

**AN EVALUATION OF INTELLIGENT TRANSPORT
SYSTEM: A CASE STUDY OF THE BUS RAPID
TRANSIT (BRT) REA-VAYA IN JOHANNESBURG,
SOUTH AFRICA**

BY:

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UNIVERSITY OF VENDA

2017

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**THIS DISSERTATION IS SUBMITTED IN PARTIAL FULFILMENT OF THE
REQUIREMENTS FOR THE AWARD OF MASTERS IN URBAN AND REGIONAL
PLANNING DEGREE TO THE DEPARTMENT OF URBAN AND REGIONAL
PLANNING, SCHOOL OF ENVIRONMENTAL SCIENCES, UNIVERSITY OF VENDA,
THOHOYANDOU, SOUTH AFRICA.**

2017

DECLARATION

I, **Khwathisi Ntsieni Colin**, student number **11602110** hereby declare that this dissertation for Masters of Urban and Regional Planning at the University of Venda is submitted by me and has not been previously submitted for a degree at this or any other University and it is my own work. All reference materials contained in this research have been duly acknowledged.

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DEDICATION

This dissertation is dedicated to the Lord God, who has given me the strength to complete this study in record time. I also dedicate this mini dissertation to my mother, father, lecturers, friends and family for the support they have given me in my entire life and for giving me hope for a better future.

ACKNOWLEDGEMENT

I highly appreciate the dedication of Dr. James Chakwizira and Professor Bikam Peter who gave me their full attention, guidance, expertise, intuitive criticism and keenness. It is due to their dedication that this dissertation became a success.

I would also like to express my uttermost gratitude and appreciation to the Department of Urban and Regional Planning at University of Venda whose staff members supported me in areas that I needed assistance.

My profound gratefulness also goes to my mother, Mudau Cecilia and Father, Khwathisi Godfrey. I am product of your unconditional love and support. Many thanks to my friends and siblings for their loyal support.

ABSTRACT

This study focuses on the evaluation of intelligent transport systems making use of the BRT-Rea-vaya in Johannesburg as a case study. This study was motivated by the observation that few studies have been conducted in the study area that tackle explicitly intelligent transport systems evaluation. Intelligent transport systems can assist in improving private and public transportation systems and operations performance. In the public sector where various modes of transport such as the taxi, metro bus, metro rail, Gautrain and the BRT Rea-vaya operates, intelligent transport systems present opportunities for improving Level of Service (LOS) delivery. In Johannesburg, the BRT Rea vaya system was adopted by the Johannesburg metropolitan municipality to provide a safe, reliable, efficient and accessible public transport system. The BRT Rea vaya system is aimed at providing a better public transport, operating systems and service. For the BRT Rea vaya systems to achieve its primary goals and objectives, an intelligent transport system was incorporated to better manage the BRT Rea-vaya systems operations and activities. The study disclosed the status quo, opinions and attitudes of commuters regarding their experiences with the BRT Rea vaya public transport systems in Johannesburg. Furthermore, the study investigated whether the original objectives and aims of intelligent transport system in the BRT Rea-vaya have been meet. A central theme of the investigation is seeking to understand constraints and opportunities regarding BRT Rea-vaya intelligent transport systems' operations and activities in Johannesburg. The use of primary and secondary data such as questionnaires, key informant interviews, observation, journals and previous researches related to intelligent transport systems were used to acquire an in-depth understanding of the operational management of BRT Rea-vaya intelligent transport system. Collected data was analyzed using Statistical Package for Social Sciences (SPSS) with the aid of Microsoft Excel making use of descriptive statistics, regression analysis, cross tabulation and chi-square test. This was presented using tables, graphs, maps etc. Qualitative data was analyzed making use of a thematic approach. The study resonates in the need for rapid public transport systems to provide lessons for improving and adopting intelligent transport systems. As an end product, the research provided a framework of analysis on how to integrate intelligent transport systems in the context of Bus rapid transit systems.

Key words: Intelligent transport systems, Operations, Sustainable transport, Traffic flow, Public transport

ACRONYMS AND ABBREVIATIONS

ADAS	Advance Driver Assistance System
AFC	Automatic Fare Collection system
AFPS	Automated Fare Payment System
APC	Automatic Passenger Counter
APTMS	Advanced Public Transport Management System
APTA	American Public Transportation Association
AVL	Automatic Vehicle Location
BRT	Bus Rapid Transit
BSD	Bus Driver
CACS	Comprehensive Automobile Control System
CAD	Computer Aided Dispatch
CAS	Collision Avoidance System
CCTV	Closed Circuit Television
CITS	Cooperative Intelligent Transport Systems
COJMM	City of Johannesburg Metropolitan Municipality
DOT	Department of Transport
DRT	Demand Responsive Transit
ETM	Electronic Toll management
ETC	Electronic Toll Collection
FNB	First National Bank
GITMP	Gauteng Integrated Transport Master Plan

GNSS	Global Navigation Satellite System
GPS	Global Position system
JCTSL	Jaipur City Transport Service Limited
JHB	Johannesburg
HOV	Heavy Occupancy Vehicles
IBL	Intermittent Bus Lane
IBM	International Business Machines
IDP	Integrated Development Plan
IT	Information Technology
ITDP	Institute for Transport and Development Policy
ITMP	Integrated Transport Master Plan
ITMS	Integrated Transport Management System
ITP	Integrated Transport Plan
ITS	Intelligent Transport system
INGS	In-vehicle Navigation and Route Guidance System
IVMS	Intelligent Vehicle Highway System
LOS	Level of Service
MBL	Moving Bus Lane
MDT	Mobile Data Terminals
MITI	Ministry of International Trade and Industry
NCMC	National Common Mobility Card
NLTFSF	National Land Transport Strategic Framework

NMT	Non-Motorized Transport
NTMP	National Transport Master Plan
OCP	Optimal Control Problems
PDM	Passenger Demand Model
PLTF	Provincial Land Transport Framework
PTM	Parking Ticket Management
PM	Particulate Matter
RSDf	Regional spatial development Framework
SANRAL	South African National Road Agency
SDF	Spatial Development Framework
SPSS	Statistical Package for Social Science
TMC	Traffic Management Center
TLP	Traffic Light Priority
TSP	Transit Signal Priority
UIT	Infrastructure and Technology Services
UJ	University of Johannesburg
USA	United States of America
VMS	Variable Message Sign

TABLE OF CONTENT

TITLE	PAGE
DECLARATION	i
DEDICATION	ii
ACKNOWLEDGEMENT	iii
ABSTRACT	iv
ACRONYMS AND ABBREVIATIONS	v
LIST OF FIGURES	xvi
LIST OF TABLES	xviii
LIST OF PLATES	xxi
LIST OF APPENDICES	xxii
1. CHAPTER ONE: INTRODUCTION AND BACKGROUND OF THE STUDY	1
1.1. Introduction	1
1.2. Research background	3
1.2.1. Transport demand	4
1.2.2. Status of intelligent transport system in Johannesburg	6
1.3. Statement of research problem	6
1.4. The aim and objectives of the research	8
1.4.1. Aim of the research	8
1.4.2. Specific objectives of the research	8
1.5. Research questions	8
1.6. Scope of the research	10
1.6.1. Geographical scope	10
1.6.2. Contextual scope	10
1.7. Significance of the research	10
1.8. Limitations of the study	10
1.9. Definition of terms	11
1.10. Chapter summary	12
2. CHAPTER TWO: RESEARCH METHODOLOGY	13
2.1. Introduction	13

2.2. The notion of intelligent transport systems.....	14
2.3. The gap analysis survey of intelligent transport system.....	14
2.4. Data collection methods.....	14
2.4.1. Primary data collection.....	14
2.4.1.1. Key Informant Interviews (KII).....	15
2.4.1.1.1. ITS operations manager within Rea-vaya.....	15
2.4.1.1.2. Fleet manager within Rea-vaya.....	15
2.4.1.1.3. Station controllers.....	15
2.4.1.2. Observation.....	16
2.4.1.3. Sampling frame.....	17
2.4.1.3.1. Sampling Techniques.....	17
2.4.1.3.2. Non-probability sampling techniques.....	17
2.4.1.3.2.1. Purposive sampling technique used to select KII.....	17
2.4.1.3.2.2. Expect sampling technique.....	17
2.4.1.3.3. Probability sampling techniques.....	17
2.4.1.3.3.1. Administration of questionnaires to commuters.....	18
2.4.1.4. Sampling size.....	18
2.4.1.5. Systematic random sampling.....	18
2.4.2. Secondary data collection.....	19
2.4.2.1. Literature review.....	20
2.4.2.1.1. Major books consulted.....	20
2.4.2.1.2. Relevant Journals.....	20
2.4.2.1.3. Official documents.....	20
2.4.2.1.4. Integrated transport legislation.....	21
2.4.2.1.5. The use of maps.....	21
2.5. Research design matrix.....	22
2.6. Data analysis method.....	23
2.6.1. Quantitative data analysis.....	23
2.6.2. Qualitative data analysis.....	23
2.6.3. The use of table, graphs.....	23
2.6.3.1. Tables.....	23
2.6.3.2. Graphs.....	24
2.6.3.3. Photographs.....	24
2.7. Chapter Summary.....	24

3. CHAPTER THREE: LITERATURE REVIEW	25
3.1. Introduction.....	25
3.2. Conceptual framework.....	25
3.3. The concept of intelligent transport systems.....	26
3.4. Theories of intelligent transport systems.....	28
3.4.1. The operational theory.....	28
3.4.2. The optimal control theory.....	29
3.4.3. The queuing theory.....	29
3.5. Evolution of ITS development.....	30
3.6. Intelligent Transport system architecture.....	30
3.6.1. Components of ITS architecture.....	33
3.6.1.1. User Services.....	33
3.6.1.2. Entities.....	33
3.6.1.3. Information and Data Flows.....	33
3.6.2. Characteristics of the architecture of ITS.....	34
3.6.2.1. Compatibility.....	34
3.6.2.2. Expandability.....	34
3.6.2.3. Interoperability.....	34
3.6.2.4. Integration.....	35
3.6.2.5. Standards.....	35
3.7. Objectives of a functional intelligent transport system.....	36
3.7.1. Safety.....	36
3.7.2. Improved mobility.....	37
3.7.3. Efficiency.....	37
3.7.4. Productivity.....	37
3.7.5. Customer satisfaction.....	37
3.8. Functional areas for intelligent transport systems.....	37
3.8.1. Vehicle control systems.....	38
3.8.2. Traffic and network management systems.....	38
3.8.3. Real-time and near time information for travellers.....	38
3.8.4. Supply chain and fleet management systems.....	39
3.8.5. Charging and payment systems.....	39
3.8.6. Infrastructure planning and development.....	39
3.8.7. Network monitoring.....	39

3.9. Advanced public transport management systems.....	40
3.9.1. ITS for the operator.....	40
3.9.1.1. Automatic vehicle location.....	40
3.9.1.2. Transit signal priority.....	41
3.9.1.3. Automatic passenger counting.....	42
3.9.1.4. Computer-aided dispatch.....	42
3.9.1.5. Lane control technologies.....	42
3.9.2. ITS for the customer.....	43
3.9.2.1. Real-time passenger information.....	43
3.9.2.2. Passenger Wi-Fi.....	44
3.9.2.3. Fare collection.....	44
3.9.2.4. Surveillance/CCTV/security systems.....	45
3.9.3. ITS for vehicle.....	46
3.9.3.1. Fleet management.....	47
3.9.3.2. Collision avoidance systems.....	47
3.9.3.3. Lane guidance.....	48
3.10. Case studies of ITS in developed and developing countries.....	51
3.10.1. Experiences of ITS in developed countries.....	51
3.10.1.1. Public Transport Payment – Oystercard.....	51
3.10.1.2. AVLS and AFCS Integration into the Ahmedabad BRTS.....	52
3.10.2. Experience of ITS in developing countries.....	52
3.10.2.1. Dartford: Intelligent public transport.....	53
3.10.2.2. Jaipur (ATPS).....	53
3.11. Emerging models for application of ITS in Bus Rapid Transport.....	54
3.11.1. Info-mobility model.....	54
3.11.2. Passenger demand model.....	55
3.11.3. Smart mobility.....	55
3.12. Chapter summary.....	57
4. CHAPTER 4: THE CASE STUDY AREA.....	58
4.1. Introduction.....	58
4.2. Johannesburg transport situation.....	60
4.3. The Johannesburg BRT (Rea-vaya).....	61
4.4. Policy perspective on intelligent transport systems.....	62
4.4.1. National transportation policies.....	63

4.4.1.1.	National Land Transport Strategic Framework.....	63
4.4.1.2.	National Transport Master Plan.....	63
4.4.1.3.	National Road Transport Act.....	63
4.4.2.	Provincial transportation policies.....	64
4.4.2.1.	Provincial Land Transport Frameworks.....	64
4.4.2.2.	Gauteng integrated transport master plan.....	64
4.4.2.3.	Gauteng Public Passenger Road Transport Act (No 7 of 2001).....	64
4.4.2.4.	The Gauteng transportation infrastructure act, no 8 of 200).....	65
4.5.	Field observations of BRT Rea-vaya facilities.....	65
4.5.1.	The BRT basics.....	65
4.5.1.1.	Dedicated right of way.....	65
4.5.1.2.	Bus-way alignment.....	66
4.5.1.3.	Off-board fare collection.....	67
4.5.1.4.	Intersection treatment.....	68
4.5.1.5.	Platform level boarding.....	69
4.5.2.	Service planning.....	70
4.5.2.1.	Multiple routes.....	70
4.5.2.2.	Express, limited and local services.....	70
4.5.2.3.	Control centre.....	71
4.5.2.4.	Hours of operations.....	71
4.5.3.	Infrastructure.....	72
4.5.3.1.	Passing lanes at the stations.....	72
4.5.3.2.	Minimising Bus emissions.....	73
4.5.3.3.	Station set back from the intersection.....	73
4.5.3.4.	Centre stations.....	74
4.5.4.	Stations.....	74
4.5.4.1.	Distance between the stations.....	75
4.5.4.2.	Safe and comfortable stations.....	75
4.5.4.3.	% of buses with 3+ or 2 doors station side.....	75
4.5.5.	Communication.....	77

4.5.5.1. Branding.....	78
4.5.5.2. Passenger information.....	78
4.5.6. Access and integration.....	80
4.5.6.1. Universal access.....	80
4.5.6.2. Integration with other public transport.....	81
4.5.6.3. Pedestrian access.....	81
4.5.7. Point deduction.....	82
4.5.7.1. Commercial speeds.....	82
4.5.7.2. Lack enforcement of right-of-way.....	82
4.5.7.3. Overcrowding	82
4.5.7.4. Maintenance.....	83
4.5.7.5. Low peak frequency.	84
4.5.8. Summary of the BRT Rea-vaya point calculation.....	85
4.6. Chapter summary.....	87

5. CHAPTER 5: DATA ANALYSIS, INTERPRETATION AND PRESENTATION OF RESEARCH FINDINGS 88

5.0. Introduction.....	89
5.1. Socio-economic status of commuters.....	89
5.1.1. Gender profile.....	89
5.1.2. Age profile.....	90
5.1.3. Employment status of respondents.....	91
5.1.4. Educational profile of respondents.....	91
5.1.5. Income level.....	92
5.1.1. Respondents place of origin and destination.....	93
5.1.2. Average origin and destination distance of commuters.....	95
5.1.3. Why respondents choose Rea-Vaya systems in terms of other modes of transport.....	96
5.1.4. Respondents preferred routes.....	97
5.1.5. Availability of commuter pre-trip information to commuters.....	99
5.1.5.1. En-route driver information to commuters.....	99
5.1.5.2. Route guidance to commuters	100
5.1.5.3. Ride matching and reservation available to commuters	101
5.1.5.4. Integrated electronic payment system available to commuters.....	102
5.1.6. Commuter's perception of ITS in managing the Rea-vaya.	103

5.1.6.1. Commuter perception of safety with the ITS.....	103
5.1.6.2. Commuter perception of productivity with the ITS.....	105
5.1.6.3. Commuter perception of efficiency with the ITS.....	106
5.1.6.4. Commuter perception of the use of ITS to ensure comfort.....	107
5.1.6.5. Commuter perception of reliability of ITS.....	108
5.1.6.6. Respondents general perception overall the ITS systems.....	109
5.1.7. Travel and traffic management of Rea-vaya in Johannesburg.....	110
5.1.7.1. Emergency management of Rea-vaya with (ITS).....	110
5.1.7.2. Integration of ITS to safety.....	111
5.1.7.3. Mobility advantages of ITS.....	113
5.1.7.4. Traffic control measures into the ITS.....	114
5.1.7.5. Incident management with the use of ITS.....	115
5.1.8. Key-informant interview.....	116
5.1.8.1. Position of key-informants.....	116
5.1.8.2. ITS infrastructure available in the operations and management.....	116
5.1.8.3. Effectiveness and efficiency of ITS in managing and operating the BRT...117	
5.1.8.4. Measure of effectiveness and efficiency of ITS in management and operations.....	118
5.1.8.5. Benefits of managing and operating BRT Rea-vaya ITS.....	119
5.1.8.6. Challenges of managing and operating the BRT Rea-Vaya through ITS.....	120
5.1.8.7. Extent to which traffic congestion is reduced in routes managed by ITS.....	121
5.1.8.8. Partnership with private sector regarding ITS management of Rea-vaya.....	122
5.1.8.9. Proposed future projects for ITS infrastructure for managing the BRT Rea-vaya.....	123
5.1.8.10. Conflict management between BRT Rea-Vaya and Taxi industry.....	123
5.2. Statistical data presentation and analysis.....	125
5.2.1. Measurement scale analysis.....	125
5.2.1.1. Reliability analysis: Estimating internal consistency.....	125
5.2.2. Regression analysis.....	127
5.2.2.1. Regression analysis: summary for influence of occupation status on the purpose of using BRT.....	127

5.2.2.2. Regression analysis: summary for influence of how purpose of travel affects commuter’s willingness to travel	129
5.2.2.3. Regression analysis: summary of how time of travel is influence by distance between place of residence and occupation.....	131
5.2.2.4. Regression analysis: summary of how purpose of travel influence the time commuters are willing to wait at bus stations.....	132
5.2.2.5. Regression analysis: summary of how commuter’s access information influences the type of information commuters will access.	132
5.3. Cross-tabulation and chi-square test	136
5.3.1. Cross tabulation and Chi-square test for the relationship between distanced travelled and time it takes.....	136
5.3.2. Cross tabulation and Chi-square test for the relation of gender on the waiting period of commuters at station.....	137
5.3.3. Cross tabulation and Chi-square test for the relation of how commuter gets information and the extent to which they are updated on traffic conditions.....	139
5.4. Chapter summary.....	140
6. CHAPTER SIX: SUMMARY OF FINDIDNGS AND RECCOMENDATIONS	141
6.1. Introduction.	141
6.2. Summary of the study.....	142
6.3. Summary of research findings.....	142
6.4. Recommendations.	144
6.4.1. Creating an integrated public transport system.....	145
6.4.2. Extension of the BRT Rea-vaya network.....	145
6.4.3. Improve public relation and marketing.....	146
6.4.4. Upgrading of intelligent transport systems.....	146
6.4.5. Training and re-training of staff on intelligent transport system.	146
6.4.6. Promote trans-oriented development	147
6.5. Areas for future research.....	147
6.6. Chapter summary.....	148
Reference list	149

LIST OF FIGURES

TITLE	PAGE
Figure 1.1 Integrated transportation networks for Johannesburg	4
Figure 1.2 Capacity of public transport during peak hours in city of Johannesburg	5
Figure 2.1 Structure of chapter two	13
Figure 3.1 Conceptual framework	26
Figure 3.2 ITS information chain	27
Figure 3.3 Theory of Routine Mode Choice Decisions	29
Figure 3.4 History of ITS developments	32
Figure 3.5 USA ITS architecture	36
Figure 3.5 VMS with real time passenger information	44
Figure 3.6 CCTV cameras for surveillance	46
Figure 3.7 Info-mobility model	55
Figure 3.8 Smart mobility and ITS framework	57
Figure 4.1 Structure of chapter four	58
Figure 4.2 City of Johannesburg	59
Figure 4.3 Rea-vaya BRT route in the city of Johannesburg	63
Figure 4.4 BRT Rea-vaya achieved points against BRT standard 2014	66
Figure 5.1 Conceptual structure of data analysis and presentation	88
Figure 5.2 Gender of respondents	89
Figure 5.3 Age of respondents	90
Figure 5.4 Employment status of respondents	91
Figure 5.5 Educational levels of the respondents	92
Figure 5.6 Commuters total monthly income levels	92
Figure 5.7 Origin and destination connectivity map	94
Figure 5.8 Commuters preferred routes	98

Figure 5.9	Spatial analysis of perception of safety with ITS	104
Figure 5.10	Integration of ITS of safety	112
Figure 5.11	Effectiveness and efficiency of ITS in management and operation	118
Figure 5.12	Scale of effectiveness and efficiency	118
Figure 5.13	Extent of reduced traffic congestion through ITS	121
Figure 5.14	Partnership with private sector on managing BRT Rea-vaya through ITS	122
Figure 5.15	Proposed projects for upgrading of ITS	123
Figure 6.1	Conceptual framework of chapter six	141

LIST OF TABLES

TITLE	PAGE	
Table 1.1	City of Johannesburg population growths	3
Table 2.1	BRT Rea-vaya achieved point	16
Table 2.2	Margin of error/level of significance	18
Table 2.3	Distribution of questionnaires along routes	19
Table 2.4	Goal achievement matrix table	22
Table 5.1	Place of origin and destination	93
Table 5.2	Average origin and destination distance of commuters	95
Table 5.3	Reason for selecting BRT Rea-vaya	96
Table 5.4	Preferred routes	97
Table 5.5	En- route driver information to commuters	99
Table 5.6	Route guidance to commuters	100
Table 5.7	Ride matching and reservation available to commuters	101
Table 5.8	Integrated electronic payment system	102
Table 5.9	Commuter perception of safety with the ITS	103
Table 5.10	Commuter perception of productivity with the ITS	105
Table 5.11	Commuter perception of efficiency with the ITS	106
Table 5.12	Commuter perception of the use of ITS to ensure comfort	107
Table 5.13	Commuter perception of reliability of ITS	108
Table 5.14	General perception of the overall ITS system	109
Table 5.15	Emergency management of Rea-vaya with (ITS)	110
Table 5.16	Integration of ITS to safety	111

Table 5.17	Mobility advantages of ITS	113
Table 5.18	Traffic control measures into the ITS	114
Table 5.19	Incident management with the use of ITS	115
Table 5.20	Positions of key-informants in the BRT Rea-Vaya management	116
Table 5.21	Intelligent transport systems infrastructure	117
Table 5.22	Benefits of managing and operating BRT Rea-vaya using ITS	119
Table 5.23	Challenges of managing and operating BRT Rea-vaya using ITS	120
Table 5.24	Cronbach's Alpha Reliability results: BRT Rea-vaya commuters	126
Table 5.25	Cronbach's Alpha Reliability results: BRT Rea-vaya management	127
Table 5.25	Model for influence of occupation status on the purpose of using BRT for	128
Table 5.27	ANOVA test for influence of occupation status on using BRT	128
Table 5.28	Coefficients for influence of occupational status on using BRT	128
Table 5.29	Model summary for the influence of the purpose of travel on commuter willingness to travel	129
Table 5.30	ANOVA test for influence of purpose of travel on commuter willingness to travel	130
Table 5.31	Coefficients for influence of purpose of travel on commuter willingness to travel	130
Table 5.32	Model summary for the influence of distance between place of residence and occupation on time of travel	131
Table 5.33	ANOVA test results for the influence of distance between place of residence and occupation on time of travel	131
Table 5.34	Coefficients for influence of distance between place of residence and occupation on time of travel	132

Table 5.35	Model summary for the influence of purpose of travel on the time commuters are willing to wait at the bus station	133
Table 5.36	ANOVA test results for the influence of purpose of travel on the time commuters are willing to wait at bus station	133
Table 5.37	Coefficients for influence of purpose of travel on the time commuters are willing to wait at bus station	133
Table 5.38	Model summary for the influence of how commuter's access information influences the type of information commuters will access	134
Table 5.39	ANOVA test results for the influence of how commuter's access information influences the type of information commuters will access	135
Table 5.40	Coefficients for influence of how commuter's access Information influences the type of information commuters will access	135
Table 5.41	Cross tabulation between distance from place of residence to occupation and time it takes from place of residence to place of occupation	136
Table 5.42	Chi-square test for distance from place of residence to occupation and time it takes from place of residence to place of occupation	137
Table 5.43	Cross tabulation between the gender of commuters and the waiting period of commuters at station	137
Table 5.44	Chi-square test for the relationship between the gender of commuters and the waiting period of commuters at station	138
Table 5.45	Cross tabulation between the extents of update on traffic conditions and how commuters get information about their journey	138
Table 5.46	Chi-square test for the extent to which commuters are updated on traffic condition and how they get the information	139

LIST OF PLATES

TITLE	PAGE
Plate 4.1 BRT Rea-Vaya Dedicated-lanes	66
Plate 4.2 Two-way median-aligned bus ways	67
Plate 4.3 An off-line turnstile	68
Plate 4.4 Bus priority signal	69
Plate 4.5 Boarding bridge	69
Plate 4.6 Passing lane	73
Plate 4.7 Centre station	74
Plate 4.8 Safe and comfortable BRT Rea-vaya station	76
Plate 4.9 BRT Rea-vaya bus doors	77
Plate 4.10 Rea-Vaya Bradding	78
Plate 4.11 Variable message sign	79
Plate 4.12 Elevated ramp for universal access	80
Plate 4.13 Encroachment on BRT Rea-Vaya dedicated lanes	83
Plate 4.14 Out of service ticket vending machine	84

LIST OF APPENDICES

TITLE	PAGE
Appendix A: Questionnaire for commuters	158
Appendix B: Questionnaire for BRT Rea-vaya management	162
Appendix C: BRT facilities observational checklist	166
Appendix D: BRT Rea-vaya Route map	176
Appendix E: Ethical Clearance	177
Appendix F: Request for permission to conduct research	178
Appendix G: BRT Rea-vaya permission to conduct research	189
Appendix H: Turn it in originality report	180
Appendix H: Letter of language editor	181

1.1. Introduction.

According to Beer et al. (2005:28), transportation is the driving force behind economic development worldwide. Newman (1999:132) explained that as standard of living increases, there is an even more demand for transportation capital and transportation infrastructure. He further argues that transport infrastructure can be a powerful catalyst, providing the building blocks for development that ensure growth, easy communication and flexibility in commuting. Behrens (2002:42) suggested that the capital required in making a transition to improved transportation and flexibility in travel time i.e. origin and destination journey is investing in mass transit and smart management. This explains why transportation planners are turning to Intelligent Transportation Systems (ITS) as a means of ensuring efficiency and/or productivity out of a given transportation investment. This ensures a smooth and coherent transport system that guarantees free and flexible movement for commuters such as the Intelligent Transport Network.

According to Piaro (2004:14-15), Intelligent Transportation Systems is a system that ensures “the collection, processing, integration and supply of information through the application of computer, control and communications technologies to enable transportation planners, operators and individual customers to make informed, i.e. “intelligent” transport decisions”. In reference to this observation, Andersen (2013:38) claimed that the overarching function of ITS is to improve the operations of transport systems to support the general transport objectives of mobility, safety, reliability, effectiveness, efficiency and environmental quality.

The merits of intelligent transport systems have been proven worldwide and as a developing country, South Africa has numerous transport related problems that are ideal candidates for intelligent transport systems solutions (Steven, 2004:88-93). With many road networks reaching capacity with little space to build more roads, concerted efforts are being made to improve the efficiency of existing infrastructure (Booyes et al., 2013:12).

According to De Jongh and Venter (2005:69), the ever-increasing demand for limited road space requires innovative measures to maximize the use of existing road infrastructure and transportation management demand more proactive planners. Pen (2002:234) argued that intelligent transport systems does not create new capacity, but rather makes more effective use of existing capacity. It encourages one to travel at more appropriate times, along better selected routes by using more efficient modes of transport.

The use of intelligent transport systems can aid planners and other professionals to improve the efficiency of the transport system (Mathew, 2010:98). This results in less frustration, less

delay, less pollution, fewer accidents and most importantly, improved road capacity because intelligent transport systems enable smarter travel. However, with a wide variety of intelligent transport systems designed to solve specific transportation challenges, it is a daunting challenge to identify the correct ITS systems for a specific transportation problem (Pearson, Black & Wanat, 2001:129).

Transport is widely accepted as a sector which provides high returns, both economically and socially, for the development of a country (Copley, 2010:25). Currently, the City of Johannesburg is characterized by a lack of user friendly, cost effective and integrated transportation systems. The unnecessarily high costs of living are a burden, especially on the most economically and geographically vulnerable residents of the region. To minimize the negative impact associated with disintegrated transport infrastructure, intelligent transport system has been implemented to improve the efficiency of transport infrastructure. In view of the positive components of ITS in ensuring mobility, safety, reliability, effectiveness and efficiency as a prelude to integrated transport, the need for ITS is becoming more and more important (Copley, 2010:25).

The introduction of the Johannesburg BRT Rea-vaya in 2009 was aimed at providing a world class urban public transport system. The system would cater for the needs of tourists that were coming to watch the FIFA world cup tournament. The major component of a world class urban public transport has been efficient and reliable, because they are supported by an intelligent transport system.

This study evaluates whether the implementation of the ITS has improved efficiency with respect to safety, reliability and mobility component in the city of Johannesburg where not less than 4.434.872 million people commute to and from work every day. The study is by no means intended to determine the rate of efficiency of ITS in Johannesburg on all modes of transport in the city. The study is limited to determining how ITS has assisted the Rea-vaya (BRT) to achieve efficiency.

1.2. Research background.

According to Statistics South Africa, the population of the City of Johannesburg is approximately 4.434.872 million people (StatsSa.org, 2011) and like many major cities, Johannesburg experiences traffic congestion, pollution and overcrowding. Recent studies have shown that Johannesburg's population is increasing by about 2 percent a year. An increase in population will result in an increase in urban problems pertaining to traffic, pollution and overpopulation (Mabena, 2010:09-13). Table 1.1 shows the population growth of the City of Johannesburg from 1996 to 2011.

Table 1.1. City of Johannesburg population growth

Year	1996-1999	2000-2003	2004-2007	2008-2011
Population growth	2 376 879- 2 680 310	2 680 310 - 2 989 400	3 209 000- 3 970 892	3 970 892- 4 434 872
Transport demand For public transport	2278945	3290328	3379702	4430482
Transport offer for public transport	1107267	2216210	2239440	3376160

Source (Zack et al., 2013:34)

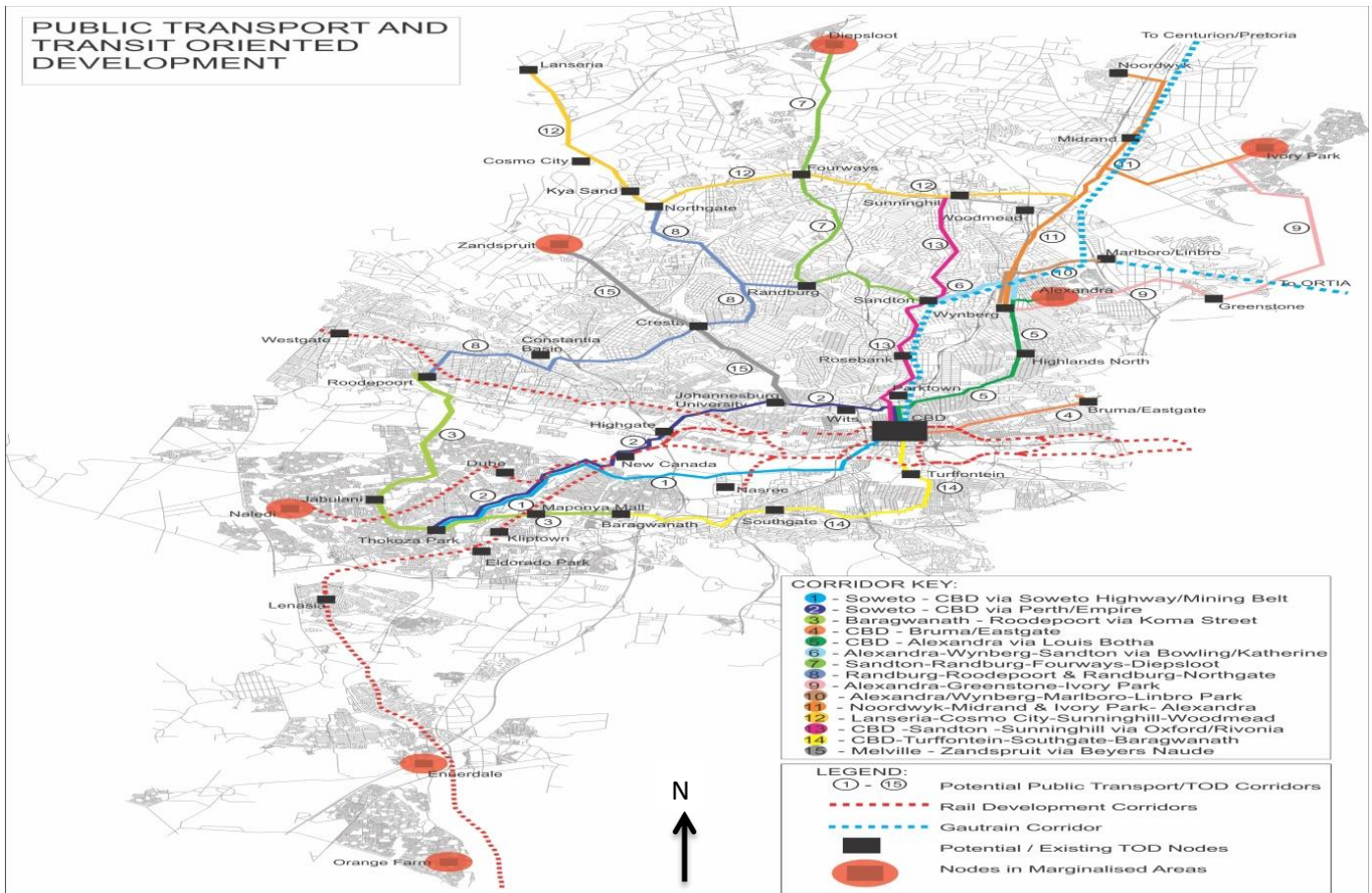
From table 1.1.

It is evident that the City of Johannesburg is not meeting the demands of commuters with respect to public transport as the supply is always insufficient for the growing population of the city.

A transportation system is a significant structuring element of the City. The Integrated Transport Plan (ITP) of the CoJMM (2013) focuses on three main elements of land transportation, of which two, namely public and private transportation mainly influence the development of Johannesburg. As demonstrated in the CoJMM ITP, the predominant modes of transport used by Johannesburg residents to commute from home to work are the private motor-vehicle (42.2%) and minibus-taxi (34.6%). Other modes of transport used by Johannesburg residents, excluding walking, include the train (8.2%) and bus (4.4%) (COJMM, 2013:47).

The minibus-taxis account for 75% of the public transport system in Johannesburg City. The demand for daily work related to commuting is 42.8% of the total population of Johannesburg (Tracey et al., 2013:67). Demand for excess public transport offers 16% and this obliges many people to use private vehicles for journeys to work on a daily basis. The local authorities came out with several strategies to ease transportation in the city including integrated network plan as illustrated in figure 1.1.

Figure 1.1 Integrated transportation networks in Johannesburg City



Source CoJMM (2013:11)

Note: Map not drawn to scale

The network plan is aimed at integrating all the transport network systems to the benefit of commuters, but more especially to provide a flexible and multi-modal approach to transportation in the City of Johannesburg.

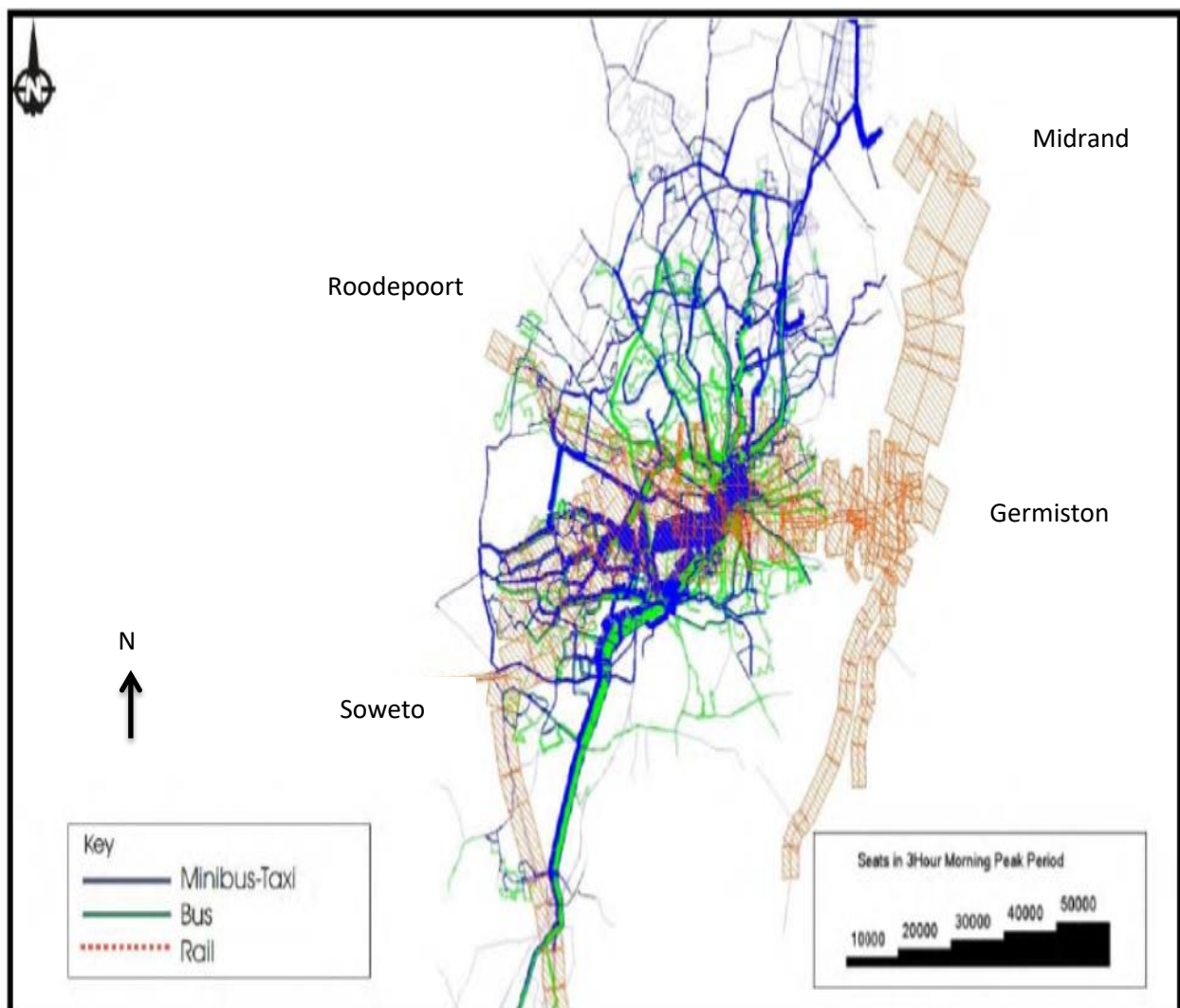
1.2.1. Transport demand

According to the City of Johannesburg Spatial Development Framework report (2015/2016), 58% of the total population lives in townships settlements. Settlements like Soweto, Diespkloof, Klipstruit and Alexandra are from areas of economic opportunities. The dominant public transport mode in the City of Johannesburg is the minibus-taxi which accounts for 72% of all public transport trips, with only 14% of commuters travelling by train and 9% commuting using bus for their travels (Rahim, 2014:90). The connection between land use planning and integrated transport plan has not been fully explored. One of the results of a lack of integration of transportation and land use planning in Johannesburg has been automobile dependence, a phenomenon that is increasing over time. This has resulted in 42% of Johannesburg inhabitants using private vehicles as their main mode of transport (Zack et al., 2012:17).

Walking is the second most important main mode of transport in Johannesburg after cars. It is the mode used for 31% of all trips made in the morning peak period according to the 2003 GHTS (cars account for 37% and minibus-taxis for 23%). The average walk trip was 23 minutes (25 minutes for work trips and 22 minutes for walking to schools and other educational institutions) (COJMM, 2013:97).

Non-Motorised Transport (NMT) mode such as cycling accounts for 0,2% of trips (3 165 trips). Average travel time spent cycling to work is 42 minutes and to education is 16 minutes. In addition to this, walking is the most significant feeder mode for access to public transport (to railway stations, bus stops and taxi ranks). The capacity of public transport system is the morning peak period depicted in Figure 1.2. It shows a spatial tendency which reflects the dependency of minibus taxis followed by public bus networks.

Figure 1.2. Capacity of public transport during peak hours in the City of Johannesburg



Source CoJMM (2013:11)

Note: Map not drawn to scale

1.2.2. Status of intelligent transport systems in Johannesburg

In 2007, a road network improvement project for Gauteng was proposed by the South African National Roads Agency Limited (SANRAL) (SANRAL, 2012). As part of GFIP, a user pays model was proposed consisting of the implementation of e-tolling gantries over a 185km network. Users of the road would have tolling fees either automatically deducted from an 'e-tag' attached to their windscreen or automatic license plate recognition using CCTV cameras attached to the gantries they pass under. The e-toll system has been implemented in Johannesburg highways such as Ben Schoeman N1 between Johannesburg and Pretoria City to ease congestion. According to Hommes and Holmner (2012:201), the linking of electronic payment and electronic licensing by using the same tags and equipment has greatly enhanced the functionality, efficiency and market penetration of such a toll system.

The BRT Rea-vaya system of Johannesburg was implemented with an advanced public transportation management system that incorporates various intelligent transport systems solutions such as fare collection systems through smart card systems, CCTV cameras for live monitoring and variable message sign for passenger information dissemination. A control centre room for system management was also implemented to improve urban mobility challenges through traffic signal priority coordination (Heather, 2013:9-10).

The Gau-train uses a different intelligent transport system from the BRT Rea-vaya for fare payment systems and creates challenges in the integration of public transport management systems through intelligent transport system. Integration of fares themselves (fare harmonization) across different operators is more difficult to achieve and will generally require that they be contracted in terms of gross cost contracts by the same authority, or by authorities that have revenue distribution agreements in place between them, or that the operators have agreements on revenue sharing between each other. There is a lack of integration across public transport systems in general i.e., information management and payments systems that create a more effective public transport system such as intelligent transport systems (Cete et al, 2015:48).

1.3. Statement of research problem

Due to increases in population density, traffic congestion, associated pollution and land use intensification, there is pressure to seek effective means of moving passengers, reduce travel time, increased travel time and number of stops. The BRT systems were adopted as an improvement on regular bus service to improve speeds and service reliability. Many countries have embarked on BRT systems to increase efficiency of travel to commuters.

The implementation of intelligent transport systems is often seen as the solution to many transportation problems. However, to ensure that intelligent transport systems' solutions are sustainable, they need to be implemented holistically with due consideration to the operational, institutional and technical aspects. It is unclear if the ITS in the BRT Rea-vaya is being utilized efficiently and effectively due to the design of the system. The fragmented management of the operational, institutional and technical aspects of ITS hinder the BRT Rea-vaya from utilizing the systems effectively and efficiently for the benefit of commuters.

There has been increased emphasis worldwide on sustainable transport to improve vehicle fuel economy and reduction carbon dioxide emissions from the transport sector (Barth, 2016:76). The role of intelligent transport system in improving environmental quality in the City of Johannesburg from BRT Rea-vaya perspective has not been well defined and it is unclear whether the system is resulting in improved environmental quality through the ITS.

Although, the intelligent transport system was incorporated in the design and development of the BRT Rea-vaya for easy information dissemination to commuters, it is unclear whether commuters are aware of the system and how it operates. There is no explicit proof that the system is beneficial to Johannesburg commuters and that they receive the appropriate information for their journey and whether the system is user friendly. There is no sufficient evidence that the system is improving the mobility options of commuters.

To meet the demand for travel in the City of Johannesburg in the public transport system, the ITS system is expected to provide adequate, reliable, efficient, effective and safe transport for commuters and transport operators. Improving road safety is the focal point of ITS work. However, it is unclear whether the ITS in the BRT Rea-vaya has resulted in a transportation which provides mobility and safety for road users.

According to Kerry (2014:39-42), various intelligent transport systems have been implemented as a solution to transport challenges facing urban areas. There is however, lack of empirical research regarding intelligent transport systems in bus rapid transport in South Africa. This makes it difficult for transport managers to take appropriate strategies in the utilization of intelligent transport systems for operations and management of systems such as the BRT Rea-vaya systems. Although, the intelligent transport system has been implemented in the BRT Rea-vaya to improve the operations and management transportation systems, it is unclear if the system has achieved its objectives in terms of operational efficiency of the system with regard to BRT Rea-vaya in the City of Johannesburg. The general research problem is that the ITS has not adequately addressed the operational challenges in terms of increased mobility, safety, reliability, efficiency and environmental quality.

It is with respect to the research problems stated above that we can itemize the research problems as follows:

- The ITS introduced to manage Rea-vaya has not addressed adequately the mobility problems of commuters.
- There is insufficient safety which the ITS sought to resolve on the Rea-vaya routes in the City of Johannesburg.
- The managers of the ITS have not resolved the problems of reliability in Rea-vaya.
- The ITS has not completely eradicated the inefficiency bottlenecks of Rea-vaya.

1.4. The aim and objectives of the research

In view of the problems discussed and outlined with respect to intelligent transport system in the BRT Rea-vaya system above, the research aim and objectives are outlined as follows:

1.4.1. Aim of the research

The study evaluates the impact of the introduction of intelligent transport system on the efficiency of management and operations of the BRT Rea-vaya system in Johannesburg.

1.4.2. Specific objectives of the research

In view of the main aim of the research objective stated above, the specific objectives of the research are outlined as follows:

- To evaluate the level of mobility of commuters with respect to the intelligent transport system in reducing traffic congestion on the routes.
- To explore the opinions and attitudes of commuters on the improvement of safety in the BRT Rea-vaya.
- To explore the managers' perceptions of the reliability of ITS with respect to Rea-vaya.
- To determine the efficiency of the ITS in the management of the BRT Rea-vaya in the City of Johannesburg.
- To determine the level to which the introduction of ITS in Rea-vaya has reduced waiting times for commuters.

1.5. Research questions

The specific research questions to probe the objectives stated above are as follows:

- To what extent has the introduction of ITS been able to reduce traffic congestion on Rea-vaya routes?

- In which ways has the ITS contributed to the improvement of safety for commuters?
- How reliable is ITS in managing BRT Rea-vaya?
- How efficient is the ITS in running the BRT Rea-vaya in the City of Johannesburg?
- To what extent has the introduction of ITS in BRT Rea-vaya been able to reduce waiting times for commuters?

To address the specific questions for the research, hypothesis was formulated to understand the relationship between the ITS in the BRT Rea-vaya and commuters.

Hypothesis 1: Occupational status of commuters will influence the reason why commuters are utilising the BRT Rea-vaya.

Null Hypothesis: Occupational status of commuters does not influence the reason why commuters are utilising the BRT Rea-vaya.

Hypothesis 2: Purpose of using the BRT Rea-vaya affects the time commuters are willing to travel.

Null Hypothesis: Purpose of using the BRT Rea-vaya does not affect the time commuters are willing to travel.

Hypothesis 3: Time commuters spend travelling is influenced by the distance between their place of residence and place of occupation.

Null Hypothesis: Time commuters spend travelling is not influenced by the distance between their place of residence and place of occupation.

Hypothesis 4: Time commuters are willing to wait at stations is influenced by the purpose of their journey.

Null Hypothesis: Time commuters are willing to wait at stations is not influenced by the purpose of their journey.

Hypothesis 5: How commuters access information influences the type of information they can access.

Null Hypothesis: How commuters access information does not influence the type of information they can access.

1.6. Scope of the research

The scope of the research covers geographical and contextual issues as follows:

1.6.1. Geographical scope

For the purpose of this study, the Bus Rapid Transit systems of Rea-vaya routes have been selected, i.e. T3 trunk route from Thokoza park (where Thokoza park is located in the

Southern western townships) to Park Station. Where Park Station will be the length of the BRT that is being studied). The study area due to the routes location covers the Southern Gauteng and Greater Gauteng regions. The routes pass through regions B, D and F. They fall within 1, 2, 4, 6, 11 and 13 wards.

1.6.2. Contextual scope

The context of the research dwells on evaluating intelligent transport system in the operation and management of the BRT Rea-vaya. The context is expanding the impact of intelligent transport system use to manage the BRT Rea-vaya. The analysis probes the application of ITS system with respect to safety, efficiency, reliability, mobility, efficiency and environmental quality as applied to Rea-vaya BRT. The study attempts to elaborate the concept of intelligent transport system in the management and operations of BRT, explicitly focusing on the BRT Rea-vaya of Johannesburg metropolitan.

1.7. Significance of the research

The study attempts to explore whether the use of ITS improved the running of the BRT system. It was undertaken to evaluate the impact of the challenge on the operations and management of the Bus Rapid Transport in a metropolitan city such as Johannesburg. The aim is to evaluate the functioning with the ultimate goal of making general consideration on the usefulness of ITS and also to find out whether it can be used as a one stop center to manage traffic in a congested city where commuters can commute with ease. The findings of this study are likely to add to the existing literature on the operational management of BRT through intelligent transport system, as it investigates not only users of the system, but non-users experience as well. Additionally, this study on the BRT is a qualitative study and is concerned with the opinions and experiences of stakeholders in order to provide an account of the social and economic effect of intelligent transport system in the BRT Rea Vaya.

1.8. Limitations of the study

The study evaluates the impact of the introduction of the ITS on a Bus Rapid Transport along certain traffic routes and not all the networks such as taxis, buses, private vehicles, trains and pedestrians in the City of Johannesburg.

1.9. Definition of terms

Bus Rapid Transit (BRT): A high quality bus based transit system that delivers fast, comfortable and cost effective urban mobility through the provision of segregated right of way infrastructure, rapid and frequent service, modern stations, on-board fare collections and high-tech vehicles (Rahim, 2013:54).



Corridor: A corridor is a broad geographical area that defines the general directional flow of traffic that may encompass a mix of streets, highways and public transport alignments (Ngoben, 2012:9).

Central Business District (CBD): The central business district is the traditional business core of a community, characterized by a relatively high concentration of business and administrative activity within a relatively small area (Cete et al., 2013:23).

Efficiency of transportation systems: The efficiency of transportation systems refers to the degree that transportation systems are comprehensive and integrated, so that individuals', short term decision support a strategic and long-term goals (Litman, 2013:6).

Integrated Transport Plan (ITP): An Integrated Transport Plan is a document setting out how to integrate transport systems in order to increase accessibility for all people by giving priority to public transport, non-motorised transport and traffic safety (COJMM, 2015:88).

Intelligent transport systems: PIARC Committee on Intelligent Transport Systems (1999) defined Intelligent Transportation Systems as the collection, processing, integration, supply and utilization of information through the application of computer, control and communications technologies to enable authorities, transportation professionals, operators and individual customers to make better informed decision (PIARC,1999:13).

Transport mobility: Mobility is the degree of free flow movement of vehicles and pedestrians. It is the ability to move at an acceptable speed and travel time without undue interruption and at acceptable levels of comfort and safety.

Mode of transport: Mode refers to a particular form of travel i.e. walking, cycling, travelling by bus, car, carpool or by train.

Peak Hour: A Peak Hour describes the hour during which the maximum demand occurs for a given transportation corridor/road, generally specified as the morning peak hour or the evening peak hour.

Peak Period: A Peak Period is a portion of the day in which the heaviest demand occurs for a given transportation corridor or road, usually defined as a morning or evening period of two or more hours.

Public transport: Public Transportation includes all multiple occupancy vehicle services designed to transport customers on local and regional routes. It is transportation by van, bus, or rail or other conveyance, either privately or publicly owned, providing to the public general or special service (Rodriguez & Targa, 2004).



Traffic management: Traffic management offers various strategies that change travel behaviour (how, when, and where people travel) to increase the efficiency of transportation systems and achieve planning objectives (Ferguson & Erik, 1999).

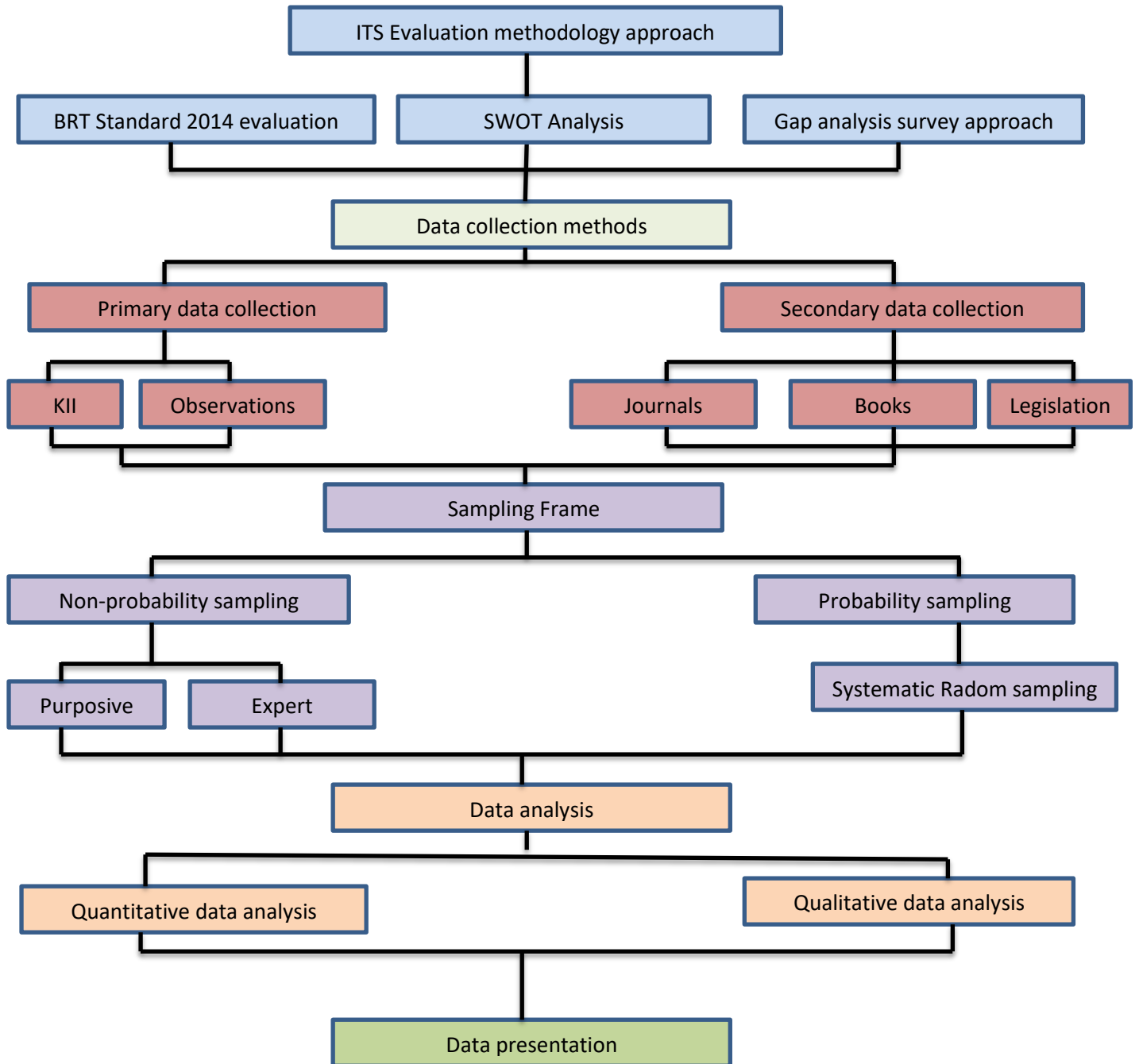
1.10. Chapter summary

This chapter introduces the theme. It outlines the background of the study with respect to the BRT Rea-vaya and intelligent transport system. It defines the research statement of the problem, the aim, objectives, research questions, scope, and significance of the research, the limitations and the definition of terms. It has also presented the scope and limitation of the research. The next chapter addresses the research methodology anchoring this study.

2.1. Introduction

This chapter discusses the methods that were adopted for data collection analysis and interpretation. It outlines how the research was conducted in terms of the approach that was used to achieve the general aim and the specific objectives of the research. Figure 2.1 illustrates the structure adopted for this chapter.

Figure 2.1 Structure of chapter two



Source : (Author construct, 2017)

2.2. The notion of intelligent transport systems

According to Patrick (2010), the notion of Intelligent Transport Systems and Services (ITS) refers to the integration of information and communication technologies with transport infrastructure to improve economic performance, safety, mobility and environmental sustainability. An intelligent transport system applied to a bus rapid system in a mega city such as Johannesburg was aimed at exploring the usefulness of the system in managing and operating public transport in a fast growth city where transport demand has been on the increase since 1994.

2.3. The gap analysis survey approach

An intelligent transport systems gap analysis survey approach was adopted for this study to evaluate the introduction of the system to manage the BRT Rea-vaya in Johannesburg with respect to safety, reliability, comfort and reduction in travel time. According to Georgia (2014), the analysis of the intelligent transport gap survey includes the operational management of the Bus-Rapid Transport such as demand and supply and route planning. Hannes (2012:17) states that gap analysis aims to identify missing/necessary needs in a selected area in relation to what outcomes are desired. This study evaluates the gaps that exist within the operations and management of the BRT Rea-vaya utilizing intelligent transport system. This to demonstrate the extent to which the system can improve the management and operations of bus rapid transit in Johannesburg and the shortcomings of the system in terms of efficiency, safety, environmental quality, effectiveness, mobility and reliability which all talk to demand and supply of the BRT to resolve commuters' ease with transportation.

2.4. Data collection methods

The study revolved around the fulfillment of the specific research objectives. This section highlights different techniques and tools that were adopted for the achievement of the objectives with respect to sampling, primary and secondary data collections methods as well as data analysis tools.

2.4.1. Primary data collection

Primary data collection involved data observed or collected directly from first-hand information (Driscoll, 2011:123). Various primary data collection tools were employed for description of the experiences that occurred. This was by extracting information on the use of intelligent transport system introduced to manage the BRT Rea-vaya in Johannesburg.

2.4.1.1. Key Informant Interviews



Key informants i.e. personnel from BRT Rea-vaya were interviewed on the implementation of Intelligent Transport Systems in the management and operation of public bus system in Johannesburg. This was done to obtain the official views on ITS operations and management of BRT Rea-vaya. The aim was to find out their perceptions on the usefulness of the ITS in providing solutions to congestion of transport routes on certain areas of Johannesburg. The following were participants that were interviewed for their input on the operations and management of the BRT Rea-vaya through intelligent transport systems:

2.4.1.1.1. ITS operations manager within Rea-vaya

The ITS operations manager was one of the key-informants because he is responsible for overseeing the operations of the BRT Rea-vaya intelligent transport systems. He implements measures to ensure the system is effective and reliable to meet the needs of commuters. The ITS operations manager provided data on the reliability of ITS in the BRT Rea-vaya and he also outlined how the system ensures safety, improves mobility and environmental quality through an effective and efficient ITS system.

2.4.1.1.2. Fleet manager within Rea-vaya

The fleet manager was selected to provide information related to the management and scheduling of buses along T3 trunk route, including time management and delay time of commuters at the bus at bus stations. He also provided information on the (scheduling and planning, duty allocation, vehicle tracking function and assets management, communication information) mass data synchronization, network management and multi-media functionality, using the intelligent transport systems. We were able to obtain information on the training that the staff underwent for effective utilization of the ITS, the smooth running of the vehicles, breakdowns and repairs.

2.4.1.1.3. Station controllers

The station controllers were selected because they are responsible for the management of the stations and the interaction of the ITS between them and the bus operators. The data that was collected related to how effective ITS system is in managing each station. They provided data on the functionality of the systems with regard to stations and the interactions that commuters have with regard to the system. The interview provided clarity from the controllers on how ITS contributes in the reduction of commuters waiting time. The questionnaires to the key-informants were of a hybrid design which included classification, factual and opinion or attitude question types. The format of the questions was open and closed ended questions because it gave them the opportunity to elaborate their

understanding of the operation of an intelligent transport system and how it operates on the ground, as well gave them the opportunity to select different answer options.

2.4.1.2. Observation of the BRT Rea-vaya infrastructure

The researcher undertook a field observation of the operations of the BRT Rea-vaya system. This was aimed at establishing how the operations of the BRT Rea-vaya conform to the BRT standard 2014 tool used to evaluate the operations of a BRT Rea-vaya based on international best practices (refer to table 2.1 on the BRT Rea-vaya international studies). This was aimed at making observation on the ground and noting to confirm whether what the key informants were saying was actually happening on the grounds. Our observation on the BRT Rea-vaya facilities was to unpack the extent the BRT Rea-vaya has succeeded in ensuring safety, reliability, reduction in waiting time, efficiency and comfort through ITS in order to explain the difference between desired level of service (BRT standard 2014) and the actual designed system of Johannesburg BRT Rea-vaya, semi structured interviews were carried out with BRT Rea-vaya management on the spot to commuters.

Table 2.1. BRT Rea-Vaya achieved points

BRT STANDARDS	BRT STANDARDS POINTS	BRT REA-VAYA ACHIEVED POINTS
BRT Basics-minimum score of 20 point needed	38	
Dedicated right-of-way-minimum 4 points	8	
Bus way alignment-minimum 4 points	8	
Off-board fare collection	8	
Intersection treatment	7	
Platform-level boarding	7	
Service planning	19	
Multiple routes	4	
Express, limited and local services	3	
Control centre	3	
Located in top ten corridors	2	
Demand profile	3	
Hours of operations	2	
Multi-corridor network	2	
Infrastructure	14	
Passing lanes at stations	4	
Minimizing bus emissions	3	
Station set back from intersection	3	
Centre station	2	
Pavement quality	2	
Stations	10	
Distance between stations	2	
Safe and comfortable stations	3	
Docking bays and sub-stop	1	
Sliding doors in BRT stations	1	
Communications	5	
Bradding	3	
Passenger information	2	
Access and Integration	14	
Universal access	3	
Integration with other public transport	3	
Pedestrian access	3	
Bicycle lanes	2	
Bicycle –sharing integration	1	
Total	100	
Points deductions	-	
Lack of enforcement of right-of-way	-4	
Maintenance	-10	
Total score	100	

Source: (The Institute for Transportation and Development Policy: ITDP, 2014)

2.4.1.3. Sampling frame



The selection of a proper sample is an obvious prerequisite to a sample survey. A sample is defined as a collection of units which in some part of a larger population and which is specially selected to represent the whole population (Jones, 2013:21).

2.4.1.3.1. Sampling Techniques

Both non-probability and probability sampling techniques were used for the study because it is accurate and reliable and easy to collect.

2.4.1.3.2. Non-probability sampling techniques

A non-probability sampling method was adopted for the selection of key-informant interviews which was purposive and an expert oriented selection.

2.4.1.3.2.1. Purposive sampling of Key-informants (KII)

The purposive sampling technique was used to identify key-informants for interviews. This is because they have a proper understating of how intelligent transport systems is used to manage bus rapid transport systems. The organogram of various transport and land use planning institution was reviewed where official/authorities with the expertise related to transport planning were identified and sampled for the study. The motivation for purposive sampling is that key-informants have an inclusive understanding of the challenges and opportunities of managing and operating the BRT Rea-vaya through the use of intelligent transport systems. In this respect, informed techniques on the ITS trunk route, gave a good account of the mode of operation of the system.

2.4.1.3.2.2. Expert sampling technique

Expert sampling takes the task of sampling away from the interviewer and places it in the hands of an "expert" in the field of study being addressed by the survey. Expert sampling was adopted for selecting the BRT Rea-vaya route with the aid of experts. The experts from the BRT Rea-vaya management selected the Thokoza park to Liberty Gardens routes of T3 trunk route. The T3 trunk route was selected as it is the major route for the BRT Rea-vaya and where the majority of the commuters use the route and where credible information was collected from that specific route.

2.4.1.3.3. Probability sampling techniques

Probability sampling is a sampling technique where the chance of a unit/element being chosen into the sample is 'known' (by its exact probability or by statistical estimates). This technique was used to select the respondents or commuters. A systematic random sampling

technique was adopted for selection of commuters using the BRT. The commuters were interviewed with questionnaires at the bus station. The first commuters were selected at random at each station along the chosen route until the desired number was achieved. The rule of thumb equation was used in calculating the interval for the selection of the respondents.

$$K = N/n$$

$$K = 16500/387 = 43$$

From the above calculation from the rule of thumb equation, the interval for the selection of the respondents for the study was 43. This means that when the first respondent was identified randomly, thereafter 43 respondents were counted and the 44th respondent was intercepted to take part in the study.

2.4.1.4. Sampling size and administering questionnaires to commuters

The sample size was determined by using a sampling formula known as the rule of thumb. If a population is between 1000 and 10 000 commuters, an ideal sample size would be 26% (Gallhofer, 2007:89). In this case, this would translate to a sample size of 387 commuters given a sample frame of 16500. The desired sample sizes and different margins of error are shown in table 2.2 (which in essence it is an extension of the rule of thumb method used to sample respondents on the BRT Rea-vaya route).

Table 2.2: Margin of error/level of significance

Population	5%	3%	2%	1%
250	151	203	226	244
400	196	291	334	384
750	254	440	571	696
2000	322	696	1091	1655
10 000	370	964	1936	4899
1,000,000	384	1066	2395	9513

Source: (Gallhofer, 2007:87).

2.4.1.5. Systematic random sampling of commuters

The systematic random sampling technique was used to select the commuters at the bus stations, considering that there is a variation in the number of BRT stations on a route. This is where the stations were randomly selected along a route. This enabled the researcher to cover bus stations that have a small and large number of commuters. To ensure reliability of data collection, the questionnaires were distributed at both peak and low-peak commuting periods from 6-8am and from 4-6pm respectively. Table 2.3 shows the distribution of questionnaires to commuters.

Table 2.3. Distribution of questionnaires along routes to commuters

Region	Ward	BRT stations From point 1 to 18	Total number of commuters per day	NQD	% to be distributed	NQR	% Returned
Region D	2	Thokoza park station	1450	35	9%	10	28%
Region D	2	Lakeview station	2600	58	15%	6	10%
Region D	2	Klipspruit valley station	1700	39	10%	8	21%
Region D	2	Boomtown station	400	12	3%	3	25%
Region D	11	Orlando police station	250	8	2%	6	75%
Region D	11	Orlando stadium station	700	15	4%	9	60%
Region B	13	Noordgession extension station	800	19	5%	12	63%
Region B	4	West burry station	1290	31	8%	28	90%
Region B	6	Hellen Joseph station	600	12	3%	8	67%
Region F	1	UJ Kingways station	1320	31	8%	24	77%
Region F	1	UJ Sophia town res station	400	12	3%	12	100%
Region F	1	SABC media park station	900	23	6%	23	100%
Region F	1	Milpark station	447	8	2%	7	87%
Region F	1	Wits stadium station	400	12	3%	12	100%
Region F	1	Park town station	800	19	5%	16	84%
Region F	1	Constitutional hill station	949	19	5%	19	100%
Region F	1	Park Station station	400	12	3%	9	75%
Region F	1	Library gardens stations	889	23	6%	17	74%
Total		18	16500	387	100%	229	

Source (Prince, 2014:23) and authors field data 2016

Proportional allocation was used to select the number of samples on each station along the T3 trunk route. The sample from each route was proportional to the number of commuters that use a single station. The proportional sample size was determined using the following formula:

$$\text{Sample size of station} = \frac{\text{Total no of commuters at a station} \times 100}{\text{Total no of all commuters in the stations}}$$

$$\text{Sample size of Thokoza park station} = \frac{1450 \times 100}{16500} = 8.78\% \approx 9\%$$

This means that 9% of the questionnaires were distributed at Thokoza park station which amount to 35 questionnaires distributed for data collection. Table 2.2 shows the distribution of questionnaires to a total of 387 respondents. Out of a total of 387 administered questionnaires to commuters, a total of 229 were returned correctly completed representing 59.2% of the respondents.

2.4.2. Secondary data collection

Secondary data was gathered from books, government documents, maps, articles and journals. Only reliable, valid and adequate secondary data were used to achieve the study objectives. Secondary data collection was achieved through:

2.4.2.1. Literature review

The documentary searches were useful in attempting to obtain transport system inventory data. Thus, timetables and route maps of the BRT transport systems provided useful information on intelligent transport systems. Data base such as Ebscohost, Academic search

complete, Master File Premier, Newspaper Sources, Jstor, Direct of access journal and Google scholar were used to collect information. Various sites such as BRT Rea-vaya website, department of transport and Gauteng department of transport website, Arup and IBM company website were also visited to acquire more secondary data.

2.4.2.1.1. Major books consulted

Several textbooks were reviewed for the purpose of understanding the evolution, development and designing of intelligent transport system for the management and operations of bus rapid transit systems around the world. A book titled “City competitiveness and improving urban subsystems” by Bulu Melish (2010) played a role in understanding how cities can improve public transport utilizing intelligent transport system. The book outlines the guidelines and parameters to be taken into consideration when a city is developing and implementing technological innovations. Another book published in 2010 by Toy S. Lee entitled “Intelligent transport systems: smart and green” explores the evolution of intelligent transport system into public transport. The book explains how physical infrastructure, economic value and policies of a country influence the type of intelligent transport system that will be implemented.

2.4.2.1.2. Relevant Journals

Various articles such as the one published by APTA (American Public Transportation Association) journal by Joseph Barr et al., in 2010 on “implementing BRT intelligent transport system” were read extensively. The articles provided insight on the crucial components to be considered when implementing an intelligent transport system such as the Johannesburg BRT Rea-vaya.

2.4.2.1.3. Official documents

Official documents from government department were reviewed for example Berling metropolis initiative, ‘Integrated Urban Governance and Johannesburg City was compiled by Micheal Abraham on “metropolis peer-review training” was used. The report reviews how the Rea Vaya BRT can achieve operational excellence in all areas of operation, including roadways, stations, buses, depots and intelligent transport systems. It gave the author enlightenment on the challenges that were hindering the BRT Rea-vaya in achieving excellence in operations of intelligent transport system. Other documents which were Johannesburg City: transportation planning and management strategy (2014/2015), the Johannesburg IDP (2013/2014), RSDF (Regional spatial development framework) for regions (F, D, B and C) to understand the impact of BRT on spatial development of the regions.



2.4.2.1.4. Integrated transport legislations

Relevant legislation, policies and strategies on the role of transportation in planning reviewed to understand how policies on urban transportation impact on commuters' attitudes towards public transport. The Gauteng integrated transport master plan (ITMP25) was read to see how it integrates intelligent transport system with other modes of transport to improve information dissemination. The Gauteng Public Passenger Road Transport Act (No 7 of 2001) was reviewed to understand how public transport in Gauteng is governed and what is the legal reference for implementing intelligent transport system into public transport system.

2.4.2.1.5. The use of maps

Secondary data sources such as maps were also sourced and used. They were used to describe the locating of the study area, as well as depicting the physical characteristics of the area, routes and the BRT Rea-vaya station location. Examples of the maps used for this research; integrated transport network for Johannesburg, integration of ITS map on safety, Rea-vaya BRT route map to mention just a few.

2.5. Research design matrix

Table 2.4 highlights how information was sourced corresponding to the research objectives outlined in chapter one and the expected outcomes.

Table 2.4. Goal achievement matrix table

Research objectives	Corresponding Research questions	Data collection tools		Sampling methods	Data analysis and presentation tools	Outcome
		Primary data sources	Secondary Data sources			
To evaluate the level of mobility of Rea-vaya with respect to the intelligent transport system in reducing traffic congestion on the routes.	To what extent has the introduction of ITS been able to reduce traffic congestion on Rea-vaya routes?	Questionnaires KII	Books Journals ITMP RSDF IDP	Random Purposive Expert	SPSS Maps Pictures Tables Graphs	The level of mobility of the BRT Rea-vaya through intelligent transport systems.
To explore the opinions and attitudes of commuters on the improvement of safety in the BRT Rea-vaya.	In which ways has the ITS contributed to the improvement of safety for commuters?	Questionnaire KII	Books Journals Newspapers	Random Purposive	SPSS Maps Tables Graphs	Understanding of the impact of intelligent transport on safety of the BRT Rea-vaya to users.
To explore the managers' perceptions on the reliability of ITS with respect to Rea-vaya.	How reliable is the ITS in relation to managing the BRT Rea-vaya	Questionnaire KII Observation	Books Journals Newspapers	Random Purposive	SPSS Maps Tables Graphs	The degree of the reliability of the systems in managing BRT Rea-vaya.
To determine the efficiency of the ITS in the management of the BRT Rea-vaya in the City of Johannesburg.	How do managers and commuters judge the reliability of ITS in managing Rea-vaya? How efficient is the ITS in the efficiency running of Rea-vaya in the City of Johannesburg?	Questionnaires KII Observation	Books Journals RSDF IDP ITMP	Purposive	SPSS Tables Graphs	A understanding of the operations efficiency for intelligent transport system management in the BRT Rea-vaya
To determine the level to which the introduction of ITS in Rea-vaya has reduced waiting times for commuters.	To what extent has the introduction of ITS in Rea-vaya been able to reduce waiting times for commuters?	Questionnaires KII Observation	Books Journals Articles	Random Purposive	Deductive Analysis Maps Tables	Improved strategies for managing the BRT Rea-vaya through intelligent transport systems

Source: Authors field data 2016

2.6. Data analysis method

Data was gathered and analyzed using major methods of analysis namely, quantitative and qualitative data analysis. This was done to present and analyze data gathered from secondary sources and primary data. The data was first processed, edited, coded where necessary and presented in the form of table, graphs, cross tabulation, bar graphs and pictures and then explained.

2.6.1. Quantitative data analysis



Quantitative analysis of the collected data was facilitated by the use of the IBM SPSS (Statistical Packages for Social Sciences, version 20). This computer software was used to manage data, i.e. data entry and editing field data gathered using intercept surveys to analyze data statistically to present the findings in the form of tables and graphs i.e. pie chart, line graph and bar graphs etc., to help draw conclusion from the field data. This type of data analysis was chosen because it offers increased objectivity in data presentation and interpretation.

2.6.2. Qualitative data analysis

Qualitative data that cannot be addressed through statistical techniques was derived, deduced, analyzed and interpreted using qualitative analysis such as texts and interviews, observation, drawing inferences in order to discover meaningful patterns descriptive of managing and operating BRT through the use of intelligent transport systems. The research design matrix table 2.3 was used to achieve this purpose.

2.6.3. The use of tables, graphs and maps

Tables, graphs i.e. pie charts, line graphs, bar graphs and maps were utilized to present visual graphical pictures of the gathered statistical data.

2.6.3.1. Tables

Field data that was gathered using questionnaires administered to commuters was orderly classified and then systematically presented in the form of tables. The reason for using tables is that data is presented in a simple manner that is simple to understand, brief, helpful in analysis and clarifies main characteristics of intelligent transport systems data. Cross tabulations were used to deepen the analysis of the various bus rapid transit systems across the nation and the world.

2.6.3.2. Graphs

Graphs of various types i.e. pie charts, line graphs and bar graphs were used to present field data. Graphs were used as they present data in the form that is simple and economical.

2.6.3.3. Photographs

Photographs were used to illustrate the observation on the ground. The pictures depicted the existing characteristics of the Rea-vaya systems with region to station appearance, commuter at station, information display to commuters etc.

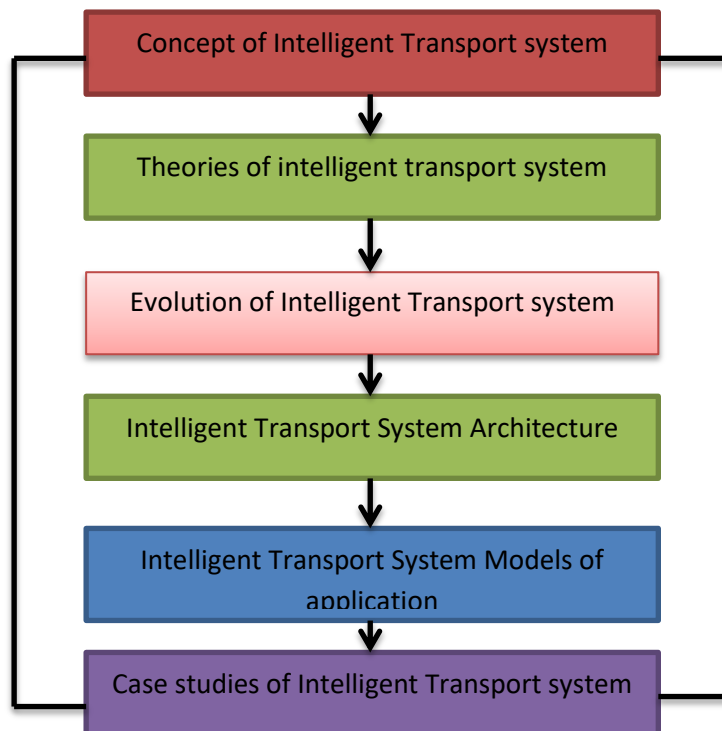
2.7. Chapter Summary

This chapter outlined the research methods that were adopted for the collection of relevant data required. It described the research approach, data collection instruments, sampling design and goal achievement matrix of the study required for the achievement of the research objectives outlined in chapter one. The chapter that follows discusses the literature review pertaining to this study.

3.1. Introduction

This chapter reviews relevant published and unpublished documents on intelligent transport systems used for managing and operating BRT services. It outlines relevant theoretical concepts with respect to the concept of the BRT operational or management through ITS. In addition to this, the theory behind BRT is outlined to explain the optimal control theory including the queue theory, the BRT architecture objective and how the system is used to organise public transport system.

Figure 3.0 Structure of chapter three

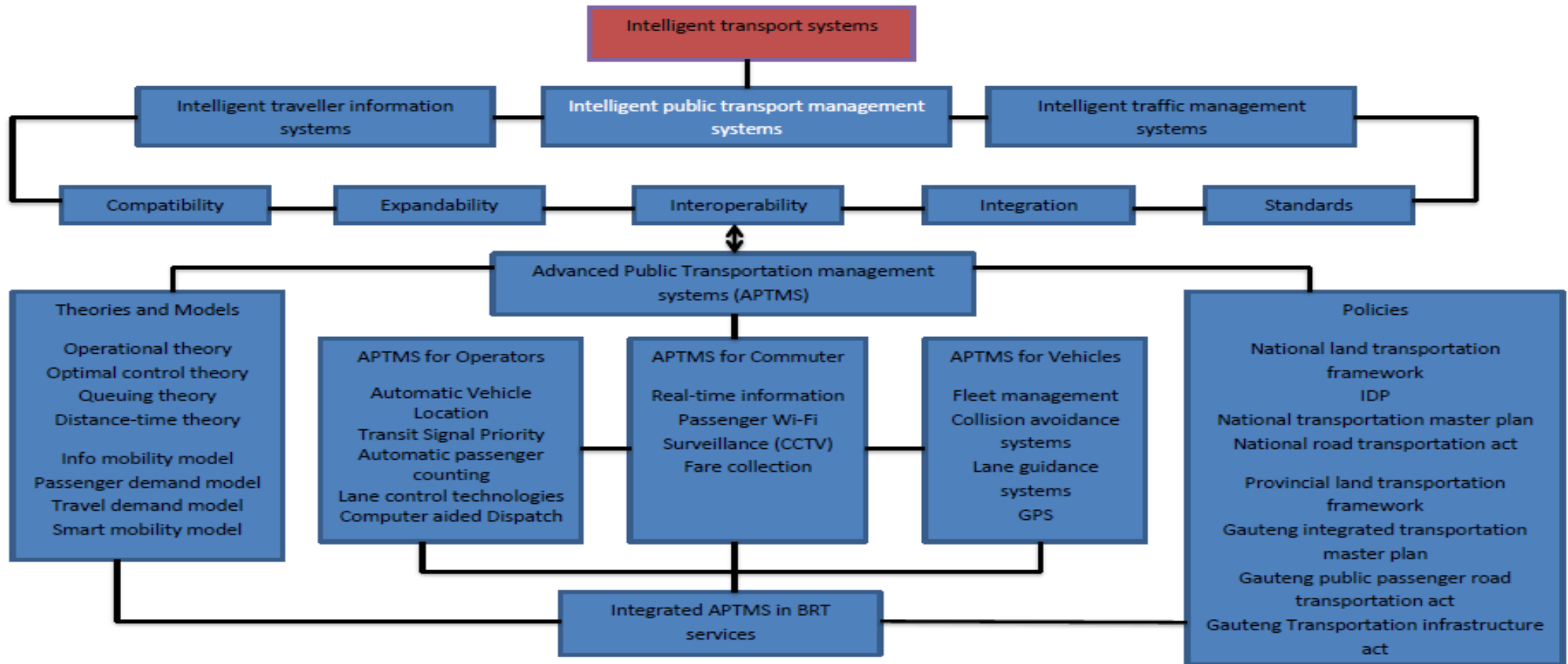


Source (Author construct.2017)

3.2. The concept of ITS in BRT

Conceptual framework provides the background of intelligent transport systems in operational management of BRT. Improved accessibility of public transport through intelligent transport systems in urban areas is important to liveability of an area, its economic, social and environmental well-being. According to Koernicke (2011:4), the concept of an ITS is geared to forward the management of organised public transport operation to ensure a good information chain, data process, surveillance, communication and route management. Figure 3.1 illustrates Koernic concept of intelligent transport system.

Figure 3.1. Concept of Intelligent Transport System according to Koernicke.2011



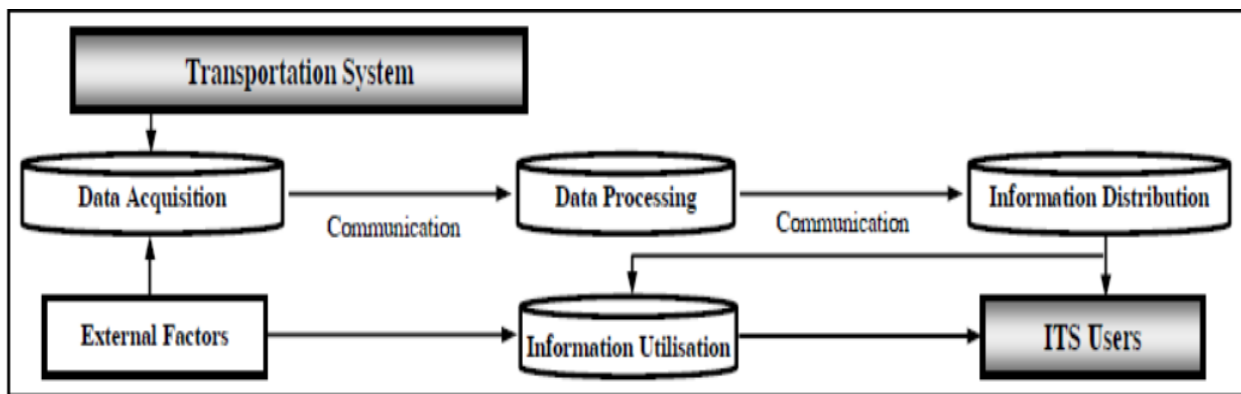
Source (adopted from Koernicke, 2011:4)

3.3. The concept of intelligent transport systems

Intelligent Transport Systems (ITS) is a system that is widely used in the management of traffic and underground trans services (John, 2015:11). According to Chosi (2008:43), intelligent transport systems support the operation of integrated transport networks, the control of vehicles operating on the networks, and the efficient planning of operations, (including individual journey planning and fleet logistics). It includes a wide range of user support functions, from simple information alerts through to highly sophisticated control systems (Andersen et al., 2010:1).

Essentially, Aldona (2008:99) asserts that ITS services can be thought of as an information chain, as shown in Figure 3.2, where information is acquired, processed and disseminated.

Figure 3.2. Aldona.2008 ITS information chain



Source (Aldona, 2008:43)

From figure 3.2, we can deduce that the system is adopted for transportation, i.e acquiring traffic data, processing it and using the information to manage traffic congestion, accident reporting, driver assistance, ensuring speed limit and the enforcement of traffic regulations.

The use of ITS is outlined as follows:

Intelligent Traffic Management Systems

According to Kate (2016:86), Intelligent Traffic Management Systems measures and analyse traffic flow information and take ITS measures to reduce problems. It consists of computerised traffic signal control, highway and traffic flow management systems, electronic licensing, incident management systems, electronic toll and pricing, traffic enforcement systems and intelligent speed adaptation (Vandershuren, 2006:47).

ITS and Passenger Information Systems

Intelligent Passenger Information Systems improve the knowledge base of Customers and consist of passenger information systems, in-vehicle route guidance systems, parking availability guidance systems, digital map database and variable messaging systems (Vandershuren, 2006:48).

Intelligent Public Transport Systems

According to Booyesen (2013:10), the Intelligent Public transport system are measures that focus on improving public transport to benefit passengers. These include information to passengers on speed, fleet management, electronic payment systems, electronic licensing, transportation demand management systems and public transport priority.

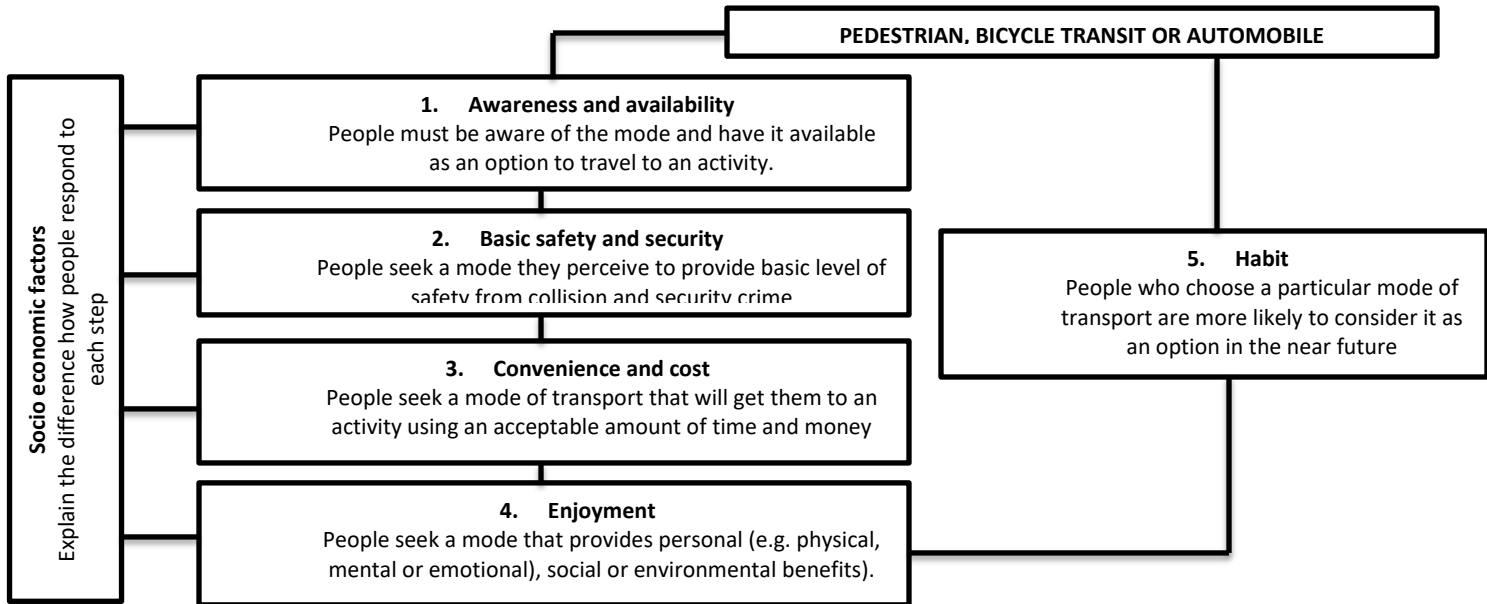
3.4. Theories of intelligent transport systems

In recent years authors such as Andersen (2014) and Emmanuel (2012) have written on the concept and theory that ITS is aimed at improving the management and operations of public bus rapid transport system. Some of the theories are summarised below:

3.4.1. The operational theory of ITS

The operational theory of ITS was discussed by Andersen (2014:23-28) on the premise that it provides information on modal split, travel times, destination and station management. In addition to this, Liaz (2011:33) suggests that they are in ITS operations. The first step is awareness and availability to determine which modes are viewed as possible choices for routine travel. The second step is basic information on safety and security. The third step is on convenience and cost, and the fourth is assessing situational trade-offs between modes in the choice set. These middle three steps may be considered simultaneously or in various sequences (Andersen, 2014:28). These steps outline how intelligent transport systems can be used for route management, information services to the public bus stops, destination and tourist attraction in the area. Andersen outlines the concept in the choice according to the schematic diagram in figure 3.3.

Fig.3.3 Andersen.2014 Routine Mode Choice Decisions concept



Source (Andersen, 2014:33)

Figure 3.3. illustrates the process which commuters utilise depending on the information available for them to choose the routes passengers should take to arrive at their destination at the shortest possible time. With reference to the Rea-vaya BRT the choice of commuters' choice of facilities was mainly because of buses safety, security and cost convenience.

3.4.2. The optimal control theory

According to Claudui (2013:152), the ever-growing pressure imposed on the existing mass transit systems calls for a better technology to resolve operational issues. In line with this argument, Emanuel (2012:13) argued that optimal control theory deals with the problem of finding a suitable control for a given system for such optimality criterion to be achieved. It is widely used in engineering, information systems and management science to solve various types of management problems. As with the integration of intelligent transport system into bus rapid transport, its value is to minimise the traditional functions of management by operators and to be managed by intelligent transport system.

3.4.3. The queuing theory according to Sundarapandian (2009)

According to Sundarapandian (2009:47), the queuing theory is the mathematical study of waiting times/queues. In queuing theory, a model is constructed so that queue lengths and waiting times can be predicted. Queuing theory is generally considered as a branch of operations research, a discipline which deals with the application of advanced analytical

methods to help make better decisions, because the results are often used when making business decisions about the resources needed to provide a service (Johos, 2010:9-16).

The Queuing Systems Attributes and Disciplines are based on a transportation queuing system for vehicles and arrivals and/or departures. The queuing system has the following attributes:

- Calling population, which represents the population of potential vehicles who may have called for an arrival and/or departure
- System capacity, which is the limit in numbers of vehicles that the queuing model can accommodate at any time
- Composition of arrivals and/or departures, which can occur at scheduled times or at random times
- Queuing discipline, which is the behaviour of the queue in reaction to its current state
- Service mechanism, which means that service times may be constant or of some random duration.

Therefore, queuing models gain information on characteristic quantities that describe the workload of the transportation system or the time the activity needs to pass through the system.

3.5.Evolution of ITS development

The development of ITS is varied in various countries due to advances in telecommunication technologies. The major developments on ITS were made in Europe, U.S. and Japan and it went through three phases. The phases consisted of the preparation stage, feasibility study and product development (Kanoungo, 2015:350-351).

The first phase of the ITS began in the 1970s and 80s where several European companies were developing more complex systems that broadcasted messages that only cars affected by the message could receive. In the United States, government sponsored in-vehicle navigation and route guidance system - ERGS was the initial stage of a larger research and development effort called the ITS (Nowacki, 2012:404). In 1973 the Ministry of International Trade and Industry (MITI) in Japan funded the Comprehensive Automobile Control System (CACS). These systems shared a common emphasis on route guidance and were based on central processing systems with huge central computers and communications systems. Due to limitations, these systems never resulted in practical application (Nowacki, 2012:404).

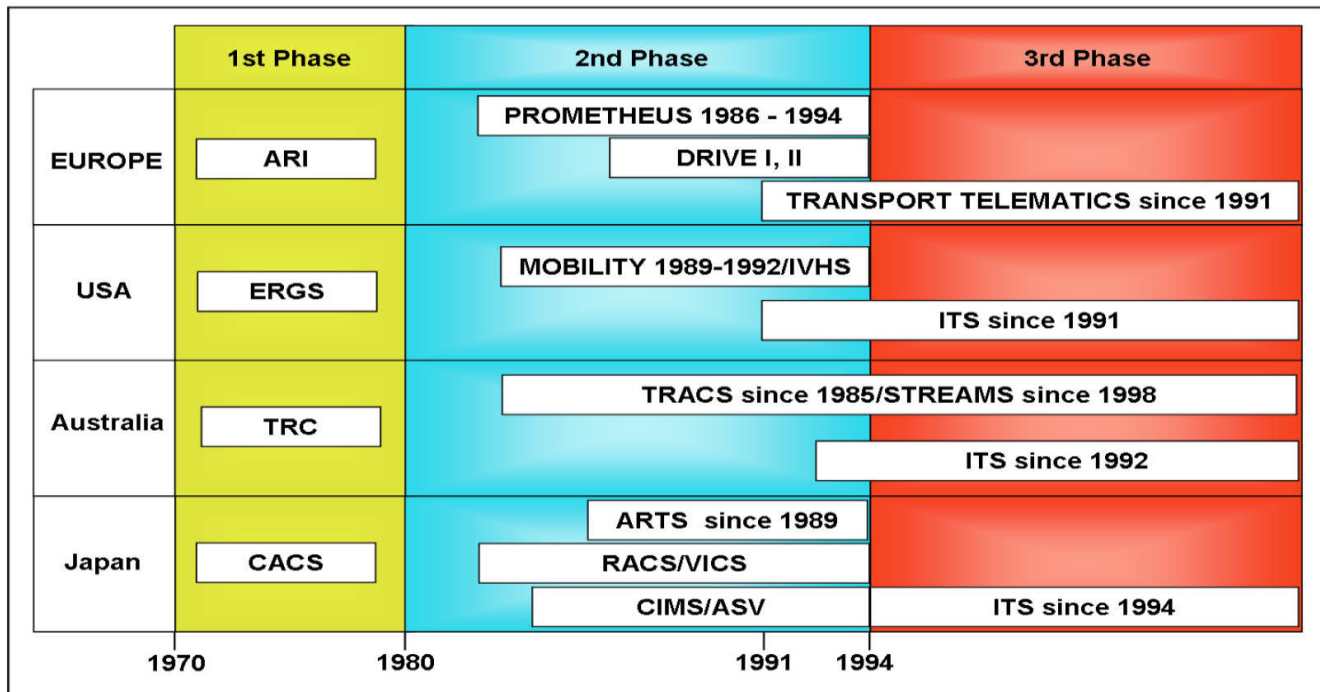
The second phase of ITS development focused on the establishment of conditions to develop an ITS system. The feasibility study made efforts for research and development for the practical

use of ITS. An example of the ITS developed at this stage was Prometheus which in 1986 was initiated as part of the EUREKA program, a pan-European initiative aimed at improving the competitive strength of Europe by stimulating development in such areas as information technology, telecommunications, robotics, and transport technology (Takaaki, 2014:53). In Japan, work on the RACS project, which formed the basis for current car navigation system, began in 1984. In 1985, a second-generation traffic management system was installed in Australia. This was known as the TRACS (Nowacki, 2012:406).

In 1989 in the USA the Mobility 2000 group was formed and this led to the formation of IVHS (Intelligent Vehicle Highway Systems) in America in 1990, whose function was to act as a Federal Advisory Committee for the US Department of Transportation. IVHS program was defined as an integral part, became law in order to develop “a national intermodal transport system that is economically sound, to provide the foundation for the nation to compete in the global economy, and to move people and goods in an energy-efficient manner” (Allen et al., 2000:03).

The third phase began in 1994, when the practical applications of earlier programs were seen and understood in intermodal terms rather than simply in terms of automobile traffic. ITS have started to gain recognition as critical elements in the national and international overall information technology hierarchy. At this stage, ITS receive attention so that it can be used in other modes of transport (Sharma, 2015:09). As a result of this, in 1994 the IVHS program (USA) was renamed the ITS (Intelligent Transportation Systems) indicating that besides car traffic, other modes of transportation receive attention and during the first world congress in Paris, the term - Intelligent Transport Systems (ITS) was accepted (Levitha et al., 2015:21). The ITS Japan established in 1994 promoted research, development and implementation of ITS in cooperation with five related national ministries in Japan and serves as the primary contact for ITS-related activities throughout the Asia Pacific region. ITS Japan is Part of a Global Advanced Information and Telecommunications Society (Takaaki, 2014:55). Figure 3.4 shows the phases of the evolution of the development of the ITS.

Figure 3.4 ITS development stages



Source (Nowacki, 2012:405)

From figure 3.4 can deduced that ITS development went through three major development phases and it was such that the benefits were disseminated through research and now in the process of being adopted by many large urban areas including Pretoria, Ekurhuleni, Cape Town, Durban and others in South Africa.

3.6. Intelligent Transport system architecture

A system architecture for ITS is an “overall framework for ITS” that shows the major ITS components and their interconnections. A very important part of the system architecture is the identification and description of the interfaces between major ITS components (Toshiyuku, 2004:3). According to Richard (2008:78), these interfaces allow the major components of an overall intelligent transportation system to communicate with one another and to work together. Many important ITS standards are written to make these interfaces consistent. An ITS system architecture provides a framework for planning, defining, deploying, and integrating intelligent transportation systems as follows:

- The user services that ITS and applications are expected to perform,
- The entities where these functions exist, and
- Information flows and data flows that connect functions and entities.

3.6.1. Components of ITS architecture

An ITS system architecture describes what ITS does (the user services), where this happens (entities), and what information moves between these components (flows). The components are explained as follows:

3.6.1.1. ITS user Services

User services describe the activities that ITS systems and applications perform or support. Typical user services include providing traveller information, managing traffic, electronically collecting tolls, helping drivers perform better (especially in emergency situations), responding to traffic incidents, managing public and private vehicle fleets, etc. (Bob, 2008:23).

3.6.1.2. Entities of ITS

Entities are physical places like traffic management centres and public transport vehicles where the user services are performed. Entities are also people like travellers and system administrators who interact with ITS applications, where information is received. Entities can also be systems, like Electronic Toll Collection (ETC) systems or Parking Ticket Management, which help to perform the ITS user services (Gary & Lissette, 2016:175). Similarly, entities can be external sources or destinations of ITS information that are not part of ITS itself. For example, the Global Positioning System (GPS) and the weather forecasting system are not themselves ITS applications or subsystems, but many ITS systems use information from GPS to determine the position of a vehicle (Kutcher, 2009:66).

3.6.1.3. Information and Data Flows

Information and data flows connect user services and entities into an overall system. For example, the electronic toll collection (ETC) includes data flows from a vehicle (physical entity) to a toll collection system (subsystem) and from the toll collection system to a central accounting system (external destination). The value of ITS applications comes from their ability to gather, analyse, and distribute information about the transportation system. This movement of information is described as “information and data flows.” The physical movement of this data is usually handled by wired or wireless communications, although some information still moves using paper and voice communications as well (Lucio & Rosaldo, 2012:4). The overall Intelligent Transportation System is a large and complex system because of its size and complexity and because it includes a large amount of Information Technology (IT).

ITS as a whole is too large and complex to install all at once even in the wealthiest and most technically advanced countries (Toshiyuku, 2004:24). In most countries, including both developed and developing countries, the right approach is to introduce ITS gradually and in stages, focusing first on the parts of ITS that provide the greatest value in proportion to cost. According to Amber (2011:4), the successful introduction of ITS must include staging, and planning for change, growth, and on-going integration as new functions are introduced and existing functions evolve.

3.6.2. Characteristics of the architecture of ITS

According to Chu-ni (2016:72), large-scale systems that are capable of evolving and expanding successfully have a number of desirable characteristics in common. The characteristics are fundamental in the designing and it has five components as follows:

3.6.2.1. Compatibility of ITS

Compatibility means that when software or hardware components in a system are replaced or upgraded, the system will still work. A clear, consistent specification of functionality and of the interfaces between components greatly aids compatibility (IBM group, 2014:12). System architecture is an important tool for achieving these clear, consistent specifications.

3.6.2.2. Expandability of ITS

Expandability means that a system can be successfully upgraded to handle greater volumes of work, operate in additional locations, or incorporate new tasks. The issues of expandability and compatibility have many points in common. Taking an ITS example, it should be easy to expand the service area of traffic control signals or enhance their functions by adding additional traffic signals and variable message signs (VMS), adding new types of equipment (e.g. Environmental sensors), or upgrading the software controlling the signals. Expandability depends on many factors, including good system design and component compatibility (Jaen, 2011:78).

3.6.2.3. Interoperability of ITS

According to Mongwe (2014:23), interoperability means that two separate systems can be linked to work cooperatively and without interfering with one another. Interoperability can be an issue for multiple systems used by a single operator, but it is a much larger challenge when connecting two systems from different operators, regions, or countries. Cillia (2002:63) also indicated that payment systems using smart cards are an ITS example. Smart cards can be used to pay tolls, train and bus fares, and for parking. If the operators of such services can

agree on technology and on administrative and financial processing issues, users will be able to use a single smart card to pay for all the services. If both systems were developed under the same overall system architecture and were developed conforming to the same standards, the likelihood of success in making the systems interoperable is greatly increased.

3.6.2.4. Integration.

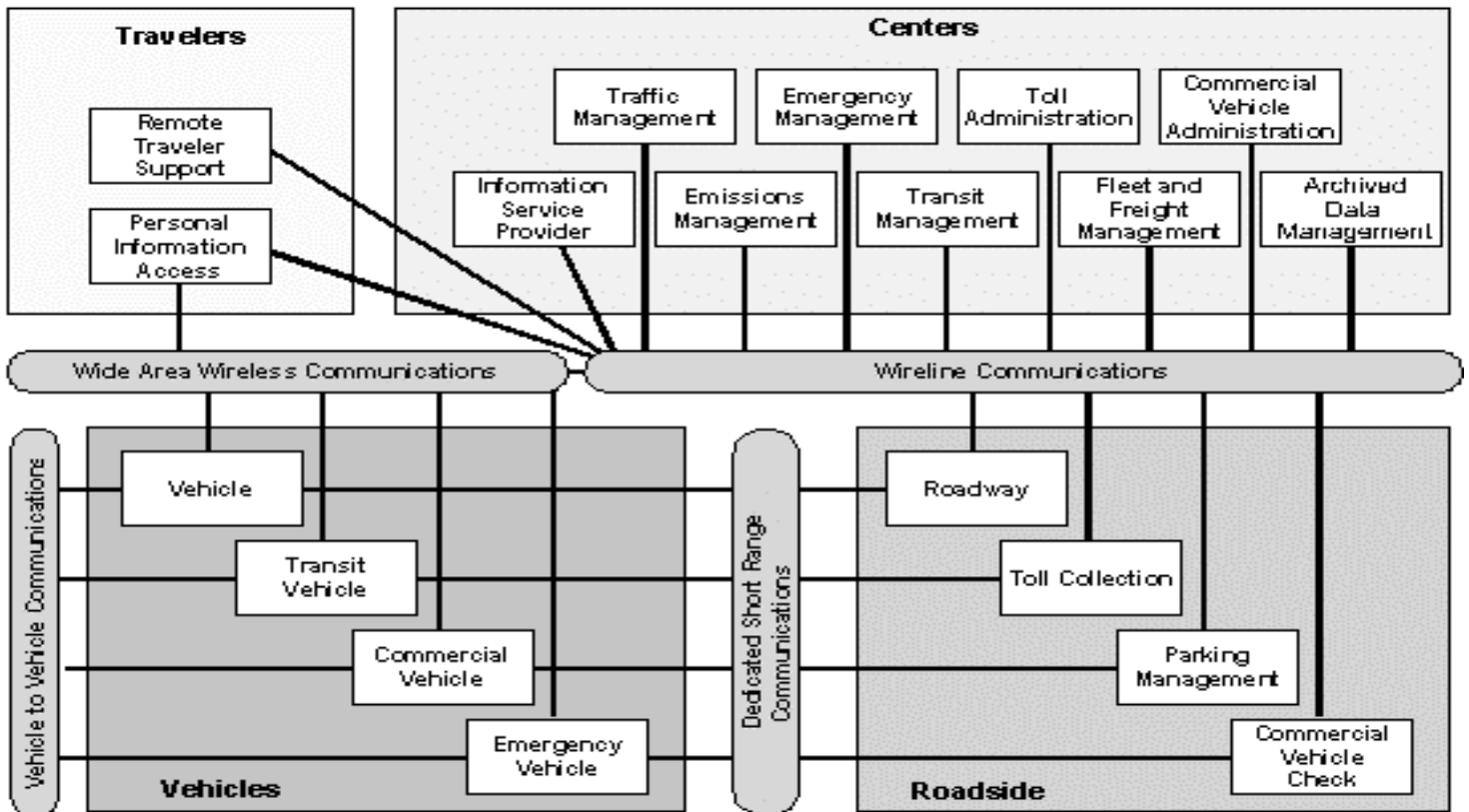
According to John (2011:12), one approach to providing interoperability is to integrate applications into a single system. Integration is the mutual connection and harmonization of multiple systems. Integration can be an effective approach, especially when planned in advance. When a single, integrated system is built to provide multiple applications, there can be significance savings in development time, effort, and cost as compared to building each application separately (Andrew, 2015:13).

However, since a single integrated system is more complex, particular care must be taken in its planning and design. Integration of existing applications is much more difficult than building an integrated system from scratch. In either case, a common architecture, especially agreeing on interfaces can make integration much more reliable (Andrew, 2015:33).

3.5.2.5. Standards.

The desirable characteristics of successful large-scale systems outlined above are easier to achieve if the developers and deplorers make use of good standards. It is through standards that data models, interfaces, and functionality are made consistent (Rodrigo, 2014:36). According to Douglas (2015:6), system architecture of intelligence transport systems can be summarised in the figure 3.5 where various functions and infrastructure of ITS are illustrated.

Figure 3.5. USA ITS architecture.



Source (Douglas, 2015:4.)

Figure 3.5. illustrates the relationship between various components for the designing of an ITS architecture system.

3.7. Objectives of a functional intelligent transport system

According to Bail (2015:56), an intelligent transport system is aimed at improving transportation management systems with a view of achieving the fundamentals of transportation system which include the following drivers:

3.7.1. The Safety objective of ITS

In order to meet the needs of commuters through traveling, to avoid crashes and fatalities in the road systems, an intelligent transport system can provide a safe environment for commuters while improving performance of the system (United Nations, 2012:2). The system focuses on reducing the number of crashes and lessening the probability of fatality should a crash occur (Mike, 2014:10).

3.7.2. Improvement in mobility

Improving mobility (and reliability) by reducing delay and travel time is a major objective of many intelligent transport systems components. According to Shirley (2016:28), delay can be measured in many ways, depending on the type of transportation system being analysed. Delay is typically measured in seconds or minutes of delay per vehicle (Runhaar, 2012:44). The intelligent transport system through the utilization of various technological and telecommunication application provides solution that eases the flow of traffic and thus improves mobility of a specific urban area (Jamie et al., 2009:13).

3.7.3. Improvement in efficiency

Mitretek (2011:97) alludes that intelligent transport systems components seek to optimise the efficiency of existing facilities and use of rights-of-way so that mobility and commerce needs can be met while reducing the need to construct or expand facilities. This is accomplished by increasing the effective capacity of the transportation system.

3.7.4. Increased productivity

Intelligent transport systems implementation frequently reduces operating costs and allows productivity improvements. Similarly, ITS alternatives may have lower acquisition and life cycle costs compared to traditional transportation improvement techniques. The measure of effectiveness for this objective is cost savings as a result of implementing ITS (Archer, 2010:15).

3.7.5. Customer satisfaction

Given that many ITS projects and programmes were specifically developed to serve the public, it is important to ensure that user (i.e., customer) expectations are being met or surpassed. Customer satisfaction measures characterise the distance between users' expectations and experiences in relation to a service or product.

3.8. Functional areas for intelligent transport systems

There are various functions that can be performed by an intelligent transport system depending on the system design objectivity and role in transport management. The functions differ from city to city, institution to institution and various mode of transport.

3.8.1. Vehicle control systems

Vehicle control systems use real-time and other information to allow vehicles to respond to incidents and network conditions more autonomously, or to support the user in responding. ITS technology based vehicle control systems range from driver assistance systems and advanced driver assistance systems (ADAS) through to semi-autonomous and autonomous vehicles (Ling, 2012:390-392). According to Matthew (2015:6), these systems can include various degrees of cooperative ITS technologies (C-ITS). Such systems can potentially bring significant safety benefits, and can also address congestion problems and reduce emissions through smoother driving.

3.8.2. Traffic and network management systems

One of the key element of the ITS is to make sure that vehicle control systems respond to real time incidents to assist the driver via semi-autonomous support. In addition to this, the traffic management systems optimise the movement of vehicles by using real-time information to intervene and adjust controls such as traffic signals to improve traffic flow. Citivas (2015:9) stated that an intelligent transport system is a strategy to increase overall transport network efficiency by encouraging a shift from single occupant vehicle trips or shifting vehicle trips out of peak periods.

Majority of motorists will prefer to use their cars regardless of any form of penalty imposed (Kalaichavi et al., 2016:174-179). Ben (2015:64) indicated that electronic means of charging (such as electronic toll collection) minimise the disruption to traffic flow, but these introduce enforcement issues requiring identification and tracing the vehicle/driver.

3.8.3. Real-time and near time information for travellers

Real-time information systems use information gathered on network demand and disruptions, sometimes combined with Global Navigation Satellite Systems (GNSS) to help vehicle operators, public transport passengers and other users to adapt and make informed travel choices (Ryan, 2014:32). According to Eric (2012:54), it can also be used to enable behaviour change, for example by providing information to drivers to allow them to adopt efficient driving styles.

3.8.4. Supply chain and fleet management systems

For fleet managers, the ITS can provide an improved vehicle effectiveness and efficiency through the monitoring of vehicle location performance and handling. The system can improve routing, fuel use, be used to co-ordinate freight arrival times and schedule vehicle and infrastructure maintenance (Mandzuka, 2015:4). According to Leal (2011:7), the ability to track cargo from the farm gate to the consumer has allowed for streamlining of the supply chain and improvement of supply chain logistics.

3.8.5. Charging and payment systems

Bethlehem (2009:13) indicated that the ITS technologies can provide a more efficient and effective means of charging for transport services that closely match pricing to the use of the service. The systems use a smart card as swipe and go travel cards on public transport networks (Tom, 2014:48). More complex systems are capable of identifying individual vehicles and automatically debiting toll charges. These systems are becoming more sophisticated, reliable and cost effective, and are currently being investigated in many jurisdictions (Guang & Roger, 2013:11).

3.8.6. Asset management with support of ITS

Asset management tools in ITS technologies are also available that support infrastructure managers in managing and maintaining their assets, most especially those that respond to BRT asset. These technologies include the following:

- Technologies that provide feedback on infrastructure (e.g. traffic counting devices, weigh-in-motion sites and monitors), allowing maintenance needs to be better informed and managed.
- Business analytics and asset management software used to provide real-time, accurate analysis and reporting of network assets to help operators manage their assets in a more efficient manner. Well-targeted and optimally-timed asset management, based on good asset condition information, can bring significant financial savings.

3.8.7. The ITS as a network monitoring device

Congested traffic conditions are often accompanied by a high incidence of rear-end and/or side swipe collisions due to the prevalence of slow moving, stop-and-go traffic. The traffic

management techniques associated with intelligent transport systems can reduce the number of collisions in two ways, by:

- Improving operational efficiency and reducing congestion. This reduces overall collisions and improves safety.
- Clearing incidents as soon as possible and informing motorists of traffic conditions ahead, thereby reducing the likelihood of secondary collisions occurring in the congested traffic stream.

Network monitoring requires that monitoring devices be installed in strategic locations throughout the transportation network to measure and record traffic flows, travel times, accidents and other security incidents, monitor ITS field equipment as well as the effect of traffic congestion on the environment (Garima, 2015:40-47). The detectors and cameras can be connected to a Traffic Management Centre (TMC) where data can be stored and images viewed. The vehicle detectors could be used to automatically select traffic signal timings (real-time traffic responsive control) and detection of incidents on expressways (Vahid, 2012:9).

3.9. Advanced public transport management systems

Advanced public transport management systems can be defined as an intelligent transport solution that seeks to apply transportation management and information technologies to public transport systems to increase their efficiency of operations and improve the safety of public transport riders (Javier, 2011:1). The systems can be divided into three categories i.e. operators, ITS systems for the customer and ITS system for the vehicle. The three categories are explained further below:

3.9.1. ITS for the operator

An intelligent transport system for the vehicle operators eases the performance of various functions for management and operations of public transport system. Five ways are as follows:

3.9.1.1. Automatic vehicle location device

An automatic vehicle location (AVL) technology is applied to monitor the location of transit vehicles in real time through the use of GPS devices or other location-monitoring methods. Information about the vehicle location is transmitted to a centralized control centre in either raw data format or as processed data. Automatic vehicle location systems (sometimes referred to as automatic vehicle monitoring or automatic vehicle location and control systems) are computer-based vehicle tracking systems (Bratislow, 2010:79-83).

The use of automatic vehicle location into public transit allows for various functions to be improved such as the following:

- Improved system control. The system can be calibrated with greater ease to distribute service times and coverage adequately through the application of signal priority and control centre and on-street supervision.
- Improved bus safety. In an emergency, the transit control centre can relay vehicle location immediately to emergency response agencies.
- Improved quality of service. Passengers can be notified in real time of the location of the next bus and its expected arrival time.
- Improved system integration. Bus transfers can be better scheduled and controlled by knowing the location of each vehicle.

An AVL can be incorporated to provide enhanced vehicle monitoring, and quicker response to breakdowns and emergencies on vehicles (Yening, 2013:1-4). It can also be integrated with transit signal priority, passenger information systems and APC system which can assist transport agencies with information on stop arrivals and transit origin and destination data (Durake, 2015:39).

3.9.1.2. Transit signal priority

Transit signal priority (TSP) is the process of altering traffic signal timing at intersections to give a priority to transit operations. TSP can be triggered by BRT vehicles operating in their own right-of-way or in mixed traffic along a street (known as “mainline” priority), or operating in an auxiliary lane at an intersection (known as a “queue jump”) (Chen & Gary, 2014:21-29).

With mainline TSP, the typical treatment is to extend the green signal or truncate the red signal to allow priority for BRT vehicles, thus reducing intersection delay. With a queue jump, the transit vehicle receives a separate green phase to go through the intersection before the adjacent through traffic (Kyoungcho et al., 2015:17-35). There are two types of TSP that are beneficial to BRT operators such as:

- Unconditional priority, where a BRT vehicle would always have priority at a particular intersection,
- Conditional priority, where the BRT vehicle would receive priority at an intersection only if certain transit or traffic operating conditions are met, and

TSP is typically applied when there is significant traffic congestion and bus delays along a roadway.

3.9.1.3. Automatic passenger counting

Automatic passenger counters (APCs) are devices on board transit vehicles used to record boarding's and alighting's at each stop and keeping a running total of passengers on board the vehicle (John & Johan, 2011:11-12). The APC units include sensors (typically infrared) at doorways to monitor passenger movements on and off a vehicle. An APC system creates an electronic record at each bus stop, typically including stop location, stop date and time, time of door opening and closing, and number of passengers boarding and alighting. APC data downloading options include manual downloading via a laptop computer, wireless data via a local area network, and real-time reporting (Nigel, 2011:4-23).

3.9.1.4. Computer-aided dispatch

Computer-aided dispatch (CAD) is often used by operators for a Demand-Responsive Transit (DRT) services. DRT services are typically used to provide disabled passengers with a complimentary transit service that usually includes door-to-door services on an as-needed basis. DRT services are often provided by a combination of one or more type of vehicle: in-house transit vehicle, taxicab, or independent service contractor operating a small bus or a modified van or car (APCO, 2015:13-45).

Because the demands on the service fluctuate greatly from day to day and from hour to hour, many transit agencies have acquired CAD software to improve the efficiency of their operations. The software can be used to send messages to the transit vehicle or taxicab via a mobile data terminal or to store and retrieve data (radio logs, field interviews, client information, schedules, etc.). A dispatcher may announce the call details to field units over a two-way radio. Some systems communicate using a two-way radio system's selective calling features. CAD systems may send text messages with call-for-service details to alphanumeric pagers or wireless telephony text services. The central idea is that people in a dispatch centre can easily view and understand the status of all units being dispatched. CAD provides displays and tools so that the dispatcher has an opportunity to handle calls for service as efficiently as possible (APCO, 2015:13-45).

3.9.1.5. Lane control technologies

An intermittent bus lane (IBL) or moving bus lane (MBL) is a restricted lane for the short time that the bus uses that particular lane. IBL can also be called a moving bus lane. This is a general-purpose lane that can be changed to a bus-only lane just for the duration of time

needed for the bus to pass. Afterward, the lane reverts to a general-purpose lane until another approaching bus needs the lane for its movement (Han-shue et al., 2009:45). This system ties into variable message signs (VMS) to inform the drivers of lane restriction. It requires integration into real-time ITS traffic monitoring systems to record levels of congestion and compute the dynamic space and approach length required to activate on and off the longitudinal embedded flashers. This system is dependent on an interconnection and special software within the signal controller system of the existing roadway (Joseph et al., 2010:11).

3.9.2. ITS for the customer

This section analyses information on the intelligent transport system technology that is usually applied to improve management and operation of the public transport systems with a focus on customers/commuters (Anne, 2009:88).

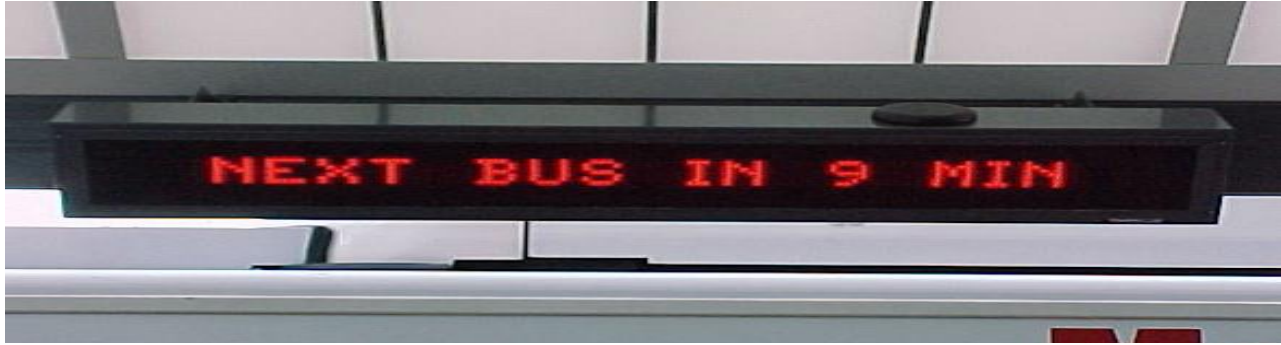
3.9.2.1. Real-time passenger information

Passenger information, specifically information related to the transit service, takes many forms, including information needed before making a trip, during the trip and at the termination of a trip. Figure 3.5 shows the display information via VMS. The main sources of information need to be provided as follows:

Through appropriate media that can be accessed before making a trip. These help with trip planning and the ultimate decision to use the transit facility.

- At stations or other points prior to boarding a transit vehicle. Relating primarily to vehicle arrival, these help instil rider confidence and comfort and can contribute to overall travel time competitiveness (e.g., a rider can do a quick errand if a vehicle arrival is several minutes away).
- On the vehicle, itself. Next-stop information, traffic updates and service disruption alerts can also instil confidence and comfort by helping passengers reach destinations and transfer connections most efficiently.
- At a termination point. Destination and transfer information can help manage rider expectations during and after the trip.

Figure 3.5. VMS with real time passenger information displayed.



Source (Joseph et al., 2010:14)

Figure 3.5. illustrates a message sign displaying for passengers to be informed when the next bus will be available.

3.9.2.2. Passenger Wi-Fi

Wi-Fi allows transit customers to connect to the Internet using enabled mobile devices, such as laptops, cell phones and tablets. Public access is provided through hotspots provided either free of charge or for a fee (pay-per-use or subscriptions models are possible). These wireless hotspots can be located both on board transit vehicles and at stations. At stations, wireless service can be provided with off-the shelf routers and modems (cable or DSL). For on-board Wi-Fi, two options exist: installing routers on each vehicle connected to satellite networks, or creating a continuous wireless mesh along the corridor through a few overlapping fixed access points.

Although the wireless Internet provision is not a critical transit component, it is however a high-quality customer amenity. Wi-Fi is used with laptops and an increasing number of mobile devices to provide higher speed access to the Internet than is available through cellular networks. One of the many potential benefits to customers is an increased enjoyment of transit. In particular, it can allow people to make use of their time in transit for entertainment or work, which could have the effect of decreasing their perceived transit travel times (Jane, 2001:98).

3.9.2.3. Fare collection

According to Joubert (2014:43), passenger transit fare collection device is an automated way which bus passengers pay their fares, either on the bus, at the station or in advance. There are various methods of fare collection that use intelligent systems and they can be incorporated into public transport; and they include the following:

Fare media: What medium/media will be used to store fare information? Options include simple tickets, flash passes, magnetic stripe passes, magnetic stripe stored value cards, and smart cards (typically contactless). Each of these fare media has advantages and disadvantages, and the selection of a specific medium should consider the fare policy that is being implemented (Jacobs, 2004:34)

Sales/vending technology: Most rail-based transit systems employ some type of vending machine technology, but these are generally less common on bus systems, with agencies relying instead on cash fare and point-of-sale merchants to sell items such as monthly passes and multi-ride tickets. Given the higher-quality image and customer-friendly experience that is often one of the goals of BRT, introducing ticket vending machines at BRT stations may be very beneficial, even if these are not typically deployed at regular bus stops (Joseph, 2014:60).

Communications: Many state-of-the-art fare collection systems now require real-time communications for activities such as credit card verification and status monitoring. Particularly in an on-street environment, hard-wired communications may be expensive and difficult to maintain. So, consideration should be given to developing a secure wireless communications network to support the fare collection system (Rian, 2008:54).

Electronic fare payment: Transit managers across the country are exploring and adopting electronic fare payment System concepts. One of the major incentives for this shift is that transit operators want to decrease expenditures on fare collection and lessen the associated security risks connected with collecting large amounts of cash and tokens while providing greater convenience for transit riders (Darn, 2012:88).

Automated Fare Payment Systems: This is a system or environment in which a card will be issued or used as a fundamental issue. Generally, cards will either be used in what is commonly referred to as an “open” (multiple card issuers and multiple service providers) or “closed” (a single card issuing organization) system (Blake, 2009:29).

3.9.2.4. Surveillance/CCTV/security systems

According to Winston (2009:89), security systems are needed to ensure safety with a CCTV surveillance device as well as alarms, both of which can be located both on board vehicles as well as off-board in stations or along guide ways. Amaru (2008:76) stated that surveillance devices are principally made up of closed-circuit television (CCTV) cameras, occasionally equipped with microphones. These enable a central dispatch and/or control centre to remotely

monitor vehicles, stations and guide ways. In addition to this, increased resolution of the recording can be triggered by an operator on board or remotely by central dispatch.

According to Corelate (2006:48), alarms can include passenger-activated alarm strips or buttons on vehicles or in stations, and operator panic buttons including those found on mobile data terminals (MDTs) as part of real-time CAD/AVL communication systems. There are two types of panic alarms: overt and covert. Once activated, overt alarms can be heard by all passengers. This type of alarm is preferred in emergencies to alert all passengers to take immediate action (i.e., evacuate the bus). In contrast, the activation of covert alarms is known only to the operator and central dispatch.

Integration to real-time CAD/AVL communications means that central dispatch is able to track the exact location and direction of travel of a bus requiring assistance and can identify what resources are accessible to the bus (law enforcement, emergency response, transit support staff and other buses. Figure 3.6 illustrates a typical example of a CCTV camera installation.

Figure 3.6. CCTV cameras for surveillance.



Source (Joseph, 2010:22)

Figure 3.6. illustrates how the CCTV cameras that can be used for surveillance across various stations of the BRT.

3.9.3. ITS for vehicle management

This section describes types of transit ITS that are most related to the transit vehicle. The various ITS systems that can be incorporated into vehicles for a smooth operation and management have been reviewed in this section and explained further below:

3.9.3.1. Fleet management

Fleet management provides the fleet manager a complete overview of all buses. A fleet management system records key performance indicator defined by the fleet manager. Some data can be stored in raw data form, while other data may be stored as average during a given period. For example, it may be worthwhile to know how many times the doors were opened (raw data = door opening count). On the other hand, fuel consumption can be reported as an average over the course of the day or route (Fiatemah, 2012:3).

The data is stored on the vehicle computer and downloaded to a central system. Usually this data does not need to be live; the data can therefore be downloaded at the end of the day. Once the data is retrieved, it can be compared to other buses, other routes, and so on. Data analysis software can be used to correlate indicators. Most commercial fleet management software has pre-defined reports (Jill, 2014:2-5).

3.9.3.2. Collision avoidance systems

Collision avoidance technologies can be divided into systems that are progressively more intrusive, starting with those that merely warn or advise the driver based on sensors inside or outside the vehicle (Beatric, 2008:1). Next are those that take over partial control of the vehicle or make safety-enhancing adjustments such as tightening seatbelts, turning down the throttle, activating the brakes and changing the suspension, without the driver acting. The third type takes over full control of the vehicle (Collins, 2011:399).

Collision warning systems act on the principle that enable drivers to accurately recognize their environment will enhance their safety. They prompt the driver with an alert when danger exists during a lane change or when the vehicle is having difficulties in lane-keeping.

There are several types of collision avoidance systems (CAS) that have been developed, tested and implemented to reduce the number and severity of collisions. Some of the vehicle-based technologies under development include the following:

- Forward collision warning systems or rear-end collision avoidance systems warn drivers that they are in a conflict situation with the vehicle in front of them. These conflicts may be due to the lead vehicle stopping, slowing or maintaining a constant speed relative to the approaching vehicle,

- Rear impact warning systems warn the lead vehicle driver that he or she is in conflict with the approaching vehicle. The warning can be given to the lead vehicle or the approaching vehicle,
- Intersection warning systems are designed to detect and warn drivers of approaching vehicles and potential right-of-way violations at intersections,
- Obstacle detection systems use vehicle-mounted sensors to detect and alert the driver to obstructions, such as other vehicles, debris or animals in the vehicle's path,
- Lane-change warning systems warn drivers that the vehicle is unintentionally drifting out of the lane,
- Rollover warning systems notify drivers that they are traveling too fast for an approaching curve, based on the vehicle's operating characteristics, and
- Road departure warning systems warn drivers that their vehicle is about to leave the roadway, whether they are approaching a curve too fast or about to drift off the road on a tangential section.

A key issue related to most CAS is the use of algorithms to accurately assess false alarms and to recognize actual dangers from trivial threats (i.e., a stopped car versus a roadside sign on a curved road). Most of these technologies are currently under development, but some have begun to be implemented on in-service transit vehicles. Due to the emergence of these CAS, there is limited data available to determine the actual benefits of these systems (Walter, 2003:261).

3.9.3.3. Lane guidance

Lane guidance, also called lane assist, is a system that provides feedback to the bus operator for more precise steering. These systems can also provide the ability for a bus to steer itself through computerized or mechanical means (Mathew, 2011:3). The bus driver still operates the throttle and brake, much like the operator on a train, but is hands-free on the steering wheel except in emergency situations.

Types of technologies used to accomplish lane guidance are described as follows:

Mechanical guide wheel: A small 4½- to 6-inch diameter “guide” wheel mounted laterally near each front bus tire that makes contact with the vertical face of the platform curb. These guide

wheels are connected directly to the vehicle's steering linkage. Guide wheels can additionally be mounted on the rear of the bus chassis. This type of guidance system is of modest cost (Max et al., 2003:32).

Optical guidance: In this vision-based technology, a camera is mounted on the vehicle that uses optics to “see” specific lane markings on the road ahead to determine the vehicle relation in the lane. A computer analyses the image looking for special striping within the bus way to steer the bus to follow (Alian, 2014:11).

Magnetic guidance: Magnets at 4-meter intervals are embedded within the bus way. A sensor on the vehicle detects the magnetic material, using it to determine the vehicle's lateral deviation from the magnet. This deviation is then relayed to an on-board computer to compute a steering correction in order to guide the vehicle along a programmed path (Wei-Bin, 2007:6).

GPS guidance: A highly accurate constellation satellite network system and antenna mounted on the bus can triangulate the precise location of the bus, and with the addition of differential correction can locate the bus to know its location within 1 to 2 inches. This technology enables the bus to be guided by comparison to the real time GPS coordinate set of the moving bus to a predetermined alignment that has coordinates established along its route (Leopoldo, 2013:192).

3.10. The Bus Rapid Transit/Transport

According to Rahim (2014:38), communities have been looking for new and innovative approaches to address increasing urban congestion and associated pollution while providing efficient and effective transportation options. Adding more highways is expensive and disruptive, and is not always an environmentally sound approach. However, light rail rapid transit systems, of interest to many communities, require a significant initial capital investment, and may not be an effective solution for all urban transportation problems. Transit buses provide an essential transportation service in metropolitan areas, but are often viewed as slow and unreliable.

Bus Rapid Transit System (BRT) is a flexible rubber-tired, rapid transit mode that combine stations, vehicles, services, running ways and intelligent transportation system elements into an integrated system, with a strong positive identity that evokes a unique image (Shongwe, 2007:2).

One innovative approach is the use of buses rather than light and/or heavy rail, in an integrated, well defined system with design features similar to light rail rapid transit systems. Some of the

features of these Bus Rapid Transit (BRT) Systems that may be similar to light rail rapid transit systems are the following:

3.10.1. Basic components of the BRT systems.

BRT systems differ from city to city because the system's design is dependent on the needs of the commuters in that city; the road networks, patterns, routes and whether the governments of cities where the BRT is available have policies in place as well as available financial resources (Cabrera, 2010:12).

The literature on BRT systems indicate that although systems may differ in design, route and size, the basic components of BRT systems are similar in each city. Depending on the factors mentioned above by Cabrera (2010), BRT systems could range from 'BRT-Lite' to full service BRT systems (Thole & Samus, 2009:23).

A full BRT system is ranked the highest of BRT systems. The minimum characteristics that a full BRT system has, is a designated bus-way that is usually situated in the middle of the road (median lanes), an integrated network of routes and corridors, improved stations that are secure, level access, pre-board fare collection, fare and physical integration between routes, corridors and feeder services and restricted entry to prescribed operators under a reformed business and administrative structure (Wright & Hook, 2007:15).

Some of the common advantages of BRT systems are:

- Dedicated bus lanes, mixed traffic lanes, reserved lanes on freeways. This provides exclusive right of way to buses allowing them to reach greater speeds than conventional buses,
- Level boarding, off-boarding fare payment and multiple doors for boarding all allow for ease of passenger flow on to buses, and
- Intelligent Transportation Systems (ITS) are more commonly used in developed countries because of its capital cost. ITS provide buses with real time information and bus signal priority (Wright & Hook, 2012:21).

In view of Naido (2011:92), the BRT is designed to address the sources of delay of traditional bus service and to be an attractive service to passengers. BRT is an incrementally enhanced transit mode, providing faster, passenger-friendly service. This is accomplished in multiple ways

including improvement to the infrastructure, vehicle road use and stops/stations; utilizing cleaner, quieter and lighter vehicles; and integrating a mixture of ITS technologies.

The goals for a BRT system are similar to the goals of other rapid transit systems. The service must be rapid, providing reduced travel times to passengers. However, there are other BRT service goals that can provide a meaningful rapid transit service. The following are the generally agreed upon list of BRT goals:

- Shorter trip times—Fewer stops; Faster travel; Less congestion,
- Short wait—More frequent service; Even spacing between vehicles,
- Easy to use—Easy and rapid embarkation and debarkation; Simple fare collection; Clear signing including indication of routing,
- Accessible—Ease of access for physically challenged and elderly,
- Welcoming—Comfortable vehicle interior designed for both seating and standing; Clean, affordable service (in line with other transit services),
- Integrated—Convenient to parking and other transportation modes including neighbourhood bus service and bicycle access, and
- Incremental development—Service can grow to meet rising demand.

3.11. Case studies of ITS in developed and developing countries

Case studies relating to intelligent transport systems have been reviewed because it is critical to understand the design, implementation and management of ITS in other parts of the world.

3.11.1. Experiences of ITS in developed countries

To understand how intelligent transport system in developed countries are been utilised and the experience of the system, the following case studies have been reviewed and lessons learned:

3.11.1.1. Public Transport Payment – Oystercard in United Kindom

The Oystercard is a public transport smartcard used in London, UK. Some Oystercards are used like season tickets (abonnements), but they can also be used as stored value tickets – passengers can charge them up with money (even if they also use their Oyster as a season ticket on another part of the network) (Catherin, 2010:5-12). It is contactless, using radio

frequencies for the card to communicate with the card reader. Oystercard also gives passengers a roughly 33% discount compared to buying cash fares. There is therefore a major incentive for passengers to move over to the Oystercard, which is particularly important on buses in London, where traditionally passengers have paid the driver if they want a cash fare, which slows down the buses (at stops) very considerably (Wei, 2011:34). The use of a Smartcard also gives operators much better data about how many passengers travelled on which trains and buses, which can (depending on the nature of the financial contract between operator and public transport authority) make the distribution of revenue to operators much more accurate than if there are only paper tickets.

3.11.1.2. AVLS and AFCS Integration into BRT Ireland.

Ahmedabad's Janmarg BRT system is the first to implement a fully integrated ITS solution for bus operations in Ireland that includes AVLS and AFCS along with financial settlement systems. Janmarg incorporated all the components: GPS, on-board computers, driver consoles, two-way voice communication, PIS inside the bus and at all bus stations, fare-gates, RFID smart-card fare payment media, and a dedicated control centre with large video wall (Priyanka & Powona, 2012:78).

One of the significant and essential improvements to the Janmarg AVLS implementation is the possibility of assigning buses to pre-defined schedules in real time. Individual buses are not fixed to a specific schedule, allowing for spare buses to replace scheduled buses while they are in maintenance (Priyanka & Powona, 2012:78). Further, if bus schedules need to be exchanged due to operational reasons, the system tracks the bus against its current operated schedule rather than a fixed one. The on-board driver console clearly displays the number of minutes by which the bus deviated from its schedule. This conveys to the driver the need to slow down or make up for lost time, thus resulting in better service reliability. A two-way line also enables communication between the driver and the control centre, in case of alerts.

Since the BRT operates on a fixed, dedicated right-of-way, the planning needs and the travel time variations by time of day are much less, thus reducing the analytics that are necessary to create schedules.

3.11.2. Experience of ITS in developing countries.

To understand how intelligent transport system in developing countries are been utilised and the experience of the system, the following case studies have been reviewed and lessons learned:

3.11.2.1. Curitiba BRT: Intelligent public transport.

ACIS implemented Intelligent Transport Systems Curitiba, Brazil to encourage the use of public transport. The system currently was adopted to provide residents with an electronic display in their homes which tells them when the next bus will arrive. Buses also use TLP (traffic light priority) to improve speed through traffic lights and bottlenecks if necessary, improving reliability and regulating the service. The systems were discontinued due to the increased cost involved with data management and dissemination of the information to residents. Infrastructure challenges such as internet connections also hampered the dissemination of bus arrival and departure time information. The case study indicates that proper consideration of the full operating cost of intelligent transport systems should be taken into consideration before implementation of the initiative.

3.11.2.2. Jaipur India (ATPS).

In August 2011, Jaipur City Transport Services Limited (JCTSL) signed an agreement with UTI Infrastructure and Technology Services Limited (UTIITSL) to provide Intelligent Transport Management Systems for common mobility cards in Jaipur (JCTSL, 2013). Initially, the project was to introduce an entire system including AFC, a vehicle tracking system, management information systems reports, a central financial settlement, a settlement house, etc. UTIITSL's role was to design, procure, develop, install, operate and maintain the project (Priyanka & Powona, 2012:84).

The project was to be implemented in a phased manner and ultimately result in a comprehensive system that included ETMs, AVLS and PIS technologies. The system however, was not launched due to three main issues: the lack of coordination, management issues and the breakdown of hardware. The National Common Mobility Card (NCMC) system requires all agencies involved to comply with standard technology requirements to ensure a cohesive system (Priyanka & Powona, 2012:84).

In the first phase of the project, several issues came up. The ETMs were introduced by UTIITSL in February 2013 and within a few months they were operating on all the bus routes. Serious issues started emerging fairly early after ETMs were put into operation, some of which are listed below:

- Poor battery life: The battery of the ETM did not last for more than 4-5 hours. To rectify the issue, UTIITSL provided battery back-up, which needed to be connected and

attached to the ETM, adding considerable weight to the machine (>800 gms). This made it cumbersome to handle and operate by the conductor.

- Additional work load: This led to 80,000- 90,000 paper tickets being issued daily, which was nearly 70-75% of the total ridership. This created extra work for the agency, to manage two systems – paper tickets and the ETM-issued tickets.
- Non-Functional ETMs: 150 out of the 221 machines were non-functional and could not be used, requiring additional paper tickets to be issued.
- Revenue Leakage: The use of paper ticket posed a problem of potential revenue leakage.

These issues led to a complete failure of ITS technology. Finally, JCTSL withdrew ETMs from 17 of a total of 18 routes.

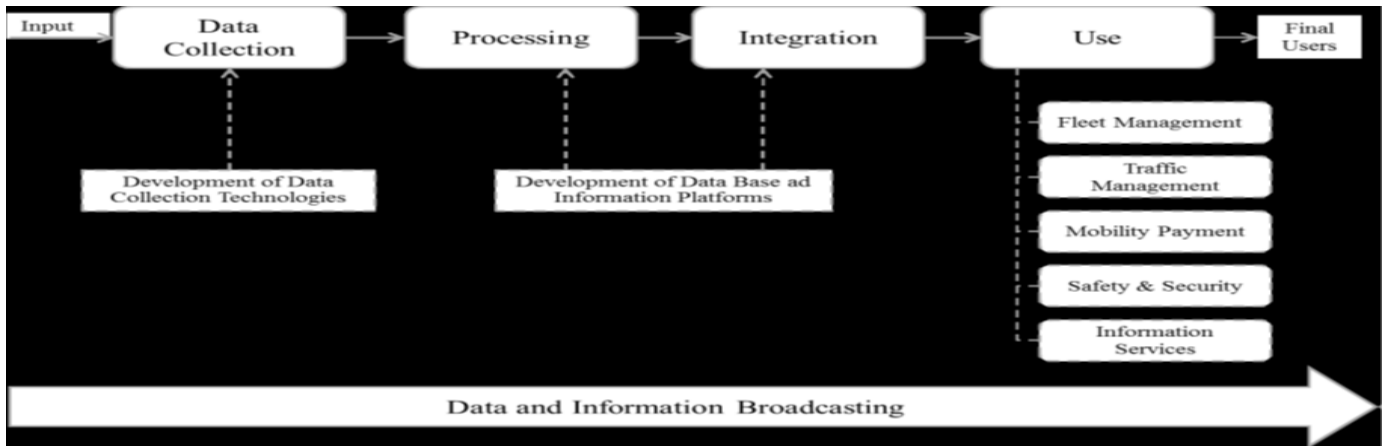
3.12. Emerging models for application of ITS in Bus Rapid Transport

The integration of intelligent transport systems in the Bus Rapid Transport has been identified as a crucial aspect of improved management of transport networks in urban areas and the following models are worth taking note of when considering the management and operations of BRT by intelligent transport networks.

3.12.1. Info-mobility model

Info-mobility encompasses the set of information management systems that aim at improving mobility systems by providing required information to transportation managers and travellers (Arena et al., 2013:87). Info-mobility is based upon the use of Intelligent Transport Systems, technologies that enable the collection, processing, storing and distribution of information on mobility systems and its criticalities. Info-mobility has the potential to improve the mobility system, in terms of its effectiveness, efficiency and sustainability contributing towards reducing traffic congestion levels and travel times, and increasing travel safety (Black, 2010:56).

Figure 3.7 Info-mobility model.



Source (Struwing, 2014).

Figure 3.7. illustrates the process of information management for better management of traffic through the utilization of intelligent transport system.

3.12.2. The Passenger Demand Model

According to Neil (2007:20), the Passenger Demand Modelling represents one perspective of the metropolitan or regional transport system. The supply side represents the other perspective in terms of infrastructure and flow-dependent costs and travel times. The whole transport system is part of a region in which people live, work, and engage in leisure activities. The development of land use patterns and location of activities strongly determine travel demands in terms of trip generation and attraction, and rely on transport systems that provide accessibility (Motos, 2007:68).

3.12.3. Smart mobility model

Smart mobility can be defined as the use of information and communication technologies to improve the mobility systems, enhancing their efficiency and improving their competitiveness (Dirk & Enrica, 2015:2). Smart Mobility Model aims to optimize individual mobility options through improved connectivity among modes, enhanced techniques to link land use planning and transportation system design, advanced information technologies, and clean-fuel vehicles.

Three elements are significant in enhancing innovative mobility through ITS. These elements are Innovative Mobility, Access and Information.

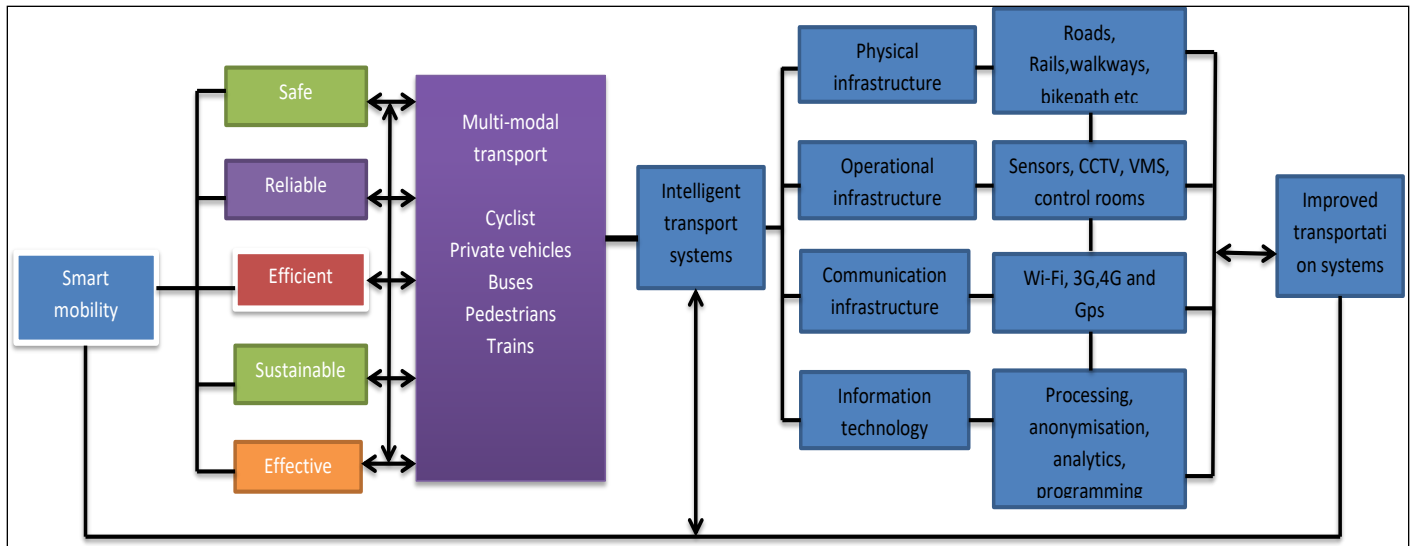
Innovative Mobility: The premise behind innovative mobility is that a transportation system should facilitate mobility by providing a variety of modes for individuals to choose from when planning a trip. This might include an automobile for some trips, public transit, bicycles, electric bikes, small electric cars, e-commerce, smart shuttles, or similar low-impact (i.e., to the environment) mode for other trips. An innovative mobility service would enable users to evaluate cost, convenience, and impacts before making a modal choice. Results could include reduced negative environmental impacts, improved social connectivity, better resource utilization, and a high degree of user (consumer) satisfaction (Azamo, 2011:13).

Access: The effect of access on transportation is to reduce the need for mobility, while still providing the same amenities (goods, social interaction, and services) to individuals. Mixed-use neighbourhoods, where residential dwellings and commercial buildings are in close proximity to each other, is a classic example of improved access. Internet shopping is another means to increase access to goods and services without requiring additional mobility (Matthew et al., 2014:5).

Information: Instant access to information and the ability to be in contact at almost any time from almost any location is a recent phenomenon. Cell phones and wireless technology can alter how we think about transportation and mobility. In the context of innovative mobility, real-time information is critical to making alternative modes competitive with the single occupancy vehicle. Real-time information can provide time sensitive information about routes, transit schedules, and even other people's schedules. Communication allows a degree of flexibility not traditionally associated with alternative modes. Together instant access to information and communication can be used to bundle modes together to facilitate "door-to-door" mobility services (Matthew et al., 2014:9).

Smart mobility integrated various intelligent transport systems infrastructure such as physical infrastructure, operational technologies, and communication and information technologies for improved transportation systems (Charbel, 2013:25).

Figure 3.8. Smart mobility and ITS framework



Source (Charbel, 2013:27).

Figure 3.8 illustrates the structure and interconnection of smart mobility and intelligent transport systems and how it supports the concept of reliability, efficiency, sustainability and effectiveness in a BRT system.

3.13. Chapter summary.

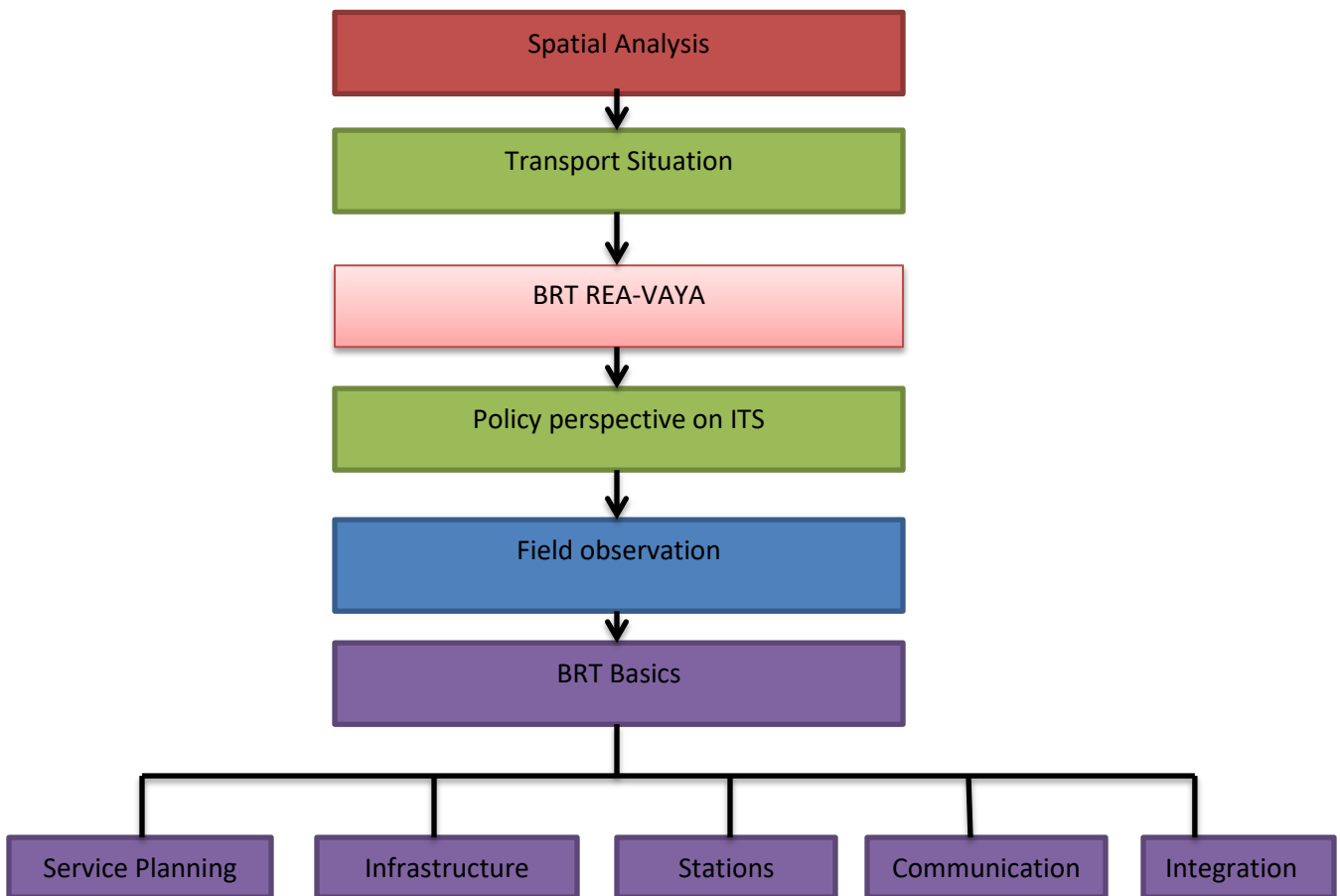
Through the literature review it was established that there are different perspectives regarding intelligent transport system for advanced public transport management. From the related literature reviewed, quoted and analysed in this chapter, it is considered that the operation and management of the public transport systems through intelligent transport is subject to various factors and characteristics of the ITS system design and the development and policies of various transportation institutions. Most of the authors have publicized how intelligent transport systems are important as a new tool for operating and managing public and private transport. The subsequent chapter deals with data analysis, interpretation and presentation of research findings pertaining this study.

CHAPTER FOUR: THE CASE STUDY AREA

4.1. Introduction

This chapter presents data on the case study area, Johannesburg with respect to the city regions, the transport situation, Johannesburg BRT (Rea-vaya) characteristics, policy perspective and related legislation. The city of Johannesburg Metropolitan Municipality is located in Gauteng province, and it covers an area of 1644km. It presents a divided spatial and socio-economic structure because it is both home to wealthy and poor, residents and refugees, many corporations. Figure 4.1 illustrates the structure of chapter four.

Figure 4.1 Structure of chapter four



Source (Author construct)

The demographics of Johannesburg indicate a large and cosmopolitan metropolitan area and its population is defined by a long history of local and international migration. Figure 4.2 shows the map of Johannesburg indicating the city regions.

Figure 4.2 City of Johannesburg.



Source (COJMM.2009)

Region D is the most densely populated region in the city with 24.4% followed by region G (16.7%), F (13.4%), A (12.6%), E (11.8%), C (11.6%) and B (9.4%) respectively Malikane et al.,2012).

The city of Johannesburg has a population of about 4 434 827 in 2011 compared to 3 225 812 in 2001 (StatsSA Census.2011). Johannesburg residents make up 36% of Gauteng population, and 8% of the population of South Africa. The city population is the young active age, a third of its residents are under 35 years of age (City of Johannesburg.2013). There are 1 434 856 household. 62% of them are male-headed and 36% female headed. Of the economically active population in Johannesburg, 72% were employed (1696.520 people), while 28% were unemployed (564 970) or discourage work seekers (105882 people) (StatsSA Census.2011). Regional analysis shows that Region D had the highest level of unemployment (42.7%) followed by Region G (28.1%), F (26.2%) and A (15.7%). Regions E, B and C have the lowest rate of unemployment at 2.3%, 9.2% and 11.7% respectively (City of Johanneburg.2012).

4.2. Johannesburg transport situation

The city transport system is characterised by two important features, i.e. majority of residents do not own cars, while middle income residents are very much car-oriented. Congestion of traffic in Johannesburg has worsened considerably with an annual increase of 7%. The Johannesburg 2040 strategy reference a recent IBM survey that Johannesburg worst in the world when it comes to commuters waiting time to board a public transport. This explains the introduction of Rea-vaya Bus Rapid Transit (BRT) and Gautrain high-speed rail link. Public transport initiatives address the challenges of congestion and as such, the city continues to focus on the goal of having 85% of the city population with a 500 metre radius of the Rea-vaya BRT feeder or trunk route. In addition, it will focus efforts on ensuring integration of the various public transport modes with ITS (City of Johannesburg, 2012:22).

The marginalised areas can broadly be described as Greater Soweto, Greater Ivory Park, Greater Orange Farm, Diepsloot and Alexandra. They are characterised by high levels of unemployment, infrastructure hot-spots and frequently lacks significant economic centres and local opportunities. This is the reason why the Rea-vaya BRT is expected to make the more mobile to look for jobs in other regions of the city.

All spheres of government play a significant role in Johannesburg transport system. The national government is responsible for the freeways (N routes), passenger and freight rail. The Gauteng Department of Roads and Transport builds and maintains various provincial-owned roads in Johannesburg and it is the contracting authority for various bus services in Johannesburg, for administrating economic regulation of public transport through the issuing of operating licences, for vehicle licencing and for the Gautrain high speed rail system in the province, and build public infrastructure on provincial roads (City of Johannesburg, 2013:6).

Johannesburg administers the Metro bus and the Rea-vaya Bus Rapid Transit system. The municipality constructed and is responsible for maintaining roads owned by the city, including two freeways (M1 and M2). In addition, the municipality builds public transport infrastructure on city-owned roads including the provision of corresponding off-street and services. The transport department is also responsible for all planning in the city (City of Johannesburg, 2013:6).

4.3. The Johannesburg BRT (Rea-vaya)

The Rea Vaya, which means ‘we are going’ in Sesotho, is Johannesburg’s own BRT system. This system was launched in 2009. The system was designed to provide a “world class public transport system” that is efficient, reliable, safe and cheap. The project is part of the city’s revitalization plan to bring business back into the city centre (Weinstock, 2010:40).

Structure of the BRT (Rea Vaya)

There are two types of buses that are used in this BRT system. The first is the articulated buses, which have a capacity of 112 passengers and the second is the complementary buses which have a capacity of 81 passengers (Rahim, 2014:39).

Related to these are the three categories of routes:

Trunk route services: this consists of articulated buses which operate only on trunk routes.

Feeder routes: these buses transport people to trunk routes. There are currently 5 feeder routes. F1 runs from Naledi via Thokoza to the CBD, F2 goes from Protea Glen via Thokoza to Ellis Park, F3 runs from Jabavu via Lakeview to the CBD, F4 runs from Mofolo via Boomtown to the CBD and F5 runs from Eldorado Park via Lakeview to Ellis Park (Rahim, 2014:39).

Complementary routes: there are three planned complimentary routes. C1 which runs directly from Dobsonville and the Central Business District (CBD), C2 runs between Dobsonville and Maponya Mall and C3 is a circular inner-city route. Complementary routes run in mixed traffic roads as well as on trunk routes (Rahim, 2014:40).

The Rea Vaya was rolled out in three phases:

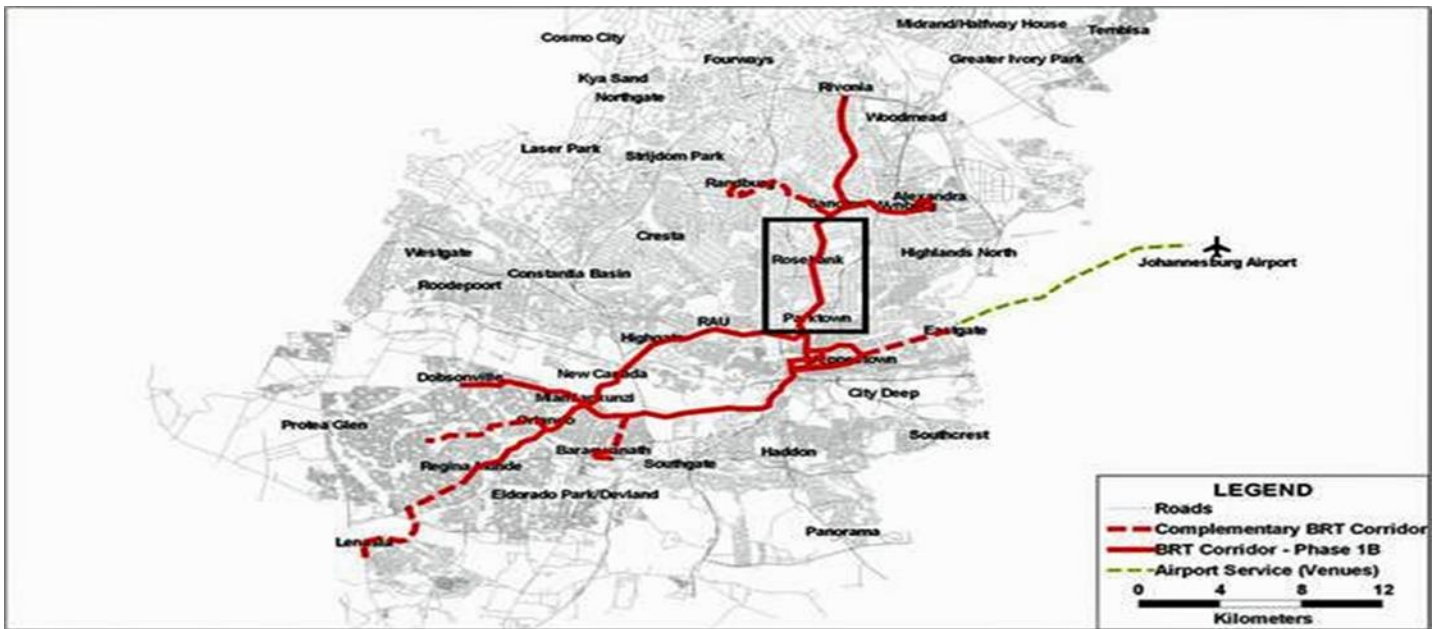
Due to the extensive cost and planning involved with the BRT system, the Rea Vaya was launched in phases. The first phase of the project included: 25.5 km of trunk route, with 70 000 trips, 10 routes made up of 1 trunk route and 5 feeder routes, 20 BRT stations from Soweto to the Ellis Park Stadium in Johannesburg, 143 buses, BRT control centre and the use of smart card technology (Debakwane, 2011:43).

The first phase (PHASE 1A) began operations in 2009 along 25.5 km from Soweto in the West to the inner city of Joburg with 30 stations and 146 buses of which 41 are articulated. They carry 43,000 passengers per day and travel 6.5 million km per annum.

The second phase (Phase 1B) was completed in February 2014. The route has made it possible for commuters to easily reach key public healthcare centres as well as educational institutions (Heather, 2013:13).

From 2016/2017 services Phase 1C will be introduced in phases. They will comprise 86.9km of road network with 242 buses, of which 45 are articulated. The Rea Vaya Phase 1C infrastructure will also feature 30.5km of extensive walking and cycling paths. Figure 4.3 shows the BRT Rea-vaya routes in the City of Johannesburg.

Figure 4.3. Rea-vaya BRT routes in the city of Johannesburg.



Source (Rea-vaya, 2014.)

Figure 4.3. illustrates the trunk and complementary routes for the BRT Rea-Vaya services.

4.4. Policy perspective on intelligent transport systems

Transport plays a significant role in the social and economic development of any country, and the government has recognised transport as one of its five main priority areas for socio-economic development. The effectiveness of the role played by transport is to a large extent dictated by the soundness of transport policy and the strategies utilised in implementing the policy. Public policy cannot be static, but must be dynamic in nature. It must always be perceptive to the environment within which it operates. Policy therefore needs to be reconsidered and if necessary, revised on a continuing basis. Most of the policies emerge from the National Department of Transport in the form of frameworks, plans and legislation.

4.4.1. National transportation policies

The following national transport policies were reviewed to give an overall view of how ITS integrates into the transport management systems.

4.4.1.1. National Land Transport Strategic Framework

The National Land Transport Strategic Framework (NLTSF) is a legal requirement in terms of Clause 21 of the National Land Transport Act (No. 05 of 2009). It embodies the overarching, national five-year (2015 to 2020) land transport strategy, which gives guidance on transport planning and land transport delivery by national government, provinces and municipalities over the five-year period. Strategies within 15 functional areas are outlined in terms of actions and outputs. The master plan for an intelligent integrated transport information hub strategy's plans are in line with the NLTSF and the strategy's development programme would facilitate the achievement of the set strategic actions as outlined in the framework (Department of Transport, 2015).

4.4.1.2. National Transport Master Plan

The National Transport Master Plan for (2005-2050) provides an integrated mechanism for land use patterns and how people could effectively interact with various modes of transportation of people. It is a framework for transport systems planning, implementation, maintenance, operations and investment as well as a monitoring tool for decisions for all modes. It is thus vital for the intelligent transport systems interventions in traffic management to be in line with the NSDP principles and other planning regimes, including the spatial planning (Department of Transport, 2010).

4.4.1.3. National Road Transport Act (no 93 of 2016)

The National Road Transport Act focuses on road safety of users and regulations for law enforcement. The implementation of this Act would ensure a proper facilitation of intelligent transport technologies in terms of road safety operational standards and in promoting other intermediate means of transport such as bicycling, pedestrian safety measures and so forth. Conformity of these low-cost modes of transport would ensure smooth integration into the transport system as licensing and permits would be required for movement of goods and passengers (Department of Transport, 2012).

4.4.2. Provincial transportation policies

The following provincial transport policies have been reviewed as they give an overall view of how ITS can be implemented for transportation management.

4.4.2.1. Provincial Land Transport Frameworks

Clause 22 of the NLTTA requires each province to annually prepare a provincial land transport framework for a five-year period. The initial Provincial Land Transport Framework (PLTF) must serve to guide land transport in the province, including intra provincial, inter-provincial and cross-border transport. Any subsequent provincial land transport frameworks must also include summaries of the local plans within the province. This entails that each province should have their own policies which will guide a smooth integration of intelligent systems in transport management.

4.4.2.2. Gauteng integrated transport master plan

The Gauteng Integrated Transport Master Plan is a 25 years plan that envisions a sustainable (green) transport system that allows the basic access and development needs of individuals, businesses and society to be met safely and in a manner consistent with human and ecosystem health. It should be affordable; operate efficiently; offer a choice of transport mode; and support a competitive economy as well as balanced regional development. The integrated transport master plan consists of annexure k which focuses on intelligent transport systems. It entails the role of intelligent transport systems in achieving the objectives of transportation. This is an ITS plan intended to guide technology deployment in a way that minimises risk for the implementation agency, as well as providing maximum integration opportunities with other systems. It is therefore the first step in the development of an ITS Implementation plan (GITMP, 2015).

4.4.2.3. Gauteng Public Passenger Road Transport Act (No 7 of 2001)

The purpose of this act is to change the law governing public passenger road transport in Gauteng and that purpose- to provide public passenger road transport systems as part of an integrated systems for land transport, compatible with national land transport systems and land transport systems of other provinces, to provide for the planning of public passenger road transport operations and infrastructure integrated with land use planning, to provide for the regulation and control of public passenger road transport by provincial and local government, and to establish institutional structure to achieve these objectives.

4.4.2.4. The Gauteng transportation infrastructure Act (no 8 of 2000)

The purpose of this act is to consolidate laws relating to road and other types of transportation infrastructure in Gauteng and to provide for the planning, design, development, construction, financing, management, control, maintenance and rehabilitation of provincial roads, railways lines and other transportation infrastructure in Gauteng (Department of Transport, 2011).

4.5. Field observations of BRT Rea-vaya facilities

Observational is defined as a method of viewing and recording the participants in real life situations. An observational template was developed using the BRT standard guide developed by Institute for transport and development policy (ITDP), Rockefeller foundation, BAAR foundation, Climate works foundation, GIZ, international council of clean transportation and UNEP.

The BRT Standard is an evaluation tool for world-class Bus Rapid Transit (BRT) based on international best practices. It is also the centrepiece of a global effort by leaders in bus rapid transit design to establish a common definition of BRT and ensure that BRT systems more uniformly deliver world-class passenger experiences, significant economic benefits, and positive environmental impacts.

The observation study was based on the following variables that formed the basis of the analysis for the BRT (Rea-Vaya) project, the BRT basic, infrastructure, service planning, stations, communication, access and integration.

4.5.1. THE BRT BASICS.

The “BRT Basics” are a set of elements that were deemed essential to defining a corridor as BRT. These elements are critical in contributing to eliminating sources of delay from congestion, conflicts with other vehicles, and passenger boarding and alighting, thus increasing efficiency and lowering operating cost. They are of critical importance in differentiating BRT from standard bus service. The elements that were observed for the BRT basics are as dedicated right of way, bus-way alignment, off-board fare collection, intersection treatment and platform level boarding.

4.5.1.1. Dedicated Right of way.

A dedicated right-of-way was observed as vital in ensuring that buses can move quickly and unimpeded by congestion. The Physical design of the lanes was observed on how they enforce right of way and thus, allowing for a free-flowing movement of the buses along the corridor.

The right of way of the BRT (Rea-vaya) buses was enforced through dedicated lanes that were separated from other vehicles through physical segregation and colorized road markings. 100% of the corridor lanes for T3 trunk route have dedicated lanes that give BRT (Rea-vaya) buses right of way. The dedicated lanes are not physically separated from the mixed traffic, but there is a physical barrier through separator blocks. The separator blocks installed do not prohibit the encroachment by private vehicles of the dedicated lanes and thus, causes delays for the buses.

Plate 4.1. BRT Rea-Vaya Dedicated-lanes.



Plate 4.1 illustrates the dedicated lanes for the BRT Rea-vaya that are highlighted through red road markings and separated from mixed traffic by means of landscaping median at Lakeview station through the T3 trunk route from Park Station to Thokhoza Park.

Source (Author field data.2016)

4.5.1.2. Bus-way alignment.

The bus way is best located where conflicts with other traffic can be minimized, especially from turning movements from mixed-traffic lanes. In most cases, a bus way in the central verge of a roadway encounters fewer conflicts with turning vehicles than those closer to the curb due to alleys and parking lots.

The BRT Rea-Vaya was designed with tier 1 configuration, where two-way median-aligned bus ways were in the central verge of a two-way road. The bus way alignment was designed not to affect the movement of the mixed traffic as there are dedicated lanes for the Rea-Vaya. Through the median-aligned bus ways, the stations are located at the centre of the busy-ways allowing for easy boarding at both directions.

Plate 4.2. Two-way median-aligned bus ways



Plate 4.2. Illustrates a two-way median-aligned bus way in the T3 trunk route, where the BRT Rea-Vaya lanes are indicated through the red markings.

Source (Author filed data, 2016)

4.5.1.3. Off-board fare collection

Off-board fare collection is vital at reducing travellers' time and improving customer services. The system for off-board fare collection was observed in terms of its availability and functionality across the various stations located along the T3 trunk route. The BRT systems uses an automated fare payment system where a smart magnetic store value card (this was a plastic card that has a magnetic strip on the back, the magnetic strip stores monetary value) is issued to commuters.

100% of the stations observed consist of off-board fare collection through turnstile-controlled machines, where commuters pass through a half-body turnstile upon entering the station where their ticket/smart card is verified and a fare is deducted. However, turnstile at Joburg Theatre, Helen Joseph hospital, Orlando stadium and Thokhoza park station were not functional and were out of service and this created queues during peak hours as people had to wait to enter the stations and thus, increasing the travelling time of commuters.

Plate 4.3. An off-line turnstile

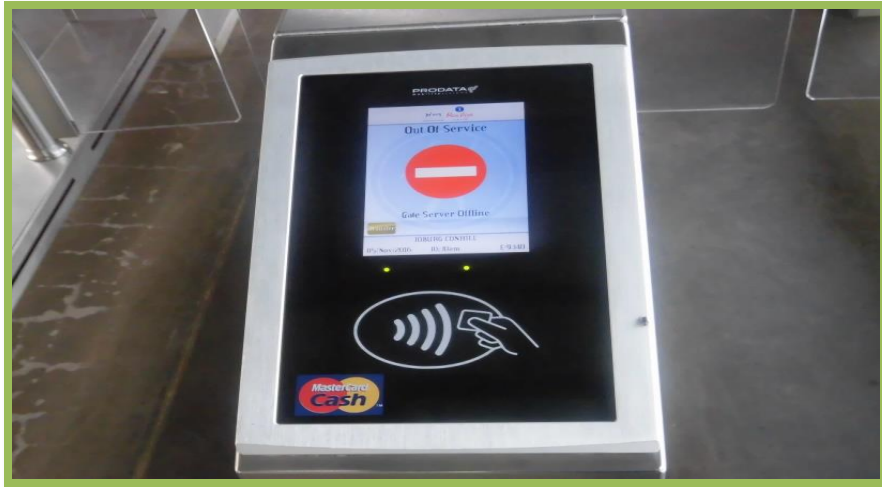


Plate 4.3. illustrates an out a service turnstile at the Joburg Theatre station. This causes delays for commuters because they have to use fewer turnstiles.

Source (Author field data, 2016).

4.5.1.4. Intersection treatment

Intersection represents a critical point along any BRT corridor. A poorly designed intersection or poorly timed signal phase can substantially reduce the system capacity. Where BRT vehicles operate in mixed traffic along an arterial street, intersection-specific running way improvements can still be developed through the development of bus bypass lanes and transit signal priority. The BRT (Rea-Vaya) operates in a mixed traffic with dedicated lanes. Intersection treatment for the BRT is crucial for the smooth movement of buses along the routes and results in reduced travels time. There are no prohibited turns across the way of the buses, but there is transit signal priority for intersection treatment. The transit signal priority was enforced through traffic signals. The traffic signals for the intersection treatment are not integrated with the control centre of the BRT (Rea-Vaya). This creates a challenge in acquiring up to date information on traffic signals that are not functional and intersection where bus is prohibited by other obstacles such as incidents or encroaching private vehicles and taxis.

Plate 4.4. Bus priority signal



Plate 4.4 illustrates a traffic light indicating the priority given to the BRT Rea-vaya buses. Buses are detected in advance of signalized intersections, and changes are made to the traffic signal cycle in order to reduce or eliminate the delay time at the intersection.

Source (Author field data, 2016).

4.5.1.5. Platform level boarding

Having the bus-station platform level with the bus floor is one of the most important ways of reducing boarding and alighting times per passenger. Passengers climbing even relatively minor steps can mean significant delay, particularly for the elderly, disabled, or people with suitcases or strollers. The reduction or elimination of the vehicle-to-platform gap is also key to customer safety and comfort. 100% of the station platforms are level with the buses allowing for an easy boarding for the elderly and the disabled in the BRT Rea-Vaya. There are system wide measures for improved level boarding through physical design of the station and the buses. The physical design is a boarding bridge that acts as connection between the station and the buses. This is in conjunction with bus ways alignment markers assist the bus to be perfectly aligned with the station doors.

Plate 4.5 Boarding bridge or platform



Plate 4.5 illustrates a boarding bridge that guides passengers into the bus and also allows for level boarding and marking for an easy access for the disabled and elderly.

Source (Author field data, 2016).

4.5.2. SERVICE PLANNING

The introduction of BRT services often results in new challenges for the operations department or contractor of the transit agency. These challenges include coming up with new procedures to manage high-frequency routes, integrating new technology and information (from automated vehicle location and transit priority systems, for example) into operating procedures, and training supervision staff.

Service planning focuses on the provision of measures that improve the operational and functionality of the BRT systems, such as the discussion between control centres versus road supervision service monitoring. The measures that were observed for service planning are multiple routes, express, limited and local services, control centre and hours of operations.

4.5.2.1. Multiple routes

The BRT is unique as a public transport system in terms of its flexibility with routing options. The ability of rubber-tyred vehicles to change lanes and directions allows for a few potential routing variations. Multiple routes variations are important as they offer avoidance of unnecessary transfer for passengers and subsequent saving in travellers' time and are critical for the assessment of the available multiple routes for the BRT corridor. The BRT (Rea-vaya) offers multiple routes on the same corridor (see annexure D). For example, the trunk routes provide three alternative routes which are named T1 (route from Thokoza park to Ellis Park East), T2 (Thokoza park to Braamfontein via Soweto Highway) and T3 (Thokoza park to Park Town and Library Gardens East) respectively. The trunk routes are serviced by complementary and feeder routes where small vehicles from residential areas provide access to transfer stations along the trunk route.

4.5.2.2. Express, limited and local services.

One of the most important ways that mass-transit systems increase operating speeds and reduce passenger travel times is by providing limited and express services. While local services stop at every station, limited services skip lower-demand stations and stop only at major stations that have higher passenger demand. Express services often collect passengers at stops at one end of the corridor, travel along much of the corridor without stopping, and drop passengers off at the other end. The BRT (Rea-vaya) provides limited and local services for commuters. There are complementary and feeder routes that serve as local services for the corridors as the buses stop at each and every station along the routes such as the Inner city

Route and also the Dobsonville to Bosmont route (see annexure D). Limited service was provided through the trunk routes where stations which are not part of that trunk route are passed and it consists of few stops along the route such as Thokoza park to Braamfontein via Soweto Highway route (see annexure D).

4.5.2.3. Control centre.

Control centres for BRT systems are increasingly becoming a requirement for a host of service improvements, such as avoiding bus bunching, monitoring bus operations, identifying problems, and rapidly responding to them. The addition of BRT service and infrastructure to a transit system often requires substantial changes to conventional control or communications centre activities. The BRT infrastructure often has closed-circuit monitoring that requires a control centre area for monitoring equipment and staff.

The control centre was observed on how it responds to the below mentioned elements for monitoring and managing the BRT systems:

Table 4.1. Control centre observations

Items	Observation
Respond to incident in real-time	The systems respond to incidents in real-time as there are CCTV cameras along the routes to monitor the conditions and thus respond to any irregularity of the system.
Control the spacing of buses	The system does not control the spacing of buses.
Determine and respond to the maintenance status of all buses in the fleet	No respond to the maintenance status of the buses in the fleet as some of the variable message sign in the buses were not functional, indicating that the system was not aware of the maintenance status of any bus in the fleet.
Record passenger boarding and alighting's for future service adjustment	No passenger boarding recording and alighting future services adjustment through either increased/decreased headway for buses.
Use computer-aided dispatch (CAD)/ Automatic Vehicles Location for bus tracking and performance monitoring	Tracking of bus locations through Automatic Vehicles location and computer-aided dispatch where a dispatcher uses a two-way radio to call details to drivers. They are also able to view and understand the status off all units through communication with drivers.

Source (Author field data, 2016)

4.5.2.4. Hours of operations.

A viable transit service must be available to passengers for as many hours throughout the day and week as possible. Otherwise, passengers could end up stranded or may simply seek another mode. It is essential to have all-day service with extended hours, which, at a minimum, enable users to get into their communities very late at night, even if they then need to call home for a ride or take a taxi for a relatively short distance. The operational hours of the BRT Rea-

vaya are from 06h00 am in the morning until 07h00pm in the evening through the weekdays and weekends. There are no late night services for commuters and this is an inconvenience for commuters who work late night shift as they have to find alternative mode of transport to get to their destination. The headway (the waiting time between buses) is constant during peak (06h00-08h00am and 17h00-19h00pm) and off-peak hours (09h00am-16h00pm), where buses pass through the station in an average of 5-10 minutes. This results in a service frequency of 12 buses every hour per station.

4.5.3. INFRASTRUCTURE.

The physical design of the BRT systems is influenced by operational and management elements such as the corridor selected, expected capacities and service options. The system is dependent on the infrastructure that is available and thus, for the BRT to function optimally, it requires a well-functioning and maintained infrastructure.

The infrastructure for the BRT Rea-Vaya was observed based on the following measures: passing lanes at station, minimising bus emissions, station setbacks from intersections and centre stations.

4.5.3.1. Passing lanes at the stations.

In order for multiple stopping bays to function properly and for services to be split between various local and limited stops routes, vehicles must be able to pass one another at the station. Therefore, multiple stopping bays should be accompanied by passing lanes in the station. The second bus way lane at the station stop allows vehicles to pass one another in accessing and exiting the correct bay. The BRT Rea Vaya provides a passing lane through a second lane in the station where buses are able to pass the station if they are not stopping in that particular station. As most of the stations are centre stations accompanied by elongated physical design of the station, they offer favourable conditions for implementing a passing lane at the station. Due the passing lanes at the station, this has impacted on the road space for private and taxi vehicles and this as a result hindered movement of traffic on some observed areas such as Westbury and Orlando police stations.

Plate 4.6. Passing lane



Plate 4.6 illustrates a passing lane at Thokhoza Park station where BRT Rea-Vaya buses have docked and there is an additional passing lane on the right-hand side of the buses. On the passing lane, there is an encroachment by people and this is evidence of the lack of enforcement on offenders and this can hinder the free flow of buses as they will have to slow down or stop for the people to move to the other side so that they can pass easily from the side.

Source (Author field data.2016)

4.5.3.2. Minimising Bus emissions.

Bus tailpipe emissions are typically a large source of urban air pollution, especially at risk where bus passengers and people live or work near roadsides. In general, the pollutant emissions of highest concern from urban buses are particulate matter (PM) and nitrogen oxides (NO_x). Minimizing these emissions is critical to the health of both passengers and the general urban population.

The BRT Rea-Vaya introduced Euro IV buses as a management strategy for minimising bus emission strategy. The BRT Rea-Vaya vehicles are using fuel of Euro II technology and this is affecting their minimising of emission as they still produce high toxicants through their vehicles.

4.5.3.3. Station set back from the intersection

Stations should be located at a minimum of 26 meters (85 feet), but ideally they should be 40 meters (130 feet), from intersections to avoid delays. When the stations are located just beyond the intersection, delays can be caused when passengers take a long time to board or alight and the docked bus blocks others from pulling through the intersection.

95% of the stations along the trunk route of T3 were located on average of 30m away from the intersection. Park Station was the only station that was located less than 10 meters away from the intersection and this creates challenges in terms of crossing the road for passengers. It is also a challenge in accessing the station for commuters who want to board the BRT Rea-Vaya buses and thus increasing their travelling time.

4.5.3.4. Centre stations.

A station is a substantial facility that can include many of the following attributes: shelter, level boarding, opportunity for advance fare collection, a unique name, a distinctive look and feel, passenger information, lighting and security, seating and other features typically associated with rapid or rail transit stations. Stations and stops may be located on-street or off-street, depending on the running way configuration. Systems may employ more than one station/stop location option.

The BRT Rea-Vaya uses a variety of off-street and on street stations. The on-street station are through centre stations that are located in between running ways. The advantage for centre stations is that they can serve both directions at the same time. 95% of the stations are centre stations on the T3 trunk route from park station to Thokoza Park with only Joburg Theatre station being a curb side station. This is due to the one-way direction of the street and thus if a centre station is provided on that street, the BRT Rea-Vaya bus will be travelling on the opposite direction to other vehicles and it might create distraction for other motorists.

The use of centre for the BRT Rea-Vaya does not create visual obstruction for businesses and it avoids having passengers waiting in front of nearby storefronts, which can be a concern for local businesses.

Plate 4.7. Centre station



Plate 4.7 illustrates a centre station located at Thokoza Park with running way on both sides of the station. This allows for buses to serve both directions at the same time and thus reducing travelling time for commuters.

Source (Author field data, 2016).

4.5.4. STATIONS.

A station is a substantial facility that can include many of the following attributes: shelter, level boarding, opportunity for advance fare collection, a unique name, a distinctive look and feel, passenger information, lighting and security, seating and other features typically associated with rapid or rail transit stations.

The parameters which were observed in terms of the station designed are as follows: distance between stations, safe and comfortable stations, % of buses with 3+ or 2 doors station side and sliding doors.

4.5.4.1. Distance between the stations

The distance between stations is crucial in the operational planning of the BRT system because it affects the speed and capacity of the BRT stations. If stations are space very far apart, they allow vehicles to reach very high speeds and high-capacities. However, this is a disadvantage to commuters that must travel additional distance in order to reach the station.

The spacing between stations was affected by the minimum distance that commuters were expected to walk on i.e. typically in the order of 0.25 to 0.33 miles (0.4 to 0.5 km), typically a five- to 10-minute walk. In higher-density or high-activity areas, expectations are usually for shorter walks. The BRT Rea –Vaya was assessed on the basis that stations should be spaced on average of 0.3km and 0.8 km apart. The spacing of the stations varies across location and the surrounding land uses. In high density areas such as Johannesburg CBD (Central Business District) the stations are spaced on average of 0.3km to 0.5 km apart and thus reducing the walking distance for commuters. In low density areas such as Protea Glen in Soweto the stations are spaced on average of 0.5-0.9km. To also reduce the walking distance of commuters, the stations are located near popular destination (Joburg Theatre station near the Joburg entertainment Theatre, commercial centre (Rissik station near the commercial centre of the FNB Bank City), education institution (the UJ Kingways campus station located near the University of Johannesburg Kingway campus). This allows commuters to have access to various services through the location of the station.

4.5.4.2. Safe and comfortable stations

A station is a substantial facility that can include many of the following attributes: shelter, level boarding, opportunity for advance fare collection, a unique name, a distinctive look and feel,

passenger information, lighting and security, seating and other features typically associated with rapid or rail transit stations.

The primary objective in providing a convenient, comfortable BRT station environment is the provision of basic shelter and seating for passengers. Consistent with the system brand and local design and development requirements, each BRT station should incorporate a reasonable degree of weather protection and places to sit while waiting.

The BRT Rea-Vaya stations are wide, attractive and weather protected. The stations were designed to be weather protected, where commuters are provided with ample standing space when waiting for the arrival of their buses. However, there are limited sitting areas in the stations and this is due to the fact that commuters are supposed to wait at the stations less than 5 minutes to board their bus.

Through the CCTV cameras and a security personnel at every single station, a safe environment has been created in the BRT Rea-Vaya stations and this allows commuters to feel free to utilise the systems as they will be protected from any criminal element.

Plate 4.8. Safety enclosed and comfortable BRT Rea-Vaya station



Plate 4.8 illustrates an indoor Joburg Theatre station, which is attractive and weather protected. The station is weather protected through its window glasses at both sides of the station, with CCTV cameras creating a safe and secure environment to reduce or eliminate any criminal element.

Source (Author field data, 2016).

4.5.4.3. % of buses with 3+ or 2 doors station side

All the efforts applied to vehicle size, station design and docking systems can be lost if the vehicle doorways inhibit smooth passenger flows. The size, number and the location of the doorway all play a role in facilitating efficient boarding and alighting. The most successful BRT systems have employed wide multiple doorways to ensure platform bottlenecks are avoided.

The BRT uses two types of buses; a 160 passenger articulated vehicle, which consist of four sets of double doors where the width is about 1.1 meter, which allows two persons to simultaneously enter and/or exit the vehicle. They also use 80 passenger vehicles which consist of two sets of double doors on each side of the buses. This improves the boarding and exiting of the buses at the stations in conjunction with the level boarding at the stations.

Plate 4.9. BRT Rea-Vaya bus doors



Plate 4.9 illustrates a BRT Rea-Vaya bus with double doors. The bus is docked at the station as it has another set of double doors which allow commuters to easily board and exit the bus.

Source (Author filed data.2016)

Sliding doors where passengers get on and off the buses inside the stations improve the quality of the station environment, reduce the risk of accidents, protect passengers from the weather, and prevent pedestrians from entering the station in unauthorized locations.

Each BRT Rea-Vaya station has automatic sliding doors on both sides of the station. The sliding doors open automatically only when there is a bus aligned with them to allow passengers to either exit or board on the bus.

4.5.5. COMMUNICATION

Communications is defined as anything that describes, explains, or otherwise discusses the project with interest groups. It is critical for the BRT to have a uniform message for their commuters through branding as they can identify with the system that they are utilising. Passenger information is a crucial component in the planning of a journey for commuters and thus access to relevant and up to date information is necessary for the commuters.

The followings parameters were observed in terms of the communication element of the BRT Rea-Vaya such as branding passenger information:

4.5.5.1. Branding

Branding gives a service or product a distinct identity that result in clear and positive public recognition of the service. BRT stations are a key element in reinforcing the brand of the service and should be highly identifiable as a major component of the BRT identity.

As a gateway into the BRT Rea-Vaya project, a strong unifying branding of the Corridor of Freedom has been presented through all the design and structure of the stations and the buses. All of the buses and stations follow single bright red and blue colours that cannot be mistaken for any other public transport services in the City of Johannesburg that emphasizes a clear and consistent message that the BRT Rea-Vaya is a safe, comfortable and reliable public transport. This is also evident through the slogan of Rea-Vaya (which means we are going) that is visible across all the buses and the stations of the BRT Rea-Vaya.

Plate 4.10 Rea-Vaya Branding logo



Plate 4.10 illustrates the BRT Rea-vaya branding that is uniform across all the stations and buses design. The Rea-Vaya brand symbolises the freedom that the corridor offers to its commuters with improved accessibility to the various services through improved mobility.

Source (Author field data, 2016).

4.5.5.2. Passenger information.

One of the most significant barriers to using buses was customer uncertainty about bus arrival times. Posting schedule information can help reduce the uncertainty, but this may be impractical where BRT stations are served by many different routes, and posted schedules cannot reflect bus delays. Providing real-time information in the form of variable message signs at stations that provide current status of bus operations would eliminate this uncertainty for transit users.

The BRT Rea-vaya uses variable message signs installed on the ceiling of every station to provide information about the schedule of the approaching buses at the station. However, the information displayed was not consistent with the traveling times of the buses as delays are not captured on the variable message sign. There is a variable message sign across all of the station platforms on the T3 trunk route, thus 100% of the variable message signs were not functioning. They were not functional and thus commuters were not informed of the approaching buses for the various stations. The variable message signs were not functional as they were not serviced or maintained due to the termination of a maintenance contract between the BRT Rea-vaya management and service provider as Mr Mpho Manzhe (Intelligent transport systems manager) highlighted. They are in the process of looking for a replacement of the service provider for the maintenance.

Plate 4.11 Variable message sign



Plate 4.11 illustrates a variable message sign at the SABC Media park station. The variable message sign is not functional and thus information about the schedule of the buses cannot be displayed on the stations.

Source (Author field data, 2016).

For passengers to orient themselves with the location of the BRT Rea-Vaya station, there were maps in each station which served as a way-finding device for passengers. The maps illustrate the route of the BRT and where that particular station is located.

An alternative to variable message sign is that passengers can get real-time information through their smart cell phones using an application that is called (*Vaya-mojo*). Commuters can access information on the location of the bus, the route to their destination, the fare of their journey and also their expected arrival time.

4.5.6. ACCESS AND INTEGRATION.

Access and integration are vital parts of a BRT system. It includes universal access, integration with other public transport network and pedestrian access. Integration of the BRT with other transportation services is vital because it reduces the operational cost and also improves access to transportation facilities for commuters.

Thus it was important for the study to observe the following elements of access and integration as universal access, integration with other public transport and pedestrian access.

4.5.6.1. Universal access

Incorporating elements of universal design improves accessibility of stations, improving accessibility for disabled people, children and elderly, as well as other transit customers, such as travellers with luggage, was an essential part of the system.

Universal access is achieved through inclusive planning and design; thus, it was important to observe if the BRT Rea-Vaya stations offer universal access through their design. All the BRT Rea-Vaya stations offer universal access through level-platform boarding and that allows people with disability to access the station with ease. The stations are designed with an elevated ramp to allow easy access for people with disability to the stations.

The BRT Rea-Vaya buses have low-floor because it allows for easy access and movement within the buses for physically impaired people. However, there are no audio signs for people that are blind, but they can hear and there are no brail signs for blind people and this makes it difficult for them to orient themselves within the station.

Plate 4.12. Elevated ramp for universal access



Plate 4.12 illustrates an elevated ramp designed to allow for easy access for physically impaired passengers at the Joburg Theatre station.

Source (Author field data, 2016).

4.5.6.2. Integration with other public transport.

When the BRT Rea-Vaya system was built, a functioning public transport network already existed, rail (metro rail and Gautrain), bus (metro buses and other conventional buses such as Pucto) and taxis. The system should be integrated with other modes of public transport.

There are three components to BRT integration with other modes of transport that were observed:

- **Physical transfer points:** Physical transfer points should minimize walking between modes, be well sized, and not require passengers to exit one system and enter another. There is no physical integration with any other modes of public transport and this creates challenges as passengers have to exit the station to access other modes of transport. This is also evident through the dedicated running ways lanes made specifically for the BRT.
- **Fare payment:** The fare system should be integrated so that one fare card may be used for all modes. All of the different modes of public transport within the City of Johannesburg use a variety of fare collection systems, where the BRT Rea-Vaya has a different smart card from the metro-bus and Gautrain. This entails that a passenger needs to have three different smart cards for each specific system.
- **Passenger information:** information about the scheduling of any public transport systems is critical in the journey planning of a commuter. In terms of the City of Johannesburg passenger information, there is no integration at all, as it is not possible to acquire any information about systems that you have not boarded on that particular moment.

Mr Mpho Manezhe claims that Johannesburg currently is far from achieving a fully integrated transport system. He suggests that there is a need for integration on different levels, such as integration with timetabling before Johannesburg can achieve a fully integrated system.

4.5.6.3. Pedestrian access.

A BRT system should be extremely well-designed and functioning through good pedestrian access. A good pedestrian access is imperative in the BRT system design. Additionally, a new BRT system is a good opportunity for street and public-space redesign, and existing pedestrian environments along the corridor should be improved. To achieve well designed pedestrians access, you need to have a well-designed transition area. The transition area is the space that

connects the station with the adjacent area and thus pedestrian access is crucial for BRT design.

There is a well-designed pedestrian access across each and every station. The transition space around the station allows for 500 meter catchment area surrounding the corridor. This is accompanied by good and safe pedestrian access at every station.

4.5.7. POINT DEDUCTION

The system of point deduction for poor design or management and performance weaknesses was used in the evaluation of the BRT Rea-Vaya in relation to the BRT standards guidelines. The point deduction focused on the following elements of the operations and management of the BRT such as commercial speeds, lack of enforcement of right of way, overcrowding, maintenance and low-peak-frequency.

4.5.7.1. Commercial speeds.

The minimum average commercial speed of the BRT Rea-Vaya is more than 24 km/h. Due to the dedicated running lanes, the BRT Rea-Vaya allows the buses to move through traffic freely without any hindrance and thus the improved commercial speed. Intersection signal priority system allows buses to move across intersection without speed reduction as they are always afforded the right of way and thus have an improved commercial speed.

4.5.7.2. Lack of enforcement of right-of-way

A BRT system may have a good alignment and physical separation, but if the right-of-way is not enforced, bus speeds will decline. There was infringement of the running lanes of the bus ways by vehicles (Private vehicles and public transport such as taxi and other conventional buses), and this affects the speeds and overall performance of the systems and thus causes delays to the BRT vehicles. This was accompanied by the lack of enforcement of right of way where the offenders are not penalized for the infringement and encouraging further encroachment. There was a cooperation with the metro-police of the City of Johannesburg in the monitoring and enforcing the exclusivity of the bus-way, but during peak-hours in the morning and evening, the enforcement is limited, the reason being that there is congestion during peak hours and to ease congestion they allow encroachment.

Plate 4.13 Encroachment on BRT Rea-Vaya dedicated lanes

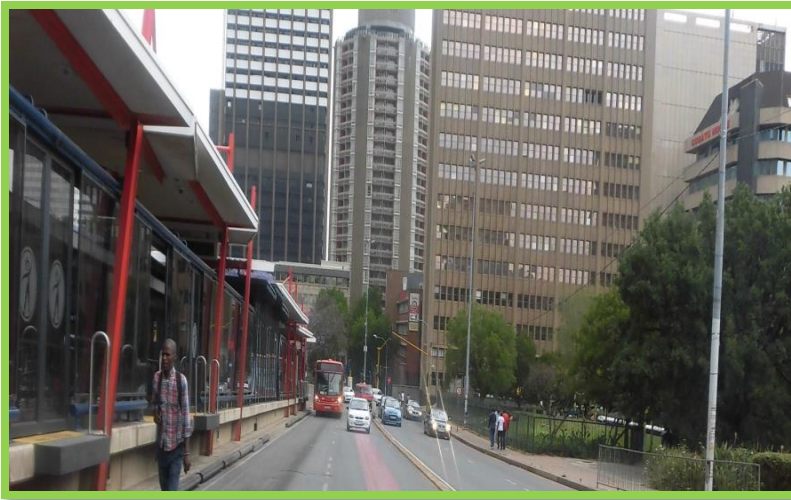


Plate 4.13. illustrates the encroachment of the colourised dedicated right of way of the BRT Rea-Vaya by a pedestrian and private vehicle. This is evidence that there is lack of enforcement and penalty on encroachment in the dedicated right of way as there is frequent encroachment.

Source (Author field data, 2016).

4.5.7.3. Overcrowding

Overcrowding at BRT station can increase the waiting time of passengers and thus resulting in longer traveling times. The BRT Rea-Vaya during off-peak hours does not suffer from any overcrowding both on the station platform and inside the buses. The head-way of 1 bus every 5 minutes allows passengers to easily board the buses and continue with their journey. However, during peak hours there is bus crowding even with increased head-way frequency. Commuters have to stand as there is limited sitting space due to bus crowding and this results in other commuters opting to wait for the next approaching bus. The overcrowding was assessed through direct observation.

4.5.7.4. Maintenance

A BRT system that is well built and attractive can fall into disrepair. It is important that the bus way, buses, stations, and technology systems be regularly maintained.

Decisions on station/stop and platform configuration, location and design should be influenced by operating and capital costs, and also by the on-going arrangements for life-cycle maintenance. The day-to-day maintenance of the station through cleaning and repairs to the station is up to date, with each and every station being cleaned every day with a personnel responsible for a single station. However, technology systems such as the fare collection machines, variable message signs and the vending machines are not being serviced and thus they are out of service. This is due to the out of contract for maintenance of intelligent transport

systems and Mr Mpho Manezhe indicated that they are in the process of looking for a new service provider for maintenance.

Plate 4.14 Out of service ticket vending machine



Plate 4.14 illustrates an out of service ticket vending machine and this shows that the machines were not maintained and commuters must purchase and load their through ticket cubicle. This results in long queues and delayed travelling times for commuters.

Source (Author field data, 2016).

4.5.7.5. Low peak hour frequency.

Average headway of buses during peak hour is a good indicator to evaluate BRT service. Each route of BRT should have minimum 8 buses per hour according to the BRT standard evaluation guideline. The BRT Rea-Vaya average a headway of 12 buses an hour during peak hours. There is a headway frequency single bus per 5 minutes there at the station platform for passengers to board. This is above the expected minimum average of the BRT standard guide and thus the system is operating optimally. All of the stations have an average of more than 8 buses per hour during peak hours.

4.5.8. Summary of the BRT Rea-Vaya point calculation.

The observation of the BRT Rea-Vaya was based on the BRT standards evaluation guide which was developed by the “Institute for Transportation and Development Policy” in 2014. The summary of the evaluation of the point awarded to the BRT Rea-Vaya is outlined in table 4.2.

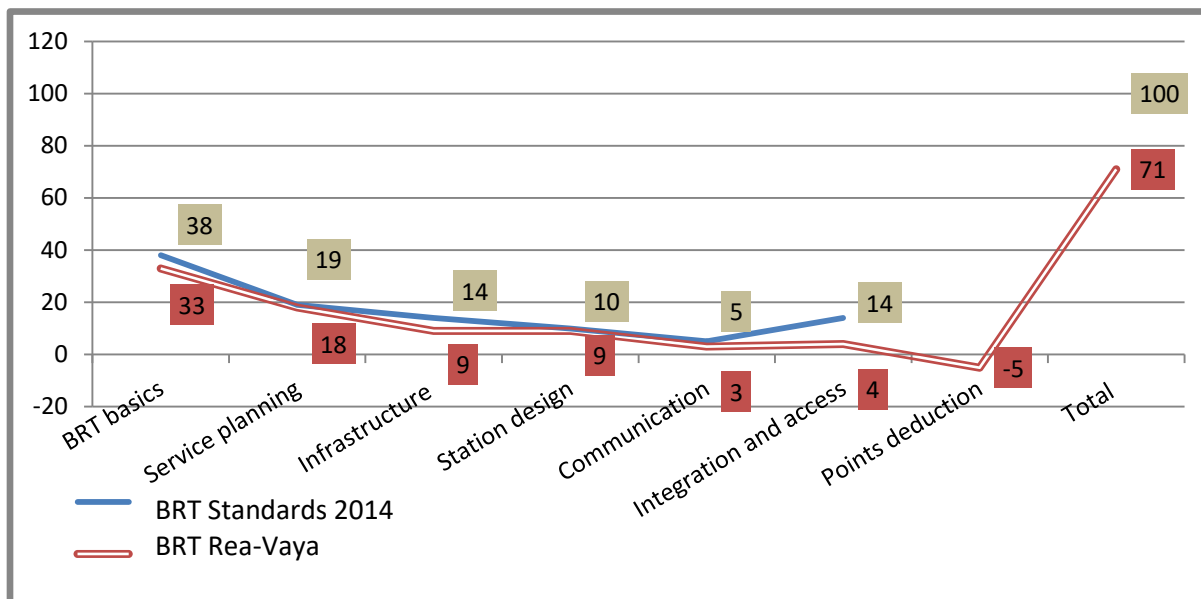
Table 4.2 BRT Rea-Vaya achieved points

BRT STANDARDS	BRT POINTS	STANDARDS	BRT REA-VAYA POINTS	ACHIEVED
BRT Basics-minimum score of 20 point needed	38		33	
Dedicated right-of-way-minimum 4 points	8		8	
Bus way alignment-minimum 4 points	8		8	
Off-board fare collection	8		8	
Intersection treatment	7		2	
Platform-level boarding	7		7	
Service planning	19		18	
Multiple routes	4		4	
Express, limited and local services	3		3	
Control centre	3		2	
Located in top ten corridors	2		2	
Demand profile	3		3	
Hours of operations	2		2	
Multi-corridor network	2		2	
Infrastructure	14		9	
Passing lanes at stations	4		4	
Minimizing bus emissions	3		1	
Station set back from intersection	3		2	
Centre station	2		2	
Pavement quality	2		0	
Stations	10		9	
Distance between stations	2		2	
Safe and comfortable stations	3		3	
Number of doors on bus	3		3	
Docking bays and sub-stop	1		0	
Sliding doors in BRT stations	1		1	
Communications	5		3	
Bradding	3		3	
Passenger information	2		0	
Access and Integration	14		4	
Universal access	3		3	
Integration with other public transport	3		1	
Pedestrian access	3		0	
Secure bicycle parking	2		0	
Bicycle lanes	2		0	
Bicycle –sharing integration	1		0	
Total	100		76	
Points deductions	-		-5	
Lack of enforcement of right-of-way	-4		-3	
Maintenance	-10		-2	
Total score	100		71	

Source: (The Institute for Transportation and Development Policy: ITDP, 2014)

Gold standard is awarded if a BRT system scores 85-100 points, silver standard is awarded if a BRT system scores 70-84 points and bronze standard is awarded if a BRT system scores 55-69 points. The BRT Rea-Vaya achieved “Silver standards” status and this means that the BRT Rea-Vaya project was well designed and implemented, even though there are minor problems here and there. Figure 4.4 shows that the BRT Rea-Vaya achieved 71 points against the BR standards in 2014.

Figure 4.4. BRT Rea-Vaya achieved points against BRT standard 2014



Source (Author field work, 2016).

Figure 4.4 illustrates the difference that exists between the BRT Rea- Vaya systems with the expected design and implementation of fully functional BRT systems as defined by the BRT standard evaluation guide. The comparison of the difference was crucial because it identified the crucial areas that the BRT Rea-Vaya is lacking, such as in the area of integration where the stations are with no secure bicycle lanes and bicycle parking space.

As indicated in figure 4.4, integration and access is where the BRT Rea-Vaya lacks significantly. This is integration across physical infrastructure, integration with other transportation modes and operational and management systems. Thus, it is important for improvement to be made in the BRT Rea-Vaya project for it to achieve a Gold standard which is the highest level according to the BRT standard evaluation template.

4.6. Chapter summary

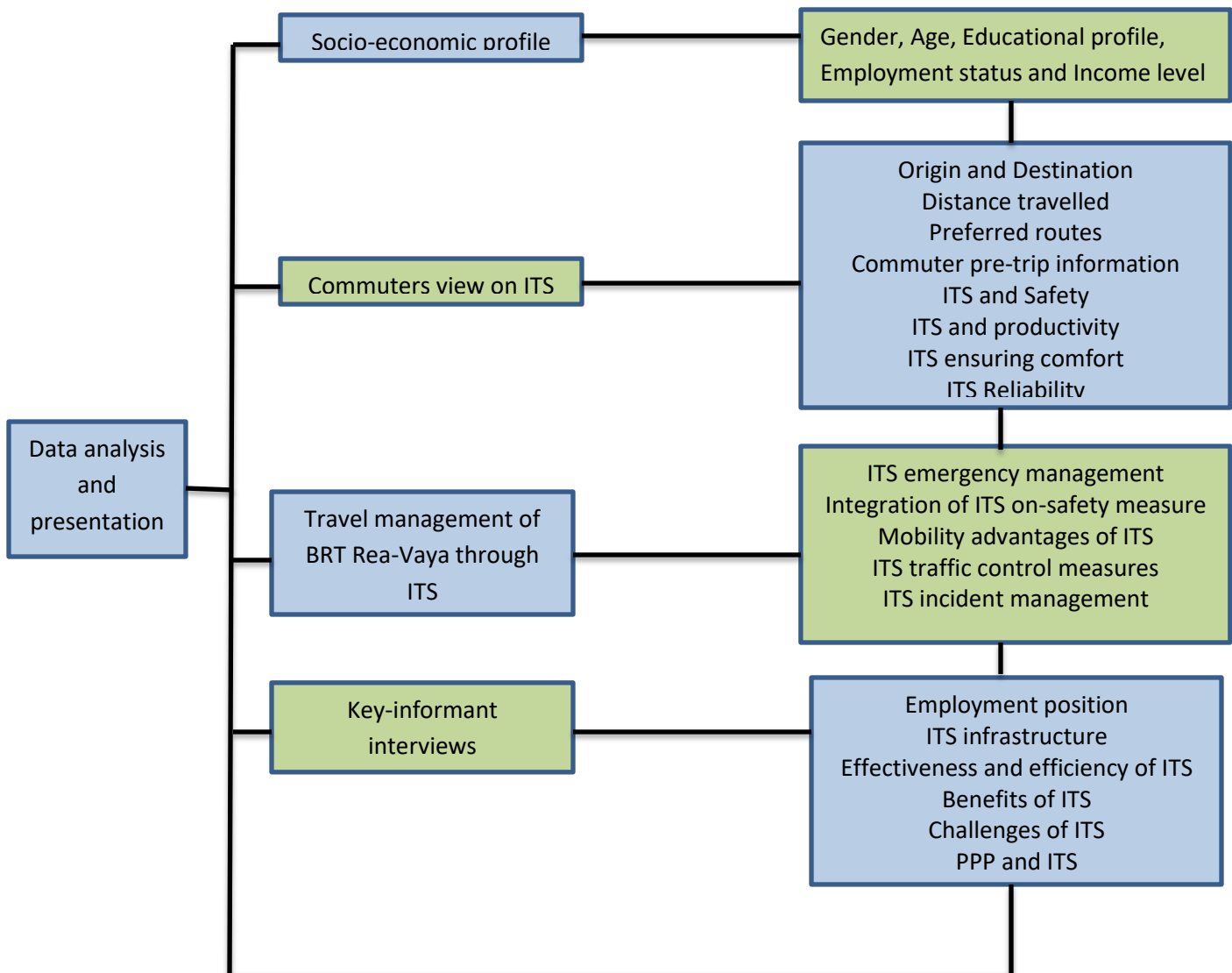
This chapter analysed and presented the findings of the research. The analysis shows that there is inadequacy in the operations and management of the BRT Rea-Vaya using intelligent transport systems. The lack of maintenance and upgrading of infrastructure for intelligent transport systems has resulted in inefficient systems, and this has led to delays in the schedule of buses and thus increasing the travel time of commuters. The lack of integration with other transport systems in terms of physical infrastructure, fare payment systems and information has resulted in a dis-jointed transportation system that is increasing travelling cost for commuters. Although, the system achieved a score of silver in the BRT standard evaluation guide, it highlighted critical components that are lacking in terms of intelligent transport systems such as controlling spacing of buses, and determining maintenance of the fleet from the control centre. The succeeding chapter addresses statistical data analysis and presentation.

CHAPTER 5: PRESENTATION OF DATA, ANALYSIS AND INTERPRETATION OF STATISTICAL DATA

5.0. Introduction

This chapter presents the findings from the investigation into the experiences of commuters and different stakeholders regarding intelligent transport systems in the BRT Rea-vaya in Johannesburg. This analysis was done on the basis of research objectives mentioned previously in chapter one. Figure 5.1 illustrates the conceptual structure of data analysis and presentation of research findings.

Figure 5.1 Conceptual structure of data analysis and presentation



Source (Author construct, 2017)

In line with the objectives of the research formulated in chapter one as well as the methodology and reviewed literature on the evaluation of ITS in Johannesburg, outlined in this chapter are data mainly from the field study. The data focuses mainly on targeted commuters with respect to the ITS management of the BRT Rea-Vaya in the City of Johannesburg. The socio-economic profiles of the respondents were analyzed to confirm what current literature says about the general status of commuters. This was followed by the origin and destination profile of commuters in order to determine their principal origin and destination journey, and their preference for BRT Rea-vaya routes. Similarly, the information made available to them en-route was analyzed to determine the reliability and use. In addition, the perceptions of the respondents were critically analyzed to unpack the efficiency of the BRT Rea-Vaya with respect to the main objectives of the research in chapter one and the key elements of smart mobility model as well as the safety, reliability of the ITS system, reduction of average time of travel productivity and general commuter satisfaction.

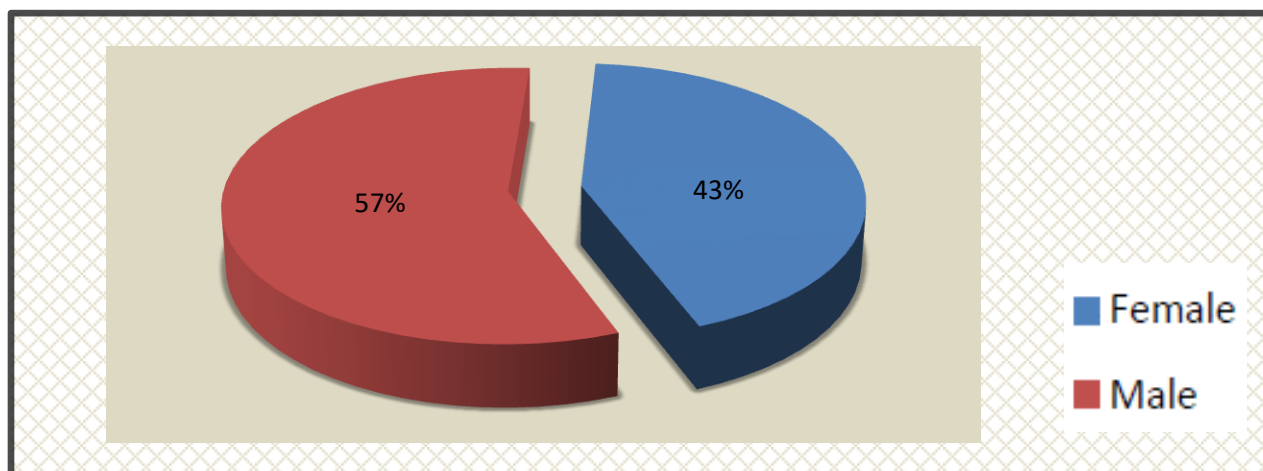
5.1. Socio-economic status of commuters

The socio demographic profile of the respondents is presented below.

5.1.1. Gender profile

The gender profile of respondents was analysed. The majority (57%) of respondents are male while female respondents constitute 43% of the population in the study area as shown in figure 5.2.

Figure 5.2 Gender of respondents



Sample size: N = 229

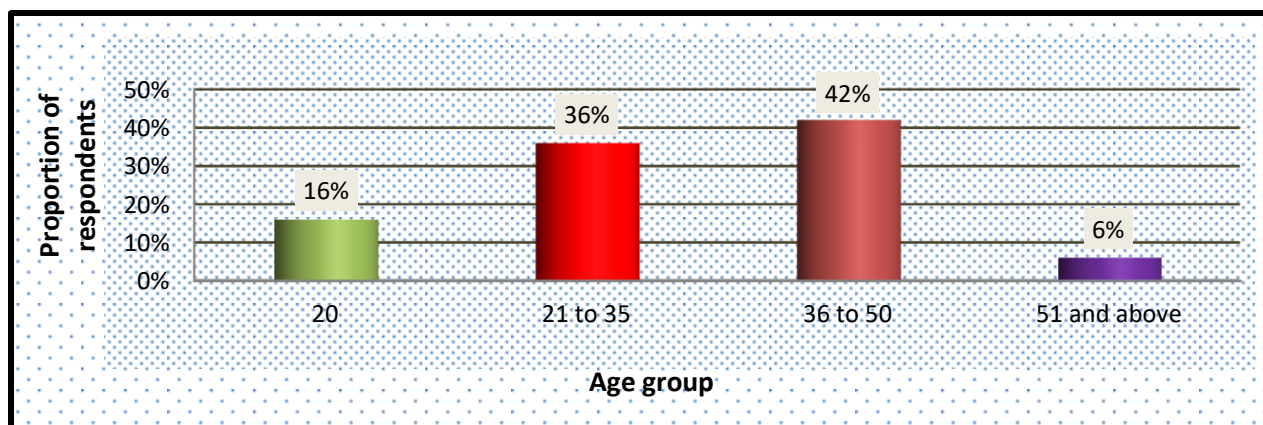
Source: Author's field data, 2016

The high ratio of male respondents was attributed to migration. The City of Johannesburg is a migration city for people in South Africa and abroad. The male group migrates to the city for better employment opportunities, leaving their families behind in mostly rural areas and thus, resulting in a high ratio of males (Statistics South Africa, 2011). On further investigation, the study revealed that majority of respondents use the BRT Rea-Vaya to access employment opportunities. This correlates with a study by Heather (2013:17) which indicated that the City of Johannesburg’s economic sector is still dominated by males and thus, resulting in a high ratio of males within the city as confirmed by this study.

5.1.2. Age profile

In order to understand the demographics of commuters who are using the BRT Rea-Vaya to meet their daily transportation needs, data on the various age groups of commuters was collected and analysed as depicted in figure 5.3.

Figure 5.3 Age of respondents



Sample size: N = 229

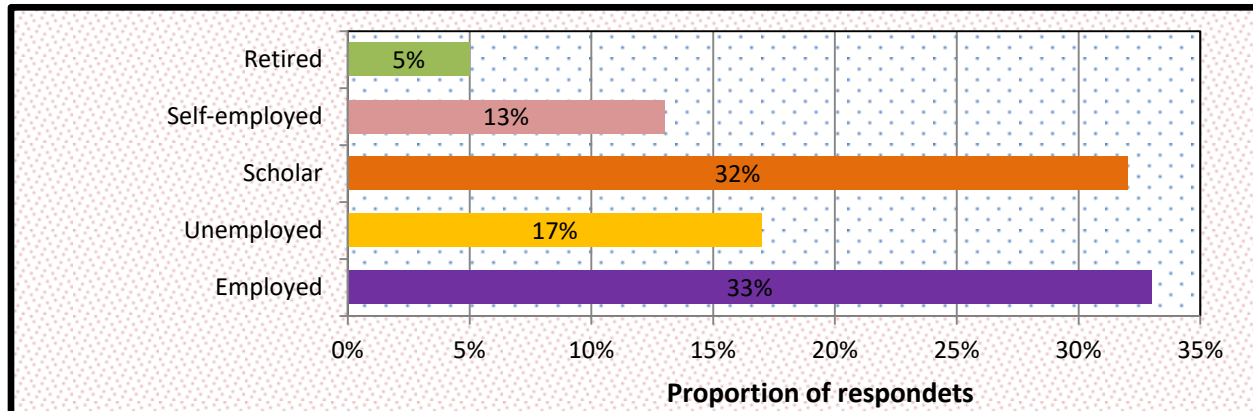
Source: Author’s field data, 2016

As shown on figure 5.3, the results indicate that the dominant age group in sample respondents is 36 to 50 years which is 42% and the lowest percentage are on group aged from 51 and above which is 6%. Age group of 20 years and below years has 16% and 36% on age group from 21 to 35 years of respondents. The age groups of the respondents partially correspond with the age group as stated by Statistics South Africa (2011) and Johannesburg IDP (2015/16) that the lower age group was lower compared to other age groups because most of the people in that age group were students or school leavers. Consequently, those who are economically active are the ones who utilize the BRT Rea-Vaya compared to other age groups as they tend to travel more looking for job opportunities

5.1.3. Employment status of respondents

In view of the fact that employment has a bearing on accessing the BRT Rea-Vaya to acquire various services, respondents were asked to indicate their employment status. Figure 5.4 shows the respondents' employment profile.

Figure 5.4 Employment status of respondents



Sample size: N = 229

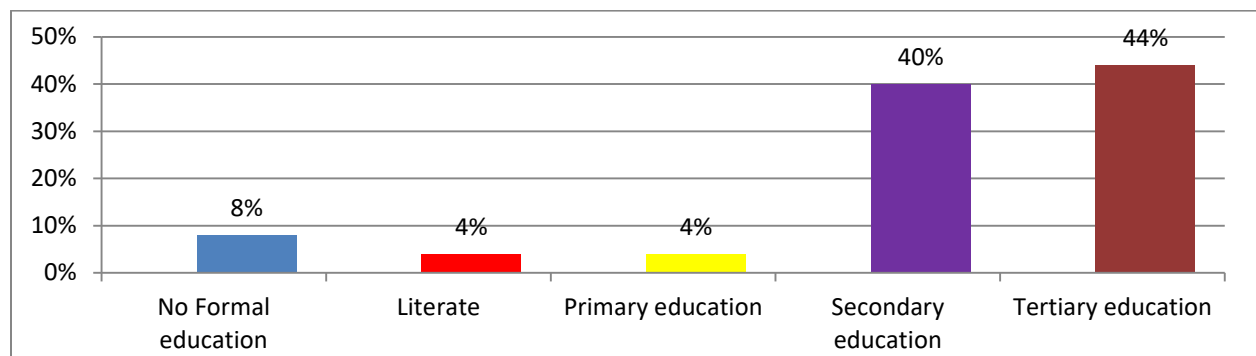
Source: Author's field data, 2016

The outcome from the analysed data as shown in figure 5.4 shows that the majority (33%) of respondents are occupied with their employment activities on their daily function. With a minority (5%) of respondents being retired. This is in conjunction with the data analysed on the age group of respondents where the age of 51 and above was 6%. According to Statistics South Africa (2011) the unemployment rate of Johannesburg metropolitan city is 27.7% and this is evident through the data analysed where 17% of respondents indicated that they were unemployed. Even though the majority of respondents interviewed are occupied through employment, most of the respondents that are using the BRT Rea-Vaya are scholars (32%) and learners from grade 1-12 (13%), meaning that they are using the BRT for educational purposes as it is highlighted in figure 5.4.

5.1.4. Educational profile of respondents.

Educational level and skills of an individual has implications on what they can afford because it plays a key role in determining their income level. It was necessary to determine the education level of respondents as shown in Figure 5.5 because the ITS in the BRT Rea-Vaya requires a certain level of education to use the system, although the system should be user friendly.

Figure 5.5 Educational level of the respondents



Sample size: N = 229

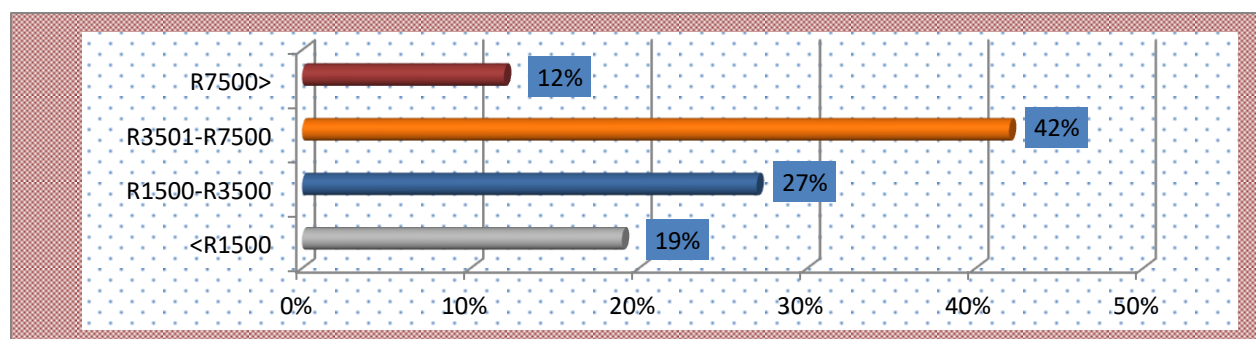
Source: Author's field data, 2016

The study revealed that 44% of the respondents had some form of education from a higher institution. Education status is not in any way a criterion in determining the people who can access the public transport. It becomes a factor when most of them with tertiary education may have better job opportunities and as a result earn higher incomes. This influences the type of public transport that they can afford, as it was shown in figure 5.5 that the majority of respondents that are utilising the BRT Rea-Vaya are employed and followed by respondents that are scholars. This corresponds with the Johannesburg (SFD, 2016:22) which outlined that 12.9% of residents are unable to access public transport services due to lack of formal education resulting in high unemployment rate and thus, unable to afford those services.

5.1.5. Income level of respondents

The income level of respondents was analysed to show that reasonable access to the BRT Rea-Vaya was related to income. In view of this, the respondents were asked to indicate their income levels. Figure 5.6 shows the income level of the respondents.

Figure 5.6 Commuters total monthly income levels



Sample size: N = 229

Source: Author's field data, 2016

The study showed that 42% of respondents have a monthly income that ranges from R3501-R7500. This is due to the slow economic growth that Johannesburg City with the rest of South Africa is facing, resulting in lower than average income levels for the majority of respondents.

From figure 5.6 we can deduce that the majority of respondents earn less than R7500 a month. According to the Gauteng transportation management strategy (GTMS, 2015) commuters in Johannesburg spend 35% of their income on transportation and this makes transportation services expensive for commuters and thus, hindering access to public transport for the majority of respondents.

5.1.2. Respondents' place of origin and destination

The place of origin and destination has an influence on the type of public transport that a commuter can utilise depending on the availability of that particular transportation service. The Locations of the various origins and destinations are summarised as Soweto (SW), Roodepoort (RD), Rosebank (RB), Midrand (MD), Johannesburg (JB), Randburg (RDM) and Diiplekloof (DP). Table 5.1 shows places of origin and destination of commuters.

Table 5.1 Place of origin and destination of commuters

BRT stations From point 1 to 20	NQD	NQR	% Returned	Place of origin							Place of destination						
				SW	RD	RB	MD	JB	RDM	DP	SW	RD	RB	MD	JB	RDM	DP
Thokoza park station	35	10	28%	4	2	-	1	-	1	2	-	-	3	-	6	-	1
Lakeview station	58	6	10%	3	-	-	-	-	1	1	-	-	-	-	6	-	-
Klipspruit valley station	39	8	21%	2	-	1	2	1	-	-	4	-	-	-	2	2	-
Boomtown station	12	3	25%	1	-	2	-	-	-	-	-	-	-	-	3	-	-
Orlando police station	8	6	75%	6	-	-	-	-	-	-	-	-	1	1	2	-	-
Orlando stadium station	15	9	60%	4	1	-	3	2	-	-	-	-	3	1	6	-	-
Noordgesion extension station	19	12	63%	-	2	4	-	1	1	4	3	-	-	1	7	2	2
West burry station	31	28	90%	8	2	6	-	7	1	4	6	2	1	7	8	-	4
Hellen Joseph station	12	8	67%	1	3	-	-	1	2	1	2	-	4	-	2	-	-
UJ Kingways station	31	24	77%	3	12	4	1	4	-	-	10	-	-	-	14	-	-
UJ Sophia town res station	12	12	100%	2	4	-	-	3	3	1	3	-	3	-	6	-	-
SABC media park station	23	23	100%	5	3	1	3	6	-	2	7	2	-	1	8	3	2
Milpark station	8	7	87%	-	-	-	-	7	-	-	-	-	-	3	4	-	-
Wits stadium station	12	12	100%	2	-	10	-	-	-	-	-	2	-	-	5	-	5
Park town station	19	16	84%	4	1	-	3	8	-	1	7	3	-	2	1	6	-
Constitutional hill station	19	19	100%	9	3	-	2	-	5	-	7	-	3	2	1	-	6
Park Station station	12	9	75%	3	-	2	-	1	-	3	1	-	-	-	8	-	-
Library gardens stations	23	17	74%	2	7	-	3	1	2	2	9	-	1	-	4	3	-
Total	387	229		25%	17%	15%	9%	18%	7%	9%	26%	5%	8%	7%	37%	8%	9%

Sample size: N = 229

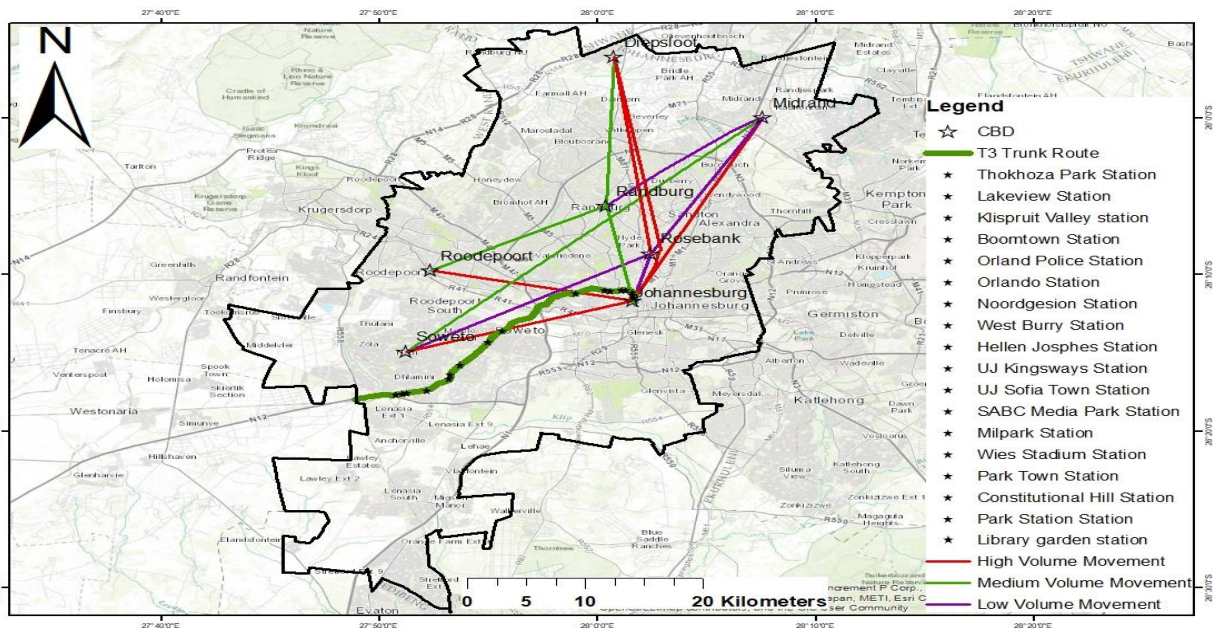
Source: Author's field data, 2016

Table 5.1 shows that the majority (25%) of respondents' journey originates from Soweto. This is due to the fact that the BRT Rea-Vaya project was rolled out in phases and the current phase 1b is only implemented in Soweto and Johannesburg CBD (Rahim, 2015:45).

However, as the majority of respondents' journey originates from Soweto, there are interstation differences where Westbury station constitutes the majority of respondents from Soweto. From table 5.1 we can deduce that commuters that are using the BRT Rea-Vaya are originating from different locations, even in areas where the BRT Rea-Vaya has not been implemented. Midrand accounted for 9% of origin of journeys for the respondents while 18% of respondents indicated that their journeys had originated from Johannesburg CBD.

As shown from Table 5.1, Johannesburg CBD accounts for the majority (37%) of respondents' destination. This is due to the diversified economic activities that are found within the city and thus, respondents originate from various locations to arrive in Johannesburg for employment. However, 26% of respondents indicated that their destination was Soweto. This is due to the fact that Soweto also offers economic activities to a wide range of respondents as it is the largest township in Gauteng. Figure 5.7 illustrates the connectivity map of the origins and destinations of respondents.

Figure 5.7 Origin and destination connectivity map



Source: Author's field data, 2016

Figure 5.7. illustrates the connectivity map of the origins and destinations of commuters from various locations within the City of Johannesburg.

5.1.3. Average origin and destination distance travelled by commuters in a day.

The distance that commuters travel affects the time it takes for them to arrive at their destination. In order to determine the time commuters spend travelling, they were asked to indicate the distance they travel from their place of residence to their place of occupation. Table 5.2. illustrates the average distance that commuters travel from their place of residence to their place of occupation.

Table 5.2. Average origin and destination distance travelled by commuters in a day

BRT stations From point 1 to 20	NQD	NQR	% Returned	Average origin and destination distance of commuters per day			
				6-10km	11-20km	21-30km	31 km>
Thokoza park station	35	10	28%	1	3	2	4
Lakeview station	58	6	10%	-	4	2	-
Klipspruit valley station	39	8	21%	2	5	3	-
Boomtown station	12	3	25%	-	-	3	2
Orlando police station	8	6	75%	-	-	6	-
Orlando stadium station	15	9	60%	-	-	8	1
Noordgession extension station	19	12	63%	-	3	9	-
West burry station	31	28	90%	-	1	3	25
Hellen Joseph station	12	8	67%	-	-	8	-
UJ Kingways station	31	24	77%	4	7	5	8
UJ Sophia town res station	12	12	100%	-	1	2	9
SABC media park station	23	23	100%	-	4	1	18
Milpark station	8	7	87%	3	3	-	1
Wits stadium station	12	12	100%	-	2	6	4
Park town station	19	16	84%	-	-	5	11
Constitutional hill station	19	19	100%	-	-	9	7
Park Station	12	9	75%	1	-	1	7
Library gardens stations	23	17	74%	-	2	-	11
Total	387	229		5%	16%	32%	47%

Source: Author's field data, 2016

The findings show that the majority (47%) of respondents travel a distance of more than 31 kilometres from their place of residence to their place of occupation, with a minority of 5% of respondents travelling a distance between 6-10 kilometres to their place of occupation every day. However, 32% of respondents travel an average distance of 21-30 kilometres and 16% of respondents indicated that they are travelling an average distance of 11-20 kilometres to their place of occupation every day. According to John (2014:36), the apartheid spatial planning has resulted in spatial inequality as people must travel long distance just to acquire different services. This means that respondents are travelling longer distance to get to their place of work, schooling and shopping, resulting in the need to either use public transport or private vehicles due to the extended distance travelled by commuters.

5.1.4. Respondents' choice of Rea-Vaya systems instead of other modes of transport.

Data on the reason why the BRT Rea-Vaya is convenient compared to other modes of transport was collected and analysed in order to understand the rationale of commuters using the BRT. This was also important for recommendations in areas that make commuters not to use the BRT Rea-Vaya.

Table 5.3. Reasons for selecting BRT Rea-Vaya, 2016

BRT stations From point 1 to 20	NQD	NQR	% Returned	Reason for choosing BRT Rea-vaya over other transport modes			
				Price	Availability	Reliability	Other
Thokoza park station	35	10	28%	2	3	3	2
Lakeview station	58	6	10%	1	5	-	-
Klipspruit valley station	39	8	21%	3	1	-	4
Boomtown station	12	3	25%	1	2	-	-
Orlando police station	8	6	75%	4	-	2	-
Orlando stadium station	15	9	60%	5	-	4	-
Noordgession extension station	19	12	63%	6	-	6	-
West burry station	31	28	90%	8	10	5	-
Hellen Joseph station	12	8	67%	3	5	-	3
UJ Kingways station	31	24	77%	10	9	3	-
UJ Sophia town res station	12	12	100%	11	1	-	-
SABC media park station	23	23	100%	9	14	-	-
Milpark station	8	7	87%	3	2	1	6
Wits stadium station	12	12	100%	5	1	-	-
Park town station	19	16	84%	-	6	6	4
Constitutional hill station	19	19	100%	-	4	10	5
Park Station station	12	9	75%	-	-	-	9
Library gardens stations	23	17	74%	-	-	13	4
Total	387	229		31%	28%	23%	18%

Source: Author's field data, 2016

Table 5.3 shows that the majority (31%) of respondents find the BRT Rea-vaya to be convenient as compared to other mode of transport due to the price. They outline that they travel more distance for a reduced price compared to taxis. This relates to the national household survey (NHS) 2013, which indicated that commuters use 37% of their disposal income on transportation. This result in commuters looking for alternative transport such as the BRT Rea-vaya (Rahim, 2013:49). Reliability plays a significant role in attracting new consumers and in keeping the old consumers in the system and thus, 23% of respondents indicated that it is reliable as it is available most of the time. 28% of the respondents gave the reason of availability for the convenience. They raised a couple of concerns such as that during weekends they found it difficult to travel with the Rea Vaya as the buses ceased operating at 18:00 on weekends "Which makes it hard for people who work on weekends".

From table 5.3 we can deduce that price is a major contributing factor commuter are using the BRT Rea-Vaya compared to other modes of transport as is evident in the UJ Kingways station and UJ Sophiatown res station. According to Hanks (2016:76) students spend 16% of their income on transport. This is attributed to the dis-integrated transport system of South Africa. With initiatives such as BRT, it allows students to access public transport at reduced rate compared to traditional transport (taxi and buses) and thus, prefer it due to price (Allen, 2015:83).

5.1.5. Respondents' preferred routes.

The routes that commuters choose may depend on a variety of factors such as price, time, congestion of the routes etc. and thus, it was important for the study to collect information on the routes that commuters prefer and the data is showed in table 5.4.

Table 5.4. Respondents' preferred routes.

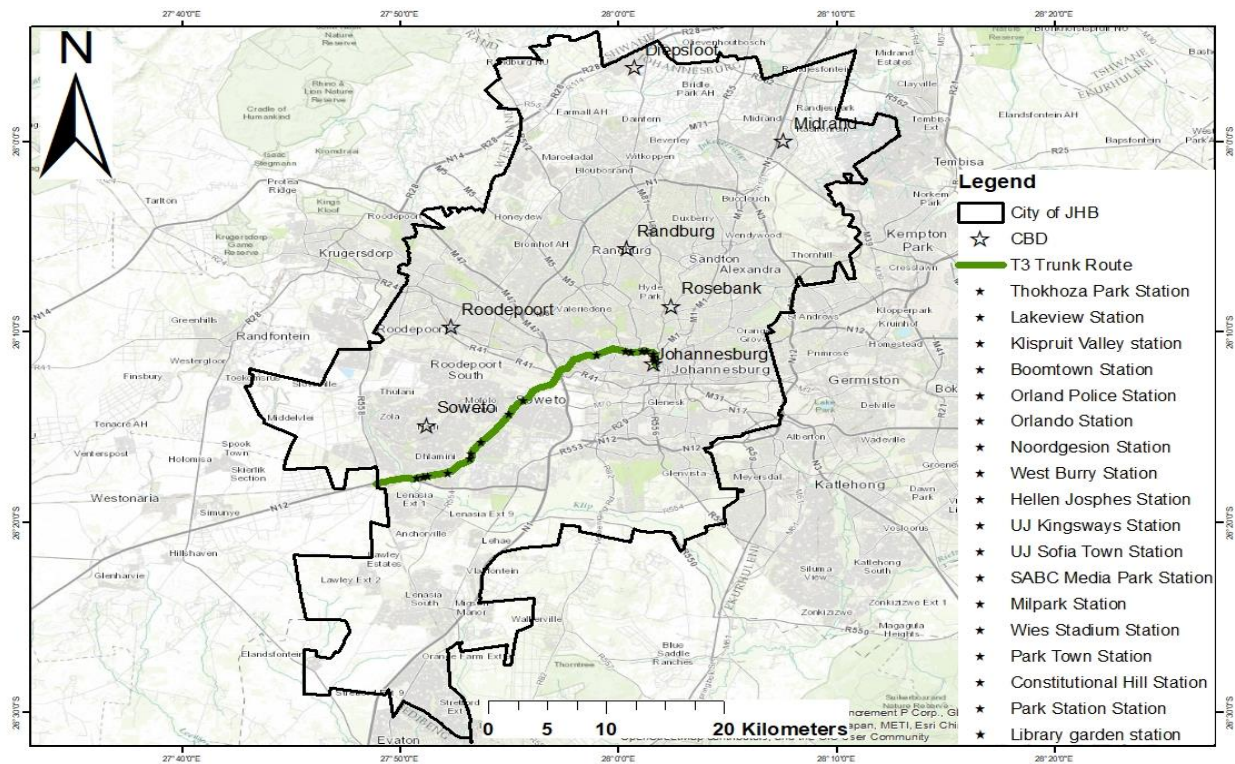
BRT stations From point 1 to 20	NQD	NQR	% Returned	Preferred routes									
				T1	T2	T3	C1	C2	C3	C402	F1	F2	F3
Thokoza park station	35	10	28%	2	-	5	-	-	2	-	-	-	-
Lakeview station	58	6	10%	1	-	3	-	-	2	-	-	-	-
Klipspruit valley station	39	8	21%	3	1	4	-	-	1	-	-	-	-
Boomtown station	12	3	25%	1	2	-	-	-	-	-	-	-	-
Orlando police station	8	6	75%	4	1	-	-	-	1	-	-	-	-
Orlando stadium station	15	9	60%	1	-	-	-	1	-	-	-	-	-
Noordgession extension station	19	12	63%	-	2	-	3	1	2	-	-	-	-
West burry station	31	28	90%	-	6	11	2	3	2	-	-	-	-
Hellen Joseph station	12	8	67%	-	-	4	1	1	1	-	-	-	-
UJ Kingways station	31	24	77%	4	-	10	3	5	-	-	-	-	-
UJ Sophia town res station	12	12	100%	1	1	8	1	-	-	-	-	-	-
SABC media park station	23	23	100%	8	2	7	-	-	-	-	-	-	-
Milpark station	8	7	87%	1	2	2	-	-	-	1	1	-	-
Wits stadium station	12	12	100%	3	3	-	-	-	-	3	3	-	-
Park town station	19	16	84%	6	-	5	2	-	-	1	2	-	-
Constitutional hill station	19	19	100%	9	2	-	1	-	-	4	3	-	-
Park Station	12	9	75%	2	1	-	1	-	-	2	3	-	-
Library gardens stations	23	17	74%	1	-	6	-	5	-	3	2	-	-
Total	387	229		23%	10%	34%	6%	7%	5%	6%	8%	0%	0%

Source: Author's field work, 2016

T1	Thokoza park to Ellis Park east	C1	Dobsonville to Ellis park east	C4	Newlands to Orlando stadium
T2	Thokoza park to Braamfontein	C2	Dobsonville to Maponya mall	F1	Naledi to Thokoza park
T3	Thokoza park to parktown	C3	City distribution route	F2	Protea Glen to Thokoza
F3	Highgate to Thokoza park				

Table 5.4 shows the routes that commuters prefer to use. The route from Thokoza park to Parktown (T3) is the most preferred route because it takes commuters from their home to their place of occupation within a short space of time as indicated by (34%) of the commuters. From table 5.4 it can be deduced that the trunk routes are the most preferred routes because they account for 67% of the commuters' preferred routes. Complementary routes were less preferred as 7% of the respondents choose Dobsonville to Maponya mall (C2) as their preferred route. Respondents indicated that they can access shopping facilities at the mall faster than travelling to the Johannesburg CBD. Since feeder routes travel short distance and result in commuters changing stations to use either Trunk or complementary routes, only 8% of respondents indicated that they preferred the Naledi to Thokoza park (F1) routes because they can then arrive at Thokoza station and change to a trunk route to arrive at their destination. Figure 5.8 illustrates the most preferred routes by respondents as shown in table 5.4.

Figure 5.8. Commuters' preferred routes



Source: Author's field data, 2016

Figure 5.8. illustrates the route that most of the respondents prefer to use. The routes that are most used by respondents are routes that offer a wide variety of services and functions such as route T3 where commuters use to go their occupation as shown in the map above.

5.1.6. Availability of commuter pre-trip information to commuters

Transportation information is crucial for the pre-trip planning and en-route journey planning for commuters and thus, data was collected on the availability of pre-trip information to commuters and analysed as follows:

5.1.6.1 En-route driver information to commuters

En-route driver information is crucial in informing commuters of the changing status of their journey and thus, data on whether respondents receive en-route driver information was collected and analysed as shown in table 5.5

Table 5.5. En-route driver information to commuters

BRT stations From point 1 to 20	NQD	NQR	% Returned	En-route driver information to commuters			
				Available	Not available	Do not know	Other
Thokoza park station	35	10	28%	3	2	5	-
Lakeview station	58	6	10%	1	3	1	1
Klipspruit valley station	39	8	21%	4	2	1	1
Boomtown station	12	3	25%	-	-	-	3
Orlando police station	8	6	75%	1	5	-	-
Orlando stadium station	15	9	60%	5	4	-	-
Noordgession extension station	19	12	63%	3	9	-	-
West bury station	31	28	90%	12	10	4	2
Hellen Joseph station	12	8	67%	1	2	4	2
UJ Kingways station	31	24	77%	4	16	-	4
UJ Sophia town res station	12	12	100%	-	-	6	6
SABC media park station	23	23	100%	19	4	-	-
Milpark station	8	7	87%	-	-	3	4
Wits stadium station	12	12	100%	4	2	3	3
Park town station	19	16	84%	4	10	2	-
Constitutional hill station	19	19	100%	13	3	6	-
Park Station	12	9	75%	6	1	1	1
Library gardens stations	23	17	74%	11	3	-	4
Total	387	229		39%	33%	15%	13%

Source: Author's field data, 2016

The en-route driver information assists commuters with their journey planning i.e. crucial for commuters to have the information at hand. The majority (39%) of respondents indicated that en-route information was available. They indicated that they receive the information through variable message signs which are mounted inside the buses. Information which they receive indicated the next coming station. However, the information is vague as it does not indicate the time they will arrive at the station and if there will be any disruption on their journey. This correlates with Qui-un (2013:19)'s study that the available ITS infrastructure is not being used effectively to improve commuter journey. According to Mathew (2013:6) the lack of awareness of ITS capabilities by commuters result in not receiving or not being updated on their en-route

information. 33% of respondents indicated that no information was available to them during their journey from their drivers, with 15% of commuters indicating that they do not know of any information that is disseminated during their journeys. This can be attributed to the lack of awareness of the ITS capabilities of the BRT from commuters.

5.1.6.2. Route guidance to commuters

According to Atsushi (2006:18), route guidance is a fundamental component for commuters during their journey and thus, all public transport should offer route guidance to commuters. Data on the availability of route guidance to commuters was collected and analysed as shown in Table 5.6.

Table 5.6. Route guidance to commuters

BRT stations From point 1 to 20	NQD	NQR	% Returned	Route guidance to commuters					
				Route map (Hard print)	Electronic map	Voice pronunciation	Smart phone application	Not available	Do not know
Thokoza park station	35	10	28%	3	-	-	-	2	2
Lakeview station	58	6	10%	1	-	-	1	3	1
Klipspruit valley station	39	8	21%	4	-	-	1	2	3
Boomtown station	12	3	25%	-	-	-	3	-	1
Orlando police station	8	6	75%	1	-	-	-	5	4
Orlando stadium station	15	9	60%	4	-	-	-	5	1
Noordgession extension station	19	12	63%	3	-	-	-	9	-
West burry station	31	28	90%	12	-	-	2	10	-
Hellen Joseph station	12	8	67%	1	-	-	2	2	-
UJ Kingways station	31	24	77%	4	-	-	4	16	-
UJ Sophia town res station	12	12	100%	-	-	-	6	-	-
SABC media park station	23	23	100%	19	-	-	-	4	-
Milpark station	8	7	87%	-	-	-	4	-	-
Wits stadium station	12	12	100%	4	-	-	3	2	-
Park town station	19	16	84%	4	-	-	-	10	-
Constitutional hill station	19	19	100%	13	-	-	-	3	9
Park Station	12	9	75%	2	-	-	1	1	2
Library gardens stations	23	17	74%	9	-	-	4	3	1
Total	387	229		47%	0%	0%	18%	23%	12%

Source: Author's field data, 2016

Considerably 47% of respondents indicated that there is route guidance at BRT Rea-Vaya station through hard print of the available routes. At each station the map shows where the respondents were located in relation to other stations. The map also highlighted which routes they should take to arrive at their different destinations. According to Ngobeni (2014:67), intelligent transport systems improves the dissemination of route guidance information. However, only a small portion of respondents (18%) use their smart phones for route guidance. This is attributed to low monthly income of respondents and expensive data cost associated

with a smart phone. This result in fewer commuters using the phones for route guidance (Ngobeni, 2014:69). 23% of respondents indicated that route guidance is not available and 12% of respondents indicated that they do not know of any route guidance systems in place within the BRT Rea-Vaya system. This was a result of the lack of awareness due to the insufficient marketing of the ITS by the Rea-Vaya management as respondents indicated.

5.1.6.3. Ride matching and reservation available to commuters

In order to understand how commuters plan for journeys, it was important to consider various options which were available to commuters to make reservation and ride matching as summarised in table 5.7.

Table 5.7. Ride matching and reservation available to commuters

BRT stations From point 1 to 20	NQD	NQR	% Returned	Ride matching and reservation available to commuters				
				Smart phone Reservation	Computer reservation	Telephonic reservation	Not available	Do not Know
Thokoza park station	35	10	28%	-	-	-	8	2
Lakeview station	58	6	10%	-	-	-	4	2
Klipspruit valley station	39	8	21%	-	-	-	3	5
Boomtown station	12	3	25%	-	-	-	-	3
Orlando police station	8	6	75%	-	-	-	6	-
Orlando stadium station	15	9	60%	-	-	-	6	3
Noordgession extension station	19	12	63%	-	-	-	12	-
West burry station	31	28	90%	-	-	-	28	-
Hellen Joseph station	12	8	67%	-	-	-	4	4
UJ Kingways station	31	24	77%	-	-	-	14	10
UJ Sophia town res station	12	12	100%	-	-	-	-	12
SABC media park station	23	23	100%	-	-	-	23	-
Milpark station	8	7	87%	-	-	-	4	3
Wits stadium station	12	12	100%	-	-	-	6	6
Park town station	19	16	84%	-	-	-	10	6
Constitutional hill station	19	19	100%	-	-	-	13	6
Park Station station	12	9	75%	-	-	-	-	9
Library gardens stations	23	17	74%	-	-	-	14	3
Total	387	229		0%	0%	0%	68%	32%

Source: Author's field data, 2016

The majority of respondents indicated that services for ride matching and reservation were not available. This was concurred by the Rea-Vaya management. They indicated that at the moment they have incorporated ride matching and reservation into the design of the ITS due to shortage of staff for managing the system as a whole, but 32% of the respondents indicated that they did not know any ITS systems for reservation and ride matching. According to Todor (2013:275) the majority of African countries have implemented the BRT with limited ITS functionality. This creates challenges in offering various services through ITS, such as ride matching and reservation. This was partly due to unavailability of the ITS system for ride

matching and reservation for commuters at the BRT Rea-Vaya because it causes inconveniences to commuters. In addition, they cannot purchase their travelling tickets or make seat reservation for a particular journey. Commuters were forced to travel to various stations to purchase tickets and even though they have purchased the tickets, they face the challenge of peak hour issues as it is not guaranteed that they will find enough space within the bus when it docks.

5.1.6.4. Was integrated electronic payment system available to commuters?

Integrated electronic payment systems are crucial because they improve the experience of commuters when traveling, such as not waiting in queues to purchase paper tickets and it is the fundamental component of intelligent transport systems for public transport. Table 5.8 shows the integrated electronic payment system available to commuters.

Table 5.8. Integrated electronic payment system

BRT stations From point 1 to 20	NQD	NQR	% Returned	Integrated electronic payment system					
				Smart card Payment	On-line computer payment	Banking card payment systems	Vending machine	Not available	Do not Know
Thokoza park station	35	10	28%	4	-	3	2	-	1
Lakeview station	58	6	10%	2	-	2	2	-	-
Klipspruit valley station	39	8	21%	3	2	1	1	-	-
Boomtown station	12	3	25%	1	-	2	-	-	-
Orlando police station	8	6	75%	2	1	-	-	2	1
Orlando stadium station	15	9	60%	3	2	1	-	1	2
Noordgession extension station	19	12	63%	4	-	1	4	3	-
West burry station	31	28	90%	10	2	1	8	2	5
Hellen Joseph station	12	8	67%	3	1	-	-	3	1
UJ Kingways station	31	24	77%	4	-	10	4	2	8
UJ Sophia town res station	12	12	100%	3	1	4	1	2	1
SABC media park station	23	23	100%	13	-	7	-	3	-
Milpark station	8	7	87%	-	-	4	3	-	-
Wits stadium station	12	12	100%	-	-	6	-	3	3
Park town station	19	16	84%	6	-	5	2	2	1
Constitutional hill station	19	19	100%	8	2	6	-	-	3
Park Station station	12	9	75%	3	1	3	-	-	2
Library gardens stations	23	17	74%	5	2	-	5	5	-
Total	387	229		32%	6%	25%	14%	12%	11%

Source: Author's field data, 2016

The majority of respondents (32%) indicated that the integrated electronic payments system that was available was the smart magnetic card, where they load money onto their cards in order to use them for journeys. Barth (2011) stated that online payments systems improve the user-experience of commuters because they can pay for their services at any location. They can access the internet. However, only 6% of respondents indicated that they use the online platform for payment of their BRT Rea-Vaya services. 25% of respondents indicated that they

can purchase their tickets or load up their smart card by paying using their traditional banking cards. The systems were not well maintained and they were forced to pay using physical cash at times. Every BRT Rea-Vaya station has a vending machine for purchasing tickets, but due to the lack of maintenance, some of them are non-functional machines. Only 14% of respondents use vending machines for ticket purchasing or smart card loading. According to Alton (2014:26), the lack of marketing of a new system made users not to be aware of the features it offers. This is evident with 12% of respondents saying that there was no integrated electronic payment system and 11% indicating that they did not know of any electronic payment system available in the BRT Rea-Vaya.

5.1.7. Commuters' perceptions of ITS in managing the Rea-Vaya

The introduction of the ITS in the BRT Rea-Vaya is to assist commuters to improve commuters experience through information dissemination, crucial in pre-trip and en-journey planning. It was important for the study to understand the perceptions of commuters regarding ITS and to discover areas that would require intervention for improved ITS management of BRT Rea-Vaya.

5.1.7.1 Commuter perception of safety with the ITS

Safety in public transport is very important because it assures commuters that they will arrive to their destinations without any incidents and thus, table 5.9 shows the level of safety opinionated by the commuters in relation to the ITS on the BRT Rea-Vaya.

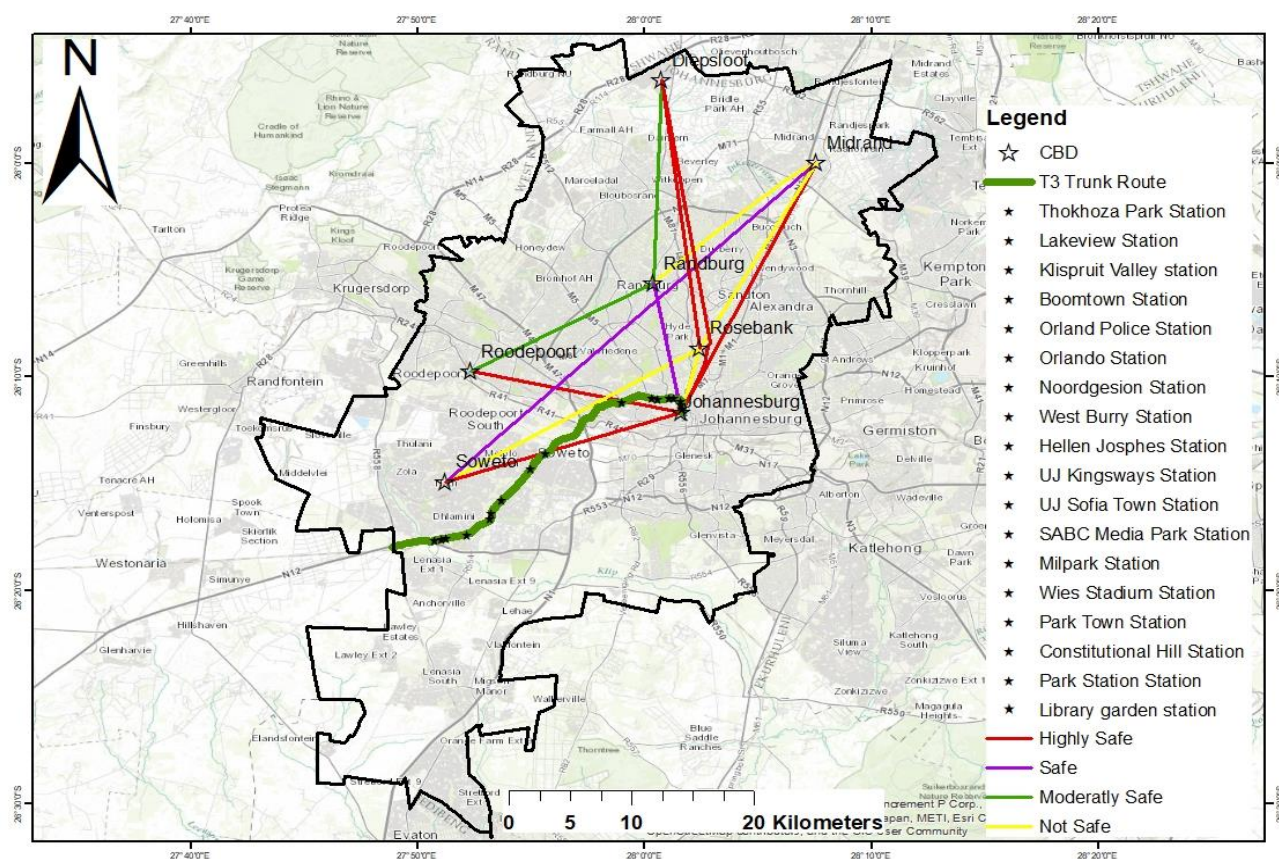
Table 5.9 Commuter perception of Safety with ITS

BRT stations From point 1 to 20	NQD	NQR	% Returned	Commuter perception of safety with the ITS				
				Safe	Moderately safe	Highly safe	Not safe	Do not know
Thokoza park station	35	10	28%	4	1	4	1	-
Lakeview station	58	6	10%	3	2	2	-	-
Klipspruit valley station	39	8	21%	2	-	-	4	2
Boomtown station	12	3	25%	-	-	-	3	-
Orlando police station	8	6	75%	1	2	-	3	-
Orlando stadium station	15	9	60%	3	3	-	-	3
Noordgession station	19	12	63%	6	1	4	1	-
West burry station	31	28	90%	8	4	6	5	5
Hellen Joseph station	12	8	67%	3	2	-	-	3
UJ Kingways station	31	24	77%	14	2	4	2	2
UJ Sophia town res station	12	12	100%	4	1	3	-	4
SABC media park station	23	23	100%	7	6	8	2	-
Milpark station	8	7	87%	5	-	2	-	-
Wits stadium station	12	12	100%	4	2	3	3	-
Park town station	19	16	84%	-	-	6	9	1
Constitutional hill station	19	19	100%	5	2	10	-	2
Park Station station	12	9	75%	4	-	5	-	-
Library gardens stations	23	17	74%	7	-	3	2	5
Total	387	229		37%	12%	26%	15%	10%

Source: Author's field data, 2016

Due to available surveillance systems at all stations through CCTV cameras, 37% of respondents indicated that they feel safe when using the BRT Rea-Vaya. 26% of respondents indicated that they feel highly safe at the stations. They attributed this to the security guards on duty. However, there are inter-station differences as stations which were located near townships indicated that they did not feel safe as shown by 15% of respondents who felt not safe. 10% of respondents said they did not know if they were safe or not due to the ITS availability. This is because they were not clear on the role that the ITS performs for their protection. From table 5.9 it is evident that stations that were located near Johannesburg felt that they were safe in comparison to stations that were located near townships as shown in figure 5.9.

Figure 5.9. Spatial analysis of perception of safety with ITS



Source: Author's field data, 2016

Figure 5.9. illustrates the spatial disparities of the perception of safety in relation to the ITS across the various stations. This shows how safety was considered in relation to the location of the station in areas such as townships where there were high crime rates. Those stations were perceived as unsafe. However, stations which were located near the Johannesburg CBD were considered safe due to the increased presence of law enforcement personnel.

5.1.7.2. Commuter perception of productivity with the ITS

The productivity of commuters in relation to ITS is crucial because it assists commuters to evaluate how they benefited from the system in relation to the traditional systems of management and operation of the bus rapid system. The productivity of the ITS would create a reliable bus rapid transit system that will make commuters arrive at their destination with relative ease on their journey and thus, table 5.10 shows how productive the ITS is according to commuters.

Table 5.10 Commuter perception of productivity with the ITS

BRT stations From point 1 to 20	NQD	NQR	% Returned	Commuter perception of productivity with the ITS				
				Productive	Moderately Productive	Highly productive	Not productive	Do not know
Thokoza park station	35	10	28%	4	1	3	2	-
Lakeview station	58	6	10%	-	-	-	-	6
Klipspruit valley station	39	8	21%	3	2	-	-	5
Boomtown station	12	3	25%	3	-	-	-	-
Orlando police station	8	6	75%	1	2	-	4	-
Orlando stadium station	15	9	60%	-	-	-	6	3
Noordgession extension station	19	12	63%	2	-	-	9	1
West burry station	31	28	90%	8	5	-	10	5
Hellen Joseph station	12	8	67%	4	-	4	-	-
UJ Kingways station	31	24	77%	6	-	4	14	-
UJ Sophia town res station	12	12	100%	3	-	-	6	3
SABC media park station	23	23	100%	8	3	7	2	3
Milpark station	8	7	87%	1	-	-	8	-
Wits stadium station	12	12	100%	3	-	-	9	-
Park town station	19	16	84%	5	3	2	5	1
Constitutional hill station	19	19	100%	9	-	-	-	10
Park Station	12	9	75%	-	-	-	9	-
Library gardens stations	23	17	74%	7	-	-	10	-
Total	387	229		29%	7%	9%	41%	14%

Source: Author's field data, 2016

Table 5.10 shows that the majority (41%) of respondents regard the ITS in the BRT Rea-Vaya as not productive. This was attributed to the lack of maintenance of the system. The available ITS infrastructure such as the variable message signs and vending machines were not functional in most of the stations and respondents indicated that the system was not productive. This corresponds with GIZ report on institutional functionality, which found that 48% of organizational ITS infrastructure is unproductive due to lack of maintenance and updating (Bearly, 2014:90). The inter-station differences from table 5.10 show that respondents from stations such as Constitutional Hill find the ITS productive because they were able to acquire information about their journeys as most of the systems are functional. 29% of respondents indicated that the system is productive, 14% indicated that they did not know if the system was making the BRT Rea-Vaya productive.

5.1.7.3. Commuters' perceptions of the efficiency of the ITS

The study sought to collect data on the scale at which the intelligent transport systems was efficient and at which ITS was managing the BRT Rea-Vaya according to commuters. Table 5.11 shows the perceptions at which commuters think the ITS was effective in managing the station.

Table 5.11. Commuter perception of efficiency with the ITS

BRT stations From point 1 to 20	NQD	NQR	% Returned	Commuter perception of efficiency with the ITS		
				Less effective	Effective	Highly effective
Thokoza park station	35	10	28%	4	3	3
Lakeview station	58	6	10%	6	-	-
Klipspruit valley station	39	8	21%	5	2	1
Boomtown station	12	3	25%	1	1	1
Orlando police station	8	6	75%	4	1	1
Orlando stadium station	15	9	60%	6	3	-
Noordgession extension station	19	12	63%	5	1	6
West burry station	31	28	90%	18	5	5
Hellen Joseph station	12	8	67%	4	2	2
UJ Kingways station	31	24	77%	12	10	2
UJ Sophia town res station	12	12	100%	6	3	3
SABC media park station	23	23	100%	15	5	3
Milpark station	8	7	87%	3	4	1
Wits stadium station	12	12	100%	7	3	2
Park town station	19	16	84%	3	5	5
Constitutional hill station	19	19	100%	-	18	1
Park Station	12	9	75%	-	6	3
Library gardens stations	23	17	74%	-	17	-
Total	387	229		43%	39%	18%

Source: Author's field data, 2016

The majority (43%) of respondents indicated that effectiveness and efficiency of intelligent transport systems on a scale of 1-10 was on the average of 1-3 which was less effective. This was due to the outdated infrastructure that was being used because it results in systems deficiency. According to Mathur (2015:43) the response time of the system depended on the speed of network transmission and the operating database performance. With a low speed of network transmission, it can result in the inefficiency of the system. This correlates with the findings of the study (which study are you referring to?) where ITS is considered to be inefficient by commuters as they are unable to connect with the system. The deficiency causes the system to be out of service and the respondents operate without proper oversight of the station, buses and the routes. 39% of respondents indicated that they could measure the system on an average of 4-7 on the effectiveness and efficiency of the system and only 18% of respondents indicated that the system was highly effective and efficient because they scored an average of 8-10.

5.1.7.4. Commuters' perceptions of the use of ITS to ensure comfort

The BRT was designed to offer an efficient, fast, cost-effective and comfortable public transport system to commuters. The study sought to understand how ITS was assisting commuters in terms of comfort while using the BRT Rea-Vaya. Table 4.12 shows how commuters perceive ITS in ensuring comfort.

Table 5.12 .Commuter perception of the use of ITS to ensure comfort

BRT stations From point 1 to 20	NQD	NQR	% Returned	Ensure comfort	Does not ensure Comfort	Do not know	Other
Thokoza park station	35	10	28%	3	5	2	-
Lakeview station	58	6	10%	-	3	3	-
Klipspruit valley station	39	8	21%	4	4	-	-
Boomtown station	12	3	25%	-	3	-	-
Orlando police station	8	6	75%	-	-	-	2
Orlando stadium station	15	9	60%	5	4	-	-
Noordgession extension station	19	12	63%	6	6	-	-
West burry station	31	28	90%	4	12	10	2
Hellen Joseph station	12	8	67%	-	4	2	2
UJ Kingways station	31	24	77%	-	13	11	1
UJ Sophia town res station	12	12	100%	7	3	1	1
SABC media park station	23	23	100%	3	7	13	-
Milpark station	8	7	87%	-	3	4	-
Wits stadium station	12	12	100%	-	6	6	-
Park town station	19	16	84%	-	11	5	-
Constitutional hill station	19	19	100%	-	13	6	-
Park Station	12	9	75%	-	9	-	-
Library gardens stations	23	17	74%	-	16	1	-
Total	387	229		14%	43%	39%	4%

Source: Author's field data, 2016

Table 5.12 shows that the majority (43%) of respondents indicated that ITS system does not ensure comfort when they use the BRT Rea-Vaya. This was attributed to the unreliable infrastructure for ITS as most of the time, it was not functional and thus, commuters are unable to acquire the information they wanted from the system. Commuters therefore had to proceed with their journey with insufficient information for their travels. However, 14% of respondents indicated that ITS ensures comfort for their journey. From the analysed data, this was found to be among university students that were technologically aware of the development and capabilities of the ITS such as the BRT Rea-Vaya application (*VAYA –MOJO*). They were able to check time of the next bus arrival at the station and they could relax or focus on other activities. The context in which ITS ensures comfort proved to be paradoxical for 39% of the respondents who indicated that they did not know how ITS can ensure comfort for their journey.

5.1.7.5. Commuter perception of reliability of ITS.

Reliable public transport systems ensure that existing commuters continue using the system and attract new commuters to the system, with respect to safety, efficient, effective and reliable commuting system. As summarised in table 5.13, the reliability of the system is analysed for the commuter benefit.

Table 5.13. Commuter perception of reliability of ITS

BRT stations From point 1 to 20	NQD	NQR	% Returned	Not reliable	Reliable	Moderately Reliable	Highly Reliable	Do not know
Thokoza park station	35	10	28%	4	1	3	-	3
Lakeview station	58	6	10%	2	-	2	-	2
Klipspruit valley station	39	8	21%	3	-	3	-	2
Boomtown station	12	3	25%	1	-	2	-	-
Orlando police station	8	6	75%	6	-	-	-	-
Orlando stadium station	15	9	60%	5	2	-	-	2
Noordgession extension station	19	12	63%	8	-	2	-	-
West burry station	31	28	90%	12	-	6	-	10
Hellen Joseph station	12	8	67%	3	3	2	-	-
UJ Kingways station	31	24	77%	14	-	5	-	6
UJ Sophia town res station	12	12	100%	7	-	2	-	3
SABC media park station	23	23	100%	19	-	-	-	4
Milpark station	8	7	87%	4	3	-	-	-
Wits stadium station	12	12	100%	8	-	3	-	-
Park town station	19	16	84%	10	2	4	-	-
Constitutional hill station	19	19	100%	11	1	4	-	4
Park Station	12	9	75%	4	-	3	-	2
Library gardens stations	23	17	74%	10	1	3	-	4
Total	387	229		57%	6%	23%	0%	14%

Source: Author's field data, 2016

The lack of maintenance of the ITS system led to the system being judged unreliable as shown in table 5.13, where 57% of the respondents indicated that the system was not reliable. The respondents also indicated that the information that was displayed on the variable message signs (VMS) was not consistent and reliable, because the VMS indicated that within the next 5 minutes the bus will be docking at the station, but when the time elapsed the bus had not arrived. Although 23% of respondents said the system is moderately reliable, they highlighted that some days the system was working well and on certain days it did not work, and thus they considered it moderately reliable. The electronic payment system was the most unreliable component of the ITS according to the respondents. This was because when they needed to load their cards, most days the system was offline, resulting in inconvenience because they have to buy paper tickets for that day only and for a single journey. This corresponds with the (Transport research knowledge centre) which found that lack of technical maintenance led to a breakdown in the ITS of the Brazilian BRT in Curitiba (Zuzana, 2009:65).

5.1.7.6. Respondents' general perception of the overall ITS systems.

To know the general perceptions of commuters on the overall ITS system of the BRT Rea-Vaya, the commuters were asked to give their opinions. Table 5.14 shows the opinions of commuters on the general view of the system.

Table 5.14 General perception of the overall ITS system

BRT stations From point 1 to 20	NQD	NQR	% Returned	Not Good	Fair	Good
Thokoza park station	35	10	28%	4	2	4
Lakeview station	58	6	10%	3	1	3
Klipspruit valley station	39	8	21%	8	-	-
Boomtown station	12	3	25%	2	-	1
Orlando police station	8	6	75%	3	-	3
Orlando stadium station	15	9	60%	4	5	-
Noordgession extension station	19	12	63%	5	7	-
West bury station	31	28	90%	-	12	16
Hellen Joseph station	12	8	67%	-	4	4
UJ Kingways station	31	24	77%	13	7	4
UJ Sophia town res station	12	12	100%	7	-	5
SABC media park station	23	23	100%	19	-	4
Milpark station	8	7	87%	4	2	1
Wits stadium station	12	12	100%	6	4	2
Park town station	19	16	84%	14	2	-
Constitutional hill station	19	19	100%	11	6	2
Park Station	12	9	75%	3	4	2
Library gardens stations	23	17	74%	7	6	4
Total	387	229		52%	27%	21%

Source: Author's field data, 2016

Table 5.14 shows that the majority (52%) of respondents found the system not to be good because it did not assist them in using the BRT Rea-Vaya because most of the infrastructure was not well-maintained, leading to inconveniences for commuters. Although the infrastructure for ITS was available, it was not utilised efficiently to improve the commuters' traveling experience through improved information dissemination. Commuters were unable to access pre-trip information and this made their journey planning difficult. However, 27% of the respondents indicated that the system was fairly good, as they can access information and know their routes as compared to other traditional bus services within the City of Johannesburg due to the ITS availability. This was in conjunction with 21% of respondents who highlighted that the system was generally good. The respondents attributed this to the user-friendly ITS systems and said it was easy to use even to a person that has not even used their payment systems. The personnel found at each station assist commuters when they have difficulties in orienting with the system and thus, improve the user experience of the system. It can however be deduced that there were contradicting views from commuters about the system. Nevertheless, the majority find the system unreliable because it was not functional most of the time.

5.1.8. Travel and traffic management of Rea-Vaya in Johannesburg

In order to understand the travel and traffic management patterns of commuters who used the BRT Rea-Vaya, it was necessary to understand the role of ITS in improving the management traffic within the City of Johannesburg as outlined in this section.

5.1.8.1. Emergency management of Rea-Vaya with (ITS)

In order to understand the integration of emergency systems in the BRT Rea-Vaya, it was crucial for the study to explore the features that operators come into contact with and how familiar they are with the systems. Table 5.15 shows the emergency management functionalities that are provided to operators by the ITS in the BRT Rea-Vaya.

Table 5.15. Emergency management of Rea-Vaya with (ITS)

Emergency management of Rea-vaya with (ITS)	BSD 1	BSD 2	BSD 3	BSD 4	BSD 5	BSD 6	BSD 7	BSD 8	BSD 9	BSD 10
Emergency electronic breaks lights			✓	✓		✓		✓	✓	
Intersection collusion warning		✓	✓	✓	✓	✓	✓	✓	✓	✓
Lane change warning										
Hazard location warning		✓	✓		✓	✓	✓			
Pre-crash sirens										
Emergency panic button	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Automatic data sharing with emergency services during incidents										
Other			✓	✓				✓	✓	✓

Source: Author's field data, 2016

BSD: Bus Driver

Table 5.15 shows the intelligent transport systems features that were available to the BRT Rea-Vaya bus operators for emergency management. Although there was a variety of features from the data, it was evident that operators were not acquainted with all the features because only 50% of the respondents indicated that there are emergency electronic breaking lights that alert them to break and reduce speed in case of a sudden collusion. However, 90% of respondents indicated that the buses had intersection collusion warning systems that prevented collusions at intersection and this worked in conjunction with the priority signal traffic systems. There were no pre-crash sirens available to the drivers to make them aware of any pending crash along the dedicated lanes that will allow the operators to take preventative measures to avoid the crash. The lack of automatic data sharing with emergency creates a challenge in the effective

management of emergency situations as respondents indicated that there was no coordination in terms of intelligent systems sharing critical data with emergency responders.

Wahle (2015:9) indicated that dis-integration of data sharing among emergency institutions resulted in ineffective management emergency incidents through ITS. 40% of respondents indicated that there are other systems in place for emergency management through intelligent transport systems such as CCTV cameras that provide a constant analysis of the station and buses to allow for easy and fast tracked respond to any emergency situation. This shows that the available systems for emergency management through intelligent transport systems were insufficient and required additional support to improve the data sharing from various emergency management service providers.

5.1.8.2. Integration of ITS to safety measures

In order to understand how the intelligent transport systems can create a safe environment for commuters and operators of the BRT Rea-Vaya, it was crucial and important to unpack the safety measures put in place at the Rea-Vaya and integrated into ITS. Table 5.16 highlights ITS features available to operators of the BRT Rea-Vaya and how it affects the management and operations.

Table 5.16 Integration of ITS to safety.

Integration of ITS to safety.	BSD 1	BSD 2	BSD 3	BSD 4	BSD 5	BSD 6	BSD 7	BSD 8	BSD 9	BSD 10
Distance warning	✓		✓	✓	✓			✓		✓
Intelligent speed adaptation	✓	✓	✓				✓	✓	✓	✓
Automotive vehicle identification										
Electronic sliding doors on station platform and buses	✓	✓		✓	✓		✓		✓	✓
Electronic ticketing system	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
CCTV cameras	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Other										

Source: Author's field work, 2016

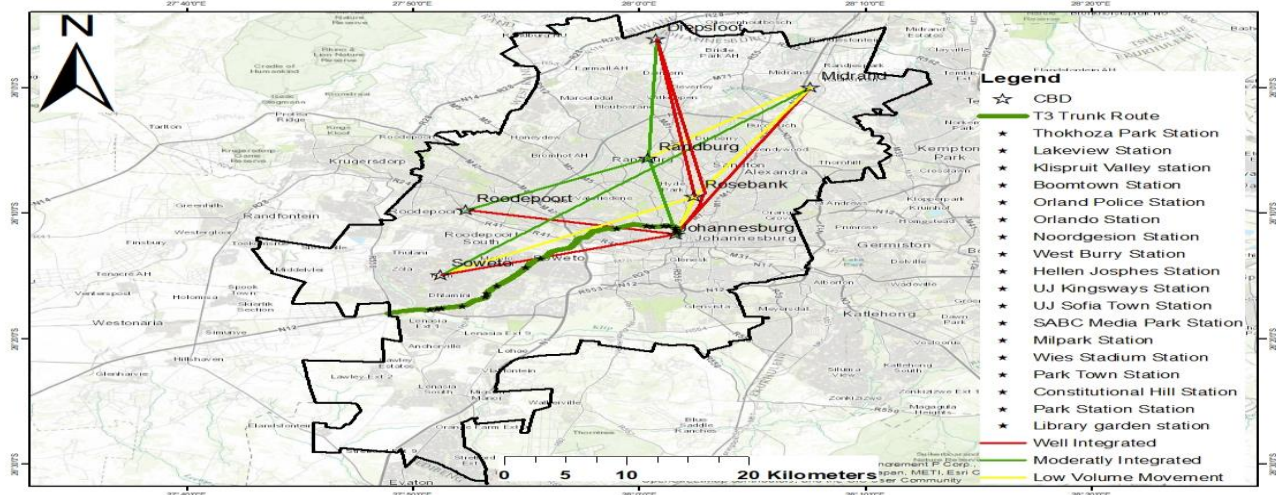
BSD: Bus Driver

The integration of ITS to safety allows the BRT Rea-Vaya management to create safe and reliable transport systems and it also prevents any negative incidents from occurring on the stations and within the buses. As shown in table 5.16, the majority (100%) of bus drivers indicated that CCTV cameras increased the safety in the buses and stations because there was

constant monitoring of the environment which allows for rapid response to any emergency. An electronic ticketing system prevents fare payment evasion and allows for commuters to pay for their journey before they can board the vehicles. This also means that drivers were not driving around with physical monetary funds that can attract hijackings and compromising the safety of passengers and drivers. According to Andrew (2016:104), the City of Johannesburg experience the highest hijacking and robberies than any provinces in South Africa and thus, it was critical in taking preventive measure such as CCTV cameras and electronic ticketing system to create a safe environment for commuters.

According to the DOT (2016:12), public transport accounts for 8% of crashes on the roads. To combat crashes and improve safety, 70% of respondents indicated that intelligent speed adaptation has been installed on the buses. This allows for the vehicles to automatically adjust the speed to prevent over speeding by the drivers. This means that the drivers will always be below the road speed limit. This works in conjunction with distance warning where 60% of the respondents indicated that they are available as a safety feature that alerts them whenever they were in close proximity with a vehicle ahead and driving beyond the safe following distance. From table 5.16 we can deduce that there are various features that have been implemented in the BRT Rea-Vaya to create a safe environment. However, from figure 4.10 it was evident that there is a disparity in terms of how commuters and drivers account for ITS improving safety.

Figure 5.10. Integration of ITS on safety



Source: Author's field work, 2016

Figure 5.10. illustrates the stations disparity that commuters and BRT Rea-Vaya operators have in relation to safety and how ITS is contributing to creating a safe environment for commuters.

5.1.8.3. Mobility advantages of ITS

The BRT Rea-Vaya was implemented as a cost effective, reliable, and safe, while providing improved mobility options for commuters. Table 5.17 indicates the mobility advantages that are provided by ITS on bus rapid transit Rea-Vaya.

Table 5.17. Mobility advantages of ITS

Mobility advantages of ITS	BSD 1	BSD 2	BSD 3	BSD 4	BSD 5	BSD 6	BSD 7	BSD 8	BSD 9	BSD 10
Reduced delays		✓		✓		✓	✓	✓	✓	
Reduced fuel consumption		✓	✓	✓	✓					
Improved safety (avoid primary and secondary crashes)	✓			✓		✓	✓	✓	✓	✓
Provide Alternative routes										
Reduced operational cost					✓		✓	✓		
Reduced traffic congestion			✓				✓	✓	✓	✓
Other										

Source: Author's field work, 2016

BSD: Bus Driver

There were various mobility advantages that contributed to the ITS and from table 5.17 we can deduce that 70% of the bus operators indicated that there was improved safety that avoided primary and secondary crashes as compared to old conventional buses that were not integrated with the ITS. This can be attributed to the safety measures that are introduced by the ITS in the BRT Rea-Vaya as highlighted in table 5.17.

The BRT Rea-Vaya operates on dedicated lanes and thus, the ITS does not provide alternative routes, as their routes were fixed and therefore, no mobility advantages for alternative route can be attributed to the ITS. However, the ITS according to 40% of the operators reduced fuel consumption. This contributes to effective and efficient management of the BRT Rea-Vaya as the operational costs are reduced. Through transit signal priority, the BRT reduces traffic congestions because it does not wait at intersections and thus, 50% of respondents indicated the mobility advantage of ITS. According to Mckain (2013:12), public transport systems need to be reliable to be able to satisfy current and attract new commuters. To ensure reliability, BRT Rea-Vaya ITS reduces delays and ensures that commuters arrive at their destination within time frames envisaged (Ngobeni, 2014:87). From table 5.17 we can deduce that 60% of respondents indicated reduced delay as a mobility advantage of ITS.

5.1.8.4. Traffic control measures into the ITS

An intelligent transport system plays a major role in road traffic management through active resource and equipment used by traffic control centres on roadway networks. In order to understand the relationship between bus rapid transit and ITS in traffic control, the study collected data on the measures that are employed by BRT Rea-Vaya management to control traffic.

Table 5.18. Traffic control measures into the ITS

Traffic control measures into the ITS	BSD 1	BSD 2	BSD 3	BSD 4	BSD 5	BSD 6	BSD 7	BSD 8	BSD 9	BSD 10
Lane management	✓		✓	✓	✓		✓	✓	✓	✓
Incident management	✓	✓	✓	✓	✓					
Automatic vehicle identification	✓		✓	✓		✓	✓	✓		
Ramp metering										
Intersection transit signal priority	✓	✓	✓	✓		✓	✓	✓		✓
Alternative route selection										
Other										

Source: Author's field data, 2016

BSD: Bus Driver

Table 5.18 shows that majority (80%) of the respondents indicated that the traffic control measure that was employed by the BRT Rea-Vaya management was the intersection transit signal priority. The NYC Global Partners (2010:10) indicated that intersection transit signal priority is an effective and reliable measure of traffic control through ITS (Ellra, 2013:6). When the bus was approaching an intersection, a signal was sent from the vehicle to the traffic lights, where traffic from the other direction was closed off to allow the BRT Rea-Vaya to pass through. This reduced traffic congestions because the buses were not stranded in slow traffic.

60% of respondents indicated that automatic vehicle identification was crucial in traffic control as it allowed operators at stations control to notify them of the measure they need to take for easy movement of the traffic, such as increasing speed to reduce delay for commuters. Incident management was a crucial component of traffic control as 50% of respondents indicated that a prompt response to incidents allows for easy movement of traffic as any bottleneck is quickly removed from the road way. The BRT Rea-Vaya operations and management does not employ ramp metering and alternative route selection as they operate on dedicated fixed lanes as a measure for traffic control.

5.1.8.5. Incident management with the use of ITS

In order to understand how the BRT Rea-Vaya provide a systematic, planned and coordinated effort to detect and respond to remove traffic incidents to restore traffic capacity as safely and quickly as possible, the study collected and analysed data on the incident management measure with the use of ITS. The data is illustrated on table 4.19 below:

Table 5.19 Incident management with the use of ITS

Incident management with the use of ITS	BSD 1	BSD 2	BSD 3	BSD 4	BSD 5	BSD 6	BSD 7	BSD 8	BSD 9	BSD 10
Traffic signal adjustment in the vicinity of disrupted areas			✓	✓	✓	✓	✓	✓	✓	✓
Data exchange among the transportation, security and emergency agencies	✓	✓				✓			✓	✓
Alarm/alert initiated by the driver		✓	✓	✓	✓	✓	✓			
Alternative routing, scheduling running times for various incidents	✓				✓	✓	✓		✓	✓
Other										

Source: Author's field data, 2016

BSD: Bus Driver

Incident management allows for traffic bottlenecks to be removed from the traffic as quickly as possible. Table 5.19 shows that 80% of respondents indicated that traffic signal adjustment in the vicinity of disrupted areas were an intelligent transport system measure for incident management. This allowed the operators to redirect traffic to areas that were not affected by the incident and therefore, keep the traffic moving. To ensure an efficient and effective incident management, 50% of respondents said that the ITS allows for data exchange among transportation, security and emergency agencies for better communication and coordination to manage the incident related to the BRT Rea-Vaya. For improved incident management, 60% of respondents indicated that the ITS alternates routes, and scheduling of running times for various incidents. This ensures that scheduling was managed to ensure commuters arrive at their destination with slight delays experienced. Table 5.19 shows that 60% of respondents indicated that alarm/alert was initiated by the drive as a measure for incident management through ITS. The BRT Rea-Vaya fleet was installed with a panic button that was available to operators so that it can make the managing authority aware of any incidents that require a speedy response to the matter.

5.1.9. Key-informant interview

The researcher saw the need to collect and analyse data from key informants in order to analyse their views of the BRT Rea-Vaya management on the use of intelligent transport systems for operating and managing the systems. The key-informants provided an insight into the challenges they encountered and how they were resolved. Thus, it was crucial for the researcher to conduct interviews with the key informants.

5.1.9.1. Position of key-informants

An intelligent transport system offers a wide range of services to achieve different functions within an organisation and thus, it was important for the study to collect information on the positions of the key-informants in relation to the intelligent transport system.

Table 5.20. Positions of key-informants in the BRT Rea-Vaya management

Positions	Number of staff
Intelligent transport systems manager	1
Station controller	2
Fleet manager	2
Communication manager	1
Metropolitan traffic officer	1
Marketing manager	1
Total	8

Source: Author's field data, 2016

Table 5.20. indicates the various positions held by the key-informants in the management for the BRT Rea-Vaya. The positions indicated the importance of the informants in providing information on the running of BRT Rea-Vaya, such as traffic officer to monitor offenders in the encroachment of the dedicated lanes.

5.1.9.2. ITS infrastructure available in the operations and management.

The management and operations of the BRT Rea-Vaya depends on the intelligent transport systems available and thus, it was important for the study to inquire on the infrastructure available. The data is summarised in Table 5.21.

Table 5.21 Intelligent transport systems infrastructure.

Available intelligent transport systems infrastructure	KII-1	KII-2	KII-3	KII-4	KII-5	KII-6	KII-7	KII-8
Variable message signs	✓	✓	✓	✓	✓	✓	✓	✓
CCTV	✓	✓	✓	✓	✓	✓	✓	✓
Adaptive traffic control			✓	✓				
Route guidance								
Ramp metering								
Intersection-signal priority	✓	✓	✓	✓	✓			
Turnstile fare payment systems	✓	✓	✓	✓	✓	✓	✓	✓
Other		✓	✓	✓				

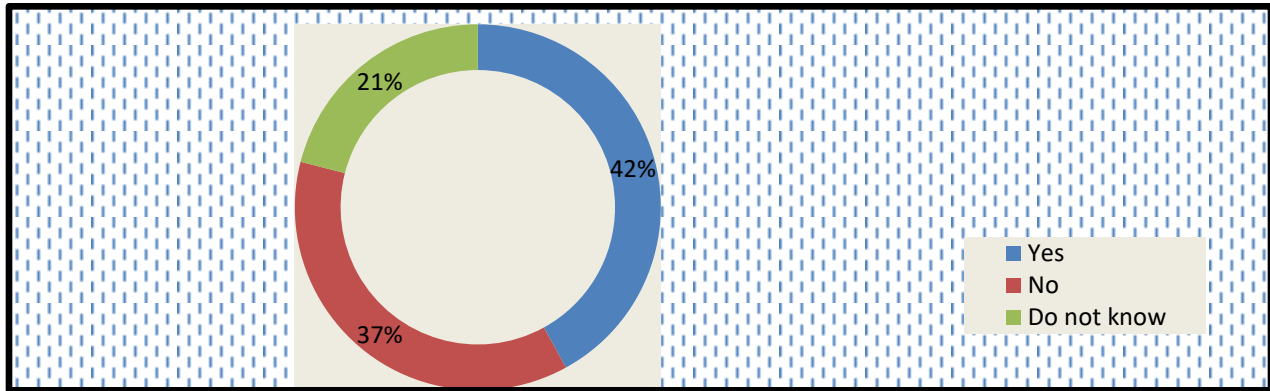
Source: Author's field work, 2016

As summarised in table 5.21, 100% of the key-informants indicated that the variable message signs, CCTV cameras and the turnstile fare payment systems were available for the management of the Rea-Vaya system. Only 62% of the key-informants indicated that they were aware of intersection-signal priority for the buses as an infrastructure available for intelligent transport systems. The reason to justify their answer was that they were only responsible for infrastructure for intelligent transport systems in the BRT Rea-Vaya, while 25% of respondents indicated that there was adaptive traffic control as infrastructure for the system. However, infrastructure such as route guidance and ramp metering are not available as the BRT Rea-Vaya uses dedicated running lanes.

5.1.9.3. Effectiveness and efficiency of ITS in managing and operating the BRT

Data on whether the intelligent transport systems was effective and efficient in the managing and operating of BRT Rea-Vaya was collected and analysed. The rationale was to understand how the informants benefited from the systems or not. The summarised findings are shown in figure 5.11. According to Terry (2011:76), ITS systems improve the management of BRT through effective and efficient functionality. However, due to lack of technical experience and expertise in the system, this can lead to ineffective and less effective management of public transport through ITS (Wray, 2011:34). This correlates with the findings of the study, where 37% of respondents illustrated that the system is ineffective and inefficient in managing the systems, as the system is difficult in operating and requires a set of skills that some of the key-informants do not have.

Figure 5.11. Effectiveness and efficiency of ITS in management and operation



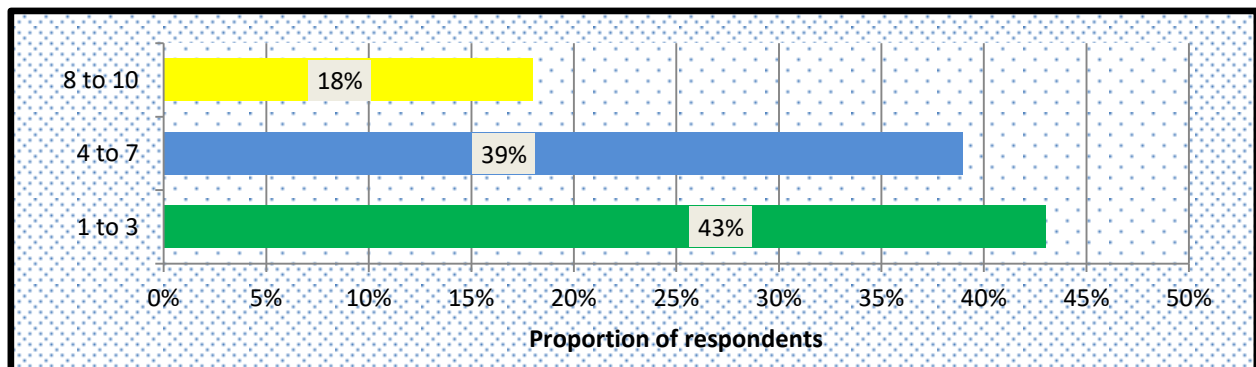
Source: Author's field data, 2016.

As indicated in figure 5.11, the majority (42%) of respondents indicated that the intelligent transport system was effective and efficient in managing and operating the BRT Rea-Vaya system. The reason they used to justify their answer was that it allows for up to date real-time monitoring of the stations, buses and the routes of Rea-Vaya. The findings show that 21% of respondents do not know if the system is effective or efficient in managing the BRT Rea-Vaya.

5.1.9.4. Measure of effectiveness and efficiency of ITS in management and operations

The study sought to collect data on the scale at which the intelligent transport systems was efficient and effective in managing and operating the BRT Rea-Vaya and the analysed data is illustrated in figure 5.12

Figure 5.12. Scale of effectiveness and efficiency



Source: Author's field work, 2016

The majority (43%) of key informants indicated that effectiveness and efficiency of intelligent transport systems on a scale of 1-10 was on the average of 1-3 which was less effective. This was due to outdated infrastructure that was being used because it results in systems deficiency. The deficiency causes the system to be out of service and the respondents operate without

proper oversight of the station, buses and the routes, while 39% of respondents indicated that they could measure the system on an average of 4-7 on the effectiveness and efficiency of the system and only 18% of respondents indicated that the system is highly effective and efficient as they scored it on an average of 8-10.

5.1.9.5. Benefits of managing and operating BRT Rea-Vaya ITS.

Intelligent transport systems offer a wide range of benefits that can be attained from managing the BRT using the system. In order to understand the reason for utilising intelligent transport systems by the Rea-Vaya management, the study gathered and analysed data on the benefits of using intelligent transport systems. The summary of the data is illustrated in table 5.22.

Table 5.22. Benefits of managing and operating BRT Rea-Vaya using ITS

Benefits of managing BRT Rea-Vaya through intelligent transport system	KII-1	KII-2	KII-3	KII-4	KII-5	KII-6	KII-7	KII-8
Improving Traffic Flow			✓	✓	✓			
Up-to-date information of the current traffic conditions	✓	✓	✓		✓	✓		
Easy data collection and processing	✓	✓				✓		
Reduced duration of incident management		✓	✓	✓	✓	✓	✓	✓
Traffic signal coordination		✓	✓	✓	✓	✓		✓
Improved safety and security	✓	✓	✓	✓	✓	✓		
Other			✓		✓	✓		

Source: Author's field data, 2016

Table 5.22 indicates that 38% of respondents suggested that utilizing intelligent transport systems for operating and managing the BRT Rea-Vaya improves traffic flow and this was due to the feature of traffic signal coordination, while 75% of respondents highlighted that traffic signal coordination allows for the buses to have intersection priority. The BRT Rea-Vaya uses dedicated lanes in conjunction with intersection priority, which allows for improved flow of traffic as the buses do not add in the creation of traffic congestion.

The use of CCTV cameras allows for the constant monitoring of the stations and buses, creating a safe environment for both commuters and the BRT Rea-Vaya staff, where 75% of the respondents indicated that improved safety and security was the one of the benefits of managing the BRT Rea-Vaya through intelligent transport system.

Deducing from the data, it showed that 62% of the key informants illustrated that acquiring up to date information of traffic conditions was a benefit of using intelligent transport systems. This allows for the management to take appropriate steps to overcome any identified adverse traffic conditions.

Unfortunately, accidents and adverse incidents were an unforeseen occurrence on the roads and a quick response to an incident was key. Thus, the intelligent transport system notifies authorities of any incidents and they can respond in a timely manner, thus reducing the response time to an incident. This was the reason why 87% indicated that it was the benefit of using intelligent transport systems.

5.1.9.6. Challenges of managing and operating the BRT Rea-Vaya through ITS.

Although, intelligent transport system offers a wide range of benefits, there were challenges that were associated with the utilisation of intelligent transport system for management and operations of the BRT. The study sought to identify the challenges so as to provide suitable solutions.

Table 5.23. Challenges of managing and operating BRT Rea-Vaya using ITS

Challenges of managing BRT Rea-Vaya through intelligent transport system	KII-1	KII-2	KII-3	KII-4	KII-5	KII-6	KII-7	KII-8
Lack of technical expertise in utilising ITS	✓	✓						
Breakdown of ITS equipment		✓	✓	✓				
Delayed information of current traffic conditions								
Out of date equipment		✓	✓					
Lack of institutional integration						✓	✓	
Other		✓	✓			✓		✓

Source: Author's field data, 2016

Lack of technical expertise accounted for 25% of respondents' view on the challenges of managing BRT Rea-Vaya using intelligent transport system. The reason to justify their answer was that the South African education was not adapting to the changing environment of the evolution of information technology. The use of intelligent transport system for BRT in South Africa is fairly new and thus, few people have the capabilities to operate and understand the system.

The intelligent transport system infrastructure being used in the BRT Rea-Vaya have reached their life cycles, resulting in frequent breakdown. This is the reason 37% of respondents indicated it as a challenge. All of the equipment were installed in 2009, thus they are out of date. 25% of respondents highlighted that this was a challenge and they justified their answer by saying that intelligent transport equipment were expensive to procure and thus, it takes a long time to replace.

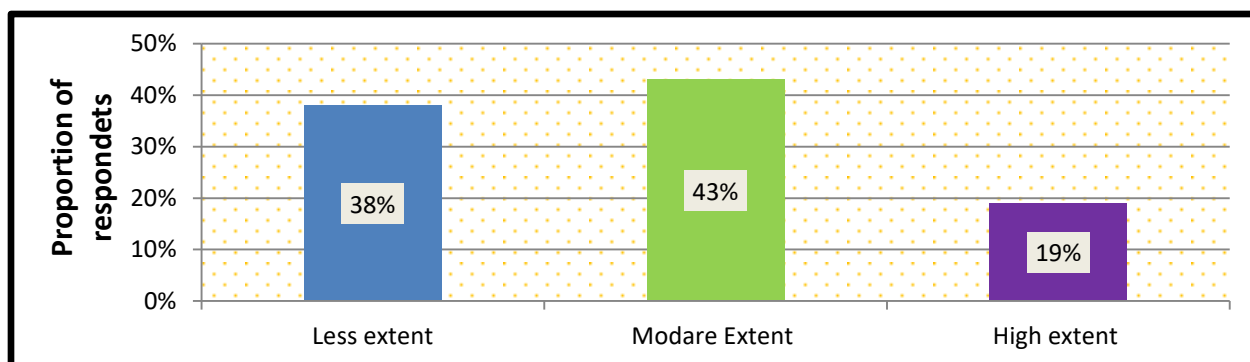
Institutional integration is key in sharing resources and information and thus, it is critical in creating an integrated transport system. 25% of the respondents indicated that lack of institutional integration was a challenge in using intelligent transport systems. The challenge was that as most institutions plan in isolation, it was difficult to share information and therefore, a duplication of information occurs as one of the respondents indicated.

The study revealed that other challenges that respondents identified were financial constraints. This created obstacles in procuring new equipment needed for updating the systems. It prevents staff personnel from getting the training they need to better understand the system, so that they can operate it at an optimal functionality.

5.1.9.7. Extent to which traffic congestion was reduced in routes managed by ITS.

Urban areas often experience traffic congestion and most BRT were implemented as a strategy to reduce traffic congestion. Intelligent transport systems were implemented to facilitate the process and it was important for the study to collect data on the extent to which traffic congestion is reduced in areas managed by intelligent transport system, which was analysed.

Figure 5.13. Extent of reduced traffic congestion through ITS



Source: Author's field data, 2016

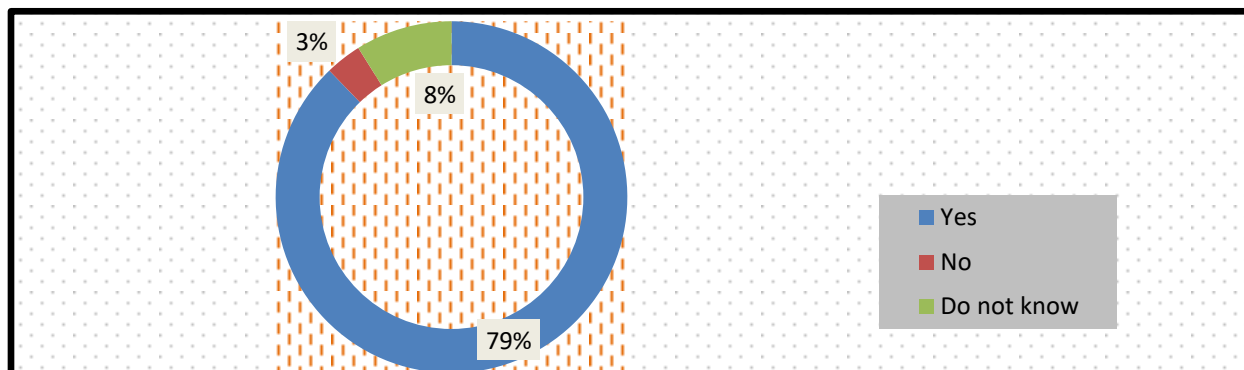
The majority (43%) of respondents indicated that the intelligent transport systems reduces traffic congestion to a moderate extent. The reason they gave to justify their answer was that it allows

for free movement of the BRT Rea-Vaya buses through intersection signal priority. 38% of respondents indicated that intelligent transport system reduces traffic congestion to a less extent due to the fact that other mixed traffic was not monitored by a fully operating intelligent transport system. 19% of respondents indicated that the intelligent transport system was reducing traffic congestion to a high extent and the reason being that they had real-time monitoring of traffic conditions and they can take measures to reduce it.

5.1.9.8. Partnership with private sector regarding ITS management of Rea-Vaya

Private public partnerships are crucial in the successful implementation of the intelligent transport systems, thus the study sought to gather data on the partnership with private sector regarding the management and operating of the BRT Rea-Vaya. The summary of the data analysed is shown in figure 5.14.

Figure 5.14. Partnership with private sector on managing BRT Rea-Vaya through ITS



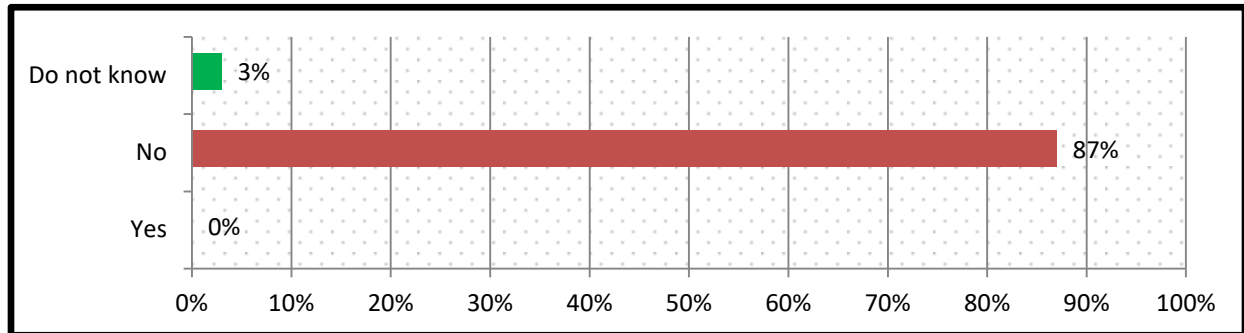
Source: Author's field data, 2016

The majority (79%) of key-informants indicated that there was a private partnership with a private company in the management and operating of the BRT Rea-Vaya through the intelligent transport systems. The private company has been contracted by the City of Johannesburg metropolitan to develop and maintain an intelligent transport system which is the Automatic public transport management system (APTMS). The company's headquarters are in Switzerland and it is called Denos. The private company works closely with the municipality in the training of BRT Rea-Vaya staff in operating the intelligent transport system. 8% of the respondents indicated that they do not know of any partnership with the private sector. The minority (3%) of respondents indicated that there are no partnerships with the private sector in terms of implementing and managing the BRT Rea-Vaya through intelligent transport systems.

5.1.9.9. Proposed future projects for ITS infrastructure for managing the BRT Rea-Vaya.

The study sought to collect information on the proposed projects for the upgrading of the intelligent transport system infrastructure. The data is summarised in figure 5.15. below.

Figure 5.15 Proposed projects for upgrading of ITS



Source: Author's field data, 2016

The majority (87%) of key-informants indicated that there were no proposed projects in the upgrading of intelligent transport systems. The respondents indicated that financial constraints were hindering the Rea-Vaya management in the upgrading of the systems because most of the infrastructure have reached and surpassed their life cycle. 3% of the key informants indicated that they do not know if there are any projects that are for upgrading of the intelligent transport system.

5.1.9.10. Conflict management between BRT Rea-Vaya and Taxi industry

Conflict between the Rea-Vaya Management and the Taxi Industry was as a result of the route assigned to the Rea-Vaya. Despite the numerous talks held between the Rea-Vaya Management and the Taxi Associations, the situation was not resolved amicably. There appears to be resentment on the part of the Taxi Industry towards the Rea-Vaya Management. According to Mr Khumalo, a taxi driver in Johannesburg, "The reason why the taxi drivers and Rea-Vaya did not see eye to eye was because they both operate on the same routes". Mr Ncube adds that the City of Johannesburg took their routes, "Without our concession, they just pick out. We are having so many questions cause of those routes, you taxis you going to use those routes, because of accidents, we appreciate that".

The sentiment that prevails among some of the members of the Taxi Associations is that their routes were "Hijacked" by the Government. Streets in the inner city such as Loveday, Rissik, Bree, Smith, Kotze, Jeppe, Harrison, Commissioner and Market Streets are amongst the

busiest streets in the inner city. These streets are used by taxis as well as by the Rea-Vaya. Mr Ncube claims that the “City has hired their drivers they gave the drivers the keys and said use the taxi routes and that’s what they are now doing”. Although this is not how the Rea-Vaya operates, this statement provides an indication of how the Taxi Industry views the Rea-Vaya bus routes.

Conflict also stemmed from the fact that the Rea-Vaya buses operate in their own designated lanes, while taxis have to drive with traffic in the general traffic lanes. According to Mr Ncube in April when the Rea-Vaya bus drivers were on strike:

“If they (JMPD) get you in the dedicated lanes they took the disc and impounded your car for using that, that’s what even happening today, you can follow the private car, to the private car they say hey, but to the taxi they take the disc and impound the car”

Using the general traffic lanes was a challenge to taxi drivers as the volume of traffic causes delays and as Mr Ncube explains “Our passengers tempted by these dedicated lanes, that we are taking 5 minutes from Soweto to Johannesburg, with the taxis it going to take 45 minutes to 1 hour”. As Rea-Vaya buses have their designated lanes, they can bypass the general traffic, thereby reducing travel time, whilst taxis have to contend with the volume of traffic. Consequently, commuters prefer the Rea-Vaya which has led to aversion towards the Rea-Vaya Bus Service by the Taxi Industry.

A few members of the Taxi Association felt that the conflict between the Taxi Associations and the Rea-Vaya Management could not be resolved, because the members of the Taxi Associations were threatened by the presence of the Rea-Vaya Bus Service. Mr Khumalo was of the opinion that “Buses were putting taxis off the road”. In other words, it is no longer lucrative for taxis to run alongside the Rea-Vaya. Mr Mnguni, a taxi driver claims that “The Rea-Vaya is a threat to our income”, and believes that “The conflict between the Rea-Vaya and taxis cannot be resolved”. As a result of the different views held by the Taxi Association and the Rea-Vaya Management, unfortunately there appears not to be a point of agreement. Additionally, Mr Jacob, a taxi owner argues that the Rea-Vaya (BRT) Management have not taken into consideration the plight of taxi drivers. However, Mr Jacob argues that the Taxi Associations were “Not presented with an impact study of the BRT” upon implementation of the system.

5.2. Statistical data presentation and analysis

This section presents analyses and interprets data on commuters' relationships between the BRT Rea-Vaya and the intelligent transport system. The analysis began with measurement scale analysis of the research instrument that was used in this study. Secondly, analysis was done in respect of determining the characteristics of intelligent transport systems in bus rapid transport and how it affects commuters.

5.2.1. Measurement scale analysis

Before the study constructs were used to analyze commuters' relationships between the BRT Rea-Vaya and the intelligent transport system, it was necessary to evaluate their reliability and validity, ensuring that research instruments (questionnaires) used for this study have internal consistency, stability and are free from random (Alshehri, 2012:13). In addition, Giannakos (2014) indicates that internal consistency was related to the extent to which participants' responses are dependable and steady across construct variables of a single data gathering instrument.

For this reason, the measurement scales used for assessing the study objectives were tested for reliability and validity. The details of such statistical processes and results are given below.

5.2.1.1. Reliability analysis: Estimating internal consistency

Cronbach's Alpha was used to perform reliability analysis (Cronbach, 1951). Internal consistency reliability analysis is an estimate of internal consistency associated with the scores that can be derived from the scale or composite score. Reliability analysis should be performed before commencing any advanced statistical analysis. It is significant to any study because without performing it, it is impossible to have any validity associated with the scores of the scales.

Alshehri (2012) posits that high values of Cronbach's Alpha are desirable and signify the reliability of measures. A four-point-likert scale measure of reliability was suggested by Hair, Black, Babin and Anderson (2014); (0.50 and below) low-reliability, (0.50 and below 0.70) high-moderate-reliability (acceptable), (0.70 and below 0.90) high-reliability and excellent-reliability (0.90 and below 1.0).

Hair et al., (2014) view that a Cronbach's Alpha score of 0.70 and above is essential for acceptable internal reliability, whereas Pallant (2013) advocates for any internal reliability score value which is above 0.60. Additionally, Nadi (2012:103) recommends that all alpha values

above 0.50 (acceptable) should be regarded as a true indicator of convergence and any values below 0.50 are unacceptable and should be discarded. The findings of the study showed that Cronbach's Alpha values for all the variables construct ranged between 0.67-0.89, for the questionnaires distributed to BRT Rea-Vaya commuters and management.

Table 5.24. Cronbach's Alpha Reliability results: BRT Rea-Vaya commuters

Research objectives	Variable construct	Number of items	Cronbach Alpha	Overall comment based on (based on Hair et al.'s, (2014) four degrees of reliability scale)
To explore the opinions and attitudes of commuters on improvement of safety in the BRT Rea-Vaya	Personal contact	2	0.85	High reliability
To explore the managers' perceptions of the reliability of ITS with respect to Rea-Vaya.	Managers inputs	1	0.67	High moderate reliability (acceptable)
To determine the efficiency of the ITS in the management of the BRT Rea-Vaya in the City of Johannesburg.	Personal Contact	3	0.87	High reliability
To determine the level to which the introduction of ITS in Rea-Vaya has reduced waiting times for commuters.	Personal contact Manager inputs	3	0.89	High reliability

Source: author 2016

Thus, overall and in line with Nadis (2012) recommendations, the Cronbach's Alpha results for this study indicated that the study instrument for BRT Rea-Vaya commuters was reliable with all the values above 0.50- thus indicating proper internal construct-reliability as shown in table 5.24.

Table 5.25. Cronbach's Alpha Reliability results: BRT Rea-Vaya management

Research objectives	Variable construct	Number of items	Cronbach Alpha	Overall comment based on <i>(based on Hair et al.'s, (2014) four degrees of reliability scale)</i>
To explore the opinions and attitudes of commuters on improvement of safety in the BRT Rea-Vaya	Variable construct	2	0.85	High reliability
To explore the managers' perceptions of the reliability of ITS with respect to Rea-Vaya.	Personal contact	1	0.67	High reliability
To determine the efficiency of the ITS in the management of the BRT Rea-Vaya in the City of Johannesburg.	Managers inputs	3	0.87	High reliability
To determine the level to which the introduction of ITS in Rea-Vaya has reduced waiting times for commuters.	Personal Contact	3	0.89	High reliability

Source: author 2016

The findings of the study showed that the Cronbach's Alpha values for all the variables construct ranged between 0.689- 0.956 for the questionnaires which were distributed to the BRT Rea-Vaya management. Thus, in line with the recommendations by Nadis (2012), the results for the study are therefore reliable.

5.2.2. Regression analysis

A regression analysis was conducted to elaborate the various relationships that exist between commuters and the BRT Rea-Vaya as a form of public transport. The analysed data indicated how commuters relate to the system and how it affects commuters on their daily journeys.

5.2.2.1. Regression analysis: summary for influence of occupation status on the purpose of using BRT

The study hypothesized that the occupational status of commuters will influence the reason why commuters are utilising the BRT Rea-Vaya. At the conceptual level, the occupation of commuters is expected to correlate with the rationale for utilising the BRT Rea-Vaya (Pienaar, Krynauw & Period, 2005). Because of the measurement criteria employed to measure successful BRT system, linear regression analysis was selected as an appropriate statistical procedure for investigating occupational status factors that influence the commuters' rational on using the BRT Rea-Vaya.

Table 5.26. Model summary for influence of occupation status on the purpose of using BRT for

Model	R	R Square ^b	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.916 ^a	.840	.839	.864	.840	1187.423	1	227	.000

a. Predictors: occupation of respondents

Source: Author 2016

Results of the study presented in table 5.26 revealed that the independent variable explains about 86.4 of the dependent variable (roles of occupation status on the purpose of using the BRT Rea-Vaya), with the R-squared equal to 0.840. The outcome of the ANOVA test confirmed the models best fit, which could predict a better outcome than using a mean with the ratio of improvement reached $F=1187.423$ and a significant value equal $0.000(p<.05)$.

Table 5.27. ANOVA test for influence of occupation status on the purpose of using BRT for

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	886.523	1	886.523	1187.423	.000 ^c
	Residual	169.477	227	.747		
	Total	1056.000 ^d	228			

a. Dependent Variable: purpose of using BRT by respondents

Source: Author 2016

Table 5.27. above presented the ANOVA test results. The study presents the Coefficients for influence of occupation status on the purpose of using BRT relationship.

Table 5.28. Coefficients for influence of occupational status on the purpose for using BRT.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	occupation of respondents	.754	.022	.916	34.459	.000	.711	.797

Source: Author 2016

The coefficient context factor for occupation of respondents (does occupation statuses influence commuters on the purpose they utilize the BRT Rea-Vaya), was found to be positively ($\beta=0.0754$) influencing a commuter's choice for the BRT. Such an association was found to be significant at $p<0.1$ (P-value = 0.000). These results suggest that the occupation of commuters played a role in the rational for utilising the BRT Rea-Vaya.

According to Crainic et al., (2009:89), the occupation role of commuters affects the reason why commuters utilize a specific public transport system. Moreover, such was the case of Brazil (Curitiba BRT) where the design of the BRT transportation system was aimed at providing services to areas with high density commercial activities and institutional functions as it will influence how commuters utilize the system.

5.2.2.2. Regression analysis: summary for influence of how purpose of travel affects commuters' willingness to travel.

The study hypothesized that the purpose of using the BRT Rea-Vaya affects the time commuters are willing to travel. At the conceptual level these factors are expected to correlate with commuter perception of the BRT operation and management systems (Martin et.al, 2005; Suarez-Balcazar et.al., 2007, & Russo et.al., 2007). Because of the measurement criteria employed to measure the influence of these factors of the BRT system operates, linear regression analysis was selected as an appropriate statistical procedure.

Table 5.29. Model summary for the influence of the purpose of travel on commuter willingness to travel

Model	R	R Square ^b	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.885 ^a	.784	.783	1.926	.784	823.926	1	227	.000

a. Predictors: occupation of respondents

Source: Author 2016

Results of this study presented in table 5.6 revealed that the influence of the purpose of travel on commuter willingness traveling time. They explain or influence about 7.84 variance, with R-square equal to 0.748 in conjunction with a significant value of 0.000. This means that the purpose for commuting significantly influence the time commuters are willing to take for travels.

Table 5.30 ANOVA test for influence of purpose of travel on commuter willingness to travel.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	886.523	1	886.523	1187.423	.000 ^c
	Residual	169.477	228	.747		
	Total	1056.000 ^d	229			

a. Dependent Variable: purpose of using BRT by respondent

b. Predictors: occupation of respondents

Source: Author 2016

The outcome of the ANOVA test (table 5.30) confirmed the models best fit, which could predict a better outcome than using the mean with the ratio of improvement reached $F=1187.423$ and a significant value equal 0.000 ($p<.05$).

Table 5.31 Coefficients for influence of purpose of travel on commuter willingness to travel.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	occupation of respondents	.754	.022	.916	34.459	.000	.711	.797

a. Dependent Variable: purpose of using BRT by respondents

Source: Author 2016

The study results indicate purpose of travel for commuters significantly influence the willingness of commuters traveling for prolonged times. Firstly, the need to travel for commuters was found to be positively ($\beta=0.75$) influencing the time that commuters will spend travelling. Such an association was found to be significant ($P\text{-value} = 0.000$). Saurez-Balcazar (2004) and Saurez-Balcazar et.al., (2005) posit that the reason why commuters are travelling for plays a role on the time they are willing to spend commuting. Therefore, having a reliable public transport that meets the various needs of commuters is critical as it reduces their travelling time and resulting in a reduced travelling time.

Aduwen (2014) stated that the time commuters are willing to travel is determined and influenced by the purpose of their journey. This is correlated by Emmanuel (2012)'s study which found that commuters who use public transport to arrive to their work place were prepared to travel long distance compared to commuters who are tourists.

5.2.1.3. Regression analysis: summary of how time of travel is influenced by distance between place of residence and occupation.

The study hypothesized that the time commuters spend travelling is influenced by the distance between their place of residence and place of occupation. At the conceptual level the distance between place of residence and occupation is expected to correlate with the rationale for utilising the BRT Rea-vaya (Pienaar, Krynauw & Period, 2005). Because of the measurement criteria employed to measure successful BRT system, linear regression analysis was selected as an appropriate statistical procedure for investigating the influence of time of travel by the distance between places of residence and occupation.

Table 5.31 Model summary for the influence of distance between place of residence and occupation on time of travel.

Model	R	R Square ^b	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.987 ^a	.974	.974	.667	.974	8527.084	1	229	.000

a. Predictors: distance between place of residence and occupation

Source: Author 2016

The model summary presented in table 5.9 shows that 84.8 variance of the influence of distance between place of residence and occupation on the time it takes commuters to travel to their destination. The significant value of 0.000 results in the great influence of the distance between place of residence and occupation on the time it takes commuters to arrive at their destination.

Table 5.32 ANOVA test results for the influence of distance between place of residence and occupation on time of travel

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3798.870	1	3798.870	8527.084	.000 ^c
	Residual	101.130	228	.446		
	Total	3900.000 ^d	229			

a. Dependent Variable: time it takes from place of residence to place of occupation

Source: Author 2016

The outcome of the ANOVA test confirmed the models best fit, which could predict a better outcome that using the mean with the ratio of improvement reached $F=8527.084$ and a significant value equal 0.000 ($p<.05$).

Table 5.33 Coefficients for influence of distance between place of residence and occupation on time of travel.

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
1 distance between place of residence and occupation	.772	.008	.987	92.342	.000	.756	.789

a. Dependent Variable: time it takes from place of residence to place of occupation
Source: Author 2016

The relationship between the distance of place of residence and occupation was found to be positively ($\beta=0.772$) influencing the time of travel for commuters. Such an association was found to be significant at $p<0.1$ ($P\text{-value}= 0.000$). These results suggest that the distance that commuters travel from their place of residence and occupation significantly influence the time they will be travelling. According to Luciano (2013), dis-integrated land use result in residents that are located far away from place of occupation. This causes an increased travelling distance for commuters and thus elongated travelling time. This corresponds with the study finding where commuters who travel longer distance take longer to arrive at their destination compared to shorter distance.

5.2.1.4. Regression analysis: summary of how purpose of travel influence the time commuters are willing to wait at bus stations.

The study hypothesized that the time commuters are willing to wait at stations is influenced by the purpose of their journey. At the conceptual level, the purpose of travelling and the willingness to wait at the station is expected to correlate with the rationale for utilising the BRT Rea-Vaya. Because of the measurement criteria employed to measure successful BRT system, linear regression analysis was selected as an appropriate statistical procedure for investigating the influence of the purpose of travel on the time commuters are willing to wait at the bus station.

Table 5.34 Model summary for the influence of purpose of travel on the time commuters.

Model	R	R Square ^b	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.852 ^a	.726	.725	1.550	.726	602.211	1	229	.000

a. Predictors: purpose of using BRT by respondents

Source: Author 2016

The purpose that commuters are travelling for was found to be influencing the time commuters are willing to wait at the bus station. Such an association was found to be significant at $p < 0.1$ (P-value = 0.000). These results suggest that the reason why a commuter is travelling is important in influencing the time commuters will wait at the bus station. This will assist the BRT management in the planning, operations and schedule management of their fleet as the study has elaborated on the importance and purpose of travel influence on time waiting for commuters.

Table 5.35 ANOVA test results for the influence of purpose of travel on the time commuters are willing to wait at the bus station.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1446.682	1	1446.682	602.211	.000 ^c
	Residual	545.318	228	2.402		
	Total	1992.000 ^d	229			

a. Dependent Variable: how long respondents wait at the station

Source: Author 2016

The outcome of the ANOVA test confirmed the models best fit, which could predict a better outcome that using the mean with the ratio of improvement reached $F=602.211$ and a significant value equal 0.000 ($p < .05$).

Table 5.36 Coefficients for influence of purpose of travel on commuters waiting time

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
	B	Std. Error	Beta			Lower Bound	Upper Bound
1 purpose of using BRT by respondents	1.170	.048	.852	24.540	.000	1.076	1.264

a. Dependent Variable: how long respondents wait at the station

Source: Author 2016

The study shows that the purpose commuters are travelling for is found to be positively ($\beta=1.170$) influencing the time commuters wait at the station. The study results show that such an association was found to be significant ($P\text{-value} = 0.000$). These results suggest that the reason of a commuter will determine if they are willing to stay for a short or long time at the station for their journey. This has instrumental impact on the headway frequency planning for the various stations of BRT rea-Vaya, as stations where commuters are travelling for employment tend to wait for short periods as compared to commuters travelling for leisure.

5.2.1.5. Regression analysis: summary of how commuters' access to information influences the type of information commuters will access.

The study hypothesized that how commuters access information influences the type of information they can access. At the conceptual level these factors are expected to correlate with commuter perception of the BRT operation and management systems (Martin, 2005). Because of the measurement criteria employed to measure the influence of these factors of the BRT system operates, linear regression analysis was selected as an appropriate statistical procedure.

Table 5.37 Model summary for the influence of how commuters access information influences the type of information commuters will access.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.069 ^a	.005	.000	.967	.005	1.081	1	226	.300

a. Predictors: (Constant), what type of information they are updated on

Source: Author 2016

Results of this study presented in table 5.37 revealed that how commuters access information does significantly influence the type of information commuters will have access to. They explain or influence about 0.69 variance, with R-square equal to 0.005 in conjunction with a significant value of 0.000. This is crucial in having different information dissemination devices in the BRT Rea-Vaya as different commuters will access the information differently and thus the need for an integrated intelligent transport system for commuters' services.

Table 5.38 ANOVA test results for the influence of how commuters' access to information influences the type of information commuters will access.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1.011	1	1.011	1.081	.300 ^b
	Residual	211.200	228	.935		
	Total	212.211	229			

a. Dependent Variable: how they get information about the schedule of trip

b. Predictors: (Constant), what type of information they are updated on

Source: Author 2016

The outcome of the ANOVA test confirmed the models best fit, which could predict a better outcome that using the mean with the ratio of improvement reached $F=1.081$ and a significant value equal 0.300 ($p<.05$). These results show that commuters' access to information is influenced by how (hard copy, smart phones or computers) commuters receive their information about the scheduling or any related BRT Rea-Vaya information.

Table 5.39 Coefficients for influence of how commuters' access to information influences the type of information commuters will access.

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1 (Constant)	2.156	.122		17.715	.000
what type of information they are updated on	.044	.043	.069	1.040	.300

a. Dependent Variable: how they get information about the schedule of trip

Source: Author 2016

The information dissemination variation for commuters depending on the system they are using was found to be positively ($\beta=0.044$) influencing how commuters access information. Such an association was found to be significant at $p<0.1$ ($P\text{-value} = 0.300$). Various technological innovations allow for commuters to access information using different methods (Abrea, 2007). However, different innovations may not be able to access all the required information and thus limiting information access. As found in this study, it suggests that commuters with different methods of acquiring information will have either limited or improved access to information depending on the device.

5.3. Cross-tabulation and chi-square test

Cross-tabulation and chi-square test was conducted to elaborate the various relationships that exist between commuters and the BRT Rea-Vaya as a form of public transport. The analysed data indicated how commuters relate to the system and how it affects commuters on their daily journeys.

5.3.1. Cross tabulation and Chi-square test for the relationship between distance travelled and time it takes.

The time it takes to travel from the place of residence is affected by the distance that respondents have to commute to arrive at their destination. The relationship between distance travelled and the times it takes was analysed through cross tabulation as indicated in table 5.40

Table 5.40 Cross tabulation between distance from place of residence to occupation and time it takes from place of residence to place of occupation

		Time it takes from place of residence to place of occupation			
		11-15min	16-30min	31-40min	41-450min
Distance between place of residence and occupation.	6-10 km	12	0	0	0
	11-20 km	0	12	24	0
	21-25 km	0	12	48	12
	26+ km	0	12	36	60
Total		12	36	108	72

Source: Author 2016

Table 5.40 Illustrates the relationship between the time it takes to travel from place of residence to place of occupation with the distance that respondents have to commute. According to Anakit (2010) developing countries with dis-iterated land use results in commuters' spending more time traveling from their household to place of work. The data indicates that as the distance travelled increase, the time it takes respondents to arrive at their destination also increase. This is evident as 26% of respondents take on average 41-50 minutes to commute a distance of above 26 kilometres to arrive at their place of occupation, as compared to 5.2% of respondents that take an average of 11-15 minutes to travel a distance of 6-10 kilometres.

Table 5.41 Chi-square test for distance from place of residence to occupation and time it takes from place of residence to place of occupation

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	285.000 ^a	9	.000
Likelihood Ratio	157.824	9	.000
Linear-by-Linear Association	89.358	1	.000
N of Valid Cases	229		

a. 5 cells (31.3%) have expected count less than 5. The minimum expected count is .63.

Source: Author 2016

A chi-square test of independence was performed to examine the relation between distance from place of occupation and residence and the time it takes to make that journey. The relation between the variables was significant (0.000) $p < 0.1$. The time it takes to travel from place of residence to place of occupation is influenced by the distance between the two locations.

5.3.2. Cross tabulation and Chi-square test for the relation of gender on the waiting period of commuters at station

The study analyzed the relationship between genders of commuters' influence on how long they are willing to wait at the station, with the notion that male commuters were willing to wait at the station longer than their female counterparts.

Table 5.42 Cross tabulation between the gender of commuters and the waiting period of commuters at the station

		how long respondents wait at the station				Total
		-5min	5-10min	11-15min	16+min	
Gender of respondents	male	12	12	48	24	96
	female	0	48	60	24	132
Total		12	60	108	48	229

Source: Author 2016

Table 5.42 illustrates the relation between the gender of commuters and their willingness to wait at the station. From the table we can deduce that females 57% are waiting at stations longer than males 34% in their journey. The data indicates that the majority of male commuters are waiting at stations for an average of 5-15 minutes, while female commuters are waiting at the

station an average 11-16+ than females. According to Brail (2014), males were found to have diminutive tolerance for waiting for buses to arrive at the Annebess bus station in Addis Ababa Ethiopia.

Table 5.43 Chi-square test for the relationship between the gender of commuters and the waiting period of commuters at station

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	29.997 ^a	3	.000
Likelihood Ratio	35.393	3	.000
Linear-by-Linear Association	.271	1	.603
N of Valid Cases	229		

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.05.

Source: Author 2016

A chi-square test of independence was performed to examine the relation between the gender of commuters and how long they will wait at the bus station. The relation between the variables was significant (0.000) $p < 0.1$ with a likelihood ratio of 35.393. The minimum expected count of less than 5.05 was found for the study which indicates that there is a significant linear association of gender and the waiting period of commuters.

5.3.3. Cross tabulation and Chi-square test for the relation of how commuters get information and the extent to which they are updated on traffic conditions

The study analyzed how commuters receive their information which impacts the extent to which they will receive update on traffic conditions for their journey.

Table 5.44 Cross tabulation between the extents of update on traffic conditions and how commuters get information about their journey

		extent of update on traffic conditions		Total
		less extent	moderate extent	
how they get information about	smartphone	24	48	72
their journey	display screen	12	84	96
Total		36	132	168

Source: Author 2016

From table 5.44 it illustrates the extent to which a commuter is updated on traffic conditions depending on how they receive information related to their journey. The results of the study indicate that the majority 37% of respondents that use variable message signs (VMS) are moderately updated on traffic conditions for their journey, while 5% of respondents highlighted that they are less updated on traffic conditions when they are using VMS to get their journey information. However, 21% of commuters that are using smart phones for update on traffic conditions indicated that they are moderately updated about traffic conditions compared to 10.4% of respondents that are updated to a less extent on traffic conditions when they are using their smart phones.

Table 5.45 Chi-square test for the extent to which commuters are updated on traffic condition and how they get the information.

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	10.606 ^a	1	.001		
Continuity Correction	9.405	1	.002		
Likelihood Ratio	10.581	1	.001		
Fisher's Exact Test				.002	.001
Linear-by-Linear Association	10.543	1	.001		
N of Valid Cases	168				

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 15.43.

A chi-square test of independence was performed to examine the relation between the extent to which commuters are updated on traffic condition and how they receive their travelling information. The relation between the variable was significant (0.001) $p < 0.1$ with a likelihood ratio of 10.581. The minimum expected count of less than 5.05 was found for the study which indicates that how commuters access their travelling information greatly affect the extent to which they will be updated on traffic condition, thus commuters that use smart phones are less updated than commuters that use VMH for information update. This is crucial in the planning and management of the BRT, as the management can improve their information dissemination systems for improved updating of commuters.

5.4. Chapter summary

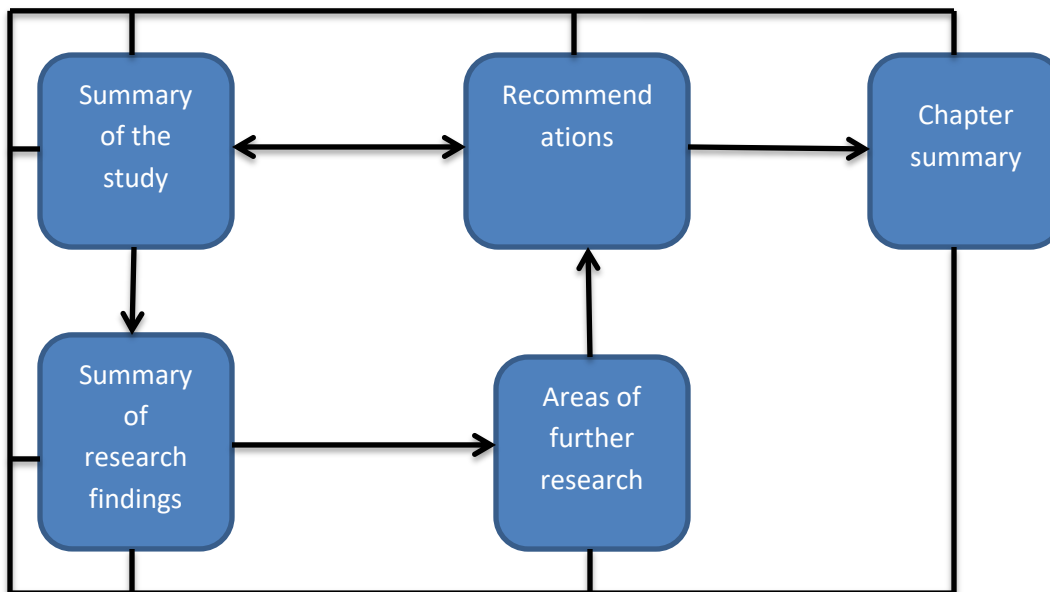
This chapter has analysed, presented, and interpreted data on commuters and their interaction with BRT Rea-Vaya system. The aspects which were covered in this chapter include the demography of respondents, measurement scale analysis, reliability analysis and validity analysis of the measurement tools that were used in this study. Data was then presented with respect to the research objectives. The chapter that follows focuses on the summary of findings and recommendations pertaining this study.

CHAPTER SIX: SUMMARY OF FINDINGS AND RECOMMENDATIONS

6.1. Introduction.

The purpose of this chapter is to present a summary of the study and summary of findings which were obtained from field study and analysis made in chapter four and attempts to propose a number of recommendations to tackle the identified challenges. Figure 6.1 illustrates the conceptual structure of the summary of findings and recommendations.

Figure 6.1 Chapter conceptual structure



Source (Author construct, 2017)

6.2. Summary of the study.

This study examined the operation and management of the BRT Rea-Vaya using intelligent transport systems in Johannesburg metropolitan city. The study aimed to identify the intelligent transport system been employed for the benefit of commuters and transport officials. It also revealed the status quo of conditions of the BRT Rea-Vaya infrastructure in relation to intelligent transport systems and outlined major challenges in operating and managing the system using intelligent transport systems. Through the analyzed data, lack of integration across physical infrastructure (43%), fare payment systems (38%) and information with the various public transportation agencies (39%) was a prominent challenge that increased operational cost and time. An observational assessment of the BRT Rea-Vaya design, planning and implementation element in accordance with the BRT standard evaluation template was evaluated. The focus of the observations was the BRT basics, infrastructure, stations, integration and access. The observation revealed that there are critical challenges in the maintenance of the systems.

Data was obtained through questionnaires administration of the sample size of 229 respondents and observation at Johannesburg metropolitan city. Moreover, key informants, pedestrians and public transport operators were also interviewed. The management of the BRT Rea-Vaya was also interviewed during the filed study.

Collected data was analyzed using Statistical Package for Social Sciences (SPSS) with the aid of Microsoft Excel.

6.3. Summary of research finding

The summary of research findings is presented based on the research objectives outlined earlier on in chapter one.

6.3.1. Reliability of ITS on BRT Rea-Vaya

The study indicated that there is a variety of challenges and opportunities that managers of the BRT Rea-Vaya encounter in utilizing the intelligent transport system, and this impacts on managers' view in relation to the reliability of the system. The major challenge that managers outlined was that the system during most days is not functional (48%) due to lack of maintenance (65%). This means that it is challenging for them to acquire information related to the management of the fleet, station and commuters journey as they will be offline. Due to the lack of technical skills (32%) in the management, repairs and maintenance of the ITS in the Rea-Vaya, this hindered the reliability (56%) of the system. Although, the system is crucial in the

ease management of the Rea-Vaya, it requires the re-skilling of staff members to familiarize with the ITS and this contributes to the low level of reliability as the system is not being operated to the optimal functionality it was designed for.

The operation and management of BRT through intelligent transport systems has its own associated challenges that need to be resolved to increase the effectiveness and efficiency of the system. The study findings indicated that the lack of technical skills (32%), financial constraints (51%) in upgrading of intelligent transport system infrastructure and inadequate human resource capital (27%) are constraints that make operating and managing BRT Rea-Vaya through intelligent transport systems difficult. The outsourcing of specialists from Switzerland to improve the systems and updating the system is the foremost constraint that key-informants outlined as this prolong the process in resolving the challenges and thus increasing the operational cost in paying the specialist.

6.3.2. The Role of ITS in reducing waiting times for commuters.

The study findings revealed that although the intelligent transport system is available for commuters, most of them (49%) were not aware of the various systems available at their disposal. They even indicated that the system is not reliable (54%) as most of the times is not functional due to lack of maintenance (65%). The perception is that the system is not assisting commuters in meeting their needs as it is not reliable and leaving commuters uninformed for their journey planning. The data collected indicated that even when the system was operational, it was not reliable (53%) as the buses were not punctual and were arriving at the station at different times from those which were displayed on the variable message signs. Thus, the system has reduced waiting times of commuters in a minimal level.

6.3.3. Efficiency provided by the ITS on the BRT Rea-vaya

Literature has shown that one of the main aims of the BRT system is to meet the needs of commuters efficiently (Mpofu, 2008:61). The study findings indicated that the intelligent transport system was not being operated efficiently in the management of the Rea-Vaya due to lack of technical skills (32%). Although intelligent transport systems were being used for the management and operations of the BRT Rea-Vaya, the outlined objectives were not being met (41%) due to the unreliability of the system (37%). The conclusion from the study is that the system has not achieved its optimal efficiency in the management of the BRT Rea-Vaya in the City of Johannesburg.

6.4. Recommendations.

Various challenges have been identified in the management and operations of the BRT Rea-Vaya management through intelligent transport system. The study has suggested measures to improve the BRT Rea-Vaya management through ITS

6.4.1. Creating an integrated public transport system

The City of Johannesburg metropolitan is responsible for providing public transport services for commuters in the city. There are multiple public transport operators, such as different bus companies (Pucto, metro-bus and the BRT Rea-Vaya). The route networks and schedule are not well coordinated, such that riders need to transfer between services at jurisdictional boundaries and have long waiting time between buses. There is a need to create integrated transportation systems for public transport through improved planning and communication among operators. The creation of integrated transport systems into one network help customers to navigate the system and it makes it more transparent and attractive to new users.

The transportation systems should be integrated in three aspects of their planning and operations, and the aspects for integration are outlined below:

- ❖ Fare-payment integration- This is a component that can improve the ease of use for commuters in terms of public transport. At the moment every single public transport operators in Johannesburg metropolitan have their own separate fare payment system and this results in commuters bearing the cost for purchasing different smart cards for payment for their journey. The City of Johannesburg metropolitan municipality in conjunction with the department of transport should create a common ticketing systems using contactless smart card as a mode of payment. The smart card should allow commuters to use it across all public transport services such as the (Gau-train, metro-rail, metro-bus, BRT Rea-Vaya and conventional buses). The smart card should be designed in way that it can be topped up in train station, bus stations, and conveniences stores and also be linked to bank accounts for automatic topping up periodically.
- ❖ Information integration- information integration is critical in improvement of the journey planning for commuters. The study proposes information integration across all public transport operators, where there should be a “Transportation link guide for the city”. The transportation link guide for the city should list all the information of the bus routes and train lines and they should also put the information on panels of major bus stations. There should be a toll-free call centre for all the integrated information on the bus and

train services and this should be done in conjunction with an electronic guide that can be accessed through a smart phone application that can be developed for access to the integrated information.

- ❖ Physical integration- The study proposes a multi-modal transportation station at major stations such as Thokoza park station. The implementation of a multi-modal transport station would allow commuters to access various transport service providers with reduced distance travelled to access them. The multi-modal station should have universal design for vehicles, station and pedestrian facilities to accommodate people with disabilities and other special needs.

The integration of fares, information and network facilities' seamless travel for commuters and thus the need for integration across all public transport operators in the City of Johannesburg metropolitan.

6.4.2. Extension of the BRT Rea-Vaya network

There are plans for the extension of the Rea Vaya to the outskirts of Johannesburg. From the findings we may infer that majority of the participants were satisfied to a certain extent with the Rea Vaya system. Consequently, a few participants suggested that the Rea Vaya Network be extended to other areas beyond the city as other cities consider developing and implementing their own BRT systems, it is critical that the Rea-Vaya network is expanded so that a seamless integrated BRT is created.

The most recent city to establish plans to develop a BRT system is Ekurhuleni. The complete phase one was projected to be completed in 2013. However, due to a number of challenges, only phase 1b was completed in 2013. More stations and more routes were suggested by participants as a solution to the transport problem. Participants recommended that the Rea-Vaya should be extended to a number of areas namely; East Rand, Kensington, Midrand, Diepsloot, Glenvista, Turfontein, Eastgate and Thembisa. A participant's suggestion was that "It should be extended into the locations", while other participants saw the expansion of the Rea-Vaya as a solution to replace taxis. "More extensive and it should be extended to all transport routes". Currently, there is talk of an integrated transport system in Johannesburg being a solution to the transport needs in the city.

6.4.3. Improve public relation and marketing

The ultimate success of any new product, no matter how good its potential may be, depends largely on how information about it is communicated. The BRT Rea-Vaya offers a wide range of services through its intelligent transport systems capabilities. The study found that most of the participants were not aware of the service that they can acquire from the system or they were not aware that the system exists at all.

There is lack of communication in relation to new services that are introduced by the Rea-vaya management such as the Vaya-Mojo application. Thus, the study proposes improved communication with commuters through creating awareness where the public will be educated on the various intelligent transport systems available and how they operate.

The Rea-Vaya application for the Vaya-Mojo was not marketed sufficiently and thus the low usage by commuters. There should be marketing through local television and radio stations and posters should be placed across the stations promoting the application.

6.4.4. Upgrading of intelligent transport systems

A key challenge that was identified through data collection and analysis was that the intelligent transport system infrastructure has been in operations for ten years as they had been implemented in 2009. The study proposes an improvement of the intelligent transport system through replacement of the outdated infrastructure with current up-to-date innovative infrastructure. There is an urgent need to replace the infrastructure as it hinders the performance of the management due to frequent shutdowns as highlighted as a major challenge for the key-informants. The upgrade will allow additional features that were absent from the intelligent transport system to be incorporated in the upgrading of the infrastructure.

6.4.5. Training and re-skilling of staff on intelligent transport system.

There is a lack of technical skills related to the use of intelligent transport system in the Rea-Vaya management and this was indicated as a prominent challenge within the institution. The study proposes the training of new staff members and the re-training to skill the staff members so that they can update their knowledge and skills to ensure that there are qualified personnel to operate the systems. The management of the Rea-Vaya should develop a training programme that their staff members can take part in once every year.

To resolve the challenge of skilled workers, it is important for the BRT Rea-Vaya to create a higher degree apprenticeship framework. They should assist academia in developing a framework that will promote the investment in the training of young students in careers related to intelligent transport systems and after their studies, they can then be employed within the organization to improve the system.

6.4.6. Promote trans-oriented development

Although, the BRT Rea-Vaya has been operational for 10 years now, there is still lack of development along the corridor. This is a challenge as it blocks the improvement of the spatial economy of areas near the corridors and this is due to the low densities areas. The study thus promotes finding measures to encourage trans-oriented development. The measures that can be employed would be to increase the density of commercial and residential development along the BRT Rea-Vaya corridors. There should be high-density residential development within a 20 minute walking distance of the stations. The high density will support the high frequency services and also provide foot traffic for shops which are near the stations.

6.5. Areas for future research.

The research saw the necessity to diversify the concept around intelligent transport systems for bus rapid transit due to the fact that intelligent transport systems promote the use of technology within the transport industry to promote mobility and level of access to social and economic amenities. This study gave the researcher an insight to perceive areas which will need to be researched in the future with a view of improving intelligent transport system in bus rapid transit system. Areas for future research are outlined below:

- ❖ An assessment of financing models for intelligent transport system in bus rapid transit system
- ❖ A feasibility study of an integrated intelligent transport system for public transport operators within Johannesburg metropolitan city.
- ❖ An evaluation of the applicability of intelligent transport system within the mini-bus (taxi) industry.

All these areas may be useful follow-ups to the study

6.6. Chapter summary.

The chapter outlined the summary of the study and discussed key findings in accordance with specific research questions with the view of attaining specific research objectives outlined in chapter one. The chapter also revealed recommended and possible strategic measures to improve the management and operations of BRT Rea-Vaya through intelligent transport systems.

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Appendix A: Questionnaire for Commuters at the BRT stations

	UNIVERSITY of VENDA
	SCHOOL OF ENVIRONMENTAL SCIENCES
	DEPARTMENT OF URBAN AND REGIONAL PLANNING

TOPIC: AN EVALUATION OF INTELLIGENT TRANSPORT SYSTEMS: A CASE STUDY OF THE BRT REA-VAYA IN JOHANESSBURG, SOUTH AFRICA

RESEARCHER: MR KHWATHISI NTSIENI COLIN

SUPERVISOR: DR CHWAKWIZIRA JAMES

CO-SUPERVISOR: Prof Bikam Peter

Questionnaire No.	
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GPS station codes -Coordinates	
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Dear Respondent: I am conducting a study, on the above mentioned topic, as a partial fulfillment for a Master's Degree in Urban and Regional Planning at the University of Venda. I therefore kindly ask you to assist me in this study by completing this questionnaire. Your participation is highly valuable because it represents views of others who have not been selected in the study. The information you provide is for the purpose of the study ONLY and remains confidential. (All participants were randomly selected).

INSTRUCTIONS

Please complete the whole questionnaire

Where you have been provided with a choice to the question, please indicate your choice by ticking or with the letter X or tick and where they are no answers please write your own view.

QUESTIONS

1. Gender.

Male	<input type="checkbox"/>	Female	<input type="checkbox"/>
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2. Age group.

Below 20	<input type="checkbox"/>	21-35	<input type="checkbox"/>	36-50	<input type="checkbox"/>	51+	<input type="checkbox"/>
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3. Occupation status.

Employed		Student (Post-secondary)		Retired	
Unemployed		Student (Grd 1-12)		Other	

If other please specify

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4. Where do you stay or live in Johannesburg?

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5. For what purpose do you use the BRT (Rea-vaya)?

Work		Leisure		Other	
School		Family visit			

If other please specify

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6. What mode of transport do you use regularly to meet your transportation needs?

Drive(own car)		Metro train		Taxis		Brt (Rea-vaya)	
Walking		Gau-train		Convectional buses		others	

7. What is the distance between your place of residence and occupation?

Less than 1km		2-5 km		6-10 km	
11-20 km		20-25km		26+ km	

8. What is the time it takes from your place of residence to your place of work?

-10min		11-15 min		16-30min	
30-40		41-50min		other	

If other please specify

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9. What is the reason for the time it takes for you to travel from your place of residence to your occupation?

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10. How long do you wait at the bus stations?

-5min		5-10min		10-15min		15min+	
-------	--	---------	--	----------	--	--------	--

11. What is the reason for staying at bus stations for that specific time period?

crowdedness		Delay of buses		Other	
Lack of seats		Long bus intervals during off-peak times			

If other please specify

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12. What is the other mode of transport that you would prefer for your journeys?

Taxi		Private vehicle	
Metro-bus		Train	Metro-train
			Gau-train

Please give a reason for your preferences

.....

13. How convenient is the BRT compared to other modes of transport in terms of the time spent from point A to point B

Less convenient		Convenient		More convenient	
Not convenient		Do not know			

14. Please give a reason for your above answer?

Time		Availability		Other	
Price		Reliability			

If other please specify

.....

15. How do you get information about the schedule of your trip

Smart Phone	
Computer	
Display screen	
Hand print	
Other	

16. Are you updated on any information about your trip?

Yes	
No	
Do not know	

17. If yes what type of information are you updated along the route of your trip?

Delays	
Change of routes	
Mechanical breakdowns	
Other	

If other please specify

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18. To what extent are you updated about the traffic condition /travelling conditions regarding the BRT using telecommunication technology?

Less extent	
Moderate extent	
High extent	

19. What do you suggest should be done to improve the dissemination of information to customers through the use of telecommunications?

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20. Is there anything else you would like to bring to the attention of the Researcher?

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The End!!!

Thanks for sparing your valued time to answer this questionnaire.

Appendix B: Questionnaires for the BRT –Rea-Vaya management officials

	UNIVERSITY OF VENDA
	SCHOOL OF ENVIRONMENTAL SCIENCES
	DEPARTMENT OF URBAN AND REGIONAL PLANNING

TOPIC: AN EVALUATION OF INTELLIGENT TRANSPORT SYSTEMS: A CASE STUDY OF THE BRT REA-VAYA IN JOHANNESBURG, SOUTH AFRICA

RESEARCHER: MR KHWATHISI N.C

SUPERVISOR: DR CHAKWIZIRA JAMES

CO-SUPERVISOR: PROF BIKAM PETER

Questionnaire No.	
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Dear Respondent : I am conducting a study, on the above mentioned topic, as a partial fulfillment to the requirement for a Master’s Degree in Urban and Regional Planning at the University of Venda. I hereby kindly ask you to assist me in this study by completing this questionnaire. Your participation is highly valuable because it represents the views of other officials who could not be made part of this study. It must be emphasized though that there is no intention to discredit the Municipality or any of its employees. The information you provide is for the purpose of the study **ONLY** and remains confidential. (All participants were randomly selected).

INSTRUCTIONS

Where you have been provided with a choice to the question, please indicate your choice by ticking or crossing (X) on the space provided and where there are no answers please write your own view. Please complete the whole questionnaire

QUESTIONS

1. Gender

Male		Female		Other	
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2. Position held

3. Years in service

4. Do you think that the Rea Vaya is accessible to the majority of the people who commute to the city?

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5. What are the intelligent transport systems infrastructures available for operations and management of the BRT Rea-vaya?

Intelligent transport systems infrastructure	
CCTV	
Variable message sign	
Adaptive traffic control	
Route guidance	
Ramp metering	
Other	

If other please specify

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6. Do you think the available intelligent transport systems infrastructure ensures effective and efficient management of the operations of the BRT Rea-Vaya ?

Yes		No		Do not Know	
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Please provide a reason to support your answer

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7. If yes to the above answer, on a scale of 1-10 where 1-3 is less effective, 4-7 effective and 8-10 is more effective, how would you measure the effectiveness of intelligent transport systems in the management of the operations of the BRT Rea-Vaya?

1-3	
4-7	
8-10	

8. What are the benefits of managing BRT-Rea Vaya through the use of intelligent transport systems?

Improving traffic flow	
Up-to-date information of the current traffic congestion	
Providing alternative routes	
Monitoring traffic conditions	
Easy data collection and processing	
Reduced duration of incidents management	
Traffic signal coordination	
Transit priority	

Other	
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If other please specify

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9. What are the challenges of managing and operating the BRT Rea-vaya through the use of intelligent transport systems?

Lack of technical expertise in utilizing ITS	
Breakdown of ITS equipment	
Delayed information of current traffic conditions	
Out of date equipment for managing traffic congestion	
Lack of institutional integration	
Other	

Please explain further on the above answer

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10. What are the routes/areas that are managed by intelligent transport systems?

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11. To what extent is the traffic congestion reduced in routes/areas that are managed by intelligent transport systems?

Less extent	
moderate extent	
High extent	

12. If the answer to the above question is less extent, please explain the reason for the continued high level of traffic congestion?

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13. Are there any future proposed projects for implementing intelligent transport systems infrastructure for managing BRT Rea-Vaya?

Yes		No		Do not Know	
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Provide a reason to support your answer?

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14. Is there any partnership with private sector in regard with managing and operating the BRT Rea-vaya through intelligent transport systems?

Yes		No		Do not Know	
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If the above answer is yes, what are the partnerships and for what reason are they there?

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15. Suggest ways in which the BRT Rea-vaya can be better managed through the use of intelligent transport systems?

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16. Do you have any other insights or issues that you would like to bring to attention to the research?

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The End!!!

Thanks for sparing your valued time to answer this questionnaire.

Appendix C: THE BRT STANDARD OBSERVATIONAL CHECKLIST

THE BRT STANDARD SCORING TEMPLATE		
THE BRT BASICS		POINTS
Dedicated right of way	Dedicated lanes and full enforcement or physical segregation applied to over 90% of the bus way corridor length	8
	Dedicated lanes and full enforcement or physical segregation applied to over 75% of the bus way corridor length	7
	Delineators only or colorized pavement only without other enforcement measures applied to over 75% of corridor length	5
	Delineators only or colorized pavement only without other enforcement measures applied to over 40% of corridor length	3
	Delineators only or colorized pavement only without other enforcement measures applied to over 20% of corridor length	2
	Camera-enforcement with signs only	1
Bus-way alignment	Tier 1 configurations	
	Two-way median-aligned bus ways that are in the central verge of a two-way road	8
	Bus-only corridors where there is a fully exclusive right-of-way and no parallel mixed traffic, such as transit malls	8
	Bus ways that run adjacent to an edge condition like a waterfront or park where there are few intersections to cause conflicts	8
	Bus ways that run two-way on the side of a one-way street	6
	Tier 2 configurations	
	Bus ways that are split into two one-way pairs but are centrally aligned in the roadway	5

Bus-way alignment	Bus ways that are split into two one-way pairs but aligned to the curb	3	
	Tier 3 configurations		
	Virtual bus way that operates bi-directionally in a single median lane that alternates direction by block. 1	1	
	non-scoring configurations		
	Curb-aligned bus way on a two-way road	0	
Off-board Fare collection	100% of stations on corridor have turnstile-controlled off-board fare collection	8	
	100% of routes that touch the corridor have proof-of-payment fare collection	7	
	80% of stations on corridor have turnstile-controlled off-board fare collection	7	
	80% of routes that touch the corridor have proof-of-payment fare collection	6	
	60% of stations on corridor have turnstile-controlled off-board fare collection	6	
	60% of routes that touch the corridor have proof-of-payment fare collection	5	
	40% of stations on corridor have turnstile-controlled off-board fare collection	5	
	40% of routes that touch the corridor have proof-of-payment fare collection	4	
	20% of stations on corridor have turnstile-controlled off-board fare collection	3	
	20% of routes that touch the corridor have proof-of-payment fare collection	2	
	< 20% of stations on corridor have turnstile-controlled off-board fare collection	0	
< 20% of routes that touch the corridor have proof-of-payment fare collection			

Intersection Treatment	All turns prohibited across the bus way	7	
	Most turns prohibited across the bus way	6	
	Approximately half of the turns prohibited across the bus way and some signal priority	5	
	Some turns prohibited across the bus way and signal priority at most intersections	4	
	Some turns prohibited across the bus way and some signal priority	3	
	No turns prohibited across the bus way but signal priority at most intersections	2	
	No turns prohibited across the bus way but some intersections have signal priority	1	
	No intersection treatments	0	
Platform level-boarding	100% of buses are platform level; system-wide measures for reducing the gap in place	7	
	80% of buses; system-wide measures for reducing the gap in place	6	
	60% of buses; system-wide measures for reducing the gap in place	5	
	100% of buses are platform level with no other measures for reducing the gap in place	4	
	40% of buses	3	
	50% of buses are platform level with no other measures for reducing the gap in place	2	
	10% of buses	1	
No platform-level boarding	0		

SERVICE PLANNING			
Routes	Two or more routes exist on the corridor, servicing at least two stations	4	
	No multiple routes	0	
Express, Limited and local services	Local services and multiple types of limited and/or express services	3	
	At least one local and one limited or express service option	2	
	No limited or express services	0	
Control centre	Full-service control center	3	
	Control center with most services	2	
	Control center with some services	1	
	No control center	0	
Multi-corridor	Corridor is one of top ten demand corridors	2	
	Corridor is outside top ten demand corridors	0	
Demand Profile	Corridor includes highest demand segment, which has a Tier 1 Trunk Corridor configuration	3	
	Corridor includes highest demand segment, which has a Tier 2 Trunk Corridor configuration	2	

	Corridor includes highest demand segment, which has a Tier 3 Trunk Corridor configuration	1	
	Corridor does not include highest demand segment	0	
Hours of operation	Both late-night and weekend service	2	
	Late-night service, no weekends OR weekend service, no late nights	3	
	No late-night or weekend service	0	
Multi-corridor Network	BRT corridor connects to an existing BRT corridor or to the next one planned in the network	2	
	BRT corridor connects to a future planned corridor in the BRT network	1	
	No connected BRT network planned or built	0	
INFRASTRUCTURE			
Passing-lanes at stations	Physical, dedicated passing lanes	4	
	Buses overtake in on-coming dedicated lanes	2	
	No passing lanes	0	
Minimising Bus emissions	Euro VI or US 2010	3	
	Euro IV or V with PM traps or US 2007	2	
	Euro IV or V or Euro III CNG or using verified PM trap retrofit	1	

	Below Euro IV or V	0	
Station set back from intersection	75% of stations on corridor are set back at least 40 m (130 ft.) from intersection or meet at least one of the following exemptions: <ul style="list-style-type: none"> • Fully exclusive bus ways with no intersections • Stations located near intersections due to block length (such as downtowns where blocks are relatively short) 	3	
	75% of stations on corridor are set back 26 m (85 ft.) from intersections or meet above exemptions	2	
	25% of stations on corridor are set back 26 m (85 ft.) from intersections or meet above exemptions	1	
	< 25% of stations on corridor are set back 26m (85 ft.) from intersections or meet above exemptions	0	
Center stations	80% and above of stations on corridor have centre platforms serving both directions of service	2	
	50% of stations on corridor	1	
	< 20% of stations on corridor	0	
Distance between stations	STATIONS		
	Stations are spaced, on average, between 0.3 km (0.2 mi.) and 0.8 km (0.5 mi.) apart	2	
Safe and comfortable stations	All stations on corridor are wide, attractive, weather-protected	3	

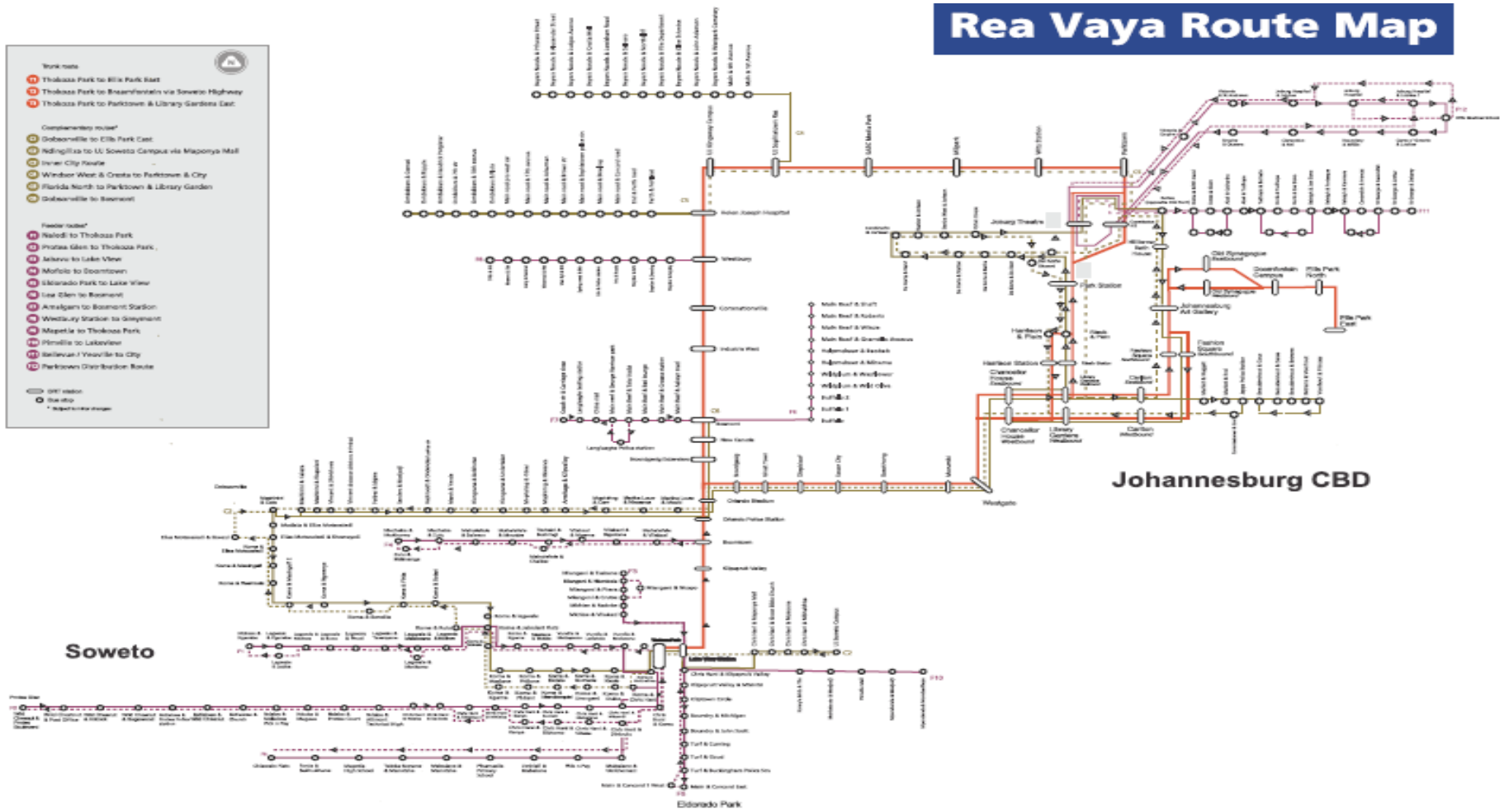
	Most stations on corridor are wide, attractive, weather-protected	2	
	Some stations on corridor are wide, attractive, weather-protected	1	
	No stations on corridor are wide, attractive, weather-protected	0	
% of buses with 3+ or 2 doors on station side	100%	3	
	65%	2	
	35%	1	
	< 35%	0	
Docking-bays or sub-stops	At least two sub-stops or docking bays at the highest-demand stations	1	
	Less than two sub-stops or docking bays at the highest-demand stations	0	
Sliding doors	All stations have sliding doors	1	
	Otherwise	0	
Branding	COMMUNICATIONS		
	All buses, routes, and stations in corridor follow single unifying brand of entire BRT system	3	
	All buses, routes, and stations in corridor follow single unifying brand, but different from rest of the system	2	

	Some buses, routes, and stations in corridor follow single unifying brand, regardless of rest of the system	1	
	No corridor brand	0	
Passenger information	Functioning real-time and up-to-date static passenger information corridor-wide	2	
	Up-to-date static passenger information	1	
	Very poor or no passenger information	0	
ACCESS AND INTEGRATION			
Universal access	Full accessibility at all stations and on all vehicles	3	
	Partial accessibility at all stations and on all vehicles	2	
	Full or partial accessibility at some stations and on some vehicles	1	
	Corridor not universally accessible	0	
Integration with other public transport	Integration of both physical design and fare payment	3	
	Integration of physical design or fare payment only	2	
	No integration	0	
Pedestrian access	Good, safe pedestrian access at every station and for a 500-meter catchment area surrounding the corridor	3	
	Good, safe pedestrian access at every station and many improvements along corridor	2	

	Good, safe pedestrian access at every station and modest improvements along corridor	1	
	Not every station has good, safe pedestrian access and little improvement along corridor	0	
POINT DEDUCTIONS			
Commercial speeds	Minimum average commercial speed is 20 kph (12 mph) and above	0	
	Minimum average commercial speed is 16 kph–19 kph (10–12 mph)	-3	
	Minimum average commercial speed is 13 kph–16 kph (8–10 mph)	-6	
	Minimum average commercial speed is 13 kph (8 mph) and below	-10	
PPHPD	PPHPD below 1,000	-5	
	Regular encroachment on BRT right-of-way	-5	
Lack of enforcement of right-of-way	Some encroachment on BRT right-of-way	-3	
	Occasional encroachment on BRT right-of-way	-1	
Overcrowding	Passenger density during peak hour on more than 25% of buses in peak direction is > 5 m ² , OR	-5	
	Passenger density during the peak hour at one or more stations is > 3 m ² , OR		
	Passengers unable to board buses or enter stations		

Maintenance	Bus way has significant wear, including potholes or warping, or debris, such as trash or snow	-4	
	Buses have graffiti, litter, seats in disrepair	-2	
	Stations have graffiti, litter, occupancy by vagrants or vendors, or structural damage	-2	
	Technology systems, including fare collection machines, are not functional	-2	
Low peak frequency	100% have at least 8 buses per hour	0	
	75% have at least 8 buses per hour	-1	
	50% have at least 8 buses per hour	-2	
	< 50% have at least 8 buses per hour	-3	

Appendix D: Brt Rea –vaya Route Map



**RESEARCH AND INNOVATION
OFFICE OF THE DIRECTOR**

NAME OF RESEARCHER/INVESTIGATOR:

Mr NC Khwathisi

Student No:

15013914

PROJECT TITLE: An evaluation of Intelligent transport system: A case study of bus rapid transit (BRT) Rea-vaya in Johannesburg South Africa.

PROJECT NO: SES/16/URP/04/0509

SUPERVISORS/ CO-RESEARCHERS/ CO-INVESTIGATORS

NAME	INSTITUTION & DEPARTMENT	ROLE
Dr J Chakwizira	University of Venda	Supervisor
Prof P Bikam	University of Venda	Co-Supervisor
Mr NC Khwathisi	University of Venda	Investigator - Student

ISSUED BY:

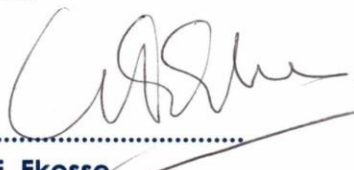
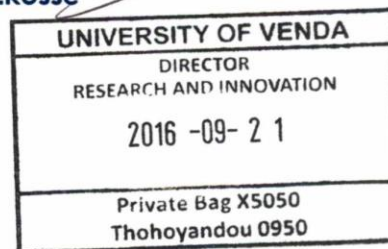
UNIVERSITY OF VENDA, RESEARCH ETHICS COMMITTEE

Date Considered: September 2016

Decision by Ethical Clearance Committee Granted

Signature of Chairperson of the Committee:

Name of the Chairperson of the Committee: Prof. G.E. Ekosse

University of Venda

PRIVATE BAG X5050, THOHoyANDOU, 0950, LIMPOPO PROVINCE, SOUTH AFRICA
TELEPHONE (015) 962 8504/8313 FAX (015) 962 9060

"A quality driven financially sustainable, rural-based Comprehensive University"

Appendix F: Request for permission to conduct research.



University of Venda

School of Environmental Sciences

Johannesburg Road Agency
BRT (Rea-Vaya) management
66 Pixely Kaisala Seme St
Johannesburg
2001

**Department of Urban and
Regional Planning**

University Road, Thohoyandou, Limpopo
Private Bag X5050, Thohoyandou, 0950
Limpopo, South Africa

☎ +27 15 962 8585

☎ +27 15 962 8597

✉ james.chakwizira@univen.ac.za

✉ azwidowi.mashangu@univen.ac.za

Ref: Request for permission to conduct an academic study in Johannesburg BRT project.

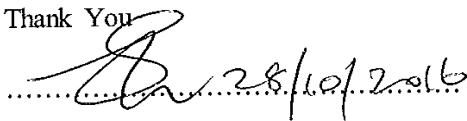
With reference to the above mentioned, I the undersigned hereby write to request permission for Mr Khwathisi Ntsieni Colin of the department of urban and regional planning in his final year of masters to conduct research on BRT (Rea-Vaya) project. The research is as follows:

Research topic: An evaluation of intelligent transport system: A case study of the Bus Rapid Transit (BRT) Rea-Vaya in Johannesburg, South Africa.

Our request is that may you kindly authorise him to conduct his master's research to enable him to obtain relevant data/documentation from the relevant section within your offices.

Your assistance in this regard will be very much appreciated. If in doubt or requiring further clarification please do not hesitate to contact the undersigned making use of the appended details.

Thank You



..... 28/10/2016

Head, Urban and Regional Planning

Appendix G: BRT Rea-vaya permission to conduct research



a world class African city



City of Johannesburg
Rea Vaya

8th Floor North Wing
JRA Building
66 Sauer Street
Johannesburg 2001

PO Box 31923
Braamfontein
South Africa
2017

Tel +27(0) 11 870 4621
Faxl +27(0) 11 870 4611

www.reavaya.org.za

02 November 2016

Mr Khwathisi Ntsieni Colin

Department of Urban and Regional Planning

University of Venda

Thohoyandou

RE: Request for permission to conduct an academic study in Johannesburg BRT project.

The BRT (Rea-Vaya) management acknowledges receipt of your letter date 28 October 2016, in relation to the above mentioned request. This office has no objection to your request; you are free to contact the undersigned for further assistance. However you are advised that the research findings of the study must be used solely for academic purposes.

Your permissions grants the following for your academic research:

- Conduct an observation study of the BRT (Rea-Vaya) project.
- Conduct a commuter's perception survey through administration of questionnaires in the BRT (Rea-Vaya) bus stations.
- Interview key personnel within the BRT management in relation to your study topic.

I trust that the data collected will be treated with confidentiality and all documents used will be correctly sourced and reference given to the author.

Yours Sincerely



Zarina Goondiwala
Knowledge Manager
Scheduled Services Business Unit
(Rea Vaya BRT Project Office)
Transport Department
Tel. (011) 870 4647

Appendix H: Turn it in originality report

Khwathisi Ntsieni Colin

ORIGINALITY REPORT

28%	23%	5%	16%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	www.apta.com Internet Source	5%
2	uir.unisa.ac.za Internet Source	3%
3	Submitted to University of Venda Student Paper	2%
4	siteresources.worldbank.org Internet Source	2%
5	www.itdp.org Internet Source	1%
6	www.rtanze.co.nz Internet Source	1%
7	www.acet-uct.org Internet Source	1%
8	www.sactaqc.org Internet Source	1%
9	www.ijmsbr.com Internet Source	1%
10	innovativemobility.org Internet Source	1%

Appendix I: Letter of Language editor.

Office No. C7-4
Department of English
University of Venda
P/Bag X 5050
Thohoyandou
0950

15 August 2017

Dear Sir/Madam

This serves to confirm that I proof-read and edited the research project entitled “An Evaluation of Intelligent Transport System: A Case Study of the Bus Rapid Transit (BRT) Rea-Vaya in Johannesburg, South Africa” by Khwathisi Ntsieni Colin, student no: 11602110.

I have also suggested a few amendments, provided the changes I recommended are effected to the text, the language is of an acceptable standard.

Please don't hesitate to contact me for any enquiry.

Regards



Hlavisio Motlhaka
Department of English
University of Venda
Tel: 015 962-8185
078 196-4459

E-mail: hlavisio.motlhaka@univen.ac.za

Website: <http://www.univen.ac.za/>



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