land uses through (BART, 2023:4-6; SFMTA, 2023:11-13; Kuncheria et al., 2024: 163-169):

- **Highways and roads:** The road infrastructure is comprised of local roads, highways and roads which allow individuals to access different land uses within the city. The transportation systems connect the residential areas with the CBD area and access to residential communities, shopping malls, and industrial zones is made possible by them;
- **Pedestrian infrastructure:** The improvements to the city's bicycle and pedestrian infrastructure have been made and include the installation of designated bike lanes, walkways, and pedestrian-friendly streets. The city's improved infrastructure makes it more accessible for individuals to travel by foot or bicycle, linking them to a variety of locations and land uses; and
- **TOD:** SF has implemented the TOD policy to improve transportation systems within the urban structure. The city supports TOD, which entails placing high-density residential, commercial, and mixed-use complexes within walking proximity to public transportation hubs. This encourages the community to utilise public transportation and reduce their reliance on private cars. This strategy improves the connectivity between different types of land use and available transportation.

The transportation networks (cf. 4.2) within SF connect various land uses. This increases accessibility as well as encourages and improves effective movement within the urban structure. Various types of public transit networks in SF link various areas of the urban structure and external areas. The public transportation units implemented within the city are illustrated as (Erhardt et al., 2022:315-317):

- **SF municipal railway (LRT):** The LRT implemented within SF is known as the “Muni” and includes the city's historic streetcars, BRT and LRT. It connects different neighbourhoods and acts as the backbone of local transportation. The LRT has been illustrated throughout the previous case studies. The public transit system is used to connect residential areas to the CBD area, which is a common principle used and illustrated in the urban models (cf. 3.2);
- **Bay Area Rapid Transit (BART):** This BRT had been implemented within SF and is known as the “BART”. It is considered to be the fastest regional transportation system. This provides a transportation service to surrounding areas and land uses within SF. The BRT connects many land uses within the city and externally, for example, Berkeley, Oakland, and the SF International Airport. This illustrates a multimodal transportation system;
- **Caltrain:** The Caltrain is a public rail transportation system used for further travel. This is similar to the LRT mentioned but differs in terms of the travel distance. This commuter rail system connects SF to southern cities, for example, Gilroy and San Jose by travelling the length of the SF Peninsula. It provides regional and local services; and
- **Golden Gate Transit:** The Golden Gate Transit system is a type of long-distance BRT system used for longer distances. The transportation system is governed by a private company and would link multiple bus routes within the city. The company maintains the transportation system which is considered to be similar to BRT systems implemented by the governing municipal authority. It offers access to specific locations on the other side of the Golden Gate Bridge, hence the name.

The above transportation networks (cf. 4.2) have a significant influence on the way land use is connected. The principle remains consistent throughout the case studies, illustrating the use of BRT and LRT systems. In addition to encouraging mixed-land use and lowering the need for excessive car use, public transit frequently promotes denser development around stations. The transit stations are based on TODs to facilitate convenient access to transportation while fostering thriving, walkable, and sustainable communities (cf. 5.8). The implementation of transportation systems within SF illustrates the connectivity of all land uses, as demonstrated in the Figure 6-11 below.

Figure 6 - 11 Transportation systems within SF

Source: Erhardt et al. (2022:316)

The above Figure 6-11 depicts the implemented transportation systems throughout the urban structure of SF, which connects all land uses and provides various modes of transportation systems. The Figure 6-11 shows a diverse transportation system which assists residents in commuting to various land uses within the urban structure. This not only improves efficiency but also accessibility.

6.6.3 Spatial policy

The city has various policies which govern all transportation systems and mobility. The policies govern land uses and regulations thereof. SF incorporated both land use and transportation policies which focus on creating a dense, sustainable urban environment. The main focus was to reduce car dependence and promote accessibility as well as efficiency of transportation systems. The various mixed land-use zonings and transportation systems create a TOD (cf. 5.8). The city encourages high-density growth around public transit hubs, balancing residential, commercial, and recreational spaces to maximise limited land use. The transportation initiatives have been implemented through the San Francisco Municipal Transportation Agency (SFMTA), which emphasises multimodal transportation options, for example, the various public transit systems (BRT, LRT, and so on) cycling, and walking, along with measures for congestion to promote efficient movements within streets. Through the integration of these policies, SF aims to reduce emissions, increase the efficiency of transportation systems, and manage growth to create a liveable and well-connected city. The land use policies determine the implementation of various land uses as discussed in the previous section. Several land use and transport policies have been implemented within SF to direct the development of the city's transport infrastructure, as discussed below (Kitamura *et al.*, 1997:125-155; Calbick *et al.*, 2003:72-82; Waddell, 2011:210-228).

6.6.3.1 Transit-First Policy

SF's Transit-First Policy is known as the city’s core urban planning framework policy; it aims to prioritise public transportation systems as well as sustainable transportation modes. This focuses on individuals moving between land uses using public transit instead of private vehicles. The policy mandates new developments and street design based on accessibility and the enhancement of transit services (Moran, 2022: 1-3). This aims to provide public transit based on an individual’s preferred choice for daily travel (cf. 3.2.9). The policy includes measures of reducing parking minimums, expanding bike lanes, and supporting dense development near transit corridors to lower car dependency (as illustrated in the above case studies). The predicted result would reduce congestion, improve the efficiency of transportation systems, improve access and flow (cf. 4.3), and improve urban liveability overall. This strategy encourages the development of TODs (cf. 5.8) to improve access to public transport and promote the effective use of roadways.

6.6.3.2 Transportation-oriented development (TOD)

The TOD strategy has been mentioned in previous case studies and within previous chapters of this study (cf. 4.4.5, 5.8, 6.2, 6.3) to focus development near significant transportation hubs. This policy promotes pedestrian-friendly neighbourhoods (cf. 5.7.3), through a variety of land use accessibility, and reduces reliance on SOVs (Barajas et al, 2020: 1-8). Travel of TOD Residents in the San Francisco Bay Area: Examining the Impact of Affordable Housing. The TOD policy encourages high-density, mixed-use development near major transit hubs. This would connect the residing community to various land uses through public and sustainable transportation systems. The TOD policy focuses on concentrating various developments, land uses and services within walking distance of public transit stations. This decreases the need for private vehicles. The land use zoning regulations as illustrated in the below subsections will increase density near transit corridors and reduce parking requirements. The policy promotes accessibility, reduces congestion (cf. 5.7.7), and lowers GHGs (cf. 5.7.2). The TOD strategy has been integrated within SF's broader urban planning goals. The compact city structure encourages transit use and pedestrian-friendly communities (Luscher, 1995:55-60).

6.6.3.3 Complete Roadway Policy

The Complete Roadway Policy implemented within SF allows roadways to be built and maintained to meet the needs of all individuals (drivers, bicycles, pedestrians, and passengers of public transportation). This policy encourages the development of roadways to increase accessibility, and efficiency, and improve safety for all forms of transportation, to provide a more accessible, pedestrian-friendly (cf. 5.7.3), and ecologically sustainable transportation system (Farrell, 2021: 1-13). SF has implemented sub-policies that regulate traffic and prioritise efficiency; one such policy is known as the "Vision Zero Policy", which aims to end traffic fatalities by lowering speed limits, redesigning crossings, and implementing traffic calming techniques (Epstein et al, 2016: 8-11). The main initiatives are to decrease reliance on cars while reducing GHG emissions. The city also places a high priority on public transportation upgrades and bicycle-friendly infrastructure, for example, bicycle lanes and shared mobility initiatives. The policy promotes fairness by strengthening climate resilience and expanding transit access in marginalised communities by encouraging public participation which guarantees that road modifications satisfy local needs (Smith et al, 2022).

6.6.3.4 Pedestrian policies

The city has implemented policies to improve bicycle infrastructure and promote cycling as a practical means of transportation. This covers the development of designated bicycle lanes, bicycle rental services, and bicycle-friendly roadway layouts. The implementation of the Vision Zero Policy strives for zero traffic fatalities by 2024. The policy focuses on lowering pedestrian fatalities and injuries by redesigning roadway corridors, lowering speed limits, increasing the number of safe crosswalks, and improving signal timing (cf. 5.7.3). The enhancement of sidewalk infrastructure and expanding pedestrian-friendly areas, allow the policy to promote walking as the main form of transportation (Farrell, 2021: 10-11). The policy also determines danger areas by monitoring progress (Chapter 4) and implementing evidence-based changes between neighbourhood organisations and data-driven methodologies (Chapter 4).

6.6.3.5 Affordable housing policies

This policy illustrates a category of land use policies implemented within SF. This addresses the issue of housing affordability and residential land use within the city, by implementing various land use policies (inclusionary zoning rules, affordable housing standards for new developments). The policy assists with creating affordable housing for working-class individuals and lower-income class groups (cf. 3.2). The combination of high demand, limited availability, and rising costs has created a significant housing affordability crisis. The main goals of the city's affordable housing policy are to protect and improve vulnerable citizens from displacement, which means maintaining the availability of affordable housing. The inclusionary housing policy mandates that market-rate developers either incorporate affordable units in new projects or contribute to an affordable housing fund (cf. 3.2.10). The affordable housing bond finances the implementation of new units and the renovation of existing buildings, which is considered a significant initiative for land use (Kalugina, 2016: 77-83).

6.6.3.6 Environmental sustainability

To encourage environmental sustainability in land use and transportation (cf. 5.6), SF has developed environmental legislation. This includes initiatives to lower GHG emissions, boost energy efficiency, and promote the use of alternative fuels and electric cars, to achieve a sustainable and resilient environment due to climate change (cf. 6.2). SF has implemented progressive environmental regulations (Wolf-Jacobs, 2019: 18-34). This includes significant projects which include waste reduction objectives, investments in green infrastructure, and aggressive carbon reduction targets (reducing of SOVs). The city's initiatives support renewable energy, environmentally friendly transportation, and energy-efficient building requirements and are considered to be the city's climate action plan that seeks to achieve carbon neutrality by 2045. The city also prioritises protecting and conserving biodiversity as well as improving green areas to achieve environmental justice (cf. 5.4.4).

The above policies governing SF’s land use and transportation regulations have been implemented to guide the growth and development of the city's infrastructure. The regulations show the city's dedication to developing a liveable, equitable, and sustainable urban environment for both its citizens and guests. The consideration of all transportation components (cf. 5.5), interactions (cf. 5.4), land use, and connectivity seek to create a sustainable and efficiently functioning city.

6.7 LAGOS (THE 21ST-CENTURY CITY MODEL)

Lagos, Nigeria is considered to have various challenges regarding land use and transportation systems due to poor infrastructure, fast urbanisation, and population expansion (cf. 5.7.9). The city is considered to be situated in a developing country and is not as efficient as the above-developed countries. This case study represents a similarity to the 21st-century city model (cf. 3.2.6). The city's urban structure is illustrated in Annexure F to demonstrate the urban structure (Lateef, 2010: 173-187; Auwalu & Bello, 2023:175-176).

The city's transport system is primarily reliant on roads, which leads to long commutes, high pollution levels, and frequent traffic congestion (cf. 5.7). The city plans to implement BRT systems, rail infrastructure, and water transportation to reduce traffic. This illustrates that the need for public transportation solutions is expanding. Lagos has implemented motorbikes and minibuses as its primary source of transportation systems despite its focus on SOVs growing. Lagos's land use can be defined as high-density, mixed-use development, with unplanned growth and informal settlements surrounding a significant urban core. The implementation of transportation systems and land use seeks to improve land use planning, transportation system integration, and the creation of more accessible areas. Lagos has recently implemented sustainable urban areas to fulfil the future goals of recent government initiatives. Lagos illustrates a case study of a developing country and the need to improve the urban structure as well as the efficiency of transportation systems. The below case study analysis addresses all components (cf. 5.5) of this developing city and possible strategies of implementation and challenges (cf. 5.7) that can be avoided (cf. 5.7).

6.7.1 Land use

Lagos has implemented land use based on high-density urbanisation as a form of quick development. The variety of land use zones defines Lagos's land use and urban structure, which is fuelled by the city's status as a significant economic centre within Nigeria. Lagos has several land use pressures, which lead to a mix of commercial, industrial, residential, and informal settlements, frequently with land use zoning regulations. The land use reclamation initiatives have increased urban sprawl and land scarcity which cause environmental damage (cf. 5.7.2), for example, coastal erosion and land coverage for future growth. Lagos experiences land use challenges (cf. 5.7.8) which include managing informal settlements and combating environmental degradation (cf. 5.7.2). The focus would be to enhance infrastructure for sustainable growth and overcome major obstacles. Lagos recently began implementing planning regulations to control urban growth, to efficiently create accessibility between development, social (cf. 5.4.2), and environmental sectors (cf. 5.4.4). Lagos has similar land use zones to the above illustrated case studies and illustrates a set format towards land use implementation for both developed and developing countries. Lagos has implemented the following land use zones to improve connectivity and functionality (Oduwaye, 2013:1062-1063; Auwalu & Bello, 2023:181-183):

- **Residential land use:** Lagos has implemented residential land use which can be defined as a combination of formal and informal settlements. The implementation of residential land use is considered through high population density and fast urbanisation. The city's constraints within land use and population growth have been segregated with various classes of individuals (as identified in most urban models). The residential areas had been divided into a complicated mix of middle-class houses, luxury estates, and large informal settlements (Oduwaye, 2013:1059-1062). The residential area for the resided community of Lagos is considered to be slums (as identified in developing countries);
- **Commercial land use (CBD):** The CBD area is considered to be the commercial area offices, retail stores, and other companies are situated in. The CBD area is considered to have high economic (cf. 5.4.1) activity (as in previous case studies) and frequently has more compact building densities. Lagos is a major economic centre in West Africa, due to its high concentration of commercial land use (Oduwaye, 2013:1059). The CBD is located on Victoria Island, Ikoyi, and the Lagos Island CBD. The CBD area focuses on preserving space through high-rise buildings (multiple stories), mixed-use complexes, and informal markets to try and increase demand for commercial space. The challenges with infrastructure, traffic congestion (cf. 5.7.7), and limited parking affect how businesses operate. Lagos has implemented several urban regeneration initiatives (Eko Atlantic) for development in an attempt to manage the social (cf. 5.4.2) and environmental effects while modernising the city's business environment to increase economic benefit;
- **Industrial land use:** Lago's industrial land use is a dynamic and constantly evolving environment. The industrial area is essential to the city's economic growth based on mass manufacturing for a highly populated and majority lower class income group. Lagos is the economic hub of Nigeria and is known for its sizable concentration of sectors. Industrial land use causes challenges (cf. 5.7) within Lagos, as the constant manufacturing of goods can negatively affect the surrounding environment (cf. 5.7.2). The city is trying to improve the movement of goods and services through efficient transport networks (cf. 4.2) by using sustainable practices and reforming industrial land use zoning policies. It also seeks to create industrial parks as well as special economic land use zones to increase economic benefit (Oduwaye, 2013:1060). The strategy and implementation of land use attempts to address the challenges (cf. 5.7) between environmental (cf. 5.4.4) sustainability and community health (cf. 5.4.5);
- **Recreational land use:** A dynamic feature of Lagos within the implementation of the urban structure and recreational land use illustrates an increasing focus on parks as well as open spaces while attempting to decrease urban expansion. Lagos has a large population which is estimated at over 20 million. This makes the implementation of

recreational land use difficult, due to the need to provide sufficient leisure amenities. The city has well-known recreational areas, such as Lekki Beach, Tafawa Balewa Square, and several waterfronts. The recreational areas are used for the resided individuals to perform both social (cf. 5.4.2) and recreational activities. Lagos has various challenges regarding enhancing public parks and green spaces, as illustrated above. However, the city encourages sustainable development, and expanding access to recreational areas as part of future initiatives;

- **Educational Institutions land use:** The city is home to numerous public and private educational institutions, ranging from primary schools to higher education facilities, strategically distributed to accommodate its diverse population. Urban planning initiatives aim to integrate educational spaces within residential and commercial areas, promoting a conducive learning environment. Lagos offers its residents and external residents' access to a wide range of educational facilities through various institutions (Oduwaye, 2013:1060);
- **Government land use:** Lagos's government-owned land use focuses on utilising land to suit the need for housing. Practical planning and urban development are governed by various policies (which will be addressed in Section 6.7.3). The implementation of these policies aimed at optimising land use for housing, transportation, and commercial activities while promoting sustainable development. The city has implemented various land use zoning regulations (as illustrated in previous case studies), as well as master plans, and redevelopment strategies. This attempts to enhance urban resilience, efficiency of transportation systems, and ensure efficient public services. The implementation of government land for clinics, hospitals, and other medical facilities are essential land uses that offer citizens healthcare and security services; and
- **Transportation land use:** Lagos makes use of land for transportation services. This would include hubs, parking facilities, infrastructure, and other components of transportation services (cf. 5.5). The infrastructure used for transportation services within Lagos illustrates mass land coverage based on the use of SOVs. The above analysis shows that road transportation is considered to be a common and predominantly used transportation service. This demonstrates that land use cover would be based on the functioning of SOVs and other transportation services required to maintain mobility.

The implementation of land use within Lagos is based on the 21st-century city urban model (cf. 3.2.6), as illustrated. The urban structure has a similar layout to the garden city urban model (cf. 3.2.1); concentric ring urban model (cf. 3.2.2); and urban structure urban model (cf. 3.2.4). It depicts a radial pattern of implementation demonstrated in the majority of the urban models (cf. 3.2). The Figure 6-12 below provides a visual of Lagos's land use.

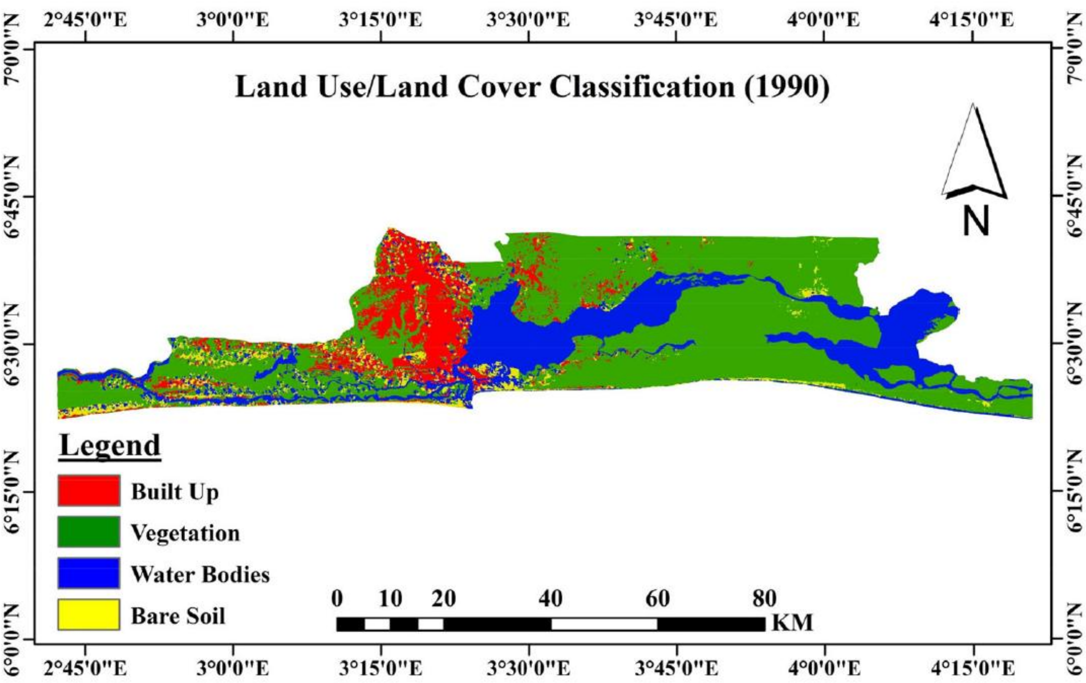


Figure 6 - 12 Land uses within Lagos

Source: Koko et al. (2021:639)

The above Figure 6-12 illustrates the implementation of land use zones, as determined within the previous case studies. The various land use zones are connected through the use of transportation systems to increase mobility. Lagos is similar to the above-mentioned case studies as it illustrates most if not all land uses implemented within the urban structure. Lagos's case study reveals inefficiency within mobility, as mentioned; thus, the structuring and planning of land use is not the only guideline to improve the efficiency of the urban structure. The following subsection refers to the implementation of transportation systems to determine the possible problems or challenges Lagos is currently attempting to rectify.

6.7.2 Transportation networks

Lagos has a variety of transport networks (cf. 4.2), from water transport to road networks. The city's road network includes BRT systems, and rail transportation networks (LRT). Lagos has recently implemented rail transportation which is known as "Blue Line transportation" and "Red Line transportation" to link land uses. Lagos has various transportation challenges (cf. 5.7) and attempts to decrease SOV dependency on road transportation. Lagos seeks to decrease traffic congestion, inadequate infrastructure, and dependence on unofficial transportation options (such as motorcycles and minibuses). The implementation of the Lagos Rail Mass Transit (LRMT) system attempts to improve these challenges. The city focuses on increasing multimodal solutions (cf. 5.8) and public transportation to accommodate Lagos's expanding population. The city's transport infrastructure is constantly evolving as a result of its growing population and fast urbanisation, with the following transportation systems implemented (Oni & Okanlawon, 2012: 29-36; Ademiluyi et al, 2016: 246-249; Otuoze, Hunt & Jefferson, 2021: 3-5; Auwalu & Bello, 2023:181-182):

- **Road networks:** The intricate road transport system implemented within Lagos has been used to provide mobility between various land uses. The expanding population continues to cause more challenges as congestion increases (cf. 5.7.7). The land uses within the urban structure are connected to a major highway and create various accesses to commercial, residential, and industrial districts (as mentioned). The use of major highways, for example, Lagos-Ibadan Motorway, Third Mainland Bridge, and Lekki-Epe Motorway may increase traffic volume. However, as mentioned, these are inefficient in addressing congestion due to high vehicle density, constrained road capacity, and few other routes. Efficiency and accessibility are impacted by rising urbanisation and maintenance deficiencies, regardless of various attempts to resolve the issue (Otuoze, Hunt & Jefferson, 2021: 4); and
- **Motorcycle taxis (Okada's):** The road network occupies various types of buses and other transportation services. The alternative type of road transportation service is known as motorcycles/ taxis, which do not improve congestion or efficiency. The implementation of motorcycles was not authorised by the governing transportation system but has been identified as an informal transportation system. Motorcycle taxis are known as "Okada's", and are frequently utilised for short-distance travel, particularly in locations with congested roads. The motorcycle taxis are smaller and able to access various land uses but as mentioned are seen as a temporary transportation solution for road congestion (Otuoze, Hunt & Jefferson, 2021: 4).

Transportation systems in Lagos are considered to be SOV-dominant, as illustrated by the increasing population and extensive road infrastructure. The transportation systems are limited when considering road transportation. The city seeks to implement public transportation systems to improve transportation efficiency, which would consider the following:

- **BRT:** The BRT system is a vital attempt to solve urban transport challenges (cf. 5.7) in the most populated metropolis in Nigeria. The BRT prioritises high-capacity buses and operates on dedicated transportation lanes to ease traffic, shorten commutes, and provide inexpensive transit. The transportation system has been crucial in minimising automobile emissions, decreasing traffic congestion on main highways, and promoting economic benefit through accessibility. The BRT system still has challenges with the expanding population, fleet upkeep, and desires for expansion. The goal of ongoing improvements, for example, new routes and electronic payment methods, is to increase accessibility and efficiency for the expanding urban population (Otuoze, Hunt & Jefferson, 2021: 15);

- **Water transportation:** Water transportation is a significant component of Lagos due to its proximity to large bodies of water and is a coastal city. The rivers and the Lagos Lagoon increase transportation modes over water. The capacity and efficiency are intended to be increased through improvements in ferry infrastructure, enhancing safety standards, and modern terminal hubs. There are still challenges (cf. 5.7) identified through the various constrained routes, safety concerns, and negative effects on the environment (cf. 5.7.2), due to waste and pollution in waterways (Ademiluyi et al, 2016: 246-249). The city's future initiatives for water transport are to increase accessibility while incorporating it with more extensive public transport options. The topography can determine certain types of transportation modes, while water travel is considered to be a crucial part of Lagos's urban mobility strategy;
- **Rail transportation (LRT):** Lagos has implemented rail travel to significantly improve mobility, as part of the country's initiatives to improve public transport and reduce traffic on the roads. The “Blue Line” and “Red Line” are the two main priorities among the various proposed lines in the LRMT system. The Lagos rail transportation system is a recently implemented public transportation system and serves as a crucial component of transportation systems. The city's master plan hopes to increase accessibility as well as improve the sustainable transit system. Lagos's LMRT system seeks to provide an efficient rail transportation network that will improve the city's mass transit system's connectivity (Oni & Okanlawon, 2012: 29-36);
- **Keke Nappe (auto-rickshaws):** In certain places, short-distance travel is done in three-wheeled auto-rickshaws, also referred to as Keke Nappe or Keke Marwa. The auto-rickshaws are an essential component of Lagos's public transportation system. They provide accessible and reasonably priced short-distance transportation in highly-populated urban structures, particularly in places with narrow roads that are inaccessible to larger vehicles. This initiative hopes to reduce the city's traffic congestion challenges (cf. 5.7.7) and increase accessibility. The auto-rickshaw transportation system is another temporary solution to reduce traffic and is still necessary for daily transportation in Lagos with the lack of other transportation options; and
- **Moule buses:** The “Moule buses” are considered to be a city bus transportation system implemented to minimise environmental effects (cf. 5.4.4), improve urban mobility, and reduce traffic congestion (cf. 5.7.7). The bus transportation system has been used to address the vital transportation needs of the city by providing an economical (cf. 5.4.1) and effective alternative for SOVs and minibuses. The transportation service is a component of

Lago’s master plan to increase public transport with environmentally sustainable options. This promotes sustainable urban development by reducing GHG emissions. Public transport is made more enticing to the resided community through the Moule buses’ amenities for passenger comfort and safety. The buses are large and can maintain a large capacity to accommodate more individuals. The buses are commonly used but struggle to maintain efficiency with the ever-expanding population.

The above transportation systems form part of Lagos's mobility system. The challenges have been emphasised through the overexpanding population (cf. 5.7.8) and dominant use of SOVs. The initiatives implemented regarding transportation are considered to be minimalistic based on the population size, as shown. The Figure 6-13 below illustrates the implementation of the above-discussed transportation systems’ infrastructure.

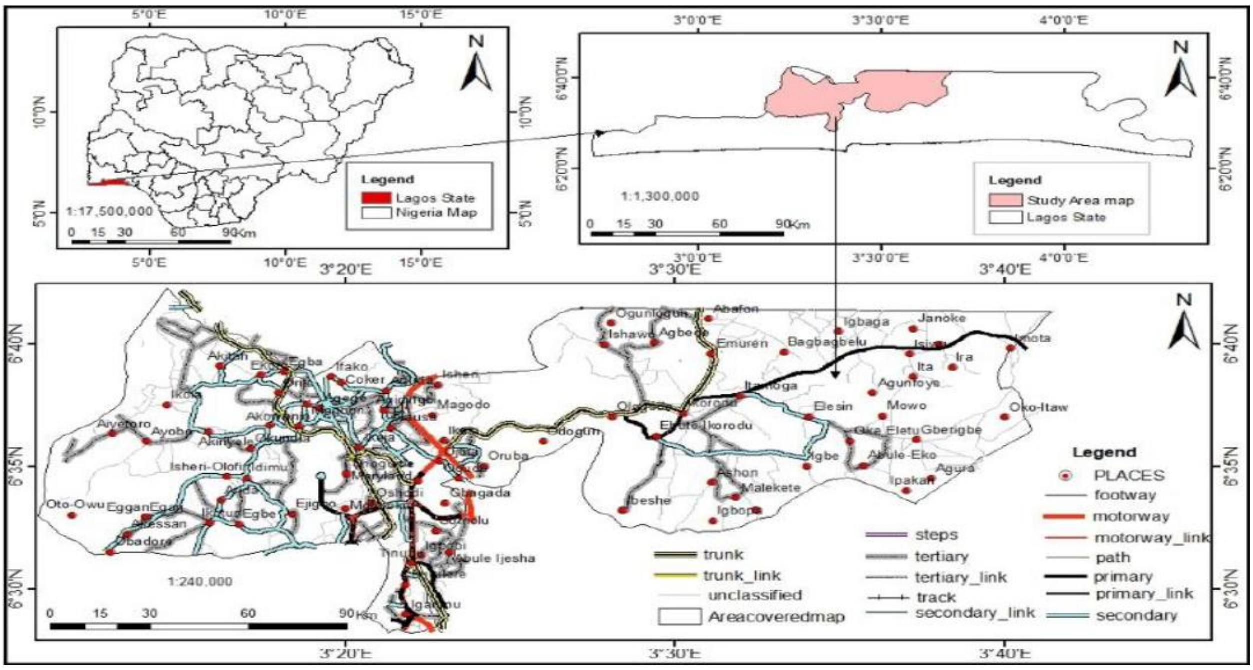


Figure 6 - 13 Transportation systems within Lagos

Source: Ajayi et al. (2022:4)

Figure 6-13 depicts the implementation of transportation systems within the urban structure. Lagos has implemented various modes of transportation but challenges, for example, population growth and urban expansion (cf. 5.7.8), congest the current transportation systems (cf. 5.7.7). The developing city of Lagos illustrates the use or future use of public transportation systems (BRT, LRT, water-taxi, and auto-rickshaw, among others). These transportation systems have been identified in the above case studies and show efficient mobility. Lagos has an ever-expanding population and insufficient transportation services which reduce transportation efficiency indefinitely (Auwalu & Bello, 2023:182-184). The following section addresses the policies that have been implemented which govern Lagos’s land use and transportation systems.

6.7.3 Spatial policy

Lagos has attempted to address challenges concerning traffic congestion (cf. 5.7.7), ever-expanding urbanisation, and implementing environmental strategies for smart land use. The connectivity of land uses is governed through transportation systems (official and unofficial) and transportation regulations. To reduce emissions and travel time, the city promotes TOD (cf. 5.8), including high-density residential and commercial land uses close to transit hubs. The policies govern the LRMT and BRT systems to reduce dependency on SOVs. This offers alternatives to provide effective mobility and affordable public transportation options. The city also prioritises promoting unofficial transportation systems in efforts to reduce SOVs, control land use through zoning reforms, and develop road infrastructure. The regulations support Lagos's future initiatives to enhance urban mobility, promote sustainable development, and reduce traffic (traffic congestion). Lagos has implemented various policies and legislation to address the above-mentioned challenges regarding traffic congestion and urban growth (cf. 5.7.7). The policies implemented govern both land use and transportation systems to reduce issues within the city and promote sustainable living.

6.7.3.1 Lagos State Law on Urban and Regional Planning and Development

This policy has been implemented to combat urbanisation and increase sustainable growth within Lagos. The policy governs land use zoning (as seen within previous case studies) and enforces building standards. The policy also emphasises order and environmental sustainability, which aims to reduce problems like traffic congestion and overpopulation. The main objectives of this legislation are policy establishment of sustainable communities, land use zones, and urban planning.

6.7.3.2 Lagos State Transport Reform Law

This policy prioritises mobility through commuter comfort and safety. This supports the growth of LRT systems and stimulates private sector involvement in transportation services. Its purpose is to promote sustainable urban mobility, decrease environmental impact (cf. 5.7.2), and enhance traffic management. Lagos hopes to improve the quality of life for its resided communities and promote economic growth by creating a more accessible and effective transportation system. The regulations enforce commercial motorcycle operations, car registration, and traffic management. The policy seeks to improve the transportation system sector through accessible and efficient transportation systems (Otunola, Kriticos & Harman, 2019: 1-27).

6.7.3.3 Lagos State Bus Reform Initiative (BRI)

To improve public transportation in Lagos, the city implemented a state bus reform initiative (BRI) to provide an integrated, efficient, and high-capacity bus transit network. The policy aims to improve accessibility and decrease travel times in response to the city's ongoing traffic congestion and insufficient transportation infrastructure (cf. 5.5.5). The focus is on implementing public buses, bus lanes (infrastructure) and a centralised fare collection system (transportation hubs). This will encourage sustainability by using environmentally friendly transportation systems in comparison to SOVs. This policy aims to increase economic growth, lower pollution, and improve overall urban liveability in addition to enhancing mobility for millions of inhabitants within the city. The objective of this policy is to enhance public transportation through organised bus transit, building bus terminals, and introducing new buses (Otunola, Kriticos & Harman, 2019: 17-19).

Whilst Lagos is a developing city, its future initiatives are considered to be similar if not the same as the above case studies. Lagos's case study can be addressed through a comparative view illustrating the possible challenges (cf. 5.7) present if transportation systems are not efficiently planned within the urban structure. The city has demonstrated possible consequences based on inefficient implementation. The urban structure is similar to the above successful case studies (cf. 6.2, 6.3, 6.4), however, the lack of public transportation and policy has led to an over-populated urban structure with the need for mobility. The model demonstrates possible problems within the implementation of transportation systems and illustrates future initiatives already implemented within the above functioning case studies (Chapter 6).

6.8 BARCELONA (THE URBAN FABRICS MODEL)

Barcelona has created an integrated transport system (cf. 4.4.5) which balances effective land use with urban mobility, creating a sustainable and accessible urban. Barcelona has been illustrated in Annexure G for further analysis.

Barcelona is situated in Spain (Kyriakidou, et al, 2015: 260), a developed country (as are other case studies previously mentioned). Barcelona demonstrates a functioning urban structure of the previously assessed urban fabrics model (cf. 3.2.7). The city has implemented various strategies to reduce dependency on SOVs and encourages the use of public transport systems (BRT and trams [LRT], among others) as well as sustainable transportation, which includes bicycling and pedestrian-friendly infrastructure. The objectives and strategies involve the implementation of superblocks (grid street patterns) to increase urban space for cyclists and pedestrians. This will decrease air pollution and traffic congestion through alternative sustainable transportation. Barcelona has implemented various land use policies which prioritise mixed land-use (as illustrated in the above case studies). This will create sustainable communities with mixed land-use in commercial, residential, and recreational areas. This city’s objectives support decreasing GHG emissions (cf. 6.2-6.7) and improving quality of life while promoting sustainable modes of transportation.

6.8.1 Land use

Barcelona has implemented various land uses based on the mixed land-use concept. Barcelona has a variety of common land uses, which include residential, business districts (CBD), industrial, parks and other green areas (recreational areas), and historical or cultural landmarks (historical). The land uses are connected through an intricate multimodal transportation system. The city has implemented an advanced public transit network that consists of metro, BRT, and trams (LRT) (cf. 6.2, 6.3, and so on). The forms of transport systems increase accessibility to cultural and recreational land uses. The land uses are well-connected between residential, business districts, and industrial zones with distribution centres. Barcelona also has incorporated pedestrian-friendly streets and bicycle lanes, which promote the use of alternative modes of transport. The land uses are carefully planned to increase the efficiency of the transportation system and facilitate the transition between various land uses. The city's transportation network is essential for integrating and connecting each land use to create a functioning system. The below land uses have been implemented within Barcelona (Baro et al, 2014: 468-470; Lenormand et al, 2015: 4-10; Crosas Armengol et al, 2024: 1-18; Montero, Mejía-Dorantes & Barceló, 2024: 22-23):

- **Residential land use:** The residential land uses within the urban structure of Barcelona are segregated into two categories known as high-density residential zones and low-density residential zones. The high-density residential (compact development) land use illustrates the implementation of primary neighbourhoods, for example, referring to mixed-use land for housing, commercial, and public areas with facilities. The low-density residential zones are situated in suburban areas which offer less housing and an increase in green areas (recreational areas). The implemented strategy is designated for income groups from high-density apartments in the city centre (close to the workplace - middle-lower class residence) to lower-density neighbourhoods (higher class income groups) on the periphery (cf. 3.2.10). The area allows for mixed-use developments, which combine residential, retail, and commercial spaces;
- **Commercial and business districts land use:** The commercial land use or CBD is located in concentrated central areas (core) and is known as “Passeig de Gràcia” and “Diagonal Avenue”, with office spaces, retail, and hospitality facilities. The mixed-use developments are implemented within more recent neighbourhoods and may include residential, commercial, and leisure land uses. The commercial land use as illustrated in the above section may include areas for retail, offices, and business centres. Barcelona

includes various commercial zones and are clustered along major roads to create activity corridors;

- **Industrial land uses:** The implementation of industrial land uses is primarily located in neighbourhoods, for example, are designated for manufacturing, warehousing, and logistics. The modernised industrial zones are used to innovate technology and improve the urban structure through hubs and business parks. The industrial area is located on the city's outskirts, which differs from the case study of Chicago (cf. 6.3). The industrial area focuses on areas away from the CBD, which can prove problematic for the distribution of goods and services;
- **Public and institutional land uses:** Public and institutional land use can be referred to as government land use and is comprised of government buildings, educational institutions, hospitals, and cultural centres that are distributed city-wide but clustered in key areas. The land use zone is considered to be a public service from the governing authority to uphold service delivery to the resided community;
- **Green and recreational land uses:** The implementation of green and open spaces for recreational use includes providing parks and public squares. They offer accessible green space across the city. The waterfront is considered to be an area of recreational land use, which includes “Barceloneta” beach, recreational green zones and promenades. The city prioritises green spaces (cf. 3.2.1). The city’s superblocks (grid street pattern layout) initiative also creates pedestrian streets (pedestrian-only) and green areas to promote walkability and reduce vehicle congestion (cf. 5.7.3);
- **Transportation and infrastructure land use:** The implementation of transportation systems requires land use to implement various transportation components (cf. 5.5) to operate various modes of transportation. The implementation of road infrastructure is a common characteristic within the urban structure and has been implemented within Barcelona. The transportation land use includes major transport hubs, including Sants Station and El Prat Airport, for easy transition between transportation systems. The transportation systems' land use includes dedicated bicycle lanes, pedestrian streets, and public transit hubs to integrate sustainable transport with urban mobility (cf. 5.7.3);
- **Cultural and heritage land uses:** The historic and cultural land uses are based on the preservation of historical culture and are not used for future development, for example, the “Sagrada Familia”, “El Born” and the “Gothic Quarter”, are preserved under special zoning. This land use zoning is specifically to maintain architectural and cultural integrity. The land use areas preserve Barcelona’s architectural heritage, particularly in neighbourhoods. The strict regulations in these land use zones protect historic buildings and restrict new developments that could disrupt the character of the area; and

- **Waterfront and port zones:** The waterfront and port in Barcelona serves as an industrial and commercial port, with dedicated spaces for logistics, tourism, and leisure activities near the waterfront. This is due to the bodies of water nearby, as well as the use of trade. This has been identified in the previous case study of Lagos, Nigeria (cf. 6.7.2) and can be implemented based on priority as well as topography.

Barcelona has various mixed land-use zonings which are combined with the preservation of historical, recreational areas, industrial, commercial areas, transportation and government land uses to create an efficient urban landscape. The various land uses are connected with a multimodal transportation system, which increases functionality and efficiency of movement. Land use has been implemented according to the urban fabrics model (cf. 3.2.7) as seen in the Figure 6-14 below.

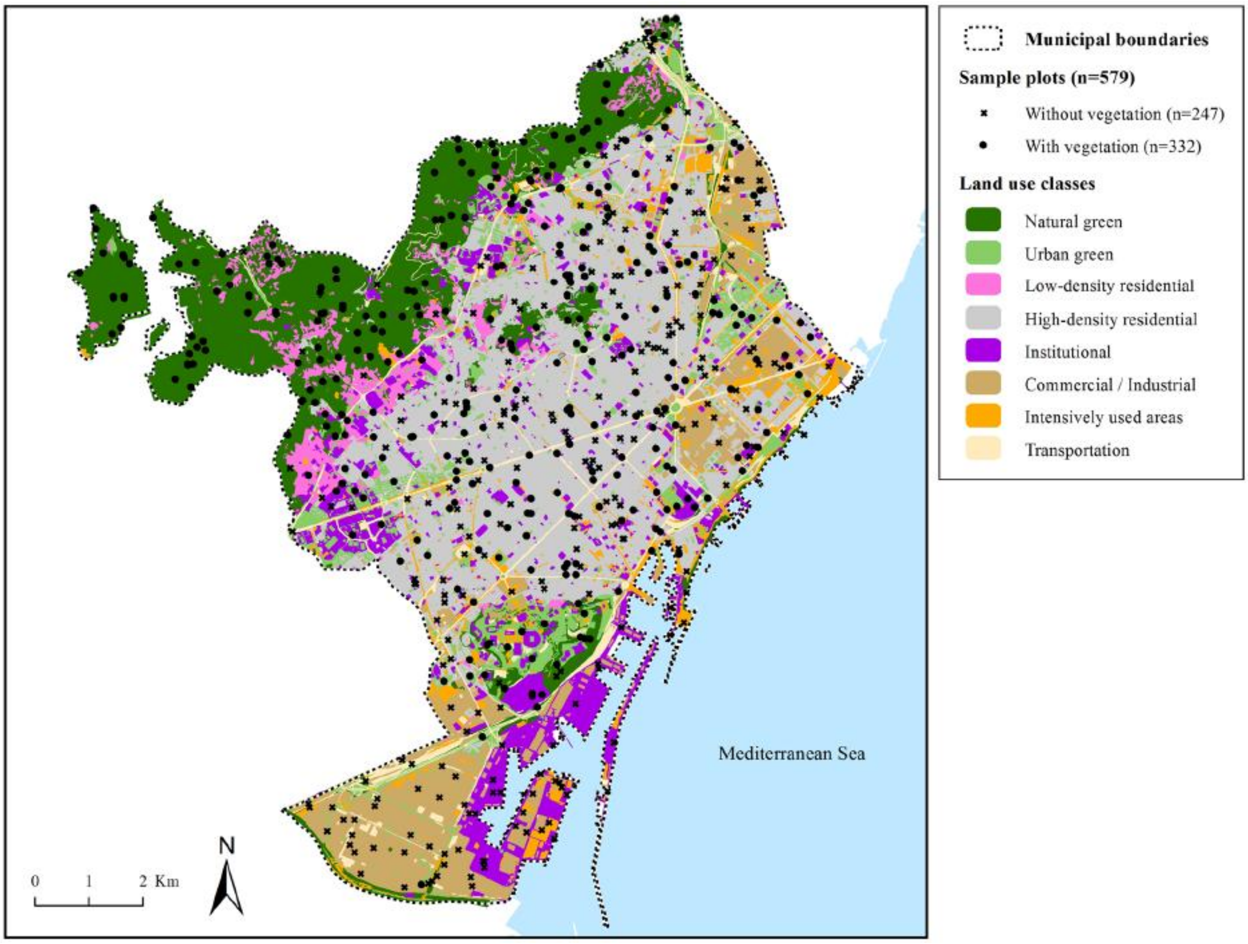


Figure 6 - 14 Land use within Barcelona

Source: Baro et al. (2014:469)

The above Figure 6-14 illustrates the planning of the urban structure regarding land use and connectivity. The centre has been delegated to the CBD and commercial land use, while the outskirts of the urban structure are used for industrial land use. The residential land use is situated in both high-density areas (CBD) and lower-density suburban areas, which are located closer to the outskirts. The high-density areas are used for lower-class individuals to decrease travel time and cost based on commuting between workplace and residential land use. The low-density areas are used for higher-class individuals who can afford to travel far and afford land based on previously illustrated urban models (cf. 3.2). The following subsection refers to Barcelona's modes of transportation based on the implemented transportation network.

6.8.2 Transportation networks

Barcelona has implemented a multimodal transportation system, as illustrated in TODs (cf. 5.8). The transportation systems are used by both locals and tourists. Barcelona has various transportation modes, which have been implemented into an effective transportation network (cf. 5.3) to improve transportation efficiency based on an ITLUP model (cf. 4.4.5). The transportation systems illustrate various options of mobility throughout the urban structure and consist of well-connected metro, buses (BRT), and trams (LRT). The implementation of both LRT and BRT transportation systems demonstrates multiple stations to increase accessibility for the residing community. The metro (rail transportation) is considered to be the transportation system's backbone, through all connected multimodal hubs. The implementation of an efficient public transportation system is to decrease reliance on SOVs and promote environmentally friendly transportation. Barcelona prioritises sustainable mobility and has incorporated an extensive bicycle-sharing strategy as illustrated in Chicago (cf. 6.3) and LA (cf. 6.4), which includes several bicycle lanes and pedestrian-friendly streets. The implementation of sustainable transportation will further enhance air quality and decrease traffic congestion. The city's future initiatives are to improve technological innovations within smart mobility strategies, which will include infrastructure for electric vehicles and its methods of decreasing emissions. The transportation systems have a similar approach towards the previously assessed developed country case studies, with the concept of sustainability demonstrated through the implementation of sustainable and public transportation systems (Aleta et al, 2017: 1-7; Jeong et al, 2023: 5-7; Montero, Mejía-Dorantes & Barceló, 2024: 13-16):

- **Metro (mass rail transportation):** The rail network is a dependable and effective choice for daily commuting due to its vast infrastructure network within the surrounding areas of Barcelona. The infrastructure consists of several metro stations (hubs) identified by their characteristic red diamond signage. The service is renowned for being dependable and on schedule due to its technological advancements (as illustrated in previous case studies). The mass rail system is considered to be of high frequency during peak hours and is operational and accessible;

- **Road infrastructure:** Barcelona has incorporated road transportation as a method to increase mobility. The increasing population and excessive use of SOVs have created congestion as illustrated in the above case studies. The implemented road infrastructure also accommodates for travel of goods and services through larger SOVs, while also being used for public transportation systems as illustrated in the above case studies. The use of roads and SOVs is considered to be a dominant transportation mode within all cities. The road infrastructure accommodates public transportation too, through the use of taxis and buses;
- **Pedestrian infrastructure:** Barcelona has various strategies for the implementation of pedestrian-friendly infrastructure. The implemented pedestrian infrastructure is of high value towards accessibility and walkability around the city. The wide pavements, large pedestrian zones and famous routes, for example, “La Rambla” and “Passeig de Gràcia” which are designed with foot traffic in mind are all part of the urban structure. The pedestrian infrastructure has been used to decrease SOV traffic and encourage safe, peaceful, and environmentally friendly pedestrian spaces (cf. 5.4.4). The city has also established superblocks, which are SOV-free or low-traffic regions. Barcelona's dedication to pedestrian safety (cf. 5.7.3) is demonstrated by numerous crosswalks, traffic-calming strategies, parks, and public squares;
- **Buses (BRT):** Barcelona has a vast bus network (BRT system) that connects places not immediately served by metro lines, which enhances the metro system (inter-modal connectivity). The most isolated communities within residential areas have access to public transit. This improves accessibility to all land uses and increases the efficiency of transportation systems. The transportation system is operational and can be accessible at any hour to provide efficient mobility. This can be identified in the above case studies;
- **Tram (LRT):** The LRT system is used to provide short-distance transportation for the residing community, The transportation system is used to access residential land uses as well as business areas which allows accessibility towards the CBD. The tram is used as a cost-efficient transportation system to commute to and from residential areas to work. This improves sustainable transportation as it decreases the use of SOVs within the urban structure. This indirectly decreases GHGs;
- **Bicycle-sharing:** The bicycle-sharing transportation system has been identified and illustrated in the above case studies (cf. 6.3, 6.4, 6.6), as a short-distance transportation system. The transportation system has been integrated with various transportation systems to improve multimodal transport. Bicycle-sharing is considered sustainable and illustrates several routes or types of infrastructure in which it can be used. The sustainable transportation system is made for short distances and provides a practical substitute for

motorised transportation, which helps to decrease pollution and traffic congestion (cf. 5.7). Barcelona's varied terrain and topography (hilly suburbs and a flat city centre) are accommodated by cycling both normal and electric bicycles. The transportation service has grown to be a crucial component of Barcelona's environmentally friendly transport system, enhancing its extensive public transport system; and

- **Electric scooters:** The implementation of electric scooters has greatly improved transportation systems through accessibility and an alternative towards SOVs. The use of electric scooters provides a flexible, effective, and environmentally responsible option for short-distance travel in the urban structure. The use of electric scooters requires the implementation of bike lanes to encourage shared mobility initiatives. The city illustrates possible problems with electric scooter implementation as it requires the same infrastructure as pedestrian transportation (cycling and walking) which creates pavement traffic and safety issues for both walkers and cyclists (cf. 5.7.3). The speed limits, parking lots, and stringent guidelines guarantee scooters are not a hazard in public locations as they are required to follow various rules and regulations that municipal authorities have put in place to solve these problems.

The implemented transportation systems are similar to the above-developed countries' case studies and future initiatives of developing countries that seek to improve transportation systems and enhance the efficiency of mobility. The Figure 6-15 below shows transportation implementation that is based on the connectivity between land uses within Barcelona's urban structure.

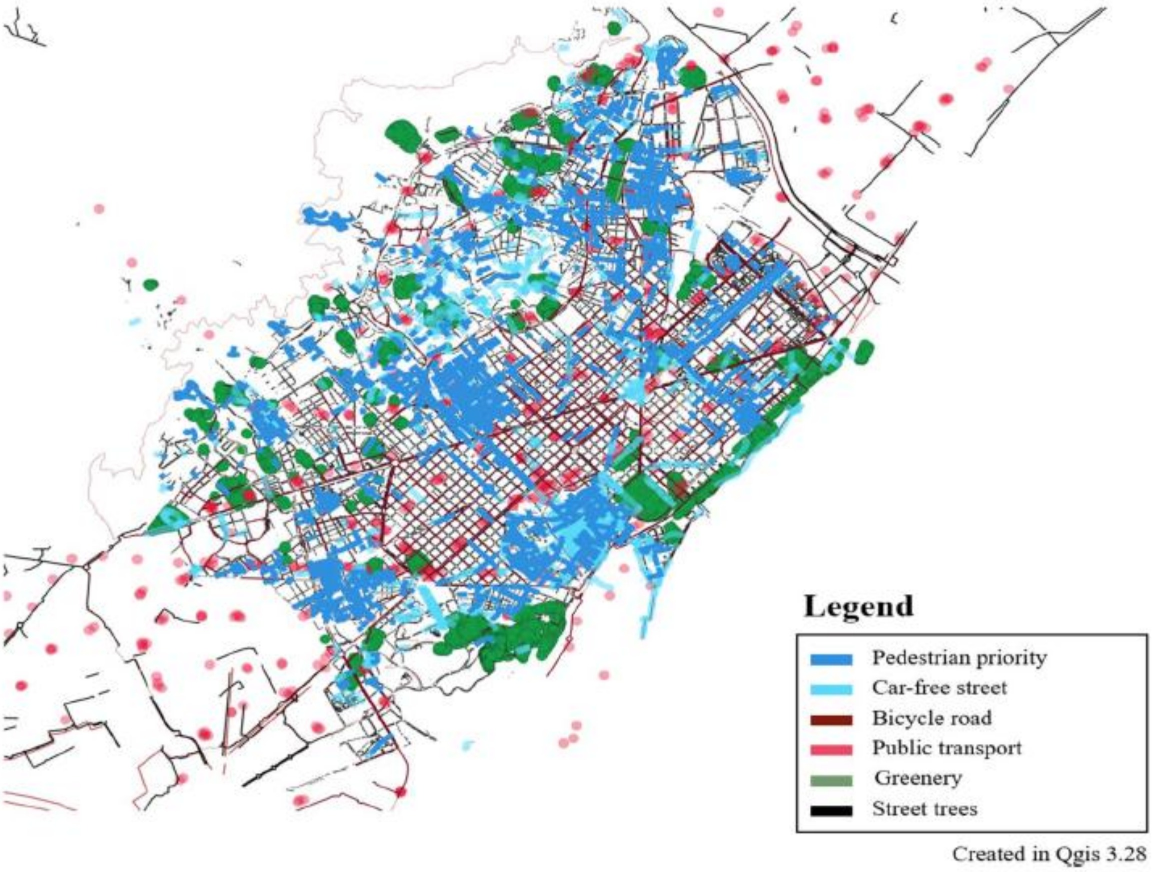


Figure 6 - 15 Transportation systems within Barcelona

Source: Jeong et al. (2023:6)

The above Figure 6-15 illustrates the transportation system implemented within Barcelona using the superblocks policy (discussed in the following sections). The implementation of these transportation systems is governed through policy and regulations to improve efficiency and functionality. Barcelona's policies and regulations guide transportation systems to improve transportation efficiency and connectivity of land uses (cf. 5.7.1). The following section illustrates Barcelona's policy implementation.

6.8.3 Spatial policy

The implementation of transportation systems demonstrates Barcelona's initiatives to enhance mobility and improve efficiency. The connectivity of land use is significant to a city's economic growth and future sustainability. The implementation of policy and regulations is significant to the functionality of a city's economic growth. The policies and regulations discussed below govern the rules and implementation strategy with an emphasis on sustainability, liveability and efficiency within the urban structure.

6.8.3.1 The Superblock Policy

Barcelona's Superblock Policy is an urban planning project designed to improve the quality of life, lower pollution, and promote social interaction (cf. 5.4.2) by reclaiming public space from automobile traffic. This policy, which is put into effect by combining nine city blocks into a single "superblock," prioritises pedestrians, cyclists, and green spaces on the inner streets while limiting traffic and permitting only local access at slower speeds (cf. 5.7.3). The strategy seeks to build safer, more liveable neighbourhoods with more public spaces, better air quality, and greater community involvement, to establish an example of sustainable, human-centred urban development. This involves restricting traffic on smaller roadways inside city blocks, establishing pedestrian-friendly areas, and encouraging alternate modes of transit (Nieuwenhuijsen et al, 2024: 2-9). The policy effectively reorganises traffic flow (cf. 4.3).

6.8.3.2 Bicycle Lane Network Expansion and Incorporation Policy

The objective of this policy is to increase cyclist safety and accessibility while enhancing sustainable urban mobility. The city's larger efforts to decrease air pollution, reduce traffic congestion (cf. 5.7.7), and promote a healthier environment include this ordinance. The expansion strategy seeks to build new bicycle lanes specifically for this purpose, connecting them to the city's current transportation system (inter-modal connectivity), and improving communication between important locations (cf. 4.4.5). The strategy places a high priority on secure, segregated pathways and supports public initiatives that promote cycling as a useful, environmentally responsible form of transport. These regulations ensure safer cycling routes and road share. Barcelona has implemented strategies to promote cycling as a sustainable mode of transportation that decreases dependency on SOVs and enhances a better urban environment (Winslow & Mont, 2019:6-10).

6.8.3.3 Green Spaces and Public Realm Enhancements Policy

The future initiatives of Barcelona's Green Spaces and Public Realm Enhancements Policy are to promote sustainable urban living, improve public areas, and increase urban greenery. The strategy will reduce the urban heat island effect and support ecological balance between urban areas and environmental areas. The policy involves the enlargement of parks, the establishment of green corridors, and improving biodiversity. The policy initiative will improve air quality and decrease emissions, while prioritising infrastructure that enhances pedestrian walkways, promotes cycling, and includes climate-resilient features. The incorporation of nature into the urban fabric (cf. 3.7), is an all-encompassing strategy that seeks to improve the quality of life for locals, encourage social interaction (cf. 5.4.2), and support public health (cf. 5.4.5). The policy indirectly improves the general quality of urban life and promotes walkability (Winslow & Mont, 2019:9-10).

6.8.3.3 Urban development and zoning laws

Barcelona's zoning and urban planning regulations emphasise sustainability and quality of life while striking a balance between urban development and historical preservation. The city promotes a compact city model that lessens the need for lengthy commutes by integrating residential, commercial, and public spaces through mixed-use zoning, which is part of its strategic urban plan. The regulations that preserve heritage assets while permitting innovative, controlled development in the surrounding areas are crucial for the preservation of famous architecture and historic districts (Domingo, Palka & Hersperger, 2021: 1-3; Jeong et al, 2023: 5-7). These priorities include pedestrian-friendly infrastructure and public green areas, which complement initiatives to reduce carbon emissions and promote environmentally friendly transportation (as illustrated in the above sections). To create more liveable and lively communities, Barcelona has put urban development laws in place that support mixed land-use, pedestrian-friendly neighbourhoods, and sustainable building techniques (demonstrated in the above sections and previously illustrated case studies).

6.8.3.4 Integrated Public Transport Policy

The Integrated Public Transport Policy is illustrated and demonstrates a multimodal inter-connected transportation system, which can be identified in TOD. This includes the implementation of multiple transportation hubs and stations to interlink different transportation systems. This will create a unified, effective, and sustainable mobility system that links several forms of transport, such as the metro, BRT, tram (LRT), and commuter trains and supports Barcelona's integrated public transport policy. The policy emphasises smooth intramodality and synchronised timetables (based on technological timeframes) to improve accessibility and lessen dependency on SOVs. The policy hopes to decrease carbon emissions and to expand the transportation network (increase accessibility), infrastructure modernisation, and environmentally friendly solutions (cf. 5.4.4). The use of electric and hybrid buses is considered to be a future initiative of the transportation system. The policy promotes Barcelona's objectives for sustainability and urban quality. The end goal of this policy refers to increasing efficiency within mobility systems and creating a sustainable urban structure which increases accessibility towards land uses.

The implementation of Barcelona’s policies demonstrates a similar initiative to the above-mentioned developed countries with an emphasis on sustainability and public transportation systems. The previous case studies illustrated significant components (cf. 5.5) of enhancing transportation systems and enhancing the urban structure. The explanatory process of the above-developed country may seem repetitive due to the same initiatives but illustrates the components required for sustainable living and improving the efficiency of transportation. Barcelona has demonstrated similar principles to Chicago (cf. 6.3), LA (cf. 6.4), SF (cf. 6.6) and some components that need improvement within Lagos (cf. 6.7). The following case study of Rome illustrates another developed country and the basic origin of connectivity.

6.9 ROME (THE MARCHETTI CONSTANT MODEL)

Rome is based on the implementation of urban structure which predates around two millennia. Rome demonstrates the implementation of the Marchetti Constant model (cf. 3.2.9), which is a more modern implementation of urban structures. Rome is one of the most famous cities in the world, and its urban structure illustrates how the city has evolved. Rome’s infrastructure had been influenced by the carefully planned and structured urban structure of ancient Rome. The city is located in the developed country of Italy and is renowned for its architectural knowledge and insight into spatial planning and connectivity. Rome's transportation system had been implemented with various types of streets, squares, and public structures. The famous saying “all roads lead to Rome” truly depicts the connectivity of Ancient Rome being superior to other urban structures. Rome is located in the developed country of Italy (Kyriakidou, et al, 2015: 260).

The network of roads and aqueducts that characterise ancient Roman urban planning is among its most enduring remnants. Rome illustrates an urban structure which had been connected to various surrounding urban structures and demonstrates a predated urban model of Christaller’s central place theory. Rome has been illustrated in Annexure H for further analysis. Rome can be considered one of the first TODs (cf. 5.8), which used transportation systems as a key growth strategy for economic benefit. The following subsections illustrate the city’s implementation of land uses and connectivity of transportation systems.

6.9.1 Land use

Rome is known as Italy's capital city with various types of land uses (as illustrated in previous case studies). Rome’s land uses share similarities to all the above case studies and demonstrate the SS of land use and accessibility. The purpose of this case study is to illustrate the necessary land uses implemented within the urban structure. Rome's land use had been implemented for many years and has illustrated relevance throughout all urban structures. The transportation system illustrates a well-thought-out intricate network which connects all land uses to produce a fully accessible, efficient transportation system. The land use discussed below may seem repetitive in comparison to the previous case studies analyses; however, it demonstrates the base of land use planning and connectivity throughout urban structures. The land use identified within

Rome can be considered as the following (Di Zio, Montanari & Staniscia, 2010: 87-89; Capotorti et al, 2015:3967; Bianchini et al, 2021: 2-3):

- **Sites of historical and cultural significance (historical land use):** Rome is renowned for its political (cf. 5.4.3), social (cf. 5.4.2), and commercial centre of the city. With an intricate combination of public areas, temples, monumental architecture, and forums like the Colosseum. The residential zones varied from dense insulae (blocks of apartments) for regular people to lavish noble estates. The historical land use focused on the preservation of churches and monasteries. This included the preservation of predated amid agricultural plots and disjointed neighbourhoods. The historical preservation of Rome is based on its rich historical background through the empire it once created. The land use is commonly used for tourists as well as preservation of the urban structure;
- **Residential regions (residential land use):** Rome is home to several residential neighbourhoods, each with a distinct personality and allure. Rome's residential land use is a combination of modern and historical developments, influenced by the city's long history and changing municipal regulations. Rome's rich architectural legacy is reflected in the densely populated, historic structures and apartments that define the city centre. The city's urban planning, which is limited by policies and laws (illustrated in the following sections) to preserve archaeological (historical land use) and cultural assets, compromises the future growth of residential areas. Rome had started to develop high-rise buildings to provide future accommodation towards the residing community;
- **Commercial land use (CBD):** A variety of retail, hospitality, and service-oriented businesses, which are located within the city centre (CBD) and offer significant business districts, define Rome's commercial land use. The commercial land use is accessible to both locals and tourists due to its historical centre. The commercial land use illustrates a balance between commercial development and cultural heritage preservation. The city's planning regulations make sure that new commercial strategies accommodate locals and tourists while enhancing Rome's ancient land use setting;
- **Institutional land use:** Rome's institutional and recreational land use is defined by a combination of modern, cultural, and historical areas that support both public interests as well as governmental functions. The institutional land use supports both government facilities and areas of public use. This can be identified in the different government buildings, embassies, and important administrative facilities. These land uses can be found near the city centre (CBD), the Vatican and Capitoline Hill. The institutional land use also accommodates various churches. Institutional land use is also often used for educational purposes, for example, universities and schools. Rome has several colleges, universities, and schools that contribute to the use of land for education;

- **Verdant areas (conservation areas/ parks and open spaces):** The city has a variety of green areas for individuals to use pedestrian transportation, including “Villa Borghese”, “Villa Doria Pamphili”, and the “Appian Way Regional” park. These parks are important locations for leisure and cultural activities, as are the “Tiber River” promenade and other public places. Rome also incorporates recreational spaces, for example, playgrounds, sports complexes, and bicycle lanes into its urban fabric (cf. 3.2.7) to encourage an active lifestyle while maintaining its historic sites. The use of parks and gardens identified as a prominent example of a large metropolitan park with green areas for leisure;
- **Hubs for transportation (transportation infrastructure/services land use):** The illustrated case studies mention the implementation of land use for transportation systems, which can include various train stations and terminal stations (hubs). Rome has various hubs to create an integrated transportation system and provide access to different transportation modes. The implementation of transportation systems requires various infrastructure, including roads, rail infrastructure, pedestrian infrastructure, stations and bicycle lanes. This has been shown in the above-mentioned case studies regarding integrated transportation models (cf. 4.4.5); and
- **Sectors of industry (industrial land use):** To reduce traffic in the city centre, Rome's industrial land use is focused in certain areas that are planned strategically on the periphery and close to important transportation hubs, including ports, highways, and railroads. Industrial land use has historically dominated the city's industrial areas. The focus has shifted to services, technology, and logistics, with previous industrial lands being renovated for residential and commercial use. The local government governs industrial zones through urban planning regulations that seek to enhance the balance between the demands of environmental sustainability (cf. 5.4.4) and economic development (cf. 5.4.1). The industrial zones in which regions are devoted to manufacturing and industrial operations. This has been illustrated in the previous land uses governing the above-assessed case studies.

It is crucial to remember that land use can range significantly among Rome's districts and neighbourhoods, and urban planning may change further in the future to meet the demands and problems of the city. The delineation of this land use area is seen in comparison to the above-analysed models, while land use has a generic criterion, Rome has multiple different land uses which are not under a single category. The land use placement of the urban structure demonstrates significant emphasis towards historical preservation and as previously mentioned, can affect the urban structure. This has been illustrated within the cities of Chicago (cf. 6.3) and Lagos (cf. 6.7) regarding topography and the use of water transportation. Generic land uses are illustrated along with more land uses, which have not been seen in the various case studies, in the Figure 6-16 below.

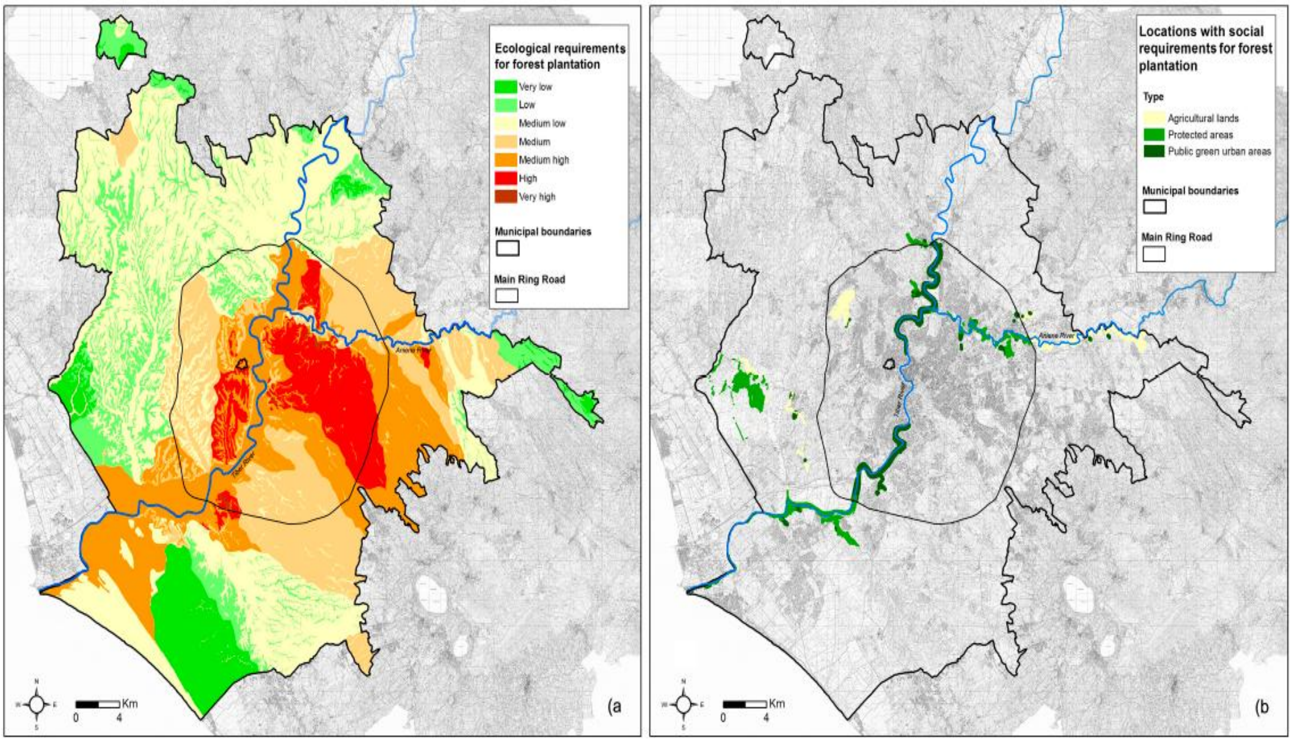


Figure 6 - 16 Land use within Rome

Source: Capotorti et al. (2015:3967)

The Figure 6-16 demonstrates a background to the implementation of land use and possible guidelines towards implementation. The types of land uses illustrated show a generic approach towards land use zoning, as seen in previous case studies. The connectivity of land use through the correct implementation of transportation will be assessed in the following subsection to possibly provide guidelines to improve the efficiency of transportation systems (cf. 5.7.1).

6.9.2 Transportation networks

Rome offers a range of transit options to meet the demands of locals and tourists. They consist of both private and public transportation options to improve the availability of transportation systems. Rome has a variety of transit options, including a vast transportation system of mixed transportation modes, such as buses, metro, trams, and commuter trains, aimed at facilitating movement within the city and its outskirts. The below analysis illustrates the implemented transportation systems under Rome's implementation plan (Gori, Nigro & Petrelli, 2012: 154-162; Serafini et al, 2018: 101-104):

- **Roads and highways:** The implementation of road infrastructure has been illustrated within the above land use section, demonstrating the required land use for implementation.

Rome has an ancient and modern past that has shaped its intricate road and highway system, which serves both local and urban traffic. The heavy traffic and maintenance issues cause challenges (cf. 5.7.7) for the city's road system. This further affects historical areas as illustrated within the land use section. The road system cannot be removed due to its historical background which contains protected landmarks and archaeological areas; and

- **Cycling and walking (pedestrian infrastructure):** Rome has expanded pedestrian zones and cycling infrastructure, though challenges (cf. 5.7.3) such as the city's historic landscape and hilly terrain hinder the broader adoption of cycling. The future initiatives are to create bicycle lanes and promote bicycle-sharing transportation systems. Certain initiatives are concentrated on improving walkability to encourage environmentally friendly (cf. 5.4.4), healthy, and effective urban transportation. Rome is progressively investing in connecting its bicycle lanes and incorporating bicycle-sharing systems to promote a culture of active mobility, this has been identified in the cities of Canberra (cf. 6.2), Chicago (cf. 6.3), LA (cf. 6.4), SF (cf. 6.6) and Barcelona (cf. 6.8).

The implementation of transportation systems has been based on public transportation systems, as per the illustration above. The roads and pedestrian transportation systems illustrate various uses. The implementation of rail transportation systems has been illustrated to be predominantly public transportation systems. The public transportation systems are vast and expand over the urban structure, which increases transportation efficiency and connectivity. The below transportation systems illustrate the public transport systems used within Rome (Ancora, Nelli & Petrelli, 2012: 1250-1259):

- **BRT:** The BRT system implemented within the city is significantly based on the preferred transportation mode used within Rome and is considered to be the backbone of public transport. The BRT system illustrates an extensive network covering almost all city areas and land uses. The BRT system faces challenges, for example, congestion (cf. 5.7.7) and delays, during peak hours. The BRT system has also implemented initiatives towards hybrid or electric buses, to decrease emissions and improve sustainable transportation systems. The BRT system has been implemented in the above case studies illustrating its relevance towards public transportation systems;
- **Metro (rail transportation):** An essential part of Rome's public transport system is the metro. The movement between central Rome and its residential land uses is increased through the system's three main lines, Line A (orange), Line B (blue) and Line C (green), which connect significant parts of the city. The transportation network has expanded, with Line C being the most recent addition intended to improve connectivity. Rome's vast bus (BRT) and tram (LRT) services are complemented by the metro system. This illustrates the

integrated transportation system (cf. 4.4.5) within the urban structure with efficient mobility to commute the congested road infrastructure of the city. The metro is considered to be an efficient public transportation service for locals and tourists. It also illustrates possible challenges (cf. 5.7.9) in future initiatives regarding population growth as well as possible maintenance problems, which may cause delays in transportation network expansion;

- **Trams (LRT):** The tram network in Rome, which is smaller than the BRT, expands primarily in the city centre. The trams are more efficient in congested areas, and there are plans to expand the network to support sustainable urban mobility. To provide effective urban mobility, Rome's LRT system, which is a component of its public transportation network, supplements buses, trams, and the metro (multimodal integration). The LRT system assists in reducing congestion by connecting outlying districts with central hubs. Rome's LRT decreases reliance on SOVs and connects with other public transport. This provides alternative mobility options through a single ticketing system. The LRT systems are smaller than the major metro systems. Rome’s LRT system is considered to connect various transportation systems and act as a link between intermodal transportation systems;
- **Commuter trains (external rail transportation):** The commuter train is a separate rail system used to connect residential areas to the CBD. The commuter train is a rail system like the metro and LRT but serves a different function. As mentioned, the LRT links various modes of transportation and the metro is used for long-distance public transportation. The commuter rail is specifically used to connect residential areas to the CBD. The commuter trains connect Rome to suburban and outlying regions, offering a vital link for daily commuters. The commuter rail increases connectivity to the metro system and is integrated into the city's public transport ticketing system. In linking suburban districts with the city centre, Rome's commuter rail system (known as “Ferrovie Urbane”) enhances the city's vast public transit infrastructure. These trains improve daily commutes and decrease traffic congestion by serving both main and outlying neighbourhoods. The transportation system seeks to increase frequency and reliability, encouraging more sustainable and effective mobility within the CBD area;
- **Electric scooters:** Rome offers a unique transportation system also illustrated in the previous case study (cf. 6.8) known as electric scooter transit. This future initiative shares a component of the city's larger initiatives to improve sustainable urban mobility and decrease pollution and SOV traffic. The transportation system is considered to be a flexible and environmentally sustainable alternative to conventional modes of transportation. (Nigro et al, 2022: 401-406). The electric scooters are widely used among both residents and visitors for short-distance travel. The electric scooter objective has been implemented by private companies and has expanded after implementation. Electric scooters may be

found and rented via smartphone apps, illustrating the technological advancements within the urban structure; and

- **Traghetti ferries (water transportation):** A lesser-known aspect of Rome's transit system, the Traghetti Ferries provide a distinctive means to cross the “Tiber” River. The water transportation system links significant locations along the river. This transportation system offers an alternative to the conventional land-based public transportation system and has been identified in previous case studies (cf. 6.3, 6.7, and so on). This enables locals and visitors to see the city from the water while avoiding traffic congestion on road infrastructure. The ferries have a smaller transportation system in comparison to the above buses and metros, but the transportation system improves the connectivity of the larger urban mobility system (Corsi, 2018: 157). The transportation system offers a sustainable mode of transit to improve environmental area and connectivity. It improves sustainable tourism and offers recreational opportunities that present Rome's historical and cultural landscape.

The above-illustrated transportation systems demonstrate a comparative approach towards implementing efficient transportation modes. Rome is no different than the previous case studies demonstrating the need for public transportation systems and innovative approaches towards mobility. It is important to note that all developed countries illustrated within the case studies thus far demonstrate the need for BRTs, LRTs, metros, and pedestrian-friendly infrastructure whilst reducing SOVs and other road transportation (cf. 5.7.3). Rome has provided an alternative approach towards TP (cf. 4.3) and how to increase flow (cf. 4.3) through the implementation of transportation and land use (cf. 5.6). The Figure 6-17 below illustrates a brief overview of Rome's transportation system implementation.

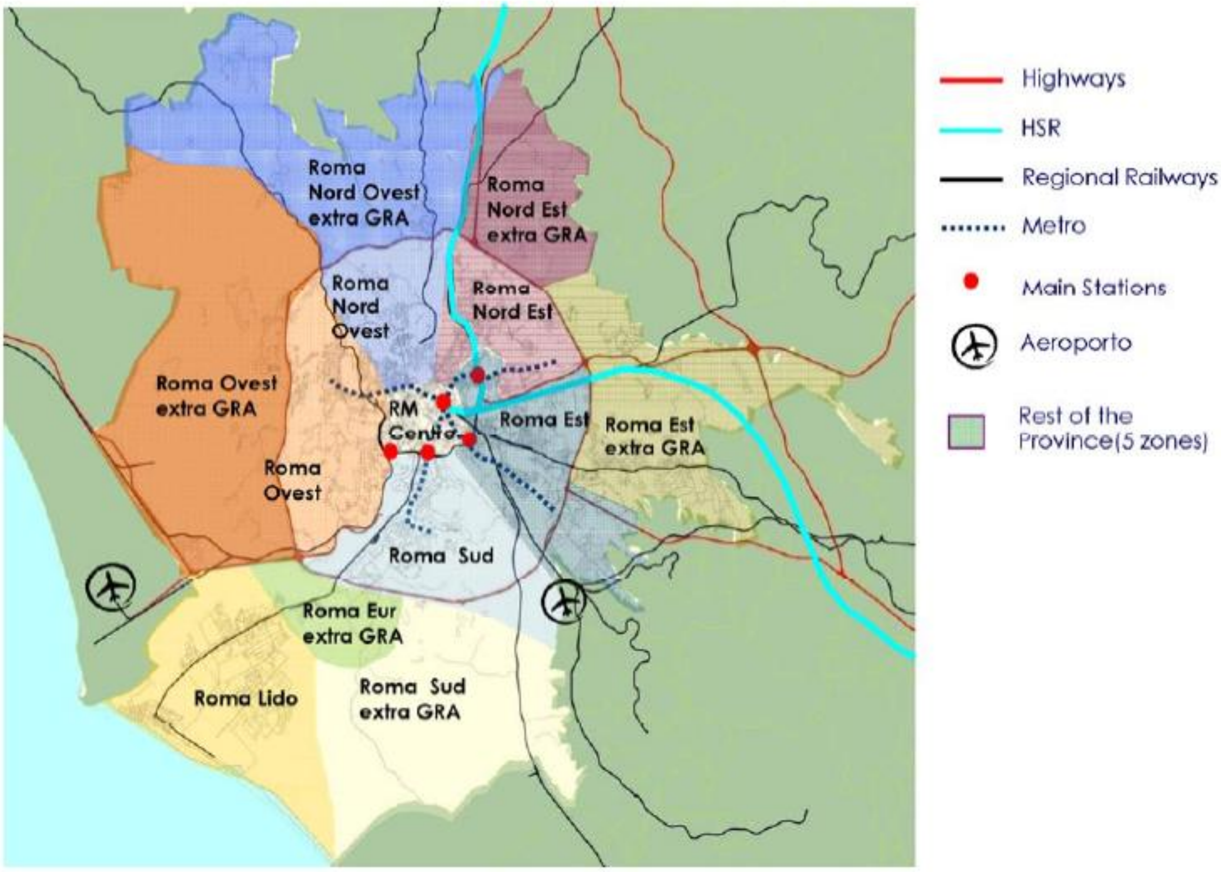


Figure 6 - 17 Transportation systems within Rome

Source: Ben-Akiva et al. (2010:5-6)

Figure 6-17 depicts Rome's implemented transportation strategy, providing an understanding of the placement of public transportation systems to improve the efficiency of mobility. The transportation systems and connectivity of land use are governed by policies based on the country's challenges. Rome has implemented several policies to govern land use management and improve the efficiency of transportation systems, as discussed in the next subsection.

6.9.3 Spatial policy

Rome's land use and transit policies are implemented to create a balance between the demands of contemporary urban development and the city's historical land use. This strategy addresses traffic congestion (cf. 5.7.7) and environmental issues (cf. 5.7.2). This involves the preservation of Rome's cultural landmarks by combining land use restrictions with sustainable transportation policies. The city's policies encourage bicycle routes, pedestrian-friendly areas, and public transportation choices while controlling the use of SOVs to decrease emissions and enhance air quality. The integration of transit hubs assists in integrating land use and transportation policy. This will increase accessibility and reduce reliance on SOVs. The future initiatives of these regulations are to establish a unified, effective, and sustainable urban structure with the inclusion of Rome's historical land use preservation. The policies discussed hereafter have been implemented to integrate land use and transportation systems within Rome’s urban structure.

6.9.3.1 Zoning ordinances

Zoning ordinances have been illustrated in the above case studies and demonstrate a guideline towards the alignment of land use regulations. Rome's zoning laws are intended to control urban growth while protecting the city's historical land use and encouraging sustainable development. The various land uses, for example, residential, commercial, industrial, and historic zones are created by the law, and each has its own set of laws which delegate building heights, land use, and architectural standards. To preserve historic sites and the city's traditional identity, strict regulations are enforced in areas of cultural and historical significance (as previously mentioned). To improve liveability, the policy also includes public facilities and green areas. The current initiatives focus on a balance between heritage protection and contemporary urban demands. This encourages development and historical preservation to coexist together. The land use zoning policies aid in the designation of particular regions for various land uses, including commercial, industrial, residential, and recreational zones.

6.9.3.2 Preservation of historic sites

Rome's historical sites are preserved through a complex process that aims to balance the city's rich cultural legacy with contemporary urban demands. The policy is used as a method to control the effects of tourism, minimise environmental harm (cf. 5.7.2), and solve structural weaknesses. The preservation techniques are further enhanced by cooperative efforts with international organisations and institutions. The historical and cultural legacy of Rome, laws and policies have been put in place to preserve historic structures, sites, and neighbourhoods. The policy governs the development of infrastructure and land use to preserve areas of significance.

6.9.3.3 Transportation policy

In the city's historic and congested metropolitan area, transport policy planning prioritises enhancing mobility, sustainability, and lowering traffic congestion. The city's strategy involves incorporating innovative modes of transportation, for example, bicycle sharing and electric scooters while also growing public transportation networks such as the metro, buses, and trams (as illustrated). The effective transfers and a single ticketing system, attempts are made to improve connectivity across various transit networks. The establishment of low-emission zones to reduce air pollution, decrease SOVs, as well as the creation of pedestrian zones to decrease SOV traffic in central locations. Rome's planning places a high priority on environmental sustainability and strives to move towards greener and more accessible transportation solutions (Nigro et al, 2022: 401-406).

6.9.3.4 Environmental policy

The policy governing the environmental aspects of the urban structure is implemented to promote sustainability, decrease pollution, and improve the standard of living for communities. The main objectives of Rome's environmental policy planning are to lower automobile (SOV) emissions and promote environmentally friendly (cf. 5.4.4) modes of transportation, for example, cycling, electric cars, and public transportation to enhance air quality. Rome also places a high priority on green areas, working to expand parks and urban greenery. Waste management plans are also implemented, aiming to reduce landfill usage and enhance recycling rates. The green initiatives and policies surrounding environmental sustainability are growing in significance. The promotion of green spaces, pedestrian-friendly zones, and environmentally friendly transit choices are a few possible initiatives.

6.9.3.5 Improvement of public transportation policy

Rome's transport policy is being improved with an emphasis on increasing mobility efficiency, decreasing traffic, and encouraging sustainability. The significance of the policy is to enhance bus services (BRT), implement eco-friendly options such as electric buses, and grow the metro and tram (LRT) networks. To promote NMT, the city has also concentrated on creating bicycle infrastructure and pedestrian-friendly areas. The objective of integrating different forms of transport through enhanced connectivity is to make city travel more efficient. Traffic is being reduced, and air quality is being improved. The implementation of public transport networks including buses, trams, and metro lines may be the subject of policies aimed at enhancing and growing. The initiative is to decrease reliance on SOVs by giving locals access to dependable and efficient transit options.

6.10 ANTIGO (THE THEORY OF AGRICULTURAL LAND-USE MODEL)

Antigo is located within the developed country of the USA (Kyriakidou, et al, 2015: 260) and serves as the county seat for Langlade County. The city illustrates the theory of the agricultural land-use model (cf. 3.2.10) and is comprised of different land uses which are surrounded by recreational areas, parks and green spaces. Antigo incorporates environmental and urban development while promoting a sustainably functioning city. This incorporates various modes of transportation systems and land uses which function together through efficient and sustainable initiatives. The city illustrates a more predated urban model which focuses on farming; the city is known for its lumber as well as its rich soils and prosperous farming land.

The case study will demonstrate the various land use and transportation implementation strategies to determine the efficiency of the urban structure. The SS has been comprised of various land uses which are connected to a transportation system, forming a functioning urban structure. The case study analysis will address both components (cf. 5.5) individually to determine guidelines towards land use planning and improving the efficiency of transportation systems. The following subsection will address the types of land use implemented within Antigo to apply a comparative analysis between the above case studies. This will be followed by the types of transportation systems applied within this developed city.

6.10.1 Land use

Antigo is a well-known farming community that shares all the same or similar traits to each above-mentioned urban model as well as illustrated case studies. It is significant to understand that the criteria of urban planning are based on a similar concept of land differentiation. The background of each city demonstrates the need for the below-mentioned and generic listing of various land uses; however, the differentiation is demonstrated in the structuring of land connectivity as well as the placement of various land uses.

Antigo expanded its economy by introducing manufacturing, services, and agriculture in response to the demise of the timber industry. It is still a thriving community today, with a variety of sectors supporting its economy. Antigo has a mix of residential, commercial, and industrial zones when it comes to land use. The land uses below are applied in Antigo and are illustrated in the urban design in Annexure I (MSA, 2004: 133 (H1)- 139 (h-7); Chi & Marcouiller, 2013: 868):

- **Residential land use:** The residential land use consists of the residing community which is majority single-family dwellings. A variety of residential land use zoning types are used to support both low-density suburban areas and higher-density residential developments (apartment buildings within the city centre). The urban structure of the city is comprised of both traditional neighbourhoods and compact housing alternatives around the CBD centre. The residential area also consists of various parks, green spaces, and necessary facilities such as local services and schools that support residential areas. The residential area is used to support the residing community and incorporates a sustainable perspective towards urban structures (MSA, 2004: 133);
- **Commercial land use (CBD):** The main purpose of commercial land use in Antigo is to promote neighbourhood companies, shops, and service sectors that meet the requirements of both locals and tourists. The city's CBD (commercial zones) also extends along main roads (activity corridors), where the local economy is supported by larger retail establishments, hotels, and industrial facilities. The land use zoning regulations that permit businesses, restaurants, retail establishments, and other commercial activity are located in commercial land use areas. The locations are along major roadways and highways or near CBD areas. This means that the CBD uses activity corridors (transportation systems) to generate economic benefits (MSA, 2004: 134);

- **Industrial land use:** To enable the effective movement of commodities, the city's industrial zones are positioned near major transportation networks, for example, highways and railroads. The focus is on providing small and medium-sized businesses space to support a variety of regional and local firms. Certain land use regulations enforce industrial land uses to comply with zoning restrictions to balance economic development with the preservation of residential and recreational areas. The city promotes economic (cf. 5.4.1) expansion and job creation while preserving a sustainable and balanced environment for everybody. The industrial land use as per previous case studies incorporates manufacturing, warehousing, and other industrial operations. The associated urban model (cf. 3.2.10) illustrates that, due to noise, pollution, and other aspects related to industrial operations, these locations are frequently situated at a distance from residential and commercial land use areas to preserve land use value (MSA, 2004: 134-135);
- **Institutional land use:** In Antigo, the main objective of institutional land use is to support community needs, education, and public services. The city's social and civic infrastructure depends heavily on key institutional land uses, including government buildings, healthcare facilities, religious institutions, and public schools. The schools and healthcare institutions are implemented close to residential areas, to ensure that these locations are easily accessible to locals. The land uses are controlled by the city's zoning regulations (as illustrated in the following sections) to preserve the community's sustainable standard of living. The initiatives illustrate the preservation of green areas while promoting mixed-use construction that satisfies institutional and residential requirements (MSA, 2004: 135);
- **Recreational land use:** The main objective of Antigo's recreational land use is to provide locals with easily accessible parks and open spaces for various activities. The recreation area will be situated near residential land uses (Antigo City Park and the neighbouring Hodag Park). The city's sustainable initiatives help to preserve natural areas and also encourage pedestrian cycling and walkability. The city places a strong emphasis on developing sustainable communities which involve parks and other open spaces utilised for leisure to improve the general well-being of its citizens (MSA, 2004: 135);
- **Mixed-land use**: The objective regarding mixed land-use within Antigo is to develop a more lively and integrated urban setting that can accommodate both residential and commercial demands. The policy emphasises walkability, decreases the need for long-distance commutes, and strengthens the sense of community by integrating residential neighbourhoods with public, commercial, and recreational spaces. This strategy promotes economic growth (cf. 5.4.1) by allowing companies to expand in residential areas, which can improve resident convenience and increase local economies. The types of developments incorporate several different land uses into one space or urban structure to

ensure a sustainable and aesthetically urban structure that improves quality of life. This encourages the use of short-distance travel while eliminating the need for long commutes towards the CBD; and

- **Agricultural land use:** In Antigo, agricultural land use is significant to the local economy and creates a sense of place. The surrounding area supports a variety of agricultural pursuits, including grain cultivation, dairy production, and potato growing. Antigo is a major contributor to the state's/municipality's agricultural output. Antigo maintains soil health and water quality while promoting both environmental (cf. 5.4.4) and economic viability (cf. 5.4.1), to incorporate sustainable methods. The agricultural land use is illustrated in most urban models (cf. 3.2) and represents crop cultivation, cattle grazing, orchards, and other agricultural operations. The areas are considered to be rural residential settlements and are essential for the production of food (MSA, 2004: 135-137).

In conclusion, Antigo's strategic land use implementation prioritises agricultural output and complements urban development, demonstrating the city's promotion and maintenance of its economic foundation while expanding development along activity corridors. The city can improve accessibility and promote economic interaction (cf. 5.4.1) by incorporating activity corridors, which link important commercial, residential, and agricultural sectors. The corridors improve economic prospects for nearby farmers and companies by facilitating the movement of people, products, and services. In addition to maximising land use efficiency, this strategy develops connected areas that increase the local economy and enhance Antigo residents' quality of life in general. The Figure 6-18 below illustrates the implementation of land use within the urban structure to promote economic development and enhance sustainable development.

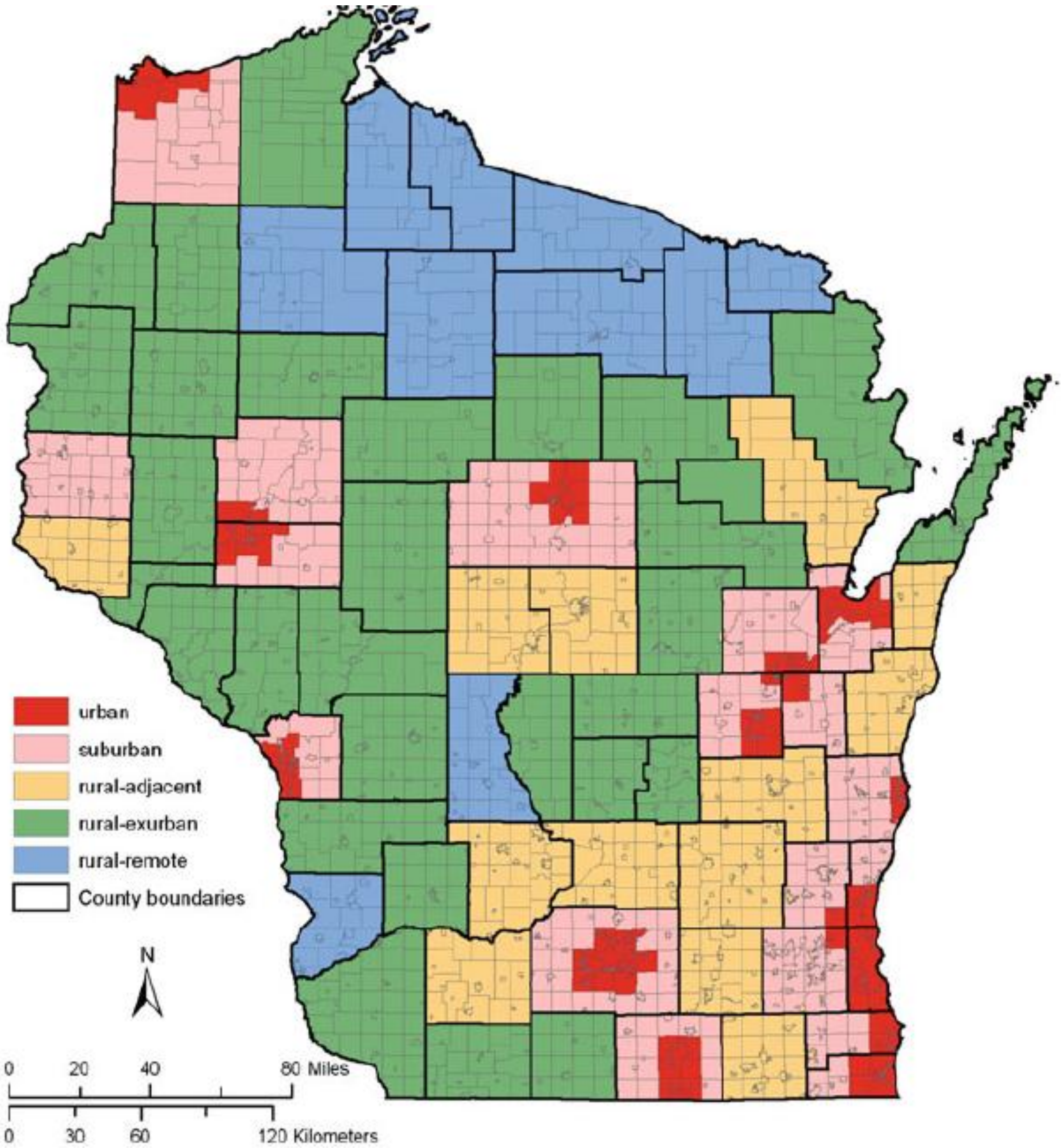


Figure 6 - 18 Land use of Wisconsin, USA

Source: Chi & Marcouiller (2013:868)

The Figure 6-18 depicts the implementation of Antigo based on increasing land value. The urban structure illustrates accessibility between land uses and large corridors to improve economic development and efficiency of transportation systems. The following subsection addresses the types of transportation systems implemented within the urban structure.

6.10.2 Transportation networks

Antigo has a multitude of transportation networks (cf. 4.2), which all connect within the urban structure. The efficiency of the networks may be evaluated based on their connectivity between various land uses. The city also illustrates a generic transportation network as illustrated in the above case studies. The planning of these transportation networks (cf. 4.2) is seen in multiple developed countries and may be seen as superior based on first sight. The below transportation networks have been implemented in Antigo (MSA, 2004: 102 (D1)- 110 (D8); Ben-Akiva et al., 2010:1-6):

- **Road system:** Antigo has implemented road systems which support both local and regional transportation by connecting its urban centre (CBD) with the surrounding rural and agricultural areas. The highways facilitate the movement of goods to bigger markets which are vital connections for local companies, inhabitants, and agricultural transportation. The use of activity corridors is facilitated within the implementation of road systems. The road system illustrates a grid-pattern network in Antigo's CBD areas to improve accessibility. The road network connects the city's commercial, residential, and agricultural sectors to promote community mobility and economic (cf. 5.4.1) prosperity. Antigo is connected to neighbouring cities and towns by a system of highways and roads. This comprises municipal and state highways that facilitate SOV transportation both inside cities and to other locations. The public transportation systems use the road infrastructure to operate. The public transportation systems are limited within the urban structure and use bus services and taxis. The implementation of transportation systems within Antigo is limited in comparison to the previously assessed case studies (cf. 6.2-6.9). The implementation of public transportation systems has been included in road infrastructure. The public transportation services available are buses and taxis. The source of transportation is confined to road infrastructure, for example, SOVs, which can prove to be problematic based on the above case study analysis. This can cause possible congestion and inefficiency of transportation systems;
- **Public transportation:** Antigo has comparatively little public transit (in comparison to the above case studies). There are few public transport options, for example, demand-response services and special transport for the elderly and disabled are considered to be public transport systems. The public transportation system available to the community is the bus system, other than that there is a reference to SOVs. The local government seeks various initiatives to improve the connection of nodes for transportation efficiency;
- **Bicycle routes/lanes:** An increasing component of Antigo's transportation and sustainability initiatives is bicycle transportation. Antigo has implemented infrastructure to encourage cycling as a practical and environmentally sustainable form of transportation. The implementation of bicycle lanes, shared-use (walkability) pathways, and connections to parks and residential areas are among the initiatives. The objective of integrating bicycle paths is to improve convenience and safety for commuters as well as recreational cyclists.

Promoting bicycle transportation helps to reduce emissions, decrease traffic, and promote active, healthy lifestyles (cf. 5.4.5). Antigo may have the necessary infrastructure to encourage riding for leisure or as a mode of transportation;

- **Walking:** In Antigo, walking is considered to be a popular form of transportation which enhances the area's accessibility and sense of community. The land use is situated in close proximity (as illustrated in the above section), whereby residents could walk to schools, parks, local stores, and community centres. The city's compact urban structure encourages pedestrian-friendly streets. The implementation of sidewalks and crosswalks contributes to safe walking routes. These improvements create safer pathways, lighting, and pedestrian crossings may further promote walking as a primary method of transportation. This promotes a healthy way of living (cf. 5.4.5), and walkability, and decreases dependency on SOVs, which encourages environmental sustainability (cf. 5.4.4). Antigo seeks to improve a connected and economically (cf. 5.4.1) viable community by extending the pedestrian infrastructure and connecting it with public areas and activity corridors; and
- **Rail Transportation:** The rail transport within Antigo is limited but plays an important role in supporting the local economy, particularly agriculture and industry. The city has historically been connected by freight rail lines that facilitate the transport of goods such as potatoes and other agricultural products, linking Antigo to larger markets and distribution networks. There is no significant passenger rail service within Antigo, the existing rail infrastructure contributes to the efficient movement of bulk commodities, which is vital for the region's economic (cf. 5.4.1) health. The rail lines help reduce reliance on long-haul trucking, reduce road congestion, and minimise environmental impact (cf. 5.7.7). Efforts to maintain and potentially expand rail connectivity could further support economic growth and regional integration (MSA, 2004: 107 (D6))

The above-illustrated transportation systems illustrate that Antigo has not focused on public transportation systems (BRT or LRT) but rather on close land use planning and the implementation of activity corridors to improve economic benefit throughout the urban structure. The lack of public transportation systems may cause possible congestion on corridors, which creates inefficiency and decreases economic benefit throughout the SS. The concept of Antigo’s transportation system is to implement land uses within walking distance, to decrease the reliance on SOVs. The following subsection illustrates the policy implementation within Antigo, which governs land use and transportation systems throughout the urban structure.

6.10.3 Spatial policy

Antigo's land use and transportation policies are intended to balance commercial, residential, and agricultural development while enhancing connectivity and economic (cf. 5.4.1) sectors. The regulations seek to protect the city's strong agricultural background (cf. 3.2.10). The land use policies promote development that balances the protection of agricultural land use through urban growth. The transportation initiatives promote effective transit systems (walkability/cycling) while activity corridors improve connectivity to various land uses. This strategy promotes accessible mobility, encourages sustainable development, and increases economic (cf. 5.4.1) prospects for both the residing community as well as enterprises. The policies discussed hereafter have been implemented to improve mobility and implementation of land uses within the city.

6.10.3.1 Zoning regulations

The city's zoning regulations are identified in the above case studies and refer to land divided into many districts under the city's zoning code, including residential, commercial, industrial, and agricultural zones. The zoning has its own set of regulations surrounding building kinds, height restrictions, setbacks, and activities that are allowed. The regulations aim to preserve property values and advance public health (cf. 5.4.5) and safety. Antigo incorporates overlay districts for particular uses, including floodplain control, in addition to regular zoning, to handle particular environmental (cf. 5.7.2) or developmental issues. The regulations govern how land can be used, separating areas designated for residential, commercial, industrial, and agricultural purposes. This helps maintain the rural character of the area while supporting sustainable urban development (Chi & Marcouiller, 2013: 868).

6.10.3.2 Comprehensive planning

The planning process incorporates land use, infrastructure, housing, transportation, and environmental factors. The objective is to improve public services including water, trash management, and transportation, as well as to revitalise the CBD or older developments while increasing green areas. The comprehensive plan hopes to promote economic (cf. 5.4.1) growth through improved accessibility and connection throughout the city. This policy places a strong emphasis on inclusiveness, long-term resilience, and prudent resource management. Antigo's comprehensive plan outlines the long-term vision for land use and infrastructure development. This includes preserving farmland, guiding residential and commercial expansion, and ensuring that growth aligns with community goals and environmental sustainability (MSA, 2004: 2-44).

6.10.3.3 Agricultural preservation policies

Antigo has agricultural preservation ordinances in place to assist local farmers and preserve the area's rural culture. The policy limits urban growth (as illustrated in the garden city’s greenbelt) and non-agricultural development in strategic agricultural areas. The strategies aim to preserve agricultural land use for future generations. The policy also provides incentives to participate in conservation initiatives or continue to utilise their land for agricultural land use. The city promotes sustainable farming methods as illustrated in the urban models (cf. 3.2.10). Antigo also supports community agriculture initiatives and local farmers' markets, which help to preserve agricultural history, sustain a thriving farming economy and preserve natural resources. Specific measures are put in place to protect farmland from being overtaken by urban sprawl.

6.10.3.4 Activity corridors development

The implementation of activity corridors in Antigo is intended to promote sustainable urban expansion, improve transportation systems, and increase economic (cf. 5.4.1) vibrancy. These corridors are created to connect important commercial, residential, and industrial sectors to facilitate the effective movement of people and commodities. The regulations prioritise mixed-use development, emphasising the integration of green infrastructure, walkable areas, and better public transportation alternatives. The activity corridors' main priority is to support a more accessible, sustainable urban environment, encourage local businesses, and reduce traffic congestion. These activity corridors are planned routes that facilitate connectivity between key areas, such as CBD, industrial zones, and agricultural sectors. They aim to enhance the economic vitality of the city by enabling efficient transport of goods and services while promoting access to local businesses (illustrated within the central place theory in Chapter 4).

6.10.3.5 Sustainability initiatives

Antigo has several sustainable strategies aimed at protecting the environment and improving green areas. The city's urban forestry policy places a high priority on planting trees, maintaining the urban canopy, and providing care, which is a crucial part of these initiatives. Antigo incorporates sustainability principles in its transportation and land use policies to reduce environmental impact (cf. 5.7.2). This includes promoting the use of eco-friendly vehicles, bicycle lanes, and pedestrian pathways to encourage NMT (MSA, 2004: 109-110).

Antigo’s policy implementation illustrates a compact urban structure with closely planned land uses. The implementation of transportation systems is lacking due to little reliance on long-distance travel. The city has incorporated road infrastructure which governs SOVs and general public transportation systems, for example, taxis and buses. The city has implemented sustainable transportation systems which are reliant on walkability and cycling to promote healthier lifestyles (cf. 5.4.5). The above case studies illustrate that possible traffic congestion can occur with limited transportation systems and reliance towards SOVs. The city's urban structure is considered to be small and compact, which allows for accessibility throughout the urban structure. The city has implemented preservation policies for agricultural land and promotes green areas. The economic aspect of the city is funded through activity corridors but may be compromised by congestion with future growth. The rail transportation system is used for freight and does not allow passengers. The city has illustrated possible guidelines as well as prevention methods of implementation. The last case study represents a compact urban structure within a developing country, which has incorporated developed country initiatives regarding land use and transportation systems.

6.11 CAPE TOWN (CPT) (APARTHEID CITY MODEL)

CPT has several spatial characteristics that make it superior in how it implements different means of mobility in SS. CPT is based on the apartheid city model (cf. 3.2.8). The city's location is one of several elements that affect spatial growth, and it is referred to as the city's SS (Pacione, 2005:786-790; Rodrigue *et al.*, 2006:87-89). The analysis of CPT is based on the density of the development; due to the restricted amount of land it had to develop on, CPT is near numerous areas/land uses. As a result, the city became more compact, which improved the effectiveness of the transit system (Wilkinson, 2006:222-225). The small city's level of efficiency in multiple land uses has led to associations with TOD. CPT was intended to serve as a centre for international sea transportation rather than as a highly productive city. This meant that it could go by water to other nations and exchange a variety of goods and services, and it was principally recognised for its renowned port. CPT's compact layout was created in response to the constrained amount of land that could be developed. CPT has been illustrated in Annexure J for further analysis.

6.11.1 Land use

As one of South Africa's most effective cities, CPT has developed to meet the country's ongoing need for commodities and supplies thanks to its ports and trade. The spatial organisation of CPT, as seen in the Figure 6-19 below, is what has contributed to its efficiency. It reveals a tightly packed physical layout that reflects a perspective akin to Johannesburg. The coastline on either side of the city prevents further expansion. It must consequently look for alternative means of development. Local towns, marketplaces, services, and companies are located close to one another as a result of this circumstance. This kind of SS ideology permits swift entry and exit from numerous land uses. The following land uses have been implemented within CPT under the zoning ordinance applied (Tamuka Moyo & Zuidgeest , 2018:521-522):

- **Residential land use:** CPT has various types of residential land uses. This includes an expansive suburban development to compact urban neighbourhoods. The outlying neighbourhoods, for example, "Claremont" and "Sea Point" offer single-family homes, townhouses and contemporary flats. This is considered to be the higher-class income group and is illustrated in the urban models (cf. 3.2.1, 3.2.2). The city's centre, including the "City Bowl" and inner-city neighbourhoods, has older apartment complexes and traditional dwellings and is based on middle-class income groups. The city's urban problems are exacerbated by the expansion of informal settlements, for example, “Khayelitsha” and “Nyanga”, which occupy a sizable amount of residential land and are used for lower-class income groups;

- **The CBD:** The CBD as in all the above case studies illustrates the commercial and retail areas. The land use is occupied by office buildings, shopping centres, and retail establishments. The Waterfront is a popular tourist destination that provides a variety of dining, shopping, and leisure options. The city's commercial zones are intended to support trade, services, and tourism. Land use is used to increase economic activity (cf. 5.4.1) as illustrated in previous case studies and within the urban model’s section (cf. 3.2);
- **Industrial land use:** The industrial land use zone is mostly found on the city's outskirts (cf. 3.2.9) and is used for manufacturing, warehousing, and logistical activities which take place in the areas known as “Paarden Eiland”, “Epping”, and “Blackheath”. The city's industrial land use and transportation infrastructure (cf. 5.5.5) allow for easy access to the CBD district for goods distribution. Sustainable initiatives and industrial land use are becoming more intertwined, emphasising green technologies and industries;
- **Agricultural land use:** The land surrounding CPT is used for agricultural land use. The agricultural land surrounds the urban structure as identified in various case studies and within the garden city urban model (cf. 3.2.1). The agricultural land use is responsible for the production of natural raw resources as illustrated in the previous case study of Antigo (cf. 6.10). This is a major contributor to the city's economy and exports; for example, CPT's agricultural land is essential to the region's wine industry as well as local food production;
- **Public and recreational land use:** The implementation of open spaces, parks, and nature reserves are essential parts of CPT's urban structure. The implementation of recreational options is offered to both locals and tourists in major natural reserves, for example, Table Mountain National Park. The coastline also places a high priority on green areas, including well-known beaches like “Camps Bay” and “Clifton”, which both have recreational and environmental (cf. 5.4.4) purposes. The conservation of the fynbos is also illustrated as a preservation strategy towards the implementation of green area conservation; and
- **Road and transport infrastructure land use:** The implementation of transportation infrastructure (cf. 5.5.5) is a common land use within all the above case studies. The implementation of roads, railroads, airports, and ports are examples of land set aside for transportation infrastructure. The different land uses, for example residential, business and industrial districts, are vitally connected by the city's vast road network and public transit services, which include the “MyCiTi” bus service and train lines. This improves the connectivity and efficiency of transportation systems.

The implementation of the above land uses illustrates a common component of land use throughout all case studies. This demonstrates the similarity in land use type implementation alongside the significant land uses and the purpose they serve towards the urban structure, regardless of a city's "developing" or "developed" nature. The following Figure 6-19 shows the land use placement.

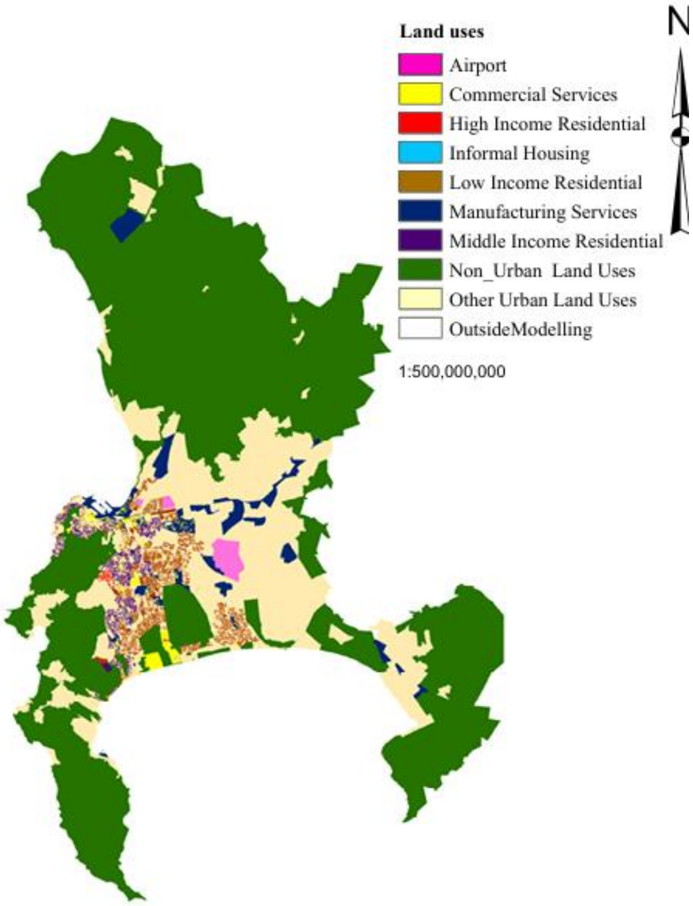


Figure 6 - 19 Land use development throughout CPT

Source: Tamuka Moyo & Zuidgeest (2018:522)

The Figure 6-19 shows the transit methods and the spatial execution of the particular nodes in CPT. This land use Figure 6-19 is important because it illustrates how connected different land uses are as a result of various modes of transportation. This enables communication between communities as well as a variety of modes of transportation for products and services. The wide variety of transport alternatives serves to provide several options for freight and passenger travel, enabling an effective system. The aforementioned diagram demonstrates both the efficiency of multimodal transport in CPT and the geographical organisation of transport in a small metropolis. The following subsection will address the connectivity of the various land uses through transportation systems.

6.11.2 Transportation networks

CPT has incorporated a variety of transport options to promote mobility and connectivity within the city and surrounding urban structures. The implemented transportation systems are used for different socioeconomic classes and accommodate the transport demands. CPT has been planned in a compact urban structure which, as illustrated, improves the connectivity of various land uses. CPT has incorporated both public transportation systems as well as other types of mobility. The following are the various transportation systems implemented within the urban structure (TDA, 2018:32-34):

- "**MyCiTi" BRT system**: The BRT system has been implemented to enhance public transportation infrastructure (cf. 5.5.5) and to reduce SOV traffic. The "MyCiTi" BRT system is considered to be an efficient transportation system which enhances mobility for mass populations. The integrated bus service travels on designated bus lanes to increase transportation efficiency and speed of travel. The BRT system is accessible to all land uses within CPT's urban structure. The BRT is integrated within a larger transportation network which provides multimodal connectivity and integrated transportation systems. The most significant aspect of the BRT transportation system within CPT is its connectivity from the residential to the CBD area. The transportation system uses a smart payment system, illustrating technological advancements to improve mobility as well as payment thereof (Haferburg, 2011: 338);
- **Western Cape Metrorail LRT:** The LRT system known as the "Metrorail" is a commuter rail service that travels through CPT and the neighbouring areas. The LRT connects various significant areas of the urban structure through efficient rail transportation systems. The LRT systems have been implemented within various above-illustrated case studies, proving the relevance of the LRT. It is considered to be among the most popular modes of public transportation, particularly for everyday commuters going to the city centre from suburban and outlying locations. There are several lines in the rail network, including ones that go to "Simon's Town", "Bellville", and "Stellenbosch". It has encountered difficulties with deteriorating infrastructure, upkeep, and safety issues, demonstrating a need for regular maintenance of the current infrastructure (Haferburg, 2011: 335-340);
- **Minibus taxi systems:** The minibus taxi system is considered to be a small but significant component of CPT's public transportation network. The accessibility to underserved areas and flexibility are possible as minibus taxis connect suburban, peri-urban, and central regions of the city via a variety of routes. The purpose of the minibus taxi transportation system is to provide transportation to areas which are not served by the provided BRT and LRT systems. This is considered to be a low-capacity public transportation system which can be affected by SOV traffic congestion as it uses road infrastructure to commute. The

transportation system is considered to be essential to urban mobility, however, the industry is mainly unregulated and frequently linked to safety and roadworthiness issues (Haferburg, 2011: 338);

- **Golden Arrow Bus Services (GABS)**: The bus transportation system is unlike the BRT system but more similar to the minibus transportation system illustrated. This bus system acts as a generic bus transportation system located in CPT. The bus system is well-known and offers traditional public transportation services. It works in tandem with the "MyCiTi" (BRT) system, but it covers greater ground, including farther-flung suburbs. The GABS system can travel longer distances than the provided BRT systems and is a crucial mode of transport for everyday commuters;
- **Private vehicles (SOVs):** The SOVs are implemented within all urban structures as illustrated within the above case studies. The high rate of SOV ownership in CPT causes traffic congestion on all road infrastructure, which can affect other transportation systems, for example, minibuses and GABS. The use of SOVs has increased on highways around the urban structure and includes major activity corridors (N1, N2, and M3) which connect the city's CBD to surrounding suburbs and areas. The reliance on SOVs is linked to more accessible mobility in more isolated areas of the city. The use of SOVs has caused major problems concerning congestion and presents sustainability issues due to carbon emissions. The use of SOVs can also impact pedestrian transportation with regard to safety concerns (cf. 5.7.3);
- **Ride-hailing and e-hailing services**: The ride-hailing system can be considered a shared SOV initiative which is provided by privately owned companies (Uber and Bolt) and is well-known in CPT for offering flexible, on-demand transportation options. This is an alternative towards conventional taxi services, as e-hailing firms serve visitors and the more tech-savvy populace. Ride-hailing can be more costly than other public transportation options, however, its appeal is mostly due to its convenience and perceived safety. The component of interest within the transportation system is illustrated in the technological advancements and use of GIS. The transportation system can access any location of the urban structure through an app requesting the service and providing the location to the operator. This illustrates the implementation of smart transportation systems but can be compromised by SOV congestion through road infrastructure use; and
- **NMT**: The NMT system illustrates the use of pedestrian infrastructure or sustainable infrastructure. CPT encourages walking and cycling, which has the necessary infrastructure. The city has sustainable mobility objectives through the implementation of bicycle lanes and pedestrian walkways in several locations to encourage active transportation. As in the other case studies, this reduces reliance on SOVs and supports

other eco-friendly, healthful modes of transportation. The NMT section can be compromised by SOVs which put pedestrians in danger if infrastructure has not been implemented within a specific area of the urban structure.

The implementation of transportation systems has illustrated both public transportation systems, pedestrian transportation systems and SOV transit. The implementation of transportation follows a specific concept identified in developed countries (cf. 6.2, 6.3, 6.4, 6.6, 6.8, 6.9). This excludes Antigo (cf. 6.10), as it has not illustrated any sustainable public transportation system, but illustrates the compact planning of land use, demonstrated in CPT. The TP initiatives provide efficient transportation systems as illustrated but are compromised through various issues created by the use of SOVs. This has been illustrated as a common problem within all case studies, while most initiatives illustrate methods to reduce reliance/ use of SOVs. The Figure 6-20 below depicts the implementation of transportation systems within the urban structure (Haferburg, 2011: 337-340).

Figure 6 - 20 Public transportation network in CPT

Source: Haferburg (2011: 339)

The Figure 6-20 shows the routes used for public transportation systems to effectively connect all land uses over the SS. The urban structure is a combination of land use and transportation systems, which are used to create a functioning system. The governing components of the SS are accomplished through the implementation of policies and regulations. This confines each component of the SS to perform a specific role within an intricate network. The following section governs the policy components of CPT and illustrates the roles of each aspect.

6.11.3 Spatial policy

CPT is based on several policies and legislation for land use and transportation systems. The policies focus on the development of land use and the implementation of efficient transportation systems. The implementation of land use policies has been created under a simple, but effective legislation which has been implemented nationally. The legislation is known as the Spatial Planning and Land Use Development Act 16 of 2013 (SPLUMA). This has created a framework for the implementation of policies, which is different based on each municipal district. The policies discussed hereafter are created and controlled by SPLUMA.

6.11.3.1 Municipal by-laws

Each municipality's by-law will differ based on the need and area of implementation. The policy focuses on enforcing the SPLUMA legislation and illustrating the various land use zonings. This is used as a manual illustrating the methods of rezoning, consolidations, subdivisions, and removal of restrictions, among others. This may differ based on the municipal departments and illustrates a fair method in which the community can collaborate with the local authority regarding land use and implementation. This also demonstrates a standard which dictates the process to be followed.

6.11.3.2 Land Use Management Scheme (LUMS)

The Land Use Management Scheme (LUMS) is based on the land use regulations and usage. This refers to the several zoning codes allocated to specific land uses as well as the regulations of implementation. The LUMS would assist in allocating the various zonings as well as the building regulations within. The policy illustrates the permitted use of land as well as its zoning codes. This is important as it may affect the bulk contributions policy (BCP) which is based on municipal service delivery.

6.11.3.3 Bulk contributions policy (BCP)

The BCP is a policy created to allow the costs of services to be equally distributed between the landowner and the municipality. The BCP illustrates multiple services and calculations used to determine the cost of the services provided based on the LUMS. The cost of these services is based on the implementation of infrastructure as well as future infrastructure if the area expands due to development. The BCP is different within municipalities and follows different processes based on the area of implementation. The cost of the services is based on the usage of zoning, which is then put into a calculation based on the type of service (electrical, water, and sewers among others) to determine the cost payable by the landowner and the municipality. The services can be broken down into three phases but can differ in each municipality:

- **Internal:** Refers to the connections within the property lines (for example, the water pipes within the house), which are normally paid by the property owner;
- **Link:** Refers to the connection between the external and internal. This represents the connection between the municipal service lines and internal property lines. This is usually paid by the property owner; and
- **External:** This refers to the service lines within the servitudes outside the property lines (municipal bulk lines), which is a large service line that connects properties to municipal services. This is generally paid by the municipality.

The BCP is a policy that allows the property owners to obtain municipal services and in return, the municipality will obtain a bulk contribution (once-off payment from the property owner) to upgrade and maintain the services within the area. Integrated transportation policies have also been included in the implementation of CPT's TOD policy to improve transportation systems within the urban structure to improve the efficiency of mobility. The TODs are formed by creating accessibility and implementation of a grid pattern if not multiple access roads (Wilkinson, 2006:220-225). This includes public transportation, which is addressed further in this study. The following section will provide a simple delineation based on the case study findings within Sections 6.2-6.11 to illustrate the guidelines and components used within the following chapter.

6.12 DISCUSSION

The delineation of the unique traits in the above case studies will identify specific aspects of a city's urban structure. The aspects of the city are determined by the various components implemented within the urban structure. To develop recommendations for the future development of urban structures, delineation of the urban structures should identify efficient and effective methods of implementation. The table below illustrates a breakdown of the above case studies in order to identify transportation guidelines. This will illustrate the required guidelines in order to implement transportation efficiently within different urban structures.

Table 6- 1 Delineation of unique traits of the case studies

Delineation of the above case studies				
CASE STUDY	**COMPONENTS OF THE CITY**	**DESCRIPTION OF COMPONENTS**	**COUNTRY RANKING**	**URBAN MODEL**
Canberra (cf. 6.2)	Types of urban land use and structure	Residential; business; commercial; industrial; institutional; municipal/government; recreational and conservation areas (green areas)	Developed country (Australia) (Kyriakidou, et al, 2015: 260)	The garden city model (cf. 3.2.1)
	Types of transportation systems	Motor-vehicles BRT LRT Walkability/ cycling (pedestrian infrastructure)		
	Urban structure	Polycentric structure (cf. 4.2.2.1)		
Chicago (cf. 6.3)	Types of urban land use and structure	Residential; business; commercial; industrial; institutional; municipal/government; recreational	Developed country (USA) (Kyriakidou, et al, 2015: 260)	The concentric ring model (cf. 3.2.2)
	Types of transportation systems	Motor-vehicles BRT LRT Rental bicycles Water taxi/water transportation Walkability/ cycling (pedestrian infrastructure)		
	Urban structure	Radial		
LA (cf. 6.4)	Types of urban land use and structure	Residential; business; commercial; industrial; institutional; municipal/government; recreational (parks and open spaces)	Developed country (USA)	The multi-nuclei model (cf. 3.2.3)

	Types of transportation systems	Motor-vehicles BRT LRT Walkability/cycling (pedestrian infrastructure)	(Kyriakidou, et al, 2015: 260)	
	Urban structure	Irregular (due to urban sprawl and multi-nuclei)		
Erbil (cf. 6.5)	Types of urban land use and structure	Residential; commercial; industrial; institutional; municipal/government	Developing country (Iraq) (Jabbar, 2019: 42)	The urban structure model (cf. 3.2.4)
	Types of transportation systems	Motor-vehicles BRT Walkability/ cycling (Pedestrian infrastructure)		
	Urban structure	Concentric rings/ radial		
SF (cf. 6.6)	Types of urban land use and structure	Residential; commercial; industrial; institutional; municipal/government; recreational (open space)	Developed country (USA) (Kyriakidou, et al, 2015: 260)	The urban realms model (cf. 3.2.5)
	Types of transportation systems	Motor-vehicles BRT (BART) Cable cars LRT The city supports TOD Walkability/cycling (pedestrian infrastructure)		
	Urban structure	Grid pattern/compact		
Lagos (cf. 6.7)	Types of urban land use and structure	Residential; commercial; industrial; institutional; municipal/government; recreational areas, health care facilities	Developing country (Nigeria) (Ademola Osho, 2022: 1-4)	The 21st-century city model (cf. 3.2.6)
	Types of transportation systems	Motor-vehicles BRT (commercial buses) LRT (New project- rail expansion) Water transportation (boats) Walkability/cycling (Pedestrian infrastructure		
	Urban structure	Irregular		

Barcelona (cf. 6.8)	Types of urban land use and structure	Residential; business; industrial; institutional; municipal/government; recreational and historical landmark areas	Developed country (Spain) (Kyriakidou, et al, 2015: 260)	The urban fabrics model (cf. 3.2.7)
	Types of transportation systems	Motor-vehicles Taxis BRT LRT (Transports Metropolitans de Barcelona) Walkability/ cycling (pedestrian infrastructure) Bicycle rentals Trams (cable lines) Electric scooters		
	Urban structure	Grid pattern		
Rome (cf. 6.9)	Types of urban land use and structure	Residential; business; commercial; industrial; institutional; municipal/government; recreational historical and cultural areas	Developed country (Italy) (Kyriakidou, et al, 2015: 260)	The Marchetti Constant model (cf. 3.2.9)
	Types of transportation systems	Motor-vehicles Taxis BRT LRT Trams Electric scooters Long distance Rail Transportation Water transportation Walkability/ cycling (pedestrian infrastructure)		
	Urban structure	mono-centric/centric rings		
Antigo (cf. 6.10)	Types of urban land use and structure	Residential; business; commercial; industrial; institutional; municipal/government; recreational areas, agricultural land use and multi-use land.	Developed country (USA) (Kyriakidou, et al, 2015: 260)	The theory of the agricultural land-use model (cf. 3.2.10)
	Types of transportation systems	Motor-vehicles Taxis Buses Walkability/cycling (pedestrian infrastructure)		

	Urban structure	Grid pattern/compact/ irregular		
CPT (cf. 6.11)	Types of urban land use and structure	Residential; business; commercial; industrial; institutional; municipal/government; recreational and conservation areas	Developing country (South Africa) (Sayef, 2017: 1-2)	The apartheid city model (cf. 3.2.8)
	Types of transportation systems	Motor-vehicles Taxis/minibus taxis Uber/ Bolt: Cab service BRT (MyCITI) LRT (Metrorail) Walkability/ cycling (pedestrian infrastructure		
	Urban structure	Compact /irregular		

The above chapter illustrates the use of case studies as a practical demonstration of the urban models (cf. 3.2). The case studies had been analysed and undergone a comparative analysis in order to address **Research Objective 4** (cf. 1.3). The chapters findings would identify spatial policy guidelines in order to efficiently implement transportation systems within the urban structure. This could improve spatial planning of land uses and transportation systems within developing countries in order to efficiently implement transportation systems.

The case studies illustrate nine international case studies and one local case study. The case study selection is comprised of three developing countries and seven developed countries. The research approach towards the qualitative data will assist towards the testing of the quantitative data. The developing countries would illustrate possible policy guidelines towards the implementation of transportation systems (Chapter 4) and SS. The guidelines will assist to illustrate methods in order to address possible challenges (cf. 5.7) within TP and urban structures. The case studies have illustrated the same if not similar land uses while majority of case studies have implemented the land use within a radial layout (cf. 6.2, 6.3, 6.5, 6.6, 6.7, 6.8, 6.9, 6.10, 6.11). This can also be illustrated in the urban structure of each city demonstrated in the urban model's chapter (cf. 3.2). The case studies illustrate The CBD (commercial) land use is situated in the centre of the urban model (Chapter 6), while the transitional zone/ industrial area (cf. 6.2-6.11) is located around or near the CBD. The multi-nuclei urban model (LA -6.4) has various land uses and multiple CBD land uses as illustrated in the urban model. This illustrates mixed-land use (cf. 6.5, 6.6, 6.7, 6.8, 6.10) within the urban structure and is illustrated within both developed (cf. 6.6, 6.8, 6.10) and developing countries (cf. 6.5, 6.7). This demonstrates a possible guideline illustrating the implementation of mixed-land use within SSs (SS1). All case studies illustrate the use of recreational areas as well as the use of green area and preservation (Chapter 6), while urban sprawl remains a common challenge (cf. 5.7) and is prominent within Lagos, Nigeria (cf. 6.7). The use of green space has been implemented in all SSs and should be considered as a possible guideline towards SS planning (SS2). All case studies have challenges regarding urban sprawl and population. The population cannot be controlled and is constantly growing within both developed and developing countries. The third guideline that should be considered is the implementation of smart growth strategies. The smart growth strategy could refer to residential land uses as well as commercial (CBD) and other land uses. The smart growth strategy has been implemented within the international best practices (cf. 5.9). The garden city urban model (cf. 3.2.1) implemented within the SS of Canberra (cf. 6.2) illustrates a greenbelt as a limitation towards the growth of the SS. This is illustrated within the theory of agricultural land use (cf. 3.2.10) as a guideline towards land value within the case study of Antigo, USA. The greenbelt supports guideline SS2 and increases greenery. The focus on smart growth strategies should be considered a guideline towards SSs (SS3), while the greenbelt example cannot be implemented in all topographies.

The case studies illustrated that all SSs are implementing or have implemented sustainable practices within spatial planning in order to improve land use, connectivity and decrease the impact on the environment (cf. 5.7.2). This would also decrease SOVs, which are considered to be dominant transportation systems within all case studies. All case studies have illustrated challenges with traffic congestion (cf. 5.7.7) due to the excessive use of SOVs. This illustrates the need towards implementing sustainable practices (SS4) which support the above guidelines. The last guideline refers to the above assessed case studies and the applied urban models illustrating the difference between each SS. This illustrates a component of resilience based on the topography of the area, which can drastically change the SS based on natural factors. The guideline of resilience (SS5) would be required for each SS, which could assist with policy creation based on the area as well as can adapt to the surrounding environment. The land uses of all the urban structures are considered to be the same or similar, but connectivity between the land uses within the SS would determine the efficiency of the SS as well as accessibility. The case studies illustrated various types of mobility based on the urban structure. The TP concept should be considered and applied through policy-based guidelines (see TP).

The implementation of TP guidelines will be based on the above assessed case studies with relevance towards the previous components illustrated within the study. All case studies have illustrated the use of SOVs and have access to road infrastructure. As mentioned, the population growth is a component which cannot be controlled, through these countries lacking public transportation systems will experience traffic congestion (cf. 5.7.7). The significance of public transportation systems or alternative modes of transportation is high due to the masses. This can be illustrated in the developing city of Lagos, Nigeria (cf. 6.7) and through their current initiatives to implement BRT and LRT systems due to congestion. The developed city of Antigo, USA (cf. 6.10) also lacks public transportation systems, but uses the compact SS for cycling and walkability. The city still has various constraints with traffic congestion, but had included active transportation systems. The case studies besides Lagos (cf. 6.7) (future initiatives) and Antigo (cf. 6.10) had implemented BRT and LRT transportation systems. This illustrates the importance of implementing public transportation systems and forms the first TP guideline (TP1). The implementation of sustainable practices and smart growth strategies illustrates the importance of sustainable transportation modes which is considered to be active transportation systems. The implementation of pedestrian walkways and bicycles has been illustrated within Canberra (cf. 6.2), Chicago (cf. 6.3), LA (cf. 6.4) and other developed country case studies. This illustrates the possibility of implementing active transportation systems within a developing country as its cost effective, sustainable approach towards mobility. This illustrates the second TP guideline illustrating the implementation of active transportation (TP2) through a sustainable, health approach as well as preserving the environment. The following guideline is created through the above-mentioned SOVs within all case studies. The SOVs had created congestion in Canberra (cf. 6.2), Chicago (cf. 6.3), Barcelona (cf. 6.8), Rome (cf. 6.9), Antigo (cf. 6.10), LA (cf. 6.4), San Fransisco (cf. 6.6) as well as the developing country case studies. This illustrates that the use of SOVs with large populations or lack of alternative transportation systems can cause challenges within TP. The third TP guideline created should reduce SOVs/ automobiles (TP3) within the urban structure. In order to reduce SOVs (cf. 5.7.7), alternative transportation systems should be implemented to provide other mobility options. The above SS guidelines and TP guidelines illustrate sustainable approaches towards reducing SOVs and improving the urban structure. The fourth TP guideline illustrates sustainable transportation systems as seen within the case studies. The most common sustainable transportation system is seen through walking, cycling and public transportation systems (all case studies), while some case studies illustrate different types of sustainable transportation systems. Chicago (cf. 6.3) illustrates the use of water transportation (water taxi, boat) alongside Lagos (cf. 6.7) and Rome (cf. 6.9). This is based on the topography of the SS and illustrates the guideline of resilience (see SS5). This would not apply to SS with no water, but Rome (cf. 6.9), Barcelona (cf. 6.8), and Chicago (cf. 6.3) offer bicycle sharing as a mobility option towards sustainable transportation. There is unique sustainable transportation modes illustrated in Rome (cf. 6.9) and Barcelona (cf. 6.8) demonstrating the use of electric scooters, while SF illustrates the use of cable cars. The fourth guideline illustrates the implementation of sustainable transportation (TP4).

The above delineation illustrates the implementation of public transportation systems (see TP1), which links to the fifth guideline. In order for TP1 to function correctly which should illustrate a schedule time and location of station and travel, which can be done through intelligent transportation systems. The fifth TP guideline incorporates the use of intelligent transportation systems (TP5). The implementation of transportation systems require accessibility for all income groups within the community. The use of public transportation systems should be available to all if not most individuals. In order to provide access to the transportation system, multiple stations and modes should be connected in order to increase usage (multimodal). This has been illustrated within the transportation components (cf. 5.5) and through the use of TODs (cf. 5.8). The TP models illustrate the various implementation of different transportation systems in order to acquire a specific goal (Chapter 4). In order to provide access to all individuals, transportation systems should provide access to all income groups within the community. This can refer to each individual income group which is serviced by a different transportation system or the same transportation system as the other income groups. The sixth transportation guideline requires implementing transportation systems based on the income group (TP6).

The findings of the chapter illustrate possible methods of implementation within the SS and TP sector. The delineation of case studies illustrated relevance towards the **Research Objective 4** in creating policy-based guidelines to improve transportation systems within developing countries. The above case study analysis illustrated developing country perspectives and developing countries perspectives. The above guidelines will be applied within the following chapters with an illustration of implementation. The case study of CPT (cf. 6.11) will be used to demonstrate implementation and how it addresses the challenges (cf. 5.7). This will evidently provide policy-based guidelines in order to improve efficiency of transportation system and SSs within developing countries. The recommendations (Chapter 7) will also demonstrate methods of application in order to achieve the final research objective.

6.13 CONCLUSION

This chapter has compared 10 urban models through a case study approach based on the literature review (cf. 3.2). The case study approach is illustrated through a mixed-method approach, which used both qualitative and quantitative methodological approaches (cf. 2.2). The qualitative approach was accomplished through the illustration of urban models and the implementation of case studies (Chapter 6). The quantitative approach has been identified through the testing of each urban model through the implementation of land use and transportation systems. The testing of the above cased studies had been done through the comparative analysis illustrated in the delineation of case studies within the previous section (cf. 6.12).

The case studies have illustrated several findings. The case studies showed that land use should be implemented in a compact urban structure. The **Research Objective 4** had been achieved within the chapter through the following findings from the above case studies. The CBD and residential areas should be well-connected for transit to occur efficiently from residential areas to places of work (cf. 6.2-6.11). The industrial land use zone should be well connected or near the CBD area (cf. 6.2-6.11). The residential areas which accommodate lower income groups and are considered to be for blue-collar workers, are located close to industrial/ CBD (cf. 6.2-6.11) areas to lessen the cost of travel from residential to work. The recommendations had been identified from the previous section and is illustrated in chapter 7. The land use should, therefore, be planned within a compact urban structure to decrease the distance of travel and promote sustainable transportation systems (cf. 6.2, 6.3, 6.4, 6.6, 6.9, 6.10, 6.11). The compact urban structure can promote sustainable transportation modes for walkability and cyclists to decrease SOVs (cf. 6.2-6.11). With regards to the incorporation of residential areas, commercial areas (CBD), industrial areas, institutional areas, government land use, recreational areas and agricultural areas (cf. 6.2-6.11):

- The agricultural land use should be situated on the outskirts of the urban structure to limit or decrease urbanisation (cf. 3.2.1, 3.2.2; 6.2-6.11);
- There should be recreational areas for the resided community (cf. 6.2, 6.3, 6.4, 6.6, 6.7, 6.8, 6.9, 6.10, 6.11);
- The preservation of green areas and historical land use must be a priority (cf. 6.2, 6.3, 6.8, 6.9, 6.10, 6.11); and
- The CBD should be located in areas of concentration (cf. 6.2-6.11).

The use of activity corridors could improve economic benefits (cf. 6.10, 6.11). The implementation of mixed land-use allows for multiple activities to be performed within a district. The purpose of implementing land use correctly is to plan to increase the resilience of the urban structure through smart growth strategies. The implementation of land use should be resilient and allow for adaptation as the urban structure evolves. The urban structure should implement strategies to decrease urbanisation as well as urban sprawl (cf. 6.7). The urban structure should also be implemented based on the topography of the surrounding area (cf. 6.2, 6.3, 6.4, 6.6, 6.7). The land use should be accompanied by efficient TP to improve economic growth and efficient mobility (cf. 4.3).

Additionally, the implementation of transportation modes should accommodate various components (cf. 5.5) of the urban structure to integrate various transportation systems through a TOD (cf. 5.8) strategy. The transportation systems should be interactive and link to all sectors of the urban structure, thus promoting various interactions (cf. 5.4). The planning of the transportation network (cf. 4.1) can be highly intricate and requires advanced strategies in transportation network planning (cf. 5.3) to improve flow (cf. 4.3). This is based on the type of TP model (cf. 4.4) used for the urban structure. The case studies have illustrated significant guidelines for TP (cf. 5.6) and possible challenges (cf. 5.7) within implementation.

The table above (6-1) illustrated the delineation of the case studies to assist with various components of each case study (cf. 6.2-6.11). Several components of transportation (cf. 5.5) have been illustrated as possible guidelines within TP through the vigorous use of public transportation systems implemented within the case study analysis. This also includes the implementation of walkability and cycling modes of transportation systems. The purpose of increasing public transportation modes is to reduce/decrease/stop reliance on SOVs, due to congestion caused on road infrastructure.

The incorporation of active transportation includes walking and cycling to improve the health of the community (cf. 5.4.5). Through the use of GIS systems, online time schedules and location from origin to destination, technological advancements can increase as seen in the cities of Chicago, Canberra, LA, SF, and CPT, among others. The last simple component is to implement transportation systems based on income groups to provide sustainable transportation modes which are cost-effective to the residing community.

The case studies illustrated various components (cf. 5.5) of implementation, however, the governing components of policy have also illustrated four main laws which should be implemented within the urban structure. These policies should i) have land use ordinance policies; ii) be designated to the topography; iii) have TOD policy administration, and iv) govern the use of SOVs in connection with pedestrian and other transportation systems. The case studies' comparative analysis has determined the practical implementation of land use and transportation. The delineation of unique traits from the case studies (cf. 6.12) has provided sustainable guidelines that can be used for the future implementation of urban structures, as discussed in the next chapter with regard to the CUrM model.

CHAPTER 7 SYNTHESIS AND RECOMMENDATIONS

7.1 INTRODUCTION

The chapter will provide a delineated breakdown of the study in order to demonstrate the connectivity between the various chapters. The study had been done in an attempt to create a more efficient spatial planning approach towards transport networks determined by the urban structure. The chapter illustrates the final sections towards the study in order to demonstrates that all research objectives have been achieved through a pragmatic approach of both quantitative and qualitative data. This final chapter is intended to achieve **Research Objective 5 (To have a more efficient spatial planning approach towards transport networks determined by the urban structure).** The chapter will illustrate the proposed recommendations based on the above applied research. The recommendations will be illustrated in two section demonstrating guidelines towards SSs (cf. 7.5) and TP (7.4). This will be applied through a proposed urban model which could be used as a template for implementing the guidelines. The theoretical proposed guidelines will be applied in a practical application over an existing urban structure (cf. 7.6) as well as a new urban structure. The study demonstrates the use of the above applied information in order to efficiently improve transportation systems within the urban structure.

7.2 SYNTHESIS

As per the applied research provided in the study, it can be determined that spatial planning approaches based on transportation systems should be determined by the urban structure. This study has analysed several urban models (cf. 3.2) and found the spatial planning approaches, as well as transportation systems applied within each urban structure. The urban structures differ based on status, size and transportation networks (cf. 4.2). This has allowed for a comparative analysis of these urban structures, to determine the need for a specific type of transportation network. This study is based on a methodological paradigm, with Chapters 3-5 representing the literature approach, and Chapters 6-7 representing the empirical approach. This chapter (Chapter 7) will also illustrate possible recommendations for implementing transportation modes more efficiently within the urban structure.

The above information applied within this research document supports the objectives and aims illustrated at the beginning of the study (cf. 1.3). The types of urban models had to be addressed based on the urban structures implemented within spatial planning to demonstrate the existing planning approaches and methods of implementation. The urban models (cf. 3.2) within several urban structures were analysed in Chapter 3. The chapter represents a literature approach based on the land use and connectivity of transportation within these various urban structures. The chapter illustrates the foundation for **Research Objective 2 (To determine how sustainable**

transportation systems function within different urban structures). To achieve this objective, it was imperative to understand how these urban models had implemented transportation systems based on their applied urban structure. This illustrated the differences between each urban model and how transportation systems can be used efficiently or if improvement towards the practical implementation of the infrastructure can occur. The urban structure is not the only factor focusing on the connectivity of transportation systems, the connectivity of different land uses is a large factor. The topography of certain models limited transportation modes, while other topographies supported multiple different modes of transportation.

Chapter 3 not only illustrated differences in the implementation of transportation but most importantly, similarities between the garden city model (cf. 3.2.1) the concentric ring model (cf. 3.2.2) and the urban structure model (cf. 3.2.4); they all showed a multi-ring layer dividing the various land uses, transportation modes also radiated out from the central CBD area and connected all land uses. These models illustrated the CBD within the centre of the urban structure as a central point of connectivity to concentrate economic (cf. 5.4.1) benefit within a single area. Transportation systems all led to the centre of the urban structure to improve mobility. Thus, the efficient implementation of transportation may improve the economic benefit of an urban structure.

The urban realms model (cf. 3.2.5), the 21st-century city model (cf. 3.2.6), the urban fabrics model (cf. 3.2.7), the apartheid city model (cf. 3.2.8), the Marchetti Constant model (cf. 3.2.9) and lastly the theory of agricultural land-use model (cf. 3.2.10), illustrated the CBD in the centre of the urban structure, which is similar to the previous models (garden city model for example), but the land use layout and its connectivity differed. These urban models (cf. 3.2) showed a similarity towards the placement of the CBD, except for one model that illustrated multiple CBD areas known as the multi-nuclei model (cf. 3.2.3). The urban structures differed in mobility and connectivity but efficiency within transportation networks (cf. 4.2) was significant due to the layout and connectivity towards the CBD. The urban models illustrated multiple urban structures which differed in some ways but were similar in others (for example, how transportation networks were incorporated). Thus, there is a need for specific and efficient TP approaches and implementation.

Chapter 3's identification of differences/similarities between the urban structures led the research toward Chapter 4's evaluation of TP models (cf. 4.4), in order to better understand mobility and TP methods. There are various approaches to TP, as with urban structures. Thus, not all urban structures and TP models (cf. 4.4) are the same, but vastly different based on multiple factors. The purpose of Chapter 4 was to identify the significant traits within the planning models as well as their problems to prevent the inefficiency of transportation systems. Travel demand models (cf. 4.4.1) consist of a collection of formulas and processes that mathematically depict the range of decisions people make about their modes of transportation and how those decisions translate into journeys on the transportation network. This shows connectivity towards the urban model illustrated in (cf. 3.2.9), the Marchetti Constant model, which is based on human behaviour and travel options as illustrated based on the options provided. The Marchetti Constant model describes the effective use of transportation systems based on a radial distance from the CBD. **Research Objective 2 had been achieved** throughout Chapter 3 through illustrating the different urban models and types of transportation systems applied within the urban model. Chapter 3 previously illustrated various models and the implementation of the SS and illustrated the implementation of TP within each urban model. The focus of the walking and cycling models is to create efficient infrastructure for the movement of pedestrians within a 5km radius and preserve the infrastructure as well as incorporate safety based on other transportation systems. This is also based on the Marchetti Constant model (cf. 3.2.9) as well as the garden city model (cf. 3.2.1), with the functionality of the 21st-century city urban model (cf. 3.2.6). These urban models situate lower-income living neighbourhoods near the transitional/industrial area. This provides lower-income groups to live near the workplace (blue-collar workers) and obtain sustainable or affordable accommodation (cycling/ walking/taxis) to efficiently commute to their workplace within the industrial areas of the urban structure. A common example is the apartheid city model (cf. 3.2.8) but it can also be identified in the concentric ring model (cf. 3.2.2), illustrating the transitional area and proximity to the lower-income group living area.

Chapter 4 illustrates various transportation models (cf. 4.4) in order to achieve **Research Objective 1**. The travel demand models' (cf. 4.4.1) formulae and statistics are based on constant variables and input data based on individuals' movement to create a presumed anticipation of human behaviour on which transportation system will be used the most as well as which will be used the least. This will address **Research Objective 1 (To review existing transportation guidelines and systems which would potentially improve efficiency within cities)** will be addressed within Chapter 4. The travel demand models (cf. 4.4.1) focus more on SOVs as transportation systems even though multimodal transportation system is used to provide various options based on origins and destinations. This should help to improve efficiency depending on the distance, time travel, destination and cost of travel. This is also seen in the central place theory (King, 2020:17-27), which uses hexagons to improve the efficiency and connectivity of nodes. Travel demand TP models (cf. 4.4.1) have been implemented to improve the mobility of individuals to all areas of the urban structure, using multimodal transportation and illustrates a similar concept of the TOD approach (cf. 5.8). Transport forecasting called "trip generation" estimates how many trips will leave or arrive at a specific traffic analysis zone, which is seen within the trip and parking generation models (cf. 4.4.2). They focus on the parking and trip guides within suburban areas with restricted pedestrian and transit access, to ascertain how to reduce vehicle journeys and how much less parking is needed in TODs. This is similar to the travel demand models (cf. 4.4.1) – only focused on trips per hour in a smaller area as opposed to larger communities. The trip and parking generation (cf. 4.4.2) models determine the number of individuals per trip towards a certain location alongside the need for alternative transportation modes and parking required if SOVs are used. There are other approaches, such as the walking and cycling models (cf. 4.4.3). Several models were created to forecast how changes in land use and transportation (building more sidewalks and pathways and developing compact, mixed-use developments) would impact the amount of time people spend walking and bicycling.

Economic evaluation models (cf. 4.4.4) are employed to assess and contrast the benefits of the current or prospective transport system with other options. This might include options such as the advantages of extending a road or highway, enhancing the availability of public transportation, and putting in place developments that are orientated towards transportation. The TP models focus on the financial implications and prospects of the implementation of various transportation systems to determine their viability within the urban structure. The economic evaluation TP models (cf. 4.4.4) have been partially implemented within all urban models (cf. 3.2). This can be identified through a simple illustration of the various land uses, all leading to the centre of the urban structure or towards the CBD of the urban model. This highlights the importance of transportation and its efficiency within an urban structure as well as the other transportation models assessed. The focus of economic evaluation (cf. 4.4.4) TP models is based on the cost of the transportation infrastructure (cf. 5.5.5), cost of transportation, cost per individual based on trip analysis, cost of maintenance, cost per trip and cost of operation. This creates profit and viability for the resided community. The economic evaluation (cf. 4.4.4) TP models differ from the previous transportation models due to the focus on the cost and operation of transportation systems, while the above models focus on the trips and actual mobility of the transportation systems. The economic evaluation (cf. 4.4.4) TP model's perspective of economic benefit proves the relevance towards transportation efficiency within the urban structure.

ITLUP (cf. 4.4.5) TP models were used to enhance land use and connection through transportation to lower land use costs and increase transportation efficiency. These TP models have been implemented as a result of the focus on improving transportation modelling as a future part of TP and implementation. There is a similarity between these transportation models. The similarity between the travel demand (cf. 4.4.1) and ITLUP (cf. 4.4.5) models is the number of individuals carried per trip based on the destination and multimodal transportation as well as the connectivity thereof. In order to implement transportation systems based on the urban structure as well as different transportation systems to create sustainable and efficient transportation systems. The above transportation models (cf. 4.4) all share similar traits towards implementation based on a statistical analysis of human mobility, trip count and movement of human behaviour. The implementation of these models differs based on the purpose of the implementation. The chapter (Chapter 4) sought to achieve **Research Objective 1** and based on the findings within the chapter had been achieved. By analysing various TP models (cf. 4.4) and providing approaches, challenges, improvements and strategies towards ultimately improving the efficiency of transportation networks (cf. 4.2) within the urban structure. Chapter 4 illustrates the transportation chapter and demonstrates the various TP models (cf. 4.4) as well as networks (cf. 4.2) and flows (cf. 4.3).

Chapter 5 had multiple sections that addressed transportation and urban structures (cf. 5.6) as a whole. The chapter addresses **Research Objective 3 (To improve the efficiency of transportation modes within each urban structure by identifying guidelines for each type).** The chapter illustrated the systematic collaboration based on operation, SS and other challenges which may be identified within the spatial planning perspective. The first section referred to urban structure planning (cf. 5.2); this is the planning of an urban structure for a specific purpose. Section (cf. 5.2) showed four different types of urban planning structures based on the efficiency of urban systems; structure and layout; heat-resistant structures and vegetation cover (as seen with the garden city [3.2.1]). The focus was simply based on the concept of efficiency of urban systems, to reduce energy output, which may include reducing fossil fuels and motor vehicles (cf. 5.2). This would increase walkability and cycling for an environmentally friendly (cf. 5.4.4) urban structure. The urban structure should be planned in a compact perspective, as identified in the urban model's chapter (cf. 3.2.1, 3.2.2, 3.2.6, 3.2.9) and within the TP models chapter (cf. 4.4.3 and 4.4.5), which illustrates the relevance towards the urban planning principle. The layout and the form of the urban structure must be considered; they can be based on multiple factors as illustrated in the urban model's chapter (cf. 3.2) and differ based on implementation. The third aspect of urban structure planning (cf. 5.2) referred to using heat-resistant materials to decrease the impact of global warming (cf. 5.4.4). Increasing greenery as well as using sustainable energy sources would reduce heat islands in cities and towns. To increase vegetation through green roofs and green paths to help protect urban structures from disasters (flooding). This is all identified in the garden city model (cf. 3.2.1) and the theory of agricultural land-use model (cf. 3.2.10), while other models have incorporated greenery based on agricultural land uses, conservation areas and parks (cf. 5.4.4). Therefore, all aspects of urban planning are significant and are within practice (cf. 5.9). These aspects all share a similarity in that they all use natural methods to improve the urban structure of the urban model, illustrating the importance of greenery and the environment (cf. 3.2.1).

The concept of urban structure planning (cf. 5.2) is achieved through different planning levels (cf. 5.5.4) and all have a specific role. The different levels of planning in descending order begin with global level planning (largest level of planning), which refers to planning approaches and strategies implemented on a global scale, for example, global warming strategies implemented by the United Nations (UN). This improves and prevents circumstances which may affect the planet (cf. 5.9). The second level of planning addresses strategies and approaches on a national level (cf. 5.5).

Section 5.3 analysed transportation network planning through a theoretical step-by-step process. The process involved all the general categories illustrated in Chapter 4 (cf. 4.4) regarding TP models and demonstrated the similarities between all the transportation models and the process of planning. This also illustrated the validity towards identifying the study area (cf. 6.11), as determined by all urban structures that may differ in Chapter 3 (cf. 3.2), while the transportation process revealed criteria for implementing transportation within each structure. Chapter 6 illustrated the components of interaction (cf. 5.4) as seen within the different land uses and several different urban models (cf. 3.2) alongside the implementation of different land uses. It also compared TP models (cf. 4.4) and their connectivity. The process of transportation network planning (cf. 5.2) showed a step-by-step criterion that directly referred to the analysis of the socio-economic (cf. 5.4.1, 5.4.2) circumstance as well as the most relevant interactions within the urban structure (cf. 5.4). Each component was evaluated to identify the possible connection between the urban structure, connectivity, transportation systems and possible challenges. These interactions (cf. 5.4) were discovered to be socio-economic; political (cf. 5.4.3); structural (urban structure); transportation-related (types of transportation modes) and environmental (cf. 5.4.4).

Section 5.6 discussed the type of networks (cf. 4.2) implemented into the urban structure and how they connect to various land uses through multimodal transportation systems. The section showed the link between urban structure and the implementation of transportation systems. The analysis revealed two methods of connectivity through a diagram illustrating the connectivity of nodes. One of the diagrams illustrated one-way access (cf. 4.2.2.1), while the other showed multiple access points, illustrating better and more efficient mobility between land uses through effective planning of transportation systems. This was shown in the TP models (cf. 4.4) as well as urban models (cf. 3.2). It was found that the connectivity of nodes through transportation is significant in improving transportation efficiency as well as interactions within the urban structure (cf. 5.4, 5.5). This could also be improved through the different types of TP models seen in Chapter 4, using transportation network planning (cf. 5.3). The network of transportation systems can also be determined by the spatial organisation of transportation (cf. 4.2.2), which was analysed through two different SSs, known as monocentric SS (cf. 4.2.2.1) and polycentric SS (cf. 4.2.2.2). The monocentric SS is known as the predated SS, due to its singular CBD area and was mentioned in the urban model's section (cf. 3.2.1, 3.2.2, 3.2.8). The model has a simplistic urban structure with all transportation routes leading to a single centre area. The polycentric SS is a modern-day SS, also illustrated in the urban model's section (cf. 3.2.3, 3.2.6, and 3.2.7). The sections described a complex or multimodal transportation system implemented within the urban structure through TP models (cf. 4.4), using the criteria mentioned in transportation network planning (cf. 5.2).

The following section on transportation flows (cf. 4.3) referred to the flow of transportation within the urban structure. It focused on the level of aggregation in comparison to the level of detail used within the system. The four categories described within the transportation flows (cf. 4.3) were macroscopic propagation, mesoscopic propagation, microscopic propagation and sub-microscopic propagation models. These determine the type of transportation that should be planned on a certain level of planning, as illustrated in the planning levels (cf. 5.4.3). The macroscopic propagation model had the highest level of aggregation and the lowest level of detail (seen at international and national planning levels). The sub-microscopic propagation model had the lowest level of aggregation and the highest level of detail (seen in regional and local planning levels). The flow of transportation systems (cf. 4.3) had an intricate process involving multimodal transportation and all the components (cf. 5.5) of transit systems. The flow of transportation systems determines the efficiency of transportation systems with regards to travel, capacity, speed, cost and accessibility to different land uses (cf. 5.5). This study sought to determine the efficiency of transportation systems and their incorporation into urban structures. Chapter 5 indirectly illustrated the implementation of the urban models (cf. 3.2) and the implementation of the TP models (cf. 4.4). The chapter referred to improving transportation systems to create a more efficient transportation network, including the flow of SOVs, public transportation, rail transportation, telecommunication and other aspects of transportation to improve supply and demand.

Section 5.8 referred to transportation components (cf. 5.5), focusing on three different models implemented to improve efficiency in transportation. The first model is known as the location and accessibility model (cf. 5.8.1), which implements the correct planning of land use and transportation to improve accessibility while focusing on multimodal transport. The focus of this model is to improve the efficiency of transportation systems to improve the supply and demand of the urban structure. This was illustrated in the concentric ring urban model (cf. 3.2.2) and the garden city model (cf. 3.2.1) with the travel demand models (cf. 4.4.1). Connectivity between the CBD and small markets is crucial for economic (cf. 5.4.1) benefit. The model uses a hexagon structure, as illustrated in the central place theory model mentioned above. The second component of transportation is the specialisation and interdependency model, which focuses on the connectivity of other urban structures and land use. The concept of this transportation component is to connect other towns, land uses, sectors and interactions (cf. 5.4). The model uses multimodal transportation and does not rely on only a single transportation unit. The model uses terminals to connect all transportation systems and unlike the previous model, focuses on external land use and mobility of both freight as well as passengers. The third and final component of transportation refers to the distribution/flow model (cf. 5.8.3), which focuses on the flow and movement of traffic. This model has similar traits to the above models but differs in a connectivity approach. The distribution/flow model uses a large corridor that connects each CBD of the external urban structures and uses other transportation to connect lower-order nodes surrounding the CBD. The focus would allow for high-volume traffic between CBD areas but lower-volume traffic between secondary nodes to prevent congestion. This is illustrated in the garden city model (cf. 3.2.1) with the large corridors connecting the CBD and the rail connecting to the CBDs of areas.

The next subchapter referred to transportation infrastructure (cf. 5.5.5) and the implementation thereof. It focused on multiple different transportation infrastructures including pedestrian walkways, roads, rail and other public transport-related infrastructure (as seen in both Chapters 3 and 4). The subsection connected to all the above chapters based on actual implementation factors; its findings are crucial for improving transportation efficiency and sustainability. This would allow multiple hubs/terminals for transportation systems to provide efficient transportation systems (cf. 5.8) and connectivity. The chapter then focused on international best practices (cf. 5.9) to determine similar implementation of transportation systems within an urban structure which could increase the efficiency of transit. The chapter (Chapter 5) sought to achieve **research objective 3** and based on the findings within the chapter had been achieved. The international best practice illustrated various methods of implementation in both developed and developing countries. These methods would be used or implemented within the recommendations (Chapter 7) if deemed relevant.

Chapter 6 illustrated the beginning of the empirical approach towards this thesis, namely a case study using the comparative approach. The chapter addresses **Research Objective 4 (To identify how urban spatial planning policy in a developing country can enhance efficient transportation systems based on the established guidelines).** The chapter illustrated all the possible implementations of the urban models (cf. 3.2). The chapter illustrated real-life implementations of the urban models, showing the efficiency and functionality of the urban structures effectively. The case studies followed specific criteria, specifically to demonstrate i) land use, ii) transportation networks and iii) special policies. The criteria helped to identify possible improvements to efficiency; possible future implementation strategies; challenges (cf. 5.7.4) within implementation and connectivity between land uses. The chapter's findings will be used to make recommendations for the plausible improvement of transportation networks (cf. 4.2) to enhance efficiency throughout the urban structure.

Chapter 6 illustrated the urban models (cf. 3.2) under study and connected them with real-life implementation. The urban models and case studies connected through a comparative approach as follows:

- Canberra (cf. 6.2) (case study) - The garden city model (cf. 3.2.1);
- Chicago (cf. 6.3) (case study) - The concentric ring model (cf. 3.2.2);
- CoLA (cf. 6.4) (case study) - the multi-nuclei model (cf. 3.2.3);
- Erbil (cf. 6.5) (case study) - The urban structure model (cf. 3.2.4);
- SF (cf. 6.6) (case study) - The urban realms model (cf. 3.2.5);
- Lagos (cf. 6.7) (case study) - The 21st-century city model (cf. 3.2.6);
- Barcelona (cf. 6.8) (case study) - The urban fabrics model (cf. 3.2.7);
- Rome (cf. 6.9) (case study) - The Marchetti Constant model (cf. 3.2.9);
- Antigo (cf. 6.10) (case study) - The theory of the agricultural land-use model (cf. 3.2.10); and
- CPT (cf. 6.11) (case study) - The apartheid city model (cf. 3.2.8).

These case studies (Chapter 6) were analysed based on their urban models (cf. 3.2) to illustrate the practical efficiency of transportation systems within the urban structure. The various models showed possible similarities towards practical implementation. The criteria used as mentioned in the above paragraph identified possible practical guidelines towards the implementation of transportation systems. The chapter (Chapter 6) sought to achieve **research objective 4** and based on the findings within the chapter had been achieved. As mentioned, these will be used to make recommendations regarding the practicality and theoretical implementation of these methods.

The final section (Chapter 7) illustrated a simple but effective delineation of unique traits (cf. 6.12) illustrated in the case studies. The delineation provided the unique components towards the practical implementation of the urban models (cf. 3.2). The chapter addresses **Research Objective 5 (To have a more efficient spatial planning approach towards transport networks determined by the urban structure)**. It simplified the comparison between the various case studies and separated the unique traits of each case study to increase the efficiency of transportation systems within the urban structure. The proposed recommendations will use the previous chapters as a theoretical approach, while the practical implementation was demonstrated through the comparative case study analysis. The recommendations should improve TP (Chapter 4) within an urban structure and illustrate the efficient modes of transportation as well as land use planning (cf. 3.2), based on both literature and empirical approaches. The thesis will use the background formulated from urban structure planning (cf. 5.2) and the incorporation of transport network planning (cf. 5.3) to increase efficiency between the various land uses. This will optimise interaction (cf. 5.4) and increase economic (cf. 5.4.1) benefit with the correct transportation components (cf. 5.5).

The following section (cf. 7.3) will illustrate possible recommendations and a contribution towards science through the guidelines and urban models produced to improve efficiency within the urban structure. The section will outline a series of recommendations focused on TP (cf. 7.4) and SS (cf. 7.5), as policy-based guidelines which had been derived from the comprehensive research conducted throughout this thesis. This follows through with the implementation of the proposed urban model (cf. 7.6) through the above illustrated guidelines (cf. 7.4, 7.5). The chapter (Chapter 7) sought to achieve **research objective 5** and based on the findings within the chapter had been achieved. The research and implementation had been conducted and achieved through the above research objectives and can be used through both TP and SS planning.

7.3 RECOMMENDATIONS

These recommendations aim to address the critical issues identified in the analysis and provide actionable strategies for improving urban mobility and land use efficiency (cf. 5.7). This will be achieved by leveraging the insights gained from the study. The guidelines could be adopted to foster sustainable development through the efficiency of transportation systems and enhance the overall functionality of urban environments.

By addressing key challenges (cf. 5.7) and opportunities identified in the analysis, these suggestions aim to inform effective planning practices that support sustainable development and improve overall accessibility as per the research objective. The recommendations are delineated and analysed through the preceding research's evident implementation strategies as well as theories that demonstrate the subsequent approaches as viable ways to improve transportation services. The recommendations will be based on a novel urban model illustrating the planning of transportation systems to enhance transportation systems and improve land use connectivity through mobility efficiency. The recommended urban model (CUrM) is based on the preceding research as well as theoretical and practical implementation.

This newly proposed urban model is considered to be a TOD urban model, which will increase efficiency and improve all aspects of the urban structure. The urban model has been derived from the above research principles and guidelines and is specifically proposed to increase efficiency.

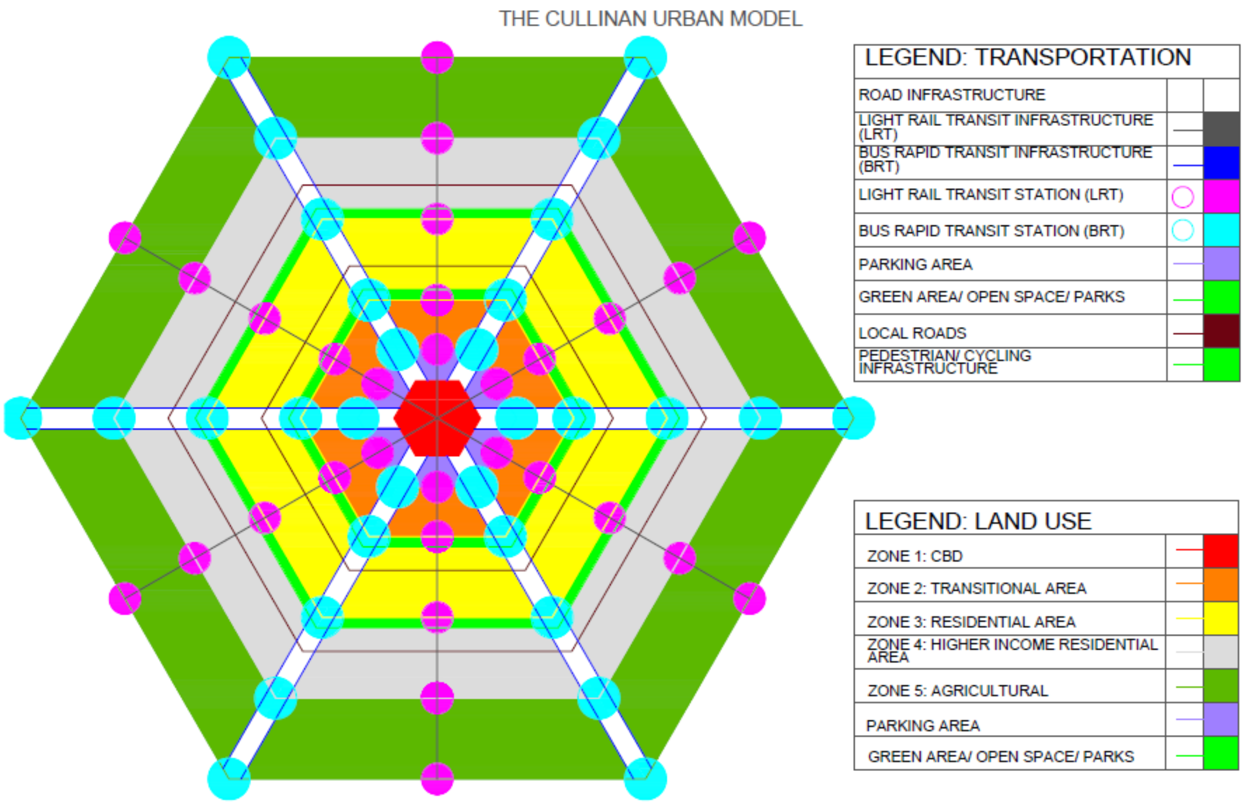


Figure 7- 1 Proposed urban model

Source: Author's own (2024)

The proposed model is a TOD tool used to implement efficient and sustainable transportation systems throughout the urban structure. The model can be implemented for both a new urban structure and an already implemented urban structure. The model has been derived from the above comprehensive study in hopes of providing a solution towards transportation efficiency within urban structures.

Figure 7-1 illustrates an implementation strategy to improve transportation efficiency within the urban structure. This model can be compared to Christaller's central place theory model (Chapter 4), which illustrates the 21st-century model perspective through the use of TP (cf. 4.3), as well as urban model planning (cf. 3.2). The purpose of the above model is to provide a proposal template for future planners to implement transportation systems efficiently. The model describes a practical implementation strategy with set guidelines to improve transportation and mobility within the urban structure (cf. 5.6). The transportation components (cf. 5.5) have been derived from the distribution and flow of TP models (cf. 4.4) previously indicated, to provide maximum accessibility (cf. 5.4). This could increase traffic flow (cf. 4.3) and the efficiency of transportation networks (cf. 4.2).

The guidelines will be illustrated in the paragraphs below, segregating SSs and transportation systems. The guidelines will improve transportation systems within the urban structure and are based on a case study analysis (Chapter 6) of multiple different SSs. The guidelines will illustrate practical and theoretical approaches towards implementation, while the CUrM will illustrate the proposed urban structure. The CUrM was developed to improve transportation systems throughout the urban structure based on the shortfall of previous urban models. The concept of land use had been derived from international best practice (cf. 5.9), through the above analysis of urban models (cf. 3.2), TP models (cf. 4.4) and case study analysis (Chapter 6).

The CUrM, as shown below, could be used as a 21st-century urban planning model in hopes of improving transportation efficiency and connectivity of land use (cf. 5.7.1). The CUrM was designed from the perspective derived from various sources throughout the study. The delineation of the model is addressed within the proposed guidelines to improve urban structure planning (cf. 5.2) and efficiently connect various land uses. The model can be divided into two sections to effectively illustrate the guidelines, namely land use implementation and transportation implementation as seen below.

THE CULLINAN URBAN MODEL

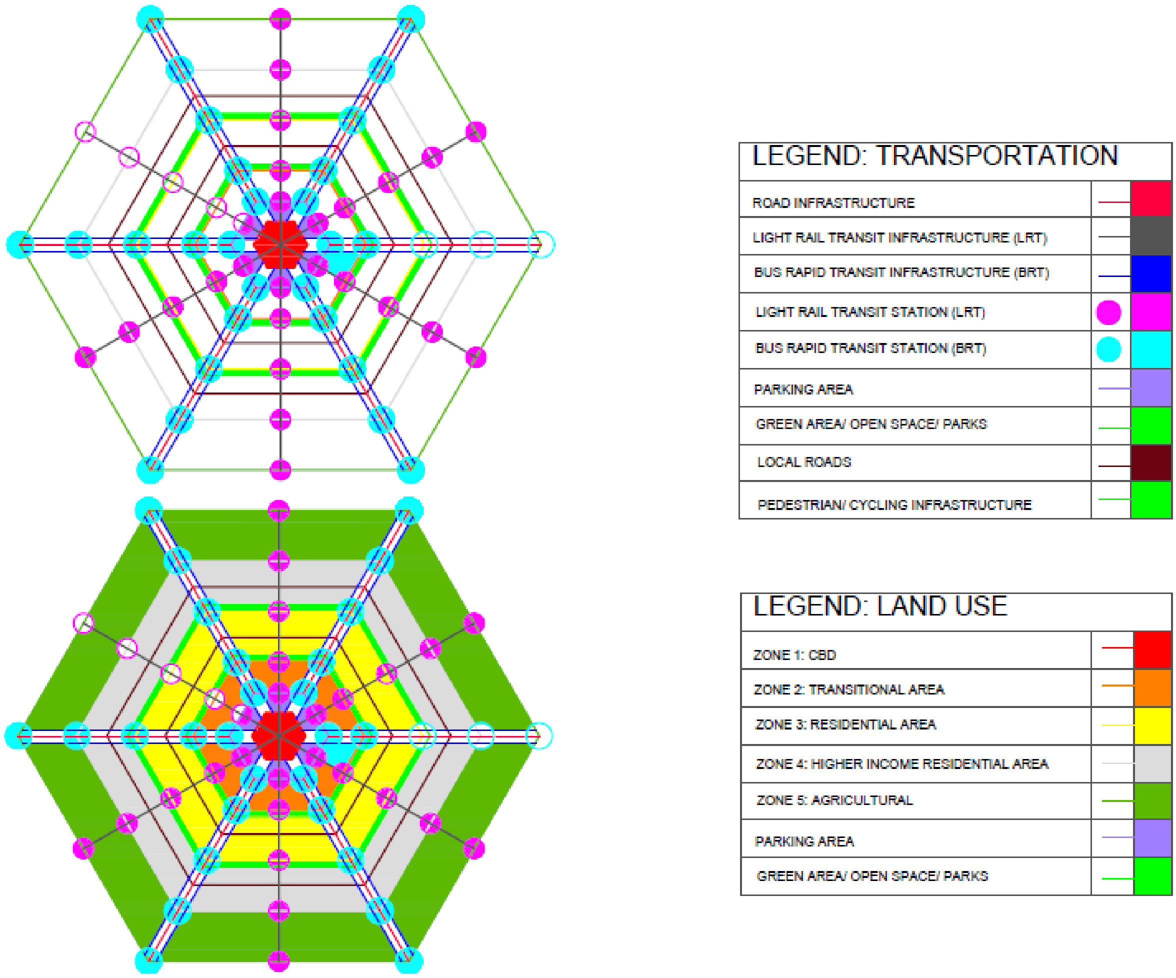


Figure 7- 2 The land use and transportation systems within the CUrM

Source: Author's own (2024)

As mentioned, the proposed urban model is a combination of various urban models analysed within the study (cf. 3.2), while the transportation systems and planning thereof, are a combination of the various TP models (cf. 4.4). The above model illustrates a breakdown of the CUrM structure beginning with the land use component and structural planning. The Figure 7-3 below shows the land use component throughout the urban model – this was used to recommend the guidelines discussed later in the chapter.

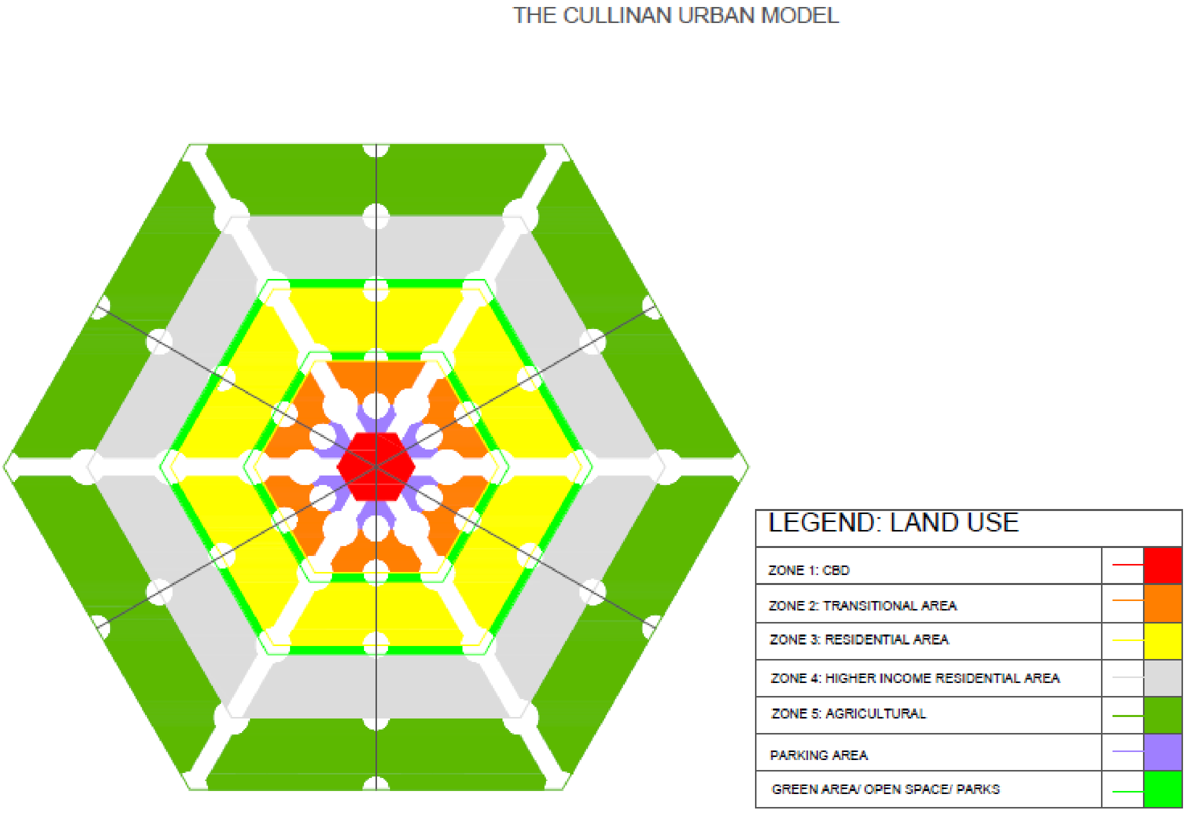


Figure 7- 3 The land use within the CUrM

Source: Author's own (2024)

The above Figure 7-3 illustrates the land use implemented within the CUrM. The land uses were planned based on previous urban models (cf. 3.2), which all included the above-mentioned land uses. The garden city model (cf. 3.2.1); the concentric ring model (cf. 3.2.2); the urban structure model (cf. 3.2.4); the 21st-century city model (cf. 3.2.6); the urban fabrics model (cf. 3.2.7); the apartheid city model (cf. 3.2.8); The Marchetti Constant model (cf. 3.2.9) and the theory of agricultural land-use model (cf. 3.2.10) all shared a radial SS. The radial SS would often start in the centre (CBD), followed by the industrial or transitional zone and the residential area thereafter.

The above model includes several land uses, as illustrated in the case study analysis (cf. 6.2-6.11). The land uses below were taken from the delineation of the case studies (cf. 6.12):

- CBD/commercial;
- Industrial area/manufacturing/transitional zone;
- Residential areas;
- Parks and open spaces;
- Agricultural; and
- Transportation.

The CUrM also adopts specific traits from each land-use model evaluated, which could improve the urban structure. The model would exclude traits illustrated in the evaluated models based on possible challenges, as well as challenges in transportation (cf. 5.7). The CUrM included the following traits from the evaluated urban models (cf. 3.2):

- The greenbelt (cf. 3.2.1);
- The green concept (cf. 3.2.1);
- The land value based on distance from CBD (cf. 3.2.1, 3.2.2, 3.2.10);
- The sectional separation in land uses (cf. 3.2.4);
- Concentric rings (cf. 3.2.2);
- Transportation structure (cf. 3.2.7);
- Distance from CBD (cf. 3.2.9); and
- SS (cf. 3.2.1, 3.2.2, 3.2.4, 3.2.6, 3.2.9).

The CUrM also has unique traits within its urban structure - it promotes public transportation, maximising multimodal connections (TOD-5.8) and includes greenbelts and pedestrian transportation within the urban structure. The greenbelts can be illustrated in the outer agricultural area, between the higher-income group residential area and between the middle-income group residential area as well as transitional zone.

The CUrM is unique as it restricts SOVs from entering the CBD district but allows for LRTs and pedestrians to enter the area. The model illustrates parking areas within the transitional area. The parking bays are situated near LRT and BRT stations which can be used for transit throughout the area. The LRTs can reach the centre of the CBD district, while BRTs can only access proximity (this will be explained in the transportation recommendations). The use of BRTs and LRTs has been explained throughout the world and can be illustrated within the case studies (Chapter 6), specifically the delineation of the case studies (cf. 6.12). This will improve the use of public transportation systems as it increases access and efficiency towards land use. The LRT transportation system crosses over the urban model to expand connectivity and link residential land uses to work/business land uses.

The agricultural land use is situated on the outskirts of the urban structure to prevent further growth and could stop urban sprawl (Boussauw, 2023:10). This concept has been seen in the garden city model (cf. 3.2.1). The rail system would link all land uses and would be accessible at various points through a multimodal perspective. This has been identified within the TOD (cf. 5.8). CUrM's land uses have been specifically planned to be joined at any point within an existing urban structure, as seen in Christaller's central place theory, mentioned in Chapter 4.

The significant concept of land use is that it must be specifically connected. The connectivity of land uses is based on the types of transportation systems and their efficiency (cf. 5.7.1). The transportation systems implemented within the CUrM have been planned to improve the efficiency of transportation systems within the urban structure. CUrM's transportation systems are shown below.

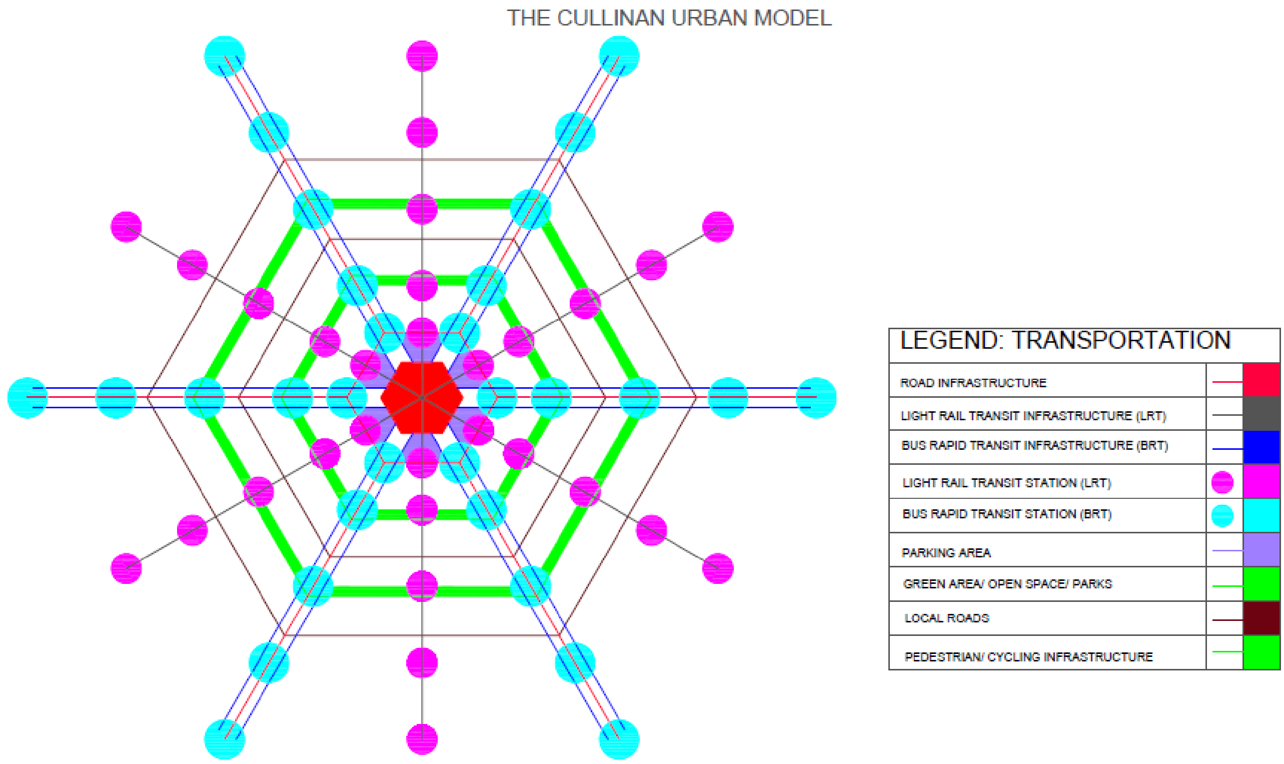


Figure 7- 4 The transportation systems within the CUrM

Source: Author's own (2024)

Figure 7-4 illustrates various transportation systems. The CUrM promotes public transportation to decrease congestion and improve the efficiency of transportation systems. The types of transportation systems implemented within the CUrM are:

- Road infrastructure (large corridors between BRT infrastructure);

- Local roads (within residential areas);
- LRT;
- BRT; and
- Pedestrian infrastructure (along open spaces and parks/ along local roads).

The CUrM shows specific traits of TP based on the above-evaluated transportation networks (cf. 4.2) and models. The model was designed to increase the efficiency of passenger transportation. The same concept can be applied to freight transportation, where one of the illustrated LRT/ BRT lines can be used for the transportation of freight based on travel demand TP models (cf. 4.4.1). The structure of the urban model had been designed to increase connectivity and access, which will increase economic benefit (cf. 4.4.4). The CUrM also represents various points of connectivity between different transportation modes. This creates an ITLUP system (cf. 4.4.5) through the implemented TP models previously evaluated. The CUrM also illustrates efficient transportation by implementing pedestrian infrastructure along green open space areas. This has been illustrated with the walking and cycling transportation models (cf. 4.4.3). The traits below have been obtained from the following research chapters:

- The radial urban structure is illustrated above;
- The large corridors (cf. 3.2.1, 3.2.2, 3.2.6, 3.2.8, 3.2.9);
- The rail system (cf. 3.2.6, 3.2.7, 3.2.8, 3.2.9);
- The road infrastructure (cf. 3.2.1, 3.2.7, 3.2.9);
- The structure of transportation systems within the urban model (cf. 3.2.7, 5.2, 5.3);
- The local roads (cf. 3.2.1, 3.2.2, 3.2.8); and
- The implementation of BRT (case studies in Chapter 6).

The CUrM illustrated in the above Figure 7-4 illustrates a type of TOD (cf. 5.8), which maximises connectivity throughout the urban model. The model illustrates all the TP models (cf. 4.4) to improve efficiency. The implementation of multiple stations allows individuals to gain easy access to mobility. The stations are situated within every zone of the urban structure and can be accessed within walking distance, as illustrated in some urban models (cf. 3.2.9). The road infrastructure is situated between BRT systems to limit the expansion of road infrastructure. This will allow for possible (yet limited) SOV travel. This will intentionally convince individuals to utilise the public transportation systems, which are very accessible. This could solve the majority of the challenges in transportation systems (cf. 5.7).

The CUrM is based on a polycentric SS (cf. 4.2.2.2), maximising connectivity between nodes through transportation systems. The movement between all points will increase transportation flow (cf. 4.3). The transportation network (cf. 4.2) will increase in efficiency through various accesses and land uses, while monocentric SSs (cf. 4.2.2.1) are limited to a single transportation flow (cf. 4.3).

As mentioned, TP challenges (cf. 5.7) could be solved through the CUrM's implementation. The challenge between land use and transportation (cf. 5.7.1) is addressed through connectivity at all land use zones, while the cost of travel will decrease with the number of individuals using public transportation services. The land use will be more accessible for economic benefit due to the limitation of road expansion. The environmental impact (cf. 5.7.2) will drastically lessen as there is a decrease in SOVs, which directly decreases the amount of GHGs released. The implementation of pedestrian infrastructure and green belts demonstrates the implementation of the walking and bicycle models (cf. 4.4.3), without compromising transportation efficiency, decreasing demand or negatively impacting economic growth (cf. 4.4.1, 4.4.4). Implementing pedestrian structures (cf. 5.7.3) has been a challenge within an urban structure with the increase in SOVs; however, due to the minimalisation of road infrastructure, SOVs will cause less damage and implementation of pedestrian infrastructure, may improve safety. The challenge regarding policy implementation (cf. 5.7.5) in transportation systems can vary; however, due to the lack of road infrastructure and the increase in public transportation systems, policy implementation would be simpler. The challenge of public transportation (cf. 5.7.6) has been addressed in detail, alongside the Figure 7-4 above. The CUrM has both BRTs and LRTs implemented within the urban structure, with multiple stations to access the facilities within connection with a multimodal transportation system. This will certainly decrease congestion (cf. 5.7.7) of transportation systems in the long term, as individuals would ultimately use public transportation systems, which would be efficient, while SOVs would have limited infrastructure and access. Parking (cf. 5.7.7) has been accommodated between the transitional area and the CBD. This would not remove SOV movement but may decrease it. This will also decrease the daily trips in SOVs while promoting public transportation (cf. 5.7.6). Population density (cf. 5.7.8) will be minimised through the green belt, which will prevent city expansion and possibly urban sprawl. The CUrM has implemented a strategy through the evaluated urban models (cf. 3.2) for maintenance (cf. 5.7.9) of LRT and BRT systems. This could be funded through the annual tariffs (budgets) as well as the municipal authority, which will decrease the budget due to fewer roads to maintain (cf. 5.7.10). The following section will illustrate the guidelines used to develop the CUrM. These can be used to improve transportation efficiency throughout the urban structure.

7.4 GUIDELINES FOR TRANSPORTATION PLANNING (TP)

Urban structures are dynamic ecosystems which require efficient transportation systems. This is crucial for enhancing economic growth, enhancing quality of life, and promoting sustainable practices. The urban structure continues to expand while the challenge of effectively managing mobility becomes increasingly complex. This necessitates innovative planning approaches that prioritise the movement of people and goods and the integration of various transportation modes, environmental sustainability, and land uses. The focus of this study was on multimodal transportation systems, leveraging technology, and incorporating best practices (cf. 5.9). It sought to create an integrated framework that addresses the current challenges of urban mobility (cf. 5.7), as well as provide possible guidelines towards improving transportation systems within an urban structure.

The section, therefore, discusses both guidelines for TP as well as the policy implementation that would accommodate these guidelines. This addresses **Research Objective 4 (namely, to identify how local spatial planning policy in a developing country can enhance efficient transportation systems based on the established guidelines).** The following subsections will illustrate guidelines implemented within the CUrM to improve the connectivity of land uses and mobility (cf. 5.7.1) and to contribute towards the future implementation of TP and urban structures. The guidelines are divided into two sets i) TP, and ii) SSs. The table below illustrates a delineation of the following guidelines addressed in the subsections that follow.

Table 7- 1 Proposed guidelines for TP and SS implementation

i) Guidelines for TP (section 7.4)		ii) Guidelines for SS (section 7.5)	
TP1	To promote public transportation.	**SS1**	To prioritise mixed-use development.
TP2	To improve active transportation infrastructure.	**SS2**	To incorporate green spaces.
TP3	To reduce the number of automobiles on the road.	**SS3**	To implement smart growth principles.
TP4	To incorporate sustainable transportation infrastructure.	**SS4**	To utilise sustainable practices.
TP5	To incorporate intelligent transportation systems.	**SS5**	To plan for resilience.
TP6	To base transportation on the income group and capacity.	**SS6**	To implement the correct policy framework.

Source: Author's own (2024)

The CUrM can be used as a framework towards improving transportation systems and increasing efficiency. The implementation of these guidelines could assist urban planners and policymakers in creating robust transportation systems that support vibrant, liveable cities for future generations. The below guidelines are a product of the CUrM and can be used within developed or developing urban structures. They should be considered to create a more efficient and sustainable transportation network.

7.4.1 Guideline TP1: To promote public transportation

The above-mentioned paragraphs illustrate the use of the CUrM, which uses public transportation systems throughout the urban structure with multiple stations for access. The public transportation services used within the model have access to all land uses (Williams, 2005:1-8). The limitation of road infrastructure and accessibility to certain areas (CBD) within the model would encourage individuals to use the public transportation systems and walkability to gain full land-use access. This then encourages individuals to utilise BRTs, LRTs, and subways instead of driving their cars; this can lessen traffic congestion and GHG emissions (Williams, 2005:1-4). The correct funding of public transportation systems would improve them into dependable, effective public transport networks that can increase their appeal to commuters. The Figure 7-5 below demonstrates the implementation of public transportation systems and the connectivity of land uses (Schiller *et al.*, 2010:1-89).

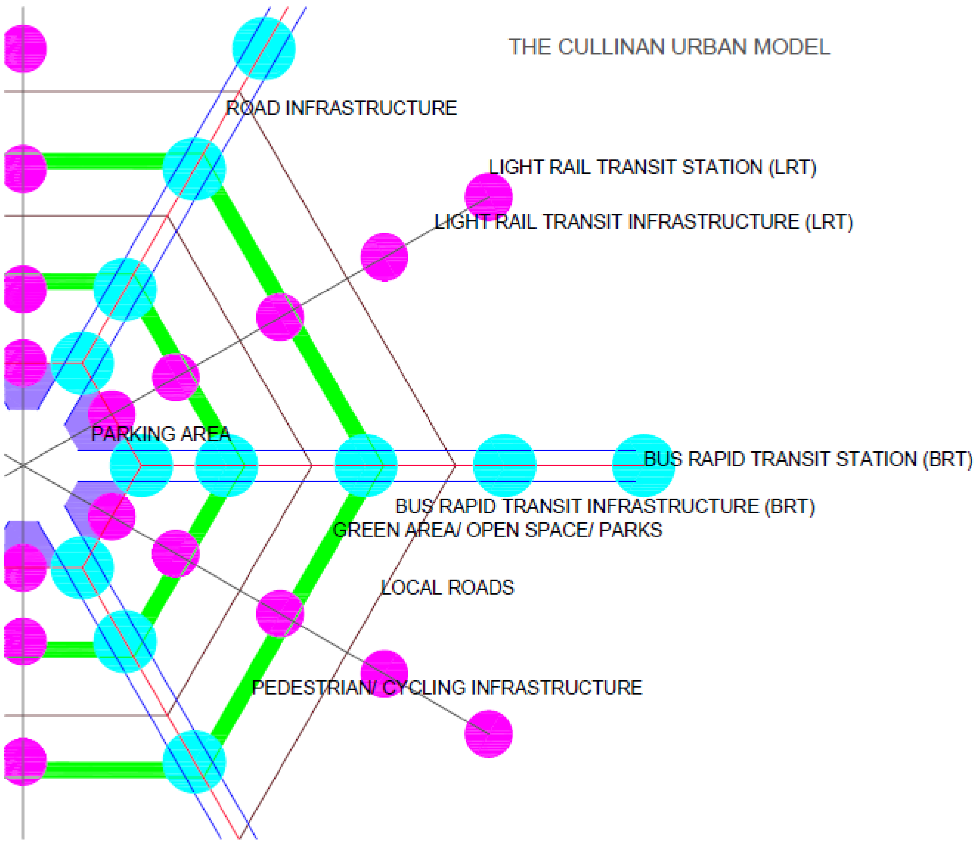


Figure 7- 5 The public transportation systems within the CUrM

Source: Author's own (2024)

The breakdown of the public transportation model can be identified in the above transportation system for the CUrM. The implementation of public transportation systems should follow five basic principles to attract individuals or encourage them to use the mode of transport, namely:

- Access all land uses;
- Easily accessible;
- Convenient;
- Affordable; and
- Efficient.

These principles should be taken into consideration when planning and promoting public transportation systems. They are used within the CUrM while restricting automobiles through limited road infrastructure.

7.4.2 Guideline TP2: To improve active transportation and pedestrian infrastructure

The following guideline seeks to improve pedestrian infrastructure. The purpose would be to create a walking and cycling-friendly environment that can persuade more individuals to use these modes of transportation for shorter distances (Schiller *et al.*, 2010:148-149). Better pedestrian infrastructure would improve the health (cf. 5.4.5) of communities (Tharan, 2004:15; Heraa, 2013:41-42; Cullinan, 2019:125-165). More active transportation could be done by enhancing and implanting dedicated bicycle lanes, pedestrian-friendly routes, and bicycle-sharing programmes (cf. 4.4.3). The CUrM included this guideline along green residential areas so that individuals could healthily experience nature. The CUrM implemented pedestrian infrastructure along LRT and BRT transportation systems; the model increased the safety of pedestrians (cf. 5.7.3) due to the limitation on roads as well as the BRT creating a barrier from said roads. The following Figure 7-6 illustrates the implementation of the pedestrian infrastructure within the CUrM.

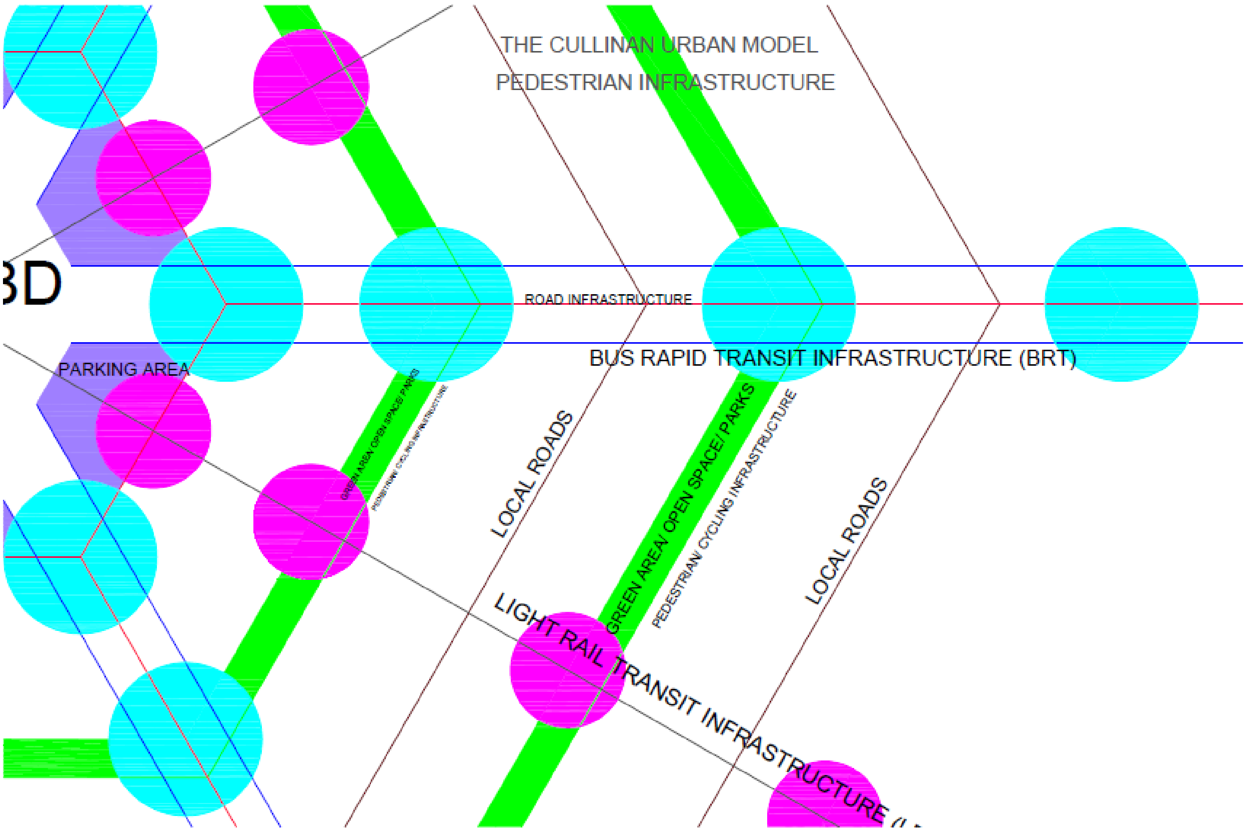


Figure 7- 6 The pedestrian infrastructure within the CUrM

Source: Author's own (2024)

The locality of the pedestrian infrastructure is illustrated above. The location of the pedestrian infrastructure is shielded by both BRT and LRT transportation. The road infrastructure is limited by the above-illustrated transportation systems and is far from pedestrian infrastructure. The pedestrian infrastructure also links to both BRT and LRT transportation systems, allowing for further travel to the CBD or anywhere within the special structure.

The pedestrian infrastructure guideline supports public transportation systems as well as improves active transportation. The concept had been derived from the garden city model (cf. 3.2.1) and its case study (cf. 6.2). The concept may vary but the purpose would remain the same as illustrated between the various garden city implementations (London, Welwyn, Canberra, Radburn, Letchworth).

7.4.3 Guideline TP3: To reduce the number of automobiles on the road

This guideline's purpose is to reduce automobile use. The CUrM implemented roads with a limitation. The major highways entering the urban structure should be enclosed by two BRT systems on either side of the road (see Figure 9-6). This will prevent the expansion of road infrastructure (lanes) and promote public transportation systems, which will ease traffic and reduce pollution (Boussauw, 2023:8).

This will also improve safety for pedestrians and enhance the environment, which will ultimately decrease congestion (cf. 5.7.7) as more individuals use public transportation services to access the CBD (Skorobogatova & Kuzmina-Merlino, 2016:320-322). The automobile is not completely neglected but limited as it can be used for further travel and other emergent situations. The CBD is surrounded by parking areas, which can be used for automobiles while walking and public transportation are promoted. The residential areas have localised roads to access private properties but congestion will be more prominent on the major highways (Schiller *et al.*, 2010:304).

To reduce automobiles, limitations must be set. This guideline supports the first guideline to promote public transportation within the urban structure. The CUrM supports both guidelines and directly supports the same initiatives.

7.4.4 Guideline TP4: To incorporate sustainable transportation infrastructure

The following guideline is to invest in and implement sustainable transportation. The CUrM has implemented sustainable transportation while including existing transportation systems, based on the above case studies (cf. 6.2-6.11). It is necessary to invest in infrastructure, which refers to designated lanes for buses, trams and cyclists, to develop sustainable transportation networks (cf. 4.2). Sustainability can also be improved by using intelligent traffic management systems and renewable energy sources to power transportation infrastructure (cf. 5.5.5). In the CUrM, transportation systems followed an efficient approach towards mobility through the use of public transportation systems (Schiller *et al.*, 2010:51-53).

The use of automobiles is not considered a sustainable transportation system; however, because it is the most common means of transportation, it is necessary to include it within the urban model. The previous guideline illustrated the use of pedestrian infrastructure and the green concept, which is known to be a sustainable transportation system. Investment and budgeting for sustainable transportation systems would improve the longevity of transport systems while maintaining transportation efficiency within the urban structure. This limitation of SOVs will improve the environment.

7.4.5 Guideline TP5: To incorporate intelligent transportation systems

The adaptation of intelligent transportation systems has been implemented within Canberra (cf. 6.2), LA (cf. 6.4), Chicago (cf. 6.3), CPT (cf. 6.11), Barcelona (cf. 6.8) and Rome (cf. 6.9). The urban structures incorporating BRT and LRT transportation systems use global positioning systems (GPS) and timeframe allocation. The advancement of the systems may differ but based on the general concept of using the Internet, an individual can obtain the times, location and direction of these BRT/LRT transportation systems. This allows individuals to plan certain trips based on a hand-held device (cell phone), which is accessible to most individuals (Schiller *et al.*, 2010:316-317).

This may optimise traffic flow (cf. 4.3), reducing congestion and increasing transportation efficiency. The use of these advancements allows individuals to plan their trips and schedule travel, which indirectly improves economic growth through functionality and time management. The BRT/ LRT systems implemented in the CUrM would be considered highly efficient, as they would be based on the same applied principles as mentioned in the case study analysis (Chapter 6)

Guideline TP5 illustrates the increased use of technology such as GPS, sensors, and real-time data. Intelligent transportation systems can make better decisions by receiving information on the most efficient travel routes, public transportation schedules, and current traffic conditions (Schiller *et al.*, 2010:168-169).

7.4.6 Guideline TP6: To base transportation on the income group and capacity

Guideline TP6 illustrates the practical implementation of transportation based on income group and capacity, as seen within Chapter 3 regarding lower and higher income groups. The lower and higher income groups within the CUrM refers to financial income, namely blue-collar and white-collar workers. Land would follow the theory of the agricultural land-use model (cf. 3.2.10) while incorporating the garden city model on land use placement (cf. 3.2.1, 3.2.2). This determines that land would be more affordable towards the transitional area.

This concept has been applied within the CUrM, but instead of illustrating the lower income groups, it is illustrated as residential to remove the stigma between hierarchy. The residential area in the CUrM has been separated by a local road, which illustrates the different land values, as the land closest to the transitional area would be considered the most affordable land, and the area closest to the agricultural area would be considered the most expensive land. The CUrM has incorporated different transportation systems available to all. The higher-income group individuals have a longer travel time/distance between public transportation stations and can afford to use automobiles, while lower-income group individuals are within walking distance from the public transportation systems. The Figure 7-7 below shows the implemented guideline through the CUrM perspective.

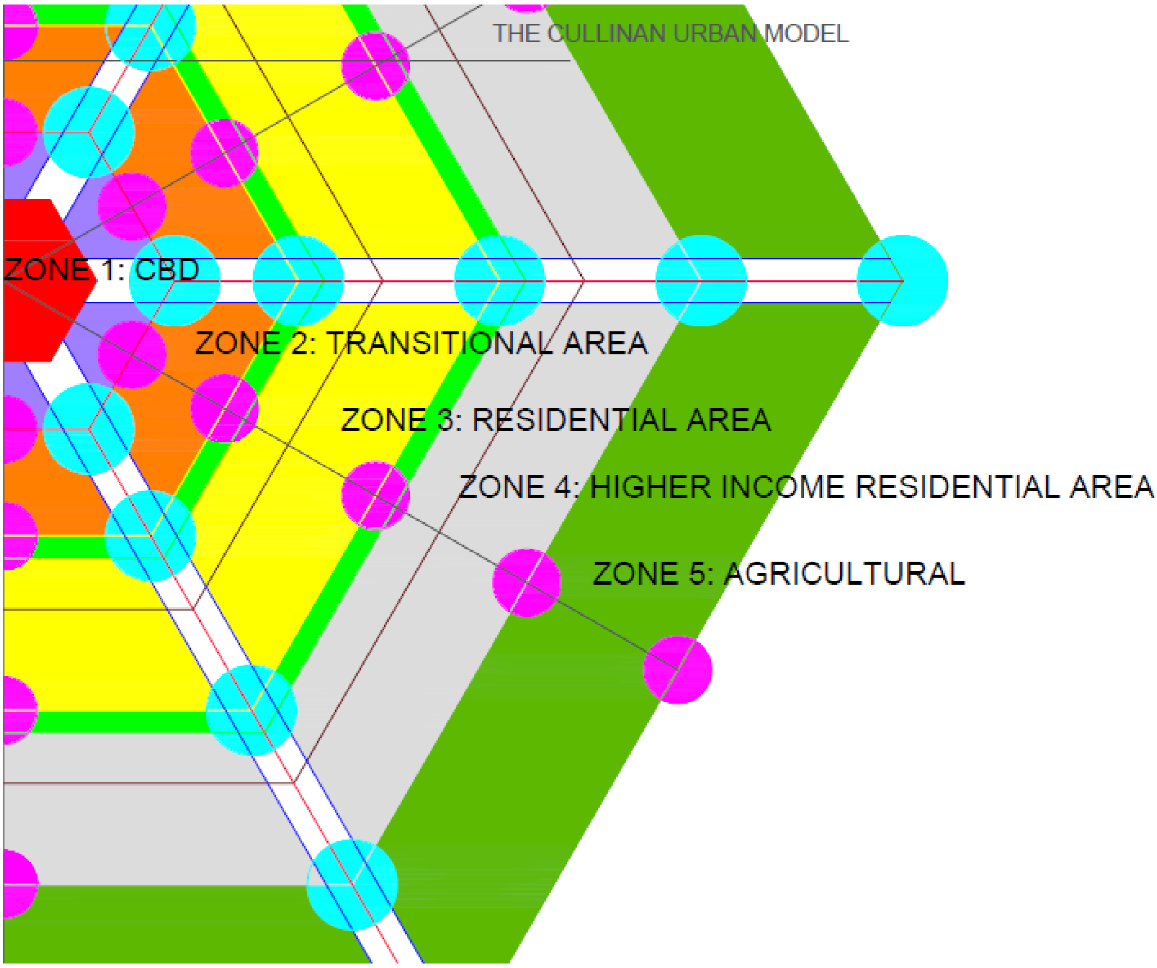


Figure 7- 7 The lower-income/middle-income and higher-income hierarchy within the CUrM

Source: Author's own (2024)

The use of transportation systems may differ between various income groups due to income and travel destination. Transportation should be planned in areas accessible to the different income income groups, based on the capacity, distance travelled and viable cost pricing, which create affordability to lower income income groups. This is particularly significant in the planning of land use within the urban structure. The above CUrM illustrates the incorporation of the guideline through the following simple concept:

- Lower income groups: Closest to public transportation systems and within walking distance from the transitional area;
- Middle income groups: Within walking/cycling distance from public transportation stations and have accessibility to use local roads; and
- Higher income groups: Further away from transportation systems but has accessibility to road infrastructure and is considered to be the most expensive land as well as it is the closest to the agricultural zone (zone 5).

The difference in income groups within transportation had been used in most of the urban models (cf. 3.2), but the CUrM rejects racial segregation of class groups (cf. 3.2.8) and is only applicable towards a financial income basis. The following SS guidelines will be based on the land use implementation of the SS to improve land use planning.

7.5 GUIDELINES FOR SPATIAL STRUCTURES (SS)

The planning of effective SS planning is crucial for creating sustainable, efficient, and liveable environments. Urban structure and land uses continue to grow and evolve, which is why it is essential to adopt a holistic approach that integrates land use and transportation, to satisfy community needs. The following guidelines serve as a framework to enhance SS planning, ensuring that development aligns with environmental (cf. 5.4.4), social (cf. 5.4.2), and economic (cf. 5.4.1) goals. Professional planners could use the guidelines to develop SSs that not only accommodate growth but also enhance resilience, equity, and the environment. The guidelines have been implemented in the above recommended urban model, which includes all aspects of transportation efficiency, land use and sustainability of urban structures. The advancements of urban structures have grown at an accelerated rate, which challenges all development professionals to create liveable and efficient sustainable structures. The below SS guidelines will assist with the planning and incorporation of land use throughout the SS. The incorporation of the CUrM will assist with practical implementation within the ever-expanding urban structure.

7.5.1 Guideline SS1: To prioritise mixed land-use development

The first guideline to improve SSs refers to prioritising mixed land-use development; planners should adopt an integrated approach that combines zoning regulations (cf. 6.2, 6.3, 6.4, 6.5, 6.6, 6.8, 6.9, 6.10, 6.11) with community engagement to ensure liveable and sustainable urban structures. The strategy involves locating developments near public transportation and essential amenities and creating walkable environments that promote pedestrian activity. The guidelines should emphasise flexible spaces that can adapt over time. The above guideline has been implemented within the CUrM. CUrM’s CBD could expand over time, by reducing the parking spaces used by automobiles as they decrease when individuals use the allocated public transportation systems. The CUrM proposed several changes over time to increase the CBD and increase economic benefit, as seen in the Figure 7-8 below.

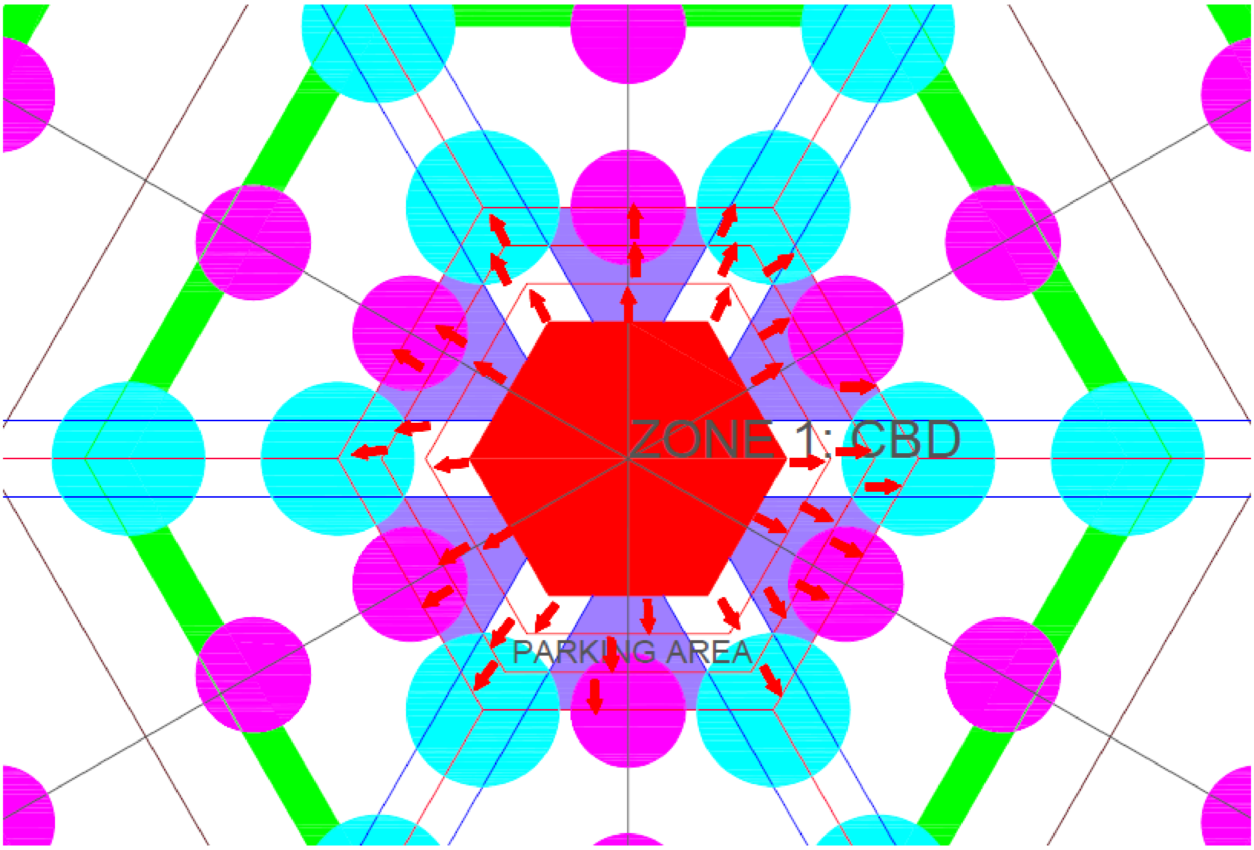


Figure 7- 8: The expanding CBD within the CUrM

Source: Author's own (2024)

The above CUrM depicts the possibility for the CBD expanding over time, as the presumed automobile usage lessens, parking facilities would be considered obsolete. This would act as a placeholder once the CBD starts to expand, through the use of the implemented public transportation services (Schiller *et al.*, 2010:26-27).

This guideline illustrates CUrM's multi-land use perspective alongside the implementation of various land uses (see Figure 7-3). This demonstrates the uses of ITLUP (cf. 4.4.5) approaches as well as zoning regulations as implemented within the case studies. The connectivity of these land uses was addressed in the guidelines for transportation systems.

The guideline promotes mixed land use through the implementation of green areas within the residential land use (see Figure 7-6). This allows for the incorporation of pedestrian infrastructure and green areas (see SS2) which promotes active transportation (see TP2). Residential areas could be used for offices and non-manufacturing industries. The SOV parking areas could be used to increase pedestrian transportation as well as green areas for recreational purposes. The above Figure 7-8 illustrates the use of parking facilities in order to expand the CBD.

The implementation of primary and secondary institutions within residential areas in order to increase active transportation (see TP2) and the use of pedestrian infrastructure through the Marchetti Constant concept (cf. 3.2.9).

7.5.2 Guideline SS2: To incorporate green spaces

Incorporating green spaces or green areas within an urban structure requires a strategic approach that integrates parks, gardens, and green corridors into the overall structure of the area. The CUrM has integrated green areas in the form of green belts (cf. 3.2.1). The CUrM has also promoted walkability within and alongside green areas as illustrated (see Figure 7-6). The CUrM has identified this land use guideline through underutilised land and transforming it into community parks or pocket gardens that serve as recreational hubs (LRT/BRT stations). The urban model has connected these green spaces through pedestrian pathways and bicycle lanes to enhance accessibility and encourage outdoor activities, as illustrated in the improving active transportation guideline (cf. 7.4.2). The guideline could adopt green approaches as previously seen in Canberra (cf. 6.2). This can also improve community engagement within the planning process to ensure that the green spaces meet local needs, creating inviting areas that promote social interaction (cf. 5.4.2) and well-being.

Guideline SS2 is supported by the above-mentioned guidelines, showing increasing public transportation systems (cf. 7.4.1). This will also improve active transportation modes (cf. 7.4.2) through the reduction in automobile transportation modes (cf. 7.4.3). This will promote sustainable transportation systems (cf. 7.4.4), while advancements provide information and knowledge towards using public transportation systems (cf. 7.4.5). Guideline SS2 demonstrates a merging of a sustainable urban structure, which enhances transportation efficiency within the urban structure.

7.5.3 Guideline SS3: To implement smart growth principles

CUrM suggests the implementation of smart growth strategies, in line with the above-mentioned guidelines. The CUrM has implemented a green belt (cf. 3.2.1) to create a more compact development, which has been identified as a crucial component of transportation systems and is illustrated in CPT (cf. 6.11) The compact city has preserved the urban structure and made commuting more efficient within close proximities.

Howard's garden city (cf. 3.2.1) model also uses a greenbelt to prevent city expansion as well as to minimise sprawl and preserve natural areas (Boussauw, 2023:10). The CUrM also implemented a green belt and agricultural land within the urban structure to prevent city expansion. It is hoped this would divert overpopulation to other SSs or form a new urban structure, which connects to the previous urban structure. As mentioned, the CUrM can be used for existing and new SSs. The below-illustrated model demonstrates a connection towards the previous urban model.

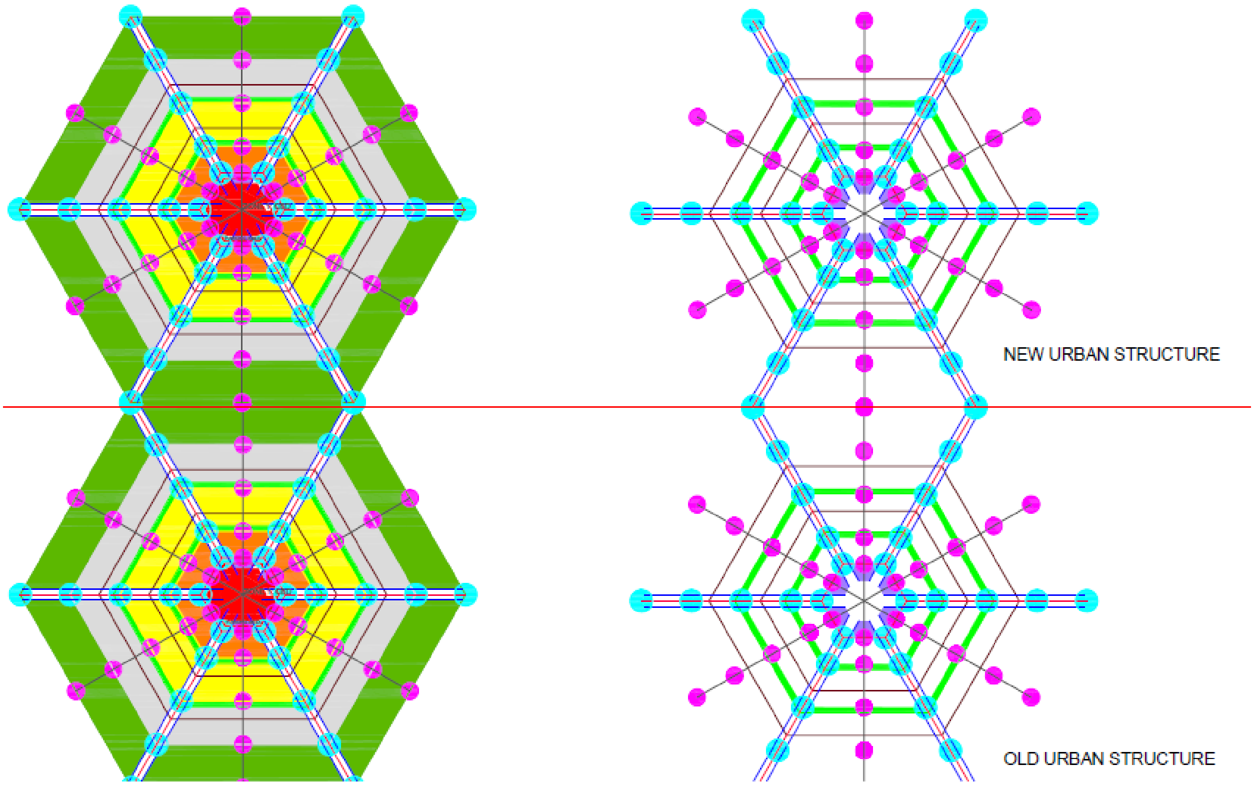


Figure 7- 9 The smart growth strategy of the CUrM

Source: Author's own (2024)

The CUrM has multiple angles to join other urban structures; the Figure 7-9 above shows connectivity at multiple points. The above SS illustrates the new urban structure and below illustrates the old urban structure based on a greenfield development concept. This has been identified in the TOD (cf. 5.8) and allows for various smart growth strategies which can connect to multiple urban structures. The above Figure 7-9 illustrates future connectivity of the proposed urban model.

7.5.4 Guideline SS4: To utilise sustainable practices

The CUrM has utilised sustainable practices within an urban structure. The urban model has represented all sustainable practices from the incorporation of green areas, implementation of public transportation systems and reducing SOVs, which will decrease fossil fuels. The incorporation of green areas acts as a barrier to natural flooding as well as reducing heat islands within the urban structure. The green areas will absorb toxic GHGs from factories within the transitional area and improve air quality (Williams, 2005:1-4). This will ultimately create a resilient urban environment that harmonises with natural ecosystems.

Guideline SS4 is once again supported by the above-illustrated guidelines (see SS2, SS3, TP1, TP2, TP3, TP4, TP5) to enhance the urban structure and improve the efficiency of transportation systems. The guideline supports sustainable urban development as illustrated in Canberra (cf. 6.2). The CUrM has included the following sustainable practices:

- Reducing SOV usage;
- Incorporation of green areas;
- Creating a compact urban structure;
- Improving the efficiency of transportation systems; and
- Promoting walkability and pedestrian infrastructure.

CUrM's planning of land use shows a natural green area as a barrier between the transitional area and the residential area. This will improve the quality of life and absorb any toxic GHGs/ liquid from the manufacturing zone (Zone 2).

7.5.5 Guideline SS5: To plan for resilience

Guideline SS5 refers to future planning to incorporate a resilient approach towards factors that may negatively affect the urban structure. Guideline SS5 refers to planning for future resilience within an urban structure and involves creating adaptive strategies that enhance any recovery from environmental, social, and economic stresses (cf. 5.7).

The topography of the climate can play a large role in the urban structure's possible stress. This can be achieved by conducting comprehensive risk assessments to identify vulnerabilities to climate change impacts. This may refer to certain natural disasters, such as flooding and extreme heat, which have been considered in the CUrM. This can be improved further through the incorporation of green infrastructure, such as green roofs, and permeable pavements, to help manage stormwater. The land use of the CUrM can be considered as flexible and multi-use. The development of flexible zoning regulations allows for rapid adaptation to changing circumstances while promoting mixed-use developments enhances economic (cf. 5.4.1) diversity and social (cf. 5.4.2) cohesion. This can be illustrated in the CUrM CBD area, which can expand to improve economic benefit.

The guidelines illustrated support one another and are used within the urban structure to improve the efficiency of transportation systems. The guidelines illustrated above are all considered to be planning strategies to improve resilience.

7.5.6 Guideline SS6: To implement the correct policy framework

Implementing land use policies is crucial for an urban structure's functionality. The incorrect policy can jeopardise an entire functional urban structure due to incorrect legislation. The policies could be implemented in a local sphere as well as regional spheres of government (cf. 5.4.4). These policies should govern:

- Zoning regulations;
- Transportation systems (TOD);
- Environmental preservation;
- The use of automobiles; and
- Any policies that may be required for that specific area.

The policy implementation is clear with CUrM; these policies focus on the efficiency of both land use and urban transportation systems. The purpose of policy implementation (cf. 5.7.5) is to support the implemented infrastructure and provide a way forward through possible challenges.

The other purpose of policy implementation is to preserve land use and transportation systems for future generations. The above guidelines have been presented to contribute towards the growth of urban structures and the sustainability of communities. **Research Objective 4** has been achieved through the established guidelines as illustrated in the above section. Guideline SS6 offers a way forward to increasing transportation efficiency and mobility throughout the urban structure. The guidelines have been implemented in the above-provided CUrM, illustrating a practical approach towards theoretical implementation (Schiller *et al.*, 2010:174-175).

7.6 PRACTICAL IMPLEMENTATION OF THE CURM MODEL

The recommended guidelines and proposed urban model can be used for new urban structures or existing guidelines for spatial planning. The chapter will address **Research Objective 5 (To have a more efficient spatial planning approach towards transport networks determined by the urban structure)**. The proposed urban model implementation refers to a step-by-step process which allows for sustainable urban growth and improves the efficiency of transportation systems. The below illustration demonstrates the implementation of the CUrM within a SS. The model has been used to expand and improve transportation efficiency. The step-by-step process will be illustrated and include the above-recommended guidelines through an illustrative example of the case study of CPT (cf. 6.11). The below example represents the above illustrated research methodology (Chapter 2) through the practical implementation of the proposed urban model. The below implementation of the proposed urban model represents both greenfield (new urban structures) and brownfield development (existing urban structures) concepts:

Figure 7- 10 Practical implementation of the CUrM Part 1

Source: Author's own (2024)

Figure 7-10 shows the use of the CUrM (cf. 7.3) over the spatial area of CPT, through the use of practical implementation strategies and connectivity to the existing urban structures. The above Figure 7-10 illustrates the implementation of a greenfield development (new urban structure). The urban model illustrates the use of the existing road network (cf. 4.2) and demonstrates the various connectivity points and implementation of public transportation infrastructure. The structure of the urban model may adapt to the implemented transportation systems and land use, as all urban models have different topographies and existing infrastructure.

The CUrM makes use of existing infrastructure to improve the efficiency of transportation systems. This uses the above policy-based guidelines (cf. 7.4-7.5) to consider various inclusive implementation strategies to optimise mobility and connectivity of land use. The following Figure 7-11 depicts how the CUrM adapts to transportation systems and how it forms a new urban structure with the surrounding urban structures.

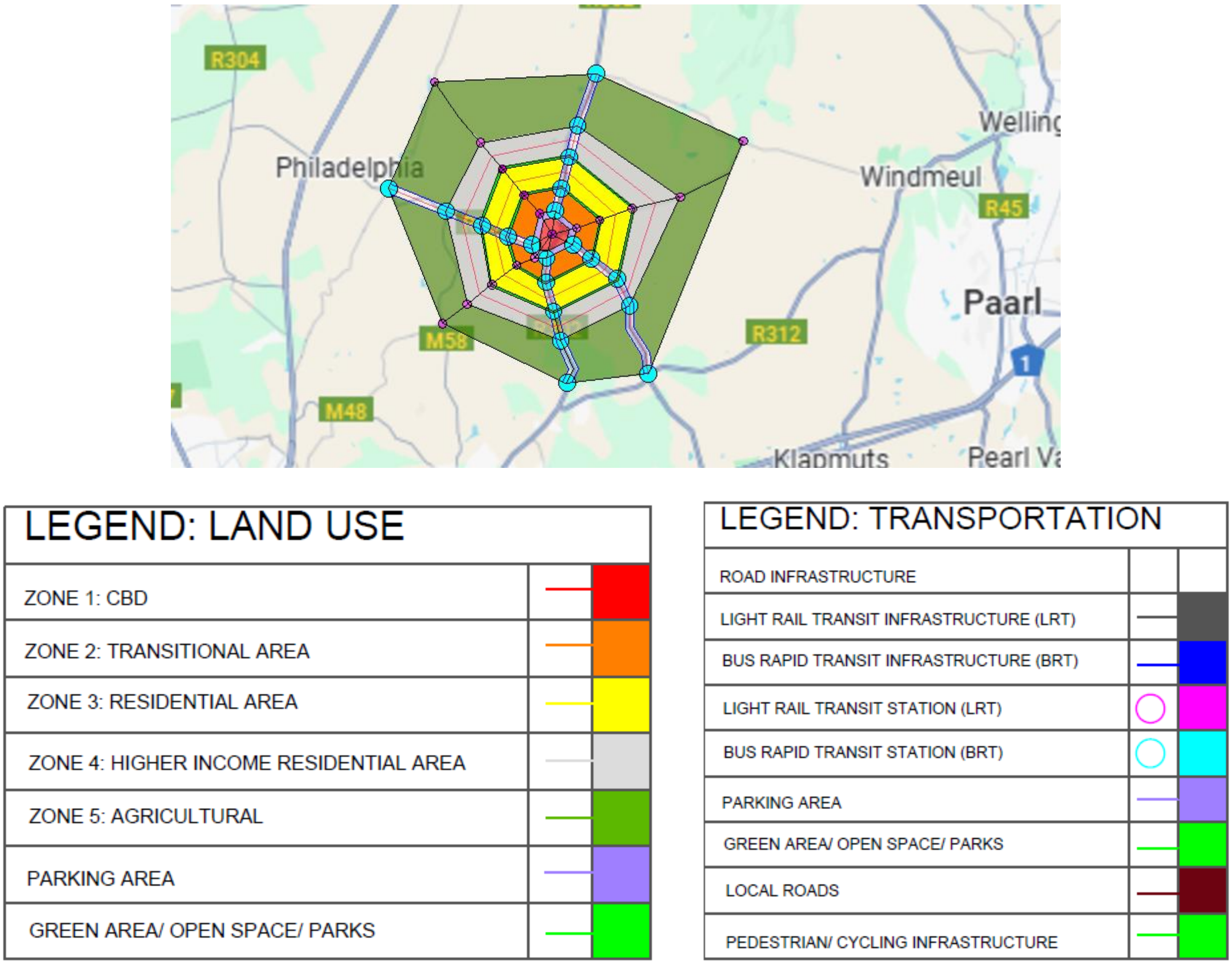


Figure 7- 11 Practical implementation of the CUrM Part 2

Source: Author's own (2024)

The above implementation of the proposed urban model illustrates the practical implementation of the greenfield development (new urban model) and previous guidelines (cf. 7.4-7.5). The implementation of the model within an existing urban structure (cf. 7.6.3) would require a remodelling of the urban structure but incorporates all of the above guidelines and principles. The proposed urban model can be applied using a step-by-step process.

The proposed urban model is governed by the above guidelines and can be implemented within any urban structure, but as mentioned all urban structures (cf. 3.2) may differ. This would align different land uses and transportation systems differently based on the applied urban structure. The proposed urban model could be used through the three-step implementation process, as discussed below.

7.6.1 Step 1: Identify arterial roads

Identify the possible arterial roads within the urban structure to understand the connectivity of road networks within the current urban structure. This illustrates the flow (cf. 4.3) and transportation network (cf. 4.2), which demonstrates the approach currently used within TP (cf. 4.4). The step will show possible areas to implement the BRT systems within the urban structure as mentioned within the recommendations (cf. 7.3). The focus would be used to improve and promote public transportation systems (see TP1) within the urban structure. This shows possible connectivity points based on the topography and current land use. The BRT system will be placed on both sides of the arterial road to reduce road expansion, which would limit SOVs (see TP3). This may cause congestion but promotes public transportation systems.

The current urban structure would possibly lack connectivity between certain land uses or be limited due to congestion. This requires the implementation of LRT transportation systems, which connect these land uses. The implementation of LRT transportation systems would provide additional access to land use and increase transportation efficiency. The implementation of public transportation systems would require easy access for pedestrians and individuals to use the facility. This would require careful walkability planning from residential areas to the public transportation station. The use and implementation of active transportation systems would be required by using existing roads, which are transformed into pedestrian walkways and cycling lanes (see TP2). Existing road infrastructure would limit SOVs and promote active transportation, considered a sustainable transportation system (see TP4). The implemented transportation systems should be directly connected to the CBD district to increase the efficiency of transportation systems within the urban structure. The concept and guidelines (cf. 7.4) are to increase transportation efficiency, promote public transportation (see TP1), increase active transportation (see TP2) and create a sustainable transportation infrastructure (see TP4). This could be achieved through the use of existing road infrastructure as a guideline and would begin to limit the use of SOVs (see TP3).

7.6.2 Step 2: Increase accessibility to public transportation systems

A systematic implementation of various guidelines is required to increase access to public transportation systems; this would require the use of pick-up and drop-off points. These points will illustrate the implementation of public transportation stations which will be designated to areas of mixed land use (see SS1) or areas centralised between land uses (within developed urban structures). The stations should be accessible within neighbourhoods and transport individuals to areas of work or business. The use of intelligent transportation systems (GPS, schedules and destination) will illustrate to the residing community where they could use the public transportation system and the times scheduled (see TP5). This will allow individuals to plan their trips, as seen in the TP models (cf. 4.4).

Furthermore, the planning of public transportation systems should be cost-effective and efficient to accommodate various income groups and capacities. The public transportation systems should connect to all residential land uses and have various stations to increase accessibility towards land uses. The public transportation stations may not always be within proximity to the area but should be close to active transportation systems (see TP2). The newly formed pedestrian infrastructure from the current road infrastructure should incorporate the use of green areas (see SS2), both to access the transportation system and various other land uses. In the scenario where the land use is considered to be further from the public transportation system, the individual could access a different public transportation system for transit. The use of sustainable practices can also be incorporated through bicycle-sharing, as illustrated in the case studies (Chapter 6). This would be illustrated to the community through the intelligent transportation system (see TP5). The bicycle-sharing concept would be considered an active transportation system (see TP2) and utilise sustainable growth principles (see SS3). The implementation of smart growth principles has been illustrated through the transformation of existing road infrastructure to pedestrian infrastructure. This would also include reducing SOVs by increasing the use of public transportation systems, and showing the use of sustainable practices as illustrated throughout the step-by-step process.

7.6.3 Step 3: Implementation of policy

The implementation of the policy within the urban structure is a crucial component towards further growth of the urban structure as well as governing the existing infrastructure. The policy component is illustrated within the guidelines (see SS6). Policy implementation may differ due to the topography, urban structure, existing land uses and transportation systems. The policy framework would govern the transportation systems' functionality and illustrate possible application methods throughout the various urban structures. The implementation of smart growth strategies (see SS3) will allow the urban structure to function more efficiently and sustainably. The transportation systems should follow a TOD (cf. 5.8) concept to promote efficiency of mobility. The policy should incorporate various land use policies which should include zoning regulations (see SS6) and mixed land use (see SS1) objectives to improve resilience (see SS5) within the urban structure. The implementation of green areas (see SS2) will improve active transportation systems (see TP2) and would require safety strategies based on the remaining SOV infrastructure. This will improve sustainable transportation systems (see TP4) within the urban structure. The concept would be applied to both SSs as well as TPs, which would increase connectivity and efficiency of transportation systems between land uses.

The implementation of the correct policy framework is dependent on the urban structure and various other factors. The policy framework within the SS guidelines (see SS6) illustrates the importance of land use regulations (Chapter 6), preservation and conservation. This refers to the above-mentioned guidelines to implement sustainable practices (see SS4), incorporate green areas (see SS2) and implement smart growth (see SS3) strategies. The smart growth strategy has been illustrated in the transformation of existing road infrastructure to pedestrian infrastructure while implementing sustainable practices that can be applied through bicycle-sharing strategies (Chapter 6). This will improve the resilience of the urban structure by increasing the efficiency of mobility and decreasing SOVs (see TP3). The smart growth strategy (see SS3) of the proposed urban model (cf. 7.3) illustrates the expansion of the CBD area by reducing parking areas as SOVs become less dominant within the urban structure. This would improve the economic benefit of the urban structure and should be governed through a policy framework.

The implementation of the policy framework governing TP should be incorporated to maintain a constant flow of mobility (cf. 4.3) and improve interactions (cf. 5.4) within all land uses. The policy should promote public transportation (see TP1) systems through increasing accessibility and efficiency. The transportation policy should govern the functionality and safety of sustainable transportation systems through the implementation of green spaces (see SS2) to increase active transportation systems (see TP2) to utilise sustainable practices (see TP4). The international best practices applied demonstrate guidelines to improve urban structures and transportation systems. This requires the decrease in SOVs (see TP3) through the promotion of public transportation systems and by restricting expansion through the implementation of sustainable transportation. The policy should govern the schedule of public transportation systems as well as the intelligent system (see TP5) implemented to improve awareness of public transportation systems and increase their use. This will allow all individuals access to policy implementation. The cost-effective approach towards mobility should allow for all income groups (see TP6) to utilise the public transportation system. This can be incorporated through cost per distance travelled, as illustrated in the urban models (cf. 3.2), since the lower income groups are situated close to the CBD (short-distance = low cost). The policy can illustrate these transportation regulations to improve the efficiency of mobility within the urban structure.

The urban structure can differ in form and layout; however, the guidelines could apply to all urban structures. The guidelines could improve the efficiency of transportation systems through effective spatial planning and TP approaches. The guidelines can address the challenges within TP (cf. 5.7) and increase the efficiency of transport. The proposed urban model could be used as a template for future urban structures. The simple three-step process illustrates how to approach and apply the template through the use of the created guidelines. The urban structure of the applied case studies (Chapter 6) demonstrates that the urban models (cf. 3.2) are not all exactly implemented according to the urban model but illustrate similar principles. The case studies have shown other possible methods of implementing sustainable transportation systems (water taxis) which could be applied based on the topography. The guidelines form a base of implementations for urban planners to efficiently implement transportation systems within the urban structure. The implementation of the proposed urban model below demonstrates the application of transportation systems within the urban structure.

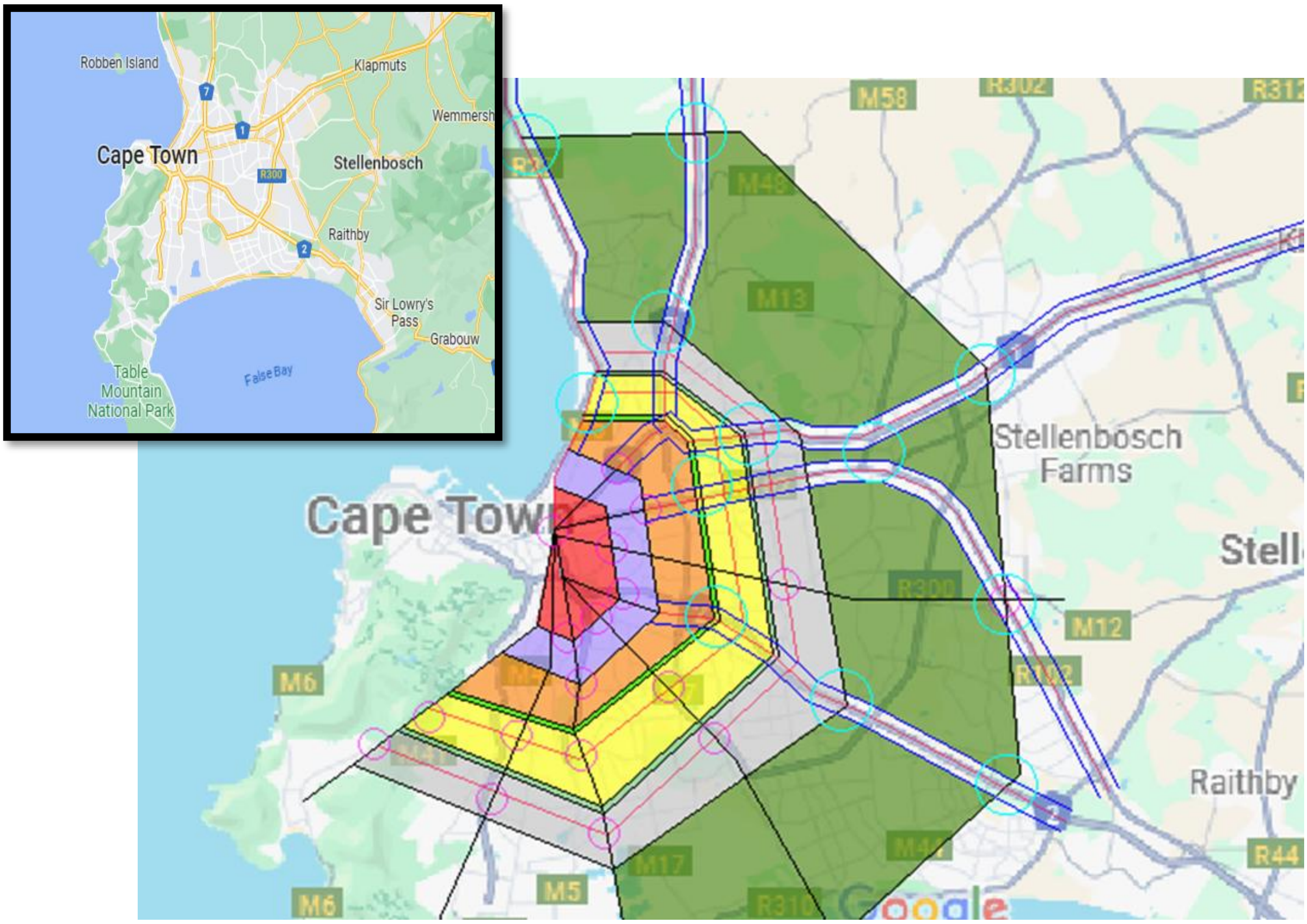


Figure 7- 12 Practical application of CUrM on existing SS

Source: Author's own (2024)

The Figure 7-12 depicts the implementation of the CUrM based on the recommended guidelines and the three-step process. The land use implementation of the urban model should be applied over a period of time with the zoning regulations implemented within SS policy. The above Figure 7-12 illustrates the implementation of a brownfield development (existing urban structure). The existing urban structure should approach various methods of application in a step-by-step process to ensure a successful transition. The SS may have current challenges which should be addressed with the recommended guidelines.

The chapter illustrated the use of the guidelines discussed in the previous section and demonstrated the implementation towards a more efficient transportation system. Therefore, **Research Objective 5 has been achieved through the above application of the proposed urban model and guidelines**. The template illustrates the practical implementation of the CUrM through policy-based guidelines to improve the efficiency of transportation systems and connectivity of land use. The proposed urban model illustrates the use of all the applied guidelines illustrated within the recommendations (see TP [7.4] and SS [7.5]) to create efficient transportation systems within the urban structure.

7.7 CONCLUSION

The above research and recommendations have illustrated that urban structures and transportation systems are two different systems which function together simultaneously to achieve a specific goal. The chapter has achieved **Research Objective 5** through the above creation and implementation of guidelines with the additional contribution of the proposed urban model (CUrM). Transportation systems have several different (cf. 4.4) models of implementation and can differ from connectivity to type of transportation system. Transportation systems are implemented in various ways, which can affect the efficiency of mobility. The incorrect implementation of transportation networks (cf. 4.2) and modes could affect the flow (cf. 4.3) of transportation, which increases congestion. The research suggests that there are various modes of transportation as well as principles of implementation; there are also many different forms (cf. 5.6) and models (cf. 3.2) of urban structures. After the evaluation, it is clear these models can change the urban structure. Thus, the principles of implementation will differ based on the policy, land use, SS and modes of transportation systems. The research suggests significant methods and several strategies of implementation to improve transportation efficiency (Chapter 5). The case studies (Chapter 6) were analysed to illustrate the plausibility of the implementation of each urban model. This demonstrated possible practical implementation strategies to improve transportation systems within the urban structure.

In conclusion, all four objectives have been addressed throughout the thesis, while illustrating the spatial implementation of efficient transportation systems within an urban structure. The comparative research illustrated in this thesis (Chapter 6) indicated that the implementation of the above recommendations (Chapter 7) is possible. The recommendations apply to all challenges within transportation systems (cf. 5.7) and land use and increase accessibility and interaction (cf. 5.4) between various sectors. The recommendations provided various guidelines for implementing transportation systems within the urban structure. The guidelines were applied to the proposed CUrM in the form of an urban structure derived from sustainable strategies which enhance transportation efficiency, based on the above research and comparative analysis. This model is, therefore, not only theoretical but can be seen as a practical solution that can be implemented for long-term sustainability and enhanced efficiency. The above recommendations can be used to effectively plan urban structures (cf. 5.2), as well as provide a background towards TP (cf. 5.3).

7.7.1 Study limitations

The thesis addressed the challenges imposed within the practical implementation of urban models (cf. 3.2) to identify possible futuristic guidelines for implementing transportation systems within various urban structures whilst still enhancing transportation efficiency. This research study was confined to certain criteria based on the objectives of the study, which implied limitations, namely:

- Accessible information for case study information;
- Traffic impact studies; and
- Unavailable future implementation plans.

7.7.2 Areas of future research

The thesis illustrated a possible solution towards future planning of urban structures and guidelines to improve transportation systems regarding accessibility of land use and efficiency of movement. The mobility systems within urban structures are considered to be the general backbone of economic development, with exemption towards implementation. The research has illustrated possible challenges (cf. 5.6) which may need to be addressed in future studies to improve the efficiency of TP within the urban structure. The research identifies that the use of SOVs and automobiles causes problematic transportation efficiency due to congestion (cf. 5.7.7), population growth and the impact on the environment (cf. 5.7.2). The following subjects and challenges should be addressed in future studies to improve transportation systems:

- How can road infrastructure be used for sustainable transportation, given the fact that millions of km have been implemented for SOVs?;
- How can the shift to sustainable transportation happen and how will it be addressed in a step-by-step process?;
- What sustainable transportation can be used, that is affordable to communities and income groups for long-distance travel?; and
- What technological advancements can help improve the planning of land use within the urban structure?

The above questions have relevance towards significant components of spatial planning and could prove valuable in the implementation of urban structures. Most special planning restrictions relate to expenditure and finances, thus future research should assess how this can be skirted to spatial planning within urban structures.

BIBLIOGRAPHY

Abdulwahab, A.A. 2021. Evaluation of Road Networks Based on Traffic Accidents in Erbil City. In IOP Conference Series: Earth and Environmental Science. IOP Publishing.754 (1): 1-12.

Acheampong, R. A., & Silva, E. A. 2015. Land use–transport interaction modelling: A review of the literature and future research directions. Journal of Transport and Land Use, 8(3): 11–38.

ACT (Australian Capital Territories). 2014. The city plan. Australian Capital Territory, Canberra 2014, 5-124. [Online]. Available at: <https://www.researchgate.net/publication/254609646_Latent_Demand_for_Transit_The_Case_of_Canberra's_Proposed_LRT/link/5ade7235aca272fdaf88fbcc/download?_tp=eyJjb250ZXh0Ijp7InBhZ2UiOiJwdWJsaWNhdGlvbiIsInByZXZpb3VzUGFnZSI6bnVsbH19> [Accessed:30 July 2024].

ACT Government. 2018. Canberra spatial plan. Canberra: ACT Government, 1-107.

ACT Government. 2019. Canberra integrated transport strategy. Canberra: ACT Government. [Online]. Available at: <https://s3.ap-southeast-2.amazonaws.com/hdp.au.prod.app.act-yoursay.files/7715/4508/8347/INTEGRATED_TRANSPORT_STRATEGY_-_181514.pdf> [Accessed:13 October 2024].

ACT Government. 2020. Active travel policy. Canberra: ACT Government, 1-38.

ACT Government. 2020. Transport for Canberra: The future of public transport in the ACT. Canberra: ACT Government. [Online]. Available at: <https://www.transport.act.gov.au/__data/assets/pdf_file/0005/887360/Transport-for-Canberra-Overview.pdf> [Accessed:13 October 2024].

ACT Government. 2020. Urban open space policy. Canberra: ACT Government, 1-84.

ACT Government. 2021. Housing choices policy. Canberra: ACT Government. [Online]. Available at: <https://participedia.net/case/5874> [Accessed:02 July 2024].

ACT Government. 2021. Light rail stage 2: Project Overview. Canberra: ACT Government. [Online]. Available at: <https://www.parliament.act.gov.au/__data/assets/pdf_file/0019/1912231/2021-Government-Response-to-AG-Report-No-8-of-2021-Canberra-Light-Rail-Stage-2A-Economic-Analysis-tabled-2-December-2021.pdf> [Accessed:13 October 2024].

ACT Government. 2022. Public transport expansion plan. Canberra: ACT Government. Available at: <https://www.builtforcbr.act.gov.au/__data/assets/pdf_file/0009/2548746/ACT-Infrastructure-Plan-Update-Transport.pdf> [Accessed:13 October 2024].

ACT government. 2022. Update to city plan 2014, 1-84.

Adams, J. S. 1970. Residential structure of midwestern cities. The annals of the Association of American Geographer, 60 (1): 37-62.

Ademiluyi, I.A., Afolabi, O.J. and Fashola, O.K. 2016. Analysis of intra–city water transportation In Lagos State. International Journal of Innovative Research and Advanced Studies, 3: 246-254.

Ademola Osho, M. 2022. Vision 2050: Nigeria as a developed country. ResearchGate, 1-4.

Adhvaryu, B. 2010. Enhancing urban planning using simplified models: SIMPLAN for Ahmedabad, India. Researchgate. Progress in Planning, 73:113–207. [Online]. Available at: <file:///C:/Users/27828/Downloads/AdhvaryuB.2010.Enhancingurbanplanningusingsimplifiedmodels--SIMPLANforAhmedabadIndia.ProgressinPlanning733113207.pdf> [Accessed:15 February 2024].

Ahmed, B. 2012. The traditional four steps transportation modelling using simplified transport network: A case study of Dhaka City, Bangladesh. IJASETR, 1(1): 19-40.

Ajayi, S.A., Adams, C.A., Dumedah, G., & Ackaah, W. 2022. Transport related air pollution and its implications on public health along selected road corridors in Lagos metropolis, Nigeria. ResearchGate, 1-14.

Aleta, A., Meloni, S., & Moreno, Y. 2017. A multilayer perspective for the analysis of urban transportation systems. Scientific reports, 7(1), p.44359.

Ali, A.A., & Eliasson, J. 2018. Dynamic origin-destination-matrix estimation using smart card data: Anentropy maximization approach. ResearchGate, 1-15.

Aljebori, S. T. H. 2017. A developed realistic urban road traffic in Erbil city using bi-directionally coupled simulations. Qalaai Zanist Scientific Journal. Researchgate. [Online]. Available at: <https://www.researchgate.net/publication/318880981_A_Developed_Realistic_Urban_Road_Traffic_in_Erbil_City_Using_Bi-directionally_Coupled_Simulations> [Accessed:12 February 2023].

Allen, H. 2013. Africa's first full rapid bus system: The Rea Vaya Bus System in Johannesburg, Republic of South Africa. Case study prepared for Global Report on Human Settlements, 1-17.

Almasri, E., Sarraj, Y., & Eljamassi, A. 2010. Transportation Planning Challenges in Developing Cities– A Practice from Rafah, Palestine. Alexandria Engineering Journal. Researchgate. [Accessed: 09 November 2021].

Alqhatani, M., Setunge, S., & Moridpour, S. 2014. Accessibility development by shifting from monocentric structure to polycentric structure: A comparison of Riyadh, Saudi Arabia and Melbourne, Australia. *Journal of Traffic and Logistics Engineering*, 2(3): 218-223.

Al-Saffar, M. 2020. How to enhance the future of urban environments through smart sustainable urban infrastructures. Researchgate. [Online]. Available at: <https://www.researchgate.net/publication/339750587> [Accessed: 16 November 2021].

Ancora, V., Nelli, C. & Petrelli, M. 2012. A microsimulation model for BRT systems analysis. Procedia-Social and Behavioral Sciences, 54: 1250-1259.

Anjomani, A. 2009. Integrated Land Use Transportation Modeling Needs and Legislative Mandates. WSEAS Transactions on Environment and Development. Researchgate, 5(11): 695- 704. [Online]. Available at: <https://www.researchgate.net/publication/237474366_Integrated_Land_Use_Transportation_Modeling_Needs_and_Legislative_Mandates/link/00463534b73b2f3d92000000/download> [Accessed: 09 September 2021].

Arora, A., & Pandey, M.K. 2011. Transportation network model and network analysis of road networks. 12th Esri India User Conference. ResearchGate, 1-8.

Asami, Y. 2012. Impact of natural disasters on railway systems: A case study of the Great East Japan Earthquake. Journal of Disaster Research, 7(6), 712-722.

Australia. 2010. Urban form analysis: Canberra's sustainability performance. Act planning and land authority. <https://www.cmtedd.act.gov.au/__data/assets/pdf_file/0007/280636/Appendix_A_-_Urban_Form_Analysis.pdf> [Accessed: 19 January 2019].

Ausubel, J., & Marchetti, C. 2001. The evolution of transport. The Industrial Physicist. ResearchGate, 20-24. [Online]. Available at: <https://www.researchgate.net/publication/293520955_The_evolution_of_transport/link/5ddd38cea6fdcc2837ec0946/download?_tp=eyJjb250ZXh0Ijp7InBhZ2UiOiJwdWJsaWNhdGlvbiIsInByZXZpb3VzUGFnZSI6bnVsbH19> [Accessed:20 July 2024].

Ausubel, J.H., Marchetti, C., & Meyer, P.S. 2000. Toward green mobility: The evolution of transport. Reprinted from European Review, 6(2):137-156.

Auwalu, F.K., & Bello, M. 2023. Exploring the contemporary challenges of urbanization and the role of sustainable urban development: a study of Lagos City, Nigeria. Journal of Contemporary Urban Affairs, 7(1): 175-188.

Aziz, S.Q., Aziz, H.A., Bashir, M.J.K., & Yusoff, M.S. 2011. Appraisal of domestic solid waste generation, components, and the feasibility of recycling in Erbil, Iraq. ResearchGate, 881-887.

Banister, D. 2008. The sustainable mobility paradigm. Transport Policy, 15(2), 73–80.

Banister, D., & Hickman, R. 2013. Transport and Climate Change: Reducing the Carbon Footprint of Urban Transport. Journal of Transport Geography, 27: 1-11.

Barajas, J., Frick, K. and Cervero, R. 2020. Travel of TOD residents in the San Francisco Bay area: Examining the impact of affordable housing, 1-76.

Baro, F., Chaparro, L., Go´mez-Baggethun, E., Langemeyer, J., Nowak, D.J., & Terradas, J. 2014. Contribution of ecosystem services to air quality and climate change mitigation policies: The case of urban forests in Barcelona, Spain. A Journal of the Human Environment (AMBIO). Springer, 43(4): 466-479.

Barret, S. 1978. The Land Market and Development Process, School for Advanced Urban Studies, University of Bristol.

BART. 2023. Bay Area Rapid Transit System Overview. [Online]. Available at: <https://www.bart.gov> [Accessed:24 November 2024].

Bates, J. 2003. Economic evaluation and transport Modelling: Theory and practice. ResearchGate. [Online]. Available at: <https://www.researchgate.net/publication/230663992> [Accessed:01 April 2022].

Batsuuri, B., Fürst, C., & Myagmarsuren, B. 2020. Estimating the impact of urban planning concepts on reducing the urban sprawl of Ulaanbaatar city using certain spatial indicators. Land, 9(495): 1-20.

Ben-Akiva, M., Cascetta, E., Coppola, P., & Velardi, V. 2010. High speed rail demand forecasting in a competitive market: The Italian case study. ResearchGate, 1-9.

Berglund, E., & Johansson, M. (2017). Public participation in urban planning: exploring challenges and possibilities for transformative change. European Planning Studies, 25(11), 2024-2042.

Bertaud, A. 2002. Note on transportation and urban spatial structure. ABCDE Conference, Washington, p. 1-11.

Bianchini, L., Egidi, G., Alhuseen, A., Sateriano, A., Cividino, S., Clemente, M., & Imbrenda, V. 2021. Toward a dualistic growth? Population increase and land-use change in Rome, Italy. Land, 10(7), p.749.

Bolleter, J., & Ramalho, C.E. 2020. Transit-Oriented Development (TOD) and its problems. Greenspace-oriented development: Reconciling urban density and nature in suburban cities. ResearchGate, 13-39.

Bourne, L. S. (1975). Urban systems: Strategies for regulation: A comparison of policies in Britain, Sweden, Australia, and Canada. USA: Oxford University Press.

Boussauw, K. 2023. Transport planning and spatial planning: Two worlds apart. Handbook on transport and land use: A holistic approach in an age of rapid technological change. ResearchGate, 11–30. [Online]. Available at: <https://www.researchgate.net/publication/371396782_Transport_planning_and_spatial_planning_two_worlds_apart> [Accessed:16 October 2024].

Bukhari, Z. 2010. Spatial multi-criteria decision analysis for safe school site selection. International Geoinformatics Research and Development Journal. ResearchGate, 1(2): 1-14. [Online]. Available at: <file:///C:/Users/27828/Downloads/IGRDG-Issue2-June2010-1.pdf.pdf> [Accessed:24 July 2024].

C40 cities. 2022. Transit oriented development. Good practice guide, 1-15. [Online]. Available at: <https://www.c40.org/wp-content/uploads/2022/02/C40-Good-Practice-Guide-Transit-Oriented-Development.pdf> [Accessed:20 February 2024].

Calbick, K.S., Day, J.C., & Gunton, T.I. 2003. Land use planning implementation: A best practices assessment. Environments, 31(3): 71-84.

Campbell, E. W. 1968. An evaluation of alternative land use and transportation systems in the Chicago area. The transportation system, 103-116. [Online]. Available at: <https://onlinepubs.trb.org/Onlinepubs/hrr/1968/238/238-006.pdf> [Accessed: 06 April 2024].

Capotorti, G., Mollo, B., Zavattero, L., Anzellotti, I., & Celesti-Grapow, L. 2015. Setting priorities for urban forest planning. A comprehensive response to ecological and social needs for the metropolitan area of Rome (Italy). Sustainability, 7: 3958-3976.

Carroli, L. 2012. Impacts and implications of urban transport. Researchgate, 1-8. [Online]. Available at: <file:///C:/Users/27828/Downloads/carroli_transport.pdf> [Accessed:20 February 2024].

Cervero, R. 2001. Efficient Urbanization: Economic Performance and the Shape of the Urban Fringe. Urban Studies, 38(5): 985-1001.

Cervero, R. 2017. Transit-Oriented Development and Public Transport. In The Routledge Handbook of Transport Economics (pp. 290-304). Routledge.

Cervero, R., & Kockelman, K. 1997. Travel demand and the 3Ds: Density, diversity, and design. Transportation research Part D: Transport and Environment, 2(3), 199-219.

Cervero, R., Ferrell, C., & Murphy, S. 2002. Transit-Oriented Development and joint development in the United States: A literature review. TCRP Research Results Digest. [Online]. Available at: <https://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rrd_52.pdf> [Accessed:30 July 2024].

Chang, M., Grant, M., Green, L., Madigasekera-Elliott, L., & Williams, C. 2022. Building the future generations of the public health spatial planning workforce: Translating healthy places policies into reality. ResearchGate, 47-56.

Chapin, F.S Jr., & Kaiser, E.J. 1979. Urban land use planning. USA: University of Illinois Press, 656 p.

Charles, C. 1964. Street patterns an analysis and evaluation. Masters of science in engineering. Princeton university. (Dissertation M.Sc.)

Chen, X. 2009. Urban planning management system in Los Angeles: An overview. Theoretical and Empirical Research in Urban Management. ResearchGate, 50-63.

Cheung, C., & Black, J. 2005. Residential location-specific travel preferences in an intervening opportunities model: Transport assessment for urban release areas. Journal of the Eastern Asia Society for Transportation Studies, 6: 3773-3788.

Chi, G., & Marcouiller, D.W. 2013. Natural amenities and their effects on migration along the urban-rural continuum. The Annals of Regional Science. Springer, 50(3): 861-883.

Chicago Department of Transportation (CDOT). 2013. Complete Streets Chicago: A policy for creating Liveable streets. Chicago: City of Chicago, 1-32.

Chicago Department of Transportation (CDOT). 2019. CDOT Policies and Procedures. Chicago: City of Chicago, 1-45.

Chicago Department of Transportation (CDOT). 2019. Chicago pedestrian plan. Chicago: City of Chicago, 1-72.

Chicago Department of Transportation (CDOT). 2020. Chicago bicycle plan: 2020 Update. Chicago: City of Chicago, 1-58.

Chicago Department of Transportation (CDOT). 2020. Complete streets guidelines. Chicago: City of Chicago, 1-50.

Chicago Department of Transportation (CDOT). 2021. Transportation equity policy. Chicago: City of Chicago, 1-30.

Chicago Department of Transportation (CDOT). 2022. Green infrastructure policy. Chicago: City of Chicago, 1-25.

Chicago Transit Authority (CTA). 2020. CTA service and ridership report. [Online]. Available at: <https://www.transitchicago.com> [Accessed: 14 October 2023].

Chicago Transit Authority (CTA). 2021. Annual report 2020. Chicago: Chicago Transit Authority, 1-100.

Chicago Transit Authority (CTA). 2022. Service and ridership report: 2021. Chicago: Chicago Transit Authority, 1-30.

Christopher, A.J. 1984. South Africa: The impact of past geographies. Kenwyn: Juta & Co, 108 p.

Cilliers, D.P. 2010. The development of a land-use suitability model in spatial planning in South Africa. Potchefstroom: NWU. (Dissertation M.Sc.)

City of Chicago. 2017. Linkon yards master plan. [Online]. Available at: <https://www.chicago.gov/content/dam/city/depts/dcd/general/mega/LYMasterPlan.pdf> [Accessed:8 February 2023].

City of Chicago. 2019. Chicago zoning ordinance: Title 17 of the Municipal Code of Chicago. Chicago: City of Chicago, 1-500.

City of Chicago. 2020. Chicago zoning ordinance. [Online]. Available at: <https://www.chicago.gov/city/en/depts/dcd/supp_info/zoningordinance.html> [Accessed: 14 October 2023].

City of Los Angeles. 2019. Los Angeles general plan: Housing element. Los Angeles: City of Los Angeles, 1-50.

City of Los Angeles. 2019. Mobility Plan 2035. Los Angeles: City of Los Angeles, 1-50.

City of Los Angeles. 2019. Sustainable city plan. Los Angeles: City of Los Angeles, 1-50.

City of Los Angeles. 2020. Complete streets design guide. Los Angeles: City of Los Angeles, 1-40.

City of Los Angeles. 2020. Green infrastructure plan. Los Angeles: City of Los Angeles, 1-40.

City of Los Angeles. 2020. Los Angeles general plan. Los Angeles: City of Los Angeles, 1-200.

City of Los Angeles. 2020. Parking Reform Initiative. Los Angeles: City of Los Angeles, 1-50.

City of Los Angeles. 2021. Los Angeles climate action plan. Los Angeles: City of Los Angeles, 1-100.

City of Los Angeles. 2021. Los Angeles municipal code: Parking regulations. Los Angeles: City of Los Angeles, 1-200.

City of Los Angeles. 2021. Sustainable communities' strategy. Los Angeles: City of Los Angeles, 1-40.

Clifton, K.J., Currans, C.M., & Muhs, C.D. 2015. Adjusting ITE's trip generation handbook for urban context. The journal of transport and land use, 8(1): 5-29.

Coppolaa, P., Papab, E., Angielloc, G., & Carpentieric, G. 2014. Urban form and sustainability: the case study of Rome. Procedia - Social and behavioral sciences. Elsevier, 160: 557 – 566.

Corsi, C. 2018. New perspectives on road-and river-stations and communication networks in Roman Italy. Archaeology and Economy in the Ancient World, p.207.

Crosas Armengol, C., Gómez Escoda, E.M., & Villavieja Martínez, E. 2024. Interplay between land use planning and functional mix dimensions: an assemblage approach for Metropolitan Barcelona. Sustainability (Switzerland), 16(17, article 7734).

CSIR. 2005. Guidelines for human settlement planning and design, 1: 1-286.

Cullinan, R.R. 2019. Spatial planning approaches towards a more sustainable local transport network. South Africa. Potchefstroom: NWU. (Dissertation M.Sc.)

Datamade. 2023. The city of Chicago. 2nd City Zoning. [Online]. Available at: <https://secondcityzoning.org/> [Accessed: 06 April 2024].

Davies, R.J. 1981. The spatial formation of the South African city. GeoJournal, 2(2): 59-72.

De Rus, G., Campos, J., Socorro, M.P., Valido, J., & Graham, D. 2020. Methodology for the cost-benefit analysis of transport projects and policies. ResearchGate. [Online]. Available at: <https://www.researchgate.net/profile/Gines-De-Rus/publication/344046498_Methodology_for_the_cost-benefit_analysis_of_transport_projects_and_policies/links/5fc17826458515b7977b99f5/Methodology-for-the-cost-benefit-analysis-of-transport-projects-and-policies.pdf> [Accessed:24 July 2024].

Delucchi, M. A. 2009. Enhancing resource sustainability by transforming urban and suburban transportation. Institute of transportation studies, UC Davis. [Online]. Available at: <Enhancing_Resource_Sustainability_by_Tra.pdf> [Accessed:13 February 2024].

Di Zio, S., Montanari, A., & Staniscia, B. 2010. Simulation of urban development in the City of Rome: Framework, methodology, and problem solving. JTLU, 3(2): 85-105.

Domingo, D., Palka, G. and Hersperger, A.M. 2021. Effect of zoning plans on urban land-use change: A multi-scenario simulation for supporting sustainable urban growth. Sustainable Cities and Society, 69, p.102833.

Du Plessis, C., Irurah, D.K., & Scholes, R.J. 2010. The built environment and climate change in South Africa. Building Research and Information. Researchgate, 31(3–4), 240–256.

Du Toit, J., & Mouton, B.J. 2011. A typology of designs for social research in the built environment. Pretoria, South Africa: Department of Town & Regional Planning, University of Pretoria, 1-22.

Du, P., Wood, A., Ditchman, N., & Stephens, B. 2017. Life satisfaction of downtown high-rise vs. suburban low-rise living: A Chicago case study. Sustainability. MDPI, 1052(9): 1-14. [Online]. Available at: <https://www.researchgate.net/publication/317684955_Life_Satisfaction_of_Downtown_High-Rise_vs_Suburban_Low-Rise_Living_A_Chicago_Case_Study/link/59493eac0f7e9b1d9b276dd3/download> [Accessed: 16 November 2021].

Du, P., Wood, A., Stephens, B., & Song, X. 2015. Life-cycle energy implications of downtown high-rise vs. suburban low-rise Living: An overview and quantitative case study for Chicago. Buildings. ResearchGate, 5: 1003-1024.

Dunn, J. 2018. Freight transportation in Chicago: Economic impact and infrastructure needs. Journal of Urban Planning, 45(2): 101-115.

Duranton, G., Turner, M.A., & A. K. Gangopadhyay. (2011). "The effects of congestion on productivity: Evidence from US cities." The Economic Journal, 121(551), 844-864.

Duthie, J., Kockelman, K., Valsaraj, V., & Zhou, B. 2007. Applications of integrated models of land use and transportation: A comparison of ITLUP and urbanism land use models. 54th Annual North American Meetings of the Regional Science Association International, Georgia, 1-16. [Online]. Available at: <https://www.caee.utexas.edu/prof/kockelman/public_html/RSAI07TELUMUrbanSim.pdf> [Accessed:07 July 2022].

El-Barmelgy, M.M., Shalaby, A.M., Nassar, U.A., & Ali, S.M. 2014. Economic land use theory and land value in value model. International journal of economics and statistics. Researchgate, 2: 91-98.

Eldeen, H.S. 2013. The heart of the city from a socio cultural perspective. Real Corp, 917-925.

Epstein, A.K., Breck, A., Cooper, C. and Peirce, S. 2016. Vision Zero San Francisco truck side guard initiative: Technical assessment and recommendations. SFMTA, 1-40.

Erhardt, G.D., Mucci, R.A., Cooper, D., Sana, B., Chen, M., & Castiglione, J. 2022. Do transportation network companies increase or decrease transit ridership? Empirical evidence from San Francisco. Transportation, 49: 313-342.

Ewing, R., & Cervero, R. 2010. Travel and the built environment: A meta-analysis. Journal of the American Planning Association, 76(3), 265–294.

Ewing, R., Tian, G., Lyons, T., & Terzano, K. 2017. Trip and parking generation at transit-oriented developments: Five US case studies. Landscape and Urban Planning. Elsevier, 69-78.

Faghfouri, M. 2013. Evaluating the reliability of rail and road transport in Iran. Journal of Transport Geography, 30, 118-128.

Farrell, C. 2021. Vision Zero and the Bay Area Response: Traffic Fatalities and Perceptions of Pedestrian Safety in Local Politics and Public Policy (Master's thesis, The University of Texas at El Paso), 1-92.

Flannery, D., Duarte, R., Norman, B., O'Donnell, T., Sinclair, H., & Steffen, W. 2015. Light rail transit and residential density in mid-size cities. Canberra Urban and Regional Futures. University of Canberra. ResearchGate, 1-72.

Frank, L.D., Sallis, J.F., Saelens, B.E., Leary, L., Cain, K., Conway, T.L., & Hess, P.M. 2009. The development of a walkability index: Application to the neighborhood quality of life study. BMJ Publishing Group Ltd, 1-29. [Online]. Available at: <Microsoft Word - Revise sm58701.doc (psu.edu)> [Accessed:01 April 2022].

Friedrich, M., Hartl, M. & Magg, C. 2018. A modeling approach for matching ridesharing trips within macroscopic travel demand models. Transportation. Springer, 45:1639–1653.

Fyfield, P.H. 2003. Transportation and land use patterns: Monitoring urban change using aerial phot urban change using aerial photography, Portland, Oregon 1925-1945. Dissertations and Theses. Paper 2242. Portland State University. [Online]. Available at: <https://doi.org/10.15760/etd.2239> [Accessed: 09 December 2021].

Gataric, D., Belij, M., Dercan, B., & Filipovic, D. 2019. The origin and development of garden cities: An overview. [Online]. Available at: <file:///C:/Users/27828/Downloads/The_origin_and_development_of_Garden_cities_An_ove%20(2).pdf> [Accessed:17 February 2024].

Gehl, J. 2010. Cities for People. Washington, DC: Island Press, p. 112.

Geurs, K. T., Zondag, B., De Jong, G., & de Bok, M. 2010. Accessibility appraisal of land-use/transport policy strategies: More than just adding up travel-time savings. Transport Policy, 17(8): 403–412.

Glaeser, E.L., & Kahn, M.E. 2004. Sprawl and urban growth. Handbook of Regional and Urban Economics. Amsterdam. Elsevier, 4: 2481-2527.

González, R.R., & Medina, J.S. 2004. Theories, models and urban realities from New York to Kathmandu, 69-81.

Google Maps, 2022. Central City of Antigo, United States of America. Google Maps. [Online]. Available at: <https://www.google.com/maps/place/Antigo,+WI+54409,+USA/@45.1382333,-89.2409861,12z/data=!3m1!4b1!4m6!3m5!1s0x4d54c61e7a2faf67:0x1de32d25b8a927c4!8m2!3d45.140245!4d-89.1523353!16zL20vMDJiOGdm?entry=ttu> [Accessed: 20 Jan 2022].

Google Maps, 2022. Central City of Barcelona, Spain. Google Maps. [Online]. Available at: <https://www.google.com/maps/place/Barcelona,+Spain/@41.3922903,1.8448389,11z/data=!3m1!4b1!4m6!3m5!1s0x12a49816718e30e5:0x44b0fb3d4f47660a!8m2!3d41.3873974!4d2.168568!16zL20vMDFmNjI?entry=ttu> [Accessed: 20 Jan 2022].

Google Maps, 2022. Central City of Canberra, Australia. Google Maps [Online]. Available at: <https://www.google.com/maps/place/Canberra+ACT,+Australia/@-35.3138679,148.96497,11z/data=!3m1!4b1!4m6!3m5!1s0x6b164ca3b20b34bb:0x400ea6ea7695970!8m2!3d-35.2801846!4d149.1310324!16s%2Fg%2F1yl472t9x?entry=ttu> [Accessed: 20 Jan 2022].

Google Maps, 2022. Central City of Chicago, United States of America. Google Maps [Online]. Available at: <https://www.google.com/maps/place/Chicago,+IL,+USA/@41.8332617,-88.0616174,10z/data=!3m1!4b1!4m6!3m5!1s0x880e2c3cd0f4cbed:0xafe0a6ad09c0c000!8m2!3d41.8781136!4d-87.6297982!16zL20vMDFfZDQ?entry=ttu> [Accessed: 20 Jan 2022].

Google Maps, 2022. Central City of Erbil, Iraqi Kurdistan. Google Maps [Online]. Available at: <https://www.google.com/maps/place/Erbil,+Iraq/@36.1972676,43.9265612,12z/data=!3m1!4b1!4m6!3m5!1s0x400722fe13443461:0x3e01d63391de79d1!8m2!3d36.190073!4d43.9930303!16zL20vMDNuN2Jy?entry=ttu> [Accessed: 20 Jan 2022].

Google Maps, 2022. Central City of Lagos, Nigeria. Google Maps [Online]. Available at: <https://www.google.com/maps/place/Lagos,+Nigeria/@6.5480282,3.119143,11z/data=!3m1!4b1!4m6!3m5!1s0x103b8b2ae68280c1:0xdc9e87a367c3d9cb!8m2!3d6.5243793!4d3.3792057!16zL20vMGxuZnk?entry=ttu> [Accessed: 20 Jan 2022].

Google Maps, 2022. Central City of Los Angeles, United States of America. Google Maps [Online]. Available at: <https://www.google.com/maps/place/Los+Angeles,+CA,+USA/@34.0200392,-118.7413939,10z/data=!3m1!4b1!4m6!3m5!1s0x80c2c75ddc27da13:0xe22fdf6f254608f4!8m2!3d34.0549076!4d-118.242643!16s%2Fm%2F030qb3t?entry=ttu> [Accessed: 20 Jan 2022].

Google Maps, 2022. Central City of Rome, Italy. Google Maps [Online]. Available at: <https://www.google.com/maps/place/Metropolitan+City+of+Rome+Capital,+Italy/@41.8499201,11.8554779,9z/data=!3m1!4b1!4m6!3m5!1s0x13258a111bd74ac3:0x3094f9ab2388100!8m2!3d41.9027008!4d12.4962352!16s%2Fm%2F012m5qrv?entry=ttu> [Accessed: 20 Jan 2022].

Google Maps, 2022. Central City of San Francisco, United States of America. Google Maps [Online]. Available at: <https://www.google.com/maps/place/San+Francisco,+CA,+USA/@37.7576713,-122.5200017,12z/data=!3m1!4b1!4m6!3m5!1s0x80859a6d00690021:0x4a501367f076adff!8m2!3d37.7749295!4d-122.4194155!16zL20vMGQ2bHA?entry=ttu> [Accessed: 20 Jan 2022].

Gordon, C. 2011. Planning for structural transit in low density environments: the case of Canberra, Australia, Australian Planner, 48:3, 148-159.

Gordon, C.E. 2010. Latent demand for transit: The case of Canberra's proposed LRT. ResearchGate, 1-19. [Online]. Available at: <https://www.researchgate.net/publication/254609646_Latent_Demand_for_Transit_The_Case_of_Canberra's_Proposed_LRT/link/5ade7235aca272fdaf88fbcc/download?_tp=eyJjb250ZXh0Ijp7InBhZ2UiOiJwdWJsaWNhdGlvbiIsInByZXZpb3VzUGFnZSI6bnVsbH19> [Accessed:28 July 2024].

Gorelik, B. 2015. The Cullinan diamond and its true story. Jewellery Studies: The Journal of The Society of Jewellery Historians. ResearchGate, 1-11.

Gori, S., Nigro, M., & Petrelli, M. 2012. The impact of land use characteristics for sustainable mobility: the case study of Rome. European transport research review, 4:153-166.

Gottdiener, M., Budd, L., & Lehtovuori, P. 2016. Key concepts in urban studies. SAGE Publications Ltd. second edition, 84-87.

Gottman, J., & Levenson, R. W. (2002). A two-factor model for predicting when a couple will divorce: Exploratory analyses using 14-year longitudinal data. Family Process, 41(1), 83–96.

Grillotti, M.G. 1986. The Rome underground railway: present situation and projects for the future. Bollettino della Società Geografica Italiana, 45-52.

Grodach, C. 2022. The institutional dynamics of land use planning: Urban industrial lands in San Francisco. ResearchGate, 88(4): 1-46.

Gundlegard, D., Rydergren, C., Breyer, N., & Rajna, B. 2016. Travel demand estimation and network assignment based on cellular network data. Computer communications. Elsevier, 95: 29-42.

Haferburg, C. 2011. South Africa under FIFA's reign: The World Cup's contribution to urban development. Development Southern Africa. Routledge, 333-348.

Hamaina, R., Leduc, T., & Moreau, G. 2016. A structural analysis of the streets' network to urban fabric characterization. HAL open science, 1-9. [Online]. Available at: <A structural analysis of the streets' network to urban fabric characterization (archives-ouvertes.fr)> [Accessed:01 April 2022].

Hansen, M. 2020. Need for Speed: Opportunities for Peak Hour Bus Lanes along parking corridors in Los Angeles. Institute of Transportation studies, 1-53.

Hasanien, S. 2022. The impact of the smart modern transportation on the urban structure of the cities. Advanced Studies in Efficient Environmental Design and City Planning. ResearchGate, 601-610.

Heikkila, E. 2007. Describing the urban structure: A factor analysis of Los Angeles. Review of urban and regional development studies. ResearchGate. [Online]. Available at: <https://www.researchgate.net/publication/229584027> [Accessed: 16 November 2021].

Herbert, D. 1972. Urban geography. Newton Abbot: David & Charles. 320 p.

Hodgson, G.M. 2006. What are institutions? Journal of Economic Issues. ResearchGate. [Online]. Available at: <file:///C:/Users/27828/Downloads/What_Are_Institutions.pdf> [Accessed:24 July 2024].

Hoehner, C.M., Brennan, L.K., Brownson, R.C., Handy, S.L., & Killingsworth, R. 2002. Opportunities for integrating public health and urban planning approaches to promote active community environments. American Journal of Health Promotion. [Online]. Available at:

<https://activelivingresearch.org/sites/activelivingresearch.org/files/AJHP_5_Hoehner_0.pdf> [Accessed: 16 November 2021].

Hoffman, A.S. 2016. Advanced network planning for Bus Rapid Transit: The "Quickway" model as a modal alternative to "Light Rail Lite". Federal Transit Administration. ResearchGate, 1-96.

Huang, H., Liang, L., Feng, Z., & Chai, S. 2020. A TOD planning model integrating transport and land use in urban rail transit station areas. IEEE Access, 1-13.

Hurley, A. K. 2014. The machine is a garden. Foreign Policy. [Online]. Available at: <http://foreignpolicy.com/2014/09/26/the-machine-is-a-garden> [Accessed: 15 January 2019].

Ibrahim, R. 2016. Assessing sustainable urban forms in Erbil city of Iraq. (Doctoral dissertation, Wolverhampton University), 1-251.

Ingemarsdotter, E., Kambanou, M.L., Jamsin, E., Sakao, T. and Balkenende, R. 2021. Challenges and solutions in condition-based maintenance implementation- A multiple case study. Journal of Cleaner Production, 296: 1-14.

Jabbar, I.J. 2019. Failure of development in Iraq reasons and ways of getting up. ResearchGate, 39-58.

James, P., Banay, R.F., Hart, J.E., Laden, F., & J.D. Richardson. (2015). "A review of the health effects of greenness in urban environments." Epidemiology, 26(6), 787-796.

Jamoliddinov, F., & Dsilva, J. 2019. Investigating the Central Place Theory: A Case Study on Uzbekistan. International Journal of Management, Entrepreneurship, Social Science and Humanities (IJMESH). ResearchGate, 2(1): 12-21.

Jayne, T.S., & Muyanga, M. 2012. Land constraints in Kenya's densely populated rural areas: implications for food policy and institutional reform. Food Security, 4:399-421.

Jeer, S., & Bain, B. 1997. Traditional color coding for land uses. American Planning Association (AICP), 1-7.

Jeong, I., Choi, M., Kwak, J., Ku, D., & Lee, S. 2023. A comprehensive walkability evaluation system for promoting environmental benefits. Scientific Reports. Nature portfolio, 1-23.

Jia, G., Ma., R., & Hu, Z. 2019. Urban transit network properties evaluation and optimization based on complex network theory. Sustainability, 11: 1-16.

Johnson, J.H. 1967. Urban geography: An introductory analysis. Oxford: Pergamon Press, 188 p.

Kahn, M.E., Walsh, R.P., & T.P. Weyant. (2007). "US greenhouse gas emissions outlook: An update." Energy Journal, 28(3), 1-24.

Kalugina, A. 2016. Affordable housing policies: An overview. Cornell baker program in real estate, 77-83.

Kane, L., & Behrens, R. 2002. Transportation planning models: An historical and critical review. Urban Transport Research Group, University of Cape Town.

Karakuyu, M. 2008. Application of the urban realms model to Istanbul. Geography Department. Fatih University: Büyükçekmece-Istanbul, Turkey. ResearchGate. [Online]. Available at: <https://www.researchgate.net/publication/237564462_APPLICATION_OF_THE_URBAN_REALMS_MODEL_TO_ISTANBUL/download?_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6Il9kaXJlY3QiLCJwYWdlIjoiX2RpcmVjdCJ9fQ> [Accessed:19 July 2024].

Katona, G., & Juhasz, J. 2020. The history of the transport system development and future with sharing and autonomous systems. Communications, 22(1): 25-34.

Khoshnaw, R. 2023. Evaluating mixed land use and connectivity: A case study of five neighborhoods in Erbil City, Iraq. Sustainability. ResearchGate, 15: 1-18. [Online]. Available at: <https://www.researchgate.net/publication/374254518_Evaluating_Mixed_Land_Use_and_Connectivity_A_Case_Study_of_Five_Neighborhoods_in_Erbil_City_Iraq/link/6515a8a93ab6cb4ec6a74510/download?_tp=eyJjb250ZXh0Ijp7InBhZ2UiOiJwdWJsaWNhdGlvbiIsInByZXZpb3VzUGFnZSI6bnVsbH19> [Accessed:13 October 2024].

King, L.J. 2020. Central place theory. The web book of regional science. Regional Research Institute. Sage. [Online]. Available at: <https://researchrepository.wvu.edu/rri-web-book> [Accessed:07 July 2022].

Kitamura, R., Mokhtarian, P.L., & Laidet, L. 1997. A micro-analysis of land use and travel in five neighbourhoods in the San Francisco Bay area. Transportation, 24: 125-158.

Kivimaa, P., & Mehari, F. 2014. The greenhouse gas emissions of freight transportation: An analysis of rail, road, and sea transportation in Finland. Journal of Cleaner Production, 66, 494-502.

Kok, N., Monkkonen, P., & Quigley, J.M. 2014. Land use regulations and the value of land and housing: An intra-metropolitan analysis. Journal of Urban Economics. Elsevier: 136–148.

Koko, A.F., Yue, W., Abubakar, G.A., Hamed, R., & Alabsi, A.A.N. 2021. Analyzing urban growth and land cover change scenario in Lagos, Nigeria using multi-temporal remote sensing data and GIS to mitigate flooding. Geomatics, natural hazards and risk, 12(1):631-652.

KOSONEN, L. 2013. Model of three urban fabrics: adapted for Finnish intermediate cities. A net based document. The Finnish Environment Institute. [Online]. Available at: <http://urbanfabrics.fi/> [Accessed:01 April 2022].

KOSONEN, L. 2015. 'The three fabrics strategy in Finland', in H. Barton, S. Thompson, M. Grant and S. Burgess (eds), Planning for Health and Well-Being: Shaping a Sustainable and Healthy Future, London. Routledge.

Kreutzberger, E., Macharis, C., Vereecken, L. and Woxenius, J. 2003. Is intermodal freight transport more environmentally friendly than all-road freight transport? A review. In Nectar conference, (7):13-15.

Kuncheria, A., Chan, C., Laurence, C., Walker, J.L. and Macfarlane, J. 2024. Evaluating the impacts of major transportation disruptions: San Francisco Bay Area case study. International Journal of Transportation Science and Technology, 15:155-169.

Kung, K.S., Greco, K., Sobolevsky, S., & Ratti, C. 2014. Exploring universal patterns in human home-work commuting from Mobile phone data, 9(6): 1-15.

Kurdistan Regional Government. 2021. Kurdistan regional government action plan for human rights. [Online]. Available at: <https://govkrd.b-cdn.net/OtherEntities/Office%20of%20the%20Coordinator%20for%20International%20Advocacy/English/Publications/Reports/Implementation%20Report%20(2021-2022)%20Kurdistan%20Regional%20Government%20Action%20Plan%20for%20Human%20Rights.pdf> [Accessed:15 October 2024].

Kyriakidou, V., Michalakelis, C., & Sphicopoulos, T. 2015. Broadband penetration as an economic growth accelerator. International Journal of Electronic Governance, 7(3): 253–265.

Lang, R.E. & Nelson, A.C. 2007. Beyond the metroplex: Examining commuter patterns at "megapolitan" scale. Lincoln Institute of Land Policy, Working Paper. 30 p.

Larsson, S., Tyrstrup, O., SSPA Sweden Dawn McCarthy, Dyodo, S., Potgieter, S., & Nelson Mandela Bay Municipality. 2007. Sustainable community planning guide. Nelson Mandela Bay Municipality, 1-142.

Lasi, F.F., Mahmood, A., Samejo, B., Khayyam, U., Waseem, M.H., & Sangrasi, S.A. 2020. The Relationship Between Physical Activity, Obesity and Overweight Among University Going Students of Jamshoro, Sindh. JRCRS.; 8(1):25-32.

Lasisi, O. 2019. History of archaeological research in the Yoruba-Edo region of Nigeria: New directions for urban earthen works. ResearchGate, 169-201.

Lateef, R.O. 2010. Nigeria and development in the 21st century: The theatre for development alternative, 173-187.

Lenormand, M., Picornell, M., Cantú-Ros, O.G., Louail, T., Herranz, R., Barthelemy, M., Frías-Martínez, E., San Miguel, M., & Ramasco, J.J. 2015. Comparing and modelling land use organization in cities. Royal Society open science, 2(12), p.150449.

Liebenberg, C. R. 2002. An analysis of Cape Town municipality's approach to urban regeneration in the central business district and other business nodes. South Africa. University of Stellenbosch (Master degree of Town and Regional Planning). [Online]. Available at: <https://core.ac.uk/download/pdf/37375222.pdf> [Accessed:07 July 2022].

Litman, T. 2019. Transportation Cost and Benefit Analysis: Techniques, Estimates and Implications. Victoria Transport Policy Institute.

Litman, T. 2020. Parking Management: Strategies. Evaluation and Planning. 3rd ed. Victoria Transport Policy Institute. p. 42.

Litman, T., Blair, R., Demopoulos, B., Eddy, N., Fritzel, A., Laidlaw, D., Maddox, H., & Forster, K. 2009. Pedestrian and bicycle planning guide to best practices. Victoria Transport Policy Institute.

Los Angeles County Metropolitan Transportation Authority (Metro). 2020. Metro strategic plan, 2020-2040. [Online]. Available at: <https://www.metro.net> [Accessed:14 October 2023].

Lucas, K. 2012. Transport and Social Exclusion: Where Are We Now?. Transport Policy, 20: 105-113.

Lundqvist, L., & Mattson, L.G. 2001. National transport models: Recent developments and prospects. Berlin, Germany: Springer.

Luscher, D.R. 1995. The odds-on TODs: Transit-oriented development as a congestion-reduction strategy in the San Francisco Bay area. Berkeley Planning Journal, 10(1):55-74.

Mackett, R.L. 1998. Role of travel demand models in appraisal and policy-making. Impact Assessment and Project Appraisal. 16(2): 91-99. [Online]. Available at:

<https://www.tandfonline.com/doi/pdf/10.1080/14615517.1998.10590193> [Accessed:01 April 2022].

Maerivoet, S., & De Moor, B. 2008. Transportation planning and traffic flow models. Department of electrical engineering ESAT-SCD (SISTA), [Online]. Available at: <http://www.esat.kuleuven.be/scd> [Accessed:18 December 2022].

Manderscheid, K. 2011. Planning sustainability: Intergenerational and intergenerational justice in spatial planning strategies. Antipode, 44(1): 197-216.

Manderscheid, K., & Richardson, T. 2010. Planning inequality: Social and economic spaces in national spatial planning. European Planning Studies, 19(10): 1798-1815.

Manville, M., & Shoup, D. 2005. Parking, people, and cities. Journal of urban planning and development. ResearchGate, 131 (4): 233-245. [Online]. Available at: <https://www.researchgate.net/publication/235358939_People_Parking_and_Cities/link/55d61b7a08aec156b9a84b33/download?_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6InB1YmxpY2F0aW9uIiwicGFnZSI6InB1YmxpY2F0aW9uIn19> [Accessed:24 July 2024].

Marchetti, C. 1994. Anthropological invariants in travel behaviour. Technological Forecasting and Social Change, 47(1): 75-88.

Mashabela, C.M. 2023. An application of Von Thunen model of location theory in South Africa: An unemployment mitigation tool. International Journal of Social Science Research and Review, 6(10): 218-226.

McDonagh, J. 1995. Theories of urban land use and their application to the Christchurch property market. Property and land economy institute of New Zealand newsletter. Core, 1-20. [Online]. Available at: <https://core.ac.uk/download/pdf/35469545.pdf> [Accessed:24 July 2024].

McDonagh, J. 1997. Theories of urban land use and their application to the Christchurch property market. New Zealand: Lincoln University, 1-20.

Meijer, J.R., Huijbregts, M.A.J., Schotten, K.C.G.J., & Schipper, A.M. 2018. Global patterns of current and future road infrastructure. Environmental research letters. ResearchGate, 13: 1-10.

Mensah, C.A., Andres, L., Beazley, M., & Roji, A. 2015. Managing urban green spaces in Africa: A collaborative governance approach. ResearchGate, 205-237.

Meyer, M. D. 2016. Transportation planning handbook. Institute of Transportation Engineers. 4th ed. John Wiley & Sons, Inc: Hoboken, New Jersey, 1-1157.

Miller, E.J., & Salvini, P.A. 1998. The integrated land use, transportation, environment (ILUTE) modeling system: a framework. Researchgate. [Online]. Available at: <The_Integrated_Land_Use_Transportation_Environment.pdf> [Accessed:07 July 2022].

Miller, E.J., Kriger, D.S., & Hunt, J.D. 1998. Integrated urban models for simulation of transit and land-use policies. *TCRP Project H-12 Final Report*.

Mills, E.S., & Simmons, C.S. 2001. Evolution of the Chicago landscape: Population dynamics, economic development, and land use change. National Academy of Sciences. ResearchGate, 275-299. [Online]. Available at: <https://www.researchgate.net/publication/259602815_Evolution_of_the_Chicago_Landscape_Population_Dynamics_Economic_Development_and_Land_Use_Change/link/5bf5a742a6fdcc3a8de8affe/download?_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6InB1YmxpY2F0aW9uIiwicGFnZSI6InB1YmxpY2F0aW9uIn19> [Accessed:13 October 2024].

Miraftab, F. 2004. Public-private partnerships: the Trojan horse of neoliberal development? Journal of Planning Education and Research, 24(1), 89-101.

Mogakabe, L., Anochie-Boateng, J., & Ochieng, G. 2018. Comparison of new peak hour trip generation rates with existing rates in South African trip manual, City of Tshwane Municipality, 1-12. [Online]. Available at: <https://pta-dspace-dmz.csir.co.za/dspace/bitstream/handle/10204/10688/Mogakabe_21932_2018.pdf?sequence=1> [Accessed:20 July 2024].

Mohammed, P.A. 2021. Evaluation of sustainable urban form: A study in Erbil, Northern Iraq (Doctoral dissertation, Near east University), 1-99.

Mol, A.M., Silva, R.S., Rocha, A.A., & Ishitani, L. 2017. Ethnography and phenomenology applied to game research: a systematic literature review. ResearchGate. [Online]. Available at: <https://www.researchgate.net/publication/326066063_Ethnography_and_Phenomenology_applied_to_game_research_a_systematic_literature_review/link/5b36498c0f7e9b0df5d986e8/download?_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6InB1YmxpY2F0aW9uIiwicGFnZSI6InB1YmxpY2F0aW9uIn19> [Accessed:13 February 2024].

Montero, L., Mejía-Dorantes, L., & Barceló, J. 2024. Land Use, Travel Patterns and Gender in Barcelona: A Sequence Analysis Approach. Sustainability, 16(20), p.9004.

Moran, M.E. 2022. Are shelters in place? Mapping the distribution of transit amenities via a bus-stop census of San Francisco. Journal of Public Transportation. Science Direct, 24: 1-15.

Moulaert, F., Martinelli, F., Swyngedouw, E., & Gonzalez, S. (2013). Can neighbourhoods save the city? Community development and social innovation. Routledge.

MSA. 2004. City of Antigo, Wisconsin Comprehensive Plan. Antigo.

Nabil, N. 2021. The concept of garden city and its relevancy in modern city planning. Southeast University Journal of Architecture, 1(1): 1-7.

Newman, P., Kosonen, L., & Kenworthy, J. 2016. Theory of urban fabrics: planning the walking, transit/public transport and automobile/motor car cities for reduced car dependency. Theory of urban fabrics, 87(4): 429-458.

Nieuwenhuijsen, M., de Nazelle, A., Pradas, M.C., Daher, C., Dzhambov, A.M., Echave, C., Gössling, S., Iungman, T., Khreis, H., Kirby, N. and Khomenko, S. 2024. The Superblock model: A review of an innovative urban model for sustainability, liveability, health and well-being. Environmental research, p.118550.

Nigro, M., Castiglione, M., Colasanti, F.M., De Vincentis, R., Liberto, C., Valenti, G., & Comi, A. 2022. Investigating potential electric micromobility demand in the city of Rome, Italy. Transportation Research Procedia, 62: 401-407.

Nooraldeen, K. 2015. Contamination of public squares and parks with parasites in Erbil city, Iraq. Annals of Agricultural and Environmental Medicine, 22(3): 418-420.

Nowakowski, T. 2004. Problems of Transportation process reliability modelling. Wrocław University of Technology. [Online]. Available at: <https://www.ue.katowice.pl/fileadmin/_migrated/content_uploads/8_T.Nowakowski_Problems_of_Transportation....pdf> [Accessed:17 February 2024].

Nuzzolo, A., Coppola, P., & Comi, A. 2013. Freight transport modeling: Review and future challenges. International journal of transportation economics. Researchgate. [Online]. Available at: <https://www.researchgate.net/publication/249649952> [15 February 2024].

O'Kelly, M., & Bryan, D. 1996. Agricultural location theory: Von Thunen's contribution to economic geography. Progress in Human Geography, 20(4): 457-475.

Oduwaye, L. 2013. Urban planning implications of changing land use structure of metropolitan Lagos, Nigeria. Proceedings of the Real Corp Tagungsband Planning Times, 1055-1065.

Oluseyi, O.F. 2006. Urban land use change analysis of a traditional city from remote sensing data: the case of Ibadan metropolitan area, Nigeria. Humanity & Social Sciences Journal, 1(1):42-64.

Oni, S.I., & Okanlawon, K.R. 2012. An assessment of the usage of the Lagos mass transit trains. International Journal of Railway, 5(1):29-37.

Otunola, B., Kriticos, S. & Harman, O. 2019. The BRT and the danfo: A case study of Lagos' transport reforms from 1999-2019.

Otuoze, S.H., Hunt, D.V., & Jefferson, I. 2021. Neural network approach to modelling transport system resilience for major cities: case studies of Lagos and kano (Nigeria). Sustainability, 13(3), p.1371.

Pacione, M. 2005. Urban geography: A global perspective. 2nd Edition. New York: Routledge, 686 p.

Parsons, K.C. & Schuyler, D. 2003. From garden city to green city: The legacy of Ebenezer Howard. Journal of the Society of Architectural Historians, 62(4): 530-532.

Patel, T. 2017. Urban landscape- garden city movement. International Journal of Architecture (IJA), 3(1): 12-17. [Online]. Available at: <https://iaeme.com/MasterAdmin/Journal_uploads/IJA/VOLUME_3_ISSUE_1/IJA_03_01_002.pdf> [Accessed:20 February 2024].

Pattaroni, L., Bihde, A., Lurtinger C. 2022. Introduction: On politics of urban planning. Politics of urban planning. The making and unmaking of the Mumbai development Plan. Springer, 1-18.

Peixoto Neto, A. G. L., Galves, M. L., Lima Júnior, O. F., & D. Tacla. 2008. Challenges of urban transport problems and city logistics: Sao Paulo city center case. Urban transport. ResearchGate, (101): 133-142. [Online]. Available at: <https://www.researchgate.net/publication/277598735> [Accessed:17 February 2024].

Peltier, H. 2011. Pedestrian and bicycle Infrastructure: A national study of employment impacts. ResearchGate, 20-24. [Online]. Available at: <https://www.researchgate.net/publication/254455436_Pedestrian_and_Bicycle_Infrastructure_A_National_Study_of_Employment_Impacts/link/54e640b30cf277664ff4d1e8/download?_tp=eyJjb250ZXh0Ijp7InBhZ2UiOiJwdWJsaWNhdGlvbiIsInByZXZpb3VzUGFnZSI6bnVsbH19> [Accessed:20 July 2024].

Phillips, R.A. 1970. The garden city movement: Its origins and influence on early modern town planning. University of British Columbia: Simon Fraser University. (Dissertation - MA)

Pissourios, I.A. 2023. Urban land use survey methods: A discussion on their evolution. Urban Science, 7 (76): 1-16.

PlanetTech. 2020?. The internal structure of cities. [Online]. Available at: <https://cronodon.com/PlanetTech/Cities_Structure.html> [Accessed: 09 March 2022].

Planning Tank. 2020. Garden city movement by Sir Ebenezer Howard. [Online]. Available at: <https://planningtank.com/planning-theory/garden-city-movement> [Accessed:19 February 2024].

Planning Tank. 2020. Multiple Nuclei Model of 1945 by C.D. Harris and Edward L. Ullman. [Online]. Available at: <https://planningtank.com/settlement-geography/multiple-nuclei-model> [Accessed:19 February 2024].

Prajapati, J., & Paneria, D. 2021. Garden city movement: development and challenges. International Journal of Research in Engineering and Science (IJRES), 9(1): 21-25.

Pucher, J., Buehler, R., & Bassette, D. 2010. Walking and Cycling to Health: A Comparative Analysis of City, State, and International Data. American Journal of Public Health. ResearchGate, 100(10): 1986- 1992. [Online]. Available at: <file:///C:/Users/27828/Downloads/Walking_and_Cycling_to_Health_AJPH_PucherBuehler_Sept_2010.pdf> [Accessed: 09 September 2021].

Puentes, R., & Tomer, A. 2008. Rail infrastructure investment and economic development: A framework for analysis. Journal of Transport Geography, 16(1), 1-9.

Rababeh, S., Al Rabady, R., & Abu-khafajah, S. 2014. Colonnaded streets within the Roman cityscape: A “Spatial” perspective. Journal of Architecture and Urbanism. Routledge, 38(4): 293–305.

Rad, V.B., & Ngah, I.B. 2013. The role of public spaces in promoting social interactions. International Journal of Current Engineering and Technology. ResearchGate, 3(1): 184-188.

Raven, J., Stone, B., Mills, G., Towers, J., Katzschner, L., Leone, M., Gaborit, P., Georgescu, M., & Hariri, M. 2018. Urban planning and design. In Rosenzweig, C., W. Solecki, P. Romero-Lankao, S. Mehrotra, S. Dhakal, and S. Ali Ibrahim (eds.), Climate Change and Cities: Second Assessment Report of the Urban Climate Change Research Network. Cambridge University Press. New York. 139–172.

Regidor, J.R.F. 2006. A review of trip and parking generation rates in the Philippines. Philippine Engineering Journal, 27 (1): 1-12.

Rickaby, P. A., Steadman, P., & Barrett, M. 1992. Patterns of land use in English towns: Implications for energy use and carbon dioxide emissions. In M. Breheny (Ed.), Sustainable development and urban form, 182–196.

Rifaat, S.M., Tay, R., & De Barros, A. 2012. Urban street pattern and pedestrian traffic safety. Journal of Urban Design. ResearchGate, 17(3): 337-352.

Roberts, P. & Sykes, H. 2000. Urban Regeneration: A Handbook. London. Cromwell Press.

Robson, K., Gharehbaghi, K. & Young, C.S. 2018. Planning effective and efficient public transport systems. International Journal of Real Estate and Land Planning, 1: 385-392

Rodrigue, J.P. 2013. Urban transportation and land use. ResearchGate, 105-118. [Online]. Available at: <07-Rodrigue-Ch-07-Section-2.pdf> [Accessed:15 February 2024].

Rodrigue, J.P., Comtois, C. & Slack, B. 2006. The geography of transport systems. New York, USA: Routledge.

Rondhi, M., Pratiwi, P.A., Handini, V.T., Sunartomo, A.F., & Budiman, S.A. 2018. Agricultural land conversion, land economic value, and sustainable agriculture: A case study in east Java, Indonesia. Land. MDPI, 148(7): 1-19.

Rosenbloom, S. 2020. The evolution of public transit in Los Angeles: A historical perspective. Transport reviews, 40(1): 35-55.

RSA. 2003. Pedestrian and bicycle facility guidelines. Engineering manual to plan and design safe pedestrian and bicycle facilities. National department of transport, 1-300.

RSA. 2011. Local government budgets and expenditure review. National treasury. Roads department. [Online]. Available at: <https://www.treasury.gov.za/publications/igfr/2011/lg/13.%20roads%202011%20lgber%20-%20final%20-%209%20sept%202011.pdf> [Accessed:8 February 2023].

RSA. 2012. South African road classification and access management manual. Committee of transport officials, 1-66.

RSA. 2013. TMH 17 South African trip data manual. Committee of transport officials, 1-23.

Sabr, C. 2014. A study on the urban form of Erbil city (the capital of Kurdistan region) as an example of historical and fast growing city. Humanities and Social Sciences Review, 03(03):325–340.

Salimbene, F.P., & Wiggins., W.P. 2020. Transit-oriented development: The quest for sustainable cities in the age of the automobile. William & Mary Law School Scholarship Repository, 45:51-101. [Online]. Available at: <https://scholarship.law.wm.edu/wmelpr/vol45/iss1/4> [Accessed:13 February 2024].

San Francisco Planning Department. 2017. San Francisco urban planning guidelines, 1-70.

Sanyal, B. 2014. Urbanising justice: (Re) imagining justice in urbanising Asia. Singapore Journal of Tropical Geography, 35(3), 309-326.

Saunders, N. K., Lewis, P., and Thornhill, A. 2019. Research Methods for Business Students, 8th Ed. London: Pearson Education, 108.

Sayef, B. 2017. Why is South Africa still a developing country? Munich Personal RePEc Archive (MPRA). University Of Tunis El Manar, Tunisia (Dissertation PhD)

Schiller, P.L., Bruun, E.C., & Kenworthy, J.R. 2010. An introduction to sustainable transportation policy, planning and Implementation. ResearchGate, 1-329.

Sebastian, A., & Sangeeth K. 2021. Integrated transportation and land use planning model: A study on traffic congestion in urban areas. International Journal of Science and Research (IJSR). ResearchGate, 10(7): 1-14.

Serafini, S., Nigro, M., Gatta, V., & Marcucci, E. 2018. Sustainable crowdshipping using public transport: A case study evaluation in Rome. Transportation Research Procedia, 30: 101-110.

Seuring, S., Stella, T., & and Stella, M. 2020. Developing and publishing strong empirical research in sustainability management: Addressing the intersection of theory, method, and empirical field. Frontiers in sustainability, 1: 1-9.

SFMTA. 2023. San Francisco Municipal Transportation Agency about Muni: Services and Operations. [Online]. Available at: <https://www.sfmta.com> [Accessed: 24 November 2024].

Shaw, S.L. & Xin, X. 2003. Integrated land use and transportation interaction: A temporal GIS exploratory data analysis approach. Journal of Transport Geography, (11): 103-115.

Sheffi, Y. 1985. Urban transportation networks: Equilibrium analysis with mathematical programming methods, 1-399. [Online]. Available at: <http://web.mit.edu/sheffi/www/selectedMedia/sheffi_urban_trans_networks.pdf> [Accessed: 09 December 2021].

Shi, H., & Gao, M. 2020. Analysis of a flexible transit network in a radial street pattern. Journal of advanced transportation. Hindawi, 1-15. [Online]. Available at: <https://www.researchgate.net/publication/338661417_Analysis_of_a_Flexible_Transit_Network_in_a_Radial_Street_Pattern/link/617bf840eef53e51e100c1d7/download> [Accessed: 28 February 2022].

Simon, D. 1989. Crisis and change in South Africa: Implications for the apartheid city. Transactions of the Institute of British Geographers,4: 189-206.

Skorobogatova, O., & Kuzmina-Merlino, I. 2016. Transport infrastructure development performance: 16th Conference on Reliability and Statistics in Transportation and Communication. ScienceDirect. Procedia Engineering, 319-329.

Smith, J., Garcia, L. and Patel, R. 2022. Urban Traffic Safety in Vision Zero Cities. Cambridge: Harvard University Press.

Sorensen, E., & Torfing, J. 2011. Theories of democratic network governance. Palgrave Macmillan.

Southworth, M. & Owens, P. (1993) The evolving metropolis: studies of community, neighborhood, and street form at the urban edge, Journal of the American Planning Association, 59(3), pp. 271–287.

Spandou, M., Garcia, C., & Macário, R. 2010. Urban revitalization and transport: local factors and driving forces from a stakeholder's view. ResearchGate. [Online]. Available at: <https://www.researchgate.net/publication/321887385> [Accessed:07 July 2022].

Statistics South Africa. 2000. 1999 October Household Survey. Statistics South Africa, Pretoria.

Stewart, C. S. 2008. The sustainable city. Transactions on ecology and the environment. WIT press, (117), 421-431. [Online]. Available at: <https://www.witpress.com/Secure/elibrary/papers/SC08/SC08040FU1.pdf> [Accessed:8 February 2023].

Suzuki, H., Cervero, R., & Iuchi, K. 2013. Transforming cities with transit. Transit and land-use integration for sustainable urban development. The World Bank Washington, DC. [Online]. Available at: <file:///C:/Users/27828/Downloads/Transforming_Cities_with_Transit.pdf> [Accessed:14 February 2024].

Talpur, M.A.H., Napiah, M., Chandio, I., & Khahro, S.H. 2012. Regional transportation planning: proposed study focusing on economic development within deprived rural regions. ResearchGate. [Online]. Available at: <https://www.researchgate.net/publication/263582058_Regional_Transportation_Planning_Proposed_Study_Focusing_Economic_Development_Within_Deprived_Rural_Regions/link/00b7d53c6643792b08000000/download?_tp=eyJjb250ZXh0Ijp7InBhZ2UiOiJwdWJsaWNhdGlvbiIsInByZXZpb3VzUGFnZSI6bnVsbH19> [Accessed:28 February 2024].

Tamuka Moyo, H.T., & Zuidgeest, M.H. 2018. Analyzing the temporal location of employment centers relative to residential areas in Cape Town: A spatial metrics approach. The Journal of Transportation and land use. JTLU, 11(1): 519-540.

Tánczos, K., & Török, A. 2007. Impact of transportation on environment. Periodica polytechnica. Transportation Engineering (36)1-2 :105-110. [Online]. Available at: <http://www.pp.bme.hu/tr> [Accessed:8 February 2023].

Tewdwr-Jones, M., & Allmendinger, P. 2013. Territory, policy, governance: co-production and co-governance in spatial planning. Regional Studies, 47(9), 1403-1412.

Thomson, G. 2016. Transitioning to regenerative urbanism. Curtin University Sustainability Policy Institute (PhD - Philosophy), 1-271.

Thomson, G., & Newman, P. 2016. Geoengineering in the Anthropocene through regenerative urbanism. Geosciences, 6(46): 1-16.

Thomson, G., & Newman, P. 2018. Urban fabrics and urban metabolism – From sustainable to regenerative cities. Resources, Conservation and Recycling, 132: 218–229. [Online]. Available at: <https://www.sciencedirect.com/science/article/pii/S0921344917300216> [Accessed: 20 September 2019].

Tight, M, Timms, P, Banister, D et al. 2011. Visions for a walking and cycling focussed urban transport system. Journal of Transport Geography, 19(6): 1580-1589. [Online]. Available at: <https://eprints.whiterose.ac.uk/84730/1/Tight%20et%20al%202011.pdf> [Accessed:24 July 2024].

Tom. 2020. Burgess concentric circle map in GIS. Bike lab. [Online]. Available at: <https://bike-lab.org/2020/08/12/burgess-concentric-circle-map-in-gis/> [Accessed:17 October 2024].

Toros, T. 2010. An ecological and sustainable solution: Transit-oriented development. Ecological and Sustainable Design. College of architecture. Planning and Design, Kansas State University, Manhattan, America. Academia. [Online]. Available at: <https://www.academia.edu/8742085/An_Ecological_and_Sustainable_Solution_Transit_Oriented_Development_2010_?email_work_card=view-paper> [Accessed:20 July 2024].

Tsekeris, T., & Tsekeris, C. 2011. Demand forecasting in transport: Overview and modeling advances. Economic Research-Ekonomska Istraživanja, 24(1): 82-94.

Tzeng, G.H., & Huang, J.J. 2011. The Application of Hybrid MCDM Model for Evaluating the Performance of Urban Transportation Systems. Expert Systems with Applications, 38(12): 14671-14677.

UNDP (United Nations Development Programme). 2015. Sustainable development goals. New York. [Online]. Available at: <http://www.undp.org/content/dam/undp/library/corporate/brochure/SDGs_Booklet_Web_En.pdf> [Accessed: 10 November 2018].

Unekwu, A.F. 2018. City morphology and effective control mechanisms: Towards land use optimization and sustainable development: A case study of Lagos mega city. South Africa. University of KwaZulu-Natal, Durban. (Dissertation PhD).

United States of America (USA). 2004. City of Antigo, Wisconsin comprehensive plan. City of Antigo comprehensive plan committee. MSA Professional Services, 1-160. [Online]. Available at: <https://antigo-city.org/wp-content/uploads/2018/02/Comprehensive_Plan.pdf> [Accessed: 06 April 2024].

US Department of Transportation. 2018. Freight facts and figures 2018. [Online]. Available at: <https://ops.fhwa.dot.gov/freight/freight_analysis/faf/index.htm> [Accessed:8 February 2023].

Van Schaick, J. 2008. Urban networks - network urbanism. ResearchGate. [Online]. Available at: <https://www.researchgate.net/publication/321071187> [Accessed:18 December 2022].

Van Wyk, J. 2012. Planning in all its (dis)guises: Spheres of government, functional areas and authority. ResearchGate, 15(5): 288-318. [Online]. Available at: <https://www.researchgate.net/publication/317331412_Planning_in_All_its_Disguises_Spheres_of_Government_Functional_Areas_and_Authority/link/593c8480aca272c4d9913467/download?_tp=eyJjb250ZXh0Ijp7ImZpcnN0UGFnZSI6InB1YmxpY2F0aW9uIiwicGFnZSI6InB1YmxpY2F0aW9uIn19> [Accessed:28 July 2024].

Vance, J.E. jr. 1964. Geography and urban evolution in the San Francisco Bay area. Berkeley: Institute of Government, University of California.

Vashisth, A., Kumar, R., & Sharma, S. 2018. Major principles of sustainable transport system: A literature review. International Journal for Research in Applied Science & Engineering Technology (IJRASET). ResearchGate, 6(11): 1597-1605.

Veisten, K., Flugel, S., Ramjerdi, F., & Minken, H. 2011. Cycling and walking for transport: Estimating net health effects from a comparison of different transport mode users' self-reported physical activity. Health Economics Review. ResearchGate, 1 (3): 1-9.

Verbas, O., & Mahmassani, H.S. 2015. Integrated frequency allocation and user assignment in multimodal transit networks: Methodology and application to large-scale urban systems. Transportation Research Record Journal of the Transportation Research Board. ResearchGate, 37-45.

Vernet, N., & Coste, A. 2017. Garden cities of the 21st century: A sustainable path to suburban reform. Urban planning. Cogitatio, 2(4): 45-60.

Vionis, A. K., & Papantoniou, G. 2019. Central place theory reloaded and revised: political economy and landscape dynamics in the Longue Durée. Land. MDPI, 36(8): 1-21.

Waddell, P. 2011. Integrated land use and transportation planning and modelling: Addressing challenges in research and practice. Transport reviews. Routledge, 31(2): 209-229.

Waldeck, L., Holloway, J., & Van Heerden, Q. 2020. Integrated land use and transportation modelling and planning: A South African journey. The Journal of Transport and Land Use (JTLU). University of Minnesota Center for Transportation Studies, 13(1): 227-254.

Walker, A.R., & Stevens, N.J. 2008. Airport city developments in Australia: land use classification and analyses. TRAIL Research School, Delft. ResearchGate, 1-23.

Wang, J., Li, G., Lu, H., & Wu, Z. 2024. Urban models: Progress and perspective. Sustainable Futures. ScienceDirect. [Online]. Available at: <Urban models: Progress and perspective (sciencedirectassets.com)> [Accessed:13 February 2024].

Wasserman, J.L., Gahbauer., J., Taylor, B.D., & Matute, J. 2022. The future of transportation and urban planning: A California 100 report on policies and future scenarios. ResearchGate, 1- 49. [Online]. Available at: <https://www.researchgate.net/publication/376235872_The_Future_of_Transportation_and_Urban_Planning_A_California_100_Report_on_Policies_and_Future_Scenarios> [Accessed:13 October 2024].

Watanabe, D. 2015. A study on analyzing the Grid Road Network Patterns using Relative neighborhood graph. ResearchGate, 112-119. [Online]. Available at: <file:///C:/Users/27828/Downloads/A_Study_on_Analyzing_the_Grid_Road_Network_Pattern.pdf> [Accessed:19 July 2024].

Waugh, D. 2002. Geography: An integrated approach. 3rd Edition. Cheltenham: Nelson Thornes. 445 p.

Wegner, M. 1995. Current and future land use models. Texas Transportation Institute, Dallas, 1-25.

Wheeler, S.M. 2013. Planning for sustainability: Creating liveable, equitable, and ecological communities. New York, Routledge, 110-130.

White, M.J. 1987. American neighborhoods and residential differentiation. New York: Russell Sage Foundation. 327p.

Wilkinson, P. 2006. 'Transit Orientated Development': A strategic instrument for spatial restructuring and public transport systems enhancement in South African cities? School of Architecture, Planning and Geomatics: University of Cape Town, 223-233.

Williams, K. 2005. Spatial planning, urban form and sustainable transport: An introduction. ResearchGate, 1-13. [Online]. Available at:

<https://www.researchgate.net/publication/242734000_Spatial_Planning_Urban_Form_and_Sustainable_Transport_An_Introduction> [Accessed:16 October 2024].

Winslow, J. and Mont, O. 2019. Bicycle sharing: Sustainable value creation and institutionalisation strategies in Barcelona. Sustainability, 11(3), p.728.

Wolf-Jacobs, A.R. 2019. Mapping Land Use Around the San Francisco Bay: A Look at Environmental Justice through SF Bay Conservation and Development Commission's Permitting History, 1-46.

Xu, J., Yang, J., & Yao, L. 2012. Transportation structure analysis using SD-MOP in world modern garden city: A case study in China. Discrete dynamics in nature and society. Hindawi Publishing Corporation, 1-23. [Online]. Available at: <file:///C:/Users/27828/Downloads/Transportation_Structure_Analysis_Using_SD-MOP_in_%20(2).pdf> [Accessed:20 February 2024].

Yang, J., Zhang, F., & Shi, B. 2019. Analysis of open space types in urban centers based on functional features. ARFEE. [Online]. Available at: <https://doi.org/10.1051/e3sconf/20197901009> [Accessed:24 July 2024].

Zahavi, Y. 2021. Supercomputing and Marchetti's Constant. The Antiplanner. Antiplanner Policy Brief Number 84, 1-4.

ANNEXURES

- Annexure A (CANBERRA)

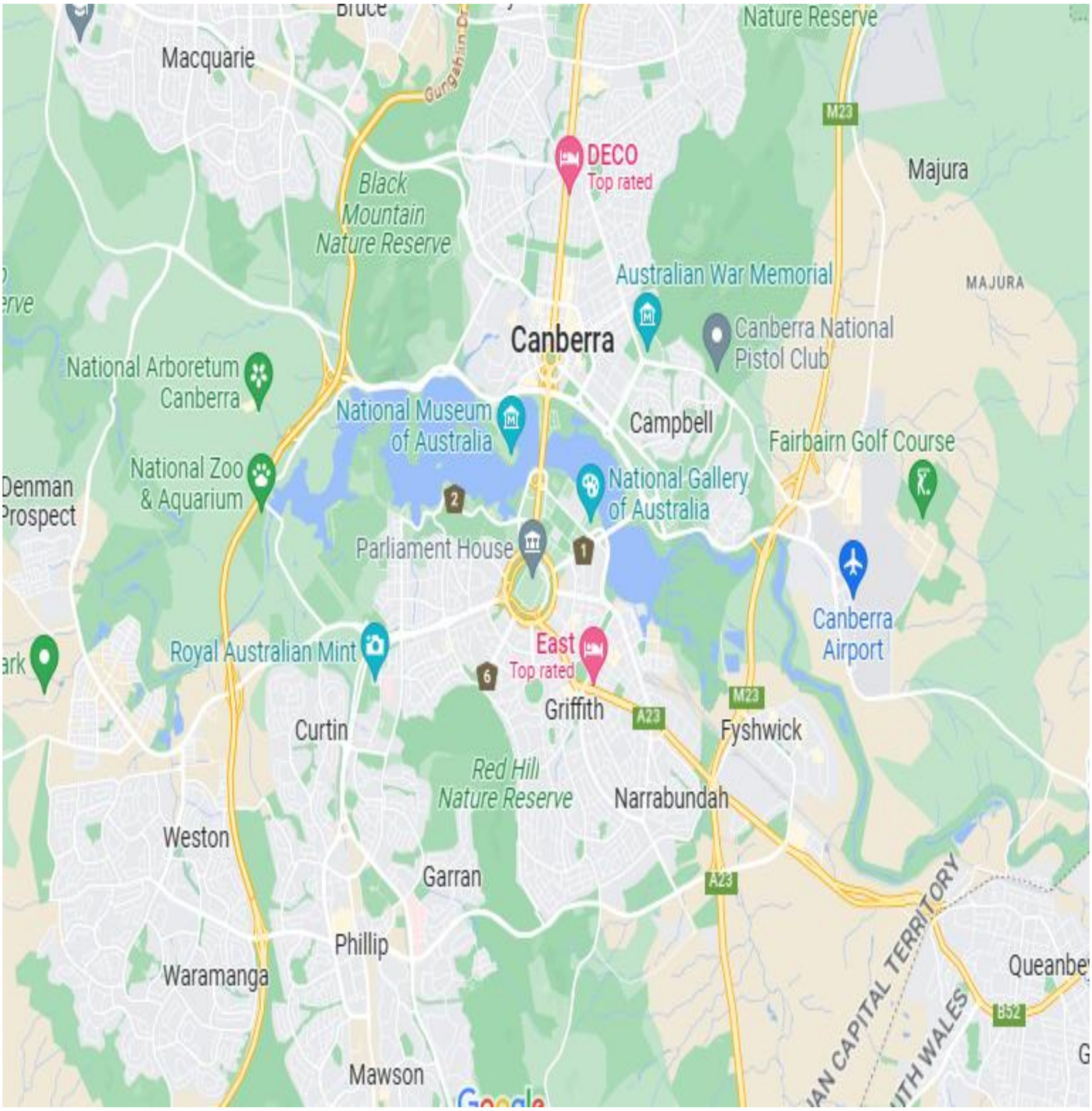


Figure A- 1: Canberra

Source: (Google Maps, 2022)

- Annexure B (CHICAGO)

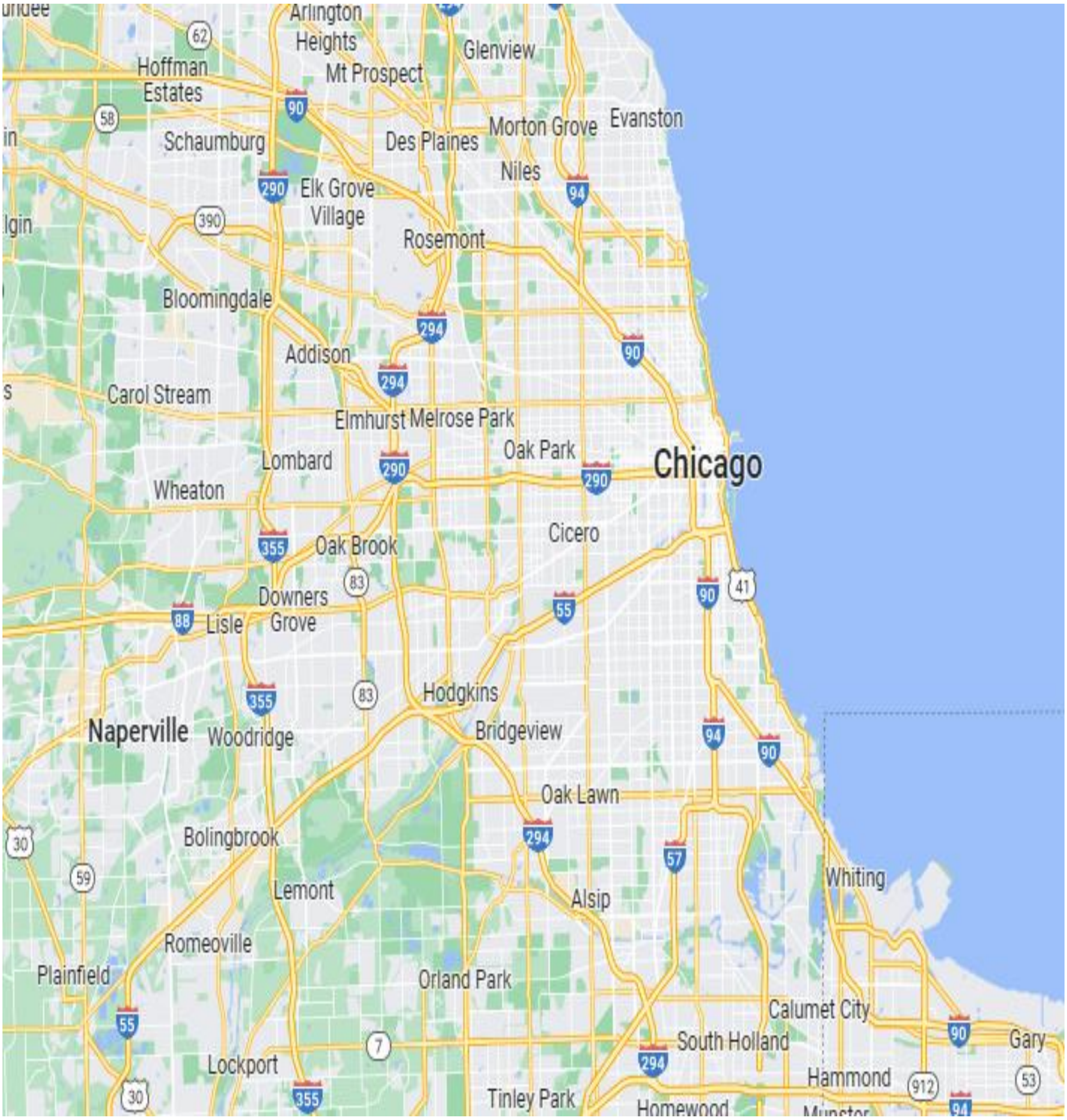


Figure A- 2: Chicago

Source: (Google Maps, 2022)

- Annexure C (LOS ANGELES)

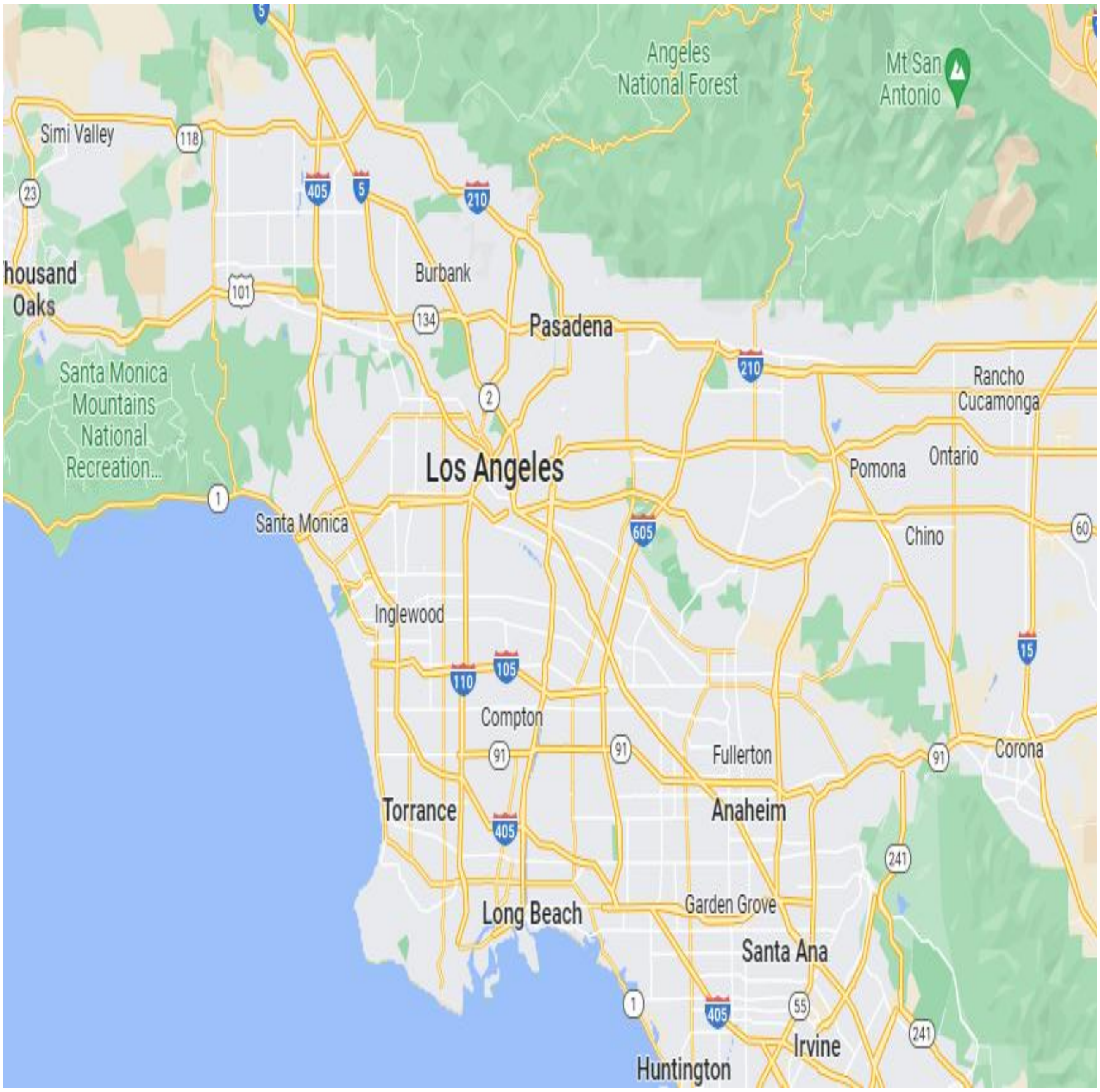


Figure A- 3: Los Angeles

Source: (Google Maps, 2022)

- Annexure D (ERBIL)

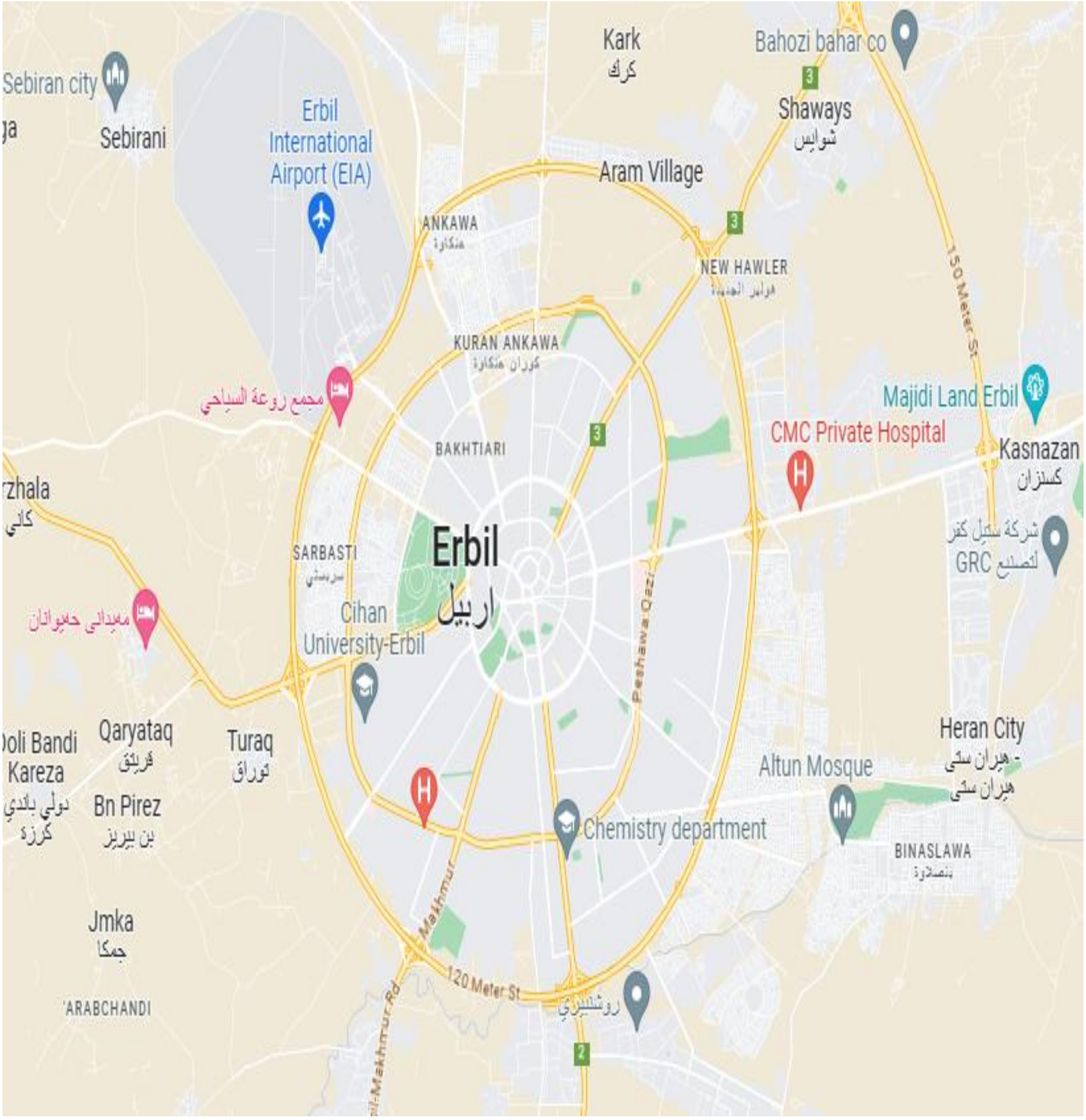


Figure A- 4: Erbil

Source: (Google Maps, 2022)

- Annexure E (SAN FRANCISCO)

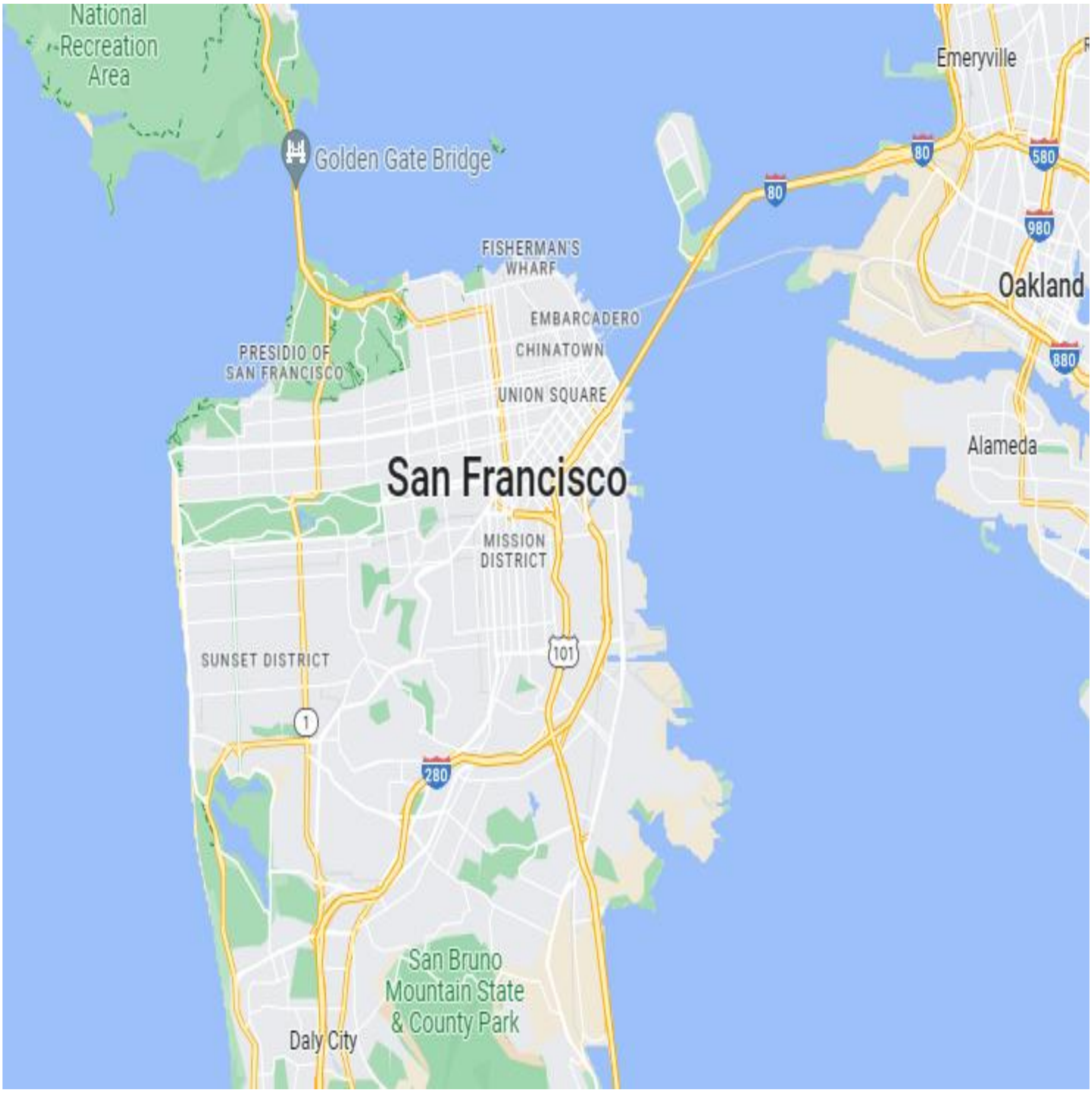


Figure A- 5: San Francisco

Source: (Google Maps, 2022)

- Annexure F (LAGOS)

Figure A- 6: Lagos

Source: (Google Maps, 2022)

- Annexure G (BARCELONA)

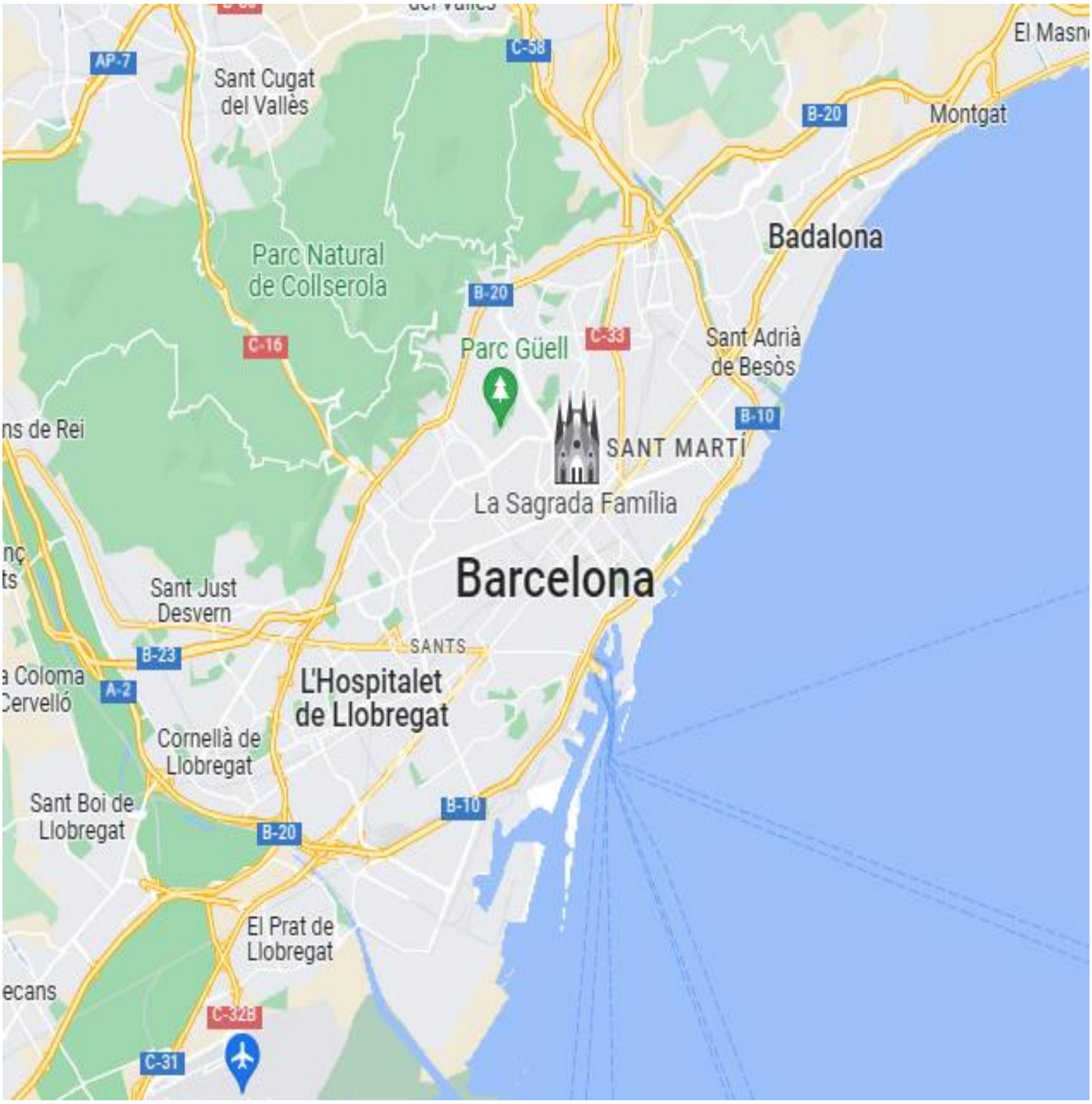


Figure A- 7: Barcelona

Source: (Google Maps, 2022)

- Annexure H (ROME)

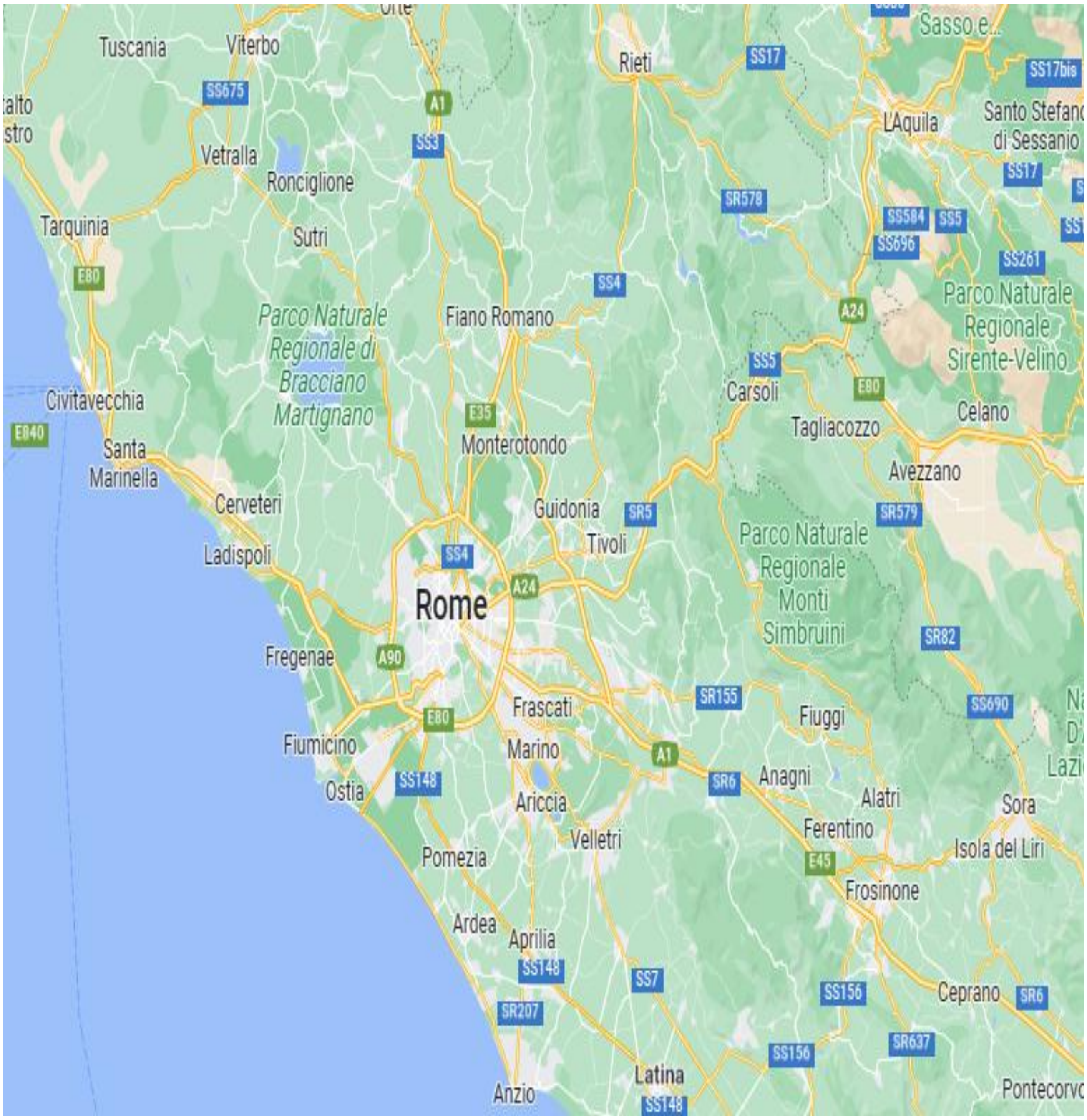


Figure A- 8: Rome

Source: (Google Maps, 2022)

- Annexure I (ANTIGO)

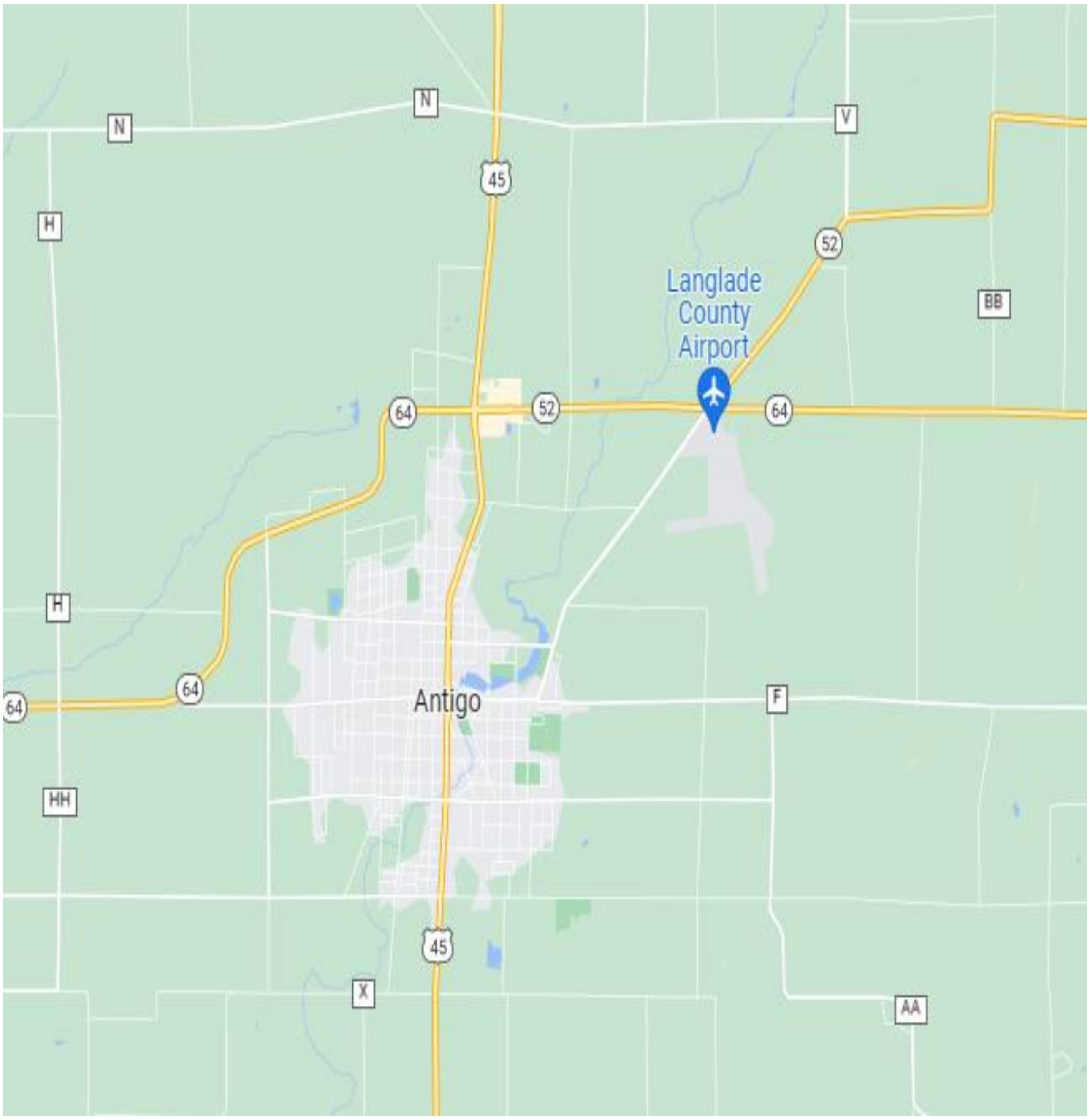


Figure A- 9: Antigo

Source: (Google Maps, 2022)

- Annexure J (CAPE TOWN)

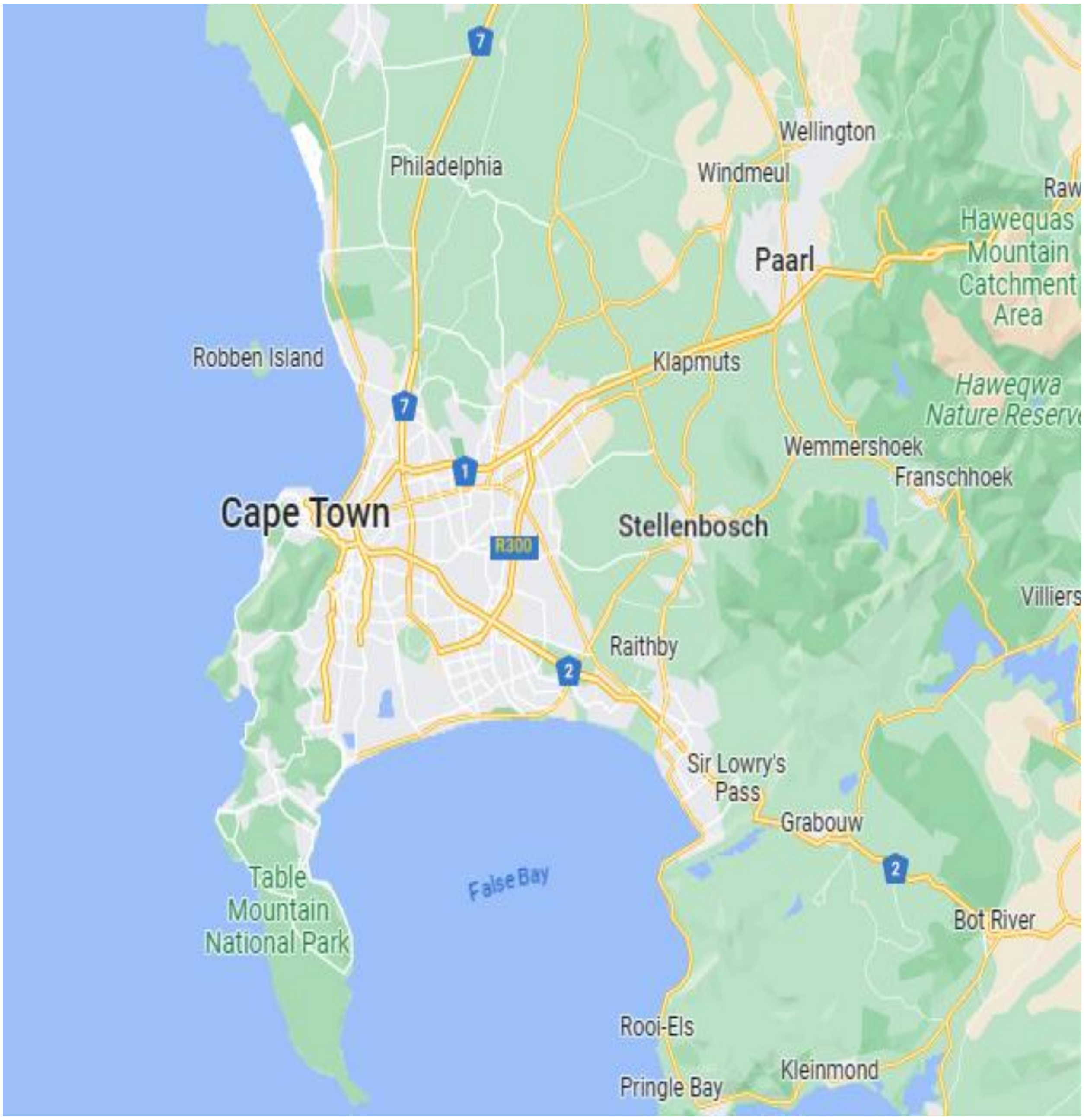


Figure A- 10: Cape Town

Source: (Google Maps, 2022)

LAST UPDATED: NOVEMBER 2024