MANAGING ROAD TRAFFIC CONGESTION ON ALLANDALE ROAD (M39) IN MIDRAND, SOUTH AFRICA

by

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submitted in accordance with the requirements for the degree

of

MASTER OF COMMERCE

in the subject

TRANSPORT ECONOMICS

at the

UNIVERSITY OF SOUTH AFRICA

SUPERVISOR: PROF I.M. AMBE

SEPTEMBER 2022

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Managing road traffic congestion on Allandale Road (M39) in Midrand, South Africa

I declare that the above dissertation is my own work and that all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

I further declare that I submitted the dissertation to originality checking software and that it falls within the accepted requirements for originality.

I further declare that I have not previously submitted this work, or part of it, for examination at Unisa for another qualification or at any other higher education institution.

______________________________   __15 September 2022____

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ACKNOWLEDGEMENTS

I would like to thank the following people and institutions for their contribution, and assistance and support during the preparation of this dissertation:

Firstly, my Heavenly Father, Jehovah, who indeed promised in His words to assist me throughout my studies, as I was always doubtful when it came to writing. I will always lean on His powerful words and remember what He promised in Isaiah 41:10: “So do not fear, for I am with you; do not be dismayed, for I am your God. I will strengthen you and help you; I will uphold you with my righteous right hand”.

Secondly, Prof Intaher Marcus Ambe, my supervisor, for his consistent guidance, continuous support, encouragement, and above all, his humbleness and laughter.

Thirdly, the University of South Africa for financial assistance (2016 - 2019) and the Southern African Transportation Conference (2020 - 2021).

Fourthly, the Netshisaulus: my beloved husband, Mbengeni-Gilbert, our beautiful children, Mulisa-Khae and Olugaho-Onalemogau, for their perseverance, continuous support and love; my family and friends for their love, moral support, encouragement and for always believing in me.

Then my heartfelt thanks goes to my mentor, Dr Ruth Dorothy Queiros, thank you for always providing guidance, and assisting me with research writing-related documents and podcasts. To Sis Thuli Ndebele and Annette Deppe, thank you so much for your *Ubuntu* and all the efforts in assisting me to distribute the questionnaire link to different contacts around the area. The community of Midrand and the surrounding areas. My friend, Dr Barbra Mabumbo-Duri, for the inspirational discussions and uplifting my attitude towards the research. My colleagues who always encouraged me to focus and work harder. Thank you for all your support.

Mr Nikki Solomon, for the transcription of the interview recordings; Dr Liz Solomon for co-coding and analysis; Mr Melvin Mothoa, for his assistance with online survey questionnaire arrangements; Mr Andries Masenge for re-assessment of the online survey questionnaire and statistical analysis and finally, Ms Retha Burger, for the editing of the text.

DEDICATION

This dissertation is dedicated to my parents, Phuti-Lucas and Raesetja-Grace Sasa. For you, education was always important even though you did not get a chance to go to school. Thank you for bringing me into this world, my beloved parents. My mother, you constantly referred me to this phrase: "*Kodumela moepathutse ga go lehumo leo le tšwago kgauswi*" (Sepedi proverb). Now I understand its meaning and what you were referring to all along. *Ke a leboga mma motswadi!* My father, *bopapa baka*, your daughter has made it to the Master's level. *Ke leboga maele le thekgo ya gago letebele lekonkwana la hloka kgomo la ja motho!*

ABSTRACT

Traffic congestion is a challenge in cities around the world, and is generated by the significant growth in vehicle ownership and rapid urbanisation. In South Africa, it has become problematic for road transport users, and challenging for policymakers. The rapid increase in the total number of vehicles per capita has resulted in the metropolitan public traffic systems, specifically, being unable to fulfil the travel demand of occupants. In Gauteng, for example, this problem causes travel delays and contributes to low economic productivity. Traffic congestion results in the irregular flow of traffic on Allandale Road, which negatively contributes to the imbalanced process of economic activities in the Midrand area. The current study aimed to investigate the management of road traffic congestion on Allandale Road (M39) in Midrand. The study employed an exploratory sequential mixed-method research approach. The first phase was a qualitative study that consisted of interviews with 18 participants. The second phase, the quantitative study, utilised an online structured questionnaire that was completed by 276 respondents.

The study revealed that traffic congestion does occur on Allandale Road in Midrand, and that it is not adequately managed. The outcomes showed a period of peak traffic congestion from 6:00 to 9:00 (mornings), and 15:30 to 18:00 (afternoons) during the week. The factors contributing to road traffic congestion are increased vehicle ownership, population growth, new developments, roadworks or construction projects, and mismanagement of the road traffic system. The study found that the key applicable pieces of legislation are the National Road Traffic Act 93 of 1996, White Paper on National Transport Policy of 1996, Road Traffic Management Corporation Act 20 of 1999, National Land Transport Act of 2009 and the Draft National Non-Motorised Transport Policy.

The results indicated that there are strategies that will better manage traffic congestion, including physical and improvement strategies. The strategies include public transport and infrastructure improvement, the introduction of carpooling, the promotion of non-motorised transport services, park-and-ride facilities, and the involvement of developers' impact assessments. The physical improvement strategies include additional new roads, street connectivity, public information systems, bottleneck relief, and dedicated lanes for buses/Bus Rapid Transport systems. The operational improvement strategies are incident management, planned special event traffic management, traffic signal timing and coordination, and active road management by the Metro Police. The study concludes with a framework that could be used to manage road traffic congestion.

KEYWORDS: Transport Planning, Transport Management, Urban Transport Systems, Traffic Management, Traffic Congestion, Policies and Private Vehicle Ownership.

TABLE OF CONTENTS

DECLARATION…………… i

ACKNOWLEDGEMENTS ii

DEDICATION…………….. iii

ABSTRACT………. iv

TABLE OF CONTENTS v

LIST OF FIGURES x

LIST OF TABLES. xii

ABBREVIATIONS. xiv

CHAPTER 1: INTRODUCTION TO THE STUDY 1

1.1 INTRODUCTION 1

1.2 BACKGROUND TO THE PROBLEM 3

1.2.1 Overview of road traffic congestion 3

1.2.2 The road traffic congestion in South Africa 4

1.2.3 The peak periods of traffic congestion in Midrand area 7

1.2.4 Problems that contribute to road traffic congestion 7

1.2.5 Policies and regulations impacting road traffic congestion 8

1.2.6 Strategies for managing road traffic congestion 10

1.3 PROBLEM STATEMENT 11

1.4 RESEARCH OBJECTIVES 13

1.4.1 Primary research objective 13

1.4.2 Secondary research objectives 13

1.5 RESEARCH DESIGN AND METHODOLOGY 13

1.5.1 Research design 14

1.5.2 Population and sampling method 14

1.5.3 Data collection and analysis 15

1.6 SIGNIFICANCE OF THE STUDY 16

1.7 OUTLINE OF CHAPTERS 17

CHAPTER 2: URBAN TRANSPORT PLANNING AND MANAGEMENT 20

2.1 INTRODUCTION 20

2.2 DEFINITIONS AND OVERVIEW OF URBAN TRANSPORT PLANNING AND MANAGEMENT 22

2.2.1 The concept of transport planning 22

2.2.2 The concept of urban transportation management 25

2.3 RELATIONSHIP BETWEEN URBANISATION AND URBAN TRANSPORTATION ………………………………………………………………………………….30

2.4 THEORIES AND MODELS SUPPORTING URBAN TRANSPORT PLANNING ... 32

2.4.1 Planning theory 33

2.4.2 Decision-making theory 33
2.4.3 Simulation model for urban transport 34
2.4.4 Queuing theory 35
2.4.5 Traffic flow theory 35
2.4.6 Location theory 36
2.4.7 Activity theory 37
2.4.8 Theory of planned behaviour 37
2.5 GLOBAL TRENDS AND DEVELOPMENTS IN URBAN TRANSPORT 40
2.5.1 Mobility as a Service (MaaS) 40
2.5.2 E-Commerce 41
2.5.3 Electric vehicles technology (EVs) 42
2.5.4 Wheel-chair accessible vehicles 43
2.5.5 Active transportation 43
2.6 CHALLENGES WITHIN URBAN TRANSPORT SYSTEMS 45
2.6.1 Distribution of freight 46
2.6.2 Insufficient public transport 47
2.6.3 Consumption in land-use patterns 47
2.6.4 High infrastructure maintenance cost 48
2.6.5 Energy consumption and environmental problems 48
2.6.6 Accidents and road safety 49
2.6.7 Difficulties for non-motorised transport 50
2.6.8 Car parking facilities 50
2.6.9 Road traffic congestion 51
2.7 CONCLUSION 55
CHAPTER 3: ROAD TRAFFIC CONGESTION IN SOUTH AFRICA 56
3.1 INTRODUCTION 56
3.2 OVERVIEW OF URBAN TRANSPORT IN SOUTH AFRICA 58
3.2.1 Historical overview of urban transport in South Africa 58
3.2.2 Classification of urban transport systems available in South Africa 60
3.3 UNDERSTANDING ROAD TRAFFIC CONGESTION IN SOUTH AFRICA 68
3.3.1 Concept of road traffic congestion 68
3.3.2 Categories of road traffic congestion 70
3.3.3 Peak periods of road traffic congestion 72
3.3.4 Problems contributing to road traffic congestion 76
3.3.5 Supporting policies and regulations impacting road traffic congestion 83
3.3.6 Strategies for managing road traffic congestion 90
3.4 INSTRUMENTS FOR MANAGING ROAD TRAFFIC CONGESTION 96
3.5 CONCEPTUAL FRAMEWORK FOR MANAGING ROAD TRAFFIC CONGESTION 102
3.6 CONCLUSION 104

CHAPTER 4: RESEARCH METHODOLOGY AND DESIGN 105
4.1 INTRODUCTION 105
4.2 RESEARCH QUESTIONS AND RESEARCH OBJECTIVES 107
4.2.1 Research questions 107
4.2.2 Research objectives 108
4.3 STUDY SITE 108
4.4 RESEARCH FOCUS 109
4.5 METHODOLOGICAL APPROACH 110
4.6 PHILOSOPHICAL PERSPECTIVE 113
4.7 MIXED-METHOD DESIGN 114
4.7.1 Exploratory sequential mixed-method design 116
4.8 PHASE 1: QUALITATIVE RESEARCH 118
4.8.1 Population and sample 118
4.8.2 Research instrument 121
4.8.3 Data collection and analysis 122
4.9 PHASE 2: QUANTITATIVE RESEARCH 126
4.9.1 Population and sampling 127
4.9.2 Data collection methods 130
4.9.3 Research instrument and measurements 131
4.9.4 Data analysis 134
4.10 ETHICAL CONSIDERATIONS 135
4.11 ENSURING CREDIBILITY AND TRUSTWORTHINESS 136
4.11.1 Credibility 136
4.11.2 Trustworthiness 137
4.11.3 Quality of research data 137
4.12 LIMITATIONS OF THE STUDY 141
4.13 RESEARCH PROCESS FOLLOWED IN THE STUDY 142
4.14 CONCLUSION 144
CHAPTER 5: QUALITATIVE DATA ANALYSIS, INTERPRETATION AND FINDINGS ... 145
5.1 INTRODUCTION 145
5.2 DEMOGRAPHIC PROFILE 146
5.2.1 Demographic profile of government department participants 147
5.3 THEMATIC ANALYSIS OF THE DATA COLLECTED 150
5.3.1 What are the peak periods of road traffic congestion on Allandale Road (M39)? 152
5.3.2 What problems contribute to the traffic congestion that users on Allandale Road (M39) experience daily? 155
5.3.3 What are the supportive policies and regulations impacting road traffic congestion? 163
5.3.4 What strategies are used to manage road traffic congestion within this urban area? 166

5.4 DEVELOPMENT OF THEMES FOR TRAFFIC CONGESTION ON ALLANDALE ROAD (M39) **175**

5.5 CONCLUSION **178**

CHAPTER 6: QUANTITATIVE DATA ANALYSIS, INTERPRETATION AND FINDINGS **179**

6.1 INTRODUCTION **179**

6.2 DEMOGRAPHIC PROFILE OF ALLANDALE ROAD USERS **180**

6.2.1 Gender 181

6.2.2 Age group 182

6.2.3 Place of residence 183

6.2.4 Educational background 184

6.2.5 Indication of the status of occupation 185

6.2.6 Approximate monthly income 186

6.2.7 Amount spent on petrol on a monthly basis 188

6.2.8 Reasons for daily travelling activities 189

6.3 DESCRIPTIVE STATISTICS FOR ROAD TRAFFIC CONGESTION **190**

6.3.1 Peak periods of traffic congestion in Midrand area 190

6.3.2 Problems contributing to road traffic congestion 194

6.3.3 Policies and regulations that have impacts and values on the management of road traffic congestion 196

6.3.4 Strategies for managing road traffic congestion 202

6.4 INFERENTIAL STATISTICS **208**

6.4.1 Differences in the perception of respondents on the problems contributing to road traffic congestion 208

6.4.2 Differences in respondents' perception on the policies and regulations that have value and impact on the management of road traffic congestion 210

6.4.3 Summary of differences in the perception of respondents on the strategies for road traffic congestion 217

6.5 CONCLUSION **223**

CHAPTER 7: CONCLUSION, SUMMARY AND RECOMMENDATIONS **225**

7.1 INTRODUCTION **225**

7.2 REVISITING RESEARCH QUESTIONS AND FINDINGS **226**

7.3 DISCUSSION OF THE RESEARCH FINDINGS **227**

7.3.1 Research question 1: Which peak periods of road traffic congestion exist on Allandale Road (M39)? 228

7.3.2 Research question 2: What problems contribute to the road traffic congestion that users on Allandale Road (M39) experience daily? 230

7.3.3 Research question 3: What are the strategies used for managing road traffic congestion within urban areas? 233

7.3.4 Research question 4: What are the supporting policies and regulations that have value and impact on the management of road traffic congestion? 238

7.3.5 What are the different perceptions on the ways of managing road traffic congestion on Allandale Road (M39)? 242

7.3.6 Main research question 248
7.4 SUMMARY AND CONCLUSION 249
7.4.1 Summary of the study 249
7.4.2 Conclusions related to research objectives 251
7.5 RESEARCH CONTRIBUTION AND RECOMMENDATION 253
7.5.1 Research contributions 253
7.5.2 Recommendations 253
7.6 LIMITATIONS OF THE STUDY AND SUGGESTIONS FOR FUTURE RESEARCH 257
7.6.1 Limitations of the study 257
7.6.2 Suggestions for future research 257
7.7 CONCLUSION 258
LIST OF REFERENCES 259
APPENDICES 312
APPENDIX A: QUALITATIVE INTERVIEW GUIDE 313
APPENDIX B: QUANTITATIVE QUESTIONNAIRE 314
APPENDIX C: ETHICAL CLEARANCE CERTIFICATE 325
APPENDIX D: CERTIFICATE FOR CO-CODING 327
APPENDIX E: PARTICIPANT INFORMATION SHEET, INFORMED CONSENT AND PERMISSION LETTERS 328
APPENDIX F: DATA TABLES 334
APPENDIX G: PROFESSIONAL EDITING CERTIFICATE 346

LIST OF FIGURES

Figure 1.1: Exploratory sequential design ... 14
Figure 1.2: Structural flow of the chapters in alignment with the study ... 19
Figure 2.1: Structural flow of Chapter 2 in alignment with the study ... 21
Figure 2.2: Transportation planning process ... 23
Figure 2.3: The transport/land-use system ... 28
Figure 2.4: The relationship between urbanisation and urban transportation ... 31
Figure 3.1: Structural flow of Chapter 3 in alignment with the study ... 57
Figure 3.2: Conceptual framework for managing road traffic congestion ... 103
Figure 4.1: Structural flow of Chapter 4 in alignment with the study ... 106
Figure 4.2: Map of Midrand in Gauteng ... 109
Figure 4.3: Phases of exploratory sequential mixed-method research design ... 117
Figure 4.4: Methods of data collection ... 130
Figure 4.5: Major fields of statistics ... 134
Figure 5.1: Structural flow of Chapter 5 in alignment with the study ... 146
Figure 6.1: Structural flow of Chapter 6 in alignment with the study ... 180
Figure 6.2: Indication of respondent's gender ... 181
Figure 6.3: Indication of the respondent's age group ... 182
Figure 6.4: Indication of the place of residence ... 183
Figure 6.5: Educational background ... 185
Figure 6.6: Indication of status of occupation ... 186
Figure 6.7: Indication of approximate monthly income ... 187
Figure 6.8: Indication of the amount spent for petrol on a monthly basis ... 188
Figure 6.9: Reasons for daily travelling activities ... 189
Figure 6.10: Level of traffic congestion on Allandale Road (M39) ... 191
Figure 6.11: Morning peak periods on Allandale Road (M39) ... 192
Figure 6.12: Afternoon peak periods on Allandale Road (M39) ... 193
Figure 6.13: Kilometres spent on a daily travelling ... 194
Figure 6.14: Problems contributing to road traffic congestion ... 195
Figure 6.15: Level of agreement on statement provided under White Paper on National Transport Policy, 1996 ... 197
Figure 6.16: Level of agreement on statements provided under National Land Transport Act, 2009 198
Figure 6.17: Level of agreement on statements provided under National Road Traffic Act 93 of 1996 199
Figure 6.18: Level of agreement on statements provided under Road Traffic Management Corporation Act 20 of 1999 ... 200

Figure 6.19: Level of agreement on statements provided under Draft National Non-Motorised Policy 201
Figure 6.20: Strategies that will best manage road traffic congestion 203
Figure 6.21: Level of agreement on physical strategies 205
Figure 6.22: Level of agreement on operational improvement strategies 206
Figure 6.23: Strategies that are still lacking on Allandale Road (M39) 207
Figure 7.1: Structural flow of Chapter 7 in alignment with the study 226
Figure 7.2: Recommended framework for managing Allandale Road (M39) traffic congestion 256

LIST OF TABLES

Table 1.1: Number of vehicles by province on South African roads in March 2021 4
Table 1.2: Congested cities in South Africa and the average hours spent in congestion..... 5
Table 2.1: Summary of definitions of the concept of transport planning from different sources 25
Table 2.2: Descriptions of the urban transportation management and the transport/ land-use system 29
Table 2.3: Summary of theories and models supporting urban transportation planning and the reasons for adoption in the study... 38
Table 2.4: Summary of the trends and developments in urban transport........................... 44
Table 2.5: Summary of challenges within the urban transport system 52
Table 3.1: Summary of classifications of urban transportation systems in SA 66
Table 3.2: Road traffic congestion definition by different sources..................................... 69
Table 3.3: Categories and causes of traffic congestion 72
Table 3.4: Summary of the road, street intersections and peak periods of traffic congestion. 75
Table 3.5: Summary of the problems contributing to road traffic congestion 81
Table 3.6: Summary of the supporting policies and regulations impacting road traffic congestion.. 88
Table 3.7: Summary of the strategies for managing road traffic congestion 95
Table 3.8: Instruments for managing road traffic congestion 97
Table 4.1: Two types of research methods 111
Table 4.2: Research philosophies employed for the study 114
Table 4.3: Types of mixed-method design 115
Table 4.4: Alignment of research questions to interview questions 122
Table 4.5: Interview schedule for the participant in the qualitative phase 124
Table 4.6: Summary of the research process utilised in the study.................................. 143
Table 5.1: Profile of participants from three government departments 147
Table 5.2: Alignment of research questions to interview questions 151
Table 5.3: Theme 1: Peak periods of traffic congestion on Allandale Road (M39)........... 155
Table 5.4: Theme 2: Problems that form the underlying contribution............................... 162
Table 5.5: Theme 3: Supporting policies and regulations impacting road traffic congestion 166
Table 5.6: Key strategies that are currently used 168
Table 5.7: Theme 4: Strategies that are lacking and still required 175
Table 5.8: Summary of the development of themes and categories about Allandale Road's (M39) traffic congestion... 176

Table 6.1: Summary of differences in the perception of respondents on the problems contributing to road traffic congestion based on educational background, status of occupation and monthly income 209

Table 6.2: Summary of differences in the perception of respondents on National Transport Policy, 1996 based on educational background, status of occupation and monthly income 211

Table 6.3: Summary of differences in the perception of respondents on National Land Transport Act, 2009 based on educational background, status of occupation and monthly income 212

Table 6.4: Summary of differences in the perception of respondents on National Road Traffic Act 93, 1996 based on educational background, status of occupation and monthly income 213

Table 6.5: Summary of differences in the perception of respondents on the Road Traffic Management Corporation Act 20, 1999 based on educational background, status of occupation and monthly income 214

Table 6.6: Summary of differences in the perception of respondents on Draft National Non-Motorised Transport Policy based on educational background, status of occupation and monthly income. 216

Table 6.7: Differences in the perception of respondents on the strategies for managing road traffic congestion in terms of educational background, status of occupation and monthly net income 218

Table 6.8: Differences in the perception of respondents on the availability of physical improvement strategies in terms of educational background, status of occupation and monthly net income 220

Table 6.9: Differences in the perception of respondents on the implementation of operational improvement strategies in terms of educational background, status of occupation and monthly net income. 222

Table 7.1: Summary of the research questions and key findings of the study 247

ABBREVIATIONS

BRT	Bus Rapid Transport
CO_2	Carbon Dioxide
DoT	Department of Transport
eNATIS	National Traffic Information System
FCEV	Fuel Cell Electric Vehicle
GDP	Gross Domestic Product
GHG	Greenhouse Gas
HEV	Hybrid Electric Vehicles
ITS	Information Technology Services
JMPD	City of Johannesburg Metropolitan Police Department
JRA	Johannesburg Road Agency
MBT	Mini-Bus Taxi
NLTA	National Land Transport Act, 2009
NMT	Non-Motorised Transport
NRC	Non-Recurrent Congestion
NRTA	National Road Traffic Act
NRTLEC	National Road Traffic Law Enforcement Code
PEV	Pure Electric Vehicles
PNR	Park-and-Ride
PT	Public Transport
RC	Recurrent congestion
RSA	Republic of South Africa
RTMC	Road Traffic Management Corporation
SA	South Africa
SANRAL	South African National Road Agency Limited
TMS	Transport Management System

CHAPTER 1:
INTRODUCTION TO THE STUDY

1.1 INTRODUCTION

This study sought to gain an understanding of traffic congestion on Allandale Road (M39) in Midrand, which is one of Gauteng's (a province in South Africa) most dense and congested roads. Traffic congestion which is a challenge in cities around the world has been generated by the significant growth in vehicle ownership and rapid urbanisation (Shah, Pan, Lee, Kim, You, Zheng & Chiang, 2021; Rajé, Tight & Pope, 2018). According to Munuhwa, Govere, Mojewa and Lusenge (2020), traffic congestion has various economic implications, including causing delays in the distribution of products and services, decreased productivity, increases in the operating cost of vehicles, and environmental contamination. Jouzdania and Govindanb (2021) articulated that traffic affects the entire supply chain process, and leads to delays, higher fuel costs and additional costs to products and services. The entire interruption typically triggers massive economic loss and tremendous environmental damage.

As stated above, traffic congestion is a global problem. For example, Haider and Papri (2021) explained that in Dhaka Metropolitan City (Bangladesh), passengers travel more than two hours a day due to the traffic queue caused by delivery vans or heavy vehicles. Afrin and Yodo (2020) stated that in United States of America (USA), traffic congestion results in a cost to society of a total of 6.9 billion more travelling hours and 3.1 billion extra tons of petrol. The congestion disrupts many businesses and companies, specifically those whose activities demand high levels of transport per unit of production (Venter, Mahendra & Hidalgo, 2019).

In Beijing (China), traffic congestion affects not only motorists but imposes costs on businesses as a result of the late arrival and unreliability of products and services, and costs related to logistics and just-in-time processing (Lasserre, Huang & Mottet, 2020). Hopkins and McKay (2019) added that in Melbourne (Australia) where the largest city-based firms are found, the use of motor vehicles leads to negative health issues, primarily through the unmitigated exposure to contaminated air and the many hours spent on travelling that additionally lead to mental stress, tiredness and headaches.

In addition to the above, traffic can be seen as a substantial threat to the urban environment. In urban areas, the high number of vehicles adversely affects the community's well-being (Thondoo, Marquet, Marquez & Nieuwenhuijsen, 2020). The World Health Organization (2016: 242) concurred by stating, "Low and middle income countries currently absorb 80% of global non-communicable disease deaths, 92% of pollution-related deaths and 90% of traffic-related deaths". Congested areas require the appropriate infrastructure and services to manage traffic congestion. Therefore, proper traffic congestion management improves the quality of life by reducing the demand for road capacity and parking spaces, fuel cost, pollution, and crashes (Mounce & Nelson, 2019; Simoni, Marcucci, Gatta & Claudel, 2019).

According to the National Planning Commission (NPC, 2012), South African roads are central to the country's economic growth, and part of the reason for the traffic congestion on the roads is the transport of bulk goods. Even though approved road networks have been planned for the urban areas, the traffic jams persist because of a lack of funding to implement the planned networks (Kruger, Lamprecht, Verwey & Johannes, 2017).

Various roads in Gauteng and the Western Cape are affected by congestion during peak hours (Das & Keetse, 2016; Kruger *et al.,* 2017). The congestion is mainly caused by the high numbers of people who have migrated to the cities, mainly because there are more opportunities and chances of economic prosperity in cities (Seuwou, Banissi & Ubakanma, 2020). However, such traffic congestion has a negative effect on any province as it leads to income loss, declined economic activity, constrained job creation, and increased costs of living (Wegener, 2021).

The current study sought to investigate how traffic congestion is managed on Allandale Road (M39), as this is one of the main congested roads in the Johannesburg area (Olayode, Tartibu, Okwu & Ukaegbu, 2021). However, limited studies have been conducted around the area, particularly on Allandale Road (M39). The current study aimed to provide insight into the current state of traffic congestion management in the area, as well as to contribute to the body of knowledge on road traffic management practices and strategies.

The remainder of the chapter presents the background to the problem, problem statement, research objectives, research design and methodology, significance of the study and an outline of the chapters in the dissertation.

1.2 BACKGROUND TO THE PROBLEM

This section firstly, provides an overview of road traffic congestion, and then focuses on road traffic congestion in South Africa. After this, the peak periods of traffic congestion in the Midrand area, the problems that contribute to traffic congestion, policies and regulations to overcome traffic congestion, and lastly, the strategies for managing road traffic congestion are discussed.

1.2.1 Overview of road traffic congestion

Globally, congestion is one of the significant concerns in the urban agglomeration of developed and developing cities (Singh, Banerjee & Chakraborty, 2020). In densely populated towns, the labour productivity is negatively affected by the hours lost during road trips because of intense traffic congestion (Nwankwo & Olayinka, 2019).

Although various measures have been taken to reduce congestion, it can be seen as a discrepancy between the traffic flow and the capacity of the roads, increasing travel time, cost, and behaviour modification (Sangaradasse & Eswari, 2019). Traffic congestion occurs when vehicles drive closer together and are forced to reduce speed because of the limited capacity of the transportation system (Nwankwo & Olayinka, 2019). Rodrigue, Comtois and Slack (2020) argued that a traffic jam arises once transport demand surpasses transport supply at a particular location and in a specific section of the transport system. When road traffic demand sufficiently increases, the interaction amongst vehicles decreases the speed of the traffic stream, and vehicle congestion occurs.

However, Nugmanova, Arndt, Hossain and Kim (2019) indicated that merely increasing the road capacity of the transport network is an ineffective solution in the long run, as newly constructed roads often give rise to the growth of private vehicles on the road. The more reachable the household is through the transport network, the more likely the family is to have more than one vehicle. The increase in motorisation has placed a high demand on traffic systems, and has increased road network overload (Lomendra, Sharmila, Ganess & Vandisha, 2018; Cats, Zhang & Nissan, 2018).

1.2.2 The road traffic congestion in South Africa

In South Africa, road traffic congestion on the main freeways is an everyday experience for most travellers, and it has an extensive economic effect on time lost while stuck in traffic (Olayode, Tartibu & Okwu, 2020, 2021a; Olivier, Andersen & Bruwer, 2017). The incidences of rural populations moving to metropolitan regions in search of improved job prospects has resulted in cities becoming overpopulated (Singh *et al.*, 2020). As the smallest province in size, Gauteng's roads deal with the highest number of heavy goods vehicles, including commercial trucks such as abnormal vehicles, fridge trucks, tippers and drop sides (Goedhals-Gerber, Freiboth & Havenga, 2018; eNaTis, 2016; Tancott, 2014).

Table 1.1 below shows the number of cars on South African roads in March 2019 to 2021 for each province.

Table 1.1: Number of vehicles by province on South African roads in March 2021

Number of registered vehicles per province	Number registered March 2019	Number registered March 2021	Change	% change	% of total March 2021
Gauteng	4 829 383	4 883 870	54 487	1,13 %	38,31 %
KwaZulu-Natal	1 670 496	1 706 524	36 028	2,16 %	13,39 %
Western Cape	2 033 704	2 054 945	21 241	1,04 %	16,12 %
Eastern Cape	832 875	852 762	19 887	2,39 %	6,69 %
Free State	634 521	642 001	7 480	1,18 %	5,04 %
Mpumalanga	906 892	920 357	13 465	1,48 %	7,22 %
North West	630 944	644 656	13 712	2,17 %	5,06 %
Limpopo	719 985	753 448	33 463	4,65 %	5,91 %
Northern Cape	282 766	289 221	6 455	2,28 %	2,27 %
RSA	**12 541 566**	**12 747 784**	**206 218**	**1,64 %**	**100 %**

Source**:** Adapted from State of the road traffic report, 2021

Table 1.1 above, presents a summary of the number of vehicles on South African roads by province. The table shows that Gauteng had the highest number of registered vehicles in 2019, ranging from 4 829 383 to 4 883 870 in 2021, with a total percentage of 38,31% of all motor vehicles in the country.

Table 1.2 below reveals the information about the top six most congested cities in South Africa, as ranked globally by the TomTom traffic index. Table 1.2 also indicates the time lost due to traffic congestion per year, the congestion level, annual changes of the traffic levels, the highest average daily congestion, and the morning and afternoon peak percentages. The major cities in Gauteng (which have the highest number of registered vehicles) are also included

Table 1.2: Congested cities in South Africa and the average hours spent in congestion

World rank	Country	City	Time lost per year	Congestion level 2021	Change from 2020 (traffic in 2021 vs 2020)	Change from 2019 (traffic in 2021 vs 2019)	Highest average daily congestion	Morning rush	Evening rush
170		East London	80 hours	35%	↑ 1%p (5% more traffic)	↑ 1%p (5% more traffic)	40%	46%	39%
179		Cape Town	50 hours	22%	↓ 10%p (31% less traffic)	↓ 1%p (4% less traffic)	39%	47%	38%
262		Johannesburg	43 hours	19%	↓ 11%p (37% less traffic)	↓ 2%p (10% less traffic)	35%	37%	36%
273		Pretoria	41 hours	18%	↓ 7%p (28% less traffic)	↓ 2%p (10% less traffic)	33%	36%	32%
310		Durban	36 hours	16%	↓ 3%p (16% less traffic)	0%p	38%	34%	30%
382		Bloemfontein	27 hours	12%	↓ 1%p (8% less traffic)	↑ 1%p (9% more traffic)	22%	27%	20%

Source: Adapted from TomTom.com, 2022

The summary of the TomTom traffic index presented in Table 1.2 shows that the city of Johannesburg is ranked at number 262 globally, with 43 hours lost during the peak periods, a morning peak of 37% and an afternoon peak of 36%. The highest average daily congestion is 35%, with a congestion level of 19% in 2021.

1.2.3 The peak periods of traffic congestion in Midrand area

During peak periods, the congestion on Allandale Road generates delays, making users late for work and other appointments. According to an e-mail report from the City of Johannesburg Metropolitan Police Department (JMPD, 2016), the traffic congestion in the Midrand area is analysed as follows:

> *The traffic peak period in Midrand area ranges between 06:00 and 09:00 and from 16:00 to 18:00 daily. It starts at Saraseen Road in Klipfontein, where vehicles start driving in the emergency lane. From the intersection of Dane and Allandale Roads (at Carstenhof Clinic), traffic from Chloorkop merges with that from Rabie Ridge. Traffic is so heavy that motorists become impatient and form four lanes, driving on the shoulder facing oncoming traffic of the road towards the intersection of Alsatian road, K101, and through Allandale Road. From there, traffic flows towards the N1. From Harry Galaun Drive towards the R55 (Kyalami) again increases, but is not too heavy until the R55, which again becomes uncontrollable. Kyalami Road is busy from Mimosa up to Shakespeare in the morning; from there onwards, the road splits into two lanes and traffic starts flowing. Old Pretoria Road congestion starts at Builders' Warehouse towards Jukskei River (South); between Jukskei and Waterfall Drive, traffic is very heavy, and motorists drive on the verge of the road. On the same route, but in a northerly direction, congestion starts at New Road, going through R562 (K27) until reaching Corporate Park north. Modderfontein is busy from P91 (Phomolong) until it intersects with Dale Road from Kaalfontein; similar events occur here with motorists driving on the shoulder of the road and others driving facing oncoming traffic.*

1.2.4 Problems that contribute to road traffic congestion

Although the South African government performs upgrades to road structures and transport services, there are still areas where road users face an insufficient level of comfort on public transport (PT), and are exposed to infrastructure that prohibits access to and mobility on the road networks (Ramos *et al.*, 2019; Swell, Desai, Mutsaa & Lottering, 2019). Limited access to economic activities typically affects low and medium income communities scattered throughout the peripheral settlements (Venter *et al.*, 2019). Inadequate road infrastructure and public transport services indicate the poor's insufficient access to essential services (Swell *et al.*, 2019; Acampa, Contino, Grasso & Ticali, 2019). Despite an initial decline after the implementation of collective traffic systems, road traffic congestion creates a challenge for the entire large and developing urban areas.

According to Olayode *et al.* (2022), various persistent problems manifest from traffic congestion, including private vehicle ownership and migration from rural settlements to urban cities, and an increase in the incidences of under maintained highways. The rapid growth in the population and urbanisation are often related to the high demand for jobs, infrastructure development, and social services within the urban areas (Agbo, Englama & Philip-Ogoh, 2014). Rodrigue *et al.* (2020:393) concurred by stating "The larger the city, the greater its complexity and the potential for disruption, mainly when the complexity is not effectively managed".

Increases in the levels of vehicle ownership emerge when there are household structure adjustments and changes in income. This occurs particularly when there are tremendous increases because of economic growth, rapid urban development, population growth, and insufficient public transport (Pojani & Stead, 2017; Rode *et al.*, 2017). Mbatha, Gumbo, Oniya and Moyo (2021) argued that personal cars are used more consistently than public transport, however, the choice of using a personal car for travelling increases traffic volumes on the roads at some point in various time intervals. The next section discusses the policies and regulations impacting road traffic congestion.

1.2.5 Policies and regulations impacting road traffic congestion

Mshali (2007:10) stated: "Transport Policy is defined as a framework adopted for action needed to overcome identified problems and achieve the stated objectives or goals in the transport system". The South African government faces complex challenges when developing legislative policies related to the implementation of strategies and approaches to create and support public transport (Moffat, Chakwizira & Ingwani, 2021; Walters, 2014).

The implementation of policies targeted at increasing the use of public transport requires a clear understanding of the travel behaviour that influences the choice of various means of transport, excluding the private car. In addition, the public transport service provider needs to be cognisant of passenger attitudes, anticipations, requirements, and their discernment of the current superiority of the public transport service (Ramos *et al.*, 2019). “The policy directives are issued at a national level, with the provinces developing legislative frameworks and policy directives in line with provincial differentiation; and the actual implementation occurs within the municipal sphere of government” (Risimati & Gumbo, 2019a:7).

Furthermore, policies in the road transport sector should be developed to administer congestion on a cost-effective basis to reduce the burden of excessive congestion (Zhou, Che, Koh & Wong, 2020). Speed limits should be enforced continuously to control driver behaviour. There are various solutions in the market to monitor speeds (Risimati & Gumbo, 2019a). The national speed limits are set for different areas and roads, which means that the speed limits for rural areas, highways and neighbourhoods are not the same. There should be harmonisation of road safety policies within regional member states to reduce road accidents locally, and this will ensure that foreign road users are also familiar with the road safety rules (Mofomme, 2019).

Policies to alleviate congestion might be supply-oriented, including the classic option of road capacity enlargement. A second option may be to improve the main alternative mode of transportation, where the government might opt to invest in the supply of public transportation (Albalate & Fageda, 2019). Although the South African government has instituted policies and strategies to improve the land transport sector in order to expand transport capacities, public transport is dependent on the government’s plans to support the community (Henseler & Maisonnave, 2018).

Berg, Deichmann, Liu and Selod (2017) argued that there is a lack of transport policies to improve growth and sustainability, especially with regard to the accumulation of transport infrastructure investment in rural and urban areas, weak governance, and insufficient regulation in the transport sector. However, as indicated by Gössling (2020) the policies guiding road traffic congestion have currently not been completely scrutinised or understood. Without appropriate policies and directives, it is difficult to effectively manage road traffic congestion (Moroni, Buitelaar, Sorel & Cozzolino, 2020). The next section presents a discussion of the strategies for managing road traffic congestion.

1.2.6 Strategies for managing road traffic congestion

It is essential to recognise and measure the quantity of traffic congestion to allow decision-makers to introduce mitigation strategies and to develop complete sustainable transportation systems (Afrin & Yodo, 2020). According to Zhou and Chen (2020), a satisfactory transport system is a crucial supply management tactic to ensure a good transportation network in congestion mitigation. However, Afrin and Yodo (2020) maintained that researchers, policymakers and transport planners have worked for many years to acquire specific measurement approaches with which to assess road traffic congestion.

While some developed countries have succeeded in dealing with the challenge of traffic congestion by implementing strategies, these methods are insufficient and might not apply to the congested road traffic conditions in South Africa (Mbatha *et al.*, 2021; Afrin & Yodo, 2020). Various traffic congestion measures are available, depending on different performance criteria, such as speed, travel time, delay, level of services, or other indices.

According to Dinh (2019), the strategies can be categorised into supply and demand strategies. Supply-side strategies include the development of new roads, and expanding the current roads to handle capacity in the network, improvements to public transport, the promotion of non-motorised transport, and improved traffic management control.

Non-motorised transportation (NMT) operates with the force of an animal or human being, and includes walking, skateboards, motorcycles, cycling, rickshaws, hand-driven vehicles, wheelchair travel and pull-carts (Risimati & Gumbo, 2019b; Mahajan & Saharkar, 2018). The majority of NMT modes are healthy, non-polluting, versatile and reliable. Mahajan and Saharkar (2018) added that NMT modes, such as bicycles and rickshaws, are responsible for the maximum number of rides generated during peak hours. NMT is known for its cost-effectiveness and should not be associated with poverty but should address the inefficient public transport systems or networks by enabling low-income communities' access to public facilities and connecting them to the public transportation network social and economic activities (Sadiki, 2021).

Therefore, it is essential to have appropriate strategies in places that will ensure there is harmony within the road traffic sector, as well as in the production and management of road traffic information (RTMC, 2019). Based on the sections discussed above, the problem statement is presented below.

1.3 PROBLEM STATEMENT

The strategic role of transport should not be underestimated, since it has not yet been fully embraced to achieve the socio-economic development mandate in South Africa. Traffic congestion has become a perpetual problem and has developed challenges for transport users and policymakers (Afrin & Yodo, 2020; McKay, 2020). Similar to many other urban areas, the population growth in Midrand has had adverse implications on the congested roads (Turok, Seeliger & Visagie, 2021; SAPOA, 2018). Freeways and road intersections are experiencing constant and systematic delays in traffic flow (Olayode *et al.*, 2021).

The increased population requires that solutions be developed to accommodate growth without compromising the quality and efficiency of services. This specifically relates to successful transportation systems to alleviate transport challenges in South African cities (Feikie, Das & Mostafa, 2018). These challenges have contributed to the negative impact on the provision of essential services, and merchandise not being rendered on time, which negatively impacts the economy (Sujatha, Nithya, Subhapradha & Srinithibharathi, 2018).

In terms of the Midrand area, the recent business developments in Waterfall City have placed additional pressure on Allandale Road (M39) (Olayode *et al.*, 2021a). This situation has caused a massive problem in the area, and vehicle drivers are experiencing excess road demand during peak hours (Malatši, 2019), leaving the entire road congested (Midrand Forum, 2016).

In addition, the road leads to OR Tambo International Airport via Zuurfontein Road (M18), which passes through Spartan in Ekurhuleni Metropolitan Municipality. It then connects many provinces in South Africa through M1, N1, N3 and R55; among these provinces are Gauteng, Mpumalanga, KwaZulu-Natal, and the Western Cape

(Olayode et al., 2021b). Although several studies have been conducted on the topic of traffic congestion, such as those by Feikie *et al.* (2018) in Bloemfontein, Iyoob and Van Niekerk (2021) in Cape Town, Duze (2019) in Durban, and Mudau, Chakwizira and Radali (2014) in Thohoyandou, there are limited studies on road traffic management, specifically focusing on Allandale Road (M39).

Some existing limited studies have investigated the impact of traffic congestion in the Greenstone Hill and Midrand areas (Malatši, 2019); improving traffic flow in the City of Johannesburg's roads (Gumbo, Oniya & Moyo, 2021); and the South African road transportation system, specifically the traffic congestion on the N1 interchange (Olayode *et al.,* 2021c). Therefore, while some of the studies were conducted in the area, they did not consider the specific issue of managing road traffic congestion on this road. Although limited studies have been conducted on Allandale Road (M39), the current research study will contribute to the traffic congestion solutions that are appropriate to increase the economic activities of the province (Luke & Heyns, 2020; Mamabolo & Sebola, 2018).

In Midrand, many people have to use Allandale Road daily, and the highest congestion on the road comes from N1 exit and entry, both of which contribute to the problematic condition of the road. Johannesburg is the economic hub of the province, and numerous residents commute from Pretoria to Johannesburg for work purposes. Consequently, an investigation of this critical challenge is of key importance because of the economic importance of the area, and therefore, there is a knowledge gap and the need for this study.

The research question posed for this study can thus be formulated as:

How can road traffic congestion on Allandale Road (M39) in Midrand, South Africa, be managed?

In support of the main research question, the following secondary research questions were formulated:

- Which peak periods of road traffic congestion exist on Allandale Road (M39)?
- Which problems contribute to the traffic congestion that users on Allandale Road (M39) experience daily?
- What are the supporting policies and regulations impacting road traffic congestion?

- What are the strategies used for managing road traffic congestion within this urban area?

1.4 RESEARCH OBJECTIVES

Based on the problem statement delineated above, the following primary and secondary objectives were formulated for the study.

1.4.1 Primary research objective

The main aim of this study is to determine how road traffic congestion on Allandale Road (M39) in Midrand, South Africa, is managed.

1.4.2 Secondary research objectives

To achieve the primary objective of the study, the following secondary research objectives were formulated:

- To determine the peak periods of road traffic congestion on Allandale Road (M39).
- To establish the problems contributing to traffic congestion that users on Allandale Road (M39) experience daily.
- To identify the supporting policies and regulations impacting road traffic congestion.
- To explore the strategies used for managing road traffic congestion within this urban area.
- To make suggestions and recommendations for Allandale Road (M39) users in a way that will overcome traffic congestion.

In order to achieve the above primary and secondary research objectives, a specific process needs to be followed. Therefore, the next section presents the research design and methodology that were adopted to achieve the results.

1.5 RESEARCH DESIGN AND METHODOLOGY

The research methodology allows the researchers to select the most suitable methods for their specific research studies. The procedure includes the research design, population and sampling, data collection and analysis, ethical clearance, reliability and validity, limitation of the study, and ethical considerations, as discussed below.

1.5.1 Research design

The mixed-method research design is a combination of the qualitative and quantitative research designs in a single study (Saunders, Lewis & Thornhill, 2019). According to Creswell and Plano Clark (2018), the methods comprise of convergent parallel, embedded, explanatory sequential and exploratory sequential mixed-method research designs. An exploratory sequential design is a mixed-method strategy that includes a two-phase project (Creswell, 2014).

The current study utilised an exploratory sequential mixed-method research design. This method was adopted because it provides a more comprehensive understanding of the research problem and integrates results to develop a practical theory (Bryman, Bell & Hirschsohn, 2021; Creswell & Plano Clark, 2018). The study first collected qualitative data. Subsequently, after analysing the qualitative data, the study proceeded with the quantitative data collection. Figure 1.1 below illustrates the flow of the mixed-method strategy.

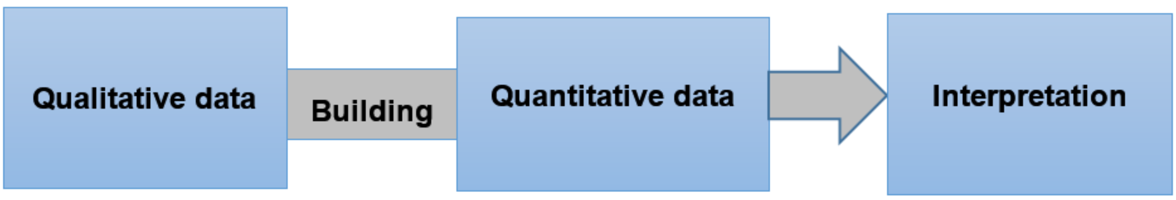


Figure 1.1: Exploratory sequential design

Source: Creswell (2014)

The approach selected for the study was appropriate, as the researcher intended to gain an in-depth understanding from the interviews with the road traffic authorities (qualitative study) and to test the perceptions of road traffic users, particularly private vehicle drivers, as related to road traffic congestion (quantitative study). The next section presents the population and sampling method followed in the study.

1.5.2 Population and sampling method

The population is defined as the group of individuals or units that meet the selection criteria for the study of a group (Leedy & Ormrod, 2019). The population for the qualitative study in this regard consisted of road authorities from the three spheres of government, namely, the local municipal, provincial and national government. The population for the quantitative study consisted of vehicle drivers (drivers of light and heavy vehicles).

Sampling is the procedure of taking a portion or a smaller number of units, for example, individuals or establishments from the relevant population (Strydom, 2018). The sample for the qualitative study consisted of 18 participants (traffic officials) who are senior staff members with more than three (3) years of experience at their organisation. The sample of 18 participants was selected based on purposive or judgmental sampling. The study employed a non-probability sampling technique, as the possibility of choosing a particular member of the population was uncertain (Faasen, 2021).

For the quantitative study, a sample of 276 drivers was selected from the population of private vehicle drivers residing in or around the Midrand area who use directions one and two on Allandale Road. According to Mikros Traffic Monitoring (2016), there are about 4 695 light and heavy vehicles passing through Allandale Road (M39) between 7:00 and 9:00 (See row 82: Mikros Traffic Monitoring Report). A sample of 276 participants was selected, based on the simple random sampling technique. Probability sampling involves random selection, allowing the researcher to make strong statistical inferences about the whole group (Bryman *et al.*, 2021).

1.5.3 Data collection and analysis

The methods used to collect data fall into two categories: primary data collection and secondary data collection (Leedy & Ormrod, 2019). According to Saunders *et al.* (2019), primary data is the data collected for the first time by the researcher through direct efforts and experience to address the research problem.

In the qualitative phase of the study, the researcher used structured interviews to collect and accumulate the qualitative data from 18 senior staff members (involved in traffic control) from the three spheres of government. A structured interview is a data collection method that relies on asking questions in a set order to collect data on a topic (Nieuwenhuis, 2016). The qualitative data derived from the structured interviews was analysed using thematic analysis.

For the quantitative phase of the study, the researcher used a system-administered online questionnaire to collect data from the sample of 276 participants. Collins and Hussey (2003:173) described questionnaires as “a method of collecting primary data where lists of pre-structured and pre-tested questions are given to a chosen sample to actively extract reliable responses”. The questionnaire was an appropriate data collection tool for the study since it collected data from the participants in a non-threatening way (Saunders *et al.*, 2019). The design of the questionnaire was based on the five-point Likert scale, ranging from ‘strongly disagree’ to ‘strongly agree’. For the purpose of the current study, the quantitative data was collected using an online platform called Survey Monkey. The questionnaires were coded and analysed on an Excel spreadsheet using the software program, Statistical Package for the Social Sciences (SPSS) for statistical analysis. The bar graphs, pie charts and tables that were generated were used for the descriptive analysis. The next section discusses the significance of the study.

1.6 SIGNIFICANCE OF THE STUDY

The policymakers, transport engineers, and transport and urban planners within the national, provincial and regional road authorities are expected to address traffic congestion, manage the problems, policies and regulations, implement the strategies and also offer the best recommendations within the land use and transport sector. While on the other hand, vehicle drivers expect the best transport systems that function well to avoid traffic congestion, especially when using private cars daily. As such, traffic congestion is the obstruction that the administration is concentrating on, and to that end, they are combining other resources to eliminate the increasing gridlock on urban roads.

The number of vehicles on South African roads by province shows the highest numbers in Gauteng, where there are about 3 735 800 light vehicles and 133 624 heavy vehicles on the roads (National Treasury, 2015). Since this research study was based in the Midrand area situated in Gauteng, the research would benefit the road authorities and drivers of private vehicles. The Gautrain has played its part in the Midrand area by introducing bus feeders to transport commuters from regions such as Noordwyk, Randjesfontein, Sunninghill and Mall of Africa to the Gautrain station.

However, according to The Midrand Forum (2013), despite the inception of the Gautrain, the congestion is worse on the N1 highway and other non-highway roads, including Allandale Road (M39). The traffic problems require a lasting transport solution that will assist commuters to travel safely and arrive at their destinations on time. By conducting this research study, the research will add value by:

- Assisting the national, provincial and regional road authorities, policymakers, urban planners and transport planners to consider the suggested strategies that will alleviate this mobility challenge;
- Helping authorities to identify the causes of congestion and to prepare a master plan to eliminate this effect.

This study addresses possible solutions that will assist private vehicle drivers who travel daily to avoid traffic congestion and consider the best alternative transport.

The study will contribute to academia by creating a strategic line of discussion about the traffic congestion on the roads that causes obstructions and setbacks to progress.

The next section presents an outline of the chapters in this dissertation.

1.7 OUTLINE OF CHAPTERS

This section presents a summary and structure of the seven chapters in the current study.

To discuss and find solutions to the research problem presented in Section 1.3 of this chapter, the chapters in the dissertation are organised as follows:

Chapter 1: This chapter presents the introduction and background to the study and discusses the general orientation of traffic congestion around the world, including South Africa. The discussion follows the presentation of the problem statement, the aim of the research, and the study’s objectives. Part of the research methodology was discussed, while complete details are elaborated in Chapter 4, according to the primary and secondary research.

Chapter 2: This chapter discusses the first phase of the literature review, including urban transport planning, development and trends within South African urban transport, the urban transport system in South Africa, urbanisation and the transport environment, and challenges within the urban transport system.

Chapter 3: This chapter discusses the peak period of traffic congestion, and strategies for managing road traffic congestion. The chapter also discusses the challenges contributing to road traffic congestion. Finally, the policies and regulations for mitigating road traffic congestion are discussed.

Chapter 4: This chapter includes a discussion of the research methodology used in the study. The discussion consists of the research design, sampling, instruments, pilot tests, data collection, data processing, and the method used to analyse the data.

Chapter 5: This chapter presents the qualitative data analysis and interpretation. The chapter includes both the results and the discussion of the results in terms of the research questions and literature. It discusses the analysis of the results, and interprets the research sample's responses to clarify and understand the data collected. The study shows the linkages of the findings to the objectives of the study. The study demonstrates the theoretical field and the implications of the results.

Chapter 6: This chapter presents the quantitative data analysis and interpretation. The chapter includes both the results and the discussion of the results in terms of the research objectives and literature. It discusses the analysis of the results, and interprets the findings of the quantitative research design. The information includes an outline of the data analysis and a description of the data collected from the completed questionnaires. The questionnaire was divided into six subsections based on the demographic profile of Allandale Road users and the research questions.

Chapter 7: This chapter presents a summary of the study, makes recommendations and draws conclusions. The summary of the study includes the overall findings of the data analysis and links them back to the research objectives.

Figure 1.2 shows the arrangement and structural flow of the chapters in the entire study.

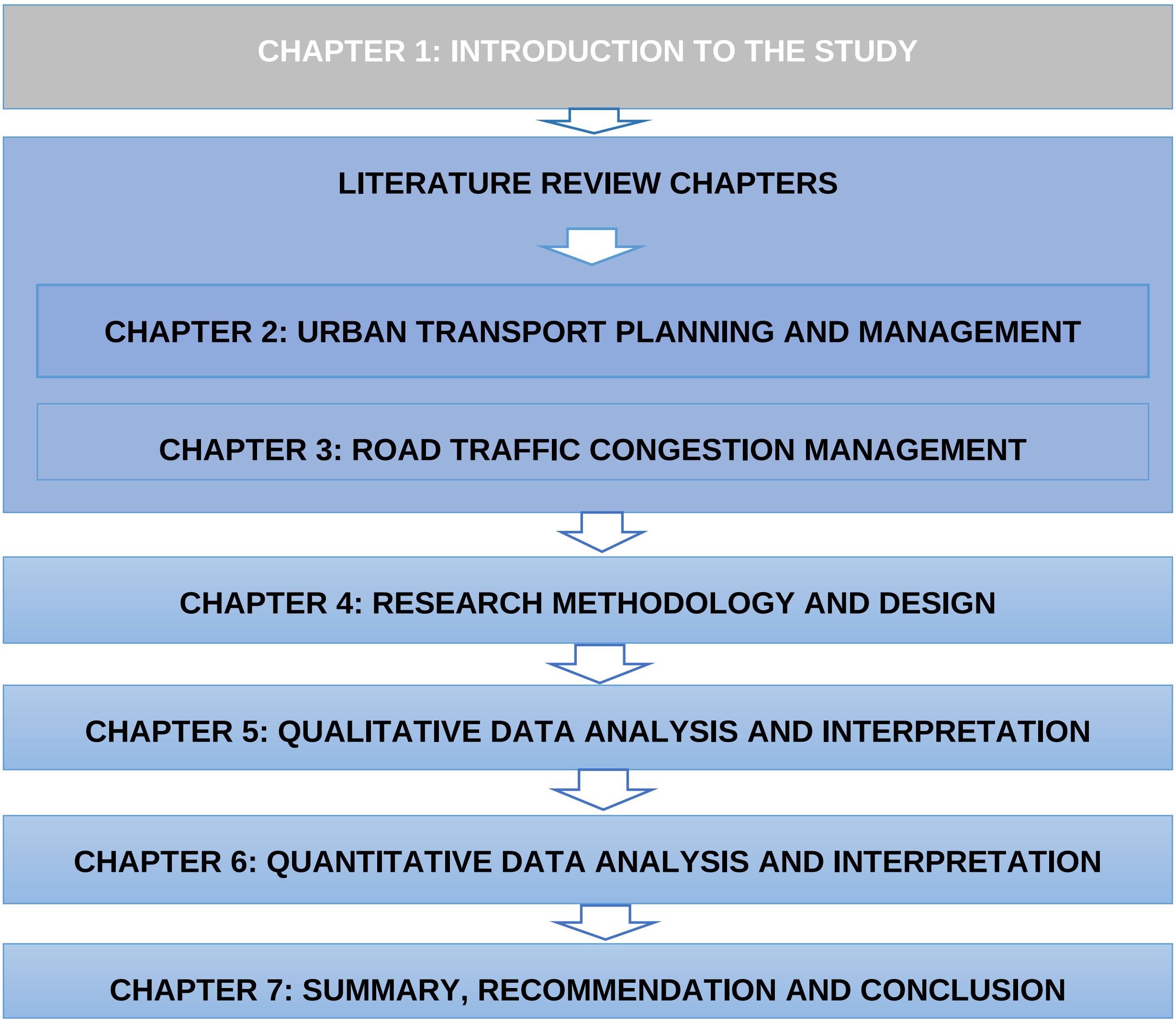


Figure 1.2: Structural flow of the chapters in alignment with the study

Sources: Researcher's own compilation

CHAPTER 2:
URBAN TRANSPORT PLANNING AND MANAGEMENT

2.1 INTRODUCTION

This chapter reviews urban transport planning and management. The literature review focuses on the global overview of urban transport. The chapter firstly, starts with the presentation of various important definitions. After this, an overview of urban transport planning and management is provided, as urban planning has experienced a radical change in the transportation environment.

This chapter focuses on the issues facing the whole transportation system and various problems within urban transportation, including traffic congestion, air pollution, the costs of motor vehicle accidents, and the future of public transportation are discussed. Urban transportation describes how the systems methodology has been applied in multimodal planning and determines how land-use zones within a transport network may represent a city.

As a result, this chapter will consider the concepts associated with transport planning and urban transportation management, taking the transport/land-use systems into account. The discussion includes the relationship between urbanisation and metropolitan transportation, theories and models supporting urban transport planning, the global trends and developments in urban transport, and lastly, the challenges within the urban transport systems.

Figure 2.1 provides an outline of how this chapter fits into the structure of the dissertation.

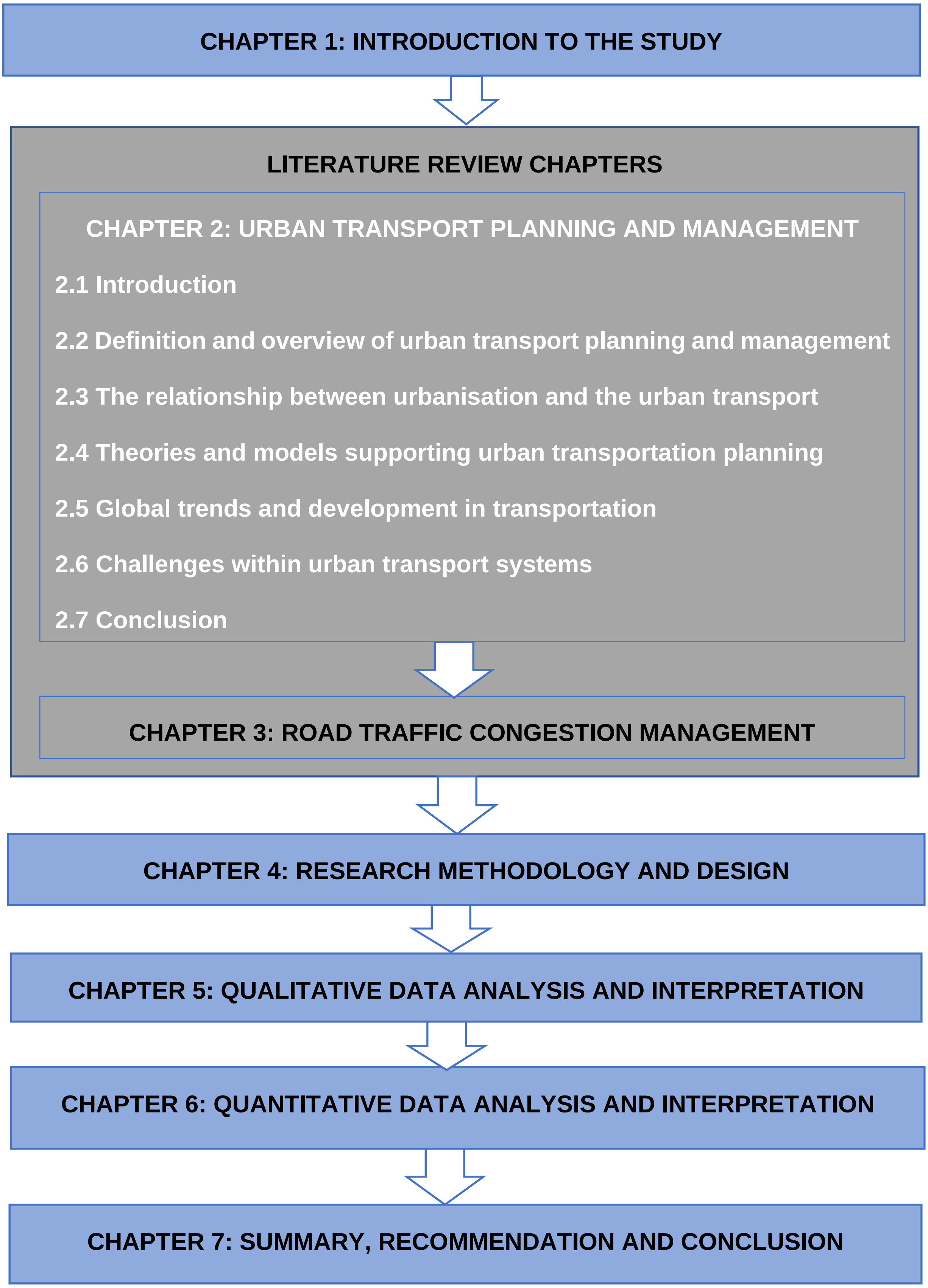


Figure 2.1: Structural flow of Chapter 2 in alignment with the study

Source: Researcher's compilation

2.2 DEFINITIONS AND OVERVIEW OF URBAN TRANSPORT PLANNING AND MANAGEMENT

This section presents a thorough background discussion of transport planning and the concepts connected to urban transport planning and management. This section then proceeds with a discussion about urbanisation and the transport environment, the global trends and development in transportation, theories and models supporting urban transport planning, and lastly, the challenges within the urban transport system.

2.2.1 The concept of transport planning

Transportation planning is the process of constructing, managing transportation and collectively locating the systems to maximise suitable solutions and minimise harmful consequences (Giuliano & Hanson, 2017). Rodrigue *et al.* (2020) described transport planning as preparing and implementing actions to address specific problems. The planning includes the avoidance of vehicles blockage all the way from capacity management and demand, improvements to the public transport segment, and expansion to urban movement (Hendrawan, Adipraja & Indraswari, 2020).

In addition, transportation planning involves developing and organising infrastructure, networks, and services. In history, transportation planning was a subdivision of civil engineering and employed reasonably technical methods (Broaddus & Cervero, 2019). Aguiléra and Boutueil (2019) maintained that transport planning is constructed on surveys and models based on the traits and elements of movement in a certain zone to measure innovative infrastructure and services to consider the societal or environmental impressions of transport policies, whether existing or planned.

According to Hendrawan *et al.* (2020:6), "Urban transport planning aims to develop an integrated transport planning that can offer an operative decision support system tool for urban planning and encourage public transport systems in urban areas". Nieuwenhuijsen (2016) added that transport planning is a vital aspect of shaping and giving form to cities, creating attractive public community areas, encouraging a sustainable, inclusive and healthy movement, allowing economic activities, encouraging community collaboration, and increasing the quality of life. The planning predicts the demand in travel opportunities and ensures all the required amenities and essential services cater to that demand.

Sustainability in transportation is frequently associated with promoting walkability, bicycling, and improved public transportation usage (Koglin & Rye, 2014; Legacy, 2017). Walking and cycling promote a healthy environment and both activities are self-evident in sustainable transport and urban development.

Figure 2.2 represents a graphical illustration of the transportation planning process.

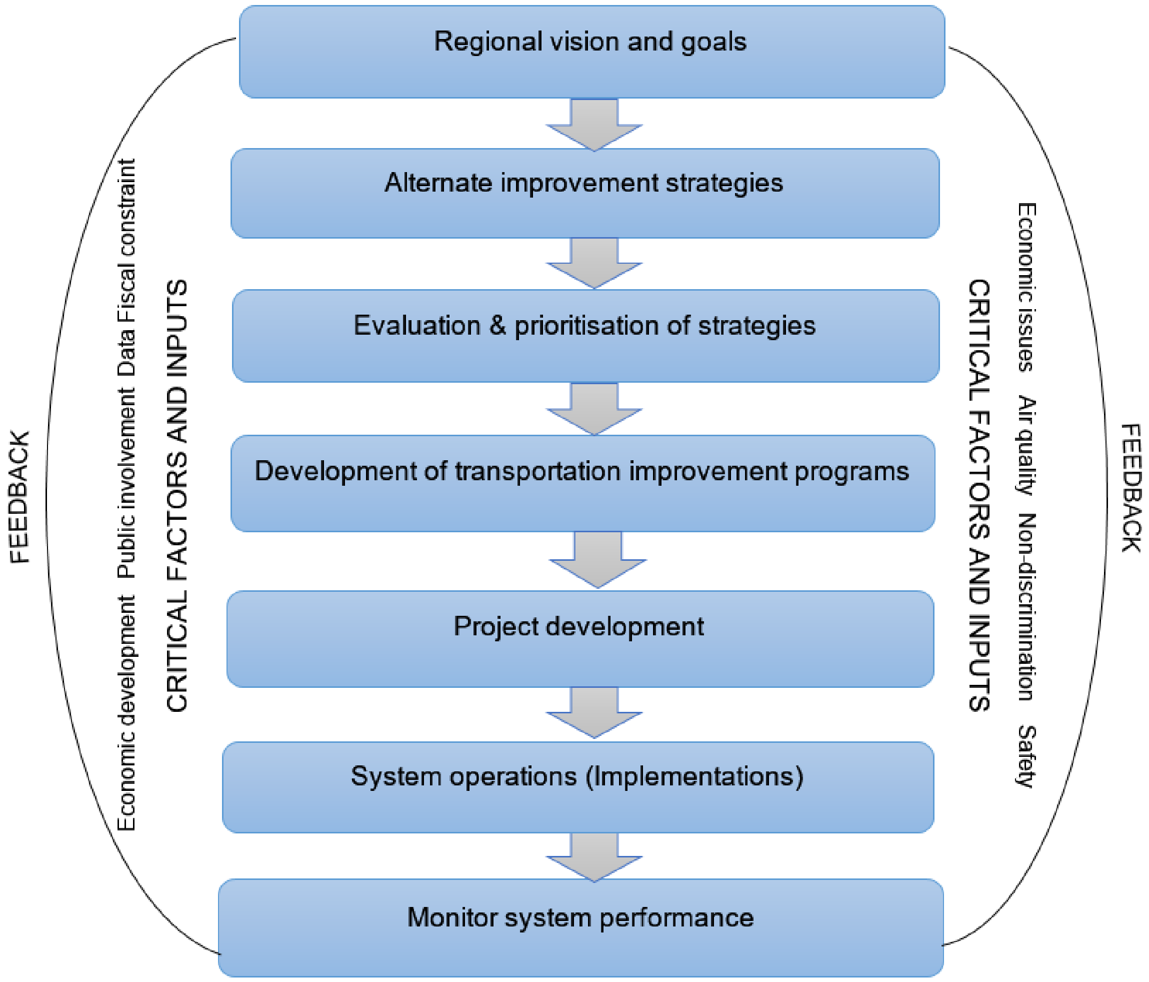


Figure 2.2: Transportation planning process

Source: U.S. Department of Transportation, 2005

Figure 2.2 shows the various aspects involved in transportation planning, and which can also guide the implementation of a plan that offers the total background for transportation planning and decision-making investment in a region. The planning process signifies the vital issues to be focused on due to the growing population, the ways in which urban borders expand, and the resulting traffic intensity (Hamurcu & Eren, 2018; Kovács *et al.,* 2019; Aloi *et al.,* 2020).

The transportation and land-use decisions that form the foundation of project development patterns are made at every level of government (Abu-Khalaf, 2018).

Donaldson (2018) indicated that transportation infrastructures have long been considered essential sources and preconditions of regional economic development. However, the lack of transparency on accessibility has caused automobile speed to be regarded as the ultimate principle for the achievement of most plans (Proffitt, Bartholomew, Ewing & Miller, 2019). Although there are various types of public transportation that make up the urban transportation system, it is impossible to assign the necessary financial capital to all the projects simultaneously (Behbahani, Nazari, Kang & Litman, 2019).

The transport field includes many projects affected by several criteria, especially budgetary restrictions (Kovács *et al.,* 2019). While the local regulatory environment significantly impacts the amount and type of development, the government has a substantial responsibility in regional development, and funding is the most obvious source of influence (Abu-Khalaf, 2018).

Urban transport planning is an illustration of how the systems approach has been applied in multimodal transport planning, and demonstrates how a city may be symbolised by the land-use geographical zone overlaid with a transport network (Black, 2020). Urban transport planning involves being familiar with the scientific and technical aspects related to urban spaces, including unified establishments, networks links, stations, user information, and fare payment systems (Yatskiv & Budilovich, 2017).

The planning mostly concentrates on particular challenges or comprehensive transport affairs at a local level, and has traditionally been the responsibility of lower-tier government (provincial and municipal level) (Rodrigue *et al.*, 2020). Profillidis and Botzoris (2019) explained that transport planning is incorporated into a business or master plan where planners attempt to classify the strategy that should be followed concerning the parameters of the internal and external environments.

Planners and policy analysts need to understand the what is required of a modern transportation system, they should be able to develop successful policies and plans, and forecast the impact of these plans (Giuliano & Hanson, 2017).

Table 2.1 below presents definitions from different sources for the concept ‘transport planning’.

Table 2.1: Summary of definitions of the concept of transport planning from different sources

Description of transport planning	Sources
Designing and building transport systems to extend good results.	Giuliano & Hanson, 2017
Developing and organising the provision of infrastructure, networks systems and public services.	Broaddus & Cervero, 2019
Constructed on surveys and models, and based on mobility traits and determinants.	Aguiléra & Boutueil, 2019
Preparing and implementing actions to address specific problems.	Rodrigue *et al.*, 2020
Planning comprises congestion modification through demand and capacity administration.	Hendrawan *et al.*, 2020

Source: Researcher's compilation

Based on Table 2.1 above, the concept 'transport-planning' has been discussed by many different sources. There are different views on how researchers describe the specific concept. The section below discusses the concept of urban transportation management.

2.2.2 The concept of urban transportation management

According to Narayanaswami (2016), transportation management was the initial task of the urban planning and development division. When managing transport, the issues that face the whole transportation system and several noticeable problems within urban transportation, such as road traffic jamming, greenhouse gasses, the costs of motor vehicle collisions, and the future of public transportation are observed (Elmansouri, Almhroog & Badi, 2020; Gössling, 2020; Seuwou *et al.*, 2020).

The administration of urban transportation aspires to support the demands engendered by the various types of urban activities that occur in the different urban contexts (Happle, Fonseca & Schlueter, 2018; Rodrigue, 2020; Williams, 2019). However, the outdated techniques used in the estimations of future travel demand are incapable of considering the new modes of transport, for instance, autonomous vehicles, on-demand ride-hailing and shared mobility, which are promptly shifting the travel patterns and intensifying the movements of cars on urban roads (Broaddus & Cervero, 2019).

For their part, Rose, Bell, Autry and Cherry (2017) indicated that in the meantime, urban areas are characterised by the interaction of various stakeholder concentrations in close proximity to each other. Kin, Verlinde and Macharis (2017) highlighted that megacities add to the rising sustainability difficulties. There is a substantial need to effectively manage the limited resources in cities (Motieyan & Mesgari, 2018). Although cities have the services of urban planners, it has been found that transport mobility, green spaces, the environment and health departments are not operating in synergy, and multi-sectoral methods are required to find solutions to the challenges (Nieuwenhuijsen, 2016).

Urban planning has a major influence on how extensively a city should reinforce business growth, and the consideration of which transportation management system should play a pivotal role (Narayanaswami, 2016). Broaddus and Cervero (2019) added that there is an extreme need for an inter-disciplinary approach, the development of multiple transportation modes, the consolidation of land use formation, and public engagement abilities. The next section discusses the transportation /land use system.

2.2.2.1 Transportation and land use system

A transportation system can be defined as the mixture of components and their connections that generate the demand for travel within a given area and the supply services of transportation to gratify this demand (Distefano, Di Giacomo & Mazzara, 2021; Cascetta, 2013; Cox, Prager & Rose, 2011). Transportation systems are indispensable to human life and business development, and play a vital responsibility in transportation supply, economic growth, settlement structures, and the social environment (Hendrawan *et al.*, 2020; Mattioli, Roberts, Steinberger & Brown, 2020).

The fundamental role of a transportation system is to allow people and businesses to engage in spatially and temporally distributed activities that physically exchange information, goods and services (Growe, 2019; Miller, 2018). Simultaneously, the transportation system is blamed for many of the negative influences on human life and the surrounding areas. Hence, the transportation system should be well organised to meet the socio-economic and environmental sustainability needs. Therefore, appropriate policies are of paramount importance, and can expand or restrict the possibility of the transportation system negatively affecting humans and the environment (Sayyadi & Awasthi, 2018).

Transportation places significant pressure on land use and presents an excessive challenge to urban sustainability in developing countries (Colsaet, Laurans & Levrel, 2018; Okeke, Gyoh & Echendu, 2021; Song *et al.*, 2019). According to Hawkins and Nurul Habib (2019), land-use systems can adapt travel demand patterns and activate modifications in transportation systems. However, transportation system development generates new accessibility stages that support variations in land use patterns (Pan, Deal, Chen & Hewings, 2018; Shaw & Xin, 2003; Verburg *et al.,* 2019). "Moreover, it becomes clear that the relationship between urban development and transport is closely linked to other urban processes, such as macroeconomic development, interregional migration, demography and household formation, and technological innovation" (Wegener, 2021:741). Nevertheless, it remains a problem to illuminate the out-dated challenges instigated by the spatial disarray of land use, and transportation services remain an indefinable goal (Ferguson, 2018; Kii, Moeckel & Thill, 2019).

Kii *et al.* (2019) indicated that serious road traffic gridlocks and excessive car dependencies initiate various problems in many developed cities, while a widespread suburbanisation compelled by high movement has increased energy consumption and negative environmental influences. According to Chen, Zhang, Ye and Yang (2020), recognising how the whole system operates is closely attached to unravelling the associations between land use, traffic and transport supply.

According to Babb and Curtis (2015), transport planning policy and urban land use have progressively attempted to increase walking rates among the public to alleviate the impact of vehicle ownership on urban environments, economies, and quality of life. An understanding of urban entities can be achieved by analysing designs and procedures of the transport–land-use system. Figure 2.3 below represents the supply (transport system), impedance (spatial interaction) and demand (land-use) within the transport/land-use system.

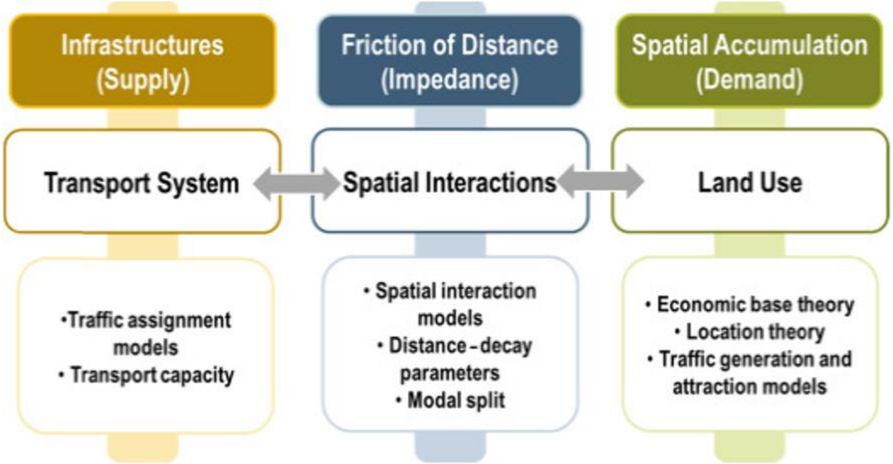


Figure 2.3: The transport/land-use system

Source: Rodrigue, 2020

This system is extremely multifaceted and contains many connections between the spatial interactions, transport system and land use (Jean-Paul Rodrigue, 2020). The interaction between land use and transportation is a vibrant progression that comprises alternatives over the spatial and temporal proportions between the two systems (Eboli, Forciniti & Mazzulla, 2012). Wegener (2021) argued that the associated involvement amongst urban development and transport is not a straightforward one-way relationship but a multidimensional two-way relationship. For example, the spatial division of labour, and the separate locations of human activities in space require spatial interaction, such as travel and goods transport.

The availability of transport infrastructures, such as roads, railways and airlines, play a role in making some locations more desirable, as houses or commercial locations influence real estate markets and the location of households and firms (Rérat, 2018; Malaitham, Fukuda, Vichiensan & Wasuntarasook, 2020).

Table 2.2 below presents the descriptions of the transport/land-use system as formulated by various authors.

Table 2.2: Descriptions of the urban transportation management and the transport/ land-use system

Descriptions on the urban transportation management	Sources
Includes the division of urban planning and development.	Narayanaswami, 2016
Issues encountered in urban transportation are traffic congestion, air pollution, and the costs of motor vehicle accidents.	Elmansouri *et al.,* 2020; Gössling, 2020; Seuwou *et al.*, 2020
Supports demands generated by the diversity of urban activities.	Happle *et al.*, 2018; Rodrigue, 2020; Williams, 2019
New modes of transport challenge established approaches to forecasting future travel demand. Increased necessity for inter-disciplinary tactics. Planning for numerous forms of transportation, incorporation with land-use planning, and public engagement skills.	Broaddus & Cervero, 2019
Substantial need for the effective management of limited resources in cities.	Motieyan & Mesgari, 2018
Transportation systems play a vital role in transportation supply, economic growth, settlement structure and social environment. Combines elements that produce travel demand interactions.	Distefano *et al.*, 2021; Cascetta, E., 2013; Cox *et al.*, 2011
Allocates access to people and businesses to involve spatial and temporal distributed activities and substitute information, goods and services. Changes in land-use systems can modify the travel demand patterns and induce changes in transportation systems. Transportation system development generates new accessibility levels that support variations in land-use patterns	Growe, 2019; Miller, 2018; Hawkins & Nurul Habib, 2019; Pan *et al.*, 2018; Shaw & Xin, 2003; Verburg *et al.*, 2019
The transport / land-use system is about understanding how the system works concerning the interactions between land use, traffic and transport supply.	Chen, Zhang, Ye & Yang, 2020

Source: Researcher's compilation

Table 2.2 above presented a summary of the descriptions of urban transport management and the concepts of transport and land-use system. The following section will discuss the relationship between urbanisation and urban transportation.

2.3 RELATIONSHIP BETWEEN URBANISATION AND URBAN TRANSPORTATION

The term ‘urbanisation’ means transitioning from a rural to an urban society or nearby cities to acquire social and economic facilities such as job opportunities, academic institutions and entertainment services (Rodrigue, 2020; Tacoli, McGranahan & Satterthwaite, 2015). Cities are growing rapidly due to urbanisation, and this is something that is seen in the global context and also on the African continent (Guneralp *et al.,* 2018; Abrahams, 2016). In African cities, the poor urban conditions have resulted from the sudden urbanisation, and this has negatively affected many people on the continent, and is considered to be the foremost contributor to urban poverty (Cobbinah, Erdiaw-Kwasie & Amoateng, 2015). Furthermore, the consequences of the migration to the cities revolves around urban land development and results in communities encountering service delivery disputes because of the excessive amount of individuals living in metropolitan zones.

Urbanisation growth contributes to the increased service delivery and transport challenges, including road infrastructures and carbon emissions (Huang, Sadiq & Chien, 2021). The continuous scarcity of services in urban zones, slum explosions, urban expansion, traffic congestion and environmental implications upsurge the susceptibility of urban residents (Cobbinah *et al.*, 2015). Gauba (2017) found that the urbanisation process requires substantial infrastructure investment flows to sustain it.

According to Liu and Su (2021), transportation improves urbanisation through government investment and regional integration. An increase in gross domestic product per capita is a central factor of urbanisation, and this is strengthened by the complementing developments in transportation systems (Rodrigue, 2021). The transportation movement in the urban areas impacts the urban spatial structure and shapes urbanisation.

Urban spatial structure variables, including destination distance, land-use density and diversity, connectivity and street density have influenced different aspects of travel behaviour, and the associated energy use and environmental impacts (Acheampong, 2020). Unsustainable urban development frequently gives rise to tough environmental circumstances, such as the burden that the escalating population places on urban infrastructure, land tenure uncertainty, and poor land use that result in resource constraints (Cobbinah *et al*., 2015; Shao *et al.,* 2021).

Transportation infrastructure positively affects urbanisation (Liu & Su, 2021). Pradhan, Arvin and Nair (2021) added that although there may be progressive economic outcomes from urbanisation, the unconstrained relocation into urban districts without the support of suitable transportation substructures can cause challenges. These can lead to adverse side effects, such as congestion and the formation of slums and diseconomies of scale. The new urbanisation is an inevitable outcome of economic development (Gauba, 2017).

Figure 2.4 describes the relationship between urbanisation and urban transportation.

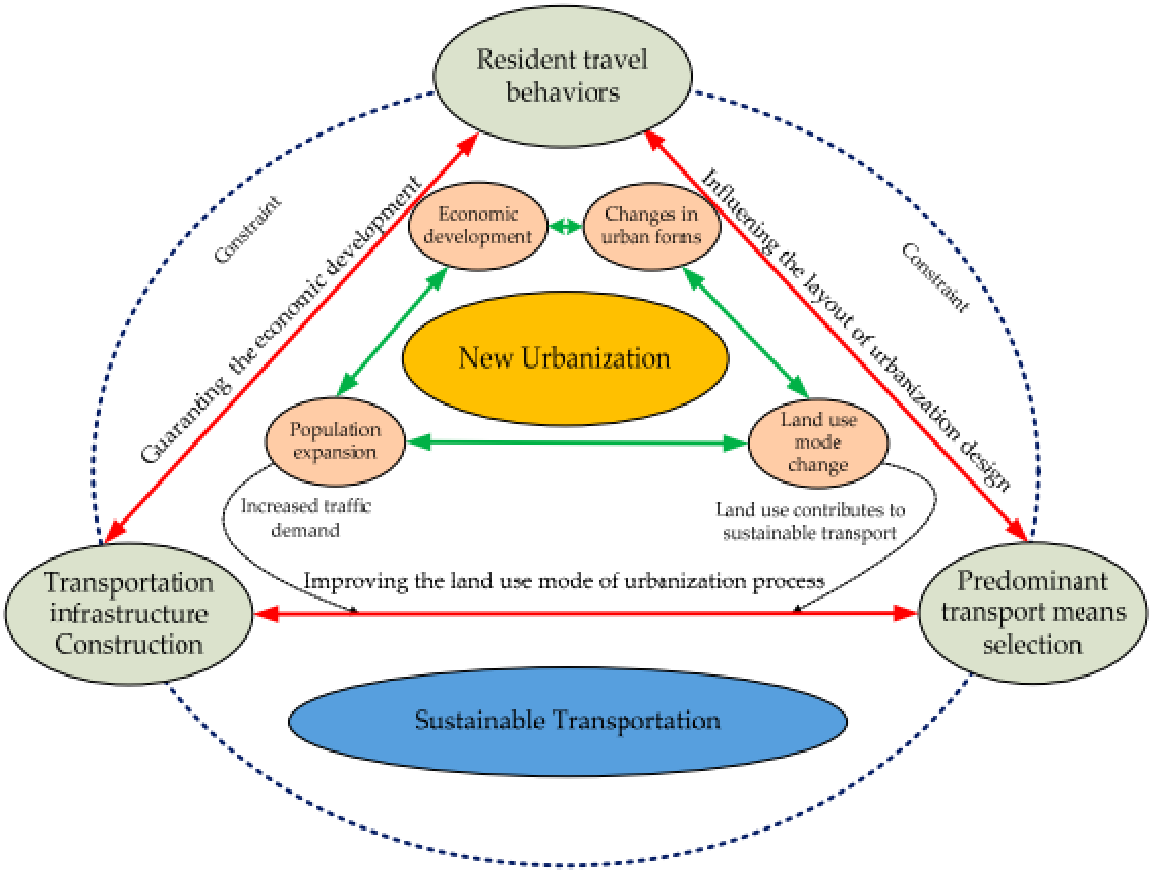


Figure 2.4: The relationship between urbanisation and urban transportation

Source: Ma, Guo, Yuen, Woo & Shi, 2019

From the above diagram, a derivative economic development demand, transportation, plays an imperative role in economic growth (Wang *et al.,* 2021). Due to the growing population, the transport sector plays a significantly role in the increased traffic demand that contributes to greenhouse gases and carbon dioxide (CO_2) emissions (Zhang, Hassan & Iqbal, 2020). According to Baloch (2018), road infrastructure and urbanisation hinders environmental quality and generates of CO_2 emissions into the atmosphere.

Urbanisation increases traffic density, which leads to longer times being spent on travel in urban areas. Dong *et al.* (2019) indicated that the number of people living in cities is continuously increasing, and the urban built-up regions keep on changing and expanding in size, causing changes to urban forms. There is a scarcity of land due to the competing demands for its use. In addition, sustainable land use and the corresponding land policies are experiencing increased pressure from industrialisation, urbanisation and ecological civilisation construction (Wang, Lin, Glendinning & Xu, 2018).

Consequently, this has resulted in numerous spatial structures arising in the urban area, with the dependence on the motor vehicles being the ultimate inequitable factor (Rodrigue, 2021). Sustainable transport aims to achieve coordinated transportation development across the community, economy, and the environment. Sustainable transport emphasises the protection of the environment and rational resources, while meeting social needs (Ma, Guo, Yuen, Woo & Shi, 2019). The next section discusses the theories and models supporting urban transport planning.

2.4 THEORIES AND MODELS SUPPORTING URBAN TRANSPORT PLANNING

This section delves into the theories related to urban transport planning and the reasons for their adoption by the current study. According to Fisher, Ragsdale and Fisher (2019), the relevant theories and models provide significant guidelines and trials for conducting research by indicating the prospective areas that should be highly fruitful, that is, areas in which meaningful relationships between variables can be found. Collins and Stockton (2018) revealed that researchers perceive the usage of theory as equivalent to a coat closet in which diverse objects can be housed, or a lens through which the literature and data in the study are viewed. The theories mentioned in this section are essential in disseminating urban transportation planning and have been adopted to accomplish the different objectives of the study.

2.4.1 Planning theory

According to Brooks (2019), planning theory refers to the philosophy governing the planning process and stages of plan formulation, such as problem definition and goal articulation. The legitimacy of planning theory is found in its application in the planning profession as a framework that directs actions, meaning and consequences (El-Kholei, 2018). Gunder, Madanipour and Watson (2018) added that planning theory encompasses scientific notions, connotations, behavioural interactions, and norms that outline the epistemology of urban planning, and leads to an understanding of how planning and other practices function and evolve.

Planning can be perceived as a set of opinions and values that strive for controlling the spatial distribution of human activities (Gunn & Var, 2002; Hall, 2008; Inskeep, 1991). For the purpose of the current study, the attention is directed to the establishment and ongoing development of urban transport planning concerning the broader field of the theory. Adding to the technological developments, environmental imperatives suggest that changes are needed throughout the transport planning process (Lovelace, Parkin & Cohen, 2020). However, government support is required to embed open-access transport models in transport planning organisations and processes (Quinn *et al.*, 2018).

In the transport environment, transport models can play a significant role in tackling these issues through the transport planning process (Milne & Watling, 2019). However, they have historically been focused on motorised modes, especially cars, and are available only to professional transport planners working within the existing paradigm.

The next theory to be discussed is based on decision-making, since the researcher presumes that decisions are taken when implementing the planning process, including making choices, gathering information, and assessing alternative resolutions.

2.4.2 Decision-making theory

Decision theory is the study of the principles and algorithms used in making a decision, and it is the crucial job of the traffic professionals associated with the planning, monitoring, and selection of optimal solutions (Škrinjar, Abramović & Brnjac, 2015; Ahmed & Omotunde, 2012). According to Cartenì *et al.* (2022), the quality of the decision-making process is a critical factor for successful planning and design. The decision-making theory relies on mathematics, where scientific discipline occurs in traffic decision-making and has developed as a process using scientific methods and systemic research to assist the decision-maker in determining the optimal action (Škrinjar *et al.*, 2015). The process is achieved by identifying values, uncertainties and other factors influencing the decision (Van der Bles *et al.*, 2019; Ahmed & Omotunde, 2012; Taylor, 2018).

Cartenì *et al.* (2022) argued that the quality of the decision-making process critically depends on how the process is structured and managed. Krishnamurthi, Nayyar and Solanki (2019) added that various activities, such as gathering, grouping, selection, and data analysis, are necessary to make efficient decisions related to traffic organisation in cities. Therefore, the current study adopted the decision-making theory to assess the regular choices made by traffic professionals about the drivers' information processing pattern in a mixed traffic environment.

Decision theories can be grouped into two categories: normative and descriptive decision theories. While normative theory explains how a decision should be made, descriptive theory describes how decisions are made (Ahmed & Omotunde, 2012). Therefore, the current study similarly engaged in the decision-making theory to apply the decisions on effectively implementing the regulations for road traffic congestion.

2.4.3 Simulation model for urban transport

The simulation model has been developed because of the system dynamics that approve the integration of various indicators of the sustainable development of urban transport, and their concurrent estimation with a dynamic approach (Strulak-Wójcikiewicz & Lemke, 2019: 502). According to Cejkaa and Šedivýa (2021:198), simulation models are frequently applied in the transport sector to simulate traffic flows. They are predominantly used to optimise the flow capacity when designing new transport routes, to determine the optimal traffic routing on an existing network, or plan long-term road closures. The simulation model uses mathematical expression and data to design, build and manage planning tools.

In transportation planning, this model has been developed to learn the transportation system behaviour that significantly impacts mobility performance, daily traffic and congestion, and it evaluates several alternatives to improve transportation system performance (Hendrawan *et al.*, 2020). The next theory is based on the method of queuing systems, since the researcher presumes that vehicles are delayed due to queuing for the same portion of the roadway capacity in traffic congestion.

2.4.4 Queuing theory

Queues transpire whenever instantaneous demand exceeds the capacity to offer a service. Queuing theory originated from mathematical programming, and the theory and method of queuing systems such as waiting lines in the field of traffic congestion, and is used to plan the execution of particular activities (Cejkaa & Šedivýa, 2021; Modi *et al.*, 2019; Humphreys, 1991).

Varghese, Varghese and Chanda (2021:55) indicated that queuing theory was developed to provide models that predict the behaviour of systems that supply services for unpredictably arising demand. The approach is applied when minimising vehicle traffic congestion using the four route channels, analysing the situation of traffic congestion at highway toll plazas, vehicle traffic flow, and traffic management systems (Agnihotri, 2016; Duhan *et al.*, 2014; Ekeocha & Ihebom, 2018; Wang, 2017).

Queuing theory in transport adopts systems to analyse the flow of traffic and to manage accidents through signalised routes that are controlled by the performance analysis of toll plazas (Varghese *et al.,* 2021:55). According to Shangavi, Megha, Prajendra and Pinte (2017), queuing theory is involved with constraints such as arrival, number of lanes, service time, waiting time, and merging area. Consequently, the current study pursued queuing theory to discuss urban transport challenges such as traffic congestion. For example, queuing theory can examine the traffic flow on approach through an intersection controlled by a traffic signal. The next section discusses traffic flow theory.

2.4.5 Traffic flow theory

According to Hoogendoorn and Knoop (2013), traffic flow theory entails the knowledge of the fundamental characteristics of traffic flow (such as road capacity, the relation between flow and density, and headway distributions) and the associated analytical methods (shockwave theory and microscopic simulation models. Ye and Yamamoto (2018) added that in the field of traffic flow theory, a statistical relationship amongst the macroscopic traffic flow variables of flow, density, and velocity can be discovered. The idea of urban traffic flow has many characteristics, such as periodicity, selfsimilarity, spatiality, time varying and uncertainty (Lin & Huang, 2021). However, traffic flow predictions are often based on historical traffic flow data.

As previously stated, traffic flow and congestion are among the main societal and economic problems related to transportation in industrialised countries (Olayode *et al.*, 2020; Hoogendoorn & Bovy, 2001; Vencataya, Pudaruth, Dirpal & Narain, 2018.). In this respect, managing traffic in congested networks requires a clear understanding of traffic flow operations. For example, insight is required in what causes the congestion, what determines the time and location of traffic breakdown, and how the congestion propagates through the network (Alam & Habib, 2021). Therefore, the current study used the traffic flow theory to focus on the interactions among various participants in traffic, such as vehicle drivers, pedestrians and cyclists, and infrastructure, such as highways and signal control devices. The aim was to determine the relationship between individual traffic participants and the resulting traffic flow occurrences (Li, Jiang, He, Chen & Zhou, 2020). The next section discusses the location theory.

2.4.6 Location theory

According to Fengru and Guitang (2019:53), locations and places are related to economic processes. Location theory is a core theory for examining how and why cities and markets have become a common area of study in economic geography and regional economics (McDonald *et al.*, 2018; Murray, 2020). The location theory originated from classical economics and can be traced back to the classical location theory of Germany, which provides the rationale for siting decision-making and service allocation (Fengru & Guitang, 2019).

According to Murray (2020), the primary theoretical developments have focused on land use, industrial production, central places, and spatial competition. This theory supports various forms of locational analysis, and highlights the significance of spatial proximity (Boudet, Zanocco, Howe & Clarke, 2018.). The location of economic activities can be defined through a broad level, such as a region or metropolitan area, or a narrow one such as a zone, neighbourhood, city block or an individual site (Brown, Sanders & Reed, 2018; Jacobs *et al.*, 2019).

Therefore, the current study used location theory to address the peak period of traffic congestion where economic activities are located, considering the daily traffic flow on urban roads. According to Rodrigue (2021:74), economic activity location is connected to nature and function, where each activity embraces a dependency level related to transportation. The following discussion will be based on activity theory, since the researcher presumes the attractiveness and accessibility of the area result from economic activities in terms of the locations where commuters travel.

2.4.7 Activity theory

Activity theory has been widely and successfully used in various fields, such as information systems or technology, management, organisational psychology, design, education, and health (Kaptelinin & Nardi, 2018; Camacho, Foth, Rakotonirainy & Rittenbruch, 2017). As proposed by Engeström, activity theory includes the three mediating elements of tools, rules and division of labour that mediate the interaction between subject, object and community (Camacho *et al.,* 2017:72; Ettema, 2018: 273). The relationship between subject (the human doer), object (the thing being done) and tool (instrument or device used) signifies what can be called an activity system (Lioutas, Charatsari, La Rocca & De Rosa, 2019:3; Hasan & Kazlauskas, 2014). An activity's outcome relates to a particular motive that propels the activity as a whole, and is associated with attaining needs (Camacho *et al.,* 2017: 72). The activity is defined as a hierarchy composed of actions and operations.

According to Mokhtarian (2019), the travel idea can contribute to walking, and is consistent with the activity theory. The activity theory is particularly useful in providing a consistent vocabulary that can be applied across distinct fields, enabling more accessible communication and knowledge transfer (Camacho *et al.,* 2017:72). Therefore, the current study used the activity theory to assess the problems contributing to road traffic congestion, based on the outcomes of activities.

2.4.8 Theory of planned behaviour

This is one of the approaches to understanding the choice of different transportation modes and is used in psychological models to explain road safety behaviours (Neto *et al.*, 2020; Ledesma, Tosi, Diaz-Lazaro & Poo, 2018.). The basic assumption of this theory includes the psychology, beliefs, behaviour attitude, subjective norms and perceived behavioural control leading to an individual's behavioural intentions and actual behaviours (Wang, Yuen, Shi & Ma, 2020).

This theory can be influenced by three factors: attitude, subjective norms, and perceived behavioural control, leading to behavioural formation (Li, Man, Chan & Zhu, 2021; Shaaban & Maher, 2020). The model selection is affected by different factors, including the characteristics of the users, type of trip, and quality of service for the various transportation modes. According to Shaaban and Maher (2020), commuters have different attitudes and beliefs about whether public transportation can fulfil their travel needs. The theory of planned behaviour (TPB) is one of the most common theories used to predict and explain the behaviour related to a transport-related activity (Shaaban & Maher, 2020: 485).

The excessive use of cars in large urban centres has negatively impacted people's quality of life, bringing about negative consequences such as congestion, accidents and pollution (Neto, 2020: 391). An attitude constitutes a positive or negative evaluation of the behaviour. Perceived behavioural control reflects people's perception of their ability to engage in the behaviour. The subjective norm signifies the perceived social pressure to carry out the behaviour (Li *et al.*, 2021). Therefore, the current study adopted the TPB to assess the driver's use of private vehicles, which contributes to road traffic congestion. Table 2.3 below presents a summary of the theories and models supporting urban transportation planning and also presents the reasons for adoption in the current study.

Table 2.3: Summary of theories and models supporting urban transportation planning and the reasons for adoption in the study

Transport planning theories	Reasons for adopting the theory in the study	Sources
Planning theory	Relevant to address the origin and development of urban transport planning. Governing the planning process and stages of plan formulation. Develop urban transport planning concerning the broader field of the theory.	Brooks, 2019; Gunn & Var, 2002; Hall, 2008; Inskeep, 1991.
Decision-making theory	Relevant to address decisions by traffic professionals associated with planning and monitoring. Occurs in traffic decision-making, and has developed as a process using scientific methods and systemic research. Identifying values, uncertainties, and other factors that might influence the decision.	Škrinjar *et al.*, 2015; Ahmed & Omotunde, 2012; Cartenì *et al.,* 2022; Van der Bles *et al.*, 2019
Simulation model for	Relevant to the integration of numerous indicators of the sustainable development of urban transport.	Strulak-Wójcikiewicz & Lemke, 2019;

Transport planning theories	Reasons for adopting the theory in the study	Sources
urban transport	Applied in the transport sector to simulate traffic flows and to develop the transportation system behaviour that significantly impacts mobility performance, daily traffic and congestion.	Cejkaa & Šedivýa, 2021; Hendrawan *et al.*, 2020
Queuing theory	Relevant to queuing systems such as waiting lines in traffic congestion, and is used to plan the execution of particular activities. Applied when minimising vehicle traffic congestion using the four route channels. Includes transport systems to manage traffic intensity in the performance analysis of toll plazas, and to reduce traffic accidents at signalised intersections.	Cejka & Šedivýa, 2021; Modi *et al.*, 2019; Humphreys, 1991; Varghese *et al.*, 2021; Agnihotri, 2016; Duhan *et al.*, 2014; Ekeocha & Ihebom, 2018; Wang, 2017

Transport planning theories	Reasons for adopting the theory in the study	Sources
Traffic flow theory	Relevant to understanding the relationship amongst the macroscopic traffic flow variables of flow, density, and velocity. Predicts the flow based on historical traffic-flow data. Focuses on the interactions among various traffic participants such as vehicles, drivers, pedestrians, and cyclists.	Ye & Yamamoto, 2018; Lin & Huang, 2021
Location theory	Relevant to recognise the ordinary area of study in economic geography and regional economics. Focuses on land use, industrial production, central places, and spatial competition. Addresses the peak period of traffic congestion where economic activities are located.	McDonald *et al.*, 2018; Murray, 2020
Activity theory	Relevant to propel the activity as a whole, and is associated with attaining needs. Addresses a hierarchy composed of actions and operations. Enabling more accessible communication and knowledge transfer.	Camacho *et al.*, 2017:72
Theory of planned behaviour	Relevant to understanding the attitude, subjective norms, and perceived behavioural control, leading to behavioural formation.	Li *et al.*, 2021; Shaaban & Maher, 2020:485

Transport planning theories	Reasons for adopting the theory in the study	Sources
	Addresses the characteristics of the users, type of trip, and quality of service for the various transportation modes. Predicts and explains the behaviour related to a transport-related activity. The current study adopted the TPB to assess the drivers' behaviour when using private vehicles.	

Source: Researcher's compilation

Table 2.3 presented a summary of the theories and models supporting urban transportation planning and the reasons for their adoption in the current study. Therefore, it is apparent that there are different research views and how they describe the specific theory. The next section discusses the global trends and developments in urban transport.

2.5 GLOBAL TRENDS AND DEVELOPMENTS IN URBAN TRANSPORT

Current transport trends culminate in urban regions and are complex systems characterised by massive numbers of interconnected networks of businesses, services, and different modes of transport (Pangbourne, Stead, Mladenović & Milakis, 2018; Pojani & Stead, 2017). The developments increase a diversity of social, economic and organisational malfunctions that tend to expose the economic and environmental sustainability of cities (Dimitriou, 2021; Neirotti *et al.*, 2014). Trends in urban transport development are starting to appear, and increased urban density is noted in many European and North American cities (Wey, 2019; Cervero, 2018). The sections below explore global trends in the transportation environment.

2.5.1 Mobility as a Service (MaaS)

Mobility as a Service (MaaS) refers to a subscription of funds to a prepaid bundle of integrated transportation trips that consists of several pricing schemes, prearranged on a digital platform that allows for the planning, booking, and payment of transportation services, and which concentrates on customer destinations (Kamargianni, Li, Matyas & Schäfer, 2016; Jittrapirom *et al.*, 2017). Alyavina, Nikitas and Njoya (2022) indicated that this service may perhaps become the foundation of a new flexible paradigm that may be able to challenge many of society's tremendous complications, such as reduced accessibility, increased traffic congestion and environmental degradation.

However, Feneri, Rasouli and Timmermans (2020) argued that it is a challenge to capture the effect of this innovative technology on travel behaviour, given the limited number of an inclusive experimental services. Lajas and Macário (2020) added that MaaS has emerged as a prospective disruption to the movement in this new mobility ecosystem.

In a study in Australia, Ho, Hensher, Mulley and Wong (2018) highlighted the impact of existing travel patterns on MaaS commitment, and the probability of interrupted car-ownership models in Australia. Karlsson *et al.* (2017) remarked on the constructive effects that sharing services and electric mobility will have on users' mobility behaviour; however, they stressed that there is a lack of information related to MaaS schemes to be able to make a complete impact assessment of a comprehensive service. This was also emphasised by Durand *et al.* (2018), who identified the possible behavioural effects of MaaS, together with its potential inferences for social and environmental sustainability. Storme, De, De and Witlox (2019) questioned the potential for MaaS to alternate car-ownership based on a relatively small-scale Belgian MaaS pilot, despite the noted reduction in the number of privately-owned cars for the duration of the involvement. Further confirmation is required from pilot studies in content and sample size.

2.5.2 E-Commerce

Improvements to network technology have transformed the shared ethics and values among people, and this has contributed to the instant development of e-commerce that has progressively improved the urban system (Lin, Xie, & Lv, 2016; Lin, 2019). The easy interactions through online social networks and relocation are also vital driving forces for current urban improvement (Le, Carrel & Shah, 2021, Lin, 2019). Xu, Lv, and Wen (2015) pointed out that the rising attractiveness of e-commerce has preceded the additional equivalent chances for human resources and economic entities in towns.

According to Visser, Nemoto and Browne (2014), the extensive number of consignment trucks on the road networks in urban areas has gradually taken the lead in environmental and social challenges, such as traffic safety, congestion and emissions. MacDonald, Yuan and Naumann (2019) added that the freight vehicles that have started appearing in local streets and arterials have triggered anxiety over traffic safety in urban areas, and that there has been incomplete investigation of the road safety influences. For their part, Chueamuangphan, Kashyap and Visvanathan (2020) argued that e-commerce has led to a decrease in personal travel for shopping activities and that has resulted in positive environmental effects.

Therefore, the promotion of e-commerce is a possible alternative demand management mechanism to relieve traffic jams and GHG emission reduction, since customers do not need to drive to physical stores (Shao, Yang, Xing & Yang, 2016; Shah, Carrel & Le, 2021). Even though there have been studies on e-commerce endorsement, there is still a scarcity of theoretical and practical research to investigate the influence of e-commerce on urbanism (Lin, 2019).

2.5.3 Electric vehicles technology (EVs)

According to Morrison, Stevens and Joseck (2018), all-electric powertrain vehicles are generally comprised of pure electric vehicles (PEVs), hybrid electric vehicles (HEVs), and fuel cell electric vehicles (FCEVs), which could assist in reducing petroleum use and emissions from on-road automobiles. There is rising consideration in organising these technologies in operation. Some optimisation models suggest that a fleet of electric vehicles, especially electric robot taxis, could lower GHG emissions by 60% (Lempert, 2021) to up to 94% (Greenblat & Saxena, 2015).

Although authorities around the world are determined to promote the development of Electric vehicles technology (EVs), this initiative has an impact on traffic and energy consumption. With a lack of sufficient public charging stations, limited battery capacity, range anxiety and long battery charging time, the vehicles may get stuck anywhere preventing the proper movement of traffic on the road (Wang, Tang, Huang & Qu, 2021; Grigorev, Mao, Berry, Tan, Purushothaman & Mihaita, 2021). Furthermore, Sun, Li, Wang and Li (2019) argued that the implementation of EVs, especially battery electric vehicles, can be a practical solution to the energy predicament and environmental concerns. Long and Axsen (2022) asserted that academia, industry and policymakers have discussed the imminent low-carbon developments of electric transport systems in depth. Sun *et al.* (2019) similarly maintained that the development of EVs has been accelerated in many countries to decrease the dependence on oil and to limit greenhouse gas emissions. However, a more precise understanding of these vehicle markets' potential size and relative costs can help policymakers prioritise investment decisions (Morrison *et al.*, 2018).

2.5.4 Wheel-chair accessible vehicles

Mobility is obligatory for various daily activities. People may be unable to move around independently due to various health conditions without the use of specific mobility aid devices (Sinyukov, Troy, Bowers & Padir, 2019). According to Ferreira *et al.* (2021), individual movement is one of the vital human rights in ensuring a productive and dignified life for people with a physical disability who require the use of a wheelchair.

Public transport plays an essential role as a significant element in ensuring justice in mobility, and enabling access to rudimentary requirements such as education, healthcare, employment and leisure (Ferreira *et al.*, 2021). Howarth (2021) asserted that the mismatch in public transport access and mobility technology regularly disturbs underserved communities. However, while ride-sourcing facilities have increased precipitously in recent years, accessibility for differently-abled people is an ongoing issue (Hassanpour, Bigazzi & MacKenzie, 2021). Citizens with disabilities often face challenges to access transport systems and public spaces (Velho, 2019; Sze & Christensen, 2017).

2.5.5 Active transportation

Active transportation is human-powered mobility such as walking and biking. According to Young *et al.* (2020), promoting human-powered transportation through policy, systems and environmental change is one of the leading evidence-based strategies to increase physical activity. According to Howarth (2021:13), "Though not the same as powered transportation, the U.S. Department of Transportation asserts that it is still the responsibility of the transportation infrastructure and industry to design active transportation opportunities". These initiatives regularly require coordination across federal, provincial and local agencies. It is necessary to establish solid and broad partnerships across professional disciplines, community members, and advocacy groups to maximise the effectiveness of all the various interventions (Young *et al.*, 2020).

Since active transportation is mainly associated with rural communities, it may be necessary to also consider bicycle-friendly travel for daily activities in well-developed urban areas (Grabow *et al.,* 2019). Walking and cycling are mutual forms of active transportation (Biehl & Stathopoulos, 2020); however, public transport can be considered active, as walking or cycling typically commences from public transportation trips (Glazener & Khreis, 2019).

According to Grabow *et al.* (2019), active transport may be a more significant challenge in rural areas because of longer distances. Active transportation varies markedly between countries, and there is consistent evidence of lower rates in urban areas than in rural areas in developing countries (Oyeyemi & Larouche, 2018). However, active transportation's environmental amenities may have benefits, since fewer rural adults are meeting the physical activity recommendations, and those living in rural areas are more likely to suffer from health challenges than their urban counterparts (Blake *et al.*, 2017; Tribby & Tharp, 2019; Wheeler & Davis, 2017).

Most cities sustain geospatial records of urban roads from interstate to local roads and their posted speeds, but databases of walkable and bikeable streets are usually not readily available (Cong, Kwak & Deal, 2022). Furthermore, the physical design of these places may also affect travel choices and how much commuters utilise active transportation methods (Wang *et al.*, 2016).

Table 2.4 presents a summary of the trends and developments in urban transport.

Table 2.4: Summary of the trends and developments in urban transport

Trends and development	Summary	Sources
Mobility as a service	Prepaid bundle of integrated transportation trips. Several pricing schemes concentrate on customer destinations. Emerges as potential mobility interruption in current mobility system. Inadequate data from MaaS schemes for an extensive comprehensive service on impact assessment.	Kamargianni *et al.,* 2016; Jittrapirom *et al.* 2017; Ho *et al.*, 2018; Karlsson *et al.,* 2017
E-Commerce	E-commerce has progressively changed the urban system. The popularity of e-commerce has led to equal opportunities for individuals and economic entities in cities. Freight vehicles triggered traffic safety in urban areas and influenced traffic safety, congestion and emissions.	Lin *et al.*, 2016; Lin, 2019; Le *et al.*, 2021; Lin, 2019; Xu *et al.*, 2015; MacDonald *et al.*, 2019; Visser *et al.*, 2014

Trends and development	Summary	Sources
Electric vehicles	Electric vehicles are considered a solution to the energy crisis and environmental issues and could reduce GHG emissions by 60% to 94%. Development of EVs established in many countries to reduce oil and environmental pollution. More understanding of vehicle markets' potential size and costs can help policymakers prioritise investment decisions.	Lempert, 2021; Greenblat & Saxena, 2015; Sun *et al.,* 2019; Li *et al.*, 2019; Morrison *et al.,* 2018.
Wheelchair accessible vehicles	The movement of disabled people is restricted without specific mobility aid devices Citizens with disabilities often face challenges accessing transport systems and public spaces.	Sinyukov *et al.,* 2019; Velho, 2019; Sze & Christensen. 2017.
Active transportation	Promotes human-powered transportation through policy, systems, and environmental change. Residing in a thoroughly maintained community may not be necessary for active travel. Walking and cycling are mutual forms of active transportation.	Young *et al.,* 2020; Grabow *et al.,* 2019; Biehl & Stathopoulos, 2020; Glazener & Khreis, 2019

Source: Researcher's compilation

As shown in Table 2.4, urban transport development promotes the constant global dialogue on the opportunity of urban transportation. The next section discusses the challenges within urban transport systems.

2.6 CHALLENGES WITHIN URBAN TRANSPORT SYSTEMS

Due to the alarming rise in demand for better transportation services, there is a need to provide an effective transport system (Olayode, Okwu & Uchechi, 2020). However, the transport system in urban cities is becoming increasingly vulnerable to a particular array of problems (Duy, Chapman & Tight, 2019). Since urban productivity depends on the effectiveness of its transportation system (Artmann, Inostroza & Fan, 2019. Rodrigue, 2020; Terfa *et al.*, 2019), cities are spatially expanded along with urban development and the following challenges were discovered within urban transport systems.

2.6.1 Distribution of freight

An effective freight transportation system performs a fundamental purpose in economic growth, enhancing the total cost of goods and services, and globalising industrial competitiveness (Pani, Sahu, Patil & Sarkar, 2018). The increasing level of urbanisation worldwide has led to higher levels of transport activity related to cargo distribution and service provision (Oliveira *et al.,* 2017). Furthermore, passenger and commodity vehicles share the inadequate road resources. Policies and regulations prioritise the safeguarding of passenger transport while constraining freight, which creates challenges for logistics service providers and their customers (Hu *et al.*, 2020). Urban economies rely on effective freight transportation to support their expansion, however, the existence of freight transportation in urban areas can be an undesirable element (Paddeu & Parkhurst, 2020). Freight transport flows have constantly increased population numbers, consumption, and production, and have led to the customising of products and services and falling trade barriers (Pani *et al.*, 2018).

According to Thompson (2015), the use of larger capacity vehicles allow more freight to be carried by fewer vehicles, which significantly reduces freight traffic and emissions. Regardless of their essential role in economic growth, consignment trucks intensify traffic congestion and air pollution, which generally impose high costs on society (Paddeu & Parkhurst, 2020; Tozzi, Corazza & Musso, 2013). A study by Chen *et al.* (2017) recommended that local authorities should establish strict regulations, such as safe speed limits, congestion charging, and an access timetable to ensure that the flow of goods into and out of a city is controlled at a certain level.

Cities need to advance their transformation to mitigate these effects and allow the innovative exploration of urban freight operations, especially in terms of the development of new technologies (Björklund & Gustafsson, 2015). For example, a mobile-depot-based delivery setup may yield slight cost advantages over the traditional setup, specifically in neighbourhoods characterised by low average delivery drop sizes (Marujoa *et al.*, 2018).

Due to the emergence of the sustainability implications of urban freight movement through e-commerce, retailers are shifting to online sales (Sultana, Salon & Kuby, 2017). A study by Wygonik and Goodchild (2016) found that in Britain, and particularly in London, the growth in e-commerce has led to the increasing use of Light Goods Vehicles (LGV) for parcel deliveries in urban areas. Furthermore, the urban infrastructure is being increasingly redesigned in favour of walking, cycling and public transport, which reduces the curbside accessibility for last-mile operations. Cargo tricycles and mobile depots significantly reduced GHG emissions and air quality pollutants in last mile delivery (Marujoa *et al.*, 2018).

2.6.2 Insufficient public transport

Mass transportation (also known as public transportation) is designed to move people to many different destinations (Farida, 2018). However, the lack of integration between the different public transport modes generates the greatest hindrance in delivering a unified, sustainable and operative public transport system (Cele, 2018). The issue of overcrowding has frustrated passengers in public transportation, and has reduced the expectations of privacy for commuters (Ababio-Donkor, Saleh & Fonzone, 2020; Yook & Heaslip, 2015). In this sense, PT cannot compete with private vehicles as the service level often does not match commuters' expectations (Suman & Bolia, 2019).

At present, people in urban areas use personal motor vehicles more often for work and other activities than public transport. Ababio-Donkor *et al.* (2020) confirmed that private motorised users are generally more sensitive to the overcrowding and anti-social behaviours on PT than active PT travellers.

Berg and Ihlström (2019) argued that a lack of transport opportunities is a barrier to accessibility and social inclusion in contemporary society. For example, in Pakistan, road infrastructure development has resulted in commuters demanding more travel choices, which has led to the supply of the required transport infrastructure being continuously expanded (Javid *et al.,* 2016). Recently, the need to mitigate urban problems has led to growing concerns about how planning practitioners can develop transport systems in a more sustainable direction (Holden *et al.*, 2017; Tennøy *et al.*, 2016).

2.6.3 Consumption in land-use patterns

Adisa (2020:335) stated, "Land-use patterns are defined as the utilisation of the accessible lands in a city as dictated by urban and regional planning and the city's social, economic, political, and geographical conditions". According to Rodrigue (2020), urban land-use reveals the site and spatial accumulation of the various residence, manufacturing and retailing activities. The supply of adequate infrastructure capacity requires proper land-use and metropolitan transportation planning (Guzma, Escobar, Peña & Cardona, 2020; Litman, 2017).

Sangaradasse and Eswari (2019) maintained that traffic depends on the location and size of the development, and they added that this influences the neighbourhood's accessibility to the local and arterial transport network. The well-being of the transport environment requires complete protection from increasing issues such as unreasonable land-use design where transportation sustainability is conducted (Khare, Villuri & Chaurasia, 2021). Sangaradasse and Eswari (2019) indicated that effective and efficient city land-use patterns rely of a thorough investigation of traffic and transportation plans for operative land use.

2.6.4 High infrastructure maintenance cost

The old transport infrastructures still found within some towns lead to high maintenance costs and the burden of renovating the infrastructure so that it becomes more sophisticated (Rodrigue, 2020). The functionality of each infrastructure depends on its structural and durability performance (Argyroudis, Mitoulis, Winter & Kaynia, 2019. Unfortunately, if resources are scarce, the maintenance of the infrastructure may come at a significant cost (Baji, Li, Scicluna & Dauth, 2017; Humphreys, Van der Kerk & Fonseca, 2018).

Urban roads deteriorate when exposed to an increased amount of heavy truck traffic (Agyapong & Ojo, 2018). As stated by Patterson and Maloney (2016:354), "Local roads will likely experience the greatest damage from unconventional oil and gas development due to their proximity to wells and their design for relatively light loads and traffic". The declining condition of the substructures in the urban areas is apparent, and the solution may be to replace the deteriorated infrastructure, which is highly costly (Abramzon *et al.*, 2014; Baji *et al.*, 2017). Larger roads should perform better, although the addition of thousands of extra truck trips will increase their rate of deterioration (Hall & Lutsey, 2019; Patterson & Maloney, 2016).

2.6.5 Energy consumption and environmental problems

Energy consumption and the dependency on fuel, largely through urban transportation, have increased dramatically. Private vehicle ownership, transport composition, fuel intensity, and transport infrastructure construction are considered essential factors of transport energy consumption (Lin & Du 2015; Zhao, Diao & Li, 2017; Rodrigue, 2020).

Some studies (Khan, Hou & Le, 2021; De Souza *et al.*, 2018; Song, Zheng & Wang, 2015) have stated that the occupation of land resources, energy consumption, and air and noise pollution are the main influences of the highway transportation system in terms of resources, energy, and the environment. However, Li, Fang and He (2018) showed that urbanisation negatively impacts transport energy consumption, specifically where the rapid development of industrialisation is characterised by many high energy-consuming industries.

Studies by Mohsin *et al.* (2019) and Wu, Zhao and Zhang (2016) indicated that transport energy consumption might positively affect a city's economic development due to the resulting economic factors such as GDP per capita. Lin and Du (2015) found that energy consumption within the road transport sector in Tunisia from 1990 to 2006 took the form of vehicle fuel intensity, vehicle intensity, GDP per capita, urbanised kilometres, and the national road network. This result may be because some of the country's economic development has reached a particular stage, rural car ownership has reached a high standard, and the rural population density is much lower than that of urban areas (Li, Miao, Chen & Hu, 2019).

2.6.6 Accidents and road safety

Accidents cause severe problems for society in terms of human costs, economic costs, property damage costs and medical costs (Theofilatos & Yannis, 2014). Increases in traffic and speed in urban areas have been associated with more accidents and fatalities (Rodrigue, 2017; Theofilatos & Yannis, 2014). However, Jung, Qin and Noyce (2010) argued that improvements to roadways and roadside design, the appropriate use of safety devices and changes in driver behaviour, may minimise crash consequences.

According to the WHO (2018), road traffic injuries are the ninth leading cause of death worldwide, and the leading cause among people aged 15-29 years, where almost 60% of road traffic deaths occur among people aged 15-44 years. More than 1.25 million people worldwide died because of road traffic injuries, where 20%-50% people involved in accidents sustained non-fatal injuries from the road traffic collisions or crashes (World Health Organisation, 2018; Touahmia, 2018).

The USA has the highest rate of fatality and severe injuries within developed countries. Furthermore, cyclists are twelve times more likely to be killed than drivers of motor vehicles (Buehler & Pucher, 2017). The WHO (2018) stated that more than 90% of the world's fatalities on the roads occur in low- and middle-income countries, even though these countries have approximately only 54% of the world's vehicles.

2.6.7 Difficulties for non-motorised transport

Non-motorised travel is seen as an affordable, convenient, inexpensive, efficient, and healthy way of travelling short distances compared to vehicles (Moyo, Kibangou & Musakwa, 2021). The fact that non-motorised transport (NMT) infrastructures are not properly recognised in government and social divisions can generate problems in the provision of acceptable public transport services that meet the needs of all users (Mabe & Chauke, 2019; Cele, 2018). Consequently, infrastructure often does not meet the needs of NMT users who are forced to use facilities that are not designed for the service and forced to operate under suboptimal conditions (Behrens, 2019). A detailed discussion of NMT follows in Chapter 3.

2.6.8 Car parking facilities

Parking has expanded in urban planning due to vehicle ownership that keeps growing, even though there is inadequate space within urban areas (Hoehne, Chester, Fraser & King, 2019; Mingardo, Wee & Rye, 2015; Sousa, Almeida, Coutinho-Rodrigues & Natividade-Jesus, 2018). The lack of appropriate car parking facilities in urban areas results in cars parking in playgrounds, lawns, sidewalks, recreation areas and domestic driveways, creating traffic congestion that might even destroy emergency services vehicles (Duvanova *et al.*, 2016; Duvanova, Bubnova & Romanovich, 2016).

According to Szumila and Pach (2017), the main instrument to regulate parking problems, both in the city and outside, is the implementation of a parking policy. According to Lam and Yang (2019), parking policies require a review, and currently technology is being developed to alleviate space shortages, and reduce the type of congestion arising from cars driving around looking for parking spaces. For example, in Melbourne, Australia, parking policy and use are encouraged to consider parking at urban levels instead of focusing only on specific parts of the central city (Young & Miles, 2019).

2.6.9 Road traffic congestion

In modern society, traffic congestion in urban networks is a long-standing and even intensifying obstruction. Congestion in the urban transport network has increased and become a severe problem in almost all major cities worldwide due to the rapid development of vehicular movement and urbanisation (Li, Yue, Mao & Xu, 2020; Koźlak & Wach, 2018). The dynamic development of urban areas poses challenges in the provision of more transport services for the increasing population. The concentration of economic potential and people in metropolitan areas result in significant transport needs (Koźlak & Wach, 2018). The extensive delays and accompanying costs have a considerable effect on the urban transportation system, especially in densely populated areas (Afrin & Yodo, 2020).

Li *et al.* (2020) indicated that numerous traffic control strategies had been initiated to alleviate congestion, and improve the performance of urban traffic control systems. Afrin and Yodo (2019) argued that although various recovery strategies have been developed to improve network performance, most of these strategies are insufficient or might not be applicable for congested road traffic conditions.

Adaptive traffic control systems (ATCS) have been extensively applied in many cities around the world to reduce vehicle delays and mitigate road congestion (Li *et al.*, 2020). The cooperative intelligent transport system (C-ITS) is a crucial enabler of future road traffic management systems (Rego, Garcia, Sendra & Lloreta, 2018). Real-time traffic control systems are needed to monitor traffic conditions on roads and implement intelligent management schemes, such as adaptive traffic light control and driving policy recommendations (Afrin & Yodo, 2020).

The above challenge is the main topic of the current study and will be addressed in detail in the next chapter. Table 2.6 summarises the obstacles within the urban transport system.

Table 2.5: Summary of challenges within the urban transport system

CHALLENGES	DESCRIPTION	SOURCES
Distribution of goods/freight	▪ Higher levels of transport activity related to cargo distribution and service provision. ▪ Policies and regulations prioritise the safeguarding of passenger transport, while constraining freight. ▪ Urban economies rely on effective freight transportation that contributes to the expansion of urban economies. ▪ Freight transport flows have constantly increased population numbers, consumption, and production, and have led to the customising of products and services.	Oliveira *et al.*, 2017; Hu *et al.*, 2020; Paddeu & Parkhurst, 2020; Pani *et al.*, 2018; Thompson, 2015
Insufficient public transport usage	▪ Lack of integration between public transport modes generates the greatest hindrance in the operative public transport system. ▪ Overcrowding and aggravated passengers within public transportation has reduced the expectations of privacy for commuters ▪ PT cannot compete with private vehicles as the service level often does not match commuters' expectations. ▪ Private vehicles users are more sensitive to overcrowding.	Cele, 2018; Ababio-Donkor *et al.*, 2020; Yook & Heaslip, 2015; Suman & Bolia, 2019
Consumption in land-use patterns	▪ The supply of adequate infrastructure capacity requires proper land-use and transportation planning. ▪ Traffic depends on the location and size of the developments, and this influences the neighbourhood's accessibility to the local and arterial transport network. ▪ Effective and efficient city land-use patterns anticipate thorough investigation of traffic and transportation plans for operative land use.	Guzma *et al.*, 2020; Litman, 2017; Sangaradasse & Eswari, 2019
High maintenance cost	▪ The ancient transport infrastructures within the towns deal with high maintenance costs.	Rodrigue, 2020; Argyroudis *et al.*, 2019;

CHALLENGES	DESCRIPTION	SOURCES
	▪ The functionality of each infrastructure depends on its structural and durability performance. ▪ Urban roads deteriorate when exposed to an increased amount of heavy truck traffic moves across local roads. ▪ The solution is to replace the deteriorated infrastructure, which is highly costly.	Agyapong & Ojo, 2018; Abramzon *et al.*, 2014; Baji *et al.*, 2017
Energy consumption and environmental problems	▪ Energy consumption and pollution are the main influences of the highway transportation system on resources, energy, and the environment. ▪ Urbanisation negatively impacts transport energy consumption; ▪ High energy-consuming industries characterise the rapid development of industrialisation. ▪ Transport energy consumption may positively affect a city's economic development	Palacio, Rocha, Renó & Venturini, 2018; Song, Zheng & Wang, 2015; Li *et al.*, 2018; Mohsin *et al.*, 2019; Wu *et al*., 2016
Accidents and road safety:	▪ Accidents cause severe problems for society in terms of human costs, economic costs, property damage costs and medical costs. ▪ The roadway and roadside design improvements, appropriate use of safety devices, and changes in driver behaviour, crash consequences can be minimised.	Theofilatos & Yannis, 2014; Jung *et al.*, 2010; WHO, 2018
Difficulties for non-motorised transport (NMT)	▪ The fact that non-motorised transport infrastructures are not properly recognised in government and social divisions generates problems in providing acceptable public transport service. ▪ The available infrastructure often does not meet the needs of NMT users who are forced to use facilities that are not designed for the service and forced to operate under the suboptimal condition.	Mabe & Chauke, 2019; Cele, 2018; Behrens, 2019
Car parking facilities	▪ Parking has expanded in urban planning due to vehicle ownership that keeps growing.	Hoehne *et al*., 2019; Mingardo *et al*., 2015;

CHALLENGES	DESCRIPTION	SOURCES
	▪ The main instrument to regulate parking problems both in the city and outside is the implementation of a parking policy. ▪ Parking policies require a review, and currently technology is being developed to alleviate space shortages and reduce the type of congestion arising from cars driving around looking for parking spaces.	Sousa *et al.,* 2018; Duvanova & Simankina
Road traffic congestion	▪ Numerous traffic control strategies had been initiated to alleviate congestion. ▪ Most strategies are insufficient or might not be applicable for congested road traffic conditions. ▪ Cooperative intelligent transport system (C-ITS) is a crucial enabler of future road traffic management systems; ▪ Real-time traffic control systems aim to monitor traffic conditions on roads and implement intelligent management schemes.	Li *et al*., 2020; Afrin & Yodo, 2019; Rego *et al*., 2018

Source: Researcher's compilation

Table 2.5 presented a summary of the challenges within the urban transport system. The section below concludes the chapter by providing a brief discussion of the narrative description included in the chapter.

2.7 CONCLUSION

This chapter reviewed the relevant literature on urban transport planning, urban transport management, and the transport/land-use system. The chapter firstly provided definitions of the relevant terminology and then proceeded with a discussion of the relationship between urbanisation and urban transportation, theories and models supporting urban transport planning, the global trends and developments in urban transport, and the challenges within the urban transport systems. The next chapter discusses traffic congestion in the South African context, where the types, causes, peak periods of congestion, problems, policies and strategies for managing road traffic congestion are addressed.

CHAPTER 3:
ROAD TRAFFIC CONGESTION IN SOUTH AFRICA

3.1 INTRODUCTION

This chapter begins with an overview of the literature on urban transport in South Africa. The section continues with a historical overview of urban transport and classifications of urban transport systems available in the country. This is followed by a review of the literature on road traffic congestion. Congestion causes global concerns, such as increased travelling times and fuel consumption, and environmental deterioration. The literature discussion progresses with the management of road traffic congestion, and the categories of road traffic congestion, followed by a discussion of the key aspects such as peak period, contributory problems, supporting policies and regulations impacting road traffic congestion and strategies for managing traffic congestion. The chapter concludes with a summary of the instruments for managing road traffic congestion and a conceptual framework for managing road traffic congestion.

The structural flow of Chapter 3 is presented in Figure 3.1.

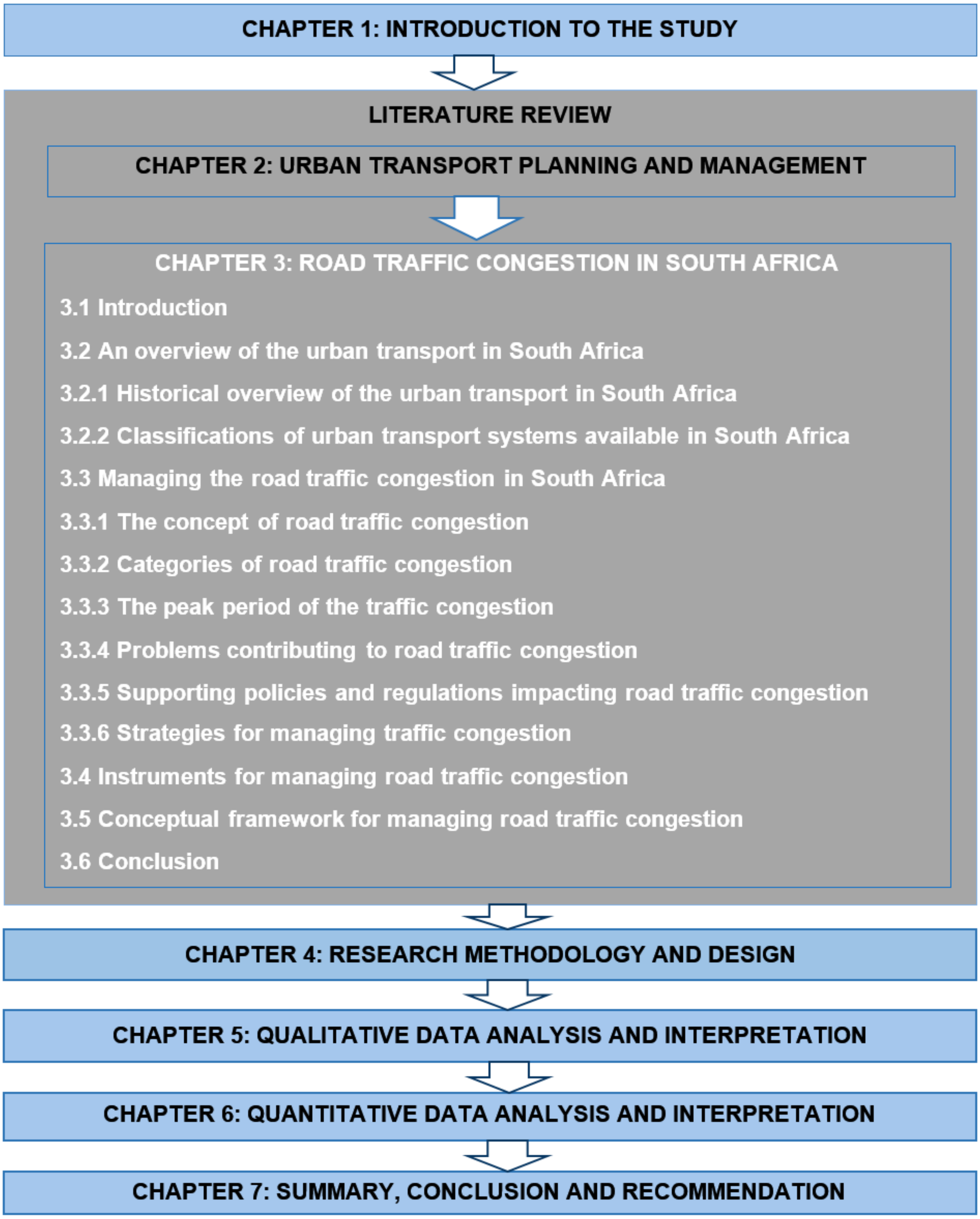


Figure 3.1: Structural flow of Chapter 3 in alignment with the study

Source: Researcher's compilation

3.2 OVERVIEW OF URBAN TRANSPORT IN SOUTH AFRICA

As the central areas of economic activities, cities require well-organised and accessible transportation for people and commodities. Appropriate transport systems are required in urbanised regions to make a great density of various activities, such as residential areas, commercial offices and industrial units physically accessible, while keeping the cities functional and appealing to people (Chao, Vuchic & Vashchukov, 2019). This section starts by presenting a historical overview of urban transport, followed by the classifications of the urban transportation systems in South Africa.

3.2.1 Historical overview of urban transport in South Africa

At the end of the apartheid era in South Africa, the new democratically elected government had to deal with various historical problems (Sewell, Desai, Mutsaa & Lottering, 2019). The cities had suffered from successive bouts of political instability, and the urban transport of the 19th century was in a poor condition. These were evident from the lack of opportunities and lack of proposal acceptance from financial institutions (Olver, 2021). The subsections below present a historical overview of urban transport during the apartheid period and in the post-1994 era.

3.2.1.1 Urban transport during the apartheid period

From 1905 through to 1945, the transport system in the country created a racially segregated urban population that was characterised by the control and reproduction of the African working class (Steenkamp, 2018; Rink, 2016). The system led to the general struggle about, discrepancies in, and disagreements over the authority, management and affordability of racially separated places (Campbell & Prasse-Freeman, 2021; Cox, 2018; Khan, 2014). The segregation ruled over millions of people who were denied access to the places where they performed their daily activities, including the workplaces. Most black people were denied social well-being opportunities, including a proper transport system, and their movements were controlled from the area of their employment and livelihood (Bell, 2018; Mbatha & Gumbo, 2019).

The country's urban transportation was limited to only buses, trams and rail travel in the cities, particularly, in Cape Town and Witwatersrand (Mitchell, 2014; Parker, 2018; Sandwith, 2018). Public transport was developed to implement, continue and strengthen the separation of racial groups (McKay, 2020; Rokem & Vaughan, 2018; Vadi, 2015). Furthermore, the system resettled black South Africans in the distant surrounding areas and prohibited them from gaining access to economic opportunities in the cities. Scoriae and Munoz-Raskin (2018) confirmed that due to apartheid, Johannesburg's urban form is characterised by inadequate average density in the spatial patterns, where the underprivileged are located far away from opportunities.

Lai, Webster, Kumari and Sarkar (2020:28) asserted that "density defines the intrinsic capacity of a city to implement preventive physical segregation policies in public transport, public spaces, and shared services and facilities". Litman (2021) and Walters (2014) highlighted that although the travellers were situated some distance away from the employment, recreation and shopping facilities, low-priced funded commuter bus services were accessible to relieve the financial travel burden. Associated with the integration of various opportunities in urban areas, Lister and Dhunpath (2016), Venter *et al.* (2020), and Ndwandwe and Gumbo (2018) all asserted that public transport in the period of apartheid was at affordable prices within the urban areas to encourage mobility.

3.2.1.2 Post-1994

After the historic political change in 1994, the new South African government made extensive efforts to alleviate the discrimination and inequalities stemming from a dispensation where spatial arrangements were predominantly based on racial exclusion (Van Niekerk, Viviers & Cilliers, 2017; Black, Spreen & Vally, 2020; Todes & Turok, 2018; Tivaringe & Kirshner, 2021). An overabundance of new legislation was endorsed by the new democratic parliament to eliminate the effect of the apartheid laws and to create new freedom for South Africans (Friedman, 2019; Nel, 2016).

McKay (2020) argued that urban transport mobility in South Africa had been a general problem since the apartheid period. The South African Cities Report (2016) added that the legacy of apartheid's spatial engineering and planning endured after more than 20 years of democratic system. However, Chakwizira, Bikam and Adeboyejo (2019) stated that since the dawn of 1994, which is over 25 years ago, the shifts in transport, spatial planning and development have made significant but arguably "microscopic gains" in seeking to reverse and advance new spatial scales and forms of transformative growth.

At the present moment it is more difficult to change apartheid geographies in the cities than it would have been in 1994. Therefore, the ideals of equity, prosperity and sustainability captured in the country's various urban development policies have yet to be realised for most South Africans (Bosworth, 2016; Moodley, 2019; Pieterse, Parnell & Haysom, 2018). South African towns and diverse role-players have come to terms with the increasing challenges related to using the transport systems to defeat the difficulties of the apartheid spatial legacy, and thereby being able to relink secluded intersections and societies previously disengaged from opportunities (Mbatha & Gumbo, 2019; Parker, 2018). The section below discusses the classification of urban transportation systems in South Africa.

3.2.2 Classification of urban transport systems available in South Africa

The government of South Africa spends millions of Rands on local transport infrastructure to ensure that road users are able to commute smoothly. Although so much money is spent, the infrastructure in South Africa is still lacking. Regardless of the available modes of transportation, South African transport is still plagued by several challenges. The following subsections discuss the categories of urban transportation systems available in South Africa, including the bus systems, minibus systems and rail systems.

3.2.2.1 Urban bus systems in South Africa

Bus services in South Africa experience many problems, including concerns about reliability and safety. It is important for public transport to make progress to reduce the growing dependence on private cars, with its accompanying negative impact on the environment (Sam, Hamidu & Daniels, 2018). According to Heyns and Luke (2017:3565), "The after effect is that service superiority in municipal or communal transport involves substantial upgrade if rules and guidelines intended to accomplish modal shifts from cars to public transport are [to be] effective".

In numerous countries, buses are vital elements in the transition to sustainable transport, and they provide service to all citizens, including communities, organisations employees and students (Bakker & Konings, 2018; Petersen, Rodrigues & Pereira, 2019). The section below discusses the urban bus systems in South Africa.

Municipal or commuter bus services:

This essential service is regarded as the factor that has the most effect on commuters' behaviour. The service quality of metropolitan buses is the ultimate struggle within the sector (Longo, Zappatore & Navathe, 2019; Majumdar *et al.,* 2020; Poku-Boansi & Marsden, 2018). Friman, Lättman and Olsson (2020) suggested that suppliers of bus services should be aware of the crucial dimensions (for example, comfort, reliability, service, safety and affordability) of service quality to be able to operate efficiently.

South Africans are concerned about the condition of communal transport amenities, and regard it as almost as important as education and health (Heyns & Luke, 2017). Majam and Uwizeyimana (2018:138) formulated their concerns as follows: "Concerning local government specifically, economic development is a key priority within the Integrated Development Plan of a municipality to improve the quality of life of communities in the country".

According to Risimati (2021), the majority of bus users in Gauteng have issues relating to the bus services, including the lack of availability of bus services. Commuters tend to prefer taxis or private vehicles, as the buses may not travel to their destinations, bus stops may be far away from their homes, or they lack information about the routes and schedules. Matthews and Takalani (2019) indicated that buses that do not keep to the timetable have a negative effect on commuters, who do not reach their destination on time if the bus is late. This results in commuters often being late for work, which strains the relationship with their employers, as they appear to lack dedication and appear unreliable. Another problem is that some routes are not covered, which forces commuters to complete the journey or reach their destination with another mode of transport (Mtizi, 2017).

The city's growing car ownership and congestion levels indicate the high gaps between the perceptions and expectations of bus services, particularly for the essentially captive users (Heyns & Luke, 2017). Walters and Manamela (2016:1) asserted that "Small-bus operators (SBOs) in South Africa operate on the periphery of the economic mainstream of scheduled subsidised commuter transport, and little progress has been made in getting these operators into the more formal subsidised industry".

Bus Rapid Transport (BRT) System:

The BRT plays a role in South African mobility, and contributes to economic development, job creation and tourism. According to Scorcia and Munoz-Raskin (2019), the successful BRT systems in Latin American cities inspired South African cities, such as Johannesburg and Cape Town, to implement a BRT network. Beier (2020) highlighted that BRT projects are executed to categorise cities as sustainable or 'world class' and enhance the authority of urban citizens, employees, and bus riders.

Compared to other services, the BRTs are considerably more functional, and offer enhanced levels of convenience and speed, and offer reasonable connectivity and consistency in terms of various facilities (Abdel Wahed Ahmed & Abd El Monem, 2020; Merkert, Mulley & Hakim, 2017; Venter *et al.*, 2018). The system presents upgraded travel time, consistency, safety and security, and speed in contrast to other public transport systems and vehicles travelling on the mixed-flow traffic lanes (Das & Ahmed, 2021; Adewumi & Allopi, 2014).

However, Mabena (2017) argued that the BRT system has been a massive failure in some areas, where commuters prefer to use mini-bus taxis and conventional buses. Venter *et al.* (2019) and Nguyen *et al.* (2019) showed that the BRT system faces comparable obstructions to other urban mobility developments demanding political, financial, public support and institutional capacity. Whatever the failures may be, the South African government's objective was to move large numbers of people from townships and suburbs to all parts of a town or city in a quick and safe manner. The next subsection discusses the minibus taxi system in South Africa.

3.2.2.2 Mini-bus taxi (MBT) system in South Africa

According to Schalekamp and Klopp (2018), the mini-bus taxi (MBT) industry plays a central role in the public transport networks in South African cities. While the South African government and policymakers are attempting to develop the transportation system, it is perceived that the taxi industry has grabbed the passengers' attention (Adebayo, 2019; Lister & Dhunpath, 2016; Ngubane, Mkhize & Olofinbiyi, 2020).

Rink (2018) asserted that mini-bus taxis are a common and omnipresent form of urban transportation. Mini-bus taxis are characterised by the flexibility and convenient journeys that provide access to other forms of public transportation. Mehran *et al.*

(2020) and Mtizi (2017) indicated that taxis are assumed to be flexible and are able to adopt any route available for flexible door-to-door services due to network agility.

Although mini-bus taxis are regarded as the foremost preferred, familiar and accessible mode of transport, they are more expensive than buses and trains, as they do not receive any government subsidies (Kgwedi & Krygsman, 2017; McKay, 2020; Kumar, Zimmerman & Arroyo, 2021).

The mini-bus taxis industry is expanding and significantly progressing in the country's economy, even though there are allegations of conflict, violence, and murder being levelled at the industry (Geldenhuys, 2019; Martin, 2021; Matiwane, 2019; Ngubane *et al.,* 2020). According to Geldenhuys (2019), the industry has become notorious for its recurrent aggression and continuous hostilities, commonly called taxi wars or taxi violence.

Mensah and Ankomah (2018) and Monama (2014) stated that while mini-buses are used by the majority of passengers, the service provided is not satisfactory. Kerr (2018) and Ntoyanto (2021) indicated that some vehicles operate with illegal documentation. Mtizi (2017) concurred and added that numerous mini-bus taxis in urban areas operate without licenses, and the operators drive without legal permits.

However, the taxi industry should not carry all the blame for operating without the proper licenses and permits, since the operators purchase fraudulent documents from corrupt officials at the traffic departments (Dlamini, 2016; Fobosi, 2021; Ramaano, 2021). Since corruption and incompetence is rampant within the traffic enforcement and licensing agencies, the community increasingly disregards the law (Lamb, 2021; Nilsson, 2022; Stander & Brink, 2016). Meanwhile, most taxi operators are not legally registered according to the Labour Relations Act (LRA), and as taxpayers, as the industry manifests as part of the informal economy (Dube, 2018; Mabitsela, 2016; Meagher, 2018). The subsection below discusses the rail transportation system in South Africa.

3.2.2.3 Urban rail transport system in South Africa

With the growing requirements for urban mobility, together with the rapid growth of the urban resident population, metro rail systems have been established as a critical resolution to enhance the movement of people and to make the city areas more accessible. These metro rail system provide more capacity, advanced reliability, and enhanced efficiency (Yang, Jin, Wu & Jiang, 2017). South Africa's rail transport system is a significant primary division and is the most highly developed connecting network in the sub-Saharan region (Brand South Africa, 2017). The sections below discuss the urban rail transport systems available in Gauteng.

Urban rail systems (PRASA trains):

While public transport in urban and metropolitan areas may be recovering, the trips are still extended, time-consuming and expensive. However, the Metrorail system is deteriorating rapidly (Onderwater & Mbambisa, 2021). Overcrowding often occurs throughout the peak-hour periods, specifically for the metro lines operating in the corridor linking suburban and urban areas (Yang *et al.*, 2017, Alawad, An & Kaewunruen, 2020). This has raised concerns about the number of commuters gathered in the station and on the platforms, and that there may not be enough trains available to meet the travel demand. The poor train services in urban areas place immense pressure on commuters on a daily basis, specifically in terms of punctuality, over-crowding, distance to the station and security (Alawad *et al.,* 2020; Fisch, 2018; Luan, Cheng, Song & Zhao, 2020).

According to Brand South Africa (2017), more than 2.2 million commuters use trains in Cape Town, Durban, the Eastern Cape, Johannesburg and Pretoria. Maswanganyi (2017) maintained that the services are able to transport many commuters simultaneously to their destinations. Although punctual rail services are a core requirement for railway passengers in South Africa, the state of commuter rail service is characterised by poor conditions, and there are wellbeing and security concerns, In addition, there is poor consistency, uncompetitive journey time and an overall scarcity of integration with other modes of transport (Risimati, 2021; Monsuur, 2021).

In his address during the conference on rail safety solutions, Maluleke (2021) emphasised the priority of safety in the rail transport industry in South Africa. Ahmed, Srivastava, Tipnis and Matsumura (2020) indicated that a reliable and safe passenger rail system is a critical aspect of any society and the growth of its economy. Facchini and Dias (2019), Mtizi (2017) and Nxele (2021) all found that the endless schedule obstructions at Metrorail trains are due to a lack of structure. During a debate at the National Council of Provinces, Maswanganyi (2017) asserted that the state had organised the programme to modernise and recapitalise rail services in the country to ensure that all the services are reliable and safe.

Rapid Rail System (Gautrain):

Similar to an increasing number of African countries, South Africa has adopted the rapid rail system to improve urban public transport. According to Rakabe (2017) and Olayode *et al.* (2020), the Gautrain has played a significant role in combating urban challenges, and is equipped to tackle these problems more efficiently in the future. The system has not only changed the perception on public transport in Gauteng but, most prominently, has substantially changed the lives of public commuters (Brill & Conte, 2020). As stated by the Gautrain Management Agency (2019:3). "In 2006, the system has yielded visible benefits since the commencement of the development period and is anticipated to increase exponentially once more nodes across the province are connected to the network".

Although the Gautrain Management Agency (GMA) needs contributions and reviews on the recommended Gautrain expansion, according to Karner and Duckworth (2019), Thomas (2013) and Netshisaulu (2021), this rapid rail system caters more for well-off people in the region. The GMA claims that the Gautrain generates work possibilities, alleviates traffic congestion, enhances talents transfer, and provides chances for citizen to build up numerous kinds of businesses in the province; however, its prohibitive pricing structure has kept the majority of the South African working class out.

According to Gumbo and Moyo (2020), the system serves specific portions of the cities, whilst the other parts are served by different urban rail systems with routes that link commuters to various destinations. The implementation of the Gautrain services has benefited the properties around the stations that are now attractive investments and have experienced high levels of growth in values (Harrison, Rubin, Appelbaum & Dittgen, 2019; Boshoff, 2017).

King and Ssamula (2008) added that the Gautrain's achievements should be grounded on the feeder's advantage and further promote transport service incorporation. Pojani and Stead (2015) disputed that emerging towns could create such systems over a few kilometres in short supplied corridors because high cost makes it unsuitable for the extensive transport needs of the population.

Table 3.1 below summarises the different forms of urban transportation systems in SA.

Table 3.1: Summary of classifications of urban transportation systems in SA

URBAN TRANSPORTATION SYSTEMS IN SA	SUMMARY	SOURCES
URBAN BUS SERVICE SYSTEMS IN SA		
Municipal bus services	▪ The service quality of metropolitan buses is the ultimate struggle, and suppliers must be aware of these crucial dimensions. ▪ Most bus users in Gauteng had issues relating to bus services, including lack of availability. ▪ The growth of car ownership and high congestion levels have indicated the gaps between the perceptions and expectations related to bus services. ▪ Lack of punctuality negatively affects commuters, since they do not reach their destination on time.	Longo *et al.,* 2019; Majumdar *et al.*, 2020; Poku-Boansi & Marsden, 2018; Friman *et al.,* 2020; Heyns & Luke, 2017; Matthews & Takalani, 2019
BRT systems	▪ The success of BRT systems in other countries inspired SA to establish the implementation of the BRT network. ▪ BRTs are more effective, with improved accessibility, mobility, and speed, and provide affordable connectivity and reliable services. ▪ The system presents upgraded travel time, consistency, safety and security, and speed. ▪ The BRT system has been a massive failure in some areas where commuters avoid the system favouring mini-bus taxis and conventional buses. ▪ The BRT faces similar barriers to other urban mobility projects requiring political, economy and community support, institutional capacity, and funding.	Scorcia & Munoz-Raskin, 2019;Abdel Wahed Ahmed & Abd El Monem, 2020; Merkert *et al.,* 2017; Venter *et al.,* 2018; Venter *et al.,* 2019; Nguyen *et al.,* 2019
MINI-BUS TAXI SYSTEMS IN SA		
Mini-bus taxis	▪ Minibus taxis are a common and omnipresent form of urban transportation. ▪ The flexibility and convenience of journeys distinguish movements.	Adebayo, 2019; Lister & Dhunpath, 2016; Ngubane *et al.,* 2020;

URBAN TRANSPORTATION SYSTEMS IN SA	SUMMARY	SOURCES
	▪ It is more expensive than buses and trains, as the government does not directly subsidise them. ▪ Although taxis are the primary source of transport for most passengers, the service provided is not satisfactory. ▪ The industry has become notorious for the recurrent occurrences of taxi violence. ▪ They often operate with illegal documentation.	Rink, 2018; Kgwedi & Krygsman, 2017; McKay, 2020; Kumar *et al.,* 2021; Mensah & Ankomah, 2018; Monama, 2014; Kerr, 2018; Ntoyanto, 2021
URBAN RAIL TRANSPORT SYSTEMS IN SA		
PRASA	▪ Metrorail is deteriorating rapidly, and during peak-hour periods, oversaturated conditions are often observed. ▪ Services are generated to transport many commuters simultaneously. ▪ The commuter rail service is blighted by poor quality, safety concerns, reliability, and uncompetitive journey time. ▪ There is a need to prioritise safety in the rail transport industry in South Africa, since the reliability and safety of the passenger rail system is a critical aspect of any society.	Onderwater & Mbambisa, 2021; Yang *et al.*, 2017; Alawad *et al.,* 2020; Maswanganyi, 2017; Risimati, 2021; Monsuur, 2021;. Maluleke, 2021; Ahmed *et al.,* 2020
Gautrain	▪ The Gautrain has played a significant role in combating urban challenges. ▪ The rapid rail system caters to the more affluent individuals in the region. ▪ The service serves specific portions of the cities. ▪ Gautrain's achievement would be grounded on the feeder's advantage and further transport service integration.	Rakabe, 2017; Olayode *et al.,* 2020; Karner & Duckworth, 2019; Thomas, 2013; Netshisaulu, 2021; Gumbo & Moyo, 2020; King & Ssamula, 2008

Sources: Researcher's compilation)

The above table presented a summary of the classifications of the urban transportation systems in South Africa. Section 3.3 discusses the management of road traffic congestion in South Africa.

3.3 UNDERSTANDING ROAD TRAFFIC CONGESTION IN SOUTH AFRICA

Many cities have introduced various traffic congestion mitigation approaches as control measures to manage road congestion, rather than expanding the infrastructure capacity (Schmidt-Dumont & Van Vuuren, 2019; Nugmanova *et al*., 2019). In South Africa, various arrangements have been introduced, from the BRT system to rapid rail systems to tackle congestion and alleviate the density of private vehicles on the roads.

This section begins by presenting a discussion of different traffic congestion definitions, the categories of traffic congestion, the peak period of road traffic congestion, problems contributing to road traffic congestion, policies and regulations impacting and mitigating road traffic congestion, and strategies for managing traffic congestion.

3.3.1 Concept of road traffic congestion

Even though the South African government has spent a fortune on traffic infrastructures, the traffic congestion problem is regarded as the primary disadvantage in the country's economy (Olayode, Tartibu, Okwu & Uchechi, 2020). Although different interpretations have been applied to explain the concept of traffic congestion, there is still no particular definition of traffic congestion.

According to Koźlak and Wach (2018), congestion is related to the level of movement of vehicle traffic that goes beyond the capacity of a given road, causing a decline in the free flow of vehicles. Singh *et al.* (2020) described traffic congestion as a situation in which the number of cars trying to utilise a roadway at any time goes beyond the road capacity to carry the load at commonly adequate service levels. Furthermore, road traffic congestion is the overloaded amount of motorcars on the road network, producing abnormal reductions in the quality of service characterised by differences in travel times (Olayode *et al.*, 2020; Lessan & Fu, 2019).

Various scholars (Sangaradasse & Eswari, 2019; Ferguson, 2018; Wen, Kenworthy, Guo & Marinova, 2019) have described congestion as a circumstance in which the transport system is unable to accommodate individuals wishing to travel simultaneously using their private vehicles at a specific time of the day. Congestion is described as the limited movement of vehicles on the road because of the speed-flow relationship, in which a specific motorway network has reached its capacity (Samaras *et al.,* 2019; Sugiyanto, 2018; Raheem, Olawoore, Olagunju & Adeokun, 2015). The term traffic congestion describes the situation on the road network in which the capacity is exceeded as a result of an increase in the use of transport networks as indicated by travel time interruptions and long queues (Das & Keetse, 2015; Olusina & Samson, 2014).

From the above definitions, researchers have extracted the arguments that congestion includes networks, the extreme usage of road spaces beyond their capacity, reduced speeds, longer journey hours and vehicle line-ups. Congestion can be seen on roads occupied by cars, trucks, heavy vehicles and buses. Table 3.2 below summarises the definitions of road traffic congestion, as obtained from various sources.

Table 3.2: Road traffic congestion definition by different sources

DEFINITIONS	SOURCES
Congestion is related to the level of movement of vehicle traffic that goes beyond the capacity of a given road, causing a decline in the free flow of vehicles.	Koźlak & Wach, 2018
The situation in which the number of cars trying to utilise a roadway at any time goes beyond the carrying capacity of the road at commonly adequate service levels.	Singh *et al.,* 2020
This is the overloaded amount of motorcars on the road network, producing abnormal reductions in the quality of service characterised by differences in travel times.	Olayode *et al.,* 2020; Lessan & Fu, 2019
The circumstance in which the transport system is unable to accommodate individuals wishing to travel simultaneously using their private vehicles at a specific time of the day.	Sangaradasse & Eswari, (2019); Ferguson, 2018; Wen *et al.*, 2019
Limited movement of vehicles on the road because of the speed-flow relationship, in which a specific motorway network reaches its capacity.	Samaras *et al.*, 2019; Sugiyanto, 2018; Raheem *et al.*, 2015
The circumstances on the road network in which the capacity is exceeded as a result of increases in the use of transport networks as indicated by travel time interruptions and long queues.	Das & Keetse, 2015; Olusina & Samson, 2014

Sources: Researcher's compilation

The table above summarises the definitions of road traffic congestion that have been formulated by various authors. In this situation, the number of vehicles trying to use the road exceeds the capacity of the traffic network to handle them. The next section discusses the categories of road traffic congestion.

3.3.2 Categories of road traffic congestion

The supply side of the country's urban transportation is suffering from severe constraints, as the demand for urban travel has increased explosively.

The conflict between the rapidly rising traffic demand and inadequate road volume within the urban motorway systems has developed gradually in modern times because of the expansion of the social economy (Ma, Zhou, Xu & Xu, 2020). As a result, the traffic in urban systems can be classified into recurring and nonrecurring congestion, as discussed below (Afrin & Yodo, 2020; Ma *et al.*, 2020).

Recurrent congestion (RC): This category of congestion is regularly caused by periodic stream of traffic, and often transpires on a permanent road during the morning and afternoon rush period. It is typically caused by inadequate traffic capacity, poor signal control and insufficient traffic infrastructure (Keler, Krisp & Ding, 2018; Ma *et al.*, 2020; Munuhwa *et al.*, 2020). Ahsani, Amin-Naseri, Knickerbocker and Sharma (2019) indicated that recurrent congestion is triggered by routine traffic in a typically expected situation, while in contrast, nonrecurring congestion is unanticipated and is probably instigated by an incident. Similarly, Afrin and Yodo (2020) argued that recurring congestion frequently occurs regardless of the number of vehicles on the roads at any point in time.

According to Bako and Agunloye (2017), these occurrences may be related to increasing population, urbanisation, and the growth in private vehicle use. The issues that play a part in congestion include synchronised work and school schedules, the population growth in urban areas, and inadequate transport systems, which are exacerbated by the fact that many companies are relocating from the mid-city areas to outlying areas (Diaz, 2017). However, the regular commuters using a particular route, place and period might know the recurrent congestion that occurs in that specific area. In support of all the above arguments, Djavadian, Tu, Farooq and Hatzopoulou (2020) maintained that road networks face recurrent congestion during peak periods because of high vehicle ownership, and the under- and over-utilisation of other roads.

Non-recurrent congestion (NRC): Agyapong and Ojo (2018), indicated that non-recurrent congestion is caused by unintentional and unforeseen occurrences. The occurrences are irregular, since they are generated from varying circumstances such as newly appearing building sites, road closures and accidents (Keler *et al.*, 2018).

Even though there are several causes of traffic congestion such as insufficient infrastructure, ineffective management of capacity (for example, poor traffic timing), emergencies and unconstrained demands (Mandhare, Kharat & Patil, 2018), random occurrences, for instance, the change of climate, employment zones, occasions, and distinctive events are reasons for nonrecurring congestion (Afrin & Yodo, 2020). Non-recurrent congestion occurs during random events on the road network.

Since traffic typically emerges on the linear road segment and lanes, these events may be linear (Dogru & Subasi, 2018; Tang *et al*., 2016). The road capacity is temporarily reduced by traffic incidents that obstruct the traffic flow, such as road construction, natural disasters, extreme weather conditions, vehicle breakdowns, weather, and work zones (Sheykhfard & Haghighi, 2020; Sun, Dubey & White, 2017). According to Ahsani *et al.* (2019), non-recurring congestion may occur due to lane blocking accidents or immobilised or stationary vehicles, work zone lane closures, adverse events, and weather conditions.

Table 3.3 below summarises the categories and causes of traffic congestion, as defined by various scholars.

Table 3.3: Categories and causes of traffic congestion

CATEGORY	CAUSES	SOURCES
Recurrent congestion	▪ Inadequate traffic capacity, poor signal control and insufficient traffic infrastructure. ▪ Occurrences may be related to increasing population, urbanisation, and growth in private vehicle use. ▪ Road networks face recurrent congestion during peak periods because of high vehicle ownership, and the underutilisation and over-utilisation of other roads.	Keler *et al.*, 2018; Ma *et al.,* 2020; Munuhwa *et al.,* 2020; Bako & Agunloye, 2017; Djavadian *et al.*, 2020
Non-recurrent congestion	▪ Issues related to traffic congestion similar to ineffectual capacity management, poor traffic timing, tragedies, unconstrained demand, and unpredictable events. ▪ Irregular occurrences such as weather, work zones, incidents, and special events.	Mandhare *et al.*, 2018; Afrin & Yodo, 2020

Sources: Compiled by the researcher

The table above presented a summary of the categories of traffic congestion, and the causes are pointed out as discussed in the paragraphs. The next section presents a discussion of the peak periods of traffic congestion.

3.3.3 Peak periods of road traffic congestion

The level of road that is congested is certainly greater than the average values throughout the morning and afternoon peak periods (Zhao & Hu, 2019). Peak or rush hour is defined as the morning and evening periods during which road traffic congestion is at its highest, and the average speed consistently falls below 60 kilometres per hour during that period (Mkulisi & Sinclair, 2021; Guo *et al.*, 2018; Ma, Ji, Yang, Jin & Tan, 2018; Sun, Li & Zuo, 2019).

Peak hour traffic congestion has become the foremost challenge in most cities worldwide, as people travel frequently for work-related matters, especially during rush hours (Chatterjee *et al.*, 2020). Although various cities have focused on simplifying the movement of motor vehicles, the development of metropolitan highways has generated excessive levels of private car utilisation, and the consequent congestion (Hickman *et al.*, 2018).

Venter and Schnackenberg (2001) revealed that Midrand is a fast-growing urban area with high levels of traffic congestion and a poorly developed public transport system.

Mnisi (2021) indicated that during peak hours, the area experiences congestion and various intersections function at an undesirable level of service. The R55 comprises a single lane road that experiences a high volume of traffic congestion and accidents due to the growing number of developments along the route (Dube, 2018). The condition is worsened as more traffic interactions lead to more safety problems (Famili *et al.*, 2018). Furthermore, the Olifantsfontein and New Road interchanges experience massive traffic queuing during peak hours, which leads to increasing traffic jams (Life Traffic Reports, 2020).

Additional traffic problems kept re-occurring, and there is a high level of congestion from seven main road junctions joining Allandale Road (Olayode *et al.*, 2021). According to the Vorna Valley traffic impact study (De Mesquita, 2016), these roads and street intersections include Le Roux Avenue and Pretorius Road that have an impact on the road networks in close proximity, especially during peak periods. A recent Johannesburg Road Agency (JRA) traffic impact study was conducted to investigate the feasibility of upgrading Le Roux Avenue from Old Pretoria Main Road to a dual carriageway road, together with the associated intersections, such as those at Lone Creek, Waterfall drive, Harry Galaun Drive and Bridal Veil Road along the stretch of Allandale Road (De Mesquita, Twilley & Associates, 2016).

However, despite the various upgrades to the roads, the residents of Midrand have expressed concern over many accidents on numerous roads, including the R55 Sandton Road along Midrand (Van Wyk & Ditlopo, 2020). In Chloorkop, there has been high traffic pressure and accidents at the T-Junction of Allandale and Zuurfontein Road, facing traffic travelling towards Kyalami (Arrive Alive, 2021). According to Olayode *et al.* (2021), drivers are experiencing an excess demand for the road during peak hours as some users have shifted from the old routes to the new extended way, creating high congestion on Allandale Road (M39).

According to Arrive Alive (2020), Dane Road in Glen Austin AH Midrand is frequently reported as a highly congested collision area, where private vehicle drivers lose control resulting in rollovers. In addition to these, there is a high necessity for a well-organised transport systems that contains solutions to mitigate transport problems in that zone (Feikie *et al.*, 2018).

It is imperative to acknowledge that travelling depends not only on the commuting conditions, resources and employment-related qualities but also on household tasks and responsibilities (Jiron & Carrasco, 2019). According to Beck and Hensher (2020), due to probable excessive household activities and commitments, commuters require different transportation necessities and levels of accessibility. Although many people undertake mono-functional journeys, most people combine multiple activities in a single trip (Jiron & Carrasco, 2019).

In Nigeria, the traffic intensifies from 7:00 to 10:00 in the morning, and then again from 12:00 to 15:00, and from 17:00 until 20:00 (Varghese *et al.*, 2021; Chakrabartty & Gupta, 2015). Countries similar to the USA experience traffic during the peak travel times of 6:00 to 9:00 in the mornings and 15:00 to 18:00 in the evenings. However, in Los Angeles, the weekday morning peak hours last from 7:00 to 10:00, and the evening peak lasts from 14:00 to 20:00 (Anderson, 2014; Ouni & Belloumi, 2018). China's sunrise peak interval primarily occurs from 7:00 to 9:00 and the evening peak commences at 17:00 and drops around 19:00 (Wen, Sun & Zhang, 2019; Caponecchia & Williamson, 2018).

According to Onderwater (2019), the actual peak periods that have been established in Cape Town range approximately from 06:00 to 09:00 in the mornings, and 16:00 to 19:00 in the afternoons, which is half an hour later than in Durban. The city initiated efforts to impress the residents by reducing traffic congestion; this included strategies to encourage telecommuting, which will remove a significant number of commuters from the roads during the busiest periods of the day (Phakathi, 2017).

Gauteng is confronted daily with traffic congestion during certain peak hours. Although the government has developed pioneering public transport systems in the region to enhance the frequency of urban transport, there is still a lack of reliability and seamless travelling (Mbatha & Gumbo, 2020). Chikwizira *et al.* (2018) confirmed that in Gauteng, commuters leave home and embark on trips between 05:31 and 06:00 in the morning, and spend an hour fighting traffic. Mikros Traffic Monitoring Report (2016) indicated that Midrand’s peak traffic period spans from 6:00 to 9:00 and from 16:00 to 18:00 daily.

Table 3.4 below summarises the road, street intersections and peak periods of traffic congestion.

Table 3.4: Summary of the road, street intersections and peak periods of traffic congestion

ROADS, STREETS AND PEAK PERIOD	DESCRIPTION	SOURCES
Levels of traffic congestion		
Allandale Road (M39)	Drivers are experiencing an excess demand for the road during peak hours, as some users have shifted from the old routes to the new extended way, creating high congestion on Allandale Road (M39).	Olayode *et al.,* 2021; Ditlopo, 2022.
Street intersections along Allandale Road	Congestion problems kept re-occurring with a high level of traffic from seven main road junctions joining Allandale Road. The roads and street intersections, such as Pretorius Road, Lone Creek, Waterfall Drive, Harry Galaun Drive and Bridal Veil Road along the stretch of Allandale Road. Dane Road in Glen Austin AH Midrand is frequently reported as a highly congested collision scene area where private vehicle drivers lose control.	Olayode *et al.,* 2021; De Mesquita, 2016; De Mesquita, Twilley & Associates 2016; Arrive Alive 2020.
Roads also congested		
As compared to Allandale	The R55 comprises a single lane road which experiences a high volume of traffic congestion and accidents. Le Roux Avenue also experiences congestion between Old Pretoria Main Road across throughfare road. There is massive queuing traffic at the Olifantsfontein and New Road interchanges during peak hours, resulting in increased traffic jams. In Chloorkop, there is high pressure traffic and accidents on the T-junction of Allandale and Zuurfontein Roads, facing traffic travelling towards Kyalami.	Dube, 2018; Life Traffic Reports, 2020; Arrive Alive, 2021.
The peak period of traffic congestion		
Morning peak period	The morning peak period ranges from 05:30 and 06:00 to 9:00. Other sources mentioned that traffic intensifies from 07:00 to 09:00 or 7:00 to 10:00.	Onderwater, 2019; Chikwizira *et al.,* 2018; Mikros Traffic Monitoring Report, 2016; Varghese *et al.*, 2021; Chakrabartty &
Afternoon peak period	The afternoon peak ranges between 15:00 and 18:00, 16:00 to 18:00, 16:00 to 19:00 and then	

ROADS, STREETS AND PEAK PERIOD	DESCRIPTION	SOURCES
	from 12:00 to 15:00, going from 17:00 until 20:00.	Gupta, 2015; Anderson, 2014; Ouni & Belloumi, 2018; Wen *et al.*, 2019; Caponecchia & Williamson, 2018.

Sources: Compiled by the researcher

The above table presents a summary of the levels of traffic congestion, the roads that are also congested compared to Allandale Road, and the peak period of road traffic congestion. Section 3.3.4 discusses the problems contributing to road traffic congestion.

3.3.4 Problems contributing to road traffic congestion

South African road infrastructure regularly experiences disruptions to the traffic flow caused by physical restrictions or blockages of urban roads. The average total motorisation rate for South Africa was estimated in mid-2016 at 192 vehicles per 1 000 inhabitants, and now exceeds the global average of 180/1000, and is considerably more than the African average of about 44 (Organisation Internationale des Constructeurs d'Automobiles, 2016; Stone, Merven, Maseela, Moonsamy, 2018).

The severe traffic congestion is the result of over-utilisation of the existing road infrastructure, leading to dense stop-and-go traffic (Schmidt-Dumont & Van Vuuren, 2019). The subsections below discuss the problems that are contributing to road traffic congestion in South African road infrastructures.

3.3.4.1 Increase in vehicle ownership

The growth in global car ownership is projected to take place in developing countries as well. With rapid economic growth, modernisation, and the development of new road infrastructure, there has been a massive increase in automobile usage and car ownership in developing countries. Road traffic accidents have emerged as a severe public health problem (Thondoo *et al.*, 2020).

The rapid convergence of people working in cities contributes to potential economic growth and intensifies the strain on transport infrastructure (Rajé *et al.*, 2018). The significant expansion of car ownership and travel demand worldwide has led to traffic congestion, which is regarded as a substantial problem in metropolitan areas. Rose (2018) asserted that in South Africa, the shortage of suitable levels of public transport facilities is the primary motivation for excessive car ownership. Private vehicles are highly concentrated in the relatively small, densely populated province of Gauteng, for example, in contrast to the arid and sparsely populated Northern Cape (Stone *et al.*, 2018).

The high levels of cars impact congestion, mobility, accessibility, heath and liveability in cities. The increasing numbers of private cars are already reflected in cities' high congestion levels, and these show no decrease, irrespective of policy interventions (Rose, 2018). Bleviss (2021), O'Brien and Aliabadi (2020), and Lu, Taiebat, Xu and Hsu (2018) all highlighted that using private cars creates traffic congestion, which in turn, increases travel time and GHG emissions and issues related to energy consumption. Soltani (2017), similarly, indicated that owning vehicles led to a mass increase in traffic and social and environmental influences.

However, Borhan, Ibrahim, Syamsunur and Rahmat (2019) argued that vehicle ownership has more benefits, such as better accessibility, than using public transport. In countries such as Iran, due to the comfort and reliability of the motor car, this mode of transport indicates freedom, privacy, success and independence for residents from middle and high-income households (Soltani, 2017). High car ownership is related to the relative lack of public transport services and the poor quality of the public service offering (Rose, 2018).

The development of India's economy encouraged the citizens to purchase vehicles, such as two and four-wheelers, as these became affordable to many in the community (Choudhary & Vasudevan, 2017). According to Clark and Rey (2017), a higher income tends to encourage vehicle ownership and contributes to urbanisation; as the countries become wealthier, people tend to relocate and become more urbanised and rely more on private vehicles. Studies by Chevallier, Motte-Baumvol, Fol and Jouffe (2018) showed that car ownership, income, and suburbanisation occur concurrently (Allen *et al*., 2021), and contributes to the use and ownership of private vehicles.

Patt, Aplyn, Weyrich and Van Vliet (2019) added that the availability of parking, other than a higher income, encourages private vehicle ownership. In contrast, Ferguson (2018) stated that the road network expansion improves the condition of the traffic on the road, while encouraging commuters to own vehicles which result in travel demand patterns. Furthermore, Stone *et al.* (2018) argued that mobility cannot be directly measured or observed but requires estimations based on several observable variables, such as how many people are driving private vehicles.

3.3.4.2 Population growth

More than 60% of the population lives in the urban regions in South Africa, and Gauteng receives the most migrants in the country (Zubaidi *et al.*, 2020). The migration of university students and workers imposes more pressure on social welfare systems and causes environmental damage, such as air pollution and traffic congestion (Hsiang, Oliva & Walker, 2020; Percival, Schroeder, Miller & Leape, 2021). Due to the increasing demand for urban mobility and the city's present logistics sector, the vehicle population has been rising gradually over several decades (Ranieri, Digiesi, Silvestri & Roccotelli, 2018; Rode *et al.*, 2017).) The population of private cars has increased motorisation and associated problems, such as traffic congestion, parking dilemmas, and pollution (Aschmann, 2019. Rajé *et al.*, 2018; Stead & Pojani, 2017).

Besides traffic accidents and congestion, there are still a variety of issues causing discomfort among people. Studies from China (Glazener, 2021) and India (Verma, Harsha & Subramanian, 2021) found that the urban transport crisis results from population growth, urbanisation, suburban sprawl, rising population growth incomes, and skyrocketing motor vehicle ownership and use. It is difficult to find an available parking space during rush hours in urban areas. People spend more than 20 minutes searching for parking spaces, which is meaningless and annoying as the searching time increases (Li, Cheng, Guo & Qiu, 2018). In Libya, Elmansouri *et al.* (2020) found that the growing population stimulates the development of infrastructure to meet the ever-changing demands, thereby encouraging urbanisation.

In publications that discuss population growth, Stead and Pojani (2017), Glazener (2021), Verma *et al.* (2021) and Elmansouri *et al.* (2020) indicated that various countries are suffering from severe and worsening transport problems, such as air pollution, noise, traffic injuries and fatalities, congestion, parking shortages, energy use, and a lack of mobility for the poor.

3.3.4.3 Cities' development

Numerous networks form a unique exchange environment that benefits economic development. Cities worldwide focus on creating a pleasant environment for the residents in which to stay, work, start, and grow businesses (Gretzel & Koo, 2021;

Koh, 2020; Ehrenfeucht & Nelson, 2020). In developing countries, the metropolises that have developed swiftly in size and density, are expected to attract higher population numbers in future decades (Zhou & Gao, 2020).

Vencataya *et al.* (2019) indicated that these massive developments have caused trouble for populations around the world, as they have worsened the problem of traffic congestion. Ewing, Tian and Lyons (2018) showed that developing more capacity may help in other network margins, but the most significant reduction in congestion appears achievable through expanding surface streets and instituting higher highway user fees. With the rapid trend of motorisation in the metropolis, building a satisfactory urban transportation system to alleviate traffic pressure is a common issue faced by many countries in the urban development process (Zhou & Gao, 2020).

An instant increase in urban development associated with rapid road-based sprawl may turn cities into dysfunctional spatial arrangements, which exacerbate air pollution for a more extended period (Mudau, Mboup, Mhangara, Sihlongonyane, 2019; Mantey & Sudra, 2019; Von Geusau, 2018). For their part, Wijaya and Imran (2019) asserted that health and transport-related issues affect many cities, and that the increased numbers of vehicles operating in the towns cause pollution, traffic congestion, and lack of parking spaces.

The growth in cities, shortage of spaces, together with an upsurge in housing prices has given rise to a migration process that leads people to relocate to suburban areas that are low in density, and in turn, force the individuals to acquire motor vehicles and long commuting times (Litman & Steel, 2017; Shoag & Muehlegger, 2015).

Wijaya and Imran (2019) showed that the city’s physical characteristics significantly impact urban transportation. Building a mutually reinforcing relationship between urban form and urban traffic modes has attracted much interest. However, Mantey and Sudra (2019) indicated that the travel demand has become increasingly diversified and complicated, bringing forth new challenges to urban transportation supply. Zhou and Gao (2020) argued that urban agglomeration changes the demographic structure of employment and industry as the outcome of urban development, prompting changes to the urban morphology.

3.3.4.4 Roadworks or constructions

Nugmanova *et al*. (2019) asserted that there are three different ways to reduce traffic congestion: adding new road capacity, using transport demand management with push and pull measures without expansion of road capacity, and combining the former and the latter. According to Gibbons, Lyytikäinen, Overman and Sanchis-Guarner (2019), the construction of new roads could temporarily reduce traffic congestion, and consequently, attract more vehicles, which will lead more people to move away from public transport. Vencatayal *et al.* (2018) argued that the congestion happens on narrow and poorly constructed roads and streets that cannot handle a range of different vehicle types. Tilak and Reddy (2018) confirmed that uneven road network features, lack of proper lanes and wrong bus stop locations foster traffic congestion.

Road construction areas have a destructive influence on safe traffic movement, since these generate bottlenecks, and consequently, congestion and accidents resulting in queues and delays (Bakaba & Ortlepp, 2016; Schwietering & Feldges, 2016; Yousif, Nassrullah & Norgate, 2017).

Based on the speech by the Gauteng MEC for Roads and Transport (2017), road constructions have a positive impact and reduce travel time, improve the transportation of people, enhance road safety and reduce the dust pollution along the route. According to Yousif (2017), traffic congestion transpires on road construction sites primarily due to high traffic demands on the roadway capacity, or possibly due to incidents/accidents. A study by Strömgren and Olstam (2016) showed that the increasing complexity of work, such as substantial bridge repair and heavy freight vehicles, has a damaging impact on the capacity of a roadwork area.

3.3.4.5 Mismanagement of road traffic system

Societies depend on a traffic management system to minimise traffic congestion and its adverse effects. The systems are composed of applications and management tools to integrate communication, and sensing and processing technologies (De Souza *et al.,* 2017; Rego et al., 2018; Singh, Saini & Bathla, 2019). Although the congestion around the cities is the result of inadequate traffic control systems (Kurzhanskiy & Varaiya, 2018), diverse role-players collaborate as a team in a complete and unified manner to promote orderly traffic road traffic safety (Mohlala, 2017: 521).

In South Africa, various dynamic highway traffic control measures have been introduced to expand capacity. Ramp metering and variable speed limits are effective dynamic highway control measures (Schmidt-Dumont & Van Vuuren, 2019). However, Liebenberg, Du Toit-Prinsloo, Saayman and Steenkamp (2020) indicated that one of the weakest pieces of road safety control mechanisms in South Africa, is an inappropriate arrangement of traffic calming methods which has a negative impact on road networks. These traffic lights that have been implemented to manage traffic flow are becoming increasingly inefficient due to their design (Liphoto, 2017; Nteziyaremye, 2018). Holmes, Bialik and Fadel (2019) asserted that traffic signals are synthetic systems subject to errors, misconception and mismanagement. Grabowski and Roberts (2019) argued that even though road agencies implemented traffic management systems to reduce drivers' frustration with dysfunctional traffic lights, faulty traffic lights were more likely to occur. Traffic signals can be effective in improving traffic flow and facilitating access. However, Oyaro, Bulose and Ben-edigbe (2021) highlighted that these signals could significantly jeopardise road users when connected and scheduled inappropriately.

Lin, Cho and Hsieh (2021) indicated that difficulties in building road structures include a scarcity of road lights and stop signs, crossroads, various dangerous corners and sharp or narrow U-turns. According to Ben Ticha, Absi, Feillet & Quilliot (2018), the root cause of traffic mismanagement is the dynamic nature of the traffic on roads, and the incapability of legacy systems to interpret such dynamics in real-time. Drivers may sometimes be confronted by poorly timed traffic lights which cause them to stop too close to the stop line (Falcocchi & Levinson, 2015; Oyaro *et al.*, 2021).

Conversely, the aggressive driving behaviour of taxi drivers is reckless, as they have a habit of breaking most road rules (Schlüter, Frewer, Sörensen & Coetzee, 2020). The taxi drivers' reputation of not following road traffic rules creates added interruptions. Sood (2021) added that reckless behaviour generates unfortunate application of traffic rules and creates societal demoralisation of traffic regulations. Table 3.5 below summarises the problems contributing to road traffic congestion.

Table 3.5: Summary of the problems contributing to road traffic congestion

PROBLEMS	DESCRIPTION	SOURCES
Increase in vehicle ownership	Migration to cities contributes to economic growth, intensifying the strain on transport infrastructure. The lack of acceptable levels of public transport services increases car ownership.	Rajé *et al.*, 2018; Rose 2018; Stone *et al.*, 2018; Patt *et al.*, 2019

PROBLEMS	DESCRIPTION	SOURCES
	The availability of parking at the workplaces encourages users to own private vehicles.	
Population growth	The movement of people imposes more pressure on social welfare systems and causes environmental damage such as air pollution and traffic congestion. The higher use private cars increased the level of motorisation and associated problems, such as traffic congestion, parking dilemmas and pollution. Increased population arouses increasing infrastructure to meet ever-changing demands, encouraging urbanisation.	Hsiang *et al.*, 2020; Percival *et al.*, 2021; Aschmann, 2019; Rajé *et al.*, 2018; Stead & Pojani, 2017; Elmansouri *et al.* 2020
Development of cities	The metropolises developed swiftly in size and density in developing countries and are expected to attract more people in future decades. An instant increase in urban development may turn cities into dysfunctional spatial arrangements. The urban form has a significant impact on urban transportation and how to build a mutually reinforcing relationship between urban form and urban traffic modes.	Zhou & Gao, 2020; Mudau*et al.*, 2019; Mantey & Sudra, 2019; Von Geusau, 2018; Wijaya & Imran, 2019
Roadworks or construction	Construction of new roads temporarily reduces traffic congestion, and then attracts more vehicles, leading more people to move away from public transport. Uneven road network features, lack of proper lanes and wrong bus stop locations foster traffic congestion. The increasing complexity of work, such as substantial bridge repair and heavy freight vehicles, has a damaging impact on roadwork area capacity.	Gibbons *et al.*, 2019, Tilak & Reddy, 2018; Strömgren & Olstam, 2016
Mismanagement of road traffic system	Societies depend on the traffic management system to minimise traffic congestion and its adverse effects. In South Africa, various dynamic highway traffic control measures have been introduced, such as ramp metering and variable speed limits as an alternative to capacity expansion. One of the weakest pieces of road safety evidence is traffic lights implemented to manage traffic flow but that are becoming increasingly inefficient due to their design.	Schmidt-Dumont & Van Vuuren, 2019; Liebenberg *et al.*, 2020; Liphoto, 2017; Nteziyaremye, 2018

Sources: Compiled by the researcher

The above table summarises the problems contributing to road traffic congestion. The next section addresses the policies and regulations impacting road traffic congestion.

3.3.5 Supporting policies and regulations impacting road traffic congestion

The SA government executed strategies and policies to promote PT systems through massive investments and planned policy instruments to develop and support public transport (Henseler & Maisonnave, 2018; Risimati & Gumbo, 2019b; Walters, 2014). Thondoo *et al.* (2020) added that policies to inhibit the use of personal cars must be motivated to allow a healthy and sustainable transport system. The subsections below present the supporting policies and regulations impacting road traffic congestion.

3.3.5.1 Urban Transport Act 78 of 1977

The Urban Transport Act 78 of 1977 was promulgated to support the planning and development of appropriate metropolitan transport services. Authors, such as Ballard *et al.* (2017), Chakwizira (2013) and Netshisaulu (2021), stated that urban areas, specifically in Gauteng, have transformed in different ways, while reinforced by transport systems that have been developed for their exceptional conditions. Klopp and Petretta (2017) found that the increasing developments in the areas have contributed to the challenges of accessing low-priced and safe public transport facilities.

"In the Act, section 22 stipulates in that any local authority may control the size, class or number of motor vehicles under any applicable approved transport plans that may enter any specified portion of the metropolitan transport area" (Government Gazette, 1990:10). According to Van Ryneveld (2018), the increasing traffic intensifies the argument of providing the kind of PT service that will eradicate the need for private vehicles among the public. The planning of South African transportation services developed into a constitutional planning action as represented by this Act.

3.3.5.2 Draft Revised White Paper on National Transport Policy, 1996

According to Smith and Hensher (2020), the national government has broad objectives for transport policy. One of the objectives stipulates the improvement of the transport arrangement and processes in South Africa to meet the needs of diverse customer groups, both locally and globally (Mulley, Nelson & Wright, 2018). González-González and Nogués (2019) maintained that the overall accessibility improvements that have been achieved by the latest transport infrastructures can be considered a significant component in lessening physical structural discrepancies amongst areas, while also providing equal opportunities.

In one of the few publications that discuss urban transport infrastructure, Davidich *et al.* (2020) and Rokicki *et al.* (2021:13) stated that “transport and infrastructure have a significant impact on the economic development of cities, the central area of employment, the productivity of people, and the cost indicators of the transport process”. However, Van Holstein, Wiesel and Legacy (2020) indicated that urban areas with commuter rail services require intermodal planning committees to organise and arrange the various transport modes to align public transport between modes. One of the topics in the policy document is connected to road and road traffic law enforcement. The policy statements under road include road traffic safety regulation policy statements.

Road traffic safety regulation policy statements.

Schoeman (2015:42) indicated that “A continued integrated road traffic quality management and monitoring approach needs to be implemented between the Department of Transport and the provincial authorities to administer and deal with the road traffic on South African roads”. For example, in 2015, Minister Dipuo Peters proposed restrictions on vehicles of more than 9000 kg that would only be allowed to drive on public roads from 09:00 to 16:00, and then from 20:00 to 06:00 during weekdays (News24, 2015).

The necessary guidelines comprise of road traffic control, administration and information systems, and road and traffic engineering. “The five pillars of safer roads and mobility, namely, safer vehicles, safer road users, post-crash response, road safety management and the related policies addressed in the National Road Safety Strategy form part of the implementation” (Department of Transport, 2017:18).

3.3.5.3 National Land Transport Act, 2009

The main objective of the National Land Transport Act, 2009 (NLTA) includes the provision of the transformation process collectively with the restructuring of the national land transport system. Klopp, Harber and Quarshie (2019) indicated that informal transport dominates public transport in most African cities, including minibus systems operated by many private actors. According to Veeneman and Mulley (2018: 430), “Governments support public transport to deliver social and environmental objectives through public value established through subsidised transport services for its inhabitants and visitors”.

Scorcia and Munoz-Raskin (2019) concurred that the regional and national governments of SA are cooperating to enhance the recognition of the public transport system, especially the BRT in the SA context to arrange the growth of these systems. However, Engelbrecht and Ramgovind (2020) added that the NLTA describes the obligations of three spheres of government concerned with community transportation. Studies by Moroke *et al.* (2019) and Esson *et al.* (2012) found that the accountability rests on the preparation of provincial transport policy and strategy within a specific province, so that it is in accordance with the framework of national policy and procedure. The NLTA requires each municipality to build up an incorporated network of community transport services (DoT, 2009). Different governments operate in various dominions, and their activities in a particular policy field are generally mutually dependent (Monstadt & Schmidt, 2019).

3.3.5.4 National Road Traffic Act 93 of 1996

The management and control, safety and capabilities of the drivers and vehicles, together with the utilisation and operations of the roads fall under the NRTA in SA (Engelbrecht and Ramgovind, 2020). Channon, McCormick and Noussia (2019) also highlighted that drivers should take complete control of the vehicle's position and speed whilst driving at a high speed, and vehicles under test on public roads must comply with all relevant road traffic laws.

The NRTA's goal is to contribute to road traffic-related affairs which shall apply equivalently throughout SA and for matters connected therewith. This goal is supported by Bishop *et al.* (2018) and Garber and Hoel (2018), who indicated that key road safety management activities are to ensure that effective legislation is in place that will assist in the reduction of fatalities and traffic infringements on the roads. The Act emphasised the empowerment of traffic law enforcement officers to stabilise and alleviate traffic on any public road and to give such direction as necessary for traffic safety and efficient regulation (Government Gazette, 1996).

The Act mainly focuses on amongst other, vehicles and drivers condition, operator capability, road safety, hazardous commodities, road signs and overall speed limit, accidents and accident reports, reckless or negligent driving, inconsiderate driving, driving while under the influence of intoxicating liquor or a drug having a narcotic effect, and miscellaneous offences, and the registration and licensing of motor vehicles, manufacturers, builders and importers.

National Road Traffic Regulations of 1999

According to Shah (2019), the state incorporates motor vehicle rules for the regulation of activities on public roads and areas associated to pedestrian activities and non-motorised road users. These activities consist of the creation of exclusive geographical zones, bicycle tracks, footpaths, pavements, and lanes devoted to NMTs. The regulations which are delineated under road traffic matters are incorporated and summarised as follows:

- Drivers and vehicles licensing;
- Licensing for transport operators of goods and people;
- Vehicle roadworthiness;
- Rules and speed limits of the roads;
- Alcohol or drug prohibition while driving;
- Negligent and reckless driving; and
- Accidents and the responsibility to adhere to the process thereof.

3.3.5.5 Road Traffic Management Corporation Act, 20 of 1999

According to Verster and Fourie (2018), the purpose of this act is to provide for a complete road traffic services quality, for instance, order, safety, security, discipline and mobility on the roads. This service contribution is significant for the safety provision, accessibility, and the affordable and reliable transportation of products and services for the development of the country (Sebola & Mamabolo, 2018). As a result, public transport and road traffic rules and guidelines are essential in developing safety and quality of life for all citizens (Netshisaulu, 2021).

Moyana (2008) argued that the excessive number of road crashes is particularly linked to the level of disorder and drivers' misconduct on SA roads. "Cooperation and coordination between the national, provincial and local spheres of government are required to support the respective road traffic strategic planning, regulation, facilitation and enforcement activities" (Government Gazette, 2001:23).

National Road Traffic Law Enforcement Code (NRTLEC)

The reduction of traffic congestion and accident hazards through the logical enforcement of traffic laws is stipulated as the vital purpose of traffic patrol officers under NRTLEC. Law enforcement prioritises manage road traffic related issues that produce repeated disruptions, unsafe circumstances, and dented infrastructure. The laws, rules and regulations of traffic involve the discipline through stringent proactive and reactive control measures (Ghadge, Wurtmann & Seuring, 2020). However, the number of road traffic deaths in the country tend to intersect the mark.

According to Moyana (2008), "Since it is a challenge to significantly reduce the number of deaths on the roads, the NRTLEC is responsible for monitoring and evaluating the quality and safety of road traffic". The code further states that traffic patrol could possibly help the law-breaker to return to the traffic flow to prevent more disturbances. Traffic law enforcement officers are obligated to physically point the pedestrians or vehicles in the right direction when traffic control signals fail.

Administrative Adjudication of Road Traffic Offences Act, 46 of 1998 (AARTO)

The AARTO Act aims to promote road traffic quality by providing a scheme to discourage road traffic contraventions and to facilitate road traffic infringements. The Act also supports the prosecution of offences regarding the national and provincial laws relating to road traffic through the implementation of a points demerit system. As mentioned by Anchang *et al.* (2020), the pilot project implementing the administration of the Act, namely, the demerit point system for traffic offences, has been rolled out in the metropolitan areas of Tshwane and Johannesburg.

The objectives of this act are to encourage compliance with the national and provincial laws relating to road traffic and to promote road traffic safety; to encourage the payment of penalties imposed for infringements and to allow alleged minor infringers to make representations; to penalise drivers and operators who are guilty of violations or offences through the imposition of demerit points leading to the suspension and cancellation of driver's licenses, professional driving permits or operator cards.

3.3.5.6 Draft National Non-Motorised Transport policy

Walking and cycling are more than just low-carbon modes that enhance urban quality and facilitate social cohesions; they are cheap, flexible, personal modes without which most people in developing and least-developed countries would be unable to participate in the economy and community, or access education, healthcare and other urban essentials (Gündel, 2018; Hunter *et al.*, 2019; Middleton, 2018 & Jennings, 2016).

The strategic objective of the Draft NMT policy to enable this system to act as a feeder to further modes of transport (Cele, 2018). “One of the strategic objectives in PT is to improve public transport and NMT services in order to attract private car drivers and increase the proportion of commuters to utilise these services instead of private cars” (Draft Revised White Paper on NTP, 2017:35). The policy further upholds a consistent, healthful, reasonable, reachable and safe transportation means which reduces traffic fatalities among susceptible non-motorised road users (Draft National NMT Policy, 2008). Municipalities increase and encourage NMT services as part of their networks, both operationally and through the provision of infrastructure.

Table 3.6 presents a summary of the policies and regulations impacting road traffic congestion.

Table 3.6: Summary of the supporting policies and regulations impacting road traffic congestion

POLICIES AND REGULATION	DESCRIPTION	SOURCES
Urban Transport Act 1977	This act promotes the support the planning and development of appropriate metropolitan transport services. The developments in the areas have increased, contributing to the challenges of accessing low-priced and safe public transport facilities.	Ballard *et al.,* 2017; Chakwizira, 2013; Netshisaulu, 2021; Klopp & Petretta, 2017
White Paper on National Transport Policy, 1996	One of the objectives of this act is the improvement of the transport infrastructure and operations in South Africa. Transport infrastructure has a significant impact on the economic development of cities, the central area of employment, the productivity of people, and the cost indicators of the transport process.	Mulley *et al.*, 2018; González-González & Nogués, 2019; Davidich *et al.,* 2020; Rokicki *et al.,* 2021
Road traffic safety regulation policy statements	This Act proposed restrictions on goods vehicles of more than 9000 kg that can only operate on public roads from 09:00 to 16:00 and 20:00 to 06:00 during weekdays. The regulations include road traffic control, administration and information systems, and road and traffic engineering.	Draft Revised White Paper on NTP, 1996; News24, 2015
National Land Transport Act, 2009	The NLTA requires that every municipality develop an integrated network of public transport services (DoT 2009). Different local governments operate in various jurisdictions, and their actions in a	Monstadt & Schmidt, 2019; Moroke *et al.,* 2019; Esson *et al.,* 2012

POLICIES AND REGULATION	DESCRIPTION	SOURCES
	specific policy field are generally mutually dependent.	
National Road Traffic Act, 1996	The main goal of this act is "to provide for road traffic matters which shall apply uniformly throughout SA and for matters connected therewith". Drivers should take complete control of the vehicle's position and speed whilst driving at high speed, and cars under test on public roads must comply with all the relevant road traffic laws.	Channon *et al.*, 2019; Bishop *et al.,* 2018; Garber & Hoel. 2018
National Road Traffic Regulations of 1999	The state incorporates Motor Vehicle Rules for regulating activities on public roads and places relating to pedestrian activities and non-motorised road users. The regulations delineated under road traffic matters are the licensing of operators of goods and people transport for gain, vehicle roadworthiness, rules and speed limits of the roads, prohibition of driving under the influence of alcohol or drugs, negligent and reckless driving, accidents and the responsibility to adhere to the process thereof.	Shah, 2019
Road Traffic Management Corporation Act, 1999	The act is sanctioned to improve road traffic services such as safety, security, order, discipline, and mobility. This provision of safe, accessible, affordable and reliable transportation of goods and passengers is critical to the country's development.	Verster & Fourie 2018; Sebola & Mamabolo, 2018
Administrative Adjudication of Road Traffic Offences Act, 46 of 1998	The demerit point system for traffic offences has been rolled out in the metropolitan areas of Tshwane and Johannesburg. The objectives of this act are to encourage compliance with the national and provincial laws relating to road traffic and to promote road traffic safety, promote the payment of penalties imposed for infringements, and allow alleged minor infringers to make representations.	Anchang *et al.,* 2020
Draft National Non-Motorised Transport policy	The strategic objective of this act embraces enabling NMT as a feeder system to other modes of transport. Walking and cycling are more than low-carbon modes that enhance urban quality and facilitate social cohesions.	Gündel, 2018; Hunter *et al.*, 2019; Middleton, 2018; Jennings, 2016; Cele, 2018.

Sources: Compiled by the researcher

The above table summarises the policies and regulations impacting road traffic congestion. The next section discusses the strategies for managing traffic congestion.

3.3.6 Strategies for managing road traffic congestion

The congested roads trigger interruptions, inconvenience, and economic losses to drivers, as well as contributing to air contamination. It is essential to identify the congested vicinities to enable the decision-makers to introduce mitigation strategies to develop the sustainability of the complete transportation system (Afrin & Yodo, 2020).

The volume of road traffic in metropolitan areas leads to a situation where the road networks become overcrowded and cannot accommodate the capacity of the traffic any more. According to Segola and Oladele (2016) and Simoni, Kockelman, Gurumurthy and Bischoff (2019), strategies for road congestion differ from one city to another. The subsections below present discussions of the various strategies for managing road traffic congestion:

3.3.6.1 Improving public transport (PT)

Occasionally, the neglect of public transport generates a shortage, and results in the unavailability of services that often constrain urban mobility. Commuters with physical or economic constraints experience restrained access to public transport and can find it difficult to balance their subsistence and maintenance activities with family life (Yu & Zhao, 2021).

While public transport is necessary to ensure the smooth mobility of road traffic, in most cases, it faces various pressures in metropolitan areas (Leonard, Mindell & Stayton, 2020; Luke & Heyns, 2020; Mamabolo & Sebola, 2018). However, numerous countries have made efforts to improve access to public transport services by restraining private vehicle usage within the communities (Mulley & Kronsell, 2018; Oeschger, Carroll & Caulfield, 2020). For example, Mamabolo and Sebola (2018) indicated that the South African government has introduced a public transport subdivision that is meant to expedite the enhancement in the sector by launching an Integrated Rapid Public Transportation Networks.

In countries such as Malaysia, Qatar and the USA, the quality of public transport is the most crucial topic that the state and urban planners have to deal with (Somasundram *et al.*, 2018; Almselati, Rahmat, Jaafar & Yahia, 2015; Anas & Lindsey, 2020). Consequently, in Taiwan, the government implemented Mass Rapid Transit (MRT) routes in urban settlements, and also more town bus routes to reduce the dependence on private car practices (Chang, Chen & Chen, 2019; Hsu, 2020). The increase in the frequency of intercity bus services around the area has decreased waiting time, resulting in the community's eagerness to use public transportation.

People with disabilities commonly encounter obstructions on public transport (Bezyak, Sabella & Gattis, 2017; Ratyela, 2017). According to Fisk *et al.* (2018), these obstacles influence the ability of disabled people to interact and appreciate the social, economic and political facilities available in their society. Lister and Dhunpath (2016) discovered that taxi operators in KwaZulu-Natal would not pick up disabled people during peak hours because of the longer time needed for the disabled person to board the taxi. Consequently, the level of service rendered by local taxis to disabled people is generally unsatisfactory.

3.3.6.2 Improvement of transport infrastructure (road capacity and networks)

One of the standards that can be used to measure the economy growth of a country is good road networks and infrastructural facilities (Eke & Ogba, 2021). According to Gibbons *et al.* (2019), road transport generates economic benefits, and the developments in transportation are often recommended as growth strategies. The potential reduction of congestion through infrastructure improvement is a sign of economic development (Harahap *et al.*, 2018; Litman, 2021). Harahap *et al.* (2018) asserted that the simplest solution to congestion is increasing the road capacity and networks. According to Nugmanova *et al*. (2019), modern dual carriageway road construction, road expansion, and existing roads can predominantly diminish traffic congestion. However, they often become unsuccessful over time due to the generation of more traffic as a result of the upgrades.

In South Africa, however, the reality is that residents cannot sufficiently access the social and economic potential of transport because of the deficient road infrastructure in the country (Sewell *et al*., 2019). Farber *et al.* (2018) indicated that poverty is entirely associated with segregated, inaccessible and deprived infrastructural development. According to Allen and Farber (2019), various communities are underprivileged because public transport does not provide sufficient access to their destinations, such as employment opportunities.

3.3.6.3 Introduction of carpooling

The developments in mobility are intensifying and driven by improvements in various technologies (Mounce & Nelson, 2019). Even though the arrangement has existed for centuries, carpooling has recently been regenerated due to cyberspaces and smartphones technology (Vanderschuren & Baufeldy, 2018). Ferrero, Perboli, Rosano and Vesco (2018) stated that the growth of carpooling as a modern and advanced sustainable approach of transportation, is changing personal mobility from ownership to service use. The service is regarded as an inexpensive, publicly acceptable, and environmentally friendly means of transport (Acheampong & Siiba, 2020; Mugion *et al.*, 2018).

Olszewski, Pałka and Turek (2018) confirmed that various qualities cause users to prefer carpooling over public transport, for example, carpooling saves money and time, and it is consistent and sociable. The travellers also supported the idea of service integration with social networks to strengthen the ridesharing experience, for it is perceived as a positive kind of transport (Lasmar *et al.*, 2019. Mounce & Nelson, 2019). However, according to Xia *et al.* (2019), although carpooling is an operative solution to overcrowded roads, social distrust and excessive commute costs are the foremost arguments for carpooling activities.

Metz (2018) stated that even though public transport could alleviate congestion problems, it can still be too expensive for some people. Therefore, if a large percentage of commuters would adopt carpooling as an operative means to reduce traffic congestion and air pollution, especially daily travellers, considerable traffic reduction would occur (Bruck *et al.*, 2017; Guidotti *et al.*, 2017).

3.3.6.4 Promotion of non-motorised transport (NMT)

According to the Department of Forestry, Fisheries and the Environment (2014:1), the promotion of NMT infrastructures permits the residents to reach public facilities in a peaceful, safe and environmentally pleasant way. The introduction of reasonable arrangements for both public transport and NMT systems in terms of operational purposes would assist in promoting the effectiveness and well-being of the transport system within the community (Calvo & Ferrer, 2018; Thombre & Agarwal, 2021).

Cooke, Zuidgeest and Koinange (2019) maintained that the recent interest in NMT is on account of the prospective environmental, social, and health benefits for pedestrian and bicycle riders. As a strategic means for society to benefit from walking and cycling, it can assist in improving the health of the community, operate as a way of recreation, and encourage social well-being by enhancing greater opportunities for collaboration amongst people (Majee *et al.*, 2020; Okrah, 2016 & Shaaban, 2020). According to Litman (2021:9), "Developed infrastructures for cyclists and pedestrians have been deliberated as a means to enhance walking and cycling and almost all communities that have encouraged NMT have achieved this by improving their walking and cycling environments".

Compared to other means of transport, NMT is perceived as non-durable well-being with much lower environmental impact and a healthy mode of transportation that plays a crucial role in short-distance trips compared to the use of other vehicles (Lundberg & Weber, 2014; Ortengon-Shanchez & Hernadez, 2016).

Mokitimi and Vanderschuren (2017) indicated that inaccessible road infrastructure, shortage of connectivity and the death of pedestrians have led to a decrease in the use of facilities within communities. However, highly connected road networks would increase NMT, but without knowledge of driving and cycling, the non-existence of laws and regulations for commuters would also discourage them from using the mode (Risimati & Gumbo, 2019a; Vanderschuren & Baufeldt, 2018).

3.3.6.5 Park-and-ride facilities

Traffic congestion is one of the central challenges related to the movement of people in urban areas. The government has established several strategies to confront this challenge, and one of them is park-and-ride (PNR) amenities. The PNR system is an arrangement aimed at reducing urban traffic congestion. Private vehicle drivers leave their vehicles in the dedicated car park facility on the city's outskirts and travel to the city centre on public transport (Thombre & Agarwal, 2021; Mounce & Nelson, 2019).

Although the primary objective of the park-and-ride system appears to be to restrain the use of private vehicles, the purpose of this service assists partly in decreasing traffic congestion, as commuters use public transport for a portion of their journey (Ibrahim, Borhan & Rahmat, 2020). However, the facilities do little to assist disadvantaged sections of the population because they require drivers to access their vehicles. Kimpton, Pojani, Sipe and Corcoran (2020) confirmed that personal cars are used only for a specific part of the journey to facilities situated in a low-density peripheral or urban area in which shifting to public transit allows travellers to escape traffic congestion and extreme parking charges.

In South Africa, PNR facilities are, in most cases, accompanied by rail systems but can also be found close to express bus services (Duncan & Cook, 2014; Webb & Khani, 2020) and therefore, an attractive facility should be located in a neighbourhood with several factors to motivate car users to switch to PNR (Rith, Fillone & Biona, 2019).

3.3.6.6 Involvement of developers

According to Mouton and Shatkin (2020), infrastructural developers have gained momentum, and have attained ongoing empowerment ever since the commencement of the postcolonial period. In South Africa, particularly in the Johannesburg municipality, the number of residential and commercial buildings of various sizes and natures has increased since 2001 (Ballard, Hamann & Mosiane, 2021; Von Holdt & Naidoo, 2019).

McGaffin, Spiropoulous and Boyle (2019) indicated that although road developers play an essential role in the property development processes, they have been neglected in the South African urban development works. Real estate developers have been the focus of a progressively large body of work that displays their role in drawing investments to specific places, and their effective involvement in urban decision-making (Robin, 2018; Ward & Swyngedouw, 2018; Geva & Rosen, 2018).

A study by Brill and Robin (2020) considered real estate developers to be a viewpoint of exploration for understanding urban governance and continuous urban restructuring. Umoh and Lemon (2020) indicated that South Africa seek project developers to assess the communities' socio-economic requirements within a 50 km radius of the project location. However, Umoh and Lemon (2020:15) indicated that "Various stakeholders reported on problems such as limitation participation of community in defining beneficiaries, and a misalignment of the project developers' economic development plan and the local government's plan".

According to Combs, McDonald and Leimenstoll (2020), the government depends on traffic impact assessments to be able to forecast the magnitude of the increased traffic generated through new developments. The state negotiates with private developers to minimise or alleviate the contrary impacts of the additional traffic that would be generated by the development. Road infrastructure that is in a satisfactory condition, decreases travel times, saves fuel and reduces production costs for the ever-growing number of goods shipments (Mashwamaa, Mushatub & Aigbavboaa, 2018; Ballard & Butcher, 2020).

Table 3.7 presents a summary of the strategies for managing traffic congestion.

Table 3.7: Summary of the strategies for managing road traffic congestion

STRATEGIES	DESCRIPTION	SOURCES
Improving public transport	▪ Public transport is essential in ensuring the smooth mobility of road traffic; however, it faces various pressures in metropolitan areas. ▪ The government has concentrated on improving access to PT services by restraining private vehicle usage within communities. ▪ The quality of public transport is the most crucial topic encountered by the state and urban planners.	Leonard *et al*., 2020; Luke & Heyns, 2020; Mamabolo & Sebola, 2018; Mulley & Kronsell, 2018; Oeschger *et al*., 2020; Somasundram *et al*., 2018; Almselati *et al*., 2015; Anas & Lindsey, 2020; Bezyak *et al*., 2017; Ratyela, 2017; Fisk *et al.,* 2018
Infrastructure improvement (road capacity and networks)	▪ The simplest solution to solve congestion is to increase the road capacity and networks. ▪ Ring road development, new road construction, and existing road expansion can reduce traffic congestion but become unsuccessful over time due to the generation of induced traffic. ▪ In South Africa, limited access to social and economic opportunities is a common challenge faced by the residents due to inadequate road infrastructures.	Harahap *et al*., 2018; Litman, 2021; Nugmanova *et al*., 2019; Sewell *et al*., 2019
Introducing carpooling (ride sharing)	▪ Carpooling has recently made a regeneration through the internet and smartphone technology. ▪ Increased carpooling as a new and more sustainable way of transportation is shifting personal mobility from ownership to service use. ▪ Even though carpooling is an effective solution to traffic congestion, lack of trust and high commute costs are the foremost challenges to carpool activities.	Vanderschuren & Baufeldy, 2018; Ferrero *et al*., 2018; Xia *et al.,* 2019
Promotion of non-motorised	▪ NMT received attention due to the potential environmental, social, and health benefits for pedestrian and bicycle riders.	Cooke *et al*., 2019; Majee *et al*., 2020; Okrah, 2016; Shaaban,

STRATEGIES	DESCRIPTION	SOURCES
transport (NMT)	▪ Walking and cycling can improve community health, operate as a way of recreation, and encourage social interaction among individuals. ▪ Inaccessible road infrastructure, a shortage of connectivity and pedestrian deaths have decreased the use of facilities within communities.	2020; Mokitimi & Vanderschuren, 2017
Park-and-ride facilities	▪ The government has established several strategies to confront the lack of parking services. ▪ Introducing PNR amenities assists partly in decreasing traffic congestion; however, it persuades commuters to use public transport for a portion of the journey. ▪ In South Africa, PNR facilities are, in most cases, accompanied by rail systems but can also be found close to express bus services. ▪ The attractive facility should be located in a neighbourhood with several factors to motivate car users to switch to PNR.	Ibrahim *et al*., 2020; Kimpton *et al*., 2020; Duncan & Cook, 2014; Webb & Khani, 2020; Rith *et al*., 2019

Sources: Compiled by the researcher

The above table summarised the strategies for managing traffic congestion. The next section discusses the instruments for managing road traffic congestion relevant to the current study.

3.4 INSTRUMENTS FOR MANAGING ROAD TRAFFIC CONGESTION

Section 3.3 discussed the peak period of road traffic congestion, problems contributing to road traffic congestion, policies and regulations impacting and mitigating road traffic congestion, and strategies for managing traffic congestion. This section presents a concise summary of the instruments for managing road traffic congestion in Table 3.8, and concludes with a conceptual framework for managing road traffic congestion.

Table 3.8: Instruments for managing road traffic congestion

PEAK PERIODS OF ROAD TRAFFIC CONGESTION (RTC) ON ALLANDALE ROAD (M39)	
ROAD, STREETS INTERSECTIONS	**DESCRIPTION**
Levels of traffic congestion	
Allandale Road (M39)	There is an excessive demand for the road during peak hours, as some users have shifted from the old routes to the new extended way, creating high congestion on Allandale Road (M39).
Street intersections along Allandale Road	Congestion problems kept re-occurring with a high level of traffic from seven major road intersections connecting to Allandale Road. The roads and street intersections involved are Pretorius Road, Lone Creek, Waterfall Drive, Harry Galaun Drive and Bridal Veil Road along the stretch of Allandale Road. Dane Road in Glen Austin AH, Midrand, is frequently reported as a highly congested collision area where private vehicle drivers lose control.
Roads also congested	
Compared to Allandale Road	The R55 comprises of single-lane roads experiencing a high volume of traffic congestion and accidents. Le Roux Avenue also experiences congestion from Old Pretoria Main Road to the dual carriageway road. The Olifantsfontein and New Road interchanges have massive queuing traffic during peak hours, resulting in increased traffic jams. In Chloorkop, there has been high traffic pressure and accidents at the T-Junction of Allandale and Zuurfontein Roads, facing traffic travelling towards Kyalami.
Peak periods of traffic congestion	
Morning peak period	The morning peak period ranges from 05:30 and 06:00 to 9:00. Other sources mentioned that traffic intensifies from 07:00 to 09:00 or 7:00 to 10:00.
Afternoon peak period	The afternoon peaks range from 15:00 to 18:00, 16:00 to 18:00, 16:00 to 19:00, and then from 12:00 to 15:00, going from 17:00 until 20:00.

PROBLEMS CONTRIBUTING TO RTC THAT USERS ON ALLANDALE ROAD (M39) EXPERIENCE DAILY	
PROBLEMS	**DESCRIPTION**
Increase in vehicle ownership	Migration in cities contributes to economic growth, intensifying the strain on transport infrastructure. The lack of acceptable levels of public transport services increases car ownership. The availability of parking in the workplaces encourages users to own private vehicles.
Population growth	The movement of people imposes more pressure on social welfare systems and causes environmental damage, such as air pollution and traffic congestion. The number of private cars has increased the level of motorisation and associated problems, such as traffic congestion, parking dilemmas, and pollution. Increased population needs increasing infrastructure to meet ever-changing demands, encouraging urbanisation.
Development of cities	The metropolises have developed swiftly in size and density in developing countries and are expected to attract more people in future decades. An instant increase in urban development may turn cities into dysfunctional spatial arrangements. The urban form has a significant impact on urban transportation and how to build a mutually reinforcing relationship between urban form and urban traffic modes.
Roadworks or constructions:	Construction of new roads temporarily reduces traffic congestion, and then attracts more vehicles, leading more people to move away from public transport. Uneven road network features, lack of proper lanes and wrong bus stop locations foster traffic congestion. The increasing complexity of work, such as substantial bridge repair and heavy freight vehicles, has a damaging impact on roadwork area capacity.
Mismanagement of road traffic system	Societies depend on the traffic management system to minimise traffic congestion and its adverse effects. In South Africa, various dynamic highway traffic control measures have been introduced, such as ramp metering and variable speed limits as an alternative to capacity expansion. One of the weakest road safety tools is traffic lights implemented to manage traffic flow but that are becoming increasingly inefficient due to their design.

POLICIES AND REGULATIONS	DESCRIPTION
Urban Transport Act 1977	This Act promotes planning and adequate urban transport facilities. Developments in the regions have increased, making it challenging to access cheap and safe public transport facilities.
White Paper on National Transport Policy, 1996	One of the objectives stipulated in this Act is the improvement of the transport infrastructure and operations in South Africa. Transport infrastructure has a significant impact on the economic development of cities, the central area of employment, the productivity of people, and the cost indicators of the transport process.
Road traffic safety regulation policy statements	This Act proposed restrictions on goods vehicles of more than 9 000 kg, so that they can only operate on public roads from 09:00 to 16:00 and 20:00 to 06:00 during weekdays. The regulations include road traffic control, administration and information systems, and road and traffic engineering.
National Land Transport Act, 2009	The NLTA requires of every municipality to develop an integrated network of public transport services (DoT 2009). Different local governments operate in various jurisdictions, and their actions in a specific policy field are generally mutually dependent.
National Road Traffic Act, 1996	The main goal of this act is “to provide for road traffic matters which shall apply uniformly throughout SA and for matters connected therewith”. Drivers should take complete control of the vehicle’s position and speed whilst driving at high speed, and cars under test on public roads must comply with all relevant road traffic laws.
National Road Traffic Regulations of 1999	The state incorporates Motor Vehicles Rules for regulating activities on public roads and places relating to pedestrian activities and non-motorised road users. The regulations which are delineated under the road traffic matters are the licensing of operators of goods and people transport for gain, vehicle's roadworthiness, rules and speed limits of the roads, prohibition of driving under the influence of alcohol or drugs, negligent and reckless driving, accidents and the responsibility to adhere to the process thereof.

Road Traffic Management Corporation Act, 1999	The Act is sanctioned to improve road traffic services such as safety, security, order, discipline, and mobility. This involvement is necessary since providing safe, accessible, affordable and reliable transportation of goods and passengers is critical to the country's development.
Administrative Adjudication of Road Traffic Offences Act, 46 of 1998	The demerit point system for traffic offences has been rolled out in the metropolitan areas of Tshwane and Johannesburg. The objectives of this Act are to encourage compliance with the national and provincial laws relating to road traffic and to promote road traffic safety; to encourage the payment of penalties imposed for infringements, and to allow alleged minor infringers to make representations.
Draft National Non-Motorised Transport policy	The strategic objective of this Act embraces enabling NMT as a feeder system to other modes of transport. Walking and cycling are more than low-carbon modes that enhance urban quality and facilitate social cohesion.
STRATEGIES FOR MANAGING RTC	**DESCRIPTION**
Improving public transport.	PT is essential in ensuring smooth mobility of road traffic; however, it faces various pressures in metropolitan areas. The government has concentrated on improving access to PT services by restraining private vehicle usage within communities. The quality of public transport is the most crucial topic state and urban planners have to deal with. Without a proper accessible service for differently-abled people, PT makes it difficult for them to interact in the economy.
Infrastructure improvement (road capacity and networks)	The simplest solution to solve congestion is to increase the road capacity and networks. Ring road development, new road construction, and existing road expansion can reduce traffic congestion but become unsuccessful over time due to the generation of induced traffic. In South Africa, limited access to social and economic opportunities is a common challenge faced by the residents due to inadequate road infrastructure.

Introducing carpooling (ride sharing)	Carpooling has recently made a regeneration through the internet and smartphone technology. Increased carpooling as a new and more sustainable way of transportation is shifting personal mobility from ownership to service use. Even though carpooling is an effective solution to traffic congestion, lack of trust and high commute costs are the foremost challenges in carpool activities.
Promotion of Non-Motorised Transport (NMT)	The focus has been on NMT due to the potential environmental, social, and health benefits for pedestrian and bicycle riders. Walking and cycling can improve community health, operate as a way of recreation, and encourage society by enhancing opportunities for interaction among individuals. Inaccessible road infrastructure, shortage of connectivity and death of pedestrians has decreased the use of facilities within communities.
Park-and-ride facilities	The government has established several strategies to confront the lack of parking services. Introducing PNR amenities assists partly in decreasing traffic congestion, as it persuades commuters to use public transport for a portion of the journey. In South Africa, PNR facilities are, in most cases, accompanied by rail systems but can also be found close to express bus services. The attractive facility should be located in a neighbourhood with several factors to motivate car users to switch to PNR.
Involvement of developers	Developers that play an essential role in property development processes, have been given limited attention in the South African urban development literature. Developers are the point of analysis for understanding urban governance and ongoing urban restructuring. Challenges such as a lack of community involvement in defining beneficiaries and a misalignment of the project have been reported by various stakeholders. The state depends on traffic impact assessments to forecast the increased traffic that will be generated through new developments.

Source: Researcher’s own compilation

Table 3.8 above indicated the instruments for managing road traffic congestion and deliberated on a summary of the peak periods of road traffic congestion, problems contributing to road traffic congestion, policies and regulations impacting and mitigating road traffic congestion, and strategies for managing traffic congestion. The next section presents the conceptual framework for managing road traffic congestion.

3.5 CONCEPTUAL FRAMEWORK FOR MANAGING ROAD TRAFFIC CONGESTION

The framework included in this section emphasises the structural domain, which relates to the road traffic system. A conceptual framework is an analytical tool that logically incorporates numerous variations and contexts of a concept to grasp a process that can provide the most probable and appropriate explanation of the subject at hand (Kumar & Rao, 2015; Shad, Lai, Fatt, Klemeš & Bokhari, 2019; Shackleton *et al.*, 2019). A conceptual framework is used to create distinctions and arrange ideas, and can be applied in different work classifications where a complete picture is needed (Casula, Rangarajan & Shields, 2021; Peeters *et al.*, 2019; Ullah, 2021).

Jabareen (2009: 51) indicated that “A conceptual framework is simply not an assortment of ideas but, fairly, a representation of the researcher's synthesis of the literature on clarifying a phenomenon in which each interpretation plays an integral role”. Jacobs and Wright (2018) asserted that a conceptual framework is an arranged structural designed that the researcher presumes can mainly describe the natural progression of the phenomenon to be studied.

Through a narrative review of the literature, a generic conceptual framework was developed in collaboration with synthesised evidence of the peak periods for road traffic congestion, problems contributing to road traffic congestion, the supportive policies and regulations impacting road traffic congestion and strategies for managing road traffic congestion. Motivated by the literature review, this conceptual framework provides a step-wise roadmap for managing road traffic congestion.

As discussed, Figure 3.2 below presents the conceptual framework of road traffic congestion management.

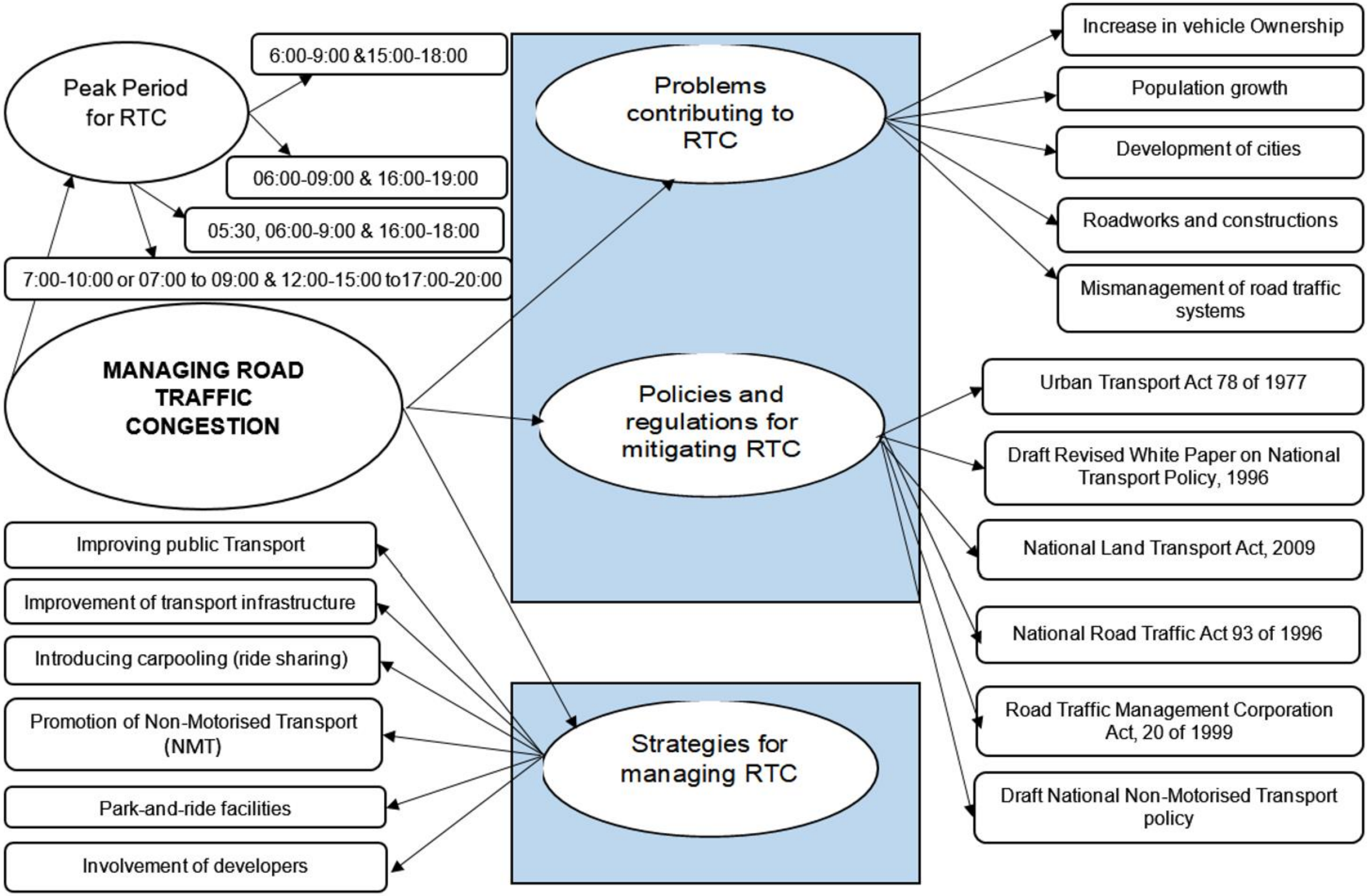


Figure 3.2: Conceptual framework for managing road traffic congestion

Source: Researcher's compilation

3.6 CONCLUSION

This chapter reviewed the literature on urban transport in South Africa. The chapter started with a historical overview of urban transport and the classifications of urban transport systems available in the country. The literature discussion progressed with a discussion of road traffic congestion and the categories of road traffic congestion. The study introduced a discussion of the key factors such as peak period, problems, supporting policies and regulations impacting road traffic congestion and strategies for managing traffic congestion. The chapter concluded with a summary of the instruments and the conceptual framework for managing road traffic congestion. The next chapter discusses the research methodology used in the study.

CHAPTER 4:
RESEARCH METHODOLOGY AND DESIGN

4.1 INTRODUCTION

This chapter outlines the research methodology and design adopted for the current study. The chapter commences with the research questions and research objectives of the study. The sections include research focus, methodological description, philosophical perspective and the mixed-method design of the study. Furthermore, the exploratory sequential mixed-method design is discussed, and the two phases of the study, namely, the qualitative and quantitative phases, were clarified.

The primary purpose of this chapter is to stipulate the direction in which the study was conducted to achieve the objectives and answer the research questions raised in Chapter 1 of the study. The chapter proceeds with a discussion of the ethical considerations, credibility and trustworthiness, limitations of the study, and the research process followed in the research study.

Figure 4.1 below shows the structural flow Chapter 4.

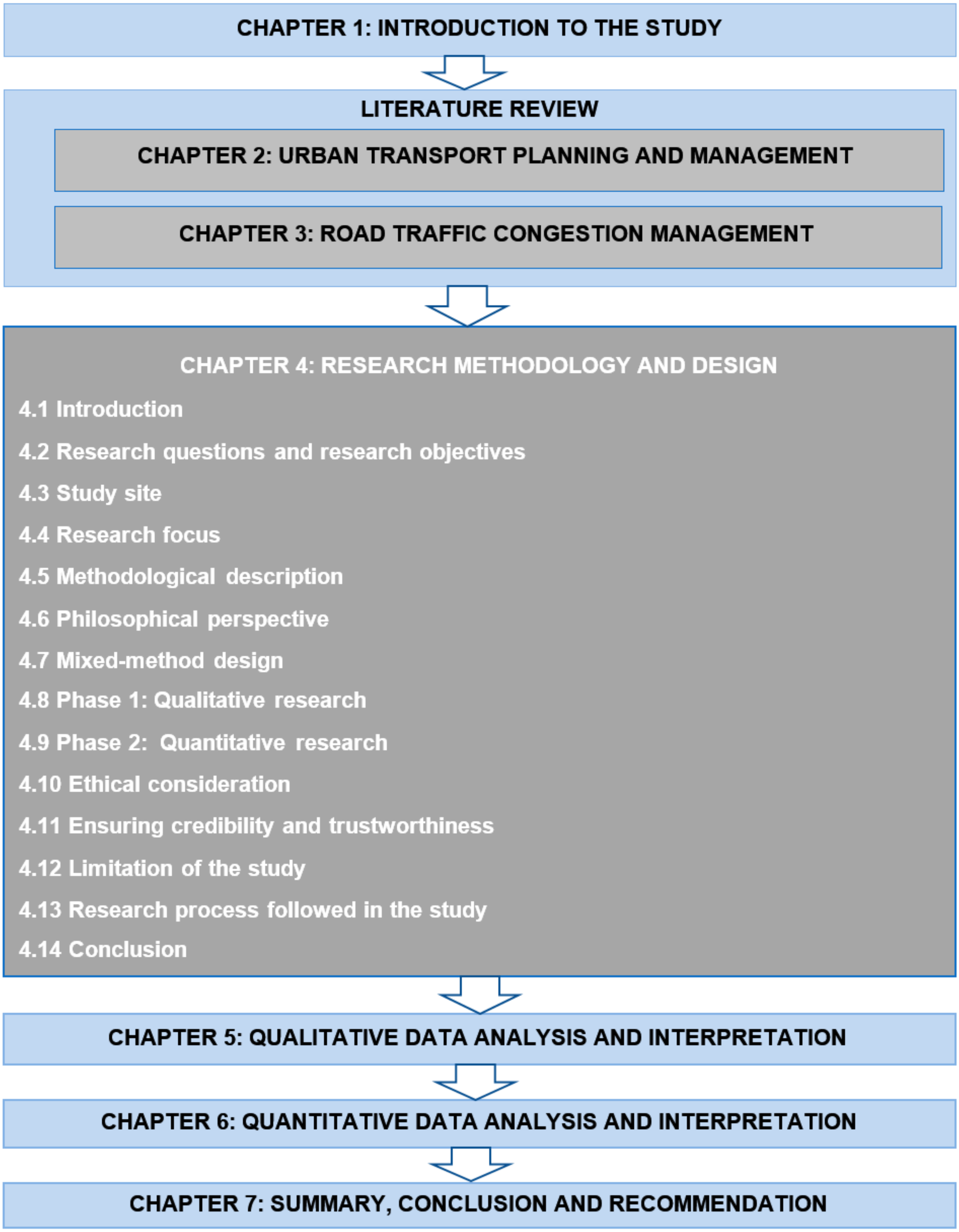


Figure 4.1: Structural flow of Chapter 4 in alignment with the study

Source: Researcher's compilation

4.2 RESEARCH QUESTIONS AND RESEARCH OBJECTIVES

Sections 1.3 and 1.4 in Chapter 1 presented the research problem, research question, and primary and secondary objectives. The primary research approach that was adopted to conduct research related to Allandale Road (M39) is the focus of this chapter.

4.2.1 Research questions

According to Jansen (2016:5), “A research question with flair or panache is therefore provocative, interesting, current and stimulating”. To that end, the research questions that were formulated for the current study are clear and well designed.

Questions asked for the research study should link with established theory and research, and potentially contribute to knowledge (Bryman *et al.*, 2021). The three categories of how research questions are formulated, as stated by Jansen (2016), are as follows:

- **Descriptive questions** – are significant for establishing the subject the researcher is investigating. These types of questions assist in accomplishing more explicit pictures about the topic at hand and comprise “how” and “what” questions.
- **Explanatory questions** – mainly, these questions are formed or created to describe the causes of the problem identified and include the “why” types of questions.
- **Exploratory questions** – in these questions, the nature of the problem might not be known so far, but the researcher could conduct initial limited research before introducing a comprehensive long-term research study.

The main research question that directed the study was: How is road traffic congestion at Allandale Road (M39), Midrand, South Africa, managed? The secondary research questions were stated as follows:

- Which peak periods of road traffic congestion exist on Allandale Road (M39)?
- Which problems contribute to the traffic congestion that users on Allandale Road (M39) experience daily?
- What are the supportive policies and regulations impacting road traffic congestion?

- What are the strategies used for managing road traffic congestion within this urban area?

4.2.2 Research objectives

The study's primary objective was to determine how road traffic congestion on Allandale Road (M39) in Midrand, South Africa, is managed. In order to achieve the primary objective, the secondary objectives as stated below were followed:

- To determine the peak periods of road traffic congestion on Allandale Road (M39).
- To establish the problems contributing to traffic congestion that users on Allandale Road (M39) experience daily.
- To identify the supporting policies and regulations impacting road traffic congestion.
- To explore the strategies used for managing road traffic congestion within this urban area.
- To make suggestions and recommendations for Allandale Road (M39) users in a way that will overcome traffic congestion.

The chapter begins with a discussion of the study site (Allandale Road, M39), where the primary data was collected. The methodology and research design were also followed to achieve the answers to the research questions that were found to attain the primary objectives.

4.3 STUDY SITE

Midrand is situated between Pretoria and Johannesburg in Gauteng, South Africa. The site lies within the traffic flowing between these two cities. Midrand has some of the busiest roads in the region, and one of them is Allandale Road (M39) which passes from the east to the south-east direction into the southern suburbs of the area. Figure 4.2 presents a map of the Midrand area.

Figure 4.2: Map of Midrand in Gauteng

Source: https://www.pinterest.com/pin/516788125985734990/

4.4 RESEARCH FOCUS

The intent of the study was to gain an understanding of the road traffic congestion in one of Gauteng's most dense and congested roads in Midrand, South Africa. Since the study followed an exploratory sequential mixed-method design, the purpose of this design was to collect the qualitative data first and then develop an understanding of the quantitative results with in-depth qualitative data (Creswell & Clark, 2017).

The following research question guided the study: "How can road traffic congestion on Allandale Road (M39) in Midrand, South Africa, be managed"? The section below will discuss the methodological approach followed in the study.

4.5 METHODOLOGICAL APPROACH

Mixed-methods research is the type of research in which the researcher merges both quantitative and qualitative research approaches into one research project (Creswell & Clark, 2017; Bryman *et al.*, 2014). The mixed research approach focuses mainly on collecting original data based on the strength of the qualitative and quantitative research methods (Kumar, 2014).

Since the current study focused on collecting data from the government officials dealing with roads and transport, and also private vehicle drivers, the research method that was selected was to conduct a survey where the questions were specific, narrow and quick to complete (Maree, 2017). However, for the purposes of the current study, both the qualitative and quantitative approaches were selected because the researcher could not rely on the findings from just a single method. The current study needed to complement the findings with the themes extracted from other research approaches, to deliver thorough responses to all the research questions (Bryman *et al.,* 2014). A further reason for the choice of the mixed-method approach is that the use of multiple approaches is able to develop a more comprehensive picture of the circumstances than a single approach can (Kumar, 2014).

Mixed research methods comprise two types of research methods, as presented in Table 4.1

Table 4.1: Two types of research methods

TYPE OF METHOD	RESEARCH PHILOSOPHY	RESEARCH APPROACH	CHARACTERISTICS	RESEARCH STRATEGIES
Qualitative research	Qualitative research presents interpretive data and emphasises exploring and identifying the respondents' meaning, articulated within the social problem being studied. Based on this method, data analysis is predominantly built inductively from specific to overall themes.	The majority of qualitative research is often portrayed by an emerging design, where the progression of the research includes emerging questions and procedures and commences with the inductive approach.	Qualitative research investigates the relationships between the individuals and meanings, using different data collection techniques such as interviews, observation, documents and audio-visual instruments.	Research strategies commonly applied in the qualitative research approach are narrative research consisting of open-ended questions, ethnography with text, image analysis, case studies, and action research.
Quantitative research	The research approach is commonly connected with positivism, particularly when using data collection techniques that are highly structured and predetermined.	The research approach used within this method is related to the deductive approach. The concentration is on testing objective theories, where the emphasis is on determining the measurement of attitude, knowledge and opinions.	The analysis is usually based on the relationship between the variables, and can be measured numerically using instrument-based questions to analyse data for statistical procedures. The methodology frequently employs probability sampling techniques and can generalise and replicate the findings.	Experimental and survey research strategies are involved, where the research study can be conducted using questionnaires and structured interviews.
Mixed research	The mixed research method concentrated on both realism and pragmatism research	Multiple research approaches may be implemented, either inductive or deductive	The researcher can choose whether to apply a qualitative approach to collect data using in-depth	Research strategies required within the mixed research method include concurrent triangulation,

TYPE OF METHOD	RESEARCH PHILOSOPHY	RESEARCH APPROACH	CHARACTERISTICS	RESEARCH STRATEGIES
	philosophies. These constitute the approach based on theory and practice. The combination of qualitative and quantitative creates a better understanding of the problem within the research environment than an isolated approach.	approaches. Both methods could be used to examine theoretical propositions to specify the accurate pathway for the research study.	interviews and diary accounts. Both open-ended and closed-ended questions are involved.	concurrent embedded, sequential explanatory and sequential exploratory strategies. All data types from both approaches are relevant.

Source: Christensen *et al.*, 2015; Creswell, 2014; Leedy & Ormrod, 2013; Cooper &Schindler, 2008; Saunders *et al.*, 2012

Just as the researcher adopts a specific worldview and philosophical perspective that provide a foundation for the qualitative and quantitative research, the researcher who undertakes a mixed-methods study is guided by philosophical assumptions that inform how they design and conduct their research study. The following section discusses the philosophical perspective adopted in the current study.

4.6 PHILOSOPHICAL PERSPECTIVE

There are four different types of paradigms, or research traditions, through which the study can flow: pragmatism, positivism, realism and interpretivism (Bougie & Sekaran, 2020; Du Plooy-Cilliers, 2014).

The current study followed a well-designed research approach with numerous phases to achieve a broad conclusion regarding the subject under investigation. A research paradigm can be described as the research traditions or worldviews, organising principle of theory, and the conviction that guides the way reality is interpreted, and it further produces a set of practices (Aliyu, Bello, Kasim & Martin, 2014; Du Plooy-Cilliers, 2014).

To achieve the required results, the current study explored the research paradigms used in qualitative and quantitative research methods (Saunders *et al.*, 2019; Ivankova, Creswell & Plano Clark, 2016). Table 4.2 below presents the research philosophies employed for the study.

Table 4.2: Research philosophies employed for the study

Research philosophy	Positivism	Interpretivism
Ontology	The researcher and reality are peripheral, separate, and independent of social actors.	The researcher and reality are socially constructed. Reality is fluid, subjective, and created by human interaction.
Epistemology	Only valid knowledge can produce credible data through empirical observation where objective reality exists.	Focusing on the situation's details and common sense is a crucial source of knowledge.
Theoretical perspective	Theories are built by predicting the effects, and consequently, act, manipulate or control phenomena.	Theories are constructed from diverse realities, and generate a thorough understanding of other people's realities.
Methodology	Reliability is crucial. Quantitative data was utilised.	Qualitative data was used.
Reason for research	To find out about the causal relationship to predict control events.	To comprehend and elucidate meaningful social action and experiences.

Source: Saunders *et al.*, 2019; Du Plooy-Cilliers, 2014; Pardede, 2018

For the purposes of the current study, the researcher followed the positivism and interpretivism or constructivism research paradigms, as indicated in Table 4.2 above. The selected research philosophies would allow the study to collect adequate credible and convincing data regarding the road traffic congestion on Allandale Road (M39) in Midrand. The following section describes the mixed-method research design followed in the study.

4.7 MIXED-METHOD DESIGN

The current study followed an exploratory sequential mixed-method design. This type of design comprises two different phases. This section discusses the diverse research design types found in mixed-method research (Halcomb & Hickman, 2015).

According to Kumar (2014:123), the research design is a plan, structure and investigation strategy through which the researcher decides what study design to use to answer research questions or problems. Table 4.3 presents the different types of research strategies that are found in mixed-method research design.

Table 4.3: Types of mixed-method design

Types of mixed-method design	Implementation	Priority	Stages of integration	Theoretical perspective
Explanatory sequential mixed-method design	Quantitative followed by qualitative	Quantitative normally dominates.	Interpretation phase.	Absolutely present.
Exploratory sequential mixed-method design	Qualitative followed by quantitative.	Qualitative dominate.	Interpretation phase.	May possibly be present.
Concurrent triangulation	Concurrent collection of quantitative and qualitative	Preferably equal; phase can be quantitative or qualitative	Analysis phase.	Absolutely present.
Concurrent transformative	Collection of quantitative and qualitative	Quantitative, qualitative or equal	Mostly analysis phase: can be during the interpretation phase.	Absolutely present.
Concurrent nested	Collection of quantitative (qualitative) or qualitative (quantitative)	It can be either qualitative or quantitative dominant.	Analysis phase.	May possibly be present.

Source: Halcomb & Hickman, 2015; Creswell, 2014

As highlighted in Table 4.3 above, an exploratory sequential mixed-method design begins with the collection and analysis of qualitative data, followed by a second phase in which quantitative data is collected and analysed. The section below discusses the exploratory sequential mixed-method design in detail.

4.7.1 Exploratory sequential mixed-method design

Based on the comparisons stated in Table 4.3 above, the current study followed an exploratory sequential mixed-method research design. Exploratory sequential mixed-method research design is a "mixed-methods design that involves a two-phased project in which the researcher collects qualitative data firstly then proceeds on building up on the database the second quantitative data collection and analysis" (Creswell, 2014:226).

The researcher selected this design for the current study because this strategy initially investigates a topic by pinpointing qualitative themes and producing theories and uses that explore and guide the quantitative findings, including theory testing, testing of new measures and measurement of new variables (Creswell & Plano Clark, 2018). Therefore, the researcher followed the selected strategy, as the appropriate constructs and measurement of crucial variables in the current study are unknown (Ivankova *et al.*, 2016).

The research design addresses how the researcher will proceed with the research process from the moment the questions are formulated, to when the information is collected, up to the end, where the data will be analysed (Davis, 2014).

Although there are numerous strengths of the exploratory sequential mixed-method design, Creswell and Plano Clark (2018) indicated some challenges that the design can present for the researcher:

- **Time**: The designing, implementing and writing of two separate phases in the same study take more time than carrying out one phase.
- **Teamwork**: Since the researcher utilises the findings from the qualitative phase to find out how to select participants for the quantitative phase, it might be challenging to obtain urgent information from the senior government officials from all three spheres of government.

- **Sampling issues**: The researcher must determine which participants will be part of the sample in the second phase of the study, and what criteria will be used to select the participants.
- **Analytic and interpretive issues**: While completing the coding and analysis of data, the researcher decides which qualitative results require further explanation and follow-up until the quantitative phase is completed.

The procedures of the exploratory sequential mixed-method research design are outlined in the schematic presentation in Figure 4.3 below.

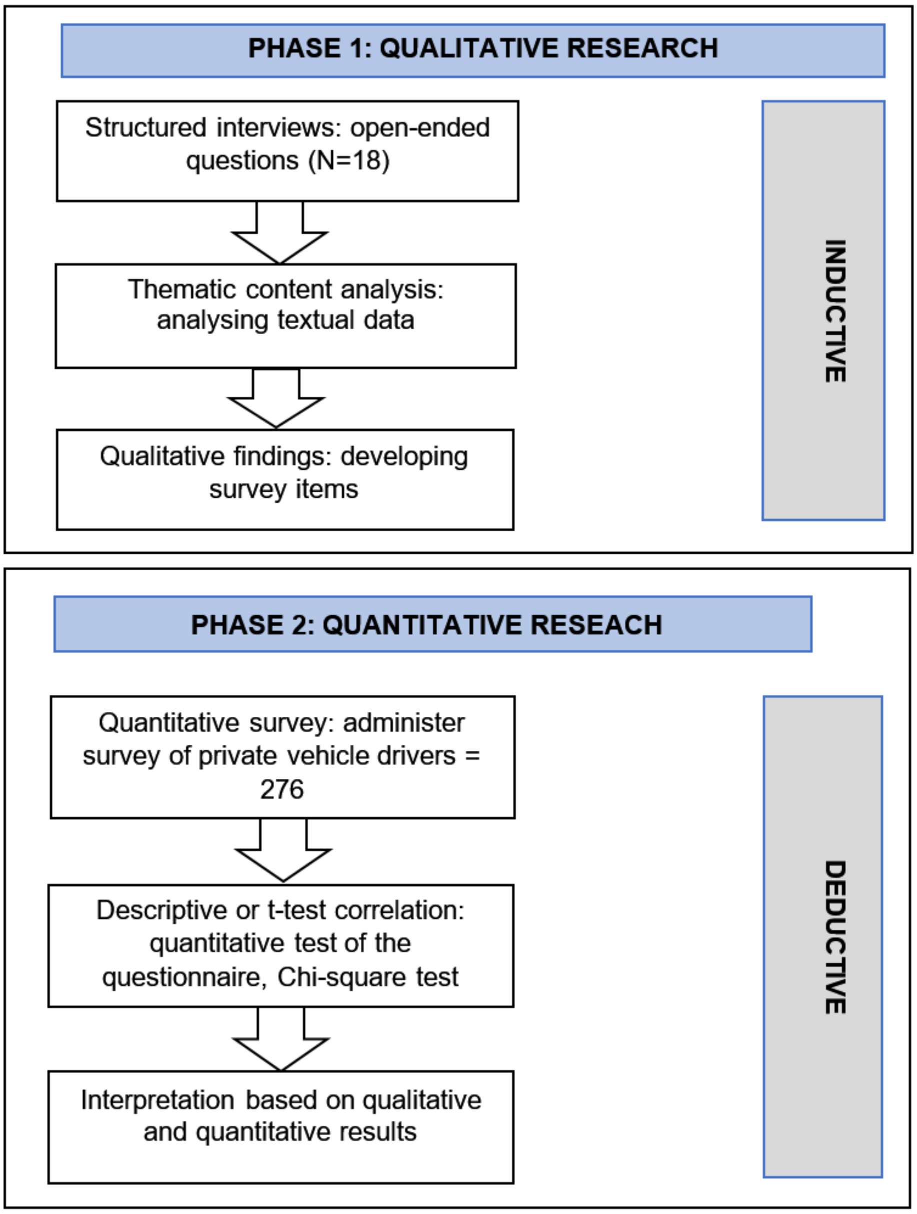


Figure 4.3: Phases of exploratory sequential mixed-method research design

Source: Adapted from: Nell, 2014; Creswell, 2014; Ivankova *et al.,* 2016

As illustrated in the above figure, the current study used the qualitative data to clarify the quantitative data, which focused on explaining the results. Guetterman, Fetter and Creswell (2015) indicated that each phase is conducted separately. The data from the first phase is collected and analysed before the second phase commences with the quantitative data collection.

For the purposes of the current study, the data was linked sequentially as the quantitative data (second database) was constructed on the qualitative findings (initial database) (Shiyanbola *et al.*, 2021; Creswell, 2014). Shiyanbola *et al.* (2021) stated that an exploratory sequential mixed-method design uses the "building approach", which involves using the data from one phase to inform the data collection approach of the second phase. The next sections discuss the phases employed in the study.

4.8 PHASE 1: QUALITATIVE RESEARCH

The purpose of the qualitative phase was to interview the selected participants, namely, senior staff members with more than three (3) years of experience in the various roads and transport government entities and agencies. The aim was to collect the data and further build the survey for the quantitative phase. The aim was also to gain an in-depth understanding of the participant's decision-making processes (Creswell & Plano Clark, 2018) that resulted in the management of road traffic congestion on Allandale Road (M39), in Midrand. The subsections below discuss the population and sample employed in the study.

4.8.1 Population and sample

This section discusses the targeted population and sample used in the study.

4.8.1.1 Target population

A population is the total units consisting of the people, entities and other things, that include the traits or descriptions from whom the information that the researcher is interested in can be obtained (Kayton, 2011:121; Wiid & Diggines 2013:186). Although any research study would prefer to include the entire applicable population for the interviews, it would not be possible and realistic (Quinlan, 2011).

The targeted population of the current study were the senior staff members in the roads and transport sector under the government entities of Gauteng. The three spheres of the government include the national entities, provincial agencies and the regional department that deals with roads and transport issues. The study targeted the national, provincial and regional departments, which included four (3) entities. The first entity had a population size of more than 10 0001 employees; the second one had 484 employees, and the third one had 164 employees.

4.8.1.2 Sampling of the study

Sampling is the process employed by a researcher to systematically select a relatively more minor number of representative items or individuals from a pre-defined population to serve as the data source for observation or experimentation as per the objectives of the research study (Sharma, 2017; Taherdoost, 2016). According to Bougie and Sekaran (2020), a sample is a subgroup or subset of the population, and through studying the sample, the researchers should be able to draw conclusions that are generalisable to the population of interest.

The participant selection for the first phase of the current study, the initial qualitative phase, occurred in different ways. Consistent with the exploratory sequential mixed-method design, the researcher purposefully or judgementally selected 18 senior staff members from the government entities associated with the roads and transport sector to be participants in the current study. The researcher assumed that since these entities included, and some were the agencies in the transportation sector dealing with road traffic management from the three spheres of government, they would have many participants from whom the sample could be selected for the interviews.

The Unisa CEMS research ethics committee approved the study. The informed consent forms were signed and obtained from all the participants who agreed to participate in the study (see Appendix E). The participants chosen for the study obtained approval from their workplaces to participate in the study (see Appendix E). The participants were closely involved with road traffic and safety, traffic engineering, transportation planning and development in the roads and transport sector.

4.8.1.3 Sampling techniques

The study used two main sampling techniques. Generally, Faasen (2021) indicated that sampling could be divided into two basic approaches, as briefly discussed below:

Probability sampling: Probability sampling is a sample that has been selected using random selection, so that each unit in the population has a known chance of being selected (Bryman & Bell, 2015: 123). According to Faasen (2021), a representative sample is more likely to result when this selection method is used.

Non-probability sampling: According to Bryman and Bell (2018), non-probability sampling is a method in which not all population members have an equal chance of participating in the study. When using a non-probability sample, there would be no random selection of the population elements, which denotes that specific units in the population are more likely to be selected than others (Maree & Pietersen, 2017: 197).

In Phase 1, the qualitative research, the study applied non-probability sampling. However, according to Taherdoost (2016), non-probability sampling is often associated with qualitative and case study research design. Although the non-probability sampling technique is a branch of sample selection that uses non-random ways to select a group of people, the method also includes the following:

Convenience sampling: Convenience sampling involves using participants who are appropriate and accessible to the researcher (Faasen, 2021). In this technique, the researcher uses the first available primary data source for the research without additional requirements, and uses no pattern of any kind in acquiring these respondents. The respondents may be conscripted simply by requesting individuals who are present in the public spaces, buildings or in a workplace (Alvinius, Holmberg & Larsson, 2018).

Purposive sampling: Hong and Cross Francis (2020) indicated that purposive sampling is the premeditated choice of informants based on their ability to explicate a precise theme, perception, or experience. This type of the technique is selected based on the personalities of a population and the unbiased nature of the study (Klar & Leeper, 2019).

Snowball sampling: Snowball sampling or chain-referral sampling is defined “as a non-probability sampling technique in which the samples have traits that are rare to find” (Geddes, Parker & Scott, 2018:352). This technique is regarded as a selection technique in which research participants are asked to assist researchers in identifying other potential subjects (Parker, Scott & Geddes, 2019).

Quota sampling: Chen, Masiero and Hsu (2019) described quota sampling as a sampling methodology wherein data is collected from a homogeneous group. This technique generally involves a two-step process where two variables can be used to filter information from the population. It can easily be administered and helps to makes quick comparisons (Guirado *et al.,* 2019). Researchers in this regard will form a sample of individuals who are representatives of a larger population.

In the qualitative phase (Phase 1), purposive sampling was used to select the exact size of 18 participants involved in the transportation sector dealing with roads and transport from the three spheres of government. The participants were chosen intentionally using this sampling technique because of their potential to supply the appropriate information (MacMillan & Schumacher, 2014).

The researcher had to extract opinions from the diverse stakeholders in the transport sector. This process would provide in-depth knowledge of how the traffic congestion on Allandale Road (M39) can be managed. The entire process required individuals who understood the transport planning and development, and who worked in the environment and participated in transport (Etikan, Musa & Alkassim, 2016).

4.8.1.4 Sampling frame

A sampling frame can be described as the list of all the items in the population that the researcher requires to study, and from which the sample will be chosen (Bryman *et al.*, 2014). In order for the researcher to select or decide on a sampling frame, the individuals or the units on the list must correspond with the characteristics of the population (Pascoe, 2014).

The next section discusses the research instrument that was used in the current study.

4.8.2 Research instrument

According to Saunders *et al.* (2012), interviews can be used to assist the researcher in refining the opinions, specifically in situations where the researcher has not yet prepared the research questions and objectives properly. Structured interviews consist of questions with impartially specific topics, and are usually called interview guides (Bryman *et al.*, 2014). The researcher included open-ended questions in the interview guide (see Appendix A). Table 4.4 below presents the research questions used in the study.

Table 4.4: Alignment of research questions to interview questions

RESEARCH QUESTIONS (RQ)	INTERVIEW QUESTIONS (IQ)
RQ1: Which peak period of traffic congestion exists on Allandale Road (M39) compared to other areas?	**IQ1**: Kindly identify roads or streets in Midrand that are congested. **IQ2**: Which other roads or streets around Midrand that you know of, are also congested? **IQ3**: What are the peak periods of road traffic congestion on Allandale Road (M39)?
RQ2: What problems contribute to the traffic congestion that users on Allandale Road (M39) experience daily?	**IQ4**: Would you identify problems that form the underlying contribution of the road traffic congestion on Allandale Road (M39)?
RQ3: What are the supportive policies and regulations that have impact on managing road traffic congestion?	**IQ5**: What are the supportive policies or Acts that have an impact when managing road traffic congestion? **IQ6**: What are the supportive regulations that have an impact when managing road traffic congestion?
RQ4: What strategies are used to manage road traffic congestion within urban areas such as Midrand?	**IQ7**: Can you identify the key strategies that are used to manage road traffic congestion on Allandale Road (M39)? **IQ8**: Which strategies are lacking and still required to manage road traffic congestion on Allandale Road (M39)?

Sources: (Researcher's compilation)

Table 4.4 above describes the alignment of the research questions to the interview questions used in the study.

4.8.3 Data collection and analysis

To collect the qualitative data for the study, the researcher conducted face-to-face interviews using open-ended questions related to the study's research question: *How is road traffic congestion at Allandale Road (M39), Midrand, South Africa, managed?*

Structured interviews consist of questions with impartially specific topics to be covered, and are usually called interview guides (Bryman *et al.*, 2014).

4.8.3.1 Data collection

Data collection is the gathering and measuring of information on variables of interest in an established systematic fashion that enables the researcher to answer stated research questions, test hypotheses, and evaluate outcomes (Bougie & Sekaran, 2020). According to Salkind (2014), the data can be collected in two ways, from primary and secondary sources, as discussed below.

Primary data sources: The primary data may be qualitative or quantitative, and the collection of data in this method can be done through personal and telephone interviews, observations, self or group-administered questionnaires and web-based surveys (Blumberg, 2014:212; Mouton, 2003:71). Primary data can be described as the information the researcher accumulated from the initial source (Quinlan, 2011).

For the current study, the primary data was collected through face-to-face structured interviews. The participants were interviewed individually in their offices. The researcher preferred to use the place the participants were familiar with to avoid awkwardness or discomfort during the interview process. In the process, the participant was requested to provide their consent to the recording. The audio recordings of the interview sessions were transcribed using Microsoft Word.

Secondary data sources: Secondary sources can be classified as the current information and divided into three groups, including raw data previously collected, such as traffic counts, conference proceedings, concise figures, academic journal articles, written books and newspapers, theses and dissertations, and government documents (Struwig & Stead, 2011:80; Mouton, 2003:7).

For the purposes of the current study, the researcher used academic journal articles, government reports, and prescribed books to compile the literature review and acquire more comprehension of road traffic congestion. The following subsection discusses the access to the research sites used in the study.

Access to the research sites

The three organisations were contacted by telephone requesting permission to conduct the interview. They all asked for a formal requisition letter, which was finally issued. The permission letters indicated that the gatekeepers had permitted the researcher to proceed with the data collection (see Appendix E for the permission letters). All the participants who were approved for participation in the interviews were provided with the participant information sheet and the consent form. The ethical clearance certificate was made available before the commencement of the interview sessions.

Schedule of the interview sessions

An interview is a qualitative research method that relies on asking questions in order to collect data. Interviews involve two or more people, one of whom is the interviewer asking the questions. The interviews also allowed the participants to express their narratives or sequence of events, involvements, perceptions, viewpoints and decisions about the management of road traffic congestion.

The researcher scheduled the interviews on different dates and times based on the availability of the participants. Table 4.5 presents the interview schedule that took place during the data collection of the qualitative phase.

Table 4.5: Interview schedule for the participant in the qualitative phase

DEPARTMENT NO.	PARTICIPANT NO.	POSITION	MONTH OF INTERVIEW	NO. OF YEARS IN THE ORGANISATION
Department No. 1	Participant 4	Law enforcement: Traffic officer	October 2018	12 years
	Participant 6	Transport researcher	October 2018	5 years
	Participant 7	Rural transportation strategic planner	October 2018	10 years
	Participant 9	Road transportation engineer	October 2018	35 years
	Participant 10	Transportation researcher	October 2018	6 years
	Participant 11	Law enforcement: Traffic officer	October 2018	8 years
	Participant 13	Road transport engineer	October 2018	11years
	Participant 14	Road transport engineer	October 2018	12 years
	Participant 17	Road transport engineer	October 2018	11 years
Department No. 2	Participant 1	Traffic engineer	February 2019	32 years
	Participant 2	Traffic engineer	February 2019	24 years

DEPARTMENT NO.	PARTICIPANT NO.	POSITION	MONTH OF INTERVIEW	NO. OF YEARS IN THE ORGANISATION
	Participant 5	Traffic engineer	February 2019	29 years
	Participant 8	Traffic engineer	February 2019	8 years
Department No. 3	Participant 15	Traffic engineer	August 2019	15 years
	Participant 3	Traffic engineer	August 2019	12 years
	Participant 12	Traffic engineer	August 2019	17 years
	Participant 16	Traffic engineer	August 2019	14 years
	Participant 18	Traffic engineer	August 2019	8-9 years

Sources: Researcher's compilation

As seen in the above table, the participants were allocated designated appellations for confidentiality, and this was done according to the sequence of the e-mail responses received for the scheduling of the appointment. For example, Department 1 included Participant 4, although Department 2 included Participants 1 and 2, and Department 3 included Participant 3.

Due to work commitments some of the participants were unable to fulfil their appointment on time, as shown in the above table (data was collected from October 2018 until August 2019). The participants were always not available, and some had international trips which prevented the session from taking place as scheduled.

The subsections below present the data analysis and coding that were used in the study.

4.8.3.2 Data analysis and coding:

Data processing can be described as the process of collecting and manipulating the items of data, especially through the use of computer software, to retrieve, transform, or classify information to extract the required information in an appropriate form of diagrams, reports or tables (Cooper & Schindler, 2008:415; Kumar, 2005:220).

Data analysis: The data analysis process assists the researcher to become familiar with the raw data. According to Leedy and Ormrod (2014), the data analysis process involves familiarisation with the initial data, reflecting on and combining the raw data, which results in the process of grouping, code generation, searching for and reviewing, and defining and naming the themes.

Data coding. Data coding can be described as arranging the data into the appropriate categories (Struwig & Stead, 2011:150). According to Bryman *et al.* (2014:336), coding indicates that the coded data will not be displayed in the original arrangement but will be converted and produced by the researcher. One of the crucial rules for coding the data includes "the usage of codes that are as reduced in clutter and as unambiguous in meaning as possible without losing the true meaning of the data" (Van Zyl, 2014:159). The characteristics that the researcher has to consider when editing and coding the data is that the editing and encoding processes have to be appropriately planned (Struwig & Stead, 2011: 150).

In this research study, the researcher, with the assistance of the transcriber and data co-coder, analysed and coded the data using Atlas. ti. The researcher hired an experienced co-coder to assist in coding the data from a different perspective. After the completion, the researcher and the co-coder had a meeting to compare the coded data and see if the information corresponded. Adjustments were made to some themes for alignment.

The next section discusses the second phase (quantitative research) of the research.

4.9 PHASE 2: QUANTITATIVE RESEARCH

The purpose of the quantitative phase of the current study was to collect the demographic data of the private vehicle drivers, and the initial information related to the experiences of the road traffic congestion on Allandale Road (M39).

The collection of this data allowed the presentation of descriptive and inferential statistics about the peak periods of traffic congestion, problems contributing to road traffic congestion, policies and regulations impacting road traffic congestion and the strategies for managing road traffic congestion. The data assisted in answering the overarching research question of the study: "How can road traffic congestion on Allandale Road (M39) in Midrand, South Africa, be managed"?

4.9.1 Population and sampling

As soon as the selection of the research design has been finalised, the researcher should consider from whom the data collection will be collected (Moutinho, 2000:93). The section below discusses the overall procedure for selecting the sample from within the target population.

4.9.1.1 Population of the study

According to Cooper and Schindler (2014), the population indicates the entire group of individuals or objects known to have similar characteristics, and about whom the researcher is willing to draw conclusions (refer to the definition in Section 4.8.1.1).

The South African Learner Driver Manual describes a driver as “any person who drives or attempts to drive any vehicle or who rides or attempts to ride any pedal cycle or who leads any draught, pack or saddle animal or herd or a flock of animals, and “drive”, or any like word has a corresponding meaning” (DoT, 2012:3). The target population for the present study was private vehicle drivers who used Allandale Road (M39) in the morning and afternoon from Monday to Friday. Allandale Road (M39) was selected as the appropriate location about which data could be collected. The motives for choosing this specific road were:

- The development of the Waterfall area is currently taking place, and more corporations are relocating to the zone. Eventually, all the companies will be operating, which will require people to travel there daily, whether for business or employment.
- The Gautrain rapid rail system was implemented between Pretoria and Johannesburg, including the assistance of bus feeder services to reduce the road traffic congestion in Midrand areas. However, the traffic is still increasing on Allandale Road (M39).
- An educational institution, Eduvos (previously known as Pearson's Institute of Higher Education), was extended to include more buildings, showing that the institution is gaining in popularity, as there are additional students willing to study through this institution.

- The area comprises the shopping centre, the Mall of Africa, which was finalised in April 2016, and more people are flowing to the mall to do shopping and for other entertainment.

As the population was broad, the researcher could not study the whole population and only selected a sample to represent the entire population. In that way, the sample, which is a subsection of the group within the population, can be chosen to represent the whole population to generalise the results of the research study (Salkind, 2014:95).

4.9.1.2 Sampling of the study

Sampling means the researcher will select a group from data will be collected in the research (refer to the definition in Section 4.8.1.2). According to Saunders *et al.* (2016:274), sampling affords an acceptable census when it would be impossible for the researcher to conduct research on the entire population through obstructions such as the nature of the research problem, budget and time constraints. Faasen (2021) indicated two basic approaches to sampling, namely probability and non-probability sampling (refer to the sampling techniques in Section 4.8.1.3).

In Phase 2 (quantitative research), the study applied probability sampling. The researcher was required to produce results from representatives of the whole population of private vehicle drivers, and perceived this technique as the most valid choice (Etikan & Bala, 2017). According to Bryman and Bell (2018), the following four types of the probability sampling techniques can be found in research:

Simple random sample:

The simple random sample is regarded as the most accessible type of probability sampling method since each individual or case of the population has an equal probability of inclusion in the sample (Bryman & Bell, 2018; De Vos, Strydom, Fouché & Delport, 2018:228). This method has a decision where every single member of the population has an evenly balanced chance of being selected (Sharma, 2017).

Systematic sample:

Systematic sampling is where every *nth* case after a random start is selected. Faasen (2021:215) stated that systematic sampling is a variation of simple random sampling, where the researcher begins with a random number and then selects every *nth* record directly from the sampling frame. The manner in which the systematic sample is drawn is by systematically moving through the sample frame and selecting every *nth* element (Maree & Pietersen, 2016: 195).

Stratified random sampling:

Maree and Pietersen (2016:195) indicated that stratified random sampling is "used to address the problem of non-homogeneous populations in the sense that it attempts to represent the population much more precisely than can be done with simple random sampling". According to Taherdoost (2016), stratified sampling is when the population is divided into strata or subgroups, and a random sample is taken from each subgroup. In such a case, a subset is a natural set of items and might be based on company size, gender or occupation.

Multi-stage cluster sampling:

Bryman *et al.* (2018) specified in terms of multi-stage cluster sampling that the primary sampling unit is not the unit of the population to be sampled but groups or clusters of those units, since cluster sampling is the only way of dealing with the potential problem. Furthermore, cluster sampling is advantageous for those researchers whose subjects are fragmented over large geographical areas as it saves time and money (Davis, 2014).

Phase 2 of the current study employed simple random sampling, as indicated in the above discussion, where 276 participants were selected based on the simple random sampling technique. Probability sampling involves random selection, allowing the researcher to make solid statistical inferences about the whole group (Bryman *et al.*, 2021).

A sampling frame can be described as the list of all the items in the population that the researcher needs to study, and from which the sample will be chosen (Bryman *et al.*, 2018). In order for the researcher to select or decide on a sampling frame, the individuals or the units on the list must correspond with the characteristics of the population (Pascoe, 2014). Since there were different vehicle drivers, such as mini-bus taxis, trucks, buses and light vehicle drivers passing through Allandale Road (M39), only specific drivers were considered. The selected sample was the private vehicle drivers using Allandale Road daily. These drivers reside in the Gauteng regions, including Midrand and the surrounding areas. Their knowledge and traffic experience in terms of the site contributed to the data collection for the current research study. The section below discusses the data collection method used in the study.

4.9.2 Data collection methods

Data collection refers to the gathering and measuring of information related to the variables of interest in an established systematic fashion that enables a research study to answer stated research questions, test hypotheses, and evaluate outcomes (Saunders *et al.*, 2019). The researcher must be vigilant when collecting the data, as incorrect data may lead to invalid results and findings (Du Plooy-Cilliers & Cronje, 2014:147).

The collection of data can be performed using different kinds of data sources. Primary and secondary sources can supply data about the condition, individuals, problems and phenomena (Kumar, 2014:171). The current research study revolved around both primary and secondary methods of data collection, as illustrated in Figure 4.4.

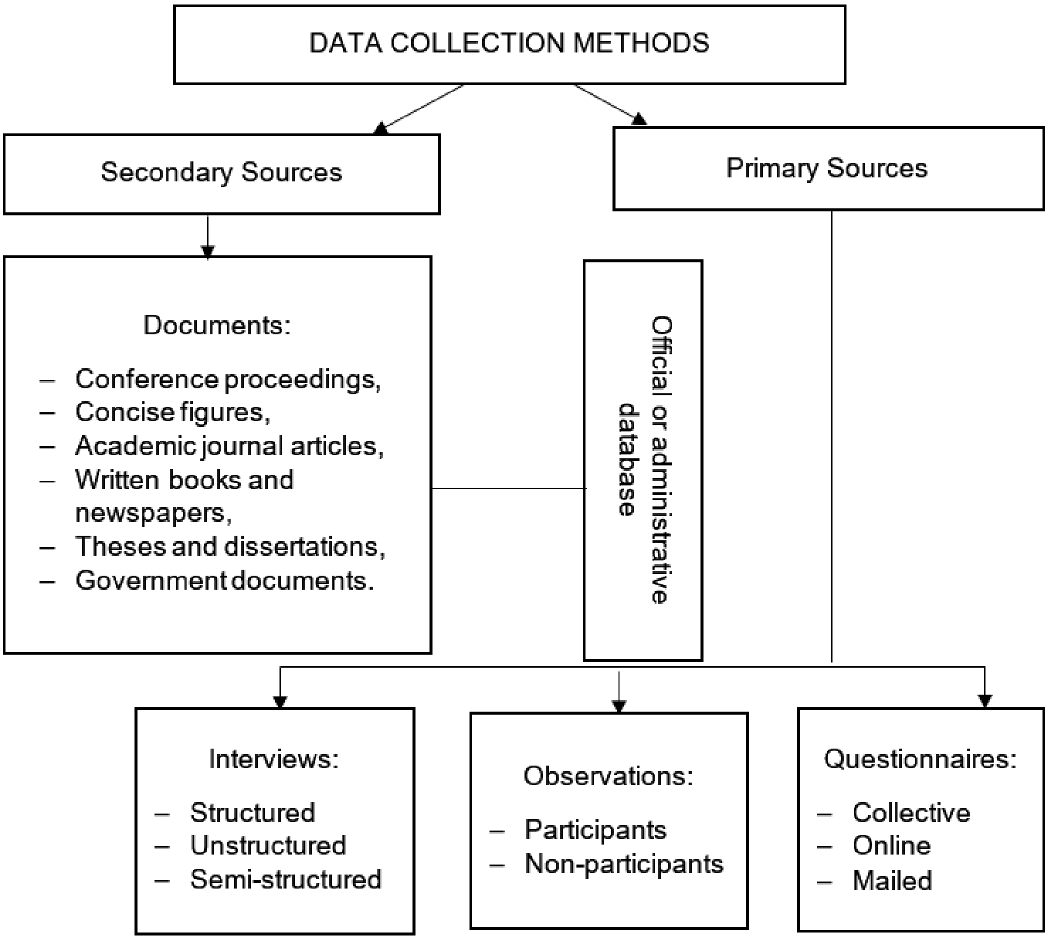


Figure 4.4: Methods of data collection

Sources: Adapted from Blumberg *et al.*, 2014; Farlex, 2012; Kumar, 2014; Saunders *et al.*, 2016

4.9.2.1 Primary data sources

(Refer to Section 4.8.3.1.) Primary sources include information that has not been collected or written somewhere else. An example of this data collection method is surveys, observations and interviews (Kumar, 2014:148).

For the current study, the primary data was collected through an online questionnaire that comprised of demographic information, a five-point Likert scale and a sequence of closed-ended questions. The questionnaire was uploaded and made available online via SurveyMonkey, a commercial online survey and the questionnaire tool. The opening statement on the questionnaire included an invitation to participate and a consent form for those willing to participate in the survey.

As explained above, the questionnaire was administered using SurveyMonkey.com, an American software company. To run through the access of the survey and ensure that the participant would have access to the online questionnaire, the researcher tested a survey link on three different devices to confirm that the responses were being saved. The testing data was deleted after the confirmation. The researcher distributed the link to the e-mail addresses, and WhatsApp groups of the estate and complex management to assist with completing the questionnaires electronically.

4.9.2.2 Secondary data sources

(Refer to Section 4.8.3.1) According to Kumar (2014:196), this type of research source transpires where another party has already collected the data and it exists as a routine for keeping the record within the company. The researcher only retrieved the data for research study purposes. Refer to Figure 4.4 for examples of secondary data collection sources. The next section discusses the research instrument and measurements used in the study.

4.9.3 Research instrument and measurements

According to Leedy and Ormrod (2014), a research instrument is a tool used to collect and measure the research data. The current study used a multiple-choice questionnaire, consisting of closed-ended and Likert scale questions. A closed-ended question is one in which a researcher provides research participants with options from which to choose a response, and the respondents have to choose from a limited number of potential answers (Taherdoost, 2016).

Closed questions may require the respondent to select from multiple response options such as multiple-choice questions, Likert scales and semantic differential scales. According to Taherdoost (2019), the type of scale may present the respondents with an ordered set from which to choose, for example, 1 to 5, coupled with anchors. Bougie and Sekaran (2020) indicated that the research instrument could be measured using four different scales. The four types of scales are discussed below.

4.9.3.1 Nominal scale

According to Maranell (2017), this type of scale authorises the researcher to allocate subjects to specific categories or groups. The nominal scale does not require using numeric values or categories ranked by class but simply unique identifiers to label each distinct type (Wallace *et al.*, 2017).

4.9.3.2 Ordinal scale

According to Borg, Groenen and Mair (2018), an ordinal scale not only assigns objects such as people, companies, countries, and products, to specific categories, but it allows the researcher to rank order the objects in some meaningful way. Ordinal scale data can be presented in tabular or graphical formats for a researcher to conveniently analyse the collected data (Greenacre, 2017).

4.9.3.3 Interval scale

In an interval or equal-interval scale, numerically equal distances on the scale, as indicated by Casper *et al.* (2020) represent similar values in the measured characteristics. According to Steinberg and Price (2020), this scale is practical as it opens doors for the statistical analysis of provided data, such as mean, median, or mode, and can be used to calculate the central tendency in this scale.

4.9.3.4 Ratio scale

According to Bonn and Cantlon (2017), the ratio scale not only measures the magnitude of the differences between points on the scale, but also taps the proportions in the differences. Mertler, Vannatta and LaVenia (2021) indicated that a ratio scale is calculated by assuming that the variables have an option for zero, the difference between the two variables is the same, and there is a specific order between the options.

For the current study, the researcher used both the ordinal and ratio scale research measurements to accommodate the closed-ended and Likert scale format questions. The questionnaire was based on the following constructs:

- **Section A**: screening questions (two items),
- **Section B**: the demographic information (eight items),
- **Section C**: the peak periods of road traffic congestion on Allandale Road (M39) (17 items),
- **Section D**: problems contributing to traffic congestion that users on Allandale Road (M39) experience daily (five items),
- **Section E**: the supporting policies and regulations impacting road traffic congestion (14 items), and
- **Section F**: the strategies used for managing road traffic congestion within this urban area (15 items).

The items included in the questionnaire were measured using the five-point Likert scale responses and the ordinal scale format ranging from 1 = strongly disagree, 2 = disagree, 3 = unsure, 4 = agree, and 5 = strongly agree. (See Appendix B.)

The following subsection will discuss the pilot test of the research instrument: used in the study.

4.9.3.5 Pilot test of the research instrument

Pilot testing is an indispensable step in structuring the research instrument (Kumar, 2014), and needs to be done before the study commences with proper data collection. The pilot survey can be described as a trial that the researcher conducts on a low quantity of participants before the definite collection of data (Christensen *et al.*, 2015). The purpose of the test is to uncover whether the participants comprehend the questions that the researcher compiled (Cooper & Schindler, 2011:89).

For the purpose of the current study, the pilot test was conducted before the questionnaire link was distributed. Ten private vehicle drivers using Allandale Road (M39) on a weekly basis from Waterfall View Estate were requested to complete the questionnaire to assess the appropriateness of the questions. Slight amendments were made to ensure proper interpretation of the questions based on the feedback received. According to Saunders *et al.* (2012), the pilot or pre-test provides the researcher with opinions to obtain judgement on a particular validation of the assessment and the possible reliability of the data that will be collected. The next section discusses the data analysis used in the study.

4.9.4 Data analysis

Data analysis can be described as examining data sets to discover helpful information to conclude the lead and support decision-making (Kumar, 2014). In analysing the data, the primary division of the statistics field, as stated in Figure 4.5 below, was followed.

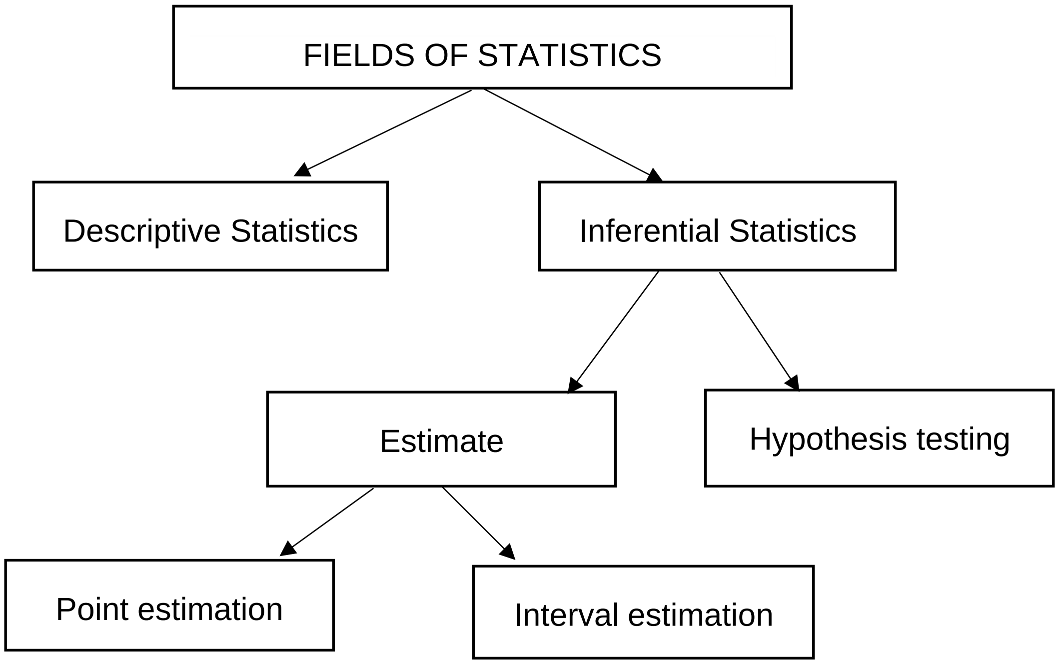


Figure 4.5: Major fields of statistics

Source: Adapted from Christensen *et al.*, 2015

When analysing data, it is imperative to consider that the process comprises various steps, such as discovering fundamental characteristics of the data set, revealing patterns within the data collected, and identifying the relationship between the data assembled and other external parameters (Khan, 2014:206). According to Quinlan (2011:365), the data analysis contains the description of the data acquired from the questionnaire, translating and extracting the assumption based on the data.

The current study used the exploratory sequential mixed-method design in the second phase that was based on quantitative research, and the data analysis encompassed descriptive and inferential statistics.

Descriptive statistics is the kind of statistical analysis that provides statistical summaries of data (Struwig & Stead, 2011:158; Van Zyl, 2014:161). According to Bickel and Lehmann (2012:465), descriptive statistics converts the data to illustrate the essential characteristics of the distribution of scores that the researcher collected, including the mean and standard deviation. The researcher used descriptive statistics to understand and summarise the numerical attributes of the data set (Christensen *et al.*, 2015:394).

Inferential statistics is the kind of statistical analysis that focuses on identifying the population differences based on the sample data (Christensen *et al.*, 2015:394). While a researcher can draw a sample from the population and make inferences about the characteristics of that population, inferential statistics can assist the researcher in generalising the research findings from the sample to the larger population (Struwig & Stead, 2011:159; Van Zyl, 2014:161). The researcher used this kind of statistical analysis to test the differences between the age group, gender, level of education, residential area and time taken on the road.

The following section will discuss the ethical concord considered in the study.

4.10 ETHICAL CONSIDERATIONS

The ethical issues that must be considered are broad and usually discovered through the research process (Creswell, 2014:92). Ethics represent the correct behaviour and addresses the moralities and procedures according to which a particular entity, community or group decides to control its behaviour based on the standards affirmed (Blumberg *et al.* 2014:121). In conducting the research study, the researcher considered the ethical issues related to human rights, such as no harm to participants, obtaining consent, ensuring privacy, avoiding deception, and the right to anonymity and confidentiality (Bryman *et al.*, 2014; Mouton, 2003:242).

In Phase 1, the qualitative data collection phase, the researcher discussed the consent form with the participant before the interview started. After the agreement was reached, the participant completed the form and handed it over to the researcher to proceed with the interview process.

During Phase 2, the quantitative data collection phase, the questionnaire link was distributed to the respondents and they were requested to complete it. Before doing so, the researcher included a message informing the respondents that completing the questionnaire was voluntary, and they had the right not to participate or withdraw if they were uncomfortable.

The researcher obtained an ethical clearance certificate for the study beforehand, provided with permission to start collecting data (see Section 4.11.3.1 for more information). The next section discusses the concepts of trustworthiness and credibility as it applied to the study.

4.11 ENSURING CREDIBILITY AND TRUSTWORTHINESS

This section briefly presents a discussion of the measures to ensure credibility and trustworthiness in research. In the research society, the credibility and trustworthiness are considered as the extreme elementary aspects of gaining confidence and trust (Chatzimparmpas *et al.,* 2020).

4.11.1 Credibility

Credibility refers to the degree to which the results are accurate and viewed as essential and believable by participants (Rose & Johnson, 2020). This is because credibility essentially asks the researcher to clearly link the research study's findings with reality in order to demonstrate the truth of the research study's findings. The researchers will often check with participants before finalising and publishing their results to ensure they agree with the findings (Snow, 2018).

In this regard, the researcher in the current study authenticated the study by personally conducting the face-to-face interviews. Prior to the study, the researcher attended workshops on the research methodology.

The credibility of the study was ensured by selecting senior staff members who are dealing with road and transport/traffic issues.

The next section discusses trustworthiness as relevant to the current study.

4.11.2 Trustworthiness

In qualitative researcher, trustworthiness is the key indicator of a good study. Trustworthiness refers to the truth value, applicability, consistency, and neutrality of the results of a research study (Chard & Tovin, 2018).

To achieve trustworthiness in the current study, the researcher implemented several strategies before and throughout the research process. One strategy to achieve both credibility and dependability of findings was prolonged engagement, and spending sufficient time with the participants and the data to establish trust and arrive at an understanding of the traffic ethos and background (Hines, Ramsbotham & Coyer, 2022).

The next section discusses the quality of research data used in the study.

4.11.3 Quality of research data

This section describes the quality of research data as applicable to both qualitative and quantitative data. The current research study adopted a mixed-method research design, and as such, the quality of qualitative data included dependability, confirmability, transcripts, authenticity and ethics. The quality of quantitative data included the validity and reliability of the research data. The quality of qualitative data, as applicable to the current study is discussed below.

4.11.3.1 Quality of qualitative data

The researcher was cognisant of the participants' uneasiness concerning their trustworthiness during the qualitative data collection. To achieve trust in a research study, the researcher should consider the measures to guarantee credibility and trustworthiness. The following aspects were included, as discussed below:

Dependability or consistency:

According to Eriksen *et al.* (2020), dependability refers to the audit trial that is provided in the study by ensuring that proper qualitative procedures were followed, and that any changes that emerged during the research process are accounted for, justified, and described in the final report. Concisely, dependability is concerned with whether the process of collecting the qualitative data was sound (Haven & Van Grootel, 2019).

In the current study, the researcher ensured dependability through the utilisation of experienced qualitative researchers to examine the data transcriptions and co-coding (see Appendix D).

Confirmability:

The criterion of confirmability refers to the degree to which the results reported are linked to the data obtained from participants. According to Haven and Van Grootel (2019) the confirmability is concerned with whether the analysis of the data was coherent and whether the interpretations based on that data were fair. Although it is expected that another researcher could view similar data and come up with a diverse analysis, confirmability guarantees that a researcher's outcomes are actually supported in what participants articulated (Maher, Hadfield, Hutchings & De Eyto, 2018).

The current study ensured confirmability through the protection of the notes on raw data, data reduction and analysis.

Transferability:

Based on the applicability raised by Schloemer and Schröder-Bäck (2018), transferability refers to the degree to which the outcomes of qualitative research can be generalised or conveyed to other perspectives or settings. For the current study, transferability was achieved by proposing a compact description of the methodology and findings to enable the study to be conducted in other areas with same traffic congestion challenges in the country or abroad.

Transcripts:

According to Clark, Birkhead, Fernandez and Egger (2017), a transcription is the action of providing a written account of spoken words, and is conducted through the individual or group interviews which are generally written down verbatim (exactly word-for- word).

For the current study, the researcher ensured that the transcriptions were accurate. The quality in interview-based qualitative research is foundational for the accuracy and validity of the study. The process was completed through the quoting of transcript data in a published data analysis section which provided the readers with necessary detail.

Authenticity:

Brown and Danaher (2019) described authenticity as the degree to which researchers capture the multiple perspectives and values of participants in their study, and foster change across participants and systems during their analysis. Authenticity in research, according to Tracy and Hinrichs (2017), implies that the conduct and evaluation of research are genuine and credible, and also that the research is worthwhile and contributes to the field.

Therefore, in the current study authenticity was ensured by reflecting all the participants' accounts genuinely and objectively, and preventing marginalisation by acting affirmatively with regard to the inclusion of the information provided. The researcher realistically included the information, such as the voices in the interview sessions, to ensure the truthful representation of the text.

Ethics:

According to Bryman and Bell (2015:511), the ethical consideration provides guidelines for the responsible conduct of research. In addition, it educates and monitors scientists conducting research to ensure high ethical standards.

When requesting permission to conduct the study, the researcher applied for an ethical clearance certificate to conduct research involving humans from the Unisa CEMS ethics committee, which was duly granted (see Appendix C).

To ensure the privacy and confidentiality of participants, no names or vehicle identification numbers of the staff in national, regional, or local road authorities and vehicle owners were requested during the interview or written down on the questionnaire. Only the researcher, supervisor, statistician and participants had access the documents.

To ensure protection from harm, the participants were informed that participation in the study was voluntary and it was for academic purposes. Therefore, no damage or injury would arise from participating in the survey. The participants were informed that they were free not to respond if they did not want to get involved in the study. The written consent form was presented during the face-to-face interviews and included in the survey link to all participants who participated in the study (see Appendix E). After the participants signed the form, the researcher kept it safe and continued with the survey. The subsection below discusses the quality of quantitative data used in the study.

4.11.3.2 Quality of quantitative data

In any quantitative study, the researcher should ensure that the instrument and the data collected are of the utmost quality. This can be performed through ensuring the validity and reliability of the data collected. According to Leedy and Ormrod (2014), a research instrument that is valid and reliable allows the researcher to draw proper conclusion from the collected data and resolves the research problem concisely.

Validity of the research data:

Validity refers to the extent to which the measurement procedure, e.g. pre-experimental, quasi-experimental or experimental measuring what the researcher thought it is measuring but nothing else and whether the researcher used and interpreted the scores correctly (Blumberg *et al.* 2014:398; Christensen *et al.* 2015:154; Struwig & Stead, 2011).

According to Salkind (2014), the validity of research data can be divided into two categories:

- **External validity** can be described as the extent to which the researcher can generalise the study's results to other populations.
- **Internal validity** addresses the issue of whether the independent variable and no other extraneous variables are responsible for variations in the dependent variable.

The researcher utilised an online survey comprising demographic information, a five-point Likert scale and a sequence of closed-ended questions in the questionnaire.

Reliability of the research data:

Reliability can be described as the consistency, accuracy or stability of the scores of the researcher’s measurement instrument (Christensen *et al.* 2015:154). For the researcher to ensure that the questionnaire was correct, credible and applicable, a pilot survey was conducted.

4.12 LIMITATIONS OF THE STUDY

This section rationalises on the limitations of the research study. A numbers of constraints were encountered during the study. The study was only based in the Midrand area, which means that the result cannot be generalised. The study also focused on the drivers using Allandale Road (M39) from Monday to Friday, yet there were also once-off drivers. The study included the age restriction up to 65 years; however, there are respondents residing in Midrand area that are older.

Since the study used mixed research methods, in the qualitative phase, the researcher only obtained 18 out of 25 expected participants due to the unavailability of the participants during the data collection period. Some participants were away with work commitments and could not carry on with the interviews as per the schedules. In the quantitative data collection phase, the questionnaire favoured respondents who had access to either a smartphone, computer or laptop because the questionnaire was only available online due to the Covid-19 pandemic restrictions of movement and lockdowns.

The study focused on senior authorities from the government departments and agencies, and drivers of private vehicles only. Not all the population in the three spheres of government and communities were included in the survey. Another limitation was based on the availability of the sample size, as the initial sample was 350. However, the data collection was discontinued when 276 questionnaires had been received because the online survey reached the expiry date as per the implementation of the contract. Previous studies conducted a survey of a total amount of 341 and 360 and received only 78% of the expected responses (Moqbel & Kock, 2018; Sidek, Bakri, Hamsa, Othman, Noor & Ibrahim, 2020). In this study, the researcher also considered a response rate of 79% during the expiry date of the survey, which is acceptable.

The next section presents a summary of the progressive procedure adopted to draw together the data for the study.

4.13 RESEARCH PROCESS FOLLOWED IN THE STUDY

The research process is the systematic manner in which a researcher approaches their area of study to produce knowledge which the community will consider to be worthwhile within the field.

Table 4.6 below presents a summary of the research process followed in the study.

Table 4.6: Summary of the research process utilised in the study

ACTIVITIES	DESCRIPTION OF THE PROCESS
Aims or purpose of the study	To determine how road traffic congestion on Allandale Road (M39) in Midrand, South Africa, is managed.
Research paradigm	Positivism: the reason for conducting the research study was to find out about the causal relationship to predicting control events. Interpretivism: the reason for conducting the research study was to understand and elucidate meaningful social action and experiences of the phenomenon.
Mixed-method design	Exploratory sequential mixed-method design.
Research approach	Inductive and deductive.
Research strategy	A survey was conducted to collect the data from both government entities and private vehicle drivers.
Population	Three (3) government entities and/or agencies in the roads and transport sector from national, provincial and regional spheres of government. The first entity had a population size of 10 0001 plus employees; the second one had 484 employees, and the third one had 164. Private vehicle drivers using Allandale Road (M39).
Sampling	Purposive or Judgmental Sampling: 18 senior management from national to regional: three government entities. Simple random sampling: 276 private vehicle drivers.
Data sources	Primary and secondary data sources were employed.
Quality of research	The quality of the research was achieved through the credibility and trustworthiness measures (for qualitative research) and reliability and validity (for quantitative research).
Data collection methods	Face-to-face interview (structured questionnaire). Online survey (closed-ended questionnaire).
Data analysis	Thematic content analysis using the Atlas.ti. Descriptive and inferential analysis using SPSS.
Ethical consideration	It was achieved through the acknowledgement of sources, confidentiality, Unisa CEMS ethical clearance approval, the participant's informed consent, right of privacy and permission letters from the government entities.

Sources: Researcher's compilation

Table 4.6 summarised the progressive procedure adopted to draw together the data for the study. The table emphasises the essential elements of the research methodology steps, such as the purpose of the survey, paradigm, design, approach, strategy, population, sampling, data sources, collection methods, data analysis and ethical considerations followed in the study. The section below presents the conclusion of Chapter 4.

4.14 CONCLUSION

This chapter concentrated on the processes applied in the research methodology followed in the study. The chapter expanded on the phases in the research process and the application executed in the current study. Further research design processes, such as data analysis and interpretation of the research findings, are discussed in detail in the following chapters. The survey design was selected, and an online self-administered questionnaire was developed. The sampling was determined based on the population available at the road and transport entities across all spheres of government in Gauteng, and the numbers of the vehicles passing through Allandale Road (M39) each day from Monday to Friday. After completing the pre-test of the questionnaire, data collection proceeded through face-to-face interviews and the distribution of the online survey link. Chapters 5 and 6 present the analysed data and research findings.

CHAPTER 5:
QUALITATIVE DATA ANALYSIS, INTERPRETATION AND FINDINGS

5.1 INTRODUCTION

The research design and methodology that the study followed were explained in Chapter 4. The purpose of this chapter is to present the qualitative findings of the road traffic congestion on Allandale Road (M39) in Midrand.

In this part of the study, face-to-face interviews were conducted. The face-to-face interviews were conducted from October 2018 to August 2019, based on the availability of the participants concerned. The interviews lasted from 30 to 40 minutes depending on the position of the participants. A structured interview guide with open-ended questions was used during the interviews. The interviews participants were eighteen (18) officials from the local, provincial and national spheres of government.

This chapter begins with a demographic profile of the respondents, followed by thematic analysis of the data, as well as content analysis. The chapter concludes with the presentation of summary of the development of themes for traffic congestion and different views of the respondents on the condition of traffic on Allandale Road (M39). Four themes, categories and sub-categories are presented, supported by the quotes derived from the data collected during the interviews.

The demographic profile of the participants is divided according to the organisation they worked for, and are presented in Table 5.1. This is followed by the thematic analysis of the data on road traffic congestion, as well as the content analysis of the qualitative data.

Figure 5.1 presents the structural flow of Chapter 5 in alignment with the study.

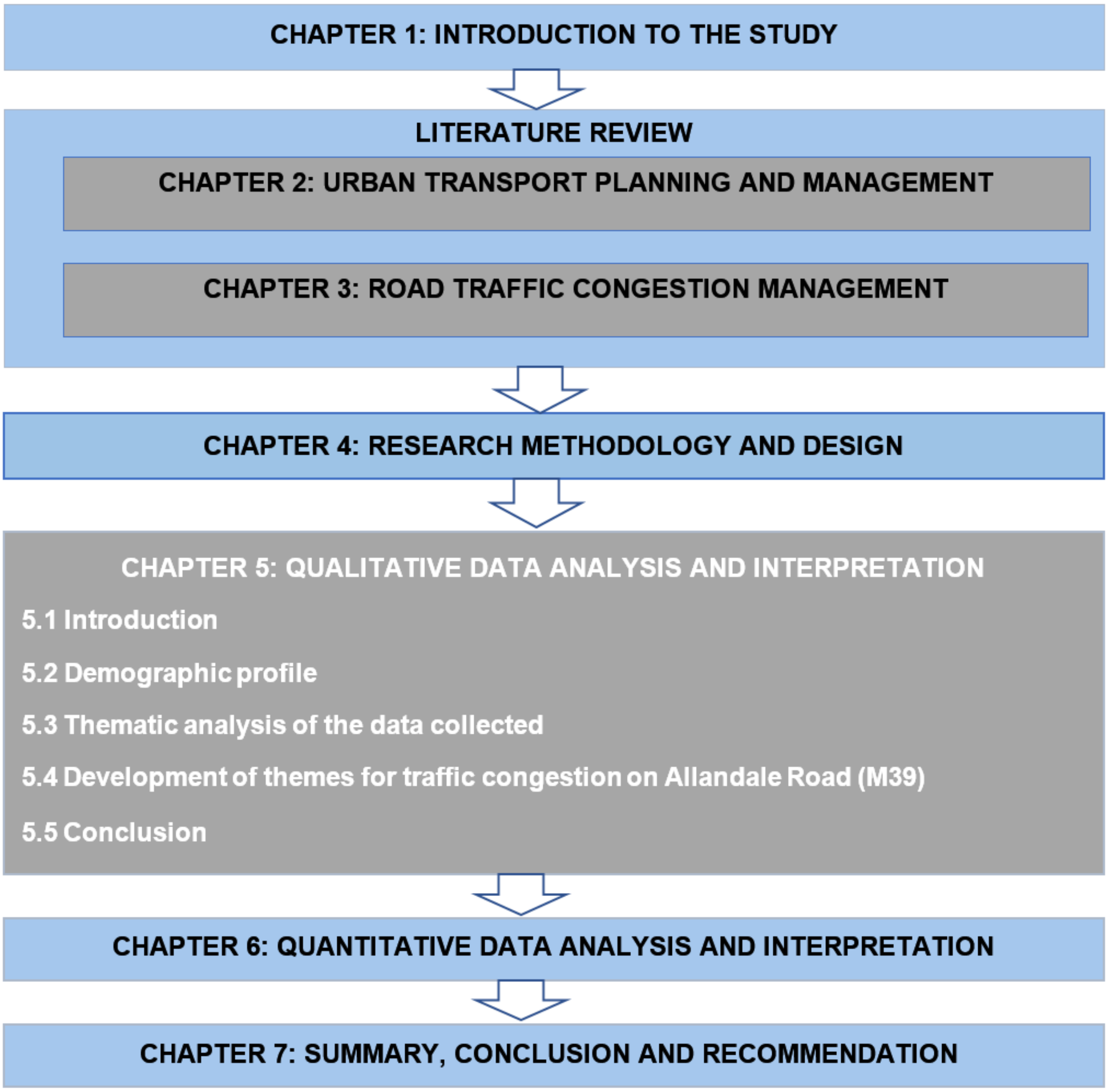


Figure 5.1: Structural flow of Chapter 5 in alignment with the study

Sources: Researcher's compilation

5.2 DEMOGRAPHIC PROFILE

This section describes the demographic profile of the respondents who participated during the face-to-face interview sessions. The roads in South Africa, including Allandale Road, are under the governance of a three-tier government system, each with its own specific sphere of governance starting from national, provincial and municipal. Each sphere has independent authority and accountability for cooperating with others to guarantee that the entire government meets their constitutional responsibilities.

The interviews were conducted with senior participants working in the road traffic services department, and the traffic engineering and transport planning fields within the departments.

The researcher conducted interviews with 18 participants who identified multiple issues related to traffic congestion on Allandale Road (M39). These are organised under four (4) major themes: 1) peak periods of traffic congestion that exist on Allandale Road, 2) strategies for managing road traffic congestion on Allandale Road, 3) supporting policies and regulations that have values and impact on managing road traffic congestion, and 4) problems that make an underlying contribution to road traffic congestion.

The section below presents the demographic profile of the participants from three government departments. The findings are presented according to each government department consulted.

5.2.1 Demographic profile of government department participants

As shown in the table below, all the participants are divided into three government departments (department number 1-3) according to the order in which the interviews were conducted.

Table 5.1 below lists the participants' positions, qualifications and years of experience at each government department.

Table 5.1: Profile of participants from three government departments

DEPARTMENT NUMBER	PARTICIPANTS	POSITION	YEARS OF EXPERIENCE
Department 1	Participant 4	Law enforcement: Traffic Officer	12 years
	Participant 6	Transport researcher	5 years
	Participant 7	Rural transportation strategic planner	10 years
	Participant 9	Road transportation engineer	35 years
	Participant 10	Transportation researcher	6 years
	Participant 11	Law enforcement: Traffic Officer	8 years
	Participant 13	Road transport engineer	11years
	Participant 14	Road transport engineer	12 years

DEPARTMENT NUMBER	PARTICIPANTS	POSITION	YEARS OF EXPERIENCE
	Participant 17	Road transport engineer	11 years
Department 2	Participant 1	Traffic engineer	32 years
	Participant 2	Traffic engineer	24 years
	Participant 5	Traffic engineer	29 years
	Participant 8	Traffic engineer	8 years
Department 3	Participant 15	Traffic engineer	15 years
	Participant 3	Traffic engineer	12 years
	Participant 12	Traffic engineer	17 years
	Participant 16	Traffic engineer	14 years
	Participant 18	Traffic engineer	8-9 years

Sources: Researcher's compilation

As show in Table 5.1 above, all the participants from government Departments 1 to 3 provided the information based on their positions and years of experience in the three organisations. Below is the description of the demographic information provided in the face-to-face interviews.

5.2.1.1 Department 1

Position: Nine participants from Department 1 participated in the interviews. Among these participants who were interviewed were two law enforcement traffic officers, two transport researchers, one rural transport strategic planner and three road transport engineers. These participants included senior staff members and also road traffic experts within their organisation. Therefore, they would have an in-depth understanding of road traffic congestion in the transport industry.

Years of experience: There were nine participants from this organisation, and the researcher realised that the majority (Participants 4, 7, 9, 13, 14 and 17) had more than 10 years of experience in the sector. Only three participants (Participants 6, 10 and 11) had less than ten years of experience. Therefore, those nine participants understood the road traffic congestion and the condition of traffic congestion in Gauteng.

Below is description of the demographic information provided by Department 2.

5.2.1.2 Department 2

Position: Four participants from Department 2 participated in the interview sessions. The participants who were interviewed included only the four traffic engineers. All these participants were senior traffic engineers within their organisation. Consequently, these participants would have extensive knowledge about transport improvements, planning and designing, including traffic control systems, intersections, junctions, parking, and public transport systems.

Years of experience: Of the four participants from Department 2, the researcher recognised that almost the entire team (Participants 1, 2 and 5) had more than 10 years of experience in the sector. Only one participant (Participant 8) had less than 10 years of experience in the sector. Therefore, those four participants had sufficient information about road traffic congestion and the condition of traffic congestion in Gauteng, including Midrand.

5.2.1.3 Department 3

Position: Five participants from Department 3 were involved in the interview sessions. The participants who were interviewed included five traffic engineers. Similar to the other two departments, all the participants in this organisation were senior staff members. Appropriately, the members had a great amount of knowledge related to the areas where there is problematic blockage of vehicles, as well as free and rapid flow of traffic in the areas.

Years of experience: There were five participants from Department 3. The researcher understood that four of the participants (Participants 15, 3, 12 and 16) had more than 10 years of experience in the sector. Only one participant (Participant 18) had less than 10 years of experience in the sector. Therefore, all the participants who were involved in the department had sufficient information and complete superiority in terms of road traffic services distribution.

In the above analysis of the participants from the three departments, and when debating about their positions and the experience, it was clear that the participants had the ability and experience to understand road traffic matters and the planning of transport, which profoundly focused on the traffic-related issues, including traffic congestion.

As illustrated from the profiles in the table above, most of the participants held positions in road traffic engineering. Traffic engineers concentrate on the project and maintenance of safe roads, which include doing traffic modelling and traffic forecasting. The engineers determine the nature of the roads that are needed to ensure that traffic flows smoothly, and they discover cost-effective ways to build and maintain them.

The traffic engineers with 24, 29 and 32 years of experience indicated that they had been hired to develop transport models, including traffic model forecasting. The other engineers hold position where they investigate the impact of adding lanes to a road, adding new roads, adding additional routes, and expanding the network to reduce congestion. However, some engineers were given the sole responsibility of timing traffic lights, the responsibility of performing traffic impact assessments, geometric designs and a few intersection upgrades, which were the concerns emanating from the traffic department.

The transportation strategic planner was responsible for evolving transportation strategies that incorporate the requirements of transport users which consider environmental, efficiency and safety issues. Certain staff members only work in the primary provincial roads, including Allandale Road, which carry heavy traffic over long distances.

The section below describes the process of how the data collected during the interviews was analysed using thematic analysis.

5.3 THEMATIC ANALYSIS OF THE DATA COLLECTED

In this section, the data collected was analysed using the thematic analysis approach. The researcher analysed the interview transcripts using thematic analysis so that the required information was discovered based on the participants' views, opinions, knowledge and experience. According to Bryman and Bell (2015), “The themes and sub-themes are the product of a thorough, repeated reading of the interview transcripts or field notes that make up the data interview”. The researcher closely examined the data to identify common categories, themes, sub-themes and patterns of repeated meanings that came out of the interview transcripts.

Bryman and Bell (2014) explained that the features in thematic analysis are familiar to those in content analysis, although are more appropriate for investigating meaning in the context. When using the thematic analysis approach, the researcher anticipates delivering a rich and detailed interpretation of the data as the theme (Vaismoradi & Snelgrove, 2016).

Table 5.2 below shows the arrangement of how interview questions correspond to the research questions as implemented during the interviews. As mentioned previously in table 4.4, the questions used were in the English language.

Table 5.2: Alignment of research questions to interview questions

Research questions (RQ)	Interview questions (IQ)
RQ1: Which peak periods of traffic congestion exist on Allandale Road (M39) compared to other areas?	***IQ1:*** *Kindly identify roads or streets in Midrand that are congested.* **IQ2:** *Which other roads or streets around Midrand that you know of, are also congested?* ***IQ3***: *What are the peak periods of road traffic congestion on Allandale Road (M39)?*
RQ2: What problems contribute to the traffic congestion that users on Allandale Road (M39) experience daily?	***IQ4:*** *Would you identify problems that form the underlying contribution of the road traffic congestion on Allandale Road (M39)?*
RQ3: What are the supportive policies and regulations that have impact when managing road traffic congestion?	***IQ5***: *What are the supportive policies or acts that have an impact when managing road traffic congestion?* ***IQ6:*** *What are the supportive regulations that have an impact when managing road traffic congestion?*
RQ4: What strategies are used to manage road traffic congestion within urban areas such as Midrand?	**IQ7:** *Can you identify the key strategies that are used to manage road traffic congestion on Allandale Road (M39)?* ***IQ8:*** *Which strategies are lacking and still required to manage road traffic congestion on Allandale Road (M39)?*

Sources: Researcher's compilation

The themes provided in this paragraph were extracted from the questions asked in the above section, and Chapter 1 of this dissertation as follows:

- Theme 1: Peak period of traffic congestion exists on Allandale Road;
- Theme 2: Strategies to manage congestion on Allandale Road;

- Theme 3: Policies and Regulations;
- Theme 4: Problems that form the underlying contribution.

Since the current study was based on mixed methods to identify the participants' responses to the management of road traffic congestion on Allandale Road, the answers to both the interview and questionnaire questions were highly autonomous.

The following section provides the themes generated from the participants' responses. The responses include similarities and discrepancies based on the participant's knowledge of the study area. In the section below, the researcher presents a discussion of the interview based on the research questions and objectives. The discussions will lead to the summary of the themes, sub-themes and description of the state of traffic congestion on Allandale Road (M39)

5.3.1 What are the peak periods of road traffic congestion on Allandale Road (M39)?

This section presents the different views, clarification and comments about the areas and peak periods of traffic congestion. In this theme, the research question (RQ1) "Which peak period of traffic congestion exists on Allandale Road (M39) compared to other areas?" was examined, and followed by the interview sub-questions (IQ1, IQ2 and IQ3, as presented in Table 5.2 above).

The peak period usually occurs during a specific time of the day. Most of the participants were familiar with the area, and answered the questions according to their own experiences. The responses supported by the quotes from the questions asked are as follows:

5.3.1.1 Roads or streets of congestion

In this sub-theme, the participants presented their responses based on the areas which are congested in Midrand and its surrounding areas. During the interviews, some participants asserted that in the Midrand area, the most congested road is Allandale Road (M39). According to some participants, not only a few places are affected, but there are various areas and streets where traffic congestion occurs. This was affirmed by the responses provided below:

> *"... the road which is congested it's Allandale Road."* (P12, August 2019).

“That’s Allandale. There’s congestion all over the place. The main road through Midrand is the N1.” (P1, February 2019).

“I just know that Midrand, in the morning, most of the areas you’ll find that there’s a problem of traffic congestions in general.” (P10, October 2018).

Some participants stated that most roads in the area are affected. The participants also identified the roads that feed into Allandale Road and contribute to the traffic congestion that is taking place on Allandale Road.

“Most of them are congested.” (P9, October 2018).

“It’s mainly the Allandale Road and that is pretty much all the way from the R55, which is at Kyalami Road in the west, pretty much right through to Tembisa.” (P1, February 2019).

“I think Allandale Road was one of the sections that were very congested as a result of the access from the N1 and then also Le Roux Street crossing as well as the section between New Road…or from New Road interchange on New Road to K101 or the R101. So, that’s from my experience where I think there’s a lot of congestion.” (P2, February 2019).

The above responses indicate that the participants acknowledge the traffic congestion setbacks taking place in the Midrand area, especially on Allandale Road. The obligation of participants P1 and P2 was to develop transport models for forecasting, including the traffic model forecasting and revenue forecasting for the Gauteng freeways, including the interchanges.

5.3.1.2 Peak periods of traffic congestion

The following were the sentiments of participants regarding the peak periods of traffic congestion. The responses based on the peak periods of traffic congestion do not differ in this sub-theme. Most participants identified that there is a morning peak hour which occurs between 6:00 and 9:00. The peak periods revealed by the participants are as follows:

“Between six and nine in the morning, that’s the peak movement.” (P3, August 2019).

“I would say from about 6am until maybe, weekdays, 9am.” (P8, February 2019).

Although some participants identified the morning peak hours between 6:00 and 9:00, one participant's reckoning is that the traffic congestion currently starts from half past six until nine o'clock.

"The morning peak period is now about…I would say it picks up from half past six and continues until about nine o'clock." (P2, February 2019).

However, there were various interpretations among the participants regarding the afternoon peak period of traffic congestion. According to the participants, the afternoon peak times start as early as 15:00 and last until 18:00, but generally the peak times are from 16:00 to 18:00.

"In the afternoons, the traffic really starts building up around three and keeps going 'til probably half past six." (P1, February 2019).

"…during the day it start from fifteen zero-zero until eighteen zero-zero." (P14, October 2018).

"...it's between I would say 4pm and 6pm, in between those two hours it's heavily blocked." (P18, August 2019).

Even though the afternoon peak period starts from three o'clock, between three and four o'clock, one participant observed that according to his records, the peak periods keep increasing yearly.

"…over the last I don't know how many years, that peak period is getting longer by fifteen minutes every year. So, now it's from six to nine thirty. Next year it'll be from, possibly, ten to six to nine thirty-five and the following year it'll probably be twenty to six to nine forty. And the same in the afternoons." (P1, February 2019).

Following the information disclosed regarding the peak periods of traffic congestion, the majority of the participants identified that traffic congestion occurs in the morning and afternoon. The findings showed that there was not a lot of variation in the responses concerning the morning peak period of traffic congestion. The periods discovered by the participants fluctuate between six and nine, which shows the corresponding flow of the traffic during the day.

However, in terms of the afternoon peak period of traffic congestion, the responses from the participants revealed that the starting time is 15:00 until 18:00 but regularly between 16:00 to 18:00. The peak periods keep increasing yearly, as people keep on buying cars and using them to travel to their destination every day. Table 5.3 below presents a summary of the sub-themes on peak periods of traffic congestion that exist on Allandale Road.

Table 5.3: Theme 1: Peak periods of traffic congestion on Allandale Road (M39)

THEME 1	SUB-THEME	DESCRIPTION
Peak periods of traffic congestion exist on Allandale Road	Roads or streets of congestion	▪ The most congested road is Allandale. ▪ Most roads in the area are also affected. ▪ There are various streets where traffic congestion takes place.
	The morning peak period of traffic congestion	▪ Morning peak hours occur between 6:00 and 9:00. ▪ Traffic congestion currently starts from half-past six until nine o'clock.
	The afternoon peak period of traffic congestion	▪ Afternoon peak times start as early as 15:00 and until 18:00 but are generally from 16:00 to 18:00. ▪ One participant observed that according to his records, the peak periods keep increasing yearly.

Sources: Researcher's compilation

Table 5.3 above summarised the peak periods of traffic congestion that exist on Allandale Road (M39). The next section presents a discussion of the problems that contribute to the traffic congestion that users on Allandale Road (M39) experience daily.

5.3.2 What problems contribute to the traffic congestion that users on Allandale Road (M39) experience daily?

This section presents the findings related to the problems that form the underlying contribution to managing traffic congestion on Allandale Road. In this theme, by responding to the research question (RQ2), "What problems contribute to the road traffic congestion that users on Allandale Road (M39) experience daily?", the sub-themes about the insufficient road capacity and planning, driver behaviour, non-operating traffic lights, lack of an integrative plan, historical injustices, and Midrand previously being a rural area were discovered.

The following sub-section outlines problems that contribute to congestion on Allandale Road.

5.3.2.1 Insufficient road capacity and planning

Multiple challenges were mentioned that have direct implications on the congestion experienced on Allandale Road. Some participants pointed to the rapid growth and development of the Midrand area.

> *"I think Midrand has been developing very fast."* (P9, October 2018).

> *"Because Midrand is really growing. You have new developments coming. So, the main thing is to control the traffic." (P16, August 2019).*

> *"New developments where there's an increase in population next to the road and an increase in vehicle capacity of the road. Two, malls as well, it is part of new developments, shopping centres and so forth, firms, they also contribute."* (P3, August 2019).

The participants' views and their understanding of the road capacity and planning detailed the various sentiments regarding the problem being discussed. This led to an increased number of different types of vehicles using the road.

> *"And how many cars are old, and they've been on the road for quite sometimes and how many cars are coming into the roads as well? So, that's the problem."* (P17, October 2018).

> *"Of course, buses, taxis utilise the road. Three, it's freight trucks as well…I mean four, it's freight trucks as well because they also travel on that road going to, is it, Kempton Park, delivering on those shopping centres as well. And then private vehicles as well."* (P3, August 2019).

Although insufficient road capacity and planning problems were revealed in the discussion, the participants asserted that road infrastructure development has not kept pace with human development.

> *"So, it's really a lack of…or a imbalance between developments that are taking place versus the road networks that are provided."* (P2, February 2019).

> *"Urbanisation. So, there's a lot of traffic… I think the area is growing faster than the capacity of the roads."* (P8, February 2019).

"So, if you really look at Midrand, it was a smallholding area in the past and the smallholdings were developed and, as it kept on developing, (and) the required road network was not implemented." (P11, October 2018).

Some participants believed that insufficient planning accounted for much of the problem. This is discussed further in Section 5.3.2.2 related to strategies that are lacking and still required.

"In the planning stages, I would think that you need to…when you're doing township planning, consider the roads. Not last but first. Because, in my opinion, people go and develop a township and then they decide we should have put in roads. And the roads people are usually the last ones to know about these developments." (P9, October 2018).

"The way we plan when we…in terms of development, especially the town planner, we have to plan." (P12, August 2019).

Part of the problem arises because different agencies govern different sections of the road and networks, while the national department is in charge of their planning and upkeep. A lack of an overarching plan and coordination between the various agencies and role-players has led to inconsistencies and increased congestion.

"…even if you go in Midrand to the K101, you will see some places it's dual, some places is single, then this intersection they've dualled it because there was a development and the next intersection is dual but, in between, there's a short section of half a kilometre that's still single road, that type of thing. I think there's not enough planning when the authority allows development to look at it in that way and say we need to look at the whole road." (P5, February 2019).

5.3.2.2 Driver behaviour

This subsection presents the findings concerning driver behaviour as a problem that forms an underlying contribution. Aggressive and hostile driving requires a firm justice system because of its many miscellaneous expressions but a clear definition is essential for police and legal action against it to succeed. Driver behaviour was identified as a dreadful contributing factor to road congestion. Some participants gave the following examples:

"We've got a huge issue with road-user behaviour." (P15, February 2019).

“If you look at any traffic stream, probably ninety percent of the traffic sits in lanes and just follows in congestion. It’s the ten percent that disobey the law, that travel down emergency lanes, cut in, speed, go through red lights, traffic lights. That’s a big cause of accidents and fatalities.” (P5, February 2019).

“It merely comes down to we have to follow the rules of the road… following those rules … makes it easier for everyone. Following the rules of the road, having patience as well.” (P18, August 2019).

There should be active crime squads to ensure that members of the community abide to the rules and regulations of the road. According to one participant, a lack of law enforcement results in bad driver behaviour.

“Road user behaviour. Traffic law enforcement. If there’s poor traffic law enforcement, then you get congestion.” (P8, February 2019).

5.3.2.3 Non-operating traffic lights

The responses below concentrated on the problems experienced with out-of-order traffic light signals, and the need for traffic patrollers to contribute to alleviating congestion. The participants stated that traffic lights required upgrading and optimising.

“The biggest thing that I’ve seen also it’s the traffic lights not working on that specific road, especially sometimes you’ll find on the bigger intersection …K101 and Allandale. If that intersection the traffic lights is not working, then there will be…traffic is going to queue there.” (P12, August 2019).

“…managing, it’s first to…having patrollers…(to) control the transport. Having, implement new technology to work with the signal.” (P5, February 2019).

“Signalling, traffic signalling, how it’s optimised and so on.” (P8, August 2019).

One participant from governmental Department 2 gave reasons why the coordination of the traffic lights is not arranged appropriately, and explained how the inclusion of a stop street could disrupt even the correct coordination of traffic lights.

“... the traffic lights can be coordinated so that traffic can just move. The coordination of the traffic lights is generally not done in a meaningful way. Then

again, as soon as you put a stop street in it, any progression you can get that improves mobility is destroyed.” (P1, February 2019).

The participant explicitly explained the interchanges and feeder road systems involved throughout Allandale Road. Traffic lights on Allandale also impact traffic flow onto the highway.

“As long as you have grade-separated interchanges, the guys on the main road can just go. As soon as you get into Allandale, this is now you have … intersections with traffic lights, so it’s a stop-start scenario.” (P1, February 2019).

5.3.2.4 Lack of an integrative plan

Participants from all three spheres of government had different views about the decision on the integrative plan. The participants inferred that each tier of government acts independently from one another.

“…at national level, we don’t have that authority to exercise because … It’s only local government that just give the, what do you call, green light to developers. From our side at national level, we don’t have any say.” (P11, October 2018).

“Allandale, on the other hand, is a provincial road. So, from a SANRAL point of view, we have no jurisdiction over Allandale Road itself. However, the interchange that has just recently been upgraded as part of the Gauteng freeway is a SANRAL asset and that was upgraded to accommodate future demands in that area.” (P2, February 2019).

There is a lack of a strategic, unified national plan coordinating the different government agencies that can address all the factors contributing to road traffic congestion.

“Another thing, the problem is that we don’t align our policies as government. We need to align transport policy with human settlement policies. Human settlement, what is it that they’re doing.” (P7, October 2018).

“But I would think one needs a policy on that level to say how do you plan for the whole of Gauteng with all its major arterials and minor roads, etcetera.” (P5, February 2019).

“From our policymaking position, we don’t have, what do you call, assessment impact where we get approvals from the national department. So, we rely on the local municipalities.” (P11, October 2018).

The responses showed that some participants understood the value of the transport planning process, particularly from the national level. A lack of planning can be seen in the following example given by a participant of people with the wrong expertise being recruited to address the problem.

“…even now when we advertise tender, we find that we need a transport planner, they will bring somebody with engineering and then, in engineering, their focus is on road construction, not on traffic. The problem is that we need somebody who understand transport planning in order to ensure that we actually reduce congestion.” (P7, October 2018).

5.3.2.5 Historical injustice

This sub-section presents the findings relating to the historical injustice experienced within the transportation sector. South Africa’s historical past of apartheid had a detrimental effect on determining where people live and their social and economic situation. This has resulted in people travelling long distances for employment, generating traffic congestion. A participant explained it as follows:

“…you need to start by checking the history of transport. Then many people were [dispossessed?] of their right in land as a result of past discriminatory roles. Act of nineteen fifty to relocate people from town, place them in Soweto, and then traffic actually started.” (P11, October 2018).

“:..then the other thing, segregation, that was the main cause. Previous segregation again. Apartheid special planning let me put it that way. Black people were put aside, they were far from social and economic opportunities. They did not have access to social and economic opportunities. Another thing, in urban areas, they created locations and townships. In rural areas, they created homelands. Now we call them communal lands. They’re all far from economic activities. That’s the main thing…the main cause of congestion.” (P7, October 2018).

5.3.2.6 *Midrand was previously a rural area*

When asked about the problems that form an underlying contribution to the traffic congestion, the responses showed that within the area, Midrand was historically a rural area with a low-density population. Its popularity has led to a drastic increase in population and private vehicle ownership.

> *"Midrand, you'll find that someone owned a stand, it was one person. All of a sudden, you have two hundred and fifty units now, likely we've got about two hundred cars coming out of Midrand."* (P13, October 2018).

> *"You had one farm or one plot with two cars. Now you're taking that same plot, you're putting a hundred houses there, each of those houses probably has two cars. So, you're going from two cars to two hundred cars and nobody's looked at the road situation. So, automatically you've got a hundred and ninety-eight more cars than you had before. That's gonna cause congestion, definitely."* (P9, October 2018).

Development in cities leads to more congestion and a high traffic death toll. While urban areas such as Midrand increase periphery, there is insufficient road capacity and planning, which prompts increases in congestion. New developments also require adequate traffic control because inadequate planning produces much of the problem.

There were some definite and numerous responses about the road-user behaviour of drivers who lack patience on the road. Vehicle drivers disobeying the law travel down the emergency lanes and pass through the red traffic lights. This behaviour is the cause of accidents and fatalities. The respondents identified poor traffic law enforcement, which requires commitment and greater insight into the activities of traffic officers.

There were responses about the traffic lights that are not working on specific roads. Proper attention to the traffic lights on the more prominent intersections such as K101 and Allandale is required more rapidly and is necessary to avoid congestion. A contemporary new technology must be implemented on the signals where traffic lights can be coordinated.

The two traffic engineers in the road agency precisely declared that Allandale Road is a provincial road. Therefore, from their point of view, they have no jurisdiction over the road itself. The local government has to give the developers the go-ahead about what needs to be done. There is a problem with policy alignment from the government. Government needs to align transport policy with human settlement policies.

From a policymaking position, according to the participant from government Department 2, they do not have an assessment impact where approvals are acquired from the national department. On the other hand, the government department requires people who understand transport planning to ensure the actual traffic congestion reduction is equipped.

Table 5.4 below presents a summary of the sub-themes on problems that form the underlying contribution to traffic congestion on Allandale Road.

Table 5.4: Theme 2: Problems that form the underlying contribution

THEME 2	SUB-THEME	DESCRIPTION
Problems that form the underlying contribution	Insufficient road capacity and planning	▪ There are new developments that are increasing rapidly in the area. ▪ Additional developments require adequate planning and control of traffic because insufficient planning produces the problem. ▪ New developments increase the population and vehicle road capacity of the road. ▪ A lack of an overarching plan and coordination between the different agencies and role-players has led to inconsistencies.
	Driver behaviour	▪ A lack of law enforcement results in bad driver behaviour. ▪ Drivers travel down emergency lanes, go through red traffic lights. ▪ An active crime squad to ensure that members of the community abide by the rules and regulations of the road is required.
	Non-operating traffic lights	▪ Traffic lights are not working on the more significant intersections such as the K101 and Allandale. ▪ The coordination of the traffic lights is generally not done in a meaningful way.

THEME 2	SUB-THEME	DESCRIPTION
		▪ There should be appropriate implementation of new technology to work with the signals. ▪ Traffic lights on Allandale also impact traffic flow onto the highway.
	Lack of an integrative plan	▪ There is a lack of a strategic, unified national plan coordinating the different government agencies. ▪ Each tier of government acts independently from one another. ▪ The local government provides the developers with proceedings.
	Historical injustice	▪ During apartheid's special planning, people were segregated into townships. ▪ There was a lack of access to social and economic opportunities. ▪ Commuters have to travel from locations and townships to the work environment.
	Midrand was previously a rural area	▪ Midrand was historically a rural area with a low-density population. ▪ The rise in popularity has led to a drastic increase in population and vehicle ownership.

Sources: Researcher's compilation

Table 5.4 above presents a summary of the problems that form the underlying contribution of traffic congestion on Allandale Road (39). The next section presents the supportive policies and regulations.

5.3.3 What are the supportive policies and regulations impacting road traffic congestion?

This subsection presents the findings related to the supportive policies and regulations that have the values and impact on managing road traffic congestion. In this theme, by responding to the research question (RQ3), "*What are the supporting policies and regulations that have values and impact on managing road traffic congestion*?", the policies and regulations that have an impact on managing road traffic congestion are discussed (IQ5 & IQ6, Table 5.2).

The following discussion outlines the policies and regulations that have been developed to manage congestion on Allandale Road.

5.3.3.1 Policies, acts and /or regulations

The participants were either traffic officers, traffic or road transport engineers, and transport researchers from the three spheres of government. The participants identified the policies, acts and procedures which they use to direct their activities. The responses below indicate that the participants generally understood the policies, acts and procedures used in their work specifications:

> *"…we use like um... the National Road Traffic Act 93 of 1996 and um, Traffic Management Corporation Act 20 of 1999. Another one is like AARTO act… those are act that we use to enforce like specific laws. We even go with the Criminal Procedure Act depending on the, um what this um, like for arresting the reckless or speeding em you know like we call negligent driving on the road. We do enforce, um, the National Road Traffic Act but then once we have to do an arrest then that's where we enforce the Criminal Procedure Act."* (P4, October 2018).

> *"…We do have the National Road Traffic Act and then the AARTO act. That is what we use to do our law enforcement. The National Road Traffic Act is the act under which we are charging people … it will be maybe a seatbelt. I am going to make an example, it will be a specific regulation let's say regulation one, two, three, four but they all fall under the Road Traffic Act… even for seatbelt, even for red robot, , even for passing through the yellow lane… these all fall under the Road Traffic Act. And then, the AARTO is the fine that we issue… the paper… the fine that we issue is an AARTO notification. AARTO is like for example any road traffic offense that is committed. Any road traffic offense, you are gonna issue the AARTO infringement on that person… I mean a driver."* (P11, October 2018).

One participant responded that while other policies that are related to the road exist, however, responsibilities may differ from the entity. The participant also identified the policies and the response below indicates that each entity has the policy that they apply in terms of the accountability for a specific involvement on the road as regions are obligatory.

> *"…other polices like ehm… White Paper on National Transport Policy it touches the road infrastructure issues, and will be maybe under the SANRAL side, just*

check with them...the same goes with the Draft National Non-Motorised Transport Policy, it might be under the provincial side as well. Those ones ehm we normally don't touch… ehm like we don't use them on our side…we only deal with the law enforcement regarding the road traffic and safety…" (P4, October 2018).

"I would suppose policies from the Department of Transport on road infrastructure and development of road infrastructure should probably address road congestion on a high level because that should put in place planning for new arterials and new roads." (P5, February 2019).

Some participants appeared uncertain about the policies and regulations addressing road traffic congestion, or indicated that policies were still incomplete. The below responses indicate that the understanding of the policies, acts and regulations by the participants is limited to their level of expertise.

"Like I said, specifically on road traffic congestion management, I'm not aware of any policy or regulation that the national have." (P10, October 2018).

"Policies and… I'm not that familiar with the…there's a red book from the housing department side that looks at township planning and stuff. From the roads side, we are busy working on a roads policy. It's not yet completed." (P9, October 2018).

From the responses by the participants above, the issue of policies generates a clear understanding that there is a considerable knowledge of the appropriate policies, acts and regulations in some of the government entities, especially among those participants responsible for traffic-related incidents to ensure the safe and free flow of traffic to prevent road jams, crashes and deaths on our roads.

The participants mentioned a few policies that are in operation in their entities and are focused specifically on roads and are responsible for making sure that the roads keep running. Although some participants indicated inadequate knowledge about the applicable policies and regulations, they revealed that the policies may be included in the housing department document that focuses on township planning.

However, the participants from government Department 2 were of the opinion that policies about road infrastructure and development from the Department of Transport should put in place planning for new arterials and roads.

Table 5.5 below presents a summary of the policies and regulations impacting road traffic congestion.

Table 5.5: Theme 3: Supporting policies and regulations impacting road traffic congestion

THEME 3: POLICIES AND REGULATIONS	DESCRIPTION
National Road Traffic Act 93 of 1996	▪ The act is used to enforce specific laws. These acts run with the criminal procedure act, depending on conditions such as arrest, reckless, speeding or negligent driving on the road.
Administrative Adjudication of Road Traffic Offences Act 46 of 1998 Traffic Management Corporation Act 20 of 1999	▪ This act supports road traffic superiority by providing for a scheme to discourage any road traffic offence being committed. Any road traffic offence, then the AARTO infringement will be issued on that specific driver.
White Paper on National Transport Policy	▪ This touches the road infrastructure issues and might include the road infrastructure and development which should put in place planning for new arterials and roads.
Draft National Non-Motorised Transport Policy	▪ This act might fall under the provincial side and is responsible for sustainable mode of transport for social and economic development within an integrated efficient transport system.

Sources: Researcher's compilation

Table 5.5 above summarised the supportive policies, acts and regulations impacting road traffic congestion. The next section presents the strategies for managing road traffic congestion in this urban area.

5.3.4 What strategies are used to manage road traffic congestion within this urban area?

This subsection presents the findings relating to the lacking and still required strategies and those that are used to manage traffic congestion on Allandale Road. In this theme, by responding to the research question (RQ4), "*What are the strategies used for managing road traffic congestion within the urban areas such as Midrand*?", the sub-themes about the key strategies that are used and that are lacking and still required were discussed in the interview questions (IQ7 & IQ8, Table 5.2).

The subsection below outlines the strategies to manage congestion on Allandale Road.

5.3.4.1 Key strategies that are currently used

This subtheme assisted in presenting the participants' responses about the strategies currently used on the road to ease traffic congestion. The candidates, such as traffic engineers, road traffic safety consultants, transport planners, or transport consultants within the three spheres of government, showed their understanding of traffic congestion and its challenges within the urban areas.

a) Upgrades already completed

During the interview, the participants stated that the upgrade was already completed in the other section of the Allandale Road (M39). The participants indicated that traffic congestion had eased since the improvement. One participant responded that most traffic congestion was relieved once the upgrade was made. The responses below indicate that the participants were only responsible for a specific part of Allandale Road, as territories are imposed.

> *"We upgraded Allandale Road interchange substantially to make it a full free-flow interchange, there's no traffic signals inside the Allandale interchange, and we also substantially upgraded the N1... I think a lot of the congestion has been alleviated following the upgrades that were implemented in twenty twelve."* (P2, February 2019).

> *"The interchange that has just recently been upgraded as part of the Gauteng freeway is a SANRAL asset and that was upgraded to accommodate future demands in that area… the roads leading to it on Allandale are already congested and cannot supply additional traffic to the interchange."* (P1, February 2019).

b) Public information systems

The following were the views of participants regarding public information systems. Information systems are already in place but only available on freeways. According to Participant 2, Intelligent Transport Systems (ITS) give travellers information to plan their trips. While on the other side, one participant confirmed that ITS is used to manage traffic congestion, which is in place on all the freeways.

> *"So, I think ITS is what we use to manage traffic congestion at all our freeways. But in terms of this we have CCTV cameras and we have variable message signs and*

the idea is that we monitor the peak periods. Actually, we monitor three hundred and sixty-five days a year." (P15, February 2019).

"I think then, if we talk about traffic congestion, how to manage it, we have information systems, so the intelligent-transport systems, that is providing information to road users so that they can plan and manage their trips and be aware of congestion on the network." (P2, February 2019).

The participants' responses during the interview pointed out only two currently used strategies. Firstly, the upgrades were already completed, and the participants were only responsible for a specific part of the Allandale Road. Secondly, the public information systems which are only available on freeways.

Table 5.6 below present a summary of the sub-themes on key strategies used to manage congestion on Allandale Road.

Table 5.6: Key strategies that are currently used

STRATEGIES THAT ARE CURRENTLY USED	DESCRIPTION
Road upgrades already completed	▪ Since the improvement was made, most of the traffic congestion was relieved. ▪ Participants were only responsible for a specific part of Allandale Road, as there are territories.
Public information systems	▪ Information systems are already in place but only available on national roads/freeways. ▪ Information Technology Services (ITS) are used to manage traffic congestion, and this is in place on all the freeways.

Sources: Researcher's compilation

Table 5.6 above summarised the key strategies that are used to manage congestion on Allandale Road. The section below presents the strategies that are lacking and still required on Allandale Road.

5.3.4.2 Strategies that are lacking and still required

This sub-theme assisted in presenting the participants' responses about the strategies that are lacking and still required to ease traffic congestion. The participants, such as the traffic engineers, road traffic safety consultants, transport planners, or transport consultants, showed their understanding and challenges of the traffic congestion problems within Midrand.

a) Improving Infrastructure, road capacity and networks

The participants emphasised the importance of increasing infrastructure and road capacity. This includes the need to develop infrastructure such as bridges and interchanges. Taking both the infrastructure and road capacity commentaries, numerous participants agreed that to reduce congestion, it is necessary to address problems occurring throughout the entire road network that impact Allandale Road.

- ***Infrastructure and road capacity***

"There are various things. I think, from a … physical infrastructure perspective, it's about providing the infrastructure itself, it is building additional road capacity to address the demand." (P2, February 2019).

"…one needs more roads because one needs more capacity." (P5, February 2019).

"…the infrastructure as well, you must grow the infrastructure, the network. You must focus on building new roads." (P16, August 2019).

- ***Networks***

".. if you want to address congestion, it's not a single solution; it is a whole network solution, so you must adequately address and provide a road network. It cannot all focus and be concentrated on a single road." (P2, February 2019).

".. what we can do is then have a look at the impact of adding lanes to a road, adding new roads, adding additional routes, expanding the network. Then we can see how that would reduce congestion on other roads because that's the whole point of these traffic models." (P1, February 2019).

Two participants gave examples demonstrating the part played by improved infrastructure and the relationship of that in terms of the network. One participant highlighted the improvements that the interchange made to traffic flow. At the same time, the other indicated that on its own, it did not address the entire problem, and that the whole network and the entire road needed to be addressed.

"The interchange that has just recently been upgraded as part of the Gauteng freeway is a SANRAL asset and that was upgraded to accommodate future demands in that area. The interchange at the moment runs practically freely." (P1, February 2019).

"…one needs more roads because one needs more capacity. And again I think …the upgrade of Allandale interchange with the N1 just shows you that, although the congestion has been relieved …around the interchange, there's still congestion further on Allandale and, so, you either need to create more capacity on Allandale itself going further east and west but you also probably need to have more capacity on supporting roads that links with Allandale." (P5, February 2019).

b) Developer involvement

The responses from the participants reiterated the importance of impact assessments on the approval of funding and public transport. This includes the necessity for the developers to encompass the traffic impact assessment during the development and construction of the facilities around the area.

- ***Impact assessment***

"…with maybe a developer wants to develop …a certain area, (they need an) environmental impact assessment … before you can do anything on the ground." (P11, October 2018).

"So, my issue is that, when these developers do this, I don't think traffic impact assessment is done, that they do justice in traffic impact assessment." (P13, October 2018).

"Then I think also, and it links to that, is that probably the authorities allow development next to Allandale, next to other roads, but not taking into account the effect of that development on the road network." (P5, February 2019).

Private developers whose development projects contribute to the traffic problems should also add financially to road development. The participants highlighted clarifications on the importance of the developers to contribute with the funding to support the investment of road expansion.

- ***Approval of funding***

"So, I will say for me it is to do with the developers and approval process with municipalities and all of that." (P13, October 2018).

"So, we also have to force these developers…because it's expensive to build roads. These developers, they need to contribute because they cannot just add, add traffic, and then they just want to make money on developing the residential area and sell properties. Some of the money also must be invested in expanding the road." (P12, August 2019).

The responses from Department 2 showed an understanding of developing and constructing the road facilities. The participants advised the developers to reserve enough spaces for future road construction.

"When we approve those things, it will be an opportunity for us to say, developer, put reserves for road so that, even after five years when we construct or decided to expand the road, there's available land." (P11, October 2018).

c) Public transport

He participants almost universally agreed that public transport would go a long way to alleviate problems with road congestion. However, there was general agreement that there is a lack of available good public transport.

"There's no decent public transport." (P1, February 2019).

"…if there was a reliable and effective and safe public transport system which is going to be very convenient." (P10, October 2018).

"Mass transit system is not there. We are suffering in terms of there, I don't know why." (P11, October 2018)

Because enough public transport might reduce the traffic congestion in the area, the participants agreed that public transport should be prioritised.

"So, public transport alone I think will solve fifty/sixty per cent of our problems." (P12, August 2019).

".. in relation to the developments that are happening along the road … around Midrand, I think the only thing that should happen is …to have a public transport

that is working and maybe not only affordable but also convenient for the road users…." (P17, October 2018).

"There's no need for me to use my private car if the public transport it's well-improved, reliable, and it's safe." (P10, October 2018).

While the participants agreed that public transport should be a priority, some sentiments deviated from the circumstances and addressed public transport's unsafe and unreliable services.

"Public transport is unreliable, some of the public transport is unsafe. Example, your rail and your minibus taxis, they are unsafe and uncomfortable." (P4, October 2018).

"But you need to ask yourself whether the public transport that we have now is integrated? No. Is it safe? No. And then, if it's not safe, I will want to buy my own car. I will not use the taxi. Then the private car will increase more congestion." (P7, October 2018).

"...another factor, it's unsafe public transport. You'll find that a lot of people are not using, for example, Shosholoza train because it's not safe, they can rob you any time." (P14, October 2018).

e) Model integration

The participants argued that public transport is ineffective unless there is a complete integrative system to ensure that the commuter has reliable, multiple options for getting to their destination.

"...model integration; I'm talking about wherein you'll find that buses can take me and put me to point B, from B I know that there's an opportunity for me to catch a taxi from here or there's a train stations nearby." (P10, October 2018).

"And also the other thing is that you can build so many roads as you want …you can even take away some lanes and put public transport but it doesn't help if you don't put in effective, reliable, attractive public transport and affordable and will not drop me and I still have to walk…." (P13, October 2018).

One participant had a unique perspective and explained the reason why the implementation of public transport is problematic. The participant went on to say that the rise of the taxi as a viable commuter transport system to address the problem has made a significant and impressive contribution to the public transport problem.

> *"There's no decent public transport besides a taxi and, because people who live there go to Kempton Park, Midrand, Centurion. Where do you put the public transport? The taxis, for what everybody says about them, without them this country's gone and it's an incredible industry because it's one of the few public transport systems that carries…the single mode that carries as many people as cars and it's not subsidised. That is an amazing public transport system. It has issues, but hey..."* (P1, February 2019).

d) Carpooling

This sub-theme helped to present the responses about the views and comments of the participants. They showed a high level of understanding of carpooling and the fact that there is often only one person per vehicle on the roads, and recommended the need for establishing lift clubs.

> *"You'll find that over forty per cent of us, we drive alone, no passengers, we are not in the lift club."* (P10, October 2018).

> *"I suggest people with private cars to do coupling."* (P4, October 2018).

> *"We have to promote public transport because you'll see a lot of cars, private cars, with one person in the car."* (P12, August 2019).

A participant specified that carpooling as a strategy has not been very effective. The repetitive suggestion of the same strategy sometimes can assist the entire community and save commuters from the struggles of traffic congestion.

> *"And I think the lift clubs … sometimes you run away from suggesting one thing that has been suggested a thousand times. … fine, you can encourage them to do that thing but … but you still; we don't see good results of those things."* (P10, October 2018).

While not much information was given by participants on how best to encourage or enforce carpooling, one participant mentioned using road user charges as a strategy for travel demand management.

"…we want to get more people into public transport, less single-occupant vehicles on the roads, that's why we do road-user charging amongst others, that people start rethinking travelling alone or not making use of public transport, and that's referred to as travel demand management." (P2, February 2019).

There is a strong need for the building of additional road capacity to address the demand of the users. The infrastructure and network capacity growth was the main point of discussion. The road users require additional lanes, routes and expansion in the network system to resolve the issue of traffic congestion. As there is still congestion to the east and west of Allandale Road, this road requires more capacity for the supporting roads that link with it.

The problems encountered in Midrand with developments is that the authorities allow development in the area of Allandale Road and other roads but do not consider the effect that the development may have on the road network. Some procedures obligate the developers to go through, irrespective of what the intentions are. When the developer is required to build up on a certain area, an environmental impact assessment should be conducted. The participants from government Department 2 suggested that since developers make money by developing the residential area and retail properties, they are required to contribute towards the road network to reduce traffic congestion.

Since the development occurs around the Midrand area, a reliable, effective and safe public transport system which is very convenient is required. There is a lack of a mass transit system, and commuters still struggle to obtain proper working and affordable public transport. There is no decent public transport, and the current road transport mode involves minibus taxis which are unsafe and uncomfortable for the users.

In most cases, over 40% of travellers drive their private vehicles with no passengers. These drivers are not engaged in lift clubs at all. Even though the lift club has been encouraged, travellers do not see good results from it.

Table 5.7 below presents a summary of the lacking and still required strategies on Allandale Road.

Table 5.7: Theme 4: Strategies that are lacking and still required

THEME 4	SUB-THEME	DESCRIPTION
Strategies that are lacking and still required	Improving Infrastructure, road capacity and networks	▪ Building additional road capacity to address the demand. ▪ To address congestion, there must be a network solution, such as providing a road network.
	Developer involvement	▪ Environmental impact assessment must be conducted before the commencement of the development. ▪ Developers must contribute the funding to invest in expanding the road. ▪ When developing the area, developers must reserve enough space for future road construction.
	Public transport	▪ A reliable, effective and safe public transport system which is very convenient is required. ▪ There is a lack of a mass transit system in the Midrand area. ▪ There is no decent public transport, and the current road transport mode involves minibus taxis. ▪ Minibus taxis are unsafe and uncomfortable for the users.
	Modal integration	▪ Current road transport mode involves minibus taxis.
	Carpooling	▪ Drivers are not engaged in lift clubs at all. ▪ Travellers do not see good results from it.

Sources: Researcher's compilation

Table 5.7 above summarised the strategies that are lacking and still required on Allandale Road. Table 5.8 in the next section presents a summary of all the instruments or themes discussed in Chapter 5.

5.4 DEVELOPMENT OF THEMES FOR TRAFFIC CONGESTION ON ALLANDALE ROAD (M39)

The themes included below are peak periods of traffic congestion that exist on Allandale Road, strategies to manage congestion on Allandale Road, policies and Regulations and problems that form the underlying contribution. Table 5.8 presents a brief summary of the development of themes for traffic congestion on Allandale Road (M39).

Table 5.8: Summary of the development of themes and categories about Allandale Road's (M39) traffic congestion

THEMES	NARRATIVE
Theme 1: Peak periods of traffic congestion exist on Allandale Road	▪ Traffic congestion exists on different roads and streets in the Midrand areas. ▪ The time interval for traffic runs around the same time, such as 6:00 to 9:00 in the morning. ▪ As the peak period keeps increasing yearly, in the afternoon, traffic starts at 15:00 until 18:00 but generally between 16:00 and 18:00.
Theme 2: Problems that form the underlying contribution	▪ New developments must involve planning and controlling traffic to reduce insufficient planning problems. ▪ Participants shared their experience of lacking an overarching plan and coordination between the different agencies. ▪ Some participants stated that drivers do not abide to the rules and regulations, and drivers travel down emergency lanes and through red traffic lights because there is a lack of law enforcement on the road. ▪ Sometimes traffic lights are not working on more significant intersections, and coordination of the traffic lights is also a problem impacting traffic flow onto the highway. ▪ Government acts independently from one another, where local government provides the developers with the go-ahead to develop the area. ▪ People were segregated to townships from where they must travel long distances, and access to social and economic opportunities was denied. ▪ Historically, Midrand was a rural area, and its popularity has led to a drastic increase in population and vehicle ownership.
Theme 3: Policies, acts and regulations	▪ There is considerable knowledge of the appropriate policies, acts and regulations in some of the government entities, especially those who are responsible for traffic-related incidents. ▪ The entities use those acts and regulations to ensure road safety and the free flow of traffic which prevent traffic gridlock, crashes and deaths on the roads. ▪ Participants mentioned a few policies that are in operation in their entities and that are focused

THEMES	NARRATIVE
	specifically on roads and responsible for making sure that the roads keep running. ▪ The housing department may also include policies that focus on township planning.
Theme 4: Strategies to manage congestion on Allandale Road	▪ There are information systems for managing traffic congestion, but they are only available on the freeways. ▪ Improvements are implemented to relieve congestion but only apply to a specific part of Allandale Road. ▪ More network solutions are required to address the demand for road space. ▪ When developing the area, environmental impact assessments must be performed. ▪ More spaces must be reserved for future use, and developers must be involved financially to invest in expanding the road. ▪ Decent, reliable, safe public roads and lift clubs must be introduced and encouraged.

Sources: Researcher's compilation

Table 5.8 above summarised the development of the themes discussed in this chapter. Based on the findings related to the peak period of traffic congestion, the traffic congestion manifests in different parts of the area, including the streets and roads. The peak times interval are from six o'clock to nine 'o'clock in the morning and four o'clock to six o'clock in the evening.

In some cases, the strategies implemented are available on specific roads, depending on the nature of the territories. This requires a network solution to address the demand for road space. Environmental impact assessments must be performed, and developers must be involved financially to invest in expanding the road.

There is an extensive knowledge regarding the appropriate policies, acts and regulations significantly impacting road traffic congestion. Some entities use those act and regulations to ensure road safety and the free flow of traffic which prevents traffic gridlock, crashes and deaths on the roads.

Finally, new developments require planning and control regarding traffic to reduce insufficient planning problems. Proper law enforcement is encouraged to ensure that the drivers abide by the rules and regulations of the road.

5.5 CONCLUSION

This chapter analysed the results of the data collected from the interview questions. The questions were based on a structured interview with open-ended questions. Eighteen interviews were conducted with 18 officials from the three spheres of government. The researcher elucidates the findings through the thematic analysis of the data collected.

The development of themes for traffic congestion on Allandale Road (M39) was discussed, and the significant findings were: (a) Traffic congestion exists on different routes and streets in Midrand areas, and the peak time intervals run from around 06:00 until 09:00 in the morning, and then starts again at 15:00 until 18:00, but generally between 16:00 and 18:00. (b) Environmental impact assessments must be performed when developing the area. More spaces must be reserved for future use, and developers must be involved financially to invest in expanding the road. (c) There is extensive knowledge regarding the appropriate policies, acts and regulations significantly impacting road traffic congestion. (d) Midrand was a rural area, and its popularity has led to a drastic increase in population and vehicle ownership.

The next chapter discusses the analysis of the study's quantitative findings.

CHAPTER 6:
QUANTITATIVE DATA ANALYSIS, INTERPRETATION AND FINDINGS

6.1 INTRODUCTION

The primary objective of the study was to find ways to manage road traffic congestion on Allandale Road (M39) in Midrand, South Africa. The purpose of this chapter is to present the quantitative findings related to the traffic congestion on Allandale Road (M39). The study followed an exploratory sequential mixed-method research design. After completing the qualitative data analysis, the researcher used the findings to create a questionnaire, and the questions asked will be analysed in this chapter. The respondents were the private vehicle drivers who used the above-mentioned road from Monday to Friday. A total of 276 questionnaires were completed. The data from the structured questions was analysed through descriptive and inferential analysis using the IMB SPSS Statistics (Version 26).

To enable the study to achieve the primary objective of the study, the following secondary research objectives were formulated:

- To determine the peak periods of road traffic congestion on Allandale Road (M39). The results of this objective are presented in section 6.3.1.
- To establish the problems contributing to traffic congestion that users on Allandale Road (M39) experience daily. Section 6.3.2 presented the results of this objective.
- To identify the supporting policies and regulations impacting road traffic congestion. The results of this objective are presented in section 6.3.3.
- To explore the strategies used for managing road traffic congestion within this urban area. Section 6.3.4 outline the results of this objective.

The final section of this chapter presents the descriptive analysis which is followed and concluded by inferential statistics analysis. Figure 6.1 presents the structural flow of Chapter 6 in alignment with the study.

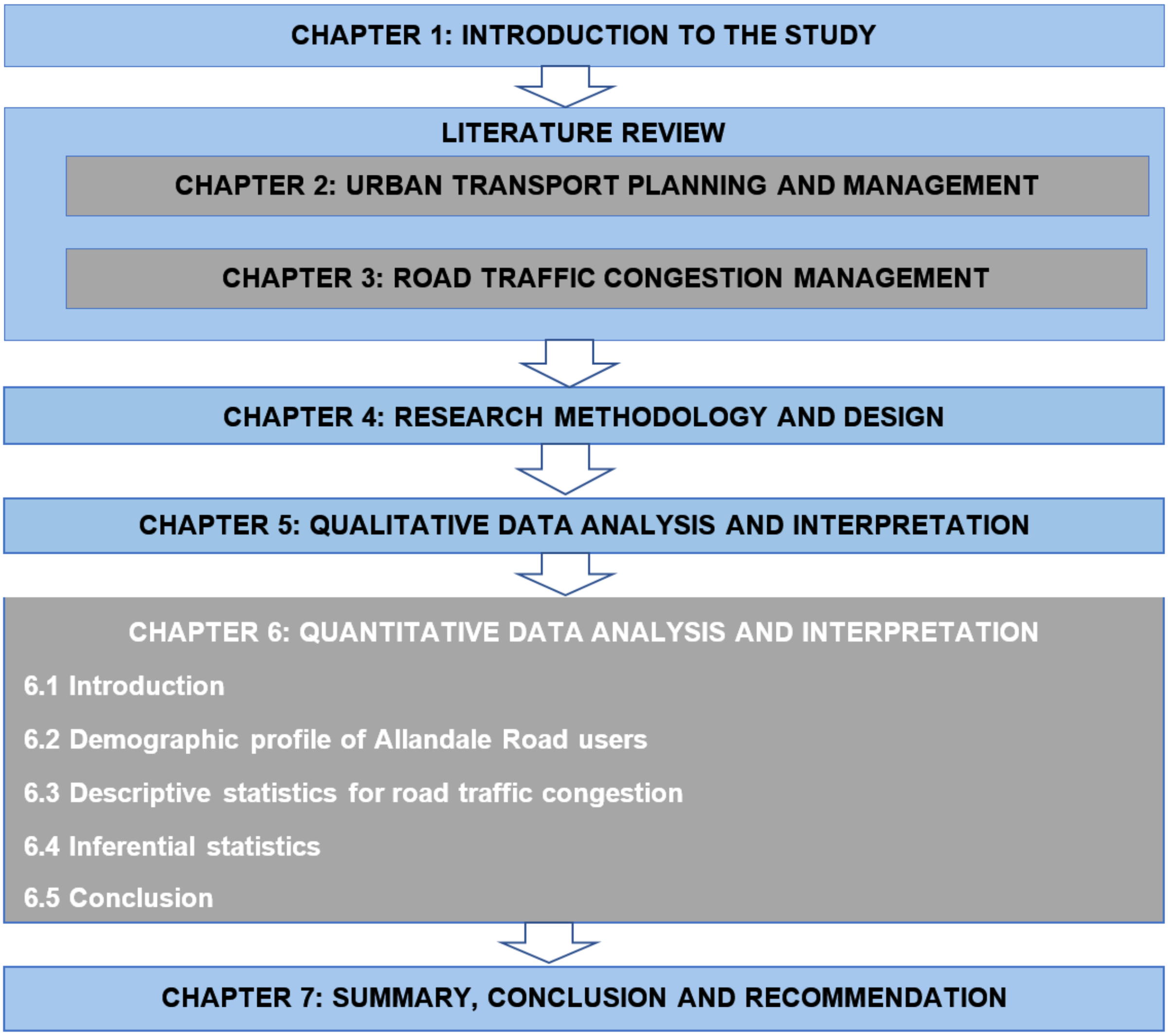


Figure 6.1: Structural flow of Chapter 6 in alignment with the study

Source: Researcher's compilation

As shown in Figure 6.1 above, this chapter will present the results and findings of the empirical study. Section 6.2 below describes the demographic profile of Allandale Road users.

6.2 DEMOGRAPHIC PROFILE OF ALLANDALE ROAD USERS

This section presents the demographic profile of Allandale Road users, such as the gender, age group, place of residence, educational background, status of occupation, approximate monthly income, the amount spent on petrol on a monthly basis, and the reasons for daily travelling activities. The results are presented from Sections 6.2.1 to 6.2.8 below.

6.2.1 Gender

Gender plays a fundamental role when it comes to driving and owning a vehicle. The gender response was included to scrutinise any possible differences in the behaviour that could generate traffic congestion on the road. According to Baratian-Ghorghi and Zhou (2015), female road users are usually associated with increased trip-making, and are cautious, relying on traffic condition information through broadcasting that guides drivers onto less congested paths. However, male drivers have more road exposure than female drivers and they are more prone to speeding, traffic violations, drugs and alcohol use which could instigate traffic congestion as an outcome of accidents (Cordellieri *et al.*, 2016).

This question was asked under Section B3 of the questionnaire. Figure 6.2 below indicates the gender differentiation of the respondents.

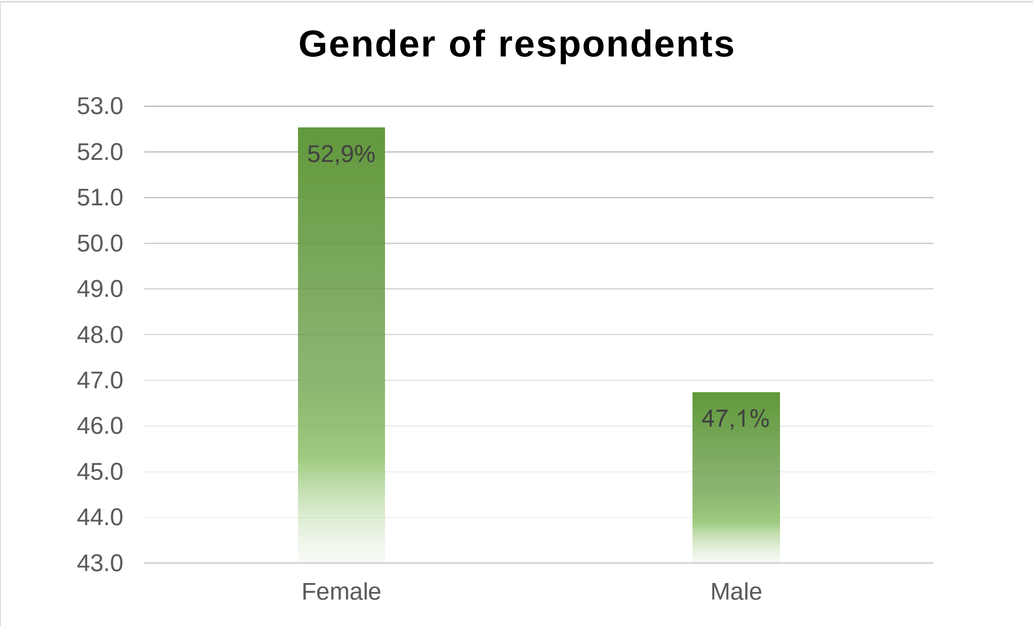


Figure 6.2: Indication of respondent's gender

A total number of 272 out of 276 respondents answered this question. Of the total, 47,1% were males and 52,9% were females. Constructed on the results disclosed regarding the driving and ownership of vehicles in the area, the results revealed that a high percentage of women (53%) in the area use their own vehicles to travel to and from the workplaces.

The findings in this section are coherent with the previous literature stating that women are more likely than men to prefer vehicle ownership, and the main reason is related to the poor public transport services (Akyuz, 2015:444; Anciaes, Metcalfe & Heywood, 2017:180). Women are also possibly more affected by the health conditions, noise, walking and accessibility to public transport (Gundersen, 2013; Anciaes *et al.,* 2017).

The next section presents the percentages related to the respondents' age groups.

6.2.2 Age group

This research study targeted only economically active respondents from the age of 18 to 64 and above. The age group is regarded as an essential element when discussing the issue of driving. According to Rolison, Regev, Moutari and Feeney (2018), inexperience and driver distraction are frequently found among young drivers, while older drivers travel cautiously at lower mean speeds. Extensively, youth drivers are more likely to create problems on the roads by positioning a significant burden, misreading signs and missing traffic signals (Zahid *et al.*, 2020).

Figure 6.3 indicates the age group of the respondents using Allandale Road (M39).

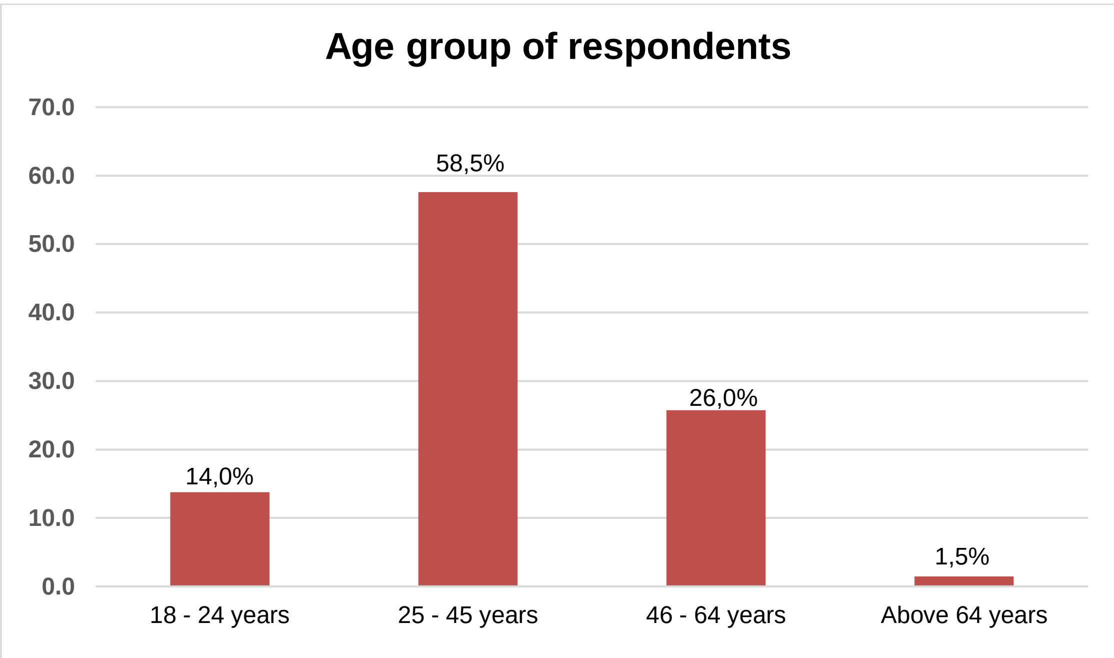


Figure 6.3: Indication of the respondent's age group

The respondents were asked to indicate the age group they fit in, which ranged from 18-24, 25-45, 46-64 and above 64 years. The highest percentage in this regard is 58,5% for the respondents between the age of 25-45, followed by 26,0% of the respondents who fell in the category of 46-64 years. Then 14,0% respondents fell in the 18-24 category, and 1,5% were above the age of 64. The findings in Figure 6.3

above show that the highest percentage of respondents who are private vehicle owners driving on Allandale Road, fell in the age group of 25-45.

A study by Agyapong and Ojo (2018:91) discovered that the majority of the respondents in their study were between the ages of 25-45 years. This age group prefers private vehicles in the area which then dominates the mode of transport, and users prefer this mode to reach their destinations. The next section indicates the percentages related to the respondent's place of residence.

6.2.3 Place of residence

The place of residence plays a pivotal role in terms of vehicle ownership and traffic congestion in Midrand area. The residential areas that the respondents originate from play an important role, as the location of the residence is based on the owner's income. Underprivileged zones with poor road networks have been established around some areas in the vicinity, which could conceivably result in prolonged traffic jams (Mokwena, 2014; Chauhan, Kansagra & Prajapati, 2017:2).

It is crucial to recognise the opinions of the people who live within the areas suffering from traffic congestion. Their reaction towards traffic jams can assist the decision-makers to find solutions, as well as developing more efficient and useful policies (Rajé *et al.*, 2018). Figure 6.4 indicates the place of residence of the respondents.

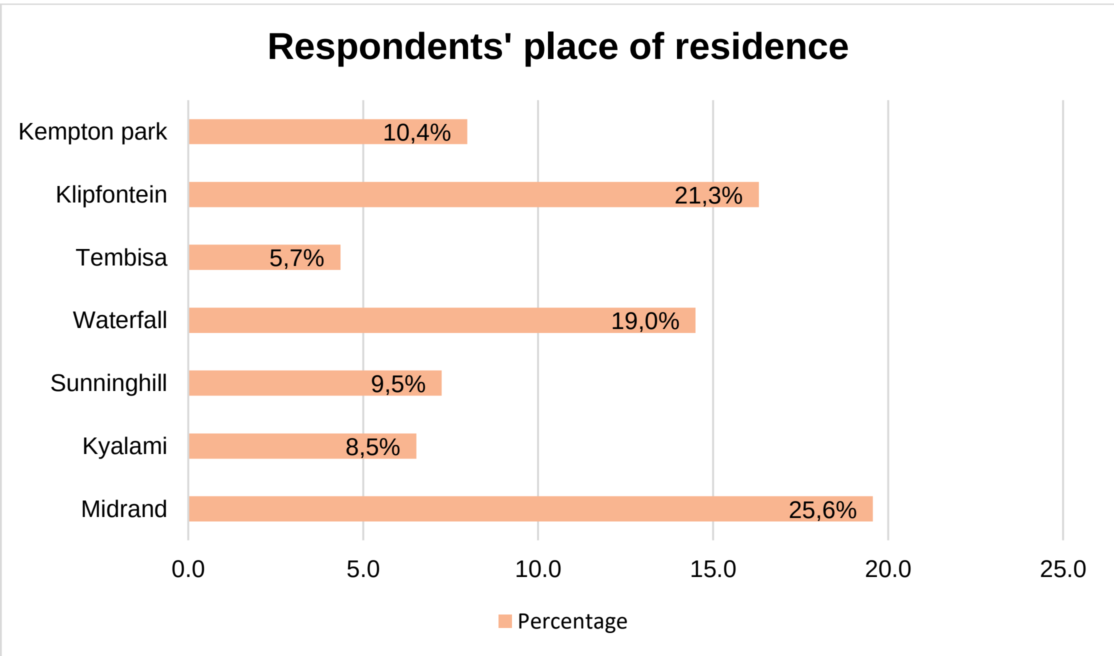


Figure 6.4: Indication of the place of residence

The figure above shows that there were 276 responses related to the place of residence. The majority of the respondents were from Midrand, with the highest percentage of 25,6%, followed by Klipfontein with 21,3%. Respondents from Waterfall made up 19,0% of the total, while 10,4% emanated from Kempton Park, followed by Sunninghill and Kyalami with 9,5% and 8,5%, respectively. The lowest percentage was 5,7% from Tembisa.

Some other places of residence that were included by the respondents are Alexandra, Buccleuch, Centurion, Edleen, Fourways, Glen Austin, Ivory Park, Juskei View (also known as Waterfall View or Waterfall View Estate), Mayibuye, Modderfontein, Morningside, Sandton and Vorna Valley (section in Midrand). The responses (See Appendix D) showed Ivory park with 4,0%, 3,6% for Glen and 2,9% for Edleen. Further, there was Juskei View (Waterfall View or Waterfall View Estate) with 1,9%, Alexandra and Fourways with 1,8%, while Buccleuch and Vorna Valley amounted to 1,1%. Of the respondents, 0,4% emanated from Centurion, Modderfontein and Sandton.

These results correspond with other traffic studies which stated that the traffic volumes have increased due to the new developments in the area (Wild, Woodward, Field & Macmillan, 2018). In this regard, Midrand seems to be growing because of the numerous developments taking place.

6.2.4 Educational background

Figure 6.5 indicates the educational background of the respondents. The respondents were asked to indicate their highest level of education. The categories were high school including Grade 12, college or university student, graduate from the university or college, postgraduate (including honours, masters and doctoral), and professional.

According to Mudau *et al.* (2014), the highest percentage of people travelling do so for educational commitments.

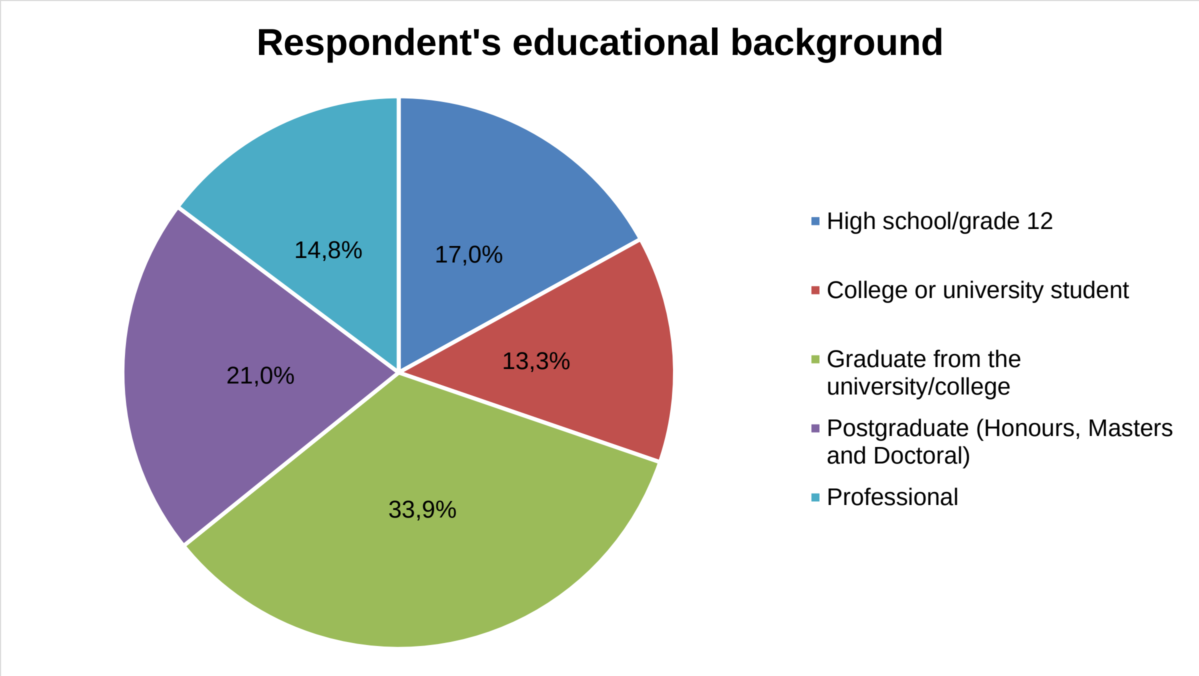


Figure 6.5: Educational background

As demonstrated in Figure 6.5 above, the highest percentage of respondents were graduates from the university or college at 33,9%. The postgraduates category, such as honours, master's and doctoral degrees, were at 21,0%, followed by 17,0% for high school or Grade 12 respondents. The professional respondents were at 14,8%, while college or university students were at 13,3%. Other educational background included Grade 11 with a percentage of 0,4%, followed by Grade 8 with the percentage level of 0,7%, then lastly, nursing student with a percentage of 0,4%.

The educational background of respondents plays an important role in travelling behaviour. According to data from a metropolitan city in Ghana, the use of private cars by private school teachers is connected to an increase in road traffic congestion (Annan, Mensah & Boso, 2015). From the information provided, it might be assumed that travellers with higher educational backgrounds might have the possibility of owning a vehicle.

6.2.5 Indication of the status of occupation

The respondent's status of occupation was categorised according to: company employee, business owner or self-employed, unemployed and student. The above aspect generates a significant impression that individual with the status of occupation, such as owning a business or company employees, may relatively have the possibility of owning a vehicle. According to Allen *et al.* (2018), increased congestion can interrupt productivity in commercial industries through additional operating costs and degrading the size of market areas served from any given business location. Figure 6.6 indicates the status of occupation.

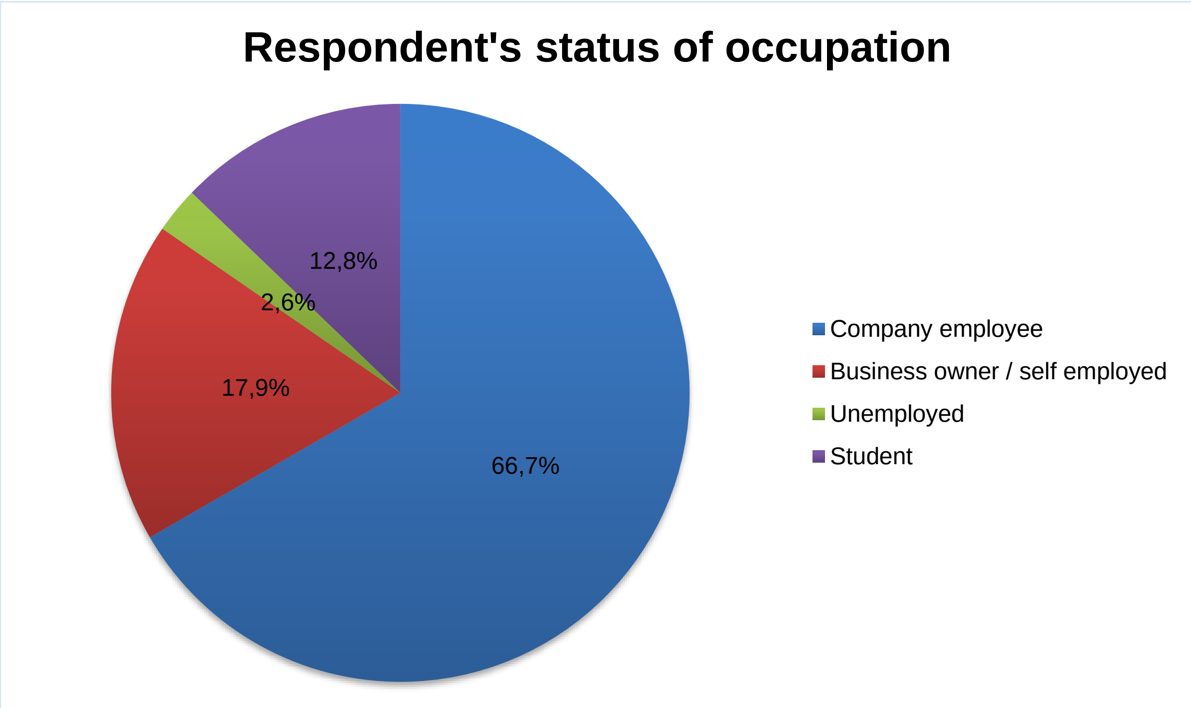


Figure 6.6: Indication of status of occupation

As shown in Figure 6.6, the highest percentage, 66,7% of the respondents was derived from company employees. The responses of business owner or self-employed indicated 17,9%, followed by students at 12,8%, while unemployed respondents amounted to 2,6%. Other status of occupation included retired respondents at 0,4%.

These results correspond with other traffic studies that found that employment patterns are regarded as one of the causes of traffic congestion (Talukdar, 2013:56; Anciaes *et al*., 2017:181). In this regard, the highest percentage 66,7% for company employees is proof that people move from one place to another for the purpose of employment.

6.2.6 Approximate monthly income

The respondents were requested to indicate their monthly income. The monthly income amounts ranged from below R10 000; R10 000-R15 000; R15 001-R20 000; R20 001-R25 000; R25 001-more and None. The none category was also included to ensure that respondents with incomes below R10 000 and above R25 001 can select the option. Under approximate monthly income, this research study targeted only private vehicle drivers. Pitesa and Pillutla (2019) indicated that the workers who are earning high salaries can afford the cost of the monthly instalment and insurance of the purchased vehicle. Figure 6.7 below indicates the approximate monthly income.

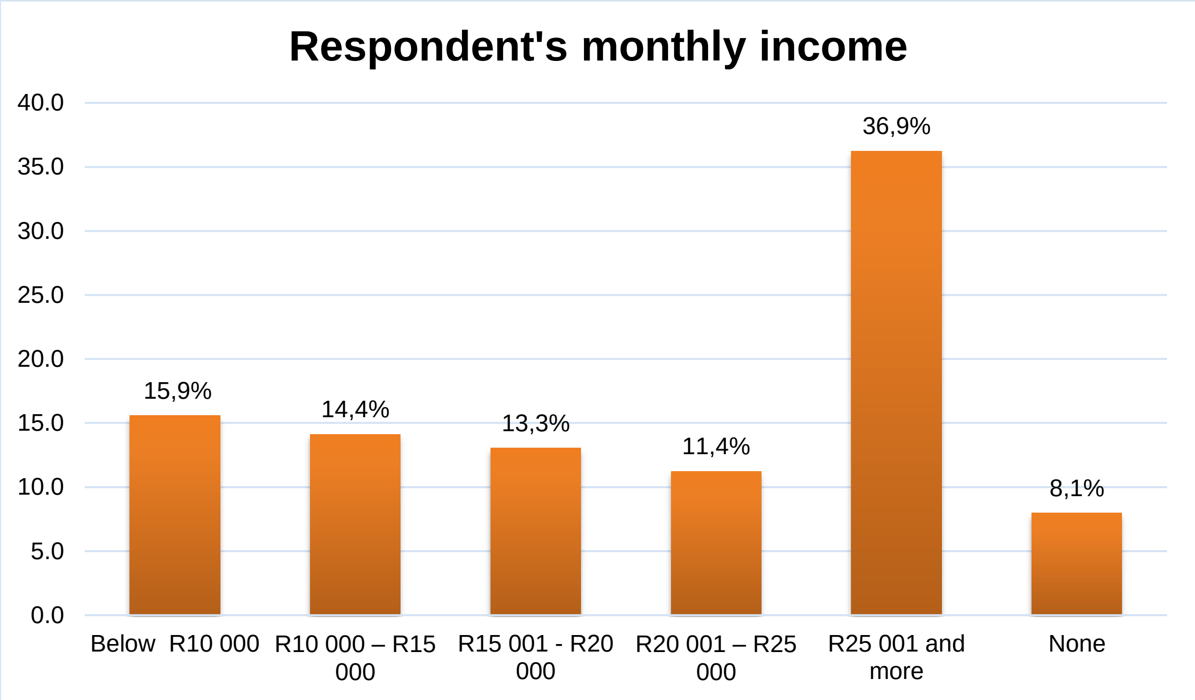


Figure 6.7: Indication of approximate monthly income

The percentages for each approximate category of monthly income were disseminated as follows: 36,9% respondents indicated their monthly income to be R25 001 and more; 15,9% respondents indicated they receive an income below R10 000, while about 14,4% receive a monthly salary between R10 000 and R15 000; 13,3% respondents indicated their monthly income between R15 000 and R20 000, while 11,4% indicated between R20 001 and R25 000; and 8,1% of the respondents indicated their monthly income under the none option.

The instant growth of income in developing countries, such as India, is increasing the demand for many goods and services, including four-wheeled passenger cars (Gilmore & Patwardhan, 2016). These findings confirm the literature in Section 3.3.4.1 that high income encourages people to buy vehicles (Clark & Rey, 2017). This also confirmed that travellers may opt to buy private vehicles when their income starts to increase.

6.2.7 Amount spent on petrol on a monthly basis

Five categories were created to indicate the vehicle drivers' expenses related to petrol during the travelling trips. The categories ranged from below R1000 to R3000 or more. The amount spent on petrol specifies a fundamental point in terms of vehicles trapped in the traffic congestion, while commuters spend numerous hours per day on their way to work in the morning and back home in the evening (Kellett, Barreto, Hengel & Vogiatzis, 2019).

Should people decide to drive less and have access to other ways of commuting, such as car sharing or public transport, this will reduce the expenditure on petrol, and this will fairly reduce road traffic congestion. Figure 6.8 indicates the respondents' indications of the amount spent on petrol on a monthly basis.

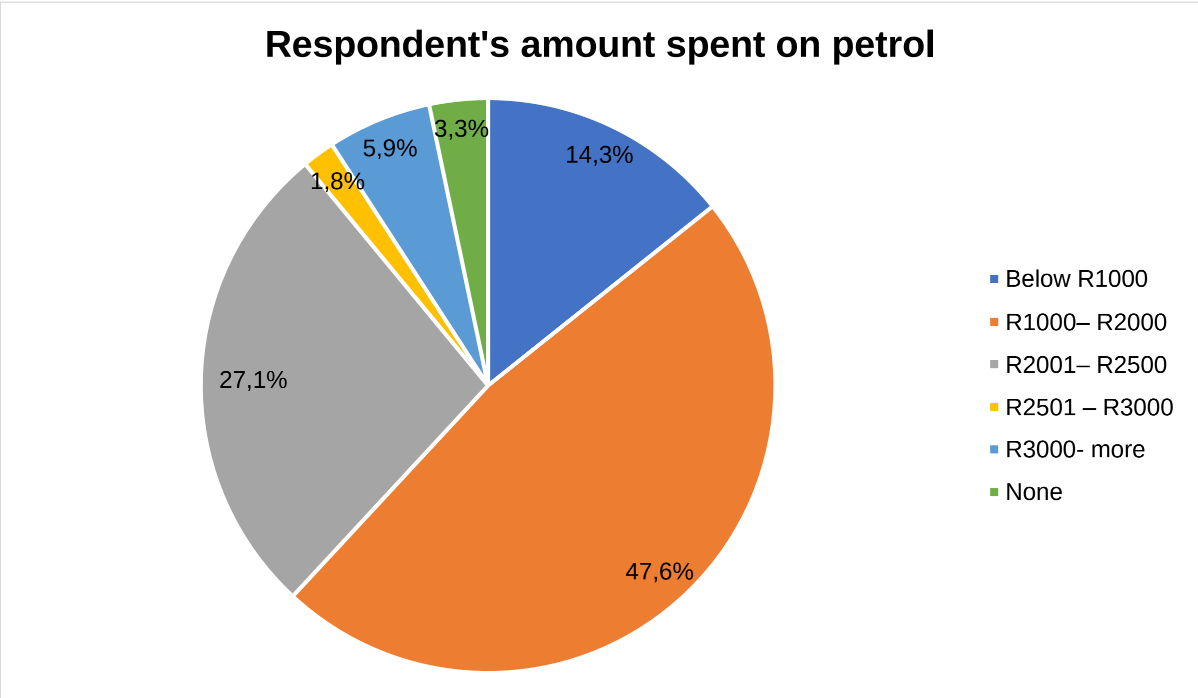


Figure 6.8: Indication of the amount spent for petrol on a monthly basis

The respondents were asked to indicate the amount spent on petrol on a monthly basis. The figure shows that the highest category of petrol expenses is the R1000 - R2000 category at 47,6%. This was followed by the R2001 – R2500 category at 27,1%, and 14,3% for the below R1000 category. The R3000 or more category constituted 5,9%, while 3,3% represented the none category, followed by 1,8% for the R2501 – R3000 category.

One of the various parameters related to traffic congestion is fuel consumption. Vehicles that are stuck longer in the stop-and-go traffic, in turn, consume more fuel. This clearly indicates that respondents who are driving their own vehicles tend to spend more money on petrol costs than those who do not.

6.2.8 Reasons for daily travelling activities

The respondents were requested to indicate the reasons for their travelling activities. Five reasons were used to indicate the daily travelling activities of the respondents. Figure 6.9 illustrates the respondents' reasons for travelling.

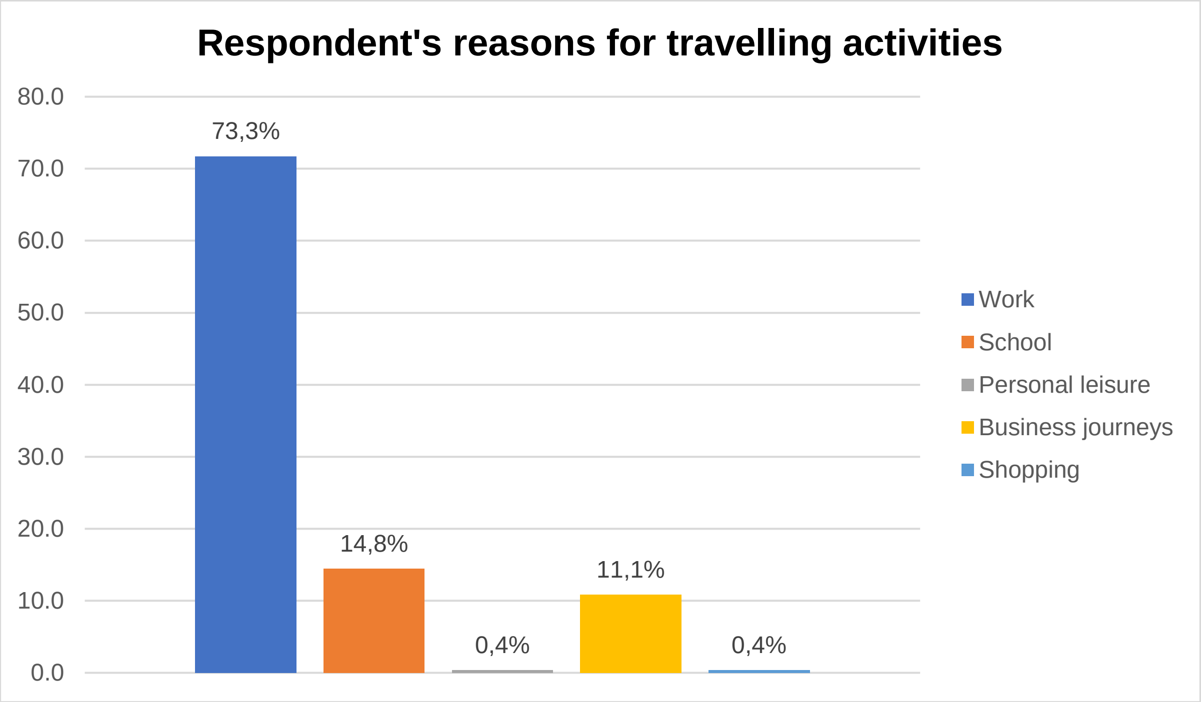


Figure 6.9: Reasons for daily travelling activities

It is evident from the highest percentage of 73,3% in Figure 6.9 above that the respondents are travelling on a daily basis because of work purposes. The outcome of this percentage agrees with previous research stating that commuters travel every day for reasons such as work, education, leisure, medical and welfare and shopping (Stolfi *et al.*, 2016:1015; Mudau *et al.*, 2014:813). Further travelling activities such as school constituted 14,8% of respondents, followed by business journeys at 11,1%. Both personal leisure and shopping had at least 0,4% of respondents each.

Furthermore, Stolfi *et al.* (2016:1016) confirmed that a detected threshold of more than 2000 vehicles is found on a road twice a day when people travel to their workplaces and when they return to their homes. This rationalises the percentages revealed above that daily travelling activities show that the roads are congested during the weekdays when the travellers have to commute from their place of residence to their work destination. The table in Appendix F shows other reasons for daily travelling activities, which include that the drivers not only use the vehicles for their own travel but also to assist family members to travel to work and school. Transporting family members to work and dropping children off at school have a percentage of about 0,4%.

Section 6.3 below presents the descriptive statistics for road traffic congestion based on roads, streets and peak periods, strategies for managing road traffic congestion, policies and regulations that have impacts and values on the management of road traffic congestion, and problems contributing to road traffic congestion.

6.3 DESCRIPTIVE STATISTICS FOR ROAD TRAFFIC CONGESTION

To gain an understanding of the data prepared in the next sections, a descriptive analysis of the data is presented. The variables used are derived from Section D to Section F in the questionnaire (refer to Appendix B). When describing the data, a descriptive statistic recapitulates the data, which provides an endorsement to the responses to elementary questions (Ross, 2014). The sections below present the results of the analysis as follows:

6.3.1 Peak periods of traffic congestion in Midrand area

This section presents the findings related to the road and street of the traffic congestion, looking into the level of traffic congestion on Allandale Road (M39), roads that are also congested, compared to Allandale Road (M39), the level of traffic congestion on street intersections along Allandale Road (39), and the morning and afternoon peak periods of traffic congestion on Allandale Road (M39).

6.3.1.1 Level of traffic congestion on Allandale Road (M39)

Figure 6.10 indicates the opinions of the respondents on the level of traffic congestion on Allandale Road (M39). The levels of traffic were tested based on the 5-point Likert-type scale ranging from “traffic congestion is very high” to “traffic congestion is very low”. The results in the form of percentages are presented below.

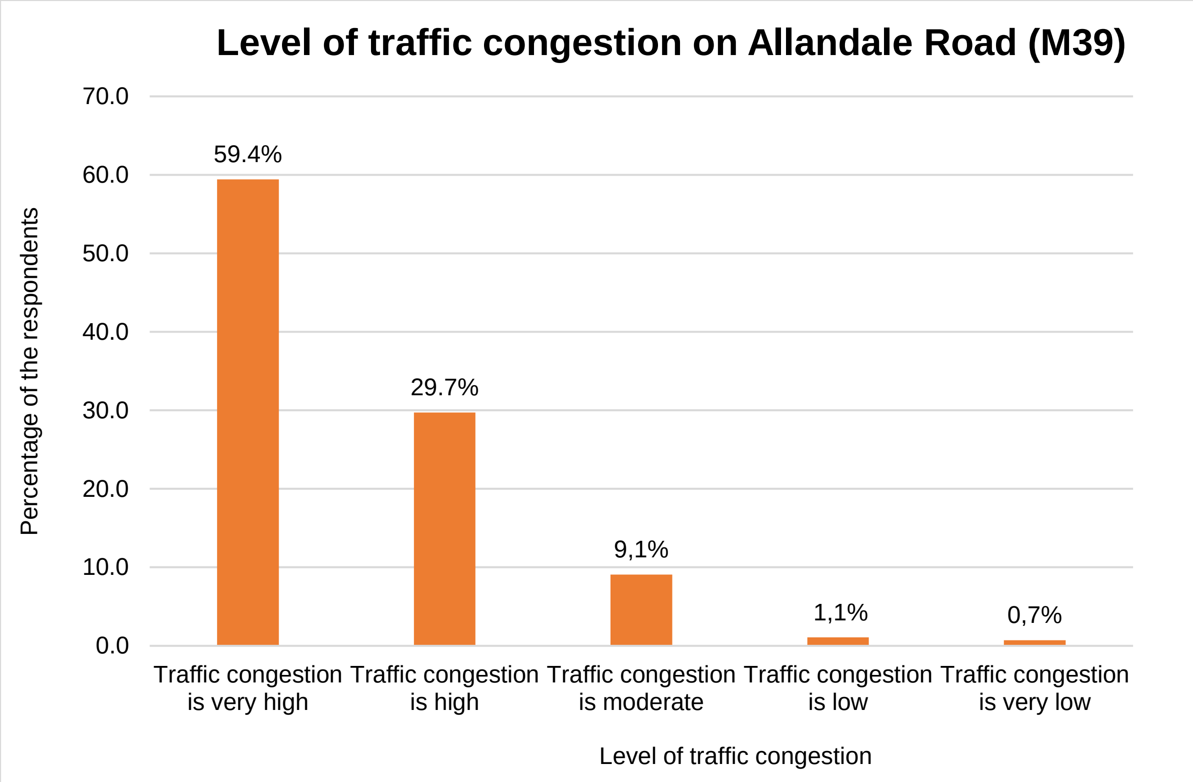


Figure 6.10: Level of traffic congestion on Allandale Road (M39)

The total number of 276 respondents responded to the question based on the level of traffic congestion on Allandale Road (M39). As illustrated in Figure 6.10 above, 59,4% of the respondents felt that "traffic congestion is very high", followed by "traffic congestion is high" at 29,7%, with "traffic congestion is moderate" at 9,1%. This is followed by "traffic congestion is low" at 1,1%, and finally, "traffic congestion is very low" at 0,7%.

The high percentage level of traffic congestion on Allandale Road (M39) might be generated by the fact that there is a lack of proper public transport in the area and travellers have to opt for private vehicle usage.

6.3.1.2 Peak periods of traffic congestion on Allandale Road (M39)

In Section C of the questionnaire, the fourth question asked the respondents to indicate the morning peak periods of traffic congestion taking place on Allandale Road (M39). The morning peak period measures ranged from 5:30 – 9:00, 6:00 – 9:00, 6:30 – 9:00, 7:00 – 9:00 and 7:30 – 9:00. Figure 6.13 represents the outcome of the morning peak periods of traffic congestion, and these are indicated in percentages as shown below.

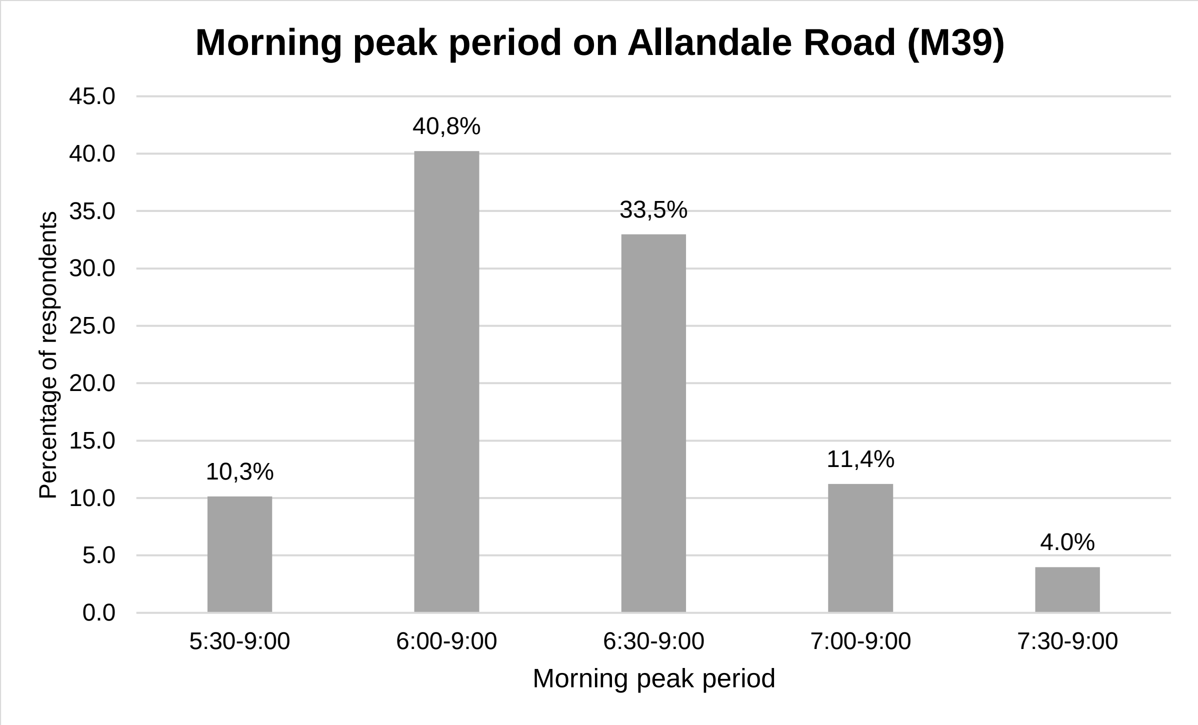


Figure 6.11: Morning peak periods on Allandale Road (M39)

As seen in the figure above, 272 respondents answered this question regarding the morning peak periods of traffic congestion on Allandale Road (M39). The majority of the respondents (40,8%) indicated that the morning peak period ranges from 6:00 – 9:00. This was followed by 33,5% of the respondents who agreed that the morning peak is from 6:30 – 9:00. Only 11:4% of the respondents chose the range from 7:00 - 9:00, followed by 10,3% of the respondents who regarded the morning peak to run from 5:30 – 9:00, and finally, 4,0% of the respondents chose from 7:30 – 9:00 in the morning.

Based on the information presented, the literature research in Section 3.8 confirmed that the morning peak period of traffic congestion in places such as Sandton, Johannesburg, Pretoria, Midrand, Midstream and Centurion starts from 6:15 and lasts until 9:00. The findings in Figure 6.13 show the highest percentage of respondents confirming that the morning peak period certainly spans from 6:00 – 9:00 and/or 6:30 – 9:00. This information could assist commuters, traffic officials, transport planners and other stakeholders to have sufficient knowledge of the traffic congestion taking place on Allandale Road (M39).

In Section C of the questionnaire, the fifth question asked the respondents to indicate the afternoon peak period of the traffic congestion on Allandale Road (M39). The afternoon peak period measure ranged from 15:00 – 18:00, 15:00 – 18:30, 15:30 – 18:00, 16:00 – 18:00, and 17:00 – 18:00. Figure 6.12 represents the outcome of the afternoon peak periods of traffic congestion indicated in percentages.

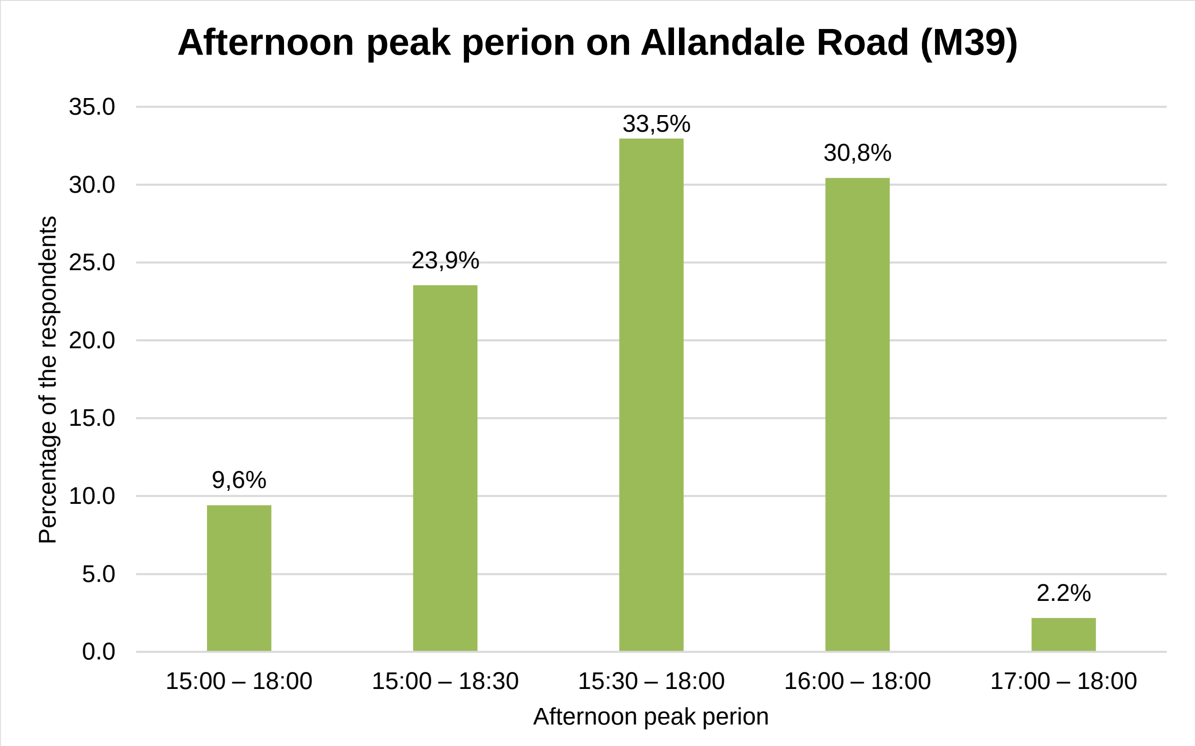


Figure 6.12: Afternoon peak periods on Allandale Road (M39)

The figure above shows that there were 272 responses regarding the afternoon peak periods of traffic congestion on Allandale Road (M39). The highest percentage of respondents (33,5%) felt that the afternoon peak period ranges from 15:30 – 18:00. This was followed by 16:00 – 18:00 with 30,8%, followed by 15:00 – 18:30 with 23,9%, while 9.6% of the respondents chose 15:00 – 18:00. Of the respondents, 2,2% chose from 17:00 – 18:00.

The above results diverge from that of Agyapong and Ojo (2018:92) revealing that in Ghana, Accra Central Market, the afternoon peak period is from 14:00 until 16:00. The results might show that the peak period of traffic congestion depends on the travelling patterns, the place and the activities taking place in that particular metropolitan area.

6.3.1.3 Kilometres spent on a daily travelling

The respondents were asked to point out the distance in kilometres spent on a daily basis when travelling to and from their destination. The options presented to the respondents ranged from 20-29 kilometres, 30-35 kilometres, 36-40 kilometres and

41-50 kilometres. The respondents were also assigned with an option to specify other kilometres. Figure 6.13 below presents the kilometres spent on a daily commute in percentages.

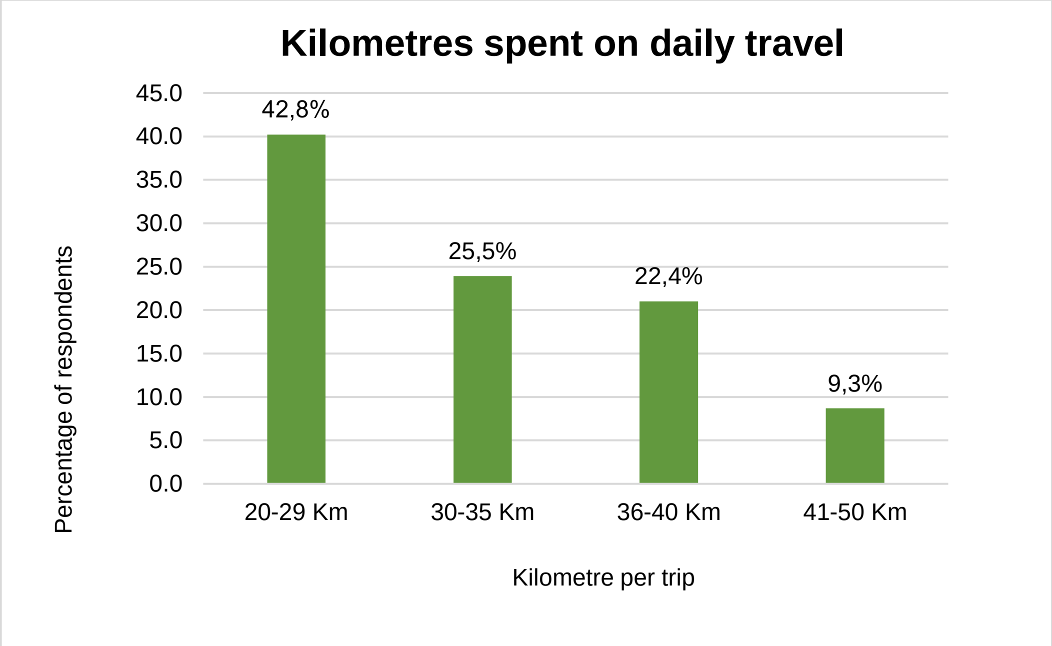


Figure 6.13: Kilometres spent on a daily travelling

As shown in the above figure, the highest percentage of respondents (42,8%) travelled the distance of 20-29 kilometres. This was followed by 25,5% of the respondents who travelled from 30-35 kilometres, followed by 22,4% who travelled from 36-40 kilometres, and 9,3% who travelled 41-50 kilometres. The option of "Other travelling distance" shows that (see Appendix D) 2,9% of the respondents travelled 15-20 kilometres, followed by 2,5% with 10-15 kilometres, and finally, 0,4% of the respondents with a travelling distance of 73 kilometres.

Travellers might find it easier to use their private vehicles to travel from their residence to their destination, especially when it is a distance of 20-29 kilometres, as indicated above. However, the public transport providers must ensure that the services are available and accessible to travellers, even on a short distance trips or specifically around the area.

6.3.2 Problems contributing to road traffic congestion

The questions related to problems aimed to discover the problems contributing to the road traffic congestion that users on Allandale Road (M39) experience on a daily basis (refer to Appendix B: Questionnaire, Section D).

The five problems, as guided by the literature were: increased vehicle ownership, growth of population in the area, new developments in the area, roadworks and construction, and mismanagement of road traffic systems. The questionnaire used a five-point Likert-type scale for these questions. The items on the questionnaire were combined into three categories for enhanced interpretation. Consequently, the ratings such as "strongly agree" to "agree" and "strongly disagree" to "disagree" were collapsed into one classification.

Figure 6.14 indicates the results related to problems contributing to road traffic congestion.

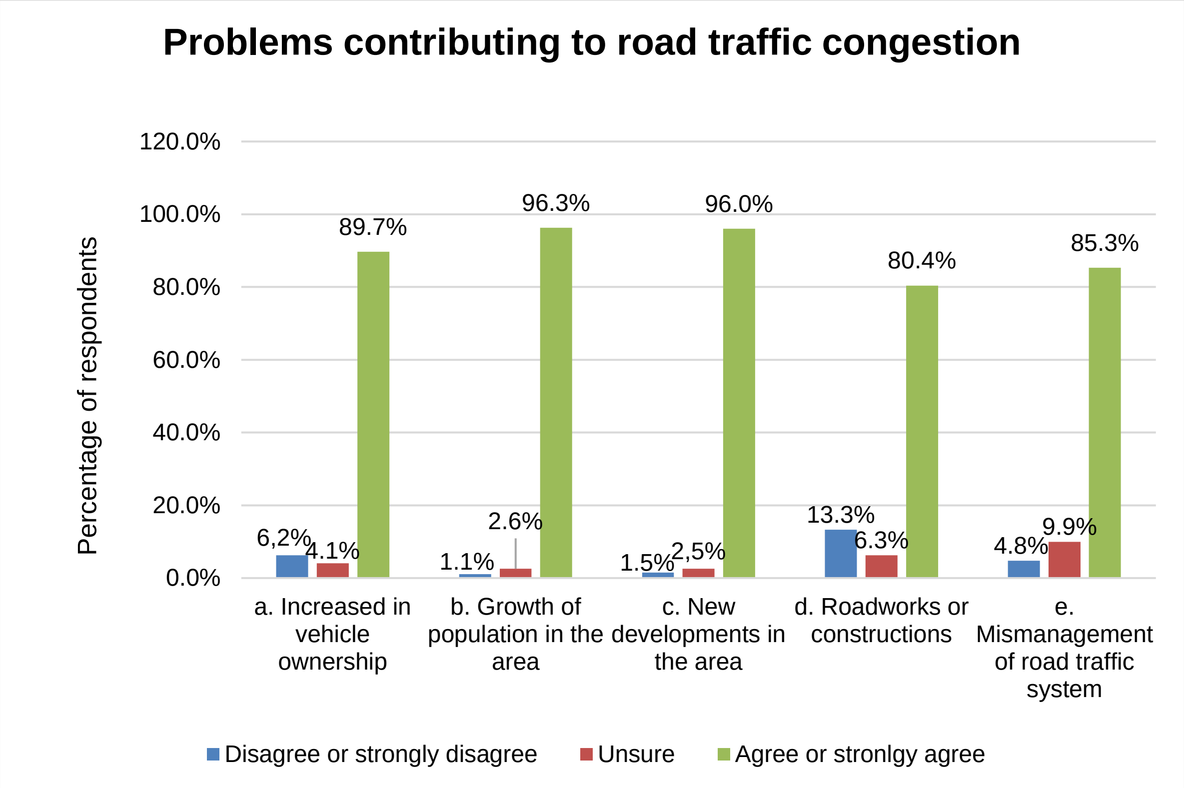


Figure 6.14: Problems contributing to road traffic congestion

As shown in Figure 6.14 above, the respondents indicated a high level of 96,3% that population growth in the Midrand area contributes to road traffic congestion, followed by 96,0% for new development in the area. These results were followed by increased vehicles ownership at 89,7%, then 85,3% for the mismanagement of road traffic systems. Finally the respondents indicated roadworks or construction at 80,4%.

Based on the information provided, this result corresponds with the literature overview in Section 3.3.4.2, that according to Li, Zhou and Rouphail (2017), population growth can lead to increased demands for travel which can create mobility challenges for capacity-limited transportation networks.

6.3.3 Policies and regulations that have impacts and values on the management of road traffic congestion

This section describes the policies and regulations which are measured on the third secondary objective of the study, namely, to identify and describe the supporting policies and regulations that have values and impact on managing road traffic congestion (refer to Appendix B: Questionnaire, Section E).

The questions used a five-point Likert-type scale. In this section, the items were collapsed into three categories for well-defined interpretation. Therefore, the ratings such as “strongly agree” to “agree” and “strongly disagree” to “disagree” were combined into one classification. The “Unsure” category remained the same. The supporting policies and regulations that have values and impact on the management of road traffic congestion are discussed below.

6.3.3.1 Level of agreement on statements provided under White Paper on National Transport Policy, 1996

The level of agreement on White Paper on National Transport Policy, 1996 included the first question related to identifying and describing the supporting policies and regulations that have values and impact on the management of road traffic congestion.

Figure 6.15 indicates the results of the level of agreement on statements provided under the White Paper on National Transport Policy.

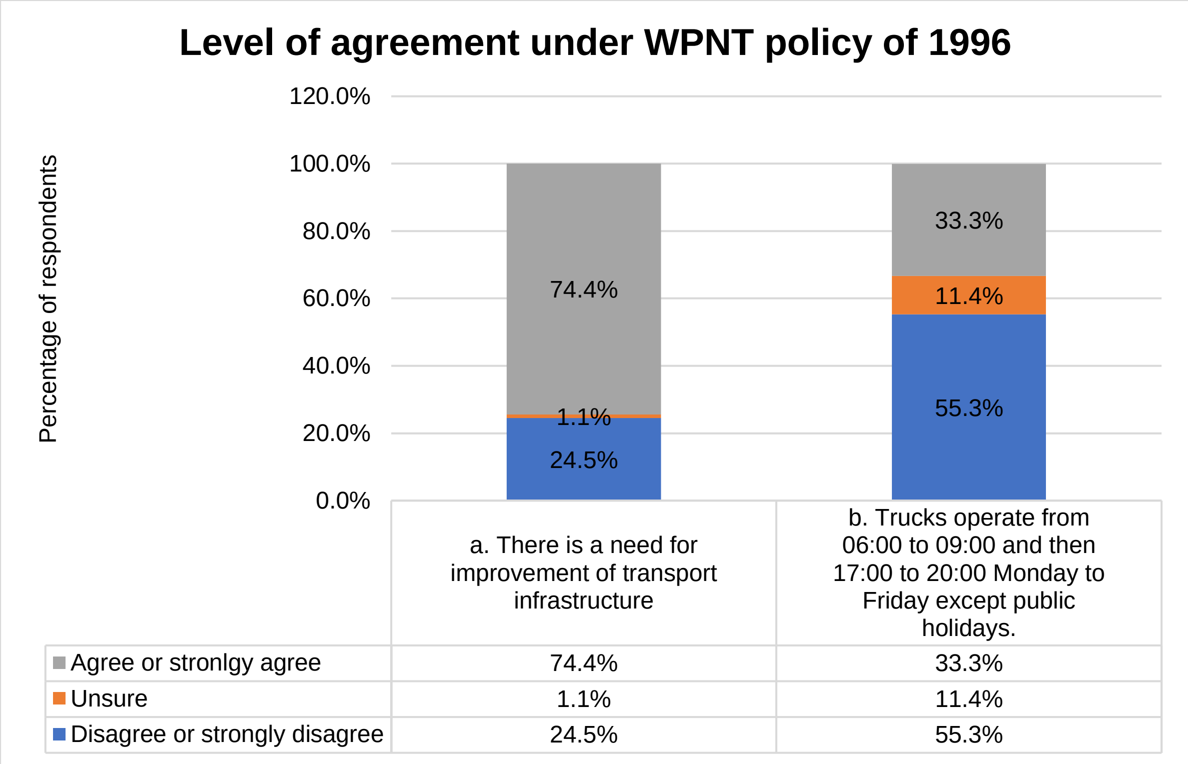


Figure 6.15: Level of agreement on statement provided under White Paper on National Transport Policy, 1996

As shown in the above figure, 74,4% of the respondents indicated that there is a need for improvement of transport infrastructure on Allandale Road (M39) to correspond with the statement provided under White Paper on National Transport Policy, 1996. Only 33,3% of the respondents indicated that trucks should operate from 06:00 to 09:00 and then from 17:00 to 20:00 Monday to Friday except public holidays.

Based on the information provided it is imperative for the infrastructure service provider to consider the provision of the public transport infrastructure on Allandale Road (M39). By doing so, commuters will deliberately plan to use public transport. The restriction of the truck movements during a specific time must also be imposed to ensure that all regulations are adhered to.

6.3.3.2 Level of agreement on statements provided under National Land Transport Act, 2009

The level of agreement on statements provided under the National Land Transport Act, 2009 were the second concept identifying and describing the supporting policies and regulations that have values and impact on the management of road traffic congestion. Figure 6.16 indicates the results of the level of agreement on the statements provided under the National Land Transport Act, 2009.

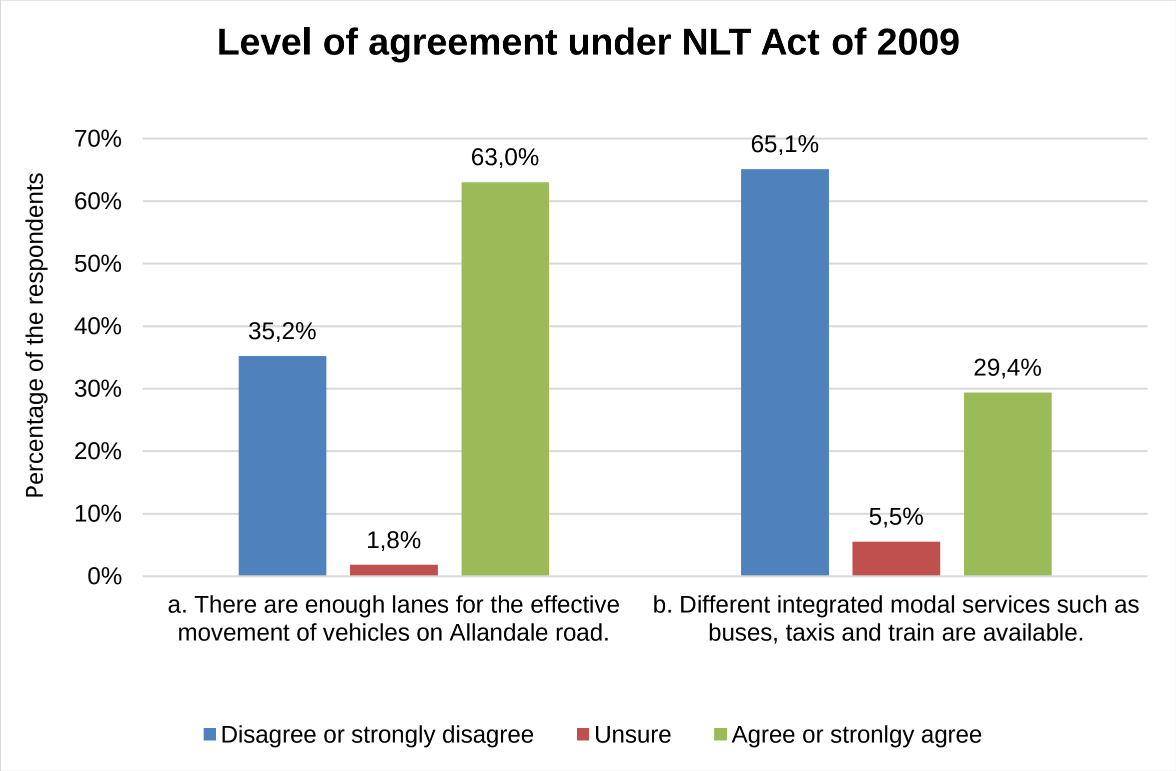
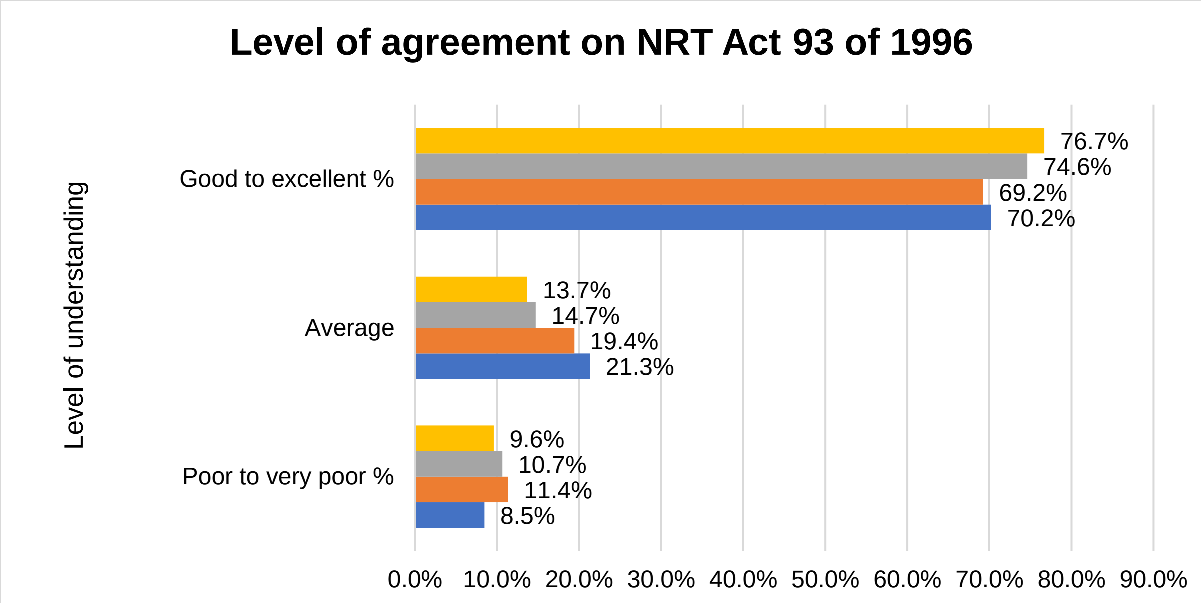


Figure 6.16: Level of agreement on statements provided under National Land Transport Act, 2009

As shown in Figure 6.19, most of the respondents (65,1%) rated the statement "different integrated modal services such as buses, taxis and trains that are available". Of the respondents, 35,2% also indicated that there are not enough lanes for the effective movement of vehicles on Allandale Road (M39). The above information well-defines the situation regarding the different modal services in the area which are either not available or not sufficient for the commuters to utilise.

6.3.3.3 Level of agreement on statements provided under National Road Traffic Act 93 of 1996

The level of agreement related to statements provided under the National Road Traffic Act 93 of 1996 were the third concepts measured in identifying and describing the supporting policies and regulations that have values and impact on the management of road traffic congestion. Figure 6.17 indicates the results of the level of agreement on statements provided under the National Road Traffic Act 93 of 1996.



	Poor to very poor %	Average	Good to excellent %
d. Understanding the rule of driving under the influence of alcohol or drugs.	9.6%	13.7%	76.7%
c. Understanding the rule of speed limits on the roads.	10.7%	14.7%	74.6%
b. Understanding the rule of vehicle roadworthiness, negligent and reckless driving.	11.4%	19.4%	69.2%
a. Understanding the rule of licensing of the vehicles and drivers.	8.5%	21.3%	70.2%

Percentage of the respondents

Figure 6.17: Level of agreement on statements provided under National Road Traffic Act 93 of 1996

Based on Figure 6.17, from 69,2% to 76,7% of the respondents had a good to excellent understanding of the rules. Remarkably, the statement on understanding the rule of roadworthiness, negligent and reckless driving rated moderately low, if compared to other statements. This shows that the drivers either drive their vehicles without adhering to the rules of the road or they completely ignore the law of the road. This indicates that vehicle drivers drive without having a full awareness of the rules of the road.

6.3.3.4 Level of agreement on statements provided under Road Traffic Management Corporation Act 20 of 1999

The level of agreement on statements provided under the Road Traffic Management Corporation Act 20 of 1999 were the fourth concepts measured to identify and describe the supporting policies and regulations that have values and impact on the management of road traffic congestion. Figure 6.18 indicates the results on level of agreement on statements provided under the Road Traffic Management Corporation Act 20 of 1999.

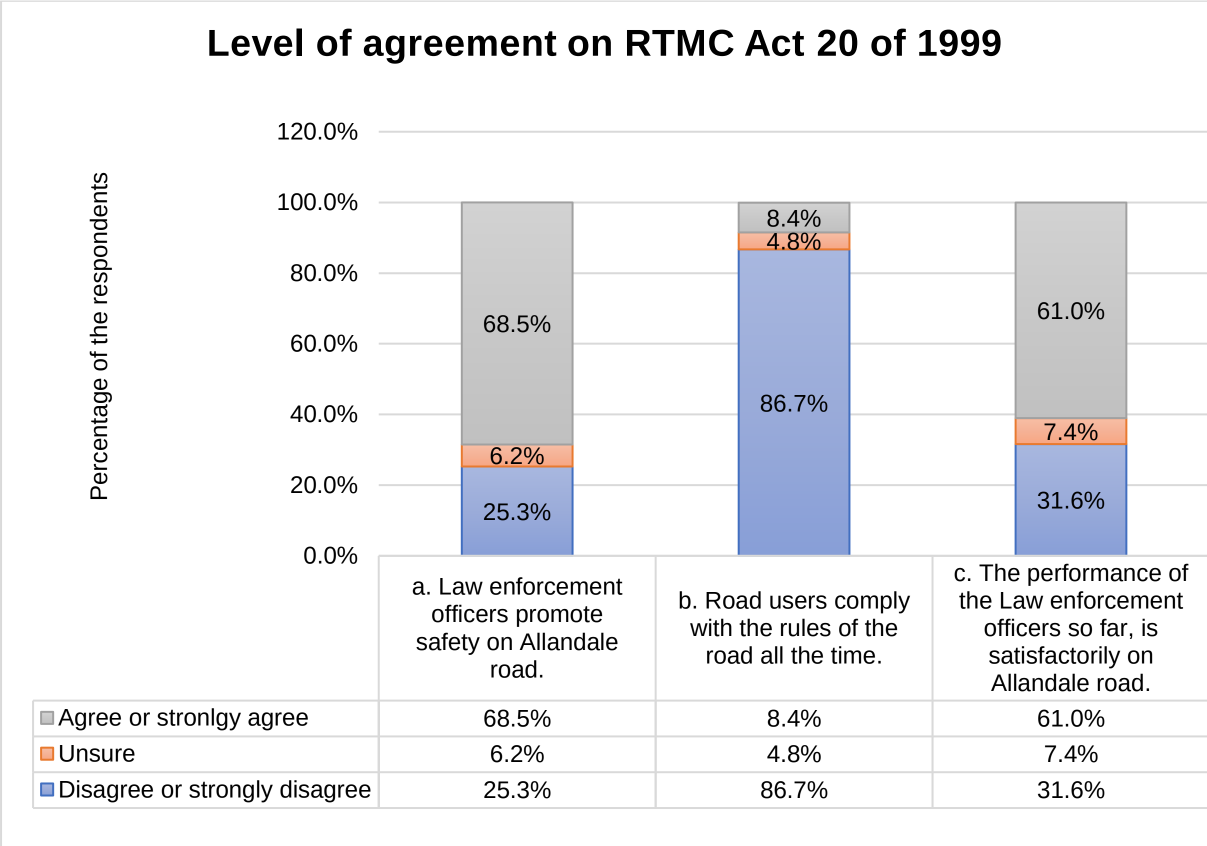


Figure 6.18: Level of agreement on statements provided under Road Traffic Management Corporation Act 20 of 1999

Figure 6.18 shows that 68,5% of the respondents strongly agreed that the law enforcement officers on Allandale Road (M39) promote safety. The respondents indicated with the level of 61,0% that the performance of law enforcement officers so far is satisfactory on Allandale Road (M39). However, only a few respondents (8,4%) indicated that road users comply with the rules of the road all the time.

Based on the information provided, the findings confirm the literature findings with regard to the compliance of road users to the rules. This indicates that corruption related to the issuing of drivers' licences authorises people with insufficient driving knowledge to acquire licences which results in increases in the accident rate and traffic congestion (Shamsher & Abdullah, 2015).

6.3.3.5 Level of agreement on statements provided under Draft National Non-Motorised Policy

The level of agreement on statements provided under the Draft National Non-Motorised Policy were the fifth concepts measured to identify and describe the supporting policies and regulations that have value and impact on the management of road traffic congestion. Figure 6.19 indicates the results on level of agreement on statements provided under the Draft National Non-Motorised Policy.

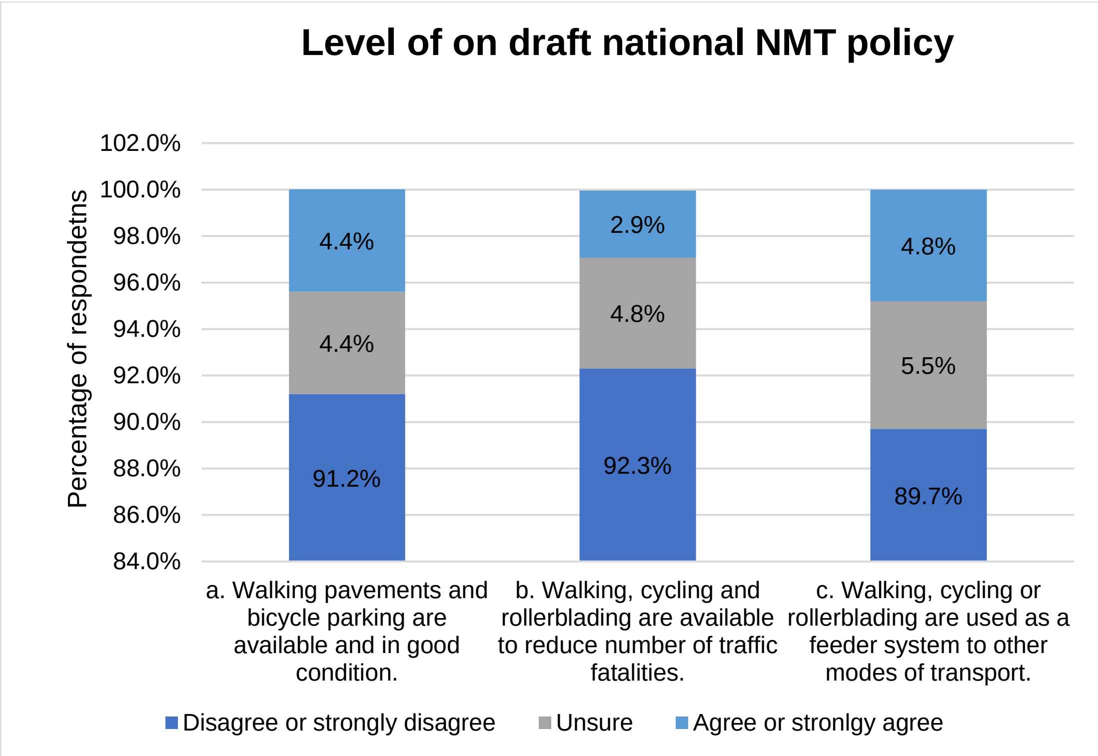


Figure 6.19: Level of agreement on statements provided under Draft National Non-Motorised Policy

Figure 6.19 above demonstrates the agreement on statements provided under the Draft National Non-Motorised Policy, where 92,3% of the respondents disagree or strongly disagree that walking, cycling and rollerblading are available to reduce the number of traffic fatalities. The respondents indicated with the level of 91,2% that walking, pavement and bicycle parking are not available. Lastly, 89,7% of the respondents indicated that walking, cycling or rollerblading are not used as a feeder system to other modes of transport.

Based on the information provided it is imperative for the road agencies to implement the services lacking. There is a need for the pavement at the side of Allandale Road (M39) to ensure that people are able to walk and cycle.

6.3.4 Strategies for managing road traffic congestion

This section describes the strategies for managing road traffic congestion, which are related to the second secondary objective of the study, namely, to identify and describe the strategies used to manage road traffic congestion within the urban areas (refer to Appendix B: Questionnaire, Section F).

The questionnaire used a five-point Likert-type scale for these questions. The items on the questionnaire were combined into three categories for enhanced interpretation. Consequently, the ratings such as “agree” and “strongly agree”; “disagree” and “strongly disagree” were collapsed into one classification. The “Unsure” category remained the same. The strategies for managing road traffic congestion are discussed below.

6.3.4.1 Strategies that will best manage road traffic congestion on Allandale Road (M39)

The respondents were asked to indicate strategies that will best manage road traffic congestion on Allandale Road. The strategies were allocated into five items, namely, improving transport in the area, improving infrastructure, road capacity and network, introducing carpooling, promoting a non-motorised transport service, park-and-ride facilities, and involving the developers in environmental impact assessments.

Figure 6.20 illustrates the results of strategies that will best manage road traffic congestion on Allandale Road.

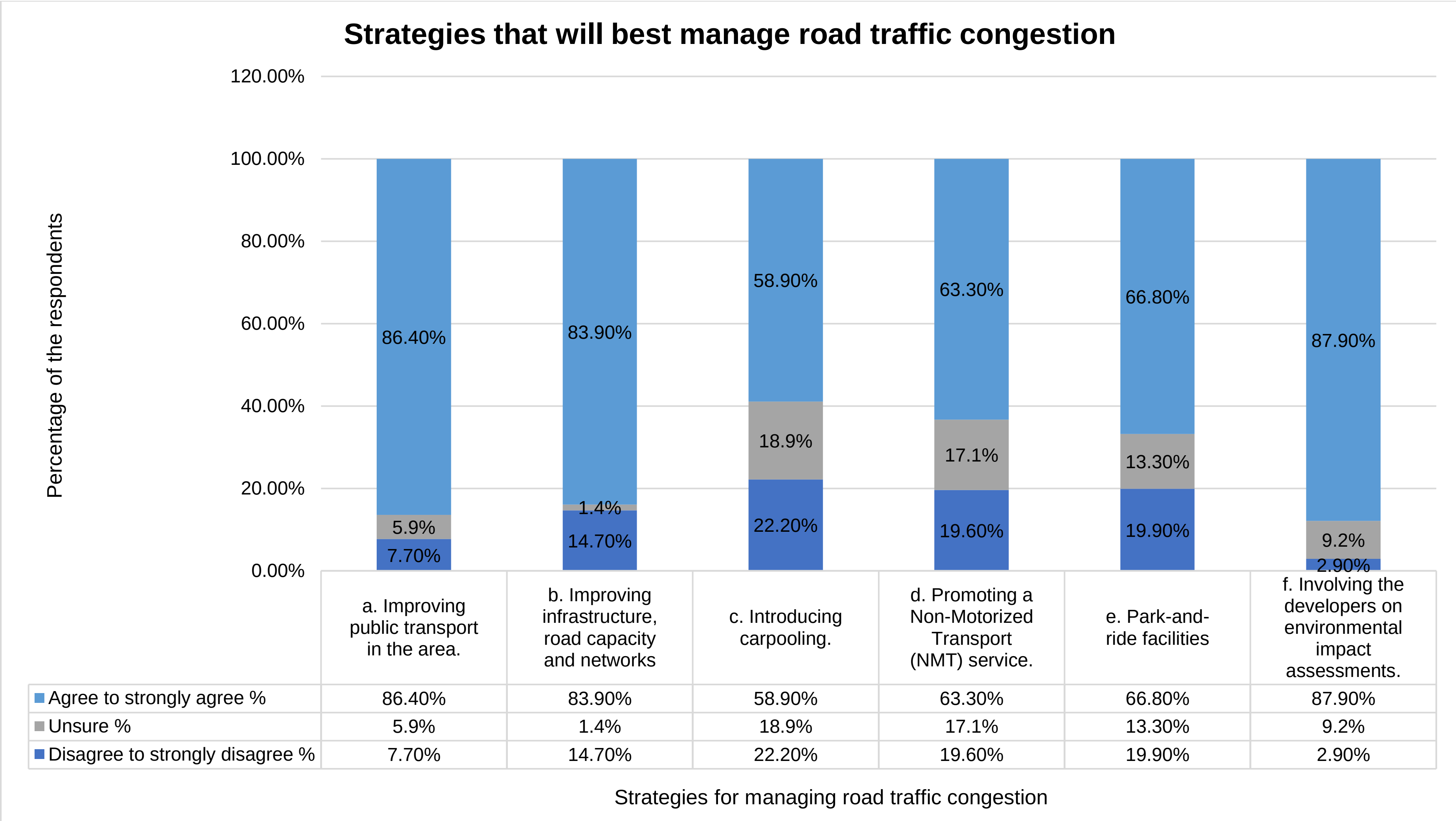


Figure 6.20: Strategies that will best manage road traffic congestion

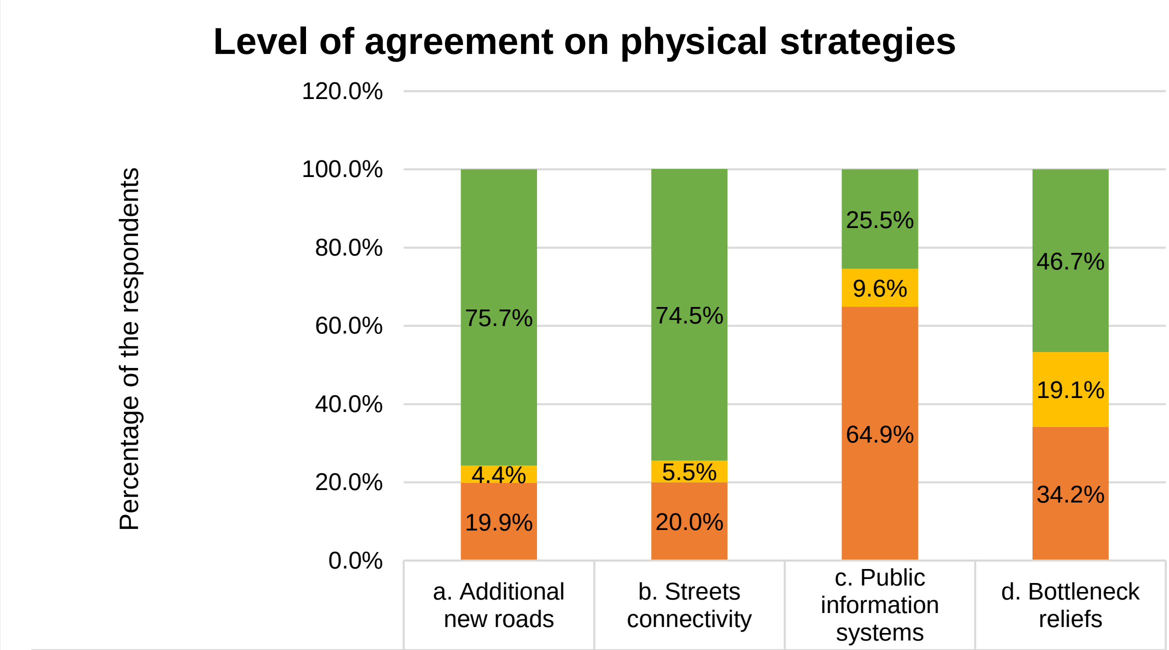
Based on the strategies presented in Figure 6.20, most of the respondents (86,40%) strongly agreed on improving public transport in the area. The second highest percentage (87,90%) of respondents agreed on involving the developers in environmental impact assessments, followed by improving infrastructure at 83,90%. Of the respondents, 66,80% were in agreement with park-and-ride facilities, followed by 63,30% on promoting non-motorised transport service. The lowest percentage was introducing carpooling at 58,90%.

Since the majority of respondents presented the highest results of involving developers in environmental assessments, public transport improvement in the area and infrastructure, road capacity and network improvement, it may be imperative that transport planners, transport service providers and engineers may in future consider the suggested strategies.

6.3.4.2 Level of agreement on available physical strategies

The respondents were asked to indicate their level of agreement on physical strategies that are available on Allandale Road. The physical strategies were allocated into four items, namely, additional new roads, street connectivity, public information systems, and bottleneck relief.

Figure 6.21 illustrates the results of the level of agreement on physical strategies that are available on Allandale Road.



	a. Additional new roads	b. Streets connectivity	c. Public information systems	d. Bottleneck reliefs
Agree to strongly agree %	75.7%	74.5%	25.5%	46.7%
Unsure %	4.4%	5.5%	9.6%	19.1%
Disagree to strongly disagree %	19.9%	20.0%	64.9%	34.2%

Figure 6.21: Level of agreement on physical strategies

Figure 6.21 demonstrates the majority of respondents (75,7%) do not agree with the fact that the physical strategies such as additional roads are not available on Allandale Road (M39). Street connectivity was also considered as not available, as the majority of the respondents (74,5%) strongly disagreed with the strategy, while 46,7% agreed with bottleneck reliefs. Therefore, only 25,5% of the respondents strongly disagreed with the availability of public information systems on Allandale Road (M39).

The present findings revealed that additional new roads and street connectivity are not available on Allandale Road (M39). Therefore, the current findings should be used as an appropriate direction for planners and engineers to improve the community's transport systems.

6.3.4.3 Level of agreement on operational improvement strategies that are implemented rapidly on Allandale Road (M39)

The respondents were requested to indicate their level of agreement on operational improvement strategies that are implemented rapidly on Allandale Road. The level of agreement on operational improvement strategies was divided into four items: active road management by the Metro Police, traffic signal timing and coordination, planned special events' traffic management, and incident management. Figure 6.22 indicates the outcome of the level of agreement on operational improvement strategies that are implemented rapidly on Allandale Road.

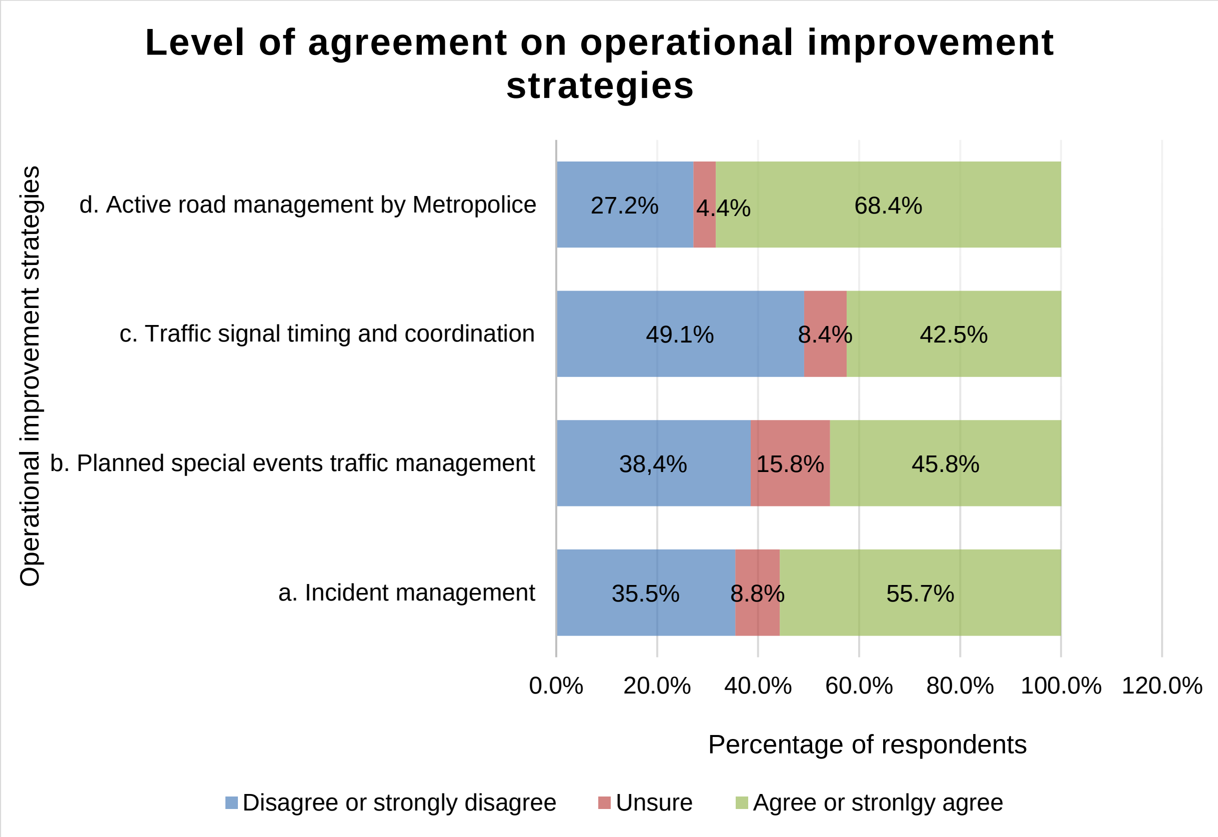


Figure 6.22: Level of agreement on operational improvement strategies

According to Figure 6.22, 68,4% of the respondents indicated that active road management by the Metro Police is implemented rapidly. These is followed by incident management strategy with the percentage level of 55,7%, then by planned special events' traffic management with the percentage of 45,8% and lastly, traffic signal timing and coordination strategy by 42,5%.

The present findings are in contrast to traffic congestion studies carried out in India (Rahane & Saharkar, 2014:161-162), stating that the numbers of traffic police are always inadequate, which result in vehicles trapped in traffic due to the lack of appropriate instructions. It might be imperative for the Johannesburg Metro Police Department to navigate properly in terms of the operational improvements on the road.

6.3.4.4 Strategies that are still lacking on Allandale Road (M39)

The respondents were asked to indicate strategies that are still lacking on Allandale Road. The strategies that are still lacking on Allandale Road were divided into four elements: improvement of infrastructure, road capacity and network, developer involvement, public transport and modal integration, for example, public transport such as bus, taxi, or train. Figure 6.23 indicates the outcome of the strategies that are still lacking on Allandale Road.

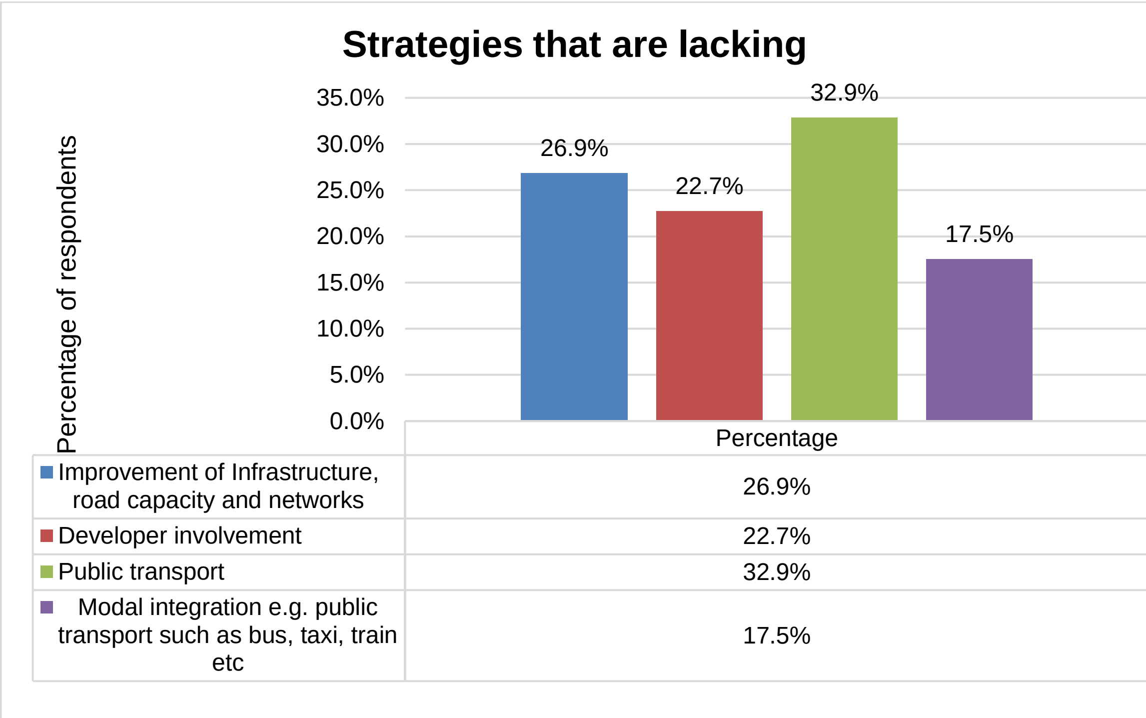


Figure 6.23: Strategies that are still lacking on Allandale Road (M39)

As shown in Figure 6.23 above, it is apparent that public transport is considered a lacking strategy on Allandale Road (M39) with the highest percentage level of 32,9%. Improvement of infrastructure, road capacity and networks followed with a level of 26,9%. The percentage level of developer involvement was 22,7%, which was followed by 17,5% for the modal integration of public transport such as bus, taxi and trains.

These results confirm that public transport, modal integration and developer involvement are still lacking in Midrand. The intention of the Public Transport Strategy is to completely expedite the improvement in public transport focusing on modal upgrades, which could assist in mutually allocating public transport between the modes (Department of Transport, 2018; Walters, 2014).

The next section discusses the inferential statistics based on the perception of respondents about road traffic congestion on Allandale Road (M39).

6.4 INFERENTIAL STATISTICS

The aim of this section is to determine whether there is a statistically significant difference between the responses regarding their perception about road traffic congestion on Allandale Road (M39). The differences will be tested based on the following objectives of the sudy:

- The problems contributing to traffic congestion that users on Allandale Road (M39) experience daily.
- The supporting policies and regulations impacting road traffic congestion.
- The strategies used for managing road traffic congestion within this urban area.

The non-parametric tests, such as Kruskal-Wallis test, were applied. The p-value of 0.05 level was used. The research study also employed the Pearson Chi-Square test to test if there is an association between the educational background, status of occupation and monthly income.

6.4.1 Differences in the perception of respondents on the problems contributing to road traffic congestion

In terms of this objective, a regular rating was obtained to establish whether there was a significant difference between the respondents in terms of the relationship between the problems contributing to road traffic congestion. As shown in Table 6.9, the hypothesis analysed for problems contributing to road traffic congestion can be stated as follows:

Null hypothesis: There is no significant difference between the problems contributing to road traffic congestion with regard to the following:

- educational background group;
- status of occupation group; and
- monthly net income group.

Alternative hypothesis: There is significant difference between problems contributing to road traffic congestion with regard to the following:

- educational background group;
- status of occupation group; and
- monthly net income group.

Table 6.1 below indicates the differences between the respondents' perceptions about the problems contributing to road traffic congestion in terms of educational background, status of occupation and monthly net income. The Kruskal -Wallis test statistics results are presented in Table 6.1. The significant level ($p < 0.05$) is therefore indicated in Table 6.1.

Table 6.1: Summary of differences in the perception of respondents on the problems contributing to road traffic congestion based on educational background, status of occupation and monthly income

Problems contributing to road traffic congestion					
Statistical tests					
Constructs		Kruskal-Wallis test			
		Total N	Test statistics	df	Asymtotic(2-sided test)
Increase in vehicle ownership	Educational background	268	3.677	4	.451
	Status of occupation	270	10.832	4	.029
	Monthly net income	268	2.831	5	.726
Growth of population in the area	Educational background	269	8.148	4	.086
	Status of occupation	271	13.654	4	.008
	Monthly net income	269	1.977	5	.852
New developments in the area	Educational background	269	7.174	4	.127
	Status of occupation	271	4.933	4	.294
	Monthly net Income	269	12.102	5	.033
Roadworks or constructions	Educational background	268	6.980	4	.137
	Status of occupation	270	3.663	4	.454
	Monthly net income	268	3.862	5	.569
Mismanagement of road traffic system	Educational background	269	3.658	4	.454
	Status of occupation	271	7.757	4	.101
	Monthly net income	269	9.097	5	.105

**Asymptotic significances (2-sided tests) are displayed. The significance level is .050.*

The results revealed in Table 6.1, indicate that the Kruskal -Wallis test was conducted to determine whether increases in vehicle ownership and growth of population in the area demonstrated a significant difference, according to the status of occupation and monthly net income at a significant level of .05.

Based on Table 18 (see Appendix F), there was statistical test that was equal to 10.832, with the significance level of .029 between increases in vehicle ownership and status of occupation; the statistical test that was equal to 13.654, with the significance level of .008 between growth of population in the area and status of occupation; the statistical test that was equal to 12.102, with the significance level of .033 between new developments in the area and monthly net Income.

According to these findings, it may be stated that the increase in vehicle ownership, growth of population in the area, and new developments in the area showed significant variations according to the status of occupation and monthly net income. Considering the results, it was found that those participants with status of occupation, such as unemployed, business owners, students, company employees, and self-employed had greater increases in vehicle ownership and growth of population perceptions. Participants who had an income of between R20 001-R25 000, and R15 000-R20 000 had greater perception regarding new developments in the area.

6.4.2 Differences in respondents' perception on the policies and regulations that have value and impact on the management of road traffic congestion

To concentrate on this objective, a regular rating was obtained. The Pearson chi-square test was used to test if there is an association between the categorical variables. As shown in Table 6.2, the hypothesis analysed for the relationship between the policies and regulations can be stated as follows:

Null hypothesis: There is no association between the policies and regulations that have value and impact on the management of road traffic congestion with regard to the following:

- educational background group;
- status of occupation group; and
- monthly net income group.

Alternative hypothesis: There is association between the policies and regulations that have value and impact on the management of road traffic congestion with regard to the following:

- educational background group;
- status of occupation group; and
- monthly net income group.

Table 6.2 below shows the statistical differences between the level of educational background, status of occupation and monthly net income of respondent's perceptions in terms of the policies and regulations that have value and impact on the management of road traffic congestion.

Table 6.2: Summary of differences in the perception of respondents on National Transport Policy, 1996 based on educational background, status of occupation and monthly income

Statistical tests				
Chi-square test				
Constructs		**Value**	**df**	**Asymptotic Significance (2-sided)**
National Transport Policy, 1996				
There is a need for improvement of transport infrastructure	Educational background	32.498	4	.000
	Status of occupation	.061	1	.805
	Monthly net income	7.686	2	.021
Trucks operate from 06:00 to 09:00 and then 17:00 to 20:00 Monday to Friday except public holidays	Educational background	7.434	4	.115
	Status of occupation	1.948	1	.163
	Monthly net income	.992	2	.609

**The standardised statistic is -.276. Interpret the Fisher exact test: p-value (0.528) is > 0.05.*

Table 6.2 indicates the results of the Chi-square test which was conducted in order to determine if there is an association between the need for improvement of transport infrastructure with educational background and monthly net income at a significant level of .05. As evident from the above table, there was a value of 32.498 with a p-value of .000 between a need for improvement of transport infrastructure and educational background; a value of 7.686 with a p-value of .021 between a need for improvement of transport infrastructure and the monthly net income.

According to these findings, it may be stated that a need for improvement of transport infrastructure is associated with educational background and monthly net income. Considering the values in the test, it was found that those participants with educational background and monthly net income require the improvement of transport infrastructure in the area.

The perception of respondents related to the National Land Transport Act, 2009 is presented in Table 6.3 below.

Table 6.3: Summary of differences in the perception of respondents on National Land Transport Act, 2009 based on educational background, status of occupation and monthly income

Statistical tests				
Constructs		Value	df	Asymptotic Significance (2-sided)
Chi-square test				
National Land Transport Act, 2009				
There are enough lanes for the effective movement of vehicles on Allandale Road.	Educational background	10.118	4	.038
	Status of occupation	6.311	1	.012
	Monthly net income	18.237	2	.000
Different integrated modal services such as buses, taxis and train are available.	Educational background	15.263	4	.004
	Status of occupation	.026	1	.872
	Monthly net income	5.518	2	.063

**The standardised statistic is -.276. Interpret the Fisher exact test: p-value (0.528) is > 0.05.*

Table 6.3 indicates the results of that Chi-square test which was conducted to determine if there is an association between the lanes for the effective movement of vehicles on Allandale Road; different integrated modal services such as buses, taxis and train that are available, with educational background, status of occupation and monthly net income at a significant level of .05.

The results above show the value of 18.237, with a p-value of .000, between enough lanes for the effective movement of vehicles on Allandale Road and monthly net income; the value of 15.263, with a p-value of .004, between the different available integrated modal services such as buses, taxis and train and educational background;

the value of 6.311, with a p-value of .012, between enough lanes for the effective movement of vehicles on Allandale Road and status of occupation.

Based on the findings, it could be that the availability of enough lanes for the effective movement of vehicles on Allandale Road, and the availability of different integrated modal services is associated with educational background, status of occupation and monthly net income. Considering the values of the statistical tests, it was found that participants with educational background, status of occupation and monthly net income preferred that Allandale Road should have enough lanes for the effective movement of vehicles and different integrated modal services.

The perception of respondents related to the National Road Traffic Act 93, 1996 is presented in Table 6.4 below.

Table 6.4: Summary of differences in the perception of respondents on National Road Traffic Act 93, 1996 based on educational background, status of occupation and monthly income

Statistical tests				
Chi-square test				
Constructs		**Value**	**df**	**Asymptotic Significance (2-sided)**
National Road Traffic Act 93, 1996				
Understanding the rule of licensing of the vehicles and drivers.	Educational background	3.791	4	.435
	Status of occupation	3.674	1	.055
	Monthly net income	.575	2	.750
Understanding the rule of vehicle roadworthiness, negligent and reckless driving.	Educational background	3.189	4	.527
	Status of occupation	2.338	1	.126
	Monthly net income	1.137	2	.566
Understanding the rule of speed limits on the roads.	Educational background	1.507	4	.825
	Status of occupation	4.093	1	.043
	Monthly net income	1.628	2	.443
Understanding the rule of driving under the influence of alcohol or drugs.	Educational background	2.028	4	.731
	Status of occupation	3.270	1	.071
	Monthly net income	1.174	2	.556

**The standardised statistic is -.276. Interpret the Fisher exact test: p-value (0.528) is > 0.05.*

Table 6.4 indicates the results of Chi-square test which was conducted to determine if there is an association between the understanding the rule of speed limits on the roads with status of occupation at a significant level of .05. The table shows the value of 4.093, with a p-value of .043, between the understanding of speed limits rules on the roads and status of occupation.

According to these results, it may be stated that understanding of speed limits rules on the roads might be associated with status of occupation. Considering the values of the statistical tests, it was found that those participants with status of occupation have a greater understanding of the rule of speed limits on the roads.

The perception of respondents related to the Road Traffic Management Corporation Act 20, 1999 is presented in Table 6.5 below.

Table 6.5: Summary of differences in the perception of respondents on the Road Traffic Management Corporation Act 20, 1999 based on educational background, status of occupation and monthly income

Statistical tests				
Chi-square test				
Constructs		**Value**	**df**	**Asymptotic Significance (2-sided)**
Road Traffic Management Corporation Act 20, 1999				
Law enforcement officers promote safety on Allandale Road.	Educational background	5.207	4	.267
	Status of occupation	7.924	1	.005
	Monthly net income	9.388	2	.009
Road users comply with the rules of the road all the time.	Educational background	4.919	4	.296
	Status of occupation	.028	1	.867
	Monthly net income	3.007	2	.222
The performance of the law enforcement officers so far, is satisfactory on Allandale Road.	Educational background	3.405	4	.492
	Status of occupation	5.748	1	.017
	Monthly net income	9.499	2	.009

**The standardized statistic is -.276. Interpret the Fisher exact test: p-value (0.528) is > 0.05.*

Table 6.5 indicates the results of Chi-square test which was conducted to determine if there is an association between the law enforcement officers that promote safety on Allandale Road, and the satisfactory performance of the law enforcement officers on

Allandale Road with status of occupation and monthly net income at a significant level of .05.

The results in the table show the statistical test value of 9.499, with a p-value of .009, between the satisfactory performance of the law enforcement officers on Allandale Road with monthly net income; a statistical test of 9.388, with a p-value of .009, between promotion of safety by law enforcement officers on Allandale Road with monthly net income; a statistical test of 7.924, with a p-value of .005, between the promotion of safety by law enforcement officers on Allandale Road with status of occupation; a statistical test of 5.748, with a p-value of .017, between the satisfactory performance of the law enforcement officers on Allandale Road with status of occupation.

According to these findings, it may be stated that the satisfactory performance of law enforcement officers on Allandale Road are associated with the status of occupation and monthly net income. Considering the values in the test, it was found that those participants with the status of occupation and monthly net income are fulfilled by the performance of law enforcement officers on Allandale Road.

The perception of respondents related to the Draft National Non-Motorised Transport Policy is presented in Table 6.6 below.

Table 6.6: Summary of differences in the perception of respondents on Draft National Non-Motorised Transport Policy based on educational background, status of occupation and monthly income.

Statistical tests				
Chi-square test				
Constructs		**Value**	**df**	**Asymptotic Significance (2-sided)**
Draft National Non-Motorised Transport Policy				
Walking pavements and bicycle parking are available and in good condition.	Educational background	2.931	4	.569
	Status of occupation	.371	1	.542
	Monthly net income	3.063	2	.216
Walking, cycling and rollerblading are available to reduce number of traffic fatalities.	Educational background	1.633	4	.803
	Status of occupation	4.076	1	.043
	Monthly net income	.760	2	.684
Walking, cycling or rollerblading are used as a feeder system to other modes of transport.	Educational background	2.709	4	.608
	Status of occupation	3.977	1	.046
	Monthly net income	1.218	2	.544

** The standardised statistic is -.276. Interpret the Fisher exact test: p-value (0.528) is > 0.05.*

Table 6.6 indicates the results of the Chi-square test which was conducted to determine if there is an association between the availability of walking, cycling and rollerblading to reduce the number of traffic fatalities; usage of walking, cycling or rollerblading as a feeder system to other modes of transport with status of occupation at a significant level of .05.

As indicated in the above table, the statistical test value of 4.076, with a p-value of .043, between the availability of walking, cycling and rollerblading to reduce the number of traffic fatalities with status of occupation; the statistical test value of 3.977, with a p-value of .046, between the usage of walking, cycling or rollerblading as a feeder system to other modes of transport with status of occupation.

According to these findings, it may be stated that the availability of walking, cycling and rollerblading to reduce the number of traffic fatalities and the usage of walking, cycling or rollerblading as a feeder system to other modes of transport are associated with status of occupation. Considering the values in the test, it was found that those participants with the status of occupation required accessible walking, cycling and rollerblading to reduce the number of traffic fatalities and the usage of walking, cycling or rollerblading as a feeder system to other modes of transport in the area.

The next section discusses the perception of respondents related the problems contributing to road traffic congestion.

6.4.3 Summary of differences in the perception of respondents on the strategies for road traffic congestion.

Statistically, data can be analysed using different types of tests that can be performed to assess the differences. To evaluate whether statistically significant differences regarding the perceptions about strategies for road traffic congestion exist for different groups, non-parametric comparisons were performed using the Kruskal-Wallis test. The Kruskal-Wallis test was used to determine if there is a difference between the mean rank scores of educational background, status of occupation and monthly net income. The following hypothesis was tested:

Null hypothesis: There is no significant difference related to the perceptions about the strategies for road traffic congestion with regard to the following:

- educational background group;
- status of occupation group; and
- monthly net income group.

Alternative hypothesis: There is a significant difference related to the perceptions about the strategies for road traffic congestion with regard to the following groups:

- educational background group;
- status of occupation group; and
- monthly net income group.

The table below indicates the differences related to the respondents' perceptions between the strategies for road traffic congestion responses in terms of educational background, status of occupation and monthly net income.

Table 6.7: Differences in the perception of respondents on the strategies for managing road traffic congestion in terms of educational background, status of occupation and monthly net income

Strategies for managing road traffic congestion					
Independent samples test					
Constructs		Kruskal-Wallis Test			
		Total N	Test statistics	df	Asymtotic (2-sided test)
Improving public transport in the area.	Educational background	270	3.304	4	.508
	Status of occupation	272	6.937	4	.139
	Monthly net income	270	12.677	5	.027
Improving infrastructure, road capacity and networks	Educational background	270	4.279	4	.370
	Status of occupation	272	.467	4	.977
	Monthly net income	270	10.891	5	.054
Introducing carpooling.	Educational background	267	1.826	4	.768
	Status of occupation	270	6.535	.4	.163
	Monthly net income	267.	8.548	5	.129
Promoting a Non-Motorised Transport (NMT) service.	Educational background	267	8.849	4	.065
	Status of occupation	269	9.881	4	.042
	Monthly net income	267	8.079	5	.152
Park-and-ride facilities	Educational background	268	2.916	4	.572
	Status of occupation	270	4.861	4	.302
	Monthly net income	268	7.440	5	.190
Involving the developers in environmental impact assessments.	Educational background	269	1.167	4	.884
	Status of occupation	271	1.255	4	.869
	Monthly net income	269	3.756	5	.585

**Asymptotic significances (2-sided tests) are displayed. The significance level is .050.*

As shown in Table 6.7 above, the Kruskal-Wallis test was conducted to determine whether improving public transport in the area, improving infrastructure, road capacity and networks and promoting a Non-Motorised Transport (NMT) service demonstrated a significant difference, based on monthly net income and status of occupation in terms of a significant level of .050.

The findings revealed a statistical test that is equal to 12.677, with the significance level of .027, between improving public transport in the area and monthly net income. According to these findings, it may be stated that improving public transport in the area demonstrates a significant difference, according to monthly net income. The results also revealed a statistical test that is equal to 9.881, with the significance level of .042, between promoting Non-Motorised Transport (NMT) service and status of occupation. Based on the results, it could be stated that promoting Non-Motorised Transport (NMT) service demonstrates a significant difference according to status of occupation.

Considering the statistical tests conducted, it was found that the participants with a monthly net income between R25 001 and more; from R10 000-R15 000; R15 001; below 10 000 and none, have greater perceptions related to the improvement of public transport in the area. However, participants with status of occupation such as business owners, students and company employees also perceived NMT as the service that should be promoted around the area (also see Appendix F: Table 6.10-Improving public transport in the area and Table 6.10-Promoting NMT services).

The table below presents the differences in the perception of respondents related to the availability of physical improvement strategies in terms of educational background, status of occupation and monthly net income.

Table 6.8: Differences in the perception of respondents on the availability of physical improvement strategies in terms of educational background, status of occupation and monthly net income

The availability of physical improvement strategies					
Independent samples test					
Constructs		**Kruskal-Wallis Test**			
		Total N	**Test statistics**	**df**	**Asymptotic (2-sided test)**
Additional new roads	Educational background	269	5.105	4	.277
	Status of occupation	271	4.315	4	.365
	Monthly net income	269	3.667	5	.598
Street connectivity	Educational background	268	3.811	4	.432
	Status of occupation	270	4.727	4	.317
	Monthly net income	268	4.441	5	.488
Public information systems	Educational background	268	8.245	4	.083
	Status of occupation	270	13.558	4	.009
	Monthly net income	268	12.622	5	.027
Bottleneck relief	Educational background	269	1.345	4	.854
	Status of occupation	271	14.036	4	.007
	Monthly net income	269	11.411	5	.044
Dedicated lanes for buses/BRT systems	Educational background	267	9.285	4	.054
	Status of occupation	269	11.726	4	.020
	Monthly net income	267	4.960	5	.421

**Asymptotic significances (2-sided tests) are displayed. The significance level is .050.*

Table 6.8 above presents the results of the Kruskal-Wallis tests. These tests were performed to determine whether the availability of physical improvement strategies on Allandale Road (M39) demonstrated a significant difference according to the participants' educational background, status of occupation and monthly net income at a significant level of .050.

The results indicated a statistical test that is equal to 13.558, with a significance level of.009, between public information systems and status of occupation; a statistical test that is equal to 14.036, with a significance level of .007, between bottleneck relief and status of occupation; a statistical test that is equal to 11.726, with a significance level of .020, between dedicated lanes for BRT systems with status of occupation. According to these findings, it may be stated that public information systems; bottleneck relief and dedicated lanes for BRT systems demonstrate a significant difference according to status of occupation.

The findings also revealed a statistical test that is equal to 12.622, with a significance level of .027, between public information systems and monthly net income; a statistical test that is equal to 11.411, with a significance level of .044, between bottleneck relief with monthly net income. According to these findings, it may be stated that public information systems and bottleneck relief demonstrate a significant difference according to monthly net income

Considering the statistical tests conducted on the road concerned, it was found that those participants with status of occupation comparison such as student-self-employed; student-company employee; student-unemployed; business owner-unemployed and self-employed-unemployed had a greater perception on public information systems, bottleneck relief, and dedicated lanes for buses/BRT systems (also see Appendix D: Table 6.11-Public information systems, Table 6.11- Bottleneck reliefs and Table 6.11-Dedicated lanes for BRT systems).

The participants with a monthly net income of R15 001-R20 000; R20 001-R25 000; below R10 000; none to R20 001-R25 000 have a greater perception related to public information systems and bottleneck relief (also see Appendix F: Table 6.11: Public information system and Table 6.11: Bottleneck reliefs under Pairwise Comparisons of B6).

As presented in Table 6:9 below, the tests indicated five groups of the implementation of operational improvement strategies. The discussion of the implementation of operational strategies is discussed next.

Table 6.9: Differences in the perception of respondents on the implementation of operational improvement strategies in terms of educational background, status of occupation and monthly net income.

The implementation of operational improvement strategies					
Statistical Tests					
Constructs		**Kruskal-Wallis Test**			
		Value	**Test statistics**	**df**	**Asymtotic (2-sided test)**
Incident management	Educational background	270	8.351	4	.080
	Status of occupation	272	6.837	4	.145
	Monthly net income	270	4.612	5	.465
Planned special events' traffic management	Educational background	270	14.614	4	.006
	Status of occupation	272	1.495	4	.828
	Monthly net income	270	9.404	5	.094
Traffic signal timing and coordination	Educational background	270	18.813	4	.001
	Status of occupation	272	4.402	4	.354
	Monthly net income	270	6.729	5	.242
Active road management by the Metro Police	Educational background	269	8.288	4	.082
	Status of occupation	272	19.030	4	.001
	Monthly net income	269	15.202	5	.010

**Asymptotic significances (2-sided tests) are displayed. The significance level is .050.*

Table 6.9 above shows the results of the Kruskal-Wallis tests which were performed to determine whether the implementation of operational improvement strategies demonstrate significant differences according to educational background, status of occupation and monthly net income at a significant level of .050.

The results revealed a statistical test that is equal to 14.614, with a significance level of .006, between planned special events traffic management and educational background; a statistical test that is equal to 18.813, with a significance level of .001, between traffic signal timing and coordination with educational background. According to these findings, it may be stated that planned special events' traffic management and traffic signal timing and coordination demonstrate a significant difference according to educational background.

The results revealed a statistical test that is equal to 19.030, with a significance level of .001, between active road management by the Metro Police and status of occupation. According to these findings, it may be stated that active road management by the Metro Police demonstrates a significant difference according to status of occupation.

The results also revealed a statistical test that is equal to 15.202, with a significance level of .010, between active road management by the Metro Police and monthly net income. According to these findings, it may be stated that active road management by the Metro Police demonstrates a significant difference according to monthly net income.

It was found that those participants with educational background comparison such as high school/grade 12-Graduate from the university/college; postgraduate (Honours, Masters and Doctoral)-Graduate from the university/college; postgraduate (Honours, Masters and Doctoral)-College or university student; professional-college or university student; graduate from the university/college-college or university student have a greater perception related to planned special events' traffic management and traffic signal timing and coordination.

It was also found that those participants with status of occupation comparison such as business owner-student; business owner-unemployed; company employee-student and company employee-unemployed have greater perception related to active road management by the Metro Police.

Those participants with a monthly net income comparison such as R15 001-R20 000-None; R20 001-R25 000-None; R25 001 and more-none and below R10 000-none have greater perception related to active road management by the Metro Police.

The next section presents the conclusion to the chapter.

6.5 CONCLUSION

This chapter presented the results of the statistical analysis of the data. The chapter narrated on the primary and secondary objectives of the study. The findings were discussed in the form of descriptive and inferential analyses to link the results to the objectives of the study. The results of the data were presented using the Kruskal-

Wallis and Chi-Square tests. Based on the descriptive analysis, the researcher discussed the demographic profile of the Allandale Road users' views which included the indication of the gender, age group, place of residence, educational background, status of occupation, the approximate monthly income, the amount spent for petrol on a monthly basis and reasons for daily travelling activities. The dialogue proceeded with results of the opinions on the level of traffic congestion, indication of the peak periods, the distance in kilometres spent on a daily basis, and the problems contributing to the road traffic congestion.

The findings revealed the level of agreement on statements provided under the policies and regulations, level of agreement on physical strategies, operational improvement strategies, strategies that will best manage road traffic congestion, and strategies that are still lacking on Allandale Road (M39). In terms of the inferential analysis, the findings were based on the differences in the perception of respondents related to the problems contributing to road traffic congestion, policies and regulations and strategies for road traffic congestion. The next chapter discusses the linking of the literature, qualitative and quantitative research findings, conclusion and the recommendation of the study.

CHAPTER 7:
CONCLUSION, SUMMARY AND RECOMMENDATIONS

7.1 INTRODUCTION

This chapter presents the conclusion, summary and recommendations of the study conducted on road traffic congestion on Allandale Road (M39) in Midrand. The research objectives, questions and conceptualisation of the research problems were examined in Chapter 1. The discussion of urban transport planning and management was presented in Chapter 2. Chapter 3 examined road traffic congestion management. Chapter 4 presented the research methodology selected for the study. Chapter 5 presented the qualitative findings of the study, and subsequently, Chapter 6 presented the quantitative findings.

This chapter will firstly, revisit the research objectives and questions posed in Chapter 1. This will be followed by the discussion of the research findings, summary and conclusions drawn from Chapters 5 and 6. The chapter will continue by stating the linking of the literature, qualitative and quantitative findings, recommendations, conclusions, the limitations of the study, and finally, present suggestions for future studies.

The structural flow of Chapter 7 is presented in Figure 7.1.

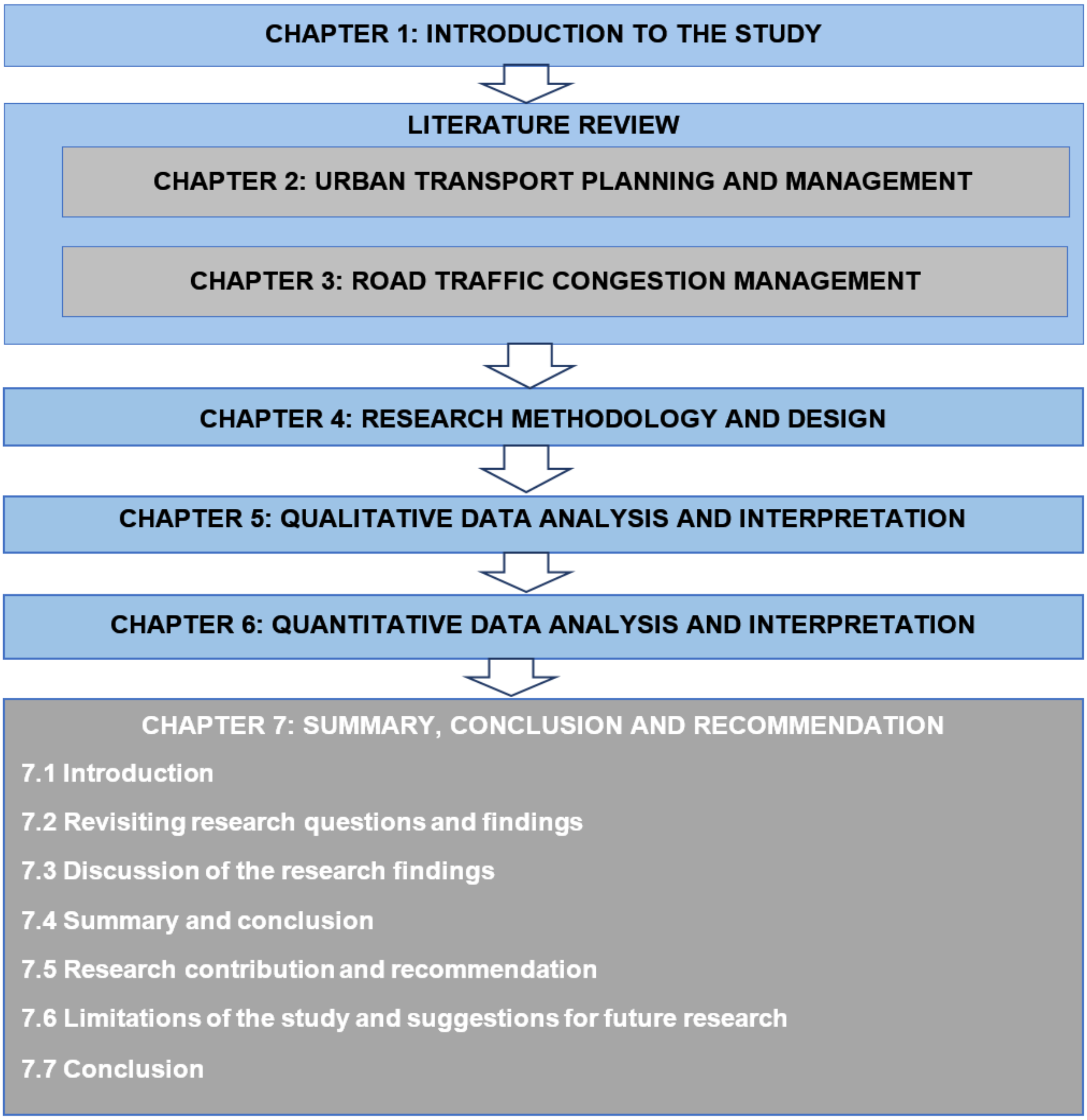


Figure 7.1: Structural flow of Chapter 7 in alignment with the study

Sources: Researcher's compilation

7.2 REVISITING RESEARCH QUESTIONS AND FINDINGS

This section will revisit the research questions and objectives of the study. As stated in Chapter 1, the main research question for the current study was presented as follows: "*How can road traffic congestion on Allandale Road (M39) in Midrand, South Africa, be managed*?"

The **sub-research questions** were stated as follows:

- Which peak periods of road traffic congestion exist on Allandale Road (M39)?
- Which problems contribute to the traffic congestion that users on Allandale Road (M39) experience daily?
- What are the supporting policies and regulations that have an impact on the management of road traffic congestion?
- What are the strategies used to manage road traffic congestion within this urban area?

The **primary research objective** of the current study was stated as: *To determine how road traffic congestion on Allandale Road (M39) in Midrand, South Africa, is managed.* To achieve the primary objective of the study, the following **secondary research objectives** were presented:

- To determine the peak periods of road traffic congestion on Allandale Road (M39).
- To establish the problems contributing to traffic congestion that users on Allandale Road (M39) experience daily.
- To identify the supporting policies and regulations impacting road traffic congestion.
- To explore the strategies used for managing road traffic congestion within this urban area.
- To make suggestions and recommendations for Allandale Road (M39) users in a way that will overcome traffic congestion.

7.3 DISCUSSION OF THE RESEARCH FINDINGS

This section of the chapter presents a discussion of the research findings based on the literature study and the empirical findings. The sections below will also debate the findings that were discussed in Chapters 5 and 6. The discussion is directed by the main research question, which is guided by the secondary research questions as mentioned in Section 7.2 above. Research question 1 will be discussed in Section 7.3.1 below.

7.3.1 Research question 1: Which peak periods of road traffic congestion exist on Allandale Road (M39)?

According to Childs (2017:580), an instant measure such as telecommuting, flexitime and staggered shifts could have a positive impact on decreasing peak period traffic congestion. This question was aimed at determining the peak periods of traffic congestion that exist on Allandale Road (M39).

During the interviews, the researcher discovered that the participants identified two peak periods of traffic congestion, namely, the morning and afternoon peak periods. Research question 1 was answered based on the qualitative and quantitative analysis of the morning peak periods followed by afternoon peak periods of road traffic congestion.

7.3.1.1 Morning peak periods of road traffic congestion

The findings gathered from the literature confirmed that in Gauteng, the morning peak periods of road traffic congestion extend for one to two hours during the busiest time of the week (Thomas, 2013). However, even outside the normal peaks, probably for about eleven to twelve hours of the day, the congestion on Allandale Road still exists.

The morning peak periods ranged from 5:30 – 9:00, 6:00 – 9:00, 6:30 – 9:00, 7:00 – 9:00 and 7:30 – 9:00. Based on the analysis of the qualitative study (see interview responses in Section 5.3 and summary in Table 5.3) and the results of the quantitative study (see Figure 6.13), it was indicated that the majority of the respondents identified the morning peak hours of traffic congestion on Allandale Road (M39) as occurring between 6:00 and 9:00, with the highest agreement percentage of 40,8%. However, the peak periods ranging from 6:30 to 9:00 obtained an agreement percentage of 33,5%.

This implies that the majority indicated that the morning peak periods ranges from 6:00-9:00, which was also confirmed by the literature study in Section 3.8. The congestion is characterised by the pattern of working hours which commence from 8:00 to 16:00 (Segola & Oladele, 2016). The results also specified that there was no traffic congestion during the weekend. This shows without a doubt that the traffic is caused by the movement of commuters travelling from their place of residence to work, and this occurs from Monday to Friday.

7.3.1.2 Afternoon peak periods of road traffic congestion

The afternoon peak periods ranged from 15:00 – 18:00, 15:00 – 18:30, 15:30 – 18:00, 16:00 – 18:00 and 17:00 – 18:00. The results indicated that 33,5% of the respondents agreed that the afternoon peak period ranges from 15:30 – 18:00, which was followed by the peak period of 16:00 – 18:00 at 30,8%.

The findings concurred with the literature that in Midrand, the afternoon peak period ranges between 16:00 to 18:00 daily (Mikros Traffic Monitoring, 2016). Subsequently, to answer this question, the analysis of the qualitative and quantitative results revealed that the afternoon peak times were stated as starting as early as 15:00 until 18:00, but generally between 16:00 and 18:00 (see Section 5.3.1.2 and Section 6.3.1.2).

The results also indicated that the records (Mikros Traffic Monitoring, 2016) on the peak periods show that they keep increasing yearly. However, this results from the increase in the number of the vehicles purchased on a yearly basis. To conclude on the above findings, since the afternoon peak periods of road traffic congestion differ in terms of the fluctuating times, the congestion in the afternoon relies solely on the activities and travelling patterns taking place during a specific time.

7.3.1.3 Summary of qualitative and quantitative findings related to peak periods of traffic congestion that exist on Allandale Road (M39)

- The traffic congestion on Allandale Road (M39) occurs from 6:00 to 9:00, as recognised by the highest percentage of respondents (40,8%).
- Another estimation of the morning peak period of road traffic congestion that 33,5% of the respondents agreed with is 6:30 to 9:00.
- This is caused by the congestion that is characterised by the pattern of working hours which commences from 8:00 to 16:00.
- There was no morning and afternoon peak periods of traffic congestion during the weekend, which means the congestion is derived from employment, school and other business activities.
- Based on Mikros Traffic Monitoring (2016), the Midrand afternoon peak period ranges between 16:00 and 18:00 daily.

- In terms of the afternoon peak periods, 33,5% of the respondents agreed that the afternoon peak ranges from 15:30 to18:00, while 30,8% of the respondents agreed with 16:00 to 18:00.

Therefore, to answer research question 2, "*Which morning and afternoon peak periods of road traffic congestion exist on Allandale Road (M39)?"* The current morning and afternoon peak periods of road traffic congestion are as follows:

- The morning peak periods of road traffic congestion transpire between 6:00 and 9:00 and / or from 6:30 to 9:00.
- The afternoon peak periods of road traffic congestion occur between 15:30 and 18:00 and / or from 16:00 to 18:00.

7.3.2 Research question 2: What problems contribute to the road traffic congestion that users on Allandale Road (M39) experience daily?

This question aimed to discover the problems contributing to the road traffic congestion that users on Allandale Road (M39) experience daily. To acquire the answers to this question, the respondents were asked to indicate their level of agreement on whether the problems of road traffic congestion indicated on the questionnaire indeed existed. The answers to this question indicated increased vehicle ownership, population growth in the area, new development in the area, road construction, and mismanagement of road traffic systems. The analysis of both the qualitative and quantitative findings is discussed below.

7.3.2.1 Problems contributing to road traffic congestion

Based on the findings of the study, it was apparent that multiple challenges exist, which have direct implications for the congestion being experienced on Allandale Road. The respondents concluded that each tier of government acts independently from one to the other.

The quantitative findings revealed that the growth of population in the area promotes the high level of road traffic congestion (see Figure 6.14). The qualitative results indicated that since Midrand had previously been a peri-urban type of environment consisting mainly of plots and farms, hundreds of houses are being built to create residences for people moving into the area. At present, the population in the area is increasing rapidly.

As the business and employment opportunities in the area have increased, the number of migrations to the area has also increased rapidly, causing more pressure due to environmental damage such as air pollution and traffic congestion (Le & Trinh, 2016).

It can therefore be concluded that the population growth in the area contributes to, and should be treated as the dominant contributor to the road traffic congestion. In relation to new developments, the respondents were requested to indicate their level of agreement regarding whether the problem of road traffic congestion exists in the area. The Midrand area has increased swiftly in size and density, and is expected to attract more population in future decades.

Based on the quantitative results, the new developments in the area also create a massive problem, and have also resulted in an increase in the movement of vehicles from one place to another (see Figure 6.14). The existence of hundreds of houses with one or two cars each, will automatically result in more cars than before. The growth in the Midrand area and the current appealing housing prices have resulted in a rise in migration processes that lead people to relocate to urban areas that are low in density, which in turn, subject the individuals to acquiring high motor vehicle ownership and long commuting times (Litman & Steel, 2017).

Based on the increased levels of vehicle ownership (see Figure 6.14), the quantitative findings revealed that the respondents agreed that the high number of cars on the road contribute to the traffic congestion. While some view car ownership as a benefit which allows better accessibility and is easier than using public transport, the findings indicated that 89,7% of the respondents agreed that road traffic congestion problems exist on Allandale Road. Private cars increase traffic congestion and greenhouse gas emissions (Jou & Chen, 2014:186).

It can therefore be concluded that the high levels of vehicle ownership in the area contribute in a high degree to the road traffic congestion and other environmental problems such as air pollution.

From the findings, it was apparent that the mismanagement of road traffic systems is another challenge that plays a role in the traffic situation on Allandale Road. The findings in the literature confirmed that the metropolitan areas suffer from inefficient traffic control systems (Kurzhanskiy & Varaiya, 2015).

The findings revealed that the majority (80,4%) of the respondents (see Figure 6.14) perceived roadworks or road constructions to be a challenge contributing to traffic congestion. The quantitative findings indicated that roadworks obstruct the traffic movement, as the situation creates bottlenecks with delays as a result.

7.3.2.2 Summary of qualitative and quantitative findings related to problems contributing to traffic congestion on Allandale Road (M39)

- In the past, the Midrand area consisted mainly of plots and farms, and the area has increased swiftly regarding size and density, and is expected to attract more population in future decades.
- The new developments that are dispersed over the area have increased the movement of vehicles from one place to another.
- From the moment development projects started in the Midrand area, the increase in population has promoted high levels of traffic congestion.
- Since the developers emerged, more companies have relocated to the area, compelling many people to seek employment in this area.
- The availability of business and employment opportunities has generated the migrations and environmental damage such as air pollution and traffic congestion.
- The many cars on the road contribute to the traffic congestion and increase greenhouse gas emissions in the area.

To answer Research question 2, “*What problems contribute to the road traffic congestion that users on Allandale Road (M39) experience daily?,* the answer can be given as follows:

- The migration and growth of the population has increased, and this has contributed to the traffic congestion.
- There are new developments being established in the area.
- Well-known companies have relocated to the Waterfall area and this has consequently led to masses of people travelling to the area.
- When out of order, the traffic light systems are left for about four to six weeks before being fixed.

7.3.3 Research question 3: What are the strategies used for managing road traffic congestion within urban areas?

The objective of this question was to identify and describe the general strategies used to manage road traffic congestion within urban areas. Both the qualitative and quantitative results of the study will be used to answer this question. The respondents were asked to identify: (i) strategies that will best manage road traffic congestion, (ii) physical strategies that are available, (iii) operational improvement strategies that are implemented, and (iv) strategies that are still lacking on Allandale Road (M39).

7.3.3.1 Strategies that will best manage traffic congestion on Allandale Road (M39)

The quantitative findings reveal that the majority of the respondents understood the concept of strategies, and how these could be used to curb the increase in road traffic congestion within the road networks in the area (see Section 6.3.4.1). This finding implies that the developers do not generally conduct proper impact assessments before taking into consideration the developments in the area. Since the land-use planning for the province and the metros is so dispersed, the people who were provided with cheap land find that they now have to travel long distances to get to their jobs.

In relation to involving the developers in environmental impact assessments, the quantitative findings revealed (see Figure 6.20) that 87.9% of the respondents agree that there must be an assessment that could be done before the development takes place. The qualitative findings indicated that the assessment thoroughly investigates the impact of adding new roads and expanding the network (see Section 5.3.4.2). This further contributes to the arrangements related to how that would reduce congestion on other roads. It is therefore concluded that prior assessments will assist the developers to consider the effect that the development will have on the road network.

Based on the improvement of infrastructure, the quantitative findings revealed that 83,9% of the respondents agreed that in order to reduce congestion it is imperative to address the problems occurring throughout the entire road network which may have an impact on Allandale Road (see Figure 6.20). To address the traffic congestion, one should not focus on a single road only; it is essential that the entire road network should be taken into consideration. This implies that the design of the roads, bridges and intersections should be relooked at, and some of the networks should be extended to create alternative routes for drivers. The improved infrastructure must be based on the flow of traffic.

The qualitative findings also indicated that the whole network of roads need to be investigated, taking into consideration all the movements turning left, right and straight on that should move freely and that will also relieve traffic to the highway (see Section 5.3.41). It is therefore concluded that the capacity on Allandale Road to the east and west on supporting/ intersection roads that link with Allandale Road must be increased.

In relation to facilities, the quantitative findings indicated that 66,80% of the respondents stated that this service might curb traffic congestion on Allandale Road (M39) (see Figure 6.20). In Midrand, the distances from the township areas are far removed from the park-and-ride services on offer. This compels commuters to firstly, travel from the residential area to the facilities. As confirmed in the literature, one of the purposes of introducing park-and-ride facilities is to encourage commuters to use public transport for a portion of the journey (Du & Wang, 2014). If the initial purpose fails to accomplish the goal, then the problems experienced will not disappear but will keep on emerging all the time.

The quantitative findings revealed that 63.30% of the respondents agreed that non-motorised transport services will best manage road traffic congestion. The literature confirmed that a lack of connection to the road infrastructure discourages commuters from using this facility within the community (Mokitimi & Vanderschuren, 2017). It is also confirmed that the proper arrangement of non-motorised transport systems will increase the effectiveness of the transport system within the community (Makarova, Pashkevich, Shubenkova & Mukhametdinov, 2017).

Based on the introduction of carpooling, the quantitative findings indicated that only 58,90% of the respondents stated that this strategy could reduce or manage traffic congestion. However, the introduction of this constriction on commuters would make a positive contribution to the problems faced. The literature confirmed that certain commuters might perceive carpooling as an agreement associated with a contribution to fuel expenses (Bento *et al.*, 2013). However, the main reason is that the system usually reduces vehicle ownership and air pollution in the environment (Nijland & Van Meerkerk, 2017). If four people are sharing the same ride, it means that three private cars are removed from the road. This could generate a huge difference in the transport environment. Even though adequate information was not presented on how to enforce this strategy, road user charges might be used to enforce the initiative, taking into consideration the travel demand management measures.

7.3.3.2 Physical strategies available on Allandale Road (M39)

The quantitative findings revealed that there are inadequate additional roads and connection of the streets leading to the main roads. The congestion causes an excessive traffic stream which commences from various surrounding areas. However, the movement deteriorates immediately after the vehicles have approached Allandale Road. In relation to additional roads (see Figure 6.21), the majority of respondents agreed that these are not available and these also add to the street connectivity challenges. The unavailability of these crucial infrastructures causes heavy traffic on the road which leads to a decrease in productivity for most of the users, as much time is lost while travelling.

Furthermore, road bottlenecks increase the volume of the traffic flow, when the lanes decrease from two to one. When the road narrows down, most of the vehicles lose their speed. As a result, the drivers become impatient and start to use the yellow emergency lane as a normal lane.

The qualitative findings also indicated that there is a lack of public information systems on this road (see Section 5.3.42). The information systems are only positioned on the highways. It imperative to provide information to road users so that they can plan and manage their trips, and be aware of congestion areas on the network.

7.3.3.3 Operational improvement strategies that are implemented rapidly on Allandale Road (M39)

There are various operational strategies that might be considered and that might improve the effective flow of traffic. These include active road management by the Metro Police, incident management, the management of traffic from special events, and planned traffic signal timing and coordination. The quantitative findings revealed that the respondents do not agree that the strategies are rapidly implemented on the road (see Section 6.3.4.3). The availability of traffic police officers on Allandale Road (M39) can act as a deterrent to the drivers displaying poor driving habits. For example, the flow of the traffic slows down immediately once the drivers notice that the traffic officers are present. In addition, a decrease in the movement of traffic could mean that some drivers are scared that they may be stopped, since they are driving unlawfully or they may be driving without proper documents and licences.

With regard to the traffic signal timing and coordination, this requires proper planning to avoid delays on the roads. The traffic lights are not generally coordinated and synchronised properly. Dysfunctional traffic lights have a direct impact and slow down the entire movement of the traffic. The respondents stated that broken traffic lights in Midrand sometimes take four to six weeks to be repaired. Since the traffic lights on Allandale Road also impact traffic flow onto the highway, it is crucial that the traffic lights be correctly coordinated and fully functioning to avoid disruption throughout the road network. Problems experienced with the breakdown of traffic light signals were seen as a contributing issue to the flow of traffic. The qualitative findings revealed that the respondents added that the traffic lights required upgrading and appropriate optimisation (see Section 5.3.2.3).

7.3.3.4 Strategies still lacking on Allandale Road (M39)

In relation to strategies that are still lacking on Allandale Road (M39), the quantitative findings indicated (see Figure 6.23) that 32,9% of the respondents experienced challenges with public transport. The qualitative findings revealed that there is a lack of reliable, effective and safe public transport systems (see Section 5.3.4.2). The current facilities accessible in the area are taxi services which sometimes deliver a less than satisfactory experience to commuters. The local taxis are damaged, wrecked and the operators every now and then are forced to overload the taxis.

The success of a proper public transport system, in most cases, depends on a safe, reliable, quality mass transit system. The problems encountered during public transport trips prohibit the travellers from using these services, which in turn, compel them directly to use their private vehicles. Furthermore, the quantitative findings revealed that other strategies that are still lacking include the improvement of infrastructure, road capacity and networks (26,9%), developer involvement (22,7%) and finally, the modal integration of public transport such as bus, taxi and train (17,5%).

The answers related to the strategies were further observed by establishing the experience and position of the respondents within the transport field. The qualitative findings indicated that the respondents (see Section 5.2.1) have 10 to 35 years of experience within the transportation industry. The section below summarises the findings revealed under strategies used for managing road traffic congestion within urban areas.

7.3.3.5 Summary of qualitative and quantitative findings related to strategies used for managing road traffic congestion within urban areas

- Prior assessment will compel the developers to consider the effect of the development on the road networks.
- Strategies should not focus on a single road, the entire road network should be taken into consideration.
- Township areas are further away from the available park-and-ride services.
- Lack of connections on the road infrastructure discourages commuters from using NMT facilities.
- Commuters perceive carpooling as an agreement about a contribution to the fuel price among themselves, however, this will reduce vehicle ownership and air pollution in the environment.
- There is a lack of public information systems on this road, since most are focusing on or positioned on the highways.
- Roads and connections on the streets leading to the main roads turn into bottlenecks, which increase the volume of the traffic flow.
- The availability of traffic police officers on Allandale Road (M39) act as a deterrent to the drivers and calm down the traffic flow.
- The coordination of the traffic lights is not generally done in a meaningful way.
- Effective and safe public transport is not available. The taxi service is the only available service, and commuters sometimes find this service disappointing.

Consequently, to answer research question 3, "*What are the strategies used for managing road traffic congestion within the urban areas?",* the strategies that are currently used for managing road traffic congestion within the urban areas include:

- Additional new roads in the networks around the roads forming the intersection.
- Traffic officers need to be available and become active on Allandale Road (M39) even during off-peak hours.

- Metro Police officers should sometimes assist with special events, such as a convoy moving to the cemetery through the traffic lights.

7.3.4 Research question 4: What are the supporting policies and regulations that have value and impact on the management of road traffic congestion?

The objective of this question was to identify and describe the supporting policies and regulations that have value and impact on the management of road traffic congestion. This question will be answered based on the analysis of the quantitative results, since the qualitative findings did not produce many responses on policies. The policies indicated in this section were the White Paper on National Transport Policy 1996, the National Land Transport Act 2009, the National Road Traffic Act 93 of 1996, Road Traffic Management Corporation Act 20 of 1999, and the Draft National Non-Motorised Transport Policy.

7.3.4.1 Level of agreement on statements provided under the policies

This section discusses how the quantitative study evaluated the level of agreement about the statements provided under each policy. It was noted that some of the participants in the qualitative study appeared uncertain in terms of the rules and regulations that could address road congestion, or indicated that the policies were still not complete. Only a few participants identified the policies and procedures which they use to direct their activities. The policies are discussed below.

- **White Paper on National Transport Policy, 1996**

The respondents in the study ranged from being own vehicle drivers, transport researcher, rural transportation strategic planner, road transportation engineer, rail transport planner and traffic engineer. The quantitative findings indicated that the majority of the respondents agreed that there is a need for the improvement of transport infrastructure on Allandale Road (M39) (see Figure 6.15). The least agreed-with statement under the policy was whether trucks should operate from 06:00 to 09:00 and then from 17:00 to 20:00 Monday to Friday, except public holidays. Unfortunately, truck drivers are not adhering to the specified time restrictions, as indicated in the White Paper on National Transport Policy, 1996. The movement of trucks occurs at any time of the day on Allandale Road (M39). This might be curbed if a well-planned arrangement could be imposed to ensure that all truck drivers have to adhere to the restrictions, as included in the policy.

- **National Land Transport Act, 2009**

From the quantitative finding, it was noted that there are various statements in the policies that the respondents disagreed with in terms of the availability of the services provided in the areas (see Section 6.3.3.2). Even though the respondents who are driving their vehicles on this road are not aware of the importance of the road policies and regulations, the majority agreed that there are no different integrated modal services such as buses, taxis and trains that are available on Allandale Road (M39). The quantitative results also indicated that despite the availability of the road provision, the respondents indicated that there are not enough lanes for the effective movement of vehicles on the road (see Figure 6.16).

- **National Road Traffic Act 93 of 1996**

The National Road Traffic Act 93 of 1996 ensures that everyone is aware of road traffic matters, and will consistently concern itself with matters connected to road traffic. The quantitative findings revealed that the drivers sometimes drive their vehicles without adhering to the rules of the roads, as stipulated in the policy (see Section 6.3.3.3). This might be the outcome of the ignorance, especially as related to the laws and adhering to the rules as indicated on the road. This indicates that vehicle drivers sometimes drive without being fully cognisant of the rules of the road.

To further verify the application of the National Road Traffic Act 93 of 1996, the supporting policies and regulations that have value towards and impact on the management of road traffic congestion were investigated. Four statements were formed and verified with a 5-point Likert scale ranging from 1 (very poor) to 5 (excellent).

The quantitative findings revealed that the respondents understood and agreed with the statements related to understanding the rule of driving under the influence of alcohol or drugs, speed limits on the roads and licensing of vehicles and drivers (see Figure 6.17). The lowest-rated statements were related to understanding the rule of roadworthiness, and negligent and reckless.

- **Road Traffic Management Corporation Act 20 of 1999**

It was established in the literature that the Road Traffic Management Corporation Act 20 of 1999 improves the entire provision of traffic services which ensure safety, security, discipline and mobility on the roads. The quantitative findings revealed (see Figure 6.18) that the law enforcement officers promote safety on Allandale Road (M39) at 68,5%, followed by the satisfactory performance of law enforcement officers at 61,0%. This signifies that the road users can make use of the information provided and ensure that they follow the road protocols all the time. Based on the level of agreement on road users complying with the rules of the road all the time, only 8,4% of the respondents agreed to the statement provided. This shows that the drivers habitually ignore traffic rules, and not all the drivers follow the rules of the roads as stipulated under the Road Traffic Management Corporation Act 20 of 1999.

- **Draft National Non-Motorised Policy**

The quantitative results revealed that there are various statements in the policies regarding services that commuters find are not available. Firstly, the respondents strongly disagreed that walking, cycling and rollerblading are available to reduce the number of traffic fatalities. Secondly, the respondents indicated that walking, pavement and bicycle parking are not available at all on Allandale Road (M39). Lastly, the respondents indicated that walking, cycling or rollerblading are not used as a feeder system to other modes of transport.

Since the above services are not provided as part of the Draft National Non-Motorised Policy, the respondents have a clear understanding about the stipulated services (see Figure 6.19). None of the NMT services have been implemented yet, and this might be the main reason that this service discourages the community from using the mode. It was confirmed by Makarova et al. (2017) that part of the initiative involves introducing reasonable arrangements for NMT systems which will assist in promoting the effectiveness and well-being of the transport system.

7.3.4.2 Summary of quantitative findings related to the level of agreement on statements provided on policies

- There is a need for the improvement of transport infrastructure on Allandale Road (M39)

- Trucks are not adhering to the specified operating time from 06:00 to 09:00 and then from 17:00 to 20:00 Monday to Friday, except public holidays.
- Drivers are not aware of the importance of the road policies and regulations.
- The majority agreed that there are no different integrated modal services available, such as buses, taxis and trains.
- Drivers do not completely follow the rules as stipulated in the policy, and they use their vehicles without adhering to the rules of the roads.
- The vehicle drivers drive without being fully cognisant about the rules of the roads concerned.
- Not all the drivers follow the rules of the roads, as stipulated under the Road Traffic Management Corporation Act 20 of 1999.
- NMT services have not yet been implemented on Allandale Road (M39), which in turn, discourages the community from using this mode.

Thus, to answer research question 4, "*What are the supporting policies and regulations that have value and impact on the management of road traffic congestion?*", although there are numerous policies stipulated under the department of transport, the typical road users do not read and are not aware of those policies and regulations as such. This might be that the:

- Policy can be unclear and complicated, especially for ordinary drivers, traffic engineers and other stakeholders.
- Drivers of the vehicles only follow what they learned during their learner driver's licence test.
- The individuals working within the traffic departments are also not familiar with the policies concerned.

Section 7.3.5 below discusses the quantitative findings based on the different perceptions between the research objectives such as problems contributing to the road traffic congestion, supporting policies and regulations that have value and impact on the management of road traffic congestion, and strategies for managing road traffic congestion.

7.3.5 What are the different perceptions on the ways of managing road traffic congestion on Allandale Road (M39)?

In order to answer the secondary research question of the study, hypotheses were formulated based on the various views of the drivers concerning the road traffic congestion on Allandale Road (M39). The hypotheses in this regard were formulated based on the quantitative findings regarding the strategies used for managing road traffic congestion within this urban area, supporting policies and regulations that have value and impact on the management of road traffic congestion, and lastly, the problems contributing to the road traffic congestion that users on Allandale Road (M39) experience daily.

7.3.5.1 Perceptions on problems contributing to the road traffic congestion that users on Allandale Road (M39) experience daily

This section describes how the first hypothesis under the problems contributing to the road traffic congestion that users on Allandale Road (M39) experience daily was formulated. This is how the hypothesis was formulated:

- **Null hypothesis**: There is no significant difference between the problems contributing to road traffic congestion with regard to educational background, status of occupation and monthly net income group.
- **Alternative hypothesis**: There is a significant difference between the problems contributing to road traffic congestion with regard to educational background, status of occupation and monthly net income group.

The findings revealed that the educational background groups differed statistically significantly based on the pairs such as growth of population in the area. However, there were no significant statistical differences found between the pairs in educational background regarding increased in vehicle ownership, new developments in the area, roadworks or constructions and mismanagement of the road traffic system. Therefore, multiple comparisons were not performed, as the overall test does not show significant differences across the samples.

7.3.5.2 Perceptions on supporting policies and regulations that have value and impact on the management of road traffic congestion

This section describes how the hypothesis regarding the supporting policies and regulations that have value and have an impact on the management of road traffic congestion was formulated. This is how the hypothesis was formulated:

- **Null hypothesis**: There is no association between the policies and regulations that have an impact on the management of road traffic congestion with regard to educational background, status of occupation, and monthly net income group.
- **Alternative hypothesis**: There is an association between the policies and regulations that have an impact on the management of road traffic congestion with regard to educational background, status of occupation and monthly net income group.

The results revealed that no associations were found between the educational background groups, of status of occupation groups and of monthly net income groups regarding truck operation from 06:00 to 09:00 and then 17:00 to 20:00 Monday to Friday, except public holidays. Significantly non-associations were found between the monthly net income group regarding the understanding of the rule of licensing of vehicles and drivers, understanding the rule of vehicle roadworthiness, negligent and reckless driving, understanding the rule of speed limits on the roads, understanding the rule of driving under the influence of alcohol or drugs, and road users complying with the rules of the road all the time, walking pavements and bicycle parking that are available and in good condition, walking, cycling and rollerblading are available to reduce number of traffic fatalities, and walking, cycling or rollerblading are used as a feeder system to other modes of transport.

No association was found between the status of occupation groups concerning the need for improvement of transport infrastructure, different integrated modal services such as buses, taxis and train, and the rule of vehicle roadworthiness, negligent and reckless driving, availability of good walking pavements and bicycle parking.

No association was found between the educational background groups concerning understanding the rule of licensing of vehicles and drivers, understanding the rule of vehicle roadworthiness, negligent and reckless driving, understanding the rule of speed limits on the roads, understanding the rule of driving under the influence of alcohol or drugs, law enforcement officers' safety on Allandale Road, road users complying with the rules of the road all the time, and the performance of the law enforcement officers, walking pavements and bicycle parking are available and in good condition, walking, cycling and rollerblading are available to reduce number of traffic fatalities, and walking, cycling or rollerblading are used as a feeder system to other modes of transport.

An association was found between the monthly net income groups concerning the need for the improvement of transport infrastructure, different integrated modal services such as buses, taxis and train, law enforcement officers promote safety on Allandale Road, and the performance of law enforcement officers.

An association was found between the status of occupation groups concerning whether there are enough lanes for the effective movement of vehicles on Allandale Road, understanding the rule of licensing of vehicles and drivers, understanding the rule of speed limits on the roads, understanding the rule of driving under the influence of alcohol or drugs, availability of walking, cycling and rollerblading to reduce the number of traffic fatalities, and walking, cycling or rollerblading used as a feeder system to other modes of transport.

7.3.5.3 Perceptions on strategies used for managing road traffic congestion within this urban area

This section describes how the hypothesis related to the strategies used for managing road traffic congestion within this urban area was formulated. This is how the hypothesis was formulated:

- **Null hypothesis**: There is no significant difference between the strategies for road traffic congestion with regard to educational background, status of occupation and monthly net income group.
- **Alternative hypothesis**: There is a significant difference between the strategies for road traffic congestion with regard to educational background, status of occupation and monthly net income group.

The findings revealed that no statistical difference was found between the status of occupation groups regarding improving public transport in the area, improving infrastructure, road capacity and networks, introducing carpooling, park-and-ride facilities and involving the developers in terms of environmental impact assessments.

In addition, no statistical difference was found between the monthly income groups on promoting a Non-Motorised Transport (NMT) service and park-and-ride facilities and involving the developers in terms of environmental impact assessments.

However, as related to the monthly income groups, the results indicated that there was a statistically significant difference with regard to improving public transport in the area and improving infrastructure, road capacity and networks.

7.3.5.4 Perceptions on the availability of physical improvement strategies within the urban area

This section describes how the hypothesis related to the availability of physical improvement strategies within the urban area was formulated. This is how the hypothesis was formulated:

- **Null hypothesis**: There is no significant difference between the availability of physical improvement strategies with regard to educational background, status of occupation and monthly net income group.
- **Alternative hypothesis**: There is a significant difference between the availability of physical improvement strategies with regard to educational background, status of occupation and monthly net income group.

No significantly statistical differences were found between the pairs in the educational background groups regarding additional new roads, street connectivity and bottleneck relief. There was no statistical difference between the monthly net income groups according to additional new roads, street connectivity and dedicated lanes for buses/BRT systems.

However, the results revealed that the educational background groups differed statistically significantly based on dedicated lanes for buses/BRT systems and public information systems. There was a statistically significant difference between the groups on monthly income in terms of the availability of physical improvement strategies such as public information systems and bottleneck relief.

7.3.5.5 Perceptions on the implementation of operational improvement strategies within the urban area

This section describes how the hypothesis related to the implementation of operational improvement strategies within the urban area was formulated. This is how the hypothesis was formulated:

- **Null hypothesis**: There is no significant difference between the implementation of the operational improvement strategies with regard to educational background, status of occupation and monthly net income group.
- **Alternative hypothesis**: There is a significant difference between the implementation of operational improvement strategies with regard to educational background, status of occupation and monthly net income group.

No statistical difference was found between the status of occupation groups regarding incident management, planned special events traffic management, traffic signal timing and coordination.

The results indicated that there was a statistically significant difference between the monthly net income groups with regard to the implementation of operational improvement strategies such as planned special events traffic management and active road management by the Metro Police.

Furthermore, the findings revealed that the educational background groups differed statistically significantly based on incident management, and active road management by the Metro Police. There was a statistically significant difference between the status of occupation regarding the implementation of operational improvement strategies.

Table 7.1 below provides a summary of the research questions and key findings of the study.

Table 7.1: Summary of the research questions and key findings of the study

Research questions	Key findings of the study
RQ1: Which peak periods of road traffic congestion exist on Allandale Road (M39)?	▪ The morning peak periods start from 6:00 to 9:00 or from 6:30 to 9:00. ▪ The afternoon peak periods develop around 15:30 to 18:00 or from 16:00 to 18:00.
RQ2: What problems contribute to the road traffic congestion that users on Allandale Road (M39) experience daily?	▪ Migration and growth of the population has increased. ▪ New developments have been established in the area. ▪ Well-known companies have relocated to the Waterfall area. ▪ The out-of-order traffic light systems are left for four to six weeks before being fixed.
RQ3: What are the supporting policies and regulations that have an impact on the management of road traffic congestion?	▪ Some participants within the department visited are not familiar with the policies and regulations related to traffic congestion. ▪ Policies can be unclear and complicated for drivers, traffic engineers and other stakeholders to understand. ▪ Drivers generally follow what they learned during their learner driver's test.
RQ4: What are the strategies used for the management of road traffic congestion within this urban area?	▪ New additional roads are emerging in the network area. ▪ Active availability of traffic officers on Allandale Road (M39) during off-peak hours. ▪ Assistance of Metro Police officers for events such as a funeral convoy to pass through the traffic lights.

Sources: Researcher's compilation

Table 7.1 above presented a summary of the research questions and key findings of the study. The key findings indicated that the peak periods develop from 6:00 to 9:00 in the mornings, and 15:30 to 18:00 in the afternoons. There are also available strategies such as new additional roads, and the assistance and availability of traffic officers. There is not yet a clear understanding of all the relevant policies among most of the individuals participating in the study, including the employees from the traffic departments. The problems that cause the congestion are migration, population growth, new developments, and inadequate or traffic light systems. The section below discusses the main research question.

7.3.6 Main research question

The main research question of the study was: How can the road traffic congestion on Allandale Road (M39) in Midrand, South Africa be managed? The section below discusses the secondary objectives and the contribution to the main research objective.

From the responses received to the secondary research questions it could be concluded that traffic congestion on Allandale Road is not successfully managed. One reasons for this situation could be because most commuters use the direct roads and streets that they are familiar with and which make them feel relaxed and safe. The majority of the drivers are under the impression that it is better to use roads with more cars for safety purposes. When looking into some of the roads leading to the main roads, the network turns into a bottleneck which increases the volume of traffic flow. The qualitative and quantitative results revealed that the period that congestion appears commences in the mornings from 6:00 to 9:00, then again from 15:30 to 18:00 in the afternoons. However this might be instigated by the pattern of working hours from 8:00 to 16:00.

The qualitative results further revealed that records on the traffic congestion peak periods keep rising on a yearly basis. There were also diverse observations regarding the management of the strategies for traffic congestion. Not many of the strategies indicated in the literature, both operational and physical were fully implemented. The inability to execute some of these important strategies could lead to traffic congestion becoming unmanageable in the future.

In addition, there are policies that are too complicated to understand, therefore, some of the quantitative findings showed that respondents are not aware of the importance of the road policies and regulations. This could be that only the information included in the K53 (learner driver test) is followed when applying for driver’s licence. The study also indicated that there are many challenges impacting road traffic congestion on Allandale Road (M39), however, population growth and the development in the area are the leading contributory aspects.

Therefore, to answer the **main research question**: the traffic congestion on Allandale Road (M39) in Midrand has not been appropriately managed up till now. However, although there is a new road being built going through the Gautrain depot, it is turning into a bottleneck. The next section presents the summary and conclusion of the study.

7.4 SUMMARY AND CONCLUSION

This section draws the summary and conclusion of the study from the findings in the literature and questions compiled in the interview guide (qualitative) and questionnaire (quantitative) as indicated in Chapters 2, 3, 5 and 6. A concise discussion of the chapters is included below. Section 7.4.2 summarises and draws the conclusion in terms of the traffic congestion on Allandale Road (M39).

7.4.1 Summary of the study

The aim of the study was to determine whether road traffic congestion on Allandale Road (M39) in Midrand can be managed. The focus of the study was to investigate ways to manage road traffic congestion on Allandale Road.

The research study comprised of seven chapters, as clarified below:

- **Chapter 1**: This chapter provided an overview of the road traffic congestion, road traffic congestion in South Africa, peak periods of traffic congestion in Midrand area, strategies for managing road traffic congestion and the problems contributing to road traffic congestion. It also highlighted the primary and secondary research objectives, significance of the study, the research design and methodology, limitations of the study, ethical considerations, and finally, the outline of the chapters.
- **Chapter 2**: The chapter presented the theoretical background review that included urban transport planning and management. This chapter discussed the background to urban transport planning, and then proceeded with the development and trends within the urban transportation system of South Africa. Different forms of transportation systems available in South Africa were discussed. This section was followed by the contribution of road transport management to the South African economy, urbanisation and the transport environment and challenges within the urban transport system.
- **Chapter 3**: The chapter provided a detailed discussion of the concept and types of traffic congestion, and the impact of road traffic congestion on urban areas. The

discussion covered various aspects such as the social, environmental and economic impacts. The impact of road traffic congestion was followed by a discussion of transport demand management and the strategies for managing traffic congestion. The chapter also discussed the problems contributing to road traffic congestion, policies and regulations that have value and can impact on the management of road traffic congestion, peak period traffic congestion and traffic congestion in South Africa.

- **Chapter 4**: This chapter outlined the research design and the methodology followed in the study. This includes the philosophical perspective and research method selected for the study. The current study adopted an exploratory sequential mixed-methods research design. A sample of three governmental departments was chosen and face-to-face interviews with open-ended questions were used during the interviews in the qualitative phase of the study. The quantitative phase of the study consisted of the distribution of an online quantitative questionnaire using Survey Monkey. The process included the sample procedure which was followed, and research instrument and measurement used to collect the data. The chapter further discussed methods of data collection, data processing, which included editing and coding, and finally, data analysis, presentation of the research findings and ethical considerations. Both processes used Atlas.ti and the IMB SPSS Statistics (Version 26) to analyse the data.
- **Chapter 5**: This chapter dealt with the findings of the qualitative phase of the study. The results of the interviews were presented starting with the demographic profile of the participants from three different spheres of government. The four research questions were divided into nine interview sub-questions. When coding the data, the categories and themes were drawn from the findings collected during the analysis. The chapter concluded with the development of themes for traffic congestion on Allandale Road (M39).
- **Chapter 6**: This chapter presented the findings of the quantitative phase of the study. The information included an outline of the data analysis and description of data collected from the questionnaire. The questionnaire was divided into six subsections based on the demographic profile of Allandale Road users and the research questions. This was followed by descriptive statistics, perception of

respondents on street intersections, strategies, policies and regulations and problems. The last section discussed the inferential statistics.

- **Chapter 7**: In this chapter, which is the final chapter and concludes the study, the presentation included the discussion of the research findings, a summary of the study and the conclusions related to the research objectives. The chapter finally presents the recommendations for future research, contributions of the study, limitations of the study and suggestions for future research.

7.4.2 Conclusions related to research objectives

Based on the qualitative and quantitative findings of this research study, the conclusions drawn from the data analysis are discussed with regard to the objectives of the study. These are presented in the sub-sections below.

7.4.2.1 Secondary research objectives

The primary research objective of the current study was to find out ways to manage road traffic congestion on Allandale Road (M39) in Midrand, South Africa. To address and respond to the main research objective, the secondary research objectives are discussed. The following conclusions can be drawn from the study.

Objective 1: To discover the peak periods of road traffic congestion on Allandale Road (M39).

Traffic congestion occurs during specific times of the day. The findings revealed that the morning and afternoon peak periods of road traffic congestion on Allandale Road (M39) start from 6:00 to 9:00, and then proceed from 15:30 to 18:00. This confirms that there is no congestion on Allandale Road (M39) outside the time specified, unless there is another reason such as accident during the day, which could happen once in a while.

Objective 2: To discover the problems contributing to the road traffic congestion that users on Allandale Road (M39) experience daily.

The findings of the study revealed that the problems contributing to the road traffic congestion that users on Allandale Road (M39) experience daily include new developments in the area, the increases in population growth, relocation of well-known companies to Waterfall, increased vehicle ownership, and the non-operating traffic light systems that go unrepaired from four to six weeks without being fixed.

Objective 3: To identify and describe the supporting policies and regulations that have value, and impact on the management of road traffic congestion.

The results of the study revealed that even though there is a comprehensive knowledge of the appropriate policies, acts and regulations in some of the sections, especially those responsible for traffic-related incidents, these policies are not accurately monitored and implemented. The road users and some individuals working within the three spheres of government are not familiar with some of the policies. It might be complicated for the drivers to get hold of the document stipulating the polices concerned. The findings further revealed that transport engineers and planners have varying views when it came to the discussion of policies. In this case, the frequently used policies are the National Road Traffic Act 93 of 1996 and the Road Traffic Management Corporation Act 20 of 1999.

Objective 4: To identify and describe the strategies used to manage road traffic congestion within this urban area.

There have been no changes to the Allandale Road (M39) network infrastructure in the last ten years. However, the findings of the study revealed that the road passing through the Gautrain depot was recently added to the network. In addition, only lately traffic officers have started to patrol the road during off-peak hours. There has been a contribution from the officers with regard to the support and monitoring of special events, such as a funeral convoy passing through the traffic lights to the cemetery. The poorly managed traffic light system still persists. The road users are adaptable to the situation and in most cases, they treat a non-operating traffic lights as a four way stop and follow the rules concerned.

7.4.2.2 Primary research objective

Based on the findings of the secondary research objectives, the following can be concluded to achieve the primary research objective of the study. The primary research objective was "*to find out ways to manage road traffic congestion on Allandale Road (M39) in Midrand, South Africa*":

The overall findings revealed that the road traffic congestion on Allandale Road (M39) in Midrand, South Africa is not being appropriately managed, and consequently, the causes of the traffic congestion in the area amount to the inadequate management of the services. The findings also revealed that there are various strategies that can be used, such as physical improvements: bottleneck relief, street connectivity, additional new roads, and a public information system. Operational improvement strategies that may be implemented: active road management by traffic officers, traffic signal timing and coordination, incident management, and the provision of mass public transport, which might relieve the congestion.

7.5 RESEARCH CONTRIBUTION AND RECOMMENDATION

This section discusses the contribution that the current study has made to the existing body of knowledge. This is followed by the recommendations and the suggested framework that can be adopted for proper road traffic management on Allandale Road (M39). The sections below present the research contribution and recommendation.

7.5.1 Research contributions

This research study makes a contribution to the existing knowledge related to the traffic congestion in an urban area such as Midrand. There is no confirmation or evidence of a previous study that has been conducted on the traffic congestion on Allandale Road (M39), and this study could therefore make a significant contribution. The research on this road could benefit the provincial and local road authorities, policy-makers and transport planners to consider the suggested strategies that will alleviate these mobility challenges.

7.5.2 Recommendations

Based on the findings revealed in the study, there are numerous challenges that restrain the free flow of the traffic on Allandale Road (M39) in Midrand. The study revealed that there is no master plan for the different agencies to follow, which will influence where developments must be situated and how all the relevant roads should be collectively upgraded or where new roads need to be situated. A master plan would also take into consideration finding the right people for the job. It may be that there is an overarching plan, but it is just not being carried out properly.

Therefore, the current study has constructed a framework that could assist in the alleviation of urban traffic congestion. The framework includes the components that are significant in the management of road traffic congestion. The recommendations are presented below and included in Figure 7.2.

- **Expansion of the road capacity for transportation systems (Supply procedures)**

Certain transport infrastructures were constructed long before the new developments started. There is a need to transform the existing transport infrastructure to suit the current circumstances. Road authorities can expand the road systems and networks to allow for the effective movement of vehicles. This can also be accomplished by adding and building new infrastructure. Effective public transport services and the introduction of mass public transit systems may assist the commuters. The introduction of a bus route, especially the Gautrain bus service, will be appreciated by most of the commuters using this road. Resolving the traffic signal problems throughout the road and its intersections could assist in reducing the delay caused by traffic congestion. There must be non-motorised transport facilities available to assist commuters. Commuters must also be introduced to ridesharing to reduce the environmental problems associated with private vehicle usage. There needs to be enhanced coordination between the three spheres of government. The next section discusses how this can be done.

- **Suitable integrative plan between the three spheres of government**

Since there is a lack of a strategic, combined national plan coordinating the different government agencies, there is a need for a master plan which will influence where developments must be situated and how all relevant roads should be collectively upgraded. The management at all three spheres of government could agree on working together on issues related to the main roads in the province. Another issue is related to a lack of planning by state officials, which results in individuals with the wrong expertise being hired to address the problems being experienced.

A master plan should also take into consideration how the right people for the job will be found. There are project plans that were not successfully executed because of a lack of expertise and a lack of available funds, taking into consideration the e-tolling system. The e-toll system was developed as an approach to address the lack of funds required to upgrade national roads. However, the e-toll system was rejected by road users.

In terms of the policies, there should a well-developed congestion management strategy available for commuters, and they should also contribute in the policy-making process. Road users should be introduced to these road-related policies.

- **Reduction of private vehicle usage (demand procedures)**

The introduction of controlling actions may need to be considered to reduce the travelling demand from drivers. Proper policies and regulations should be implemented to reduce the use of private vehicles on the roads.

In addition, there must be a flexible working arrangement between the commuters and their employers, for example, working from home (also known as telecommuting) should be implemented for those able to perform these activities without disruptions in their location. The authorities may also consider the introduction of congestion pricing and area licensing schemes to hinder the expansion of traffic congestion on Allandale Road.

Figure 7.2 (on the next page) presents the recommended framework for managing the traffic congestion on Allandale Road (M39) that has been compiled by the current study.

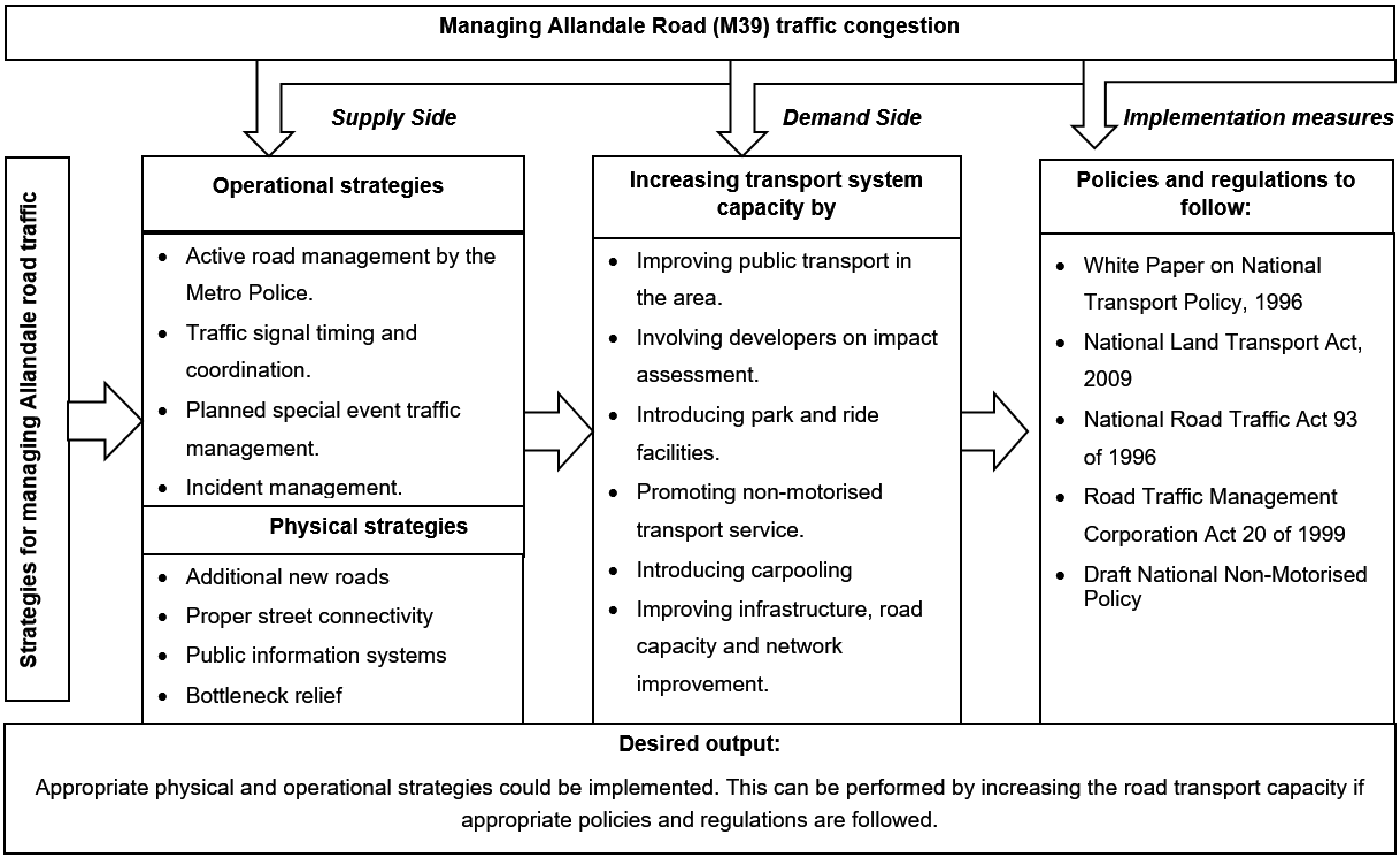


Figure 7.2: Recommended framework for managing Allandale Road (M39) traffic congestion

7.6 LIMITATIONS OF THE STUDY AND SUGGESTIONS FOR FUTURE RESEARCH

During the research process, the researcher encountered some limitations, and can make some suggestions that can be considered for future research. The sections below present the limitations of the study and suggestions for future research.

7.6.1 Limitations of the study

A number of limitations were encountered during the study, such as the following:

- The study was only based in the Midrand area, and therefore, the results cannot be generalised. The study also focused on drivers using the road from Monday to Friday, yet there were also once-off drivers.
- The study had an age restriction up to 65 years, however, some respondents residing in the Midrand area may be older, and were excluded from the study.
- Since the study used mixed research methods, the researcher only interviewed 18 participants in the qualitative data collection phase.
- The quantitative data collection phase, the online questionnaire format favoured respondents who had access to a smart phone, computer or laptops. The questionnaire was only available online due to the Covid-19 lockdown and restriction of movement.
- The study focused on government officials and drivers of private vehicles only and not all the drivers were included in the survey.
- Another limitation was based on the availability of the sample size. For the qualitative data collection, only 18 out of 25 participants were interviewed due to the availability during the data collection period. For the quantitative data collection, the initial sample was 350; however, the study was discontinued at 276 responses because of the interruption of the due date of the contract of an online survey.

7.6.2 Suggestions for future research

The study aimed to find ways to manage road traffic congestion on Allandale Road (M39) in Midrand, South Africa. In order to achieve the objectives and gain an in-depth understanding of the traffic congestion taking place in the Midrand area, specifically on Allandale Road (M39), the study adopted an exploratory sequential mixed-method research design. Based on the qualitative and quantitative findings of the study, there is a need for further research on the management of road traffic congestion in South Africa. However, it is recommended that future research should thoroughly investigate the techniques for managing road traffic congestion. It also recommended that the current study be replicated to provide the provincial government with feedback, or a comparison study to investigate how the drivers understand and react to the traffic congestion issue.

7.7 CONCLUSION

This research study focused on the research question: How can the road traffic congestion on Allandale Road (M39) in Midrand, South Africa, be managed? In order to achieve the objective, secondary questions were formulated to ensure that more evidence was gathered from the literature, based on the morning and afternoon peak periods, strategies for managing road traffic congestion, policies and regulations and problems contributing to the road traffic congestion. The questions were all addressed, and the traffic congestion related aspects were understood.

The study adopted an exploratory sequential mixed-methods approach, consisting of face-to-face interviews and an online questionnaire survey. The 18 interviews with participants from the three spheres of government were conducted at the hand of a semi-structured interview schedule of open-ended questions. The findings revealed that Allandale Road (M39) suffers from traffic congestion challenges that require urgent attention. This congestion wastes time, increases expenses, and prevents the commuters from performing their daily activities appropriately.

There is a lack of implementation of strategies such as mass transport and modal integration, which requires consideration, since most commuters have no choice but to use their own vehicles to travel from their place of residence to work and other business activities. Therefore, to assist with the arrangement for proper road traffic management, the study developed a framework.

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APPENDICES

APPENDIX A:
QUALITATIVE INTERVIEW GUIDE

SECTION A: THE PARTICIPANT'S PROFILE
What is your position in the organisation? *How long have you been working in the organisation?*
RQ1: RESEARCH QUESTION 1: WHICH PEAK PERIOD OF TRAFFIC CONGESTION EXISTS ON ALLANDALE ROAD (M39) COMPARED TO OTHER AREAS?
IQ1: Kindly identify roads or streets in Midrand that are congested. *IQ2: Which other roads or streets around Midrand that you know of are also congested?* *IQ3: What are the peak periods of road traffic congestion on Allandale Road (M39)?*
RQ2: RESEARCH QUESTION 2: WHAT PROBLEMS CONTRIBUTE TO THE TRAFFIC CONGESTION THAT USERS ON ALLANDALE ROAD (M39) EXPERIENCE DAILY?
IQ4: Would you identify problems that form the underlying contribution of the road traffic congestion on Allandale Road (M39)?
RQ3: WHAT ARE THE SUPPORTIVE POLICIES, ACTS AND REGULATIONS THAT HAVE THE VALUES AND IMPACT ON MANAGING ROAD TRAFFIC CONGESTION?
IQ5: What are the supportive policies that have an impact when managing/alleviating road traffic congestion? *IQ6: What are the supportive regulations that have an impact when managing/alleviating road traffic congestion?*
RQ4: WHAT STRATEGIES ARE USED TO MANAGE ROAD TRAFFIC CONGESTION WITHIN URBAN AREAS SUCH AS MIDRAND?
IQ7: Can you identify the key strategies that are used to manage road traffic congestion on Allandale Road (M39)? *IQ8: Which strategies are lacking and still required to manage road traffic congestion on Allandale Road (M39?*

APPENDIX B:
QUANTITATIVE QUESTIONNAIRE

MANAGING ROAD TRAFFIC CONGESTION ON ALLANDALE ROAD (M39) IN MIDRAND, SOUTH AFRICA.

INSTRUCTIONS TO COMPLETE THE QUESTIONNAIRE

This questionnaire comprises of numerous statements about the road traffic congestion on Allandale Road (M39). You are requested to put an X on the number that shows how you evaluate each statement. Once you have read each question, please decide the extent to which your answer describes your own expectation using the following 5-point Likert scale.

EXAMPLE:

a.	The cause of road traffic congestion is private vehicles	Strongly disagree	disagree	Unsure	Agree	Strongly agree
		1	2	3	4	5

If you feel that indeed **the cause of road traffic congestion is private vehicles,** put an X on 5. On the other hand, if you feel that private vehicle are not the causes of road traffic congestion, place an X on 1. If you neither agree nor disagree with the statement, place an X on 3.

Please read each statement carefully and decide which option best describes your experience regarding the road traffic congestion on Allandale Road (M39). After completing all the statements, please return the questionnaire to the field workers.

SECTION A: SCREENING QUESTIONS

A1 - Are you driving a car on Allandale Road (M39) on Monday-Friday?

Yes		No	

A2 – Are you above 18 years old?

Yes		No	

If your answers on questions A1 and A2 are YES, please carry on to section B

Please note that only participant of the age from 18 above can complete this questionnaire. If you are below 18, please return the questionnaire to the field worker.

SECTION B: DEMOGRAPHIC INFORMATION

(*Mark with an **X** or complete your answer on the space provided*)

B1 –Please indicate your place of residence

Midrand	1	Tembisa	5
Kyalami	2	Klipfontein	6
Sunninghill	3	Kempton park	7
Waterfall	4	If other, please specify:	

B2 – Please indicate your age group as provided below:

18-24 years	1	25-45 years	2	Above 65 years	3

B3 – Please indicate your gender:

Female	1	Male	2

B4 – Please indicate your educational background:

High school/grade 12	1
College or university student	2
Graduate from the university/college	3
Postgraduate (Honours, Masters and Doctoral)	4
Professional	5
If other, please specify:	

B5 – Please indicate your status of occupation:

Company employee	1
Business owner	2
Self-employed	3
Unemployed	4
Student	5
If other, please specify:	

B6 – Please indicate your approximate monthly net income:

R5000 – R10 000	1
R11 000 – RR15 000	2
R16000 - R20 000	3
R21 000 – R25 000	4
R26 000 and more	5
None	6

B7 – Please indicate the amount you spend for petrol on a monthly basis:

Below R1000	1
R1000– R2000	2
R2001– R2500	3
R2501 – R3000	4
R3000- more	5
None	6

B8 – Which of the following is the reason for your daily travelling activities?

Work	1
School	2
Personal leisure	3
Business journeys	4
Shopping	5
If other, please specify:	

You are now proceeding to sections C, D, E and F. Please make sure that you read and follow the correct instruction. If you require any clarity regarding the questions stated in any of the sections provided, you are more than welcome to direct your queries to the research administrator at Sasams@unisa.ac.za

Please continue with Section C.

SECTION C: PEAK PERIOD OF TRAFFIC CONGESTION IN MIDRAND

To select your choice below, please tick, based on traffic congestion occurrences starting from "Traffic congestion is very high" to "Traffic congestion is very low" by also rate on the numbers from 1-5

C1: Indicate the level of traffic congestion on Allandale Road?

1. Traffic congestion is very high
2. Traffic congestion is high
3. Traffic congestion is moderate
4. Traffic congestion is low
5. Traffic congestion is very low

C2: How do you evaluate the level of traffic congestion on the following streets intersections on Allandale Road?

		Traffic congestion is very low	Traffic congestion is low	Traffic congestion is moderate	Traffic congestion is high	Traffic congestion is very high
a	Harry Galaun Drive	1	2	3	4	5
b	Waterfall Drive	1	2	3	4	5
c	Pretorius road	1	2	3	4	5
d	Lone Creek	1	2	3	4	5
e	Alsatian road	1	2	3	4	5
f	Bridal veil road	1	2	3	4	5
g	Dane road	1	2	3	4	5
h	Mastiff road	1	2	3	4	5
i	Kynoch road	1	2	3	4	5
j	Saraseen road	1	2	3	4	5
k	Chloor road	1	2	3	4	5

C3: Which of the following roads are also congested as compared to Allandale Road?

1. Le Roux Road
2. New Road
3. Olifantsfontein Road
4. R101/K101 - Old Johannesburg Road
5. R55 - Sandton Road
6. M18 – Zuurfontein Street

C4: Which of the following represent the <u>morning peak periods</u> of the traffic congestion on Allandale Road (M39)?

1. 5:30 – 9:00
2. 6:00 – 9:00
3. 6:30 – 9:00
4. 7:00 – 9:00
5. 7:30 – 9:00
6. Other, please specify:

C5: Which of the following represent the <u>afternoon peak periods</u> of the traffic congestion on Allandale Road (M39)?

1. 15:00 – 18:00
2. 15:00 – 18:30
3. 15:30 – 18:00
4. 16:00 – 18:00
5. 17:00 – 18:00
6. Other, please specify:

C6: As a driver when you travel to your destination, can you please indicate the kilometres that you spend daily?

1. 20-29 Km
2. 30-35 Km
3. 36-40 Km
4. 41-50 Km
5. Other, please specify:

Please continue with Section D below:

SECTION D: PROBLEMS CONTRIBUTING TO ROAD TRAFFIC CONGESTION

To select your choice below, please tick, based on problem, policies and strategies on road traffic congestion starting from "<u>Strongly disagree</u>" to "<u>Strongly agree</u>" by also rate on the numbers from 1-5

D: PROBLEMS CONTRIBUTING TO ROAD TRAFFIC CONGESTION.

D1: Indicate your level of agreement on whether the following problems of road traffic congestion exist?

		Strongly disagree	disagree	Unsure	Agree	Strongly agree
a	Increased in vehicle ownership	1	2	3	4	5
b	Growth of population in the area	1	2	3	4	5
c	New developments in the area	1	2	3	4	5
d	Roadworks or constructions	1	2	3	4	5
e	Mismanagement of road traffic system	1	2	3	4	5

Please continue with Section E below:

SECTION E: SUPPORTING POLICIES AND REGULATIONS

E: SUPPORTING POLICIES AND REGULATIONS THAT HAVE THE VALUES AND IMPACT ON MANAGING ROAD TRAFFIC CONGESTION.

E1: How do you evaluate the level of agreement about the statements provided under White Paper on National Transport Policy, 1996

		Strongly disagree	disagree	Unsure	Agree	Strongly agree
a	There is a need for improvement of transport infrastructure	1	2	3	4	5
b	Trucks operate from 06:00 to 09:00 and then 17:00 to 20:00 Monday to Friday except public holidays.	1	2	3	4	5

E2: How do you evaluate the level of agreement about the statements provided under National Land Transport Act, 2009

		Strongly disagree	disagree	Unsure	Agree	Strongly agree
a	There are enough lanes for the effective movement of vehicles on Allandale Road.	1	2	3	4	5
b	Different integrated modal services such as buses, taxis and train are available.	1	2	3	4	5

E2: How do you evaluate the level of understanding about the statements provided under National Road Traffic Act 93 of 1996?

		Very poor	Poor	Average	Good	Excellent
a	Understanding the rule of licensing of the vehicles and drivers.	1	2	3	4	5
b	Understanding the rule of vehicle roadworthiness, negligent and reckless driving.	1	2	3	4	5
c	Understanding the rule of speed limits on the roads.	1	2	3	4	5
d	Understanding the rule of driving under the influence of alcohol or drugs.	1	2	3	4	5

E3: How do you evaluate the level of agreement about the statements provided under Road Traffic Management Corporation Act 20 of 1999?

		Strongly disagree	disagree	Unsure	Agree	Strongly agree
a	Law enforcement officers promote safety on Allandale Road.	1	2	3	4	5
b	Road users comply with the rules of the road all the time.	1	2	3	4	5
c	The performance of the law enforcement officers so far, is satisfactory on Allandale Road.	1	2	3	4	5

E4: How do you evaluate the level of agreement about the statements provided under Draft National Non-Motorised Transport policy?

		Strongly disagree	disagree	Unsure	Agree	Strongly agree
a	Walking pavements and bicycle parking are available and in good condition.	1	2	3	4	5
b	Walking, cycling and rollerblading are available to reduce number of traffic fatalities.	1	2	3	4	5
c	Walking, cycling or rollerblading are used as a feeder system to other modes of transport.	1	2	3	4	5

Please continue with Section F below:

SECTION F: STRATEGIES FOR MANAGING ROAD TRAFFIC CONGESTION

F: STRATEGIES FOR MANAGING ROAD TRAFFIC CONGESTION.

F1 Indicate your level of agreement on the following *strategies* that will best manage traffic congestion on Allandale Road (M39)?

		Strongly disagree	disagree	Unsure	Agree	Strongly agree
a	Improving public transport in the area.	1	2	3	4	5
b	Improving infrastructure, road capacity and networks	1	2	3	4	5
c	Introducing carpooling.	1	2	3	4	5
d	Promoting a Non-Motorised Transport (NMT) service.	1	2	3	4	5
e	Park-and-ride facilities	1	2	3	4	5
f	Involving the developers on environmental impact assessments.	1	2	3	4	5

F2 Indicate your level of agreement on whether the following *physical improvement strategies* are available on Allandale Road (M39)?

		Strongly disagree	disagree	Unsure	Agree	Strongly agree
a	Additional new roads	1	2	3	4	5
b	Streets connectivity	1	2	3	4	5

c	Public information systems	1	2	3	4	5
d	Bottleneck reliefs	1	2	3	4	5
e	Dedicated lanes for buses/BRT systems.	1	2	3	4	5

F3 Indicate your level of agreement on whether the following *operational improvement strategies* are implemented rapidly on Allandale Road (M39)?

		Strongly disagree	disagree	Unsure	Agree	Strongly agree
a	Incident management	1	2	3	4	5
b	Planned special events traffic management	1	2	3	4	5
c	Traffic signal timing and coordination	1	2	3	4	5
d	Active road management by Metro Police	1	2	3	4	5

F4 Indicate which of the following *strategies are still lacking* on Allandale Road (M39)?

1. Improvement of Infrastructure, road capacity and networks
2. Developer involvement
3. Public transport
4. Modal integration e.g. public transport such as bus, taxi, train etc.
5. Carpooling/lift club
6. Other, please specify:

THANK YOU!!

APPENDIX C:
ETHICAL CLEARANCE CERTIFICATE

UNISA university of south africa

UNISA DESTTL ETHICS REVIEW COMMITTEE

Date: 1 November 2018

Dear Ms Mosebudi Shalyne Sasa

Decision: Ethics Approval from 11/2018 to 11/2021

ERC Reference # : 2018_CEMS_ESTTL_010
Name : Ms Mosebudi Shalyne Sasa
Student #: 40832279
Staff #: 90186745

Researcher(s): Mosebudi Shalyne Sasa
sasams@unisa.ac.za

Supervisor (s): Prof Intaher Marcus Ambe
ambeim@unisa.ac.za

Working title of research:

Managing road traffic congestion on Allandale Road (M39) in Midrand, South Africa.

Qualification: Masters in Transport Economics

Thank you for the application for research ethics clearance by the Unisa Department of Entrepreneurship, Supply Chain, Transport, Tourism and Logistics Management's Ethics Review Committee for the above mentioned research. Ethics approval is granted for three (3) years/

*The **low risk application** was **reviewed** by the Department of Entrepreneurship, Supply Chain, Transport, Tourism and Logistics Management's (DESTTL) Ethics Review Committee on 30/10/2018 in compliance with the Unisa Policy on Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment. The decision will be tabled at the next Committee meeting.*

The proposed research may now commence with the provisions that:

University of South Africa
Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa
Telephone: +27 12 429 3111 Facsimile: +27 12 429 4150
www.unisa.ac.za

Open Rubric

1. The researcher(s) will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.
2. Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study should be communicated in writing to the *DESTTL* Committee.
3. The researcher(s) will conduct the study according to the methods and procedures set out in the approved application.
4. Any changes that can affect the study-related risks for the research participants, particularly in terms of assurances made with regards to the protection of participants' privacy and the confidentiality of the data, should be reported to the Committee in writing, accompanied by a progress report.
5. The researcher will ensure that the research project adheres to any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study. Adherence to the following South African legislation is important, if applicable: Protection of Personal Information Act, no 4 of 2013; Children's act no 38 of 2005 and the National Health Act, no 61 of 2003.
6. Only de-identified research data may be used for secondary research purposes in future on condition that the research objectives are similar to those of the original research. Secondary use of identifiable human research data require additional ethics clearance.
7. No field work activities may continue after the expiry date (xxx). Submission of a completed research ethics progress report will constitute an application for renewal of Ethics Research Committee approval.

Note:

The reference number ***2018_CEMS_ESTTL_010*** *should be clearly indicated on all forms of communication with the intended research participants, as well as with the Committee.*

Yours sincerely,

Chair of DESTTL ERC
E-mail: esttl_rerc@unisa.ac.za
Tel: (012) 429-4298

Executive Dean : Prof MT Mogale
E-mail: mogalmt@unisa.ac.za
Tel: (012) 429-4805

URERC 25.04.17 - Decision template (V2) - Approve

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APPENDIX D:
CERTIFICATE FOR CO-CODING

QUALITATIVE DATA ANALYSES

CODING CERTIFICATE

For

Ms Mosebudi Shalyne

For the study titled

Managing Road Traffic Congestion on Allandale Road (M39) in Midrand, South Africa

This is to certify that

Dr EM Solomon coded and analysed the data from eighteen (18) transcribed interviews using the strategies suggested by Rapley[1] (2011:274-275) and the method described by Creswell[2] (2013:193-225). After conferring with the candidate I can confirm that consensus was reached with regards to the major themes and categories of the study.

In accordance with ethical standards, all information related to the co-coding and analysis of the above study was anonymous and any information related to the study is destroyed upon completion of the process

Dr E.M. Solomon DTech:Hom. (UJ)

10th February 2020

1. Rapley, T. (2011). Some Pragmatics of Data Analysis "in" Silverman, D. Ed. *Qualitative Research 3rd Edition.* Sage Publications. Chapter 15.

2. Creswell, J.W., (2013). *Qualitative inquiry and research design. Choosing among five traditions.* Third ed. Sage Publications

APPENDIX E:
PARTICIPANT INFORMATION SHEET, INFORMED CONSENT AND PERMISSION LETTERS

Dear Prospective Participant

My name is Mosebudi Shalyne Netshisaulu and I am doing a research with Prof IM Amber, a professor in the Department of Applied Management, towards Mcom in Transport Economics at the University of South Africa. We are inviting you to participate in a study entitled: **Managing road traffic congestion on Allandale Road (M39) in Midrand, South Africa**

WHAT IS THE PURPOSE OF THE STUDY?

The research aims to find out how the road traffic congestion on Allandale Road (M39) in Midrand could be managed in order to provide guidelines to government road authorities, policy-makers, road users and other affected stakeholders.

WHY AM I BEING INVITED TO PARTICIPATE?

Please note that the participants in this research project are government officials and road users specifically the vehicle drivers who use Allandale Road (M39) on a daily and are above the age of 18. The research project requires 350 participants. Midrand is one of the areas in Gauteng experiencing traffic congestion problems on a daily basis.

WHAT IS THE NATURE OF MY PARTICIPATION IN THIS STUDY?

The study involves answering a questionnaire. The questionnaire has sections that need to be completed starting from personal information (age, gender, income) and traffic related questions. It may take 5-10 mins to answer all the questions.

CAN I WITHDRAW FROM THIS STUDY EVEN AFTER HAVING AGREED TO PARTICIPATE?

Participating in this study is voluntary and you are under no obligation to consent to participation. If you do decide to take part, you will be given this information sheet to keep and be asked to sign a written consent form. You are free to withdraw at any time and without giving a reason.

WHAT ARE THE POTENTIAL BENEFITS OF TAKING PART IN THIS STUDY?

The information obtained from the questionnaires will help to provide guidelines to transport planners and providers, affected stakeholders and interested community members. The guidelines will hopefully contribute to a better understanding and satisfaction of public demands.

ARE THEIR ANY NEGATIVE CONSEQUENCES FOR ME IF I PARTICIPATE IN THE RESEARCH PROJECT?

There is no harm anticipated from participating in this research project.

WILL THE INFORMATION THAT I CONVEY TO THE RESEARCHER AND MY IDENTITY BE KEPT CONFIDENTIAL?

Your name will not be recorded anywhere, and no one will be able to connect you to the answers you give. Please note that your anonymous data may be used for other purposes, such a research report, journal articles and/or conference proceedings. Your identity will remain anonymous.

HOW WILL THE RESEARCHER(S) PROTECT THE SECURITY OF DATA?

The researcher will store hard copies of your answers for a period of five years in a locked cupboard/filing cabinet *at* University of South Africa for future research or academic purposes; electronic information will be stored on a password-protected computer. Future use of the stored data will be subject to further Research Ethics Review and approval if applicable. The information will be destroyed after five years by shredding paper copies and permanently deleting electronic information from the hard drive of the computer

WILL I RECEIVE PAYMENT OR ANY INCENTIVES FOR PARTICIPATING IN THIS STUDY?

Participation is voluntary and therefore neither gifts nor compensation will be given to participants. Participants will also not incur any losses. However, an investment of time to participate will be requested.

HAS THE STUDY RECEIVED ETHICS APPROVAL?

This study has received written approval from the Research Ethics Review Committee of the Department of Entrepreneurship, Supply Chain, Transport, Tourism and Logistics Management, Unisa. A copy of the approval letter can be obtained from the researcher if you so wish.

HOW WILL I BE INFORMED OF THE FINDINGS/RESULTS OF THE RESEARCH?

If you would like to be informed of the final research findings, please contact Mrs. Mosebudi S Netshisaulu on 012 433 4645 or Sasams@unisa.ac.za. Should you have concerns about the way in which the research has been conducted, you may contact Prof IM Ambe, 012 429 4500 or Ambeim@unisa.ac.za. Alternatively, contact the research ethics chairperson of the Department of Applied Management, Unisa, Mrs. Carmen Poole, on 012 433 4668 or loedoc@unisa.ac.za .

Thank you for taking time to read this information sheet and for participating in this study.

Your sincerely,

Mosebudi Sasa

CONSENT TO PARTICIPATE IN THIS STUDY

I_(participant name), confirm that the person asking my consent to take part in this research has told me about the nature, procedure, potential benefits and anticipated inconvenience of participation.

I have read (or had explained to me) and understood the study as explained in the information sheet.

I have had sufficient opportunity to ask questions and am prepared to participate in the study.

I understand that my participation is voluntary and that I am free to withdraw at any time without penalty.

I am aware that the findings of this study will be processed into a research report, journal publications and/or conference proceedings, but that my participation will be kept confidential unless otherwise specified.

I have received a signed copy of the informed consent agreement.

Participant Name & Surname…………………………………………………………….

Participant Signature……………………………………. Date…………………………

Researcher's Name & Surname…………………………………………………………

Researcher's signature…………………………………… Date………………………

APPROVAL LETTER 1

GAUTENG PROVINCE
ROADS AND TRANSPORT
REPUBLIC OF SOUTH AFRICA

Private Bag X83 Marshalltown 2107,45 Commissioner Street
Tel (011) 355 7080 Fax: (011) 355 7509

Enquiry / Navrae : Mr Victor Phala: Roads and Transport

Ref / Verw : MS Sasa (student no 4083-227-9) authorization to conduct interviews for thesis

University of South Africa
P.O Box 392
UNISA
Pretoria
0003

Dear Sir/Madam

RE: REQUEST FOR PERMISSION TO CONDUCT RESEARCH INTERVIEWS AT GAUTENG DEPARTMENT OF ROADS AND TRANSPORT

This letter serves to confirm that Ms Mosebudi Shalyne Sasa (student number: 4083 – 227 – 9) is authorised to conduct her research study pertaining to the below topic:

> **Managing road traffic congestion on Allandale Road (M39) in Midrand, South Africa**

The Department confirm that interviews can be carried out within the below mentioned business units dealing with projects i.e.:

- Roads Maintenance Directorate including Benoni, Krugersdorp Regions and outsourced routine roads maintenance service providers (contact Director : Ms Lindeni Dhlamini at lindeni.dhlamini@gauteng.gov.za)
- Traffic Engineering Directorate (contact Director: Mr Eyase Ramokhoase at eyase.ramokhoase@gauteng.gov.za)

Furthermore, it will be appreciated that, the report be submitted to the Department before submission to the University. In addition to that, the report can be used for public domain including for conferences and academic purposes.

Trust you find all above in order. Please contact undersigned for any clarity seeking purposes.

Kind regards,

RB Swartz
Head of Department: Roads and Transport
Date: 03 September 2018

MS Sasa (student no 4083-227-9) authorization to conduct interviews for thesis

APPROVAL LETTER 2

SANRAL

BUILDING SOUTH AFRICA THROUGH BETTER ROADS

Reference:	#4516420	Fax Number:	+27 (0) 12 844 8200
Date:	13 September 2018	Direct Line:	+27 (0) 12 844 8067
Email:	louwk@nra.co.za	Website:	www.sanral.co.za

Ms Mosibudi Sasa
Student number 4083 227 9 – University of South Africa (UNISA)

APPROVAL TO CONDUCT RESEARCH INTERVIEWS AT THE SOUTH AFRICAN NATIONAL ROADS AGENCY SOC LTD

It is my pleasure to inform you that your request to conduct research interview on the topic "***Managing Road Traffic congestion on Allandale Road (M39) in Midrand, South Africa***" has been reviewed and permission is hereby granted for you to conduct research interviews.

It is noted that the aim of the study is to investigate the techniques on how road traffic congestion on Allandale road (M36) in Midrand can be managed in order to suggest proper guidelines to road users, transport planners, policy makers and other affected stakeholders. In addition, please be informed that as a researcher you are required to sign the Confidentiality Agreement with the South African National Roads Agency SOC Ltd to conduct the said research. Our Toll division will be facilitating the whole process therefore communication should be directed to the following colleagues:

Name	Telephone number	e-mail address
Mr Alex van Niekerk Senior Project Manager ITS/TOLL	+27 (0) 12 426 6200/ +27 (0) 12 426 6226	niekerka@nra.co.za
Ms Siveshni Pillay Traffic Engineer	+27 (0) 12 426 6200 +27 (0) 12 426 6238	pillaysh@nra.co.za
Mr Alan Robinson Traffic Engineer	+27 (0) 12 426 6200 +27 (0) 12 426 6299	robinsona@nra.co.za
Mr Abdul Hay Project Manager PS & Maintenance	+27 (0) 12 426 6200 +27 (0) 12 426 6216	haya@nra.co.za

Yours sincerely

Louw Kannemeyer
ENGINEERING EXECUTIVE

c.c.:
1. Mr Alex van Niekerk - Senior Project Manager ITS/TOLL
2. Ms Siveshni Pillay, Traffic Engineer
3. Mr Alan Robinson, Traffic Engineer
4. Mr Abdul Hay, Project Manager PS & Maintenance

Head Office 48 Tambotie Avenue, Val de Grace, Pretoria, 0184 | PO Box 415, Pretoria, South Africa, 0001 | Telephone +27 (0) 12 844 8000 Fax +27 (0) 12 844 8200
Email: info@sanral.co.za | Visit us at www.sanral.co.za

Page 1 of 1

Open Rubric

APPENDIX F:
DATA TABLES

Table 6.10: Pairwise Comparisons of B5 – Please indicate your status of occupation: Promoting NMT services

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
Business owner-Company employee	5.673	15.289	.371	.711	1.000
Business owner-Self-employed	-17.293	18.985	-.911	.362	1.000
Business owner-Unemployed	-22.096	28.478	-.776	.438	1.000
Business owner-Student	-41.311	18.177	-2.273	.023	.230
Company employee-Self-employed	-11.620	13.179	-.882	.378	1.000
Company employee-Unemployed	-16.423	24.985	-.657	.511	1.000
Company employee-Student	-35.638	11.985	-2.974	.003	.029
Self-employed-Unemployed	-4.804	27.403	-.175	.861	1.000
Self-employed-Student	-24.018	16.442	-1.461	.144	1.000
Unemployed-Student	-19.214	26.849	-.716	.474	1.000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .050. a. Significance values have been adjusted by the Bonferroni correction for multiple tests

Table 6.10: Pairwise Comparisons of B6 – Please indicate your approximate monthly net income: Improving public transport in the area

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
R25 001 and more-R20 001 – R25 000	1.144	9.235	.124	.901	1.000
R25 001 and more-R10 000 – R15 000	16.888	8.483	1.991	.047	.698
R25 001 and more-R15 001 - R20 000	19.773	8.733	2.264	.024	.354
R25 001 and more-Below R10 000	20.994	8.195	2.562	.010	.156
R25 001 and more-None	-21.136	10.576	-1.998	.046	.685
R20 001 – R25 000-R10 000 – R15 000	15.744	10.797	1.458	.145	1.000
R20 001 – R25 000-R15 001 - R20 000	18.629	10.995	1.694	.090	1.000
R20 001 – R25 000-Below R10 000	19.850	10.572	1.878	.060	.907
R20 001 – R25 000-None	-19.993	12.509	-1.598	.110	1.000
R10 000 – R15 000-R15 001 - R20 000	-2.885	10.371	-.278	.781	1.000
R10 000 – R15 000-Below R10 000	4.106	9.922	.414	.679	1.000
R10 000 – R15 000-None	-4.248	11.964	-.355	.723	1.000
R15 001 - R20 000-Below R10 000	1.221	10.137	.120	.904	1.000
R15 001 - R20 000-None	-1.364	12.143	-.112	.911	1.000
Below R10 000-None	-.143	11.762	-.012	.990	1.000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .050. a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

Table 6.11: Pairwise Comparisons of B5 – Please indicate your status of occupation: Public information system

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
Student-Business owner	16.393	16.536	.991	.322	1.000
Student-Self-employed	29.893	14.957	1.999	.046	.457
Student-Unemployed	34.714	24.425	1.421	.155	1.000
Student-Company employee	38.143	10.898	3.500	.000	.005
Business owner-Self-employed	-13.500	17.271	-.782	.434	1.000
Business owner-Unemployed	-18.321	25.907	-.707	.479	1.000
Business owner-Company employee	21.750	13.905	1.564	.118	1.000
Self-employed-Unemployed	-4.821	24.929	-.193	.847	1.000
Self-employed-Company employee	8.250	11.984	.688	.491	1.000
Unemployed-Company employee	3.429	22.727	.151	.880	1.000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .050. a Significance values have been adjusted by the Bonferroni correction for multiple tests.

Table 6.11: Pairwise Comparisons of B5 – Please indicate your status of occupation: Bottleneck reliefs

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
Student-Business owner	27.100	18.988	1.427	.154	1.000
Student-Self-employed	35.811	17.176	2.085	.037	.371
Student-Company employee	43.270	12.509	3.459	.001	.005
Student-Unemployed	69.686	28.048	2.485	.013	.130
Business owner-Self-employed	-8.711	19.833	-.439	.661	1.000
Business owner-Company employee	16.170	15.962	1.013	.311	1.000
Business owner-Unemployed	-42.586	29.749	-1.431	.152	1.000

Self-employed-Company employee	7.459	13.757	.542	.588	1.000
Self-employed-Unemployed	-33.875	28.626	-1.183	.237	1.000
Company employee-Unemployed	-26.416	26.094	-1.012	.311	1.000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .050. a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

Table 6.11: Pairwise Comparisons of B5 – Please indicate your status of occupation: Dedicated lanes for BRT systems

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
Student-Business owner	2.882	13.576	.212	.832	1.000
Student-Self-employed	10.568	12.280	.861	.389	1.000
Student-Company employee	20.953	8.951	2.341	.019	.192
Student-Unemployed	53.800	20.053	2.683	.007	.073
Business owner-Self-employed	-7.686	14.180	-.542	.588	1.000
Business owner-Company employee	18.071	11.419	1.583	.114	1.000
Business owner-Unemployed	-50.918	21.269	-2.394	.017	.167
Self-employed-Company employee	10.385	9.843	1.055	.291	1.000
Self-employed-Unemployed	-43.232	20.467	-2.112	.035	.347
Company employee-Unemployed	-32.847	18.660	-1.760	.078	.784

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .050. a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

Table 6.11: Pairwise Comparisons of B6 – Please indicate your approximate monthly net income: Public information system

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
None-Below R10 000	.283	15.387	.018	.985	1.000
None-R10 000 – R15 000	24.034	15.803	1.521	.128	1.000
None-R15 001 - R20 000	28.763	15.885	1.811	.070	1.000
None-R20 001 – R25 000	31.044	16.364	1.897	.058	.867
None-R25 001 and more	31.131	13.836	2.250	.024	.367
Below R10 000-R10 000 – R15 000	-23.751	13.163	-1.804	.071	1.000
Below R10 000-R15 001 - R20 000	-28.479	13.261	-2.148	.032	.476
Below R10 000-R20 001 – R25 000	-30.761	13.830	-2.224	.026	.392
Below R10 000-R25 001 and more	-30.848	10.721	-2.877	.004	.060
R10 000 – R15 000-R15 001 - R20 000	-4.728	13.742	-.344	.731	1.000
R10 000 – R15 000-R20 001 – R25 000	-7.010	14.292	-.490	.624	1.000
R10 000 – R15 000-R25 001 and more	-7.097	11.311	-.627	.530	1.000
R15 001 - R20 000-R20 001 – R25 000	-2.281	14.383	-.159	.874	1.000
R15 001 - R20 000-R25 001 and more	-2.369	11.424	-.207	.836	1.000
R20 001 – R25 000-R25 001 and more	-.087	12.081	-.007	.994	1.000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .050. a. Significance values have been adjusted by the Bonferroni correction for multiple tests

Table 6.11: Pairwise Comparisons of B6 – Please indicate your approximate monthly net income: <u>Bottleneck reliefs</u>

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
None-Below R10 000	4.123	17.626	.234	.815	1.000
None-R15 001 - R20 000	5.774	18.196	.317	.751	1.000
None-R10 000 – R15 000	24.455	18.014	1.358	.175	1.000
None-R25 001 and more	27.851	15.849	1.757	.079	1.000
None-R20 001 – R25 000	43.979	18.745	2.346	.019	.284
Below R10 000-R15 001 - R20 000	-1.651	15.190	-.109	.913	1.000
Below R10 000-R10 000 – R15 000	-20.331	14.971	-1.358	.174	1.000
Below R10 000-R25 001 and more	-23.728	12.281	-1.932	.053	.800
Below R10 000-R20 001 – R25 000	-39.856	15.843	-2.516	.012	.178
R15 001 - R20 000-R10 000 – R15 000	18.681	15.639	1.194	.232	1.000
R15 001 - R20 000-R25 001 and more	-22.077	13.087	-1.687	.092	1.000
R15 001 - R20 000-R20 001 – R25 000	-38.205	16.475	-2.319	.020	.306
R10 000 – R15 000-R25 001 and more	-3.396	12.832	-.265	.791	1.000
R10 000 – R15 000-R20 001 – R25 000	-19.524	16.274	-1.200	.230	1.000
R25 001 and more-R20 001 – R25 000	16.128	13.839	1.165	.244	1.000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .050. a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

Table 6.12: Pairwise Comparisons of B4 – Please indicate your educational background: <u>Planned special events traffic management</u>

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
High school/grade 12-Postgraduate (Honours, Masters and Doctoral)	-12.473	13.420	-.929	.353	1.000
High school/grade 12-Professional	-22.598	14.580	-1.550	.121	1.000
High school/grade 12-Graduate from the university/college	-35.217	12.178	-2.892	.004	.038
High school/grade 12-College or university student	-48.098	15.007	-3.205	.001	.014
Postgraduate (Honours, Masters and Doctoral)-Professional	-10.125	13.961	-.725	.468	1.000
Postgraduate (Honours, Masters and Doctoral)-Graduate from the university/college	22.745	11.430	1.990	.047	.466
Postgraduate (Honours, Masters and Doctoral)-College or university student	35.625	14.407	2.473	.013	.134
Professional-Graduate from the university/college	12.620	12.773	.988	.323	1.000
Professional-College or university student	25.500	15.493	1.646	.100	.998

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .050. a. Significance values have been adjusted by the Bonferroni correction for multiple tests

Table 6.12: Pairwise Comparisons of B4 – Please indicate your educational background: <u>Traffic signal timing and coordination</u>

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
High school/grade 12-Postgraduate (Honours, Masters and Doctoral)	-2.830	13.323	-.212	.832	1.000
High school/grade 12-Professional	-19.223	14.475	-1.328	.184	1.000
High school/grade 12-Graduate from the university/college	-26.413	12.090	-2.185	.029	.289
High school/grade 12-College or university student	-55.598	14.898	-3.732	.000	.002
Postgraduate (Honours, Masters and Doctoral)-Professional	-16.393	13.860	-1.183	.237	1.000
Postgraduate (Honours, Masters and Doctoral)-Graduate from the university/college	23.583	11.348	2.078	.038	.377
Postgraduate (Honours, Masters and Doctoral)-College or university student	52.768	14.303	3.689	.000	.002
Professional-Graduate from the university/college	7.190	12.680	.567	.571	1.000
Professional-College or university student	36.375	15.381	2.365	.018	.180
Graduate from the university/college-College or university student	29.185	13.162	2.217	.027	.266
Graduate from the university/college-College or university student	12.880	13.258	.972	.331	1.000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .050. a. Significance values have been adjusted by the Bonferroni correction for multiple tests

Table 6.12: Pairwise Comparisons of B5 – Please indicate your status of occupation: Active road management by Metro Police

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
Business owner-Company employee	10.387	14.925	.696	.486	1.000
Business owner-Self-employed	-27.200	18.548	-1.466	.143	1.000
Business owner-Student	-53.429	17.759	-3.009	.003	.026
Business owner-Unemployed	-61.200	27.822	-2.200	.028	.278
Company employee-Self-employed	-16.813	12.861	-1.307	.191	1.000
Company employee-Student	-43.042	11.693	-3.681	.000	.002
Company employee-Unemployed	-50.813	24.402	-2.082	.037	.373
Self-employed-Student	-26.229	16.063	-1.633	.103	1.000
Self-employed-Unemployed	-34.000	26.772	-1.270	.204	1.000
Student-Unemployed	7.771	26.231	.296	.767	1.000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .050. a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

Table 6.12: Pairwise Comparisons of B6 – Please indicate your approximate monthly net income: Active road management by Metro Police

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
R20 001 – R25 000-R15 001 - R20 000	8.436	15.250	.553	.580	1.000
R20 001 – R25 000-R25 001 and more	-15.012	12.795	-1.173	.241	1.000
R20 001 – R25 000-Below R10 000	23.207	14.665	1.583	.114	1.000
R20 001 – R25 000-R10 000 – R15 000	28.026	15.155	1.849	.064	.966
R20 001 – R25 000-None	-60.742	17.351	-3.501	.000	.007
R15 001 - R20 000-R25 001 and more	-6.576	12.097	-.544	.587	1.000
R15 001 - R20 000-Below R10 000	14.771	14.061	1.051	.293	1.000
R15 001 - R20 000-R10 000 – R15 000	19.589	14.571	1.344	.179	1.000
R15 001 - R20 000-None	-52.306	16.843	-3.105	.002	.029
R25 001 and more-Below R10 000	8.195	11.350	.722	.470	1.000
R25 001 and more-R10 000 – R15 000	13.014	11.977	1.087	.277	1.000
R25 001 and more-None	-45.730	14.657	-3.120	.002	.027

Below R10 000-R10 000 – R15 000	-4.819	13.957	-.345	.730	1.000
Below R10 000-None	-37.535	16.315	-2.301	.021	.321
R10 000 – R15 000-None	-32.716	16.757	-1.952	.051	.763

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .050.

a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

Table 6.18: Pairwise Comparisons of B4 – Please indicate your status of occupation: Increased in vehicle ownership

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
Unemployed-Company employee	20.571	15.885	1.295	.195	1.000
Unemployed-Self-employed	28.929	17.425	1.660	.097	.969
Unemployed-Business owner	38.571	18.108	2.130	.033	.332
Unemployed-Student	-38.571	17.073	-2.259	.024	.239
Company employee-Self-employed	-8.357	8.377	-.998	.318	1.000
Company employee-Business owner	-18.000	9.719	-1.852	.064	.640
Company employee-Student	-18.000	7.617	-2.363	.018	.181
Self-employed-Business owner	9.643	12.072	.799	.424	1.000
Self-employed-Student	-9.643	10.455	-.922	.356	1.000
Business owner-Student	.000	11.558	.000	1.000	1.000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .050. a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

Table 6.18: Pairwise Comparisons of B5 – Please indicate your status of occupation: <u>Growth of population in the area</u>

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
Unemployed-Business owner	31.939	11.239	2.842	.004	.045
Unemployed-Self-employed	33.875	10.814	3.132	.002	.017
Unemployed-Company employee	34.223	9.858	3.472	.001	.005
Unemployed-Student	-38.714	10.596	-3.654	.000	.003
Business owner-Self-employed	-1.936	7.492	-.258	.796	1.000
Business owner-Company employee	2.283	6.030	.379	.705	1.000
Business owner-Student	-6.775	7.173	-.944	.345	1.000
Self-employed-Company employee	.348	5.197	.067	.947	1.000
Self-employed-Student	-4.839	6.489	-.746	.456	1.000
Company employee-Student	-4.492	4.725	-.951	.342	1.000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .050. a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

Table 6.18: Pairwise Comparisons of B6 – Please indicate your approximate monthly net income: <u>New development in the area.</u>

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.[a]
R20 001 – R25 000-None	-5.128	7.439	-.689	.491	1.000
R20 001 – R25 000-R10 000 – R15 000	10.276	6.459	1.591	.112	1.000
R20 001 – R25 000-Below R10 000	10.950	6.319	1.733	.083	1.000
R20 001 – R25 000-R15 001 - R20 000	13.619	6.539	2.083	.037	.559
R20 001 – R25 000-R25 001 and more	-17.355	5.486	-3.164	.002	.023
None-R10 000 – R15 000	5.148	7.149	.720	.471	1.000
None-Below R10 000	5.823	7.023	.829	.407	1.000
None-R15 001 - R20 000	8.491	7.222	1.176	.240	1.000
None-R25 001 and more	12.227	6.284	1.946	.052	.775
R10 000 – R15 000-Below R10 000	.674	5.975	.113	.910	1.000
R10 000 – R15 000-R15 001 - R20 000	-3.343	6.207	-.539	.590	1.000
R10 000 – R15 000-R25 001 and more	-7.079	5.085	-1.392	.164	1.000
Below R10 000-R15 001 - R20 000	-2.669	6.061	-.440	.660	1.000
Below R10 000-R25 001 and more	-6.405	4.907	-1.305	.192	1.000
R15 001 - R20 000-R25 001 and more	-3.736	5.187	-.720	.471	1.000

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .050. a. Significance values have been adjusted by the Bonferroni correction for multiple tests.

APPENDIX G:
PROFESSIONAL EDITING CERTIFICATE

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Independent Skills Development Facilitator

Dear Ms Netshisaulu

This letter is to record that I have completed a language edit of your dissertation entitled, "Managing road traffic congestion on Allandale Road (M39) in Midrand, South Africa".

The edit that I carried out included the following:

-Spelling	-Grammar
-Vocabulary	-Punctuation
-Pronoun matches	-Word usage
-Sentence structure	-Correct acronyms (matching your supplied list)

-Captions and labels for figures and tables
-Spot checking of 10 references

The edit that I carried out excluded the following:

-Content
-Correctness or truth of information (unless obvious)
-Correctness/spelling of specific technical terms and words (unless obvious)
-Correctness/spelling of unfamiliar names and proper nouns (unless obvious)
-Correctness of specific formulae or symbols, or illustrations

Yours sincerely

Retha Burger

1 September 2022