DETERMINATION OF THE MOST APPROPRIATE BUS RAPID TRANSIT SYSTEM FOR THE ETHEKWINI MUNICIPAL AREA

By

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DECLARATION

I, Emmanuel Olusegun Adewumi, hereby declare that this dissertation, except where indicated in the text, is my work and has not been submitted in part, or in whole, at any other University or University of Technology.

This research was conducted at the Durban University of Technology under the supervision of Professor Dhiren Allopi.

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ABSTRACT

Invariably, a high percentage of the population of South Africa depends on public transport. In order to continue to satisfy commuters in terms of comfort, travel time, reliability of service and traffic congestion, there is a need to improve the efficiency of moving passengers to reduce travel time, delay time and number of stops. In the quest for advancement and improvement in public transport, many countries now embark on Bus Rapid Transit (BRT) systems based on the successful implementation of the system by cities like Curitiba (Brazil) and Bogota (Columbia). Government departments/transport authorities are often faced with the challenge of selecting the most suitable BRT system relative to the unique features of its transport demands and urban layout. Hence, this study proposes the determination of the most appropriate BRT system for the eThekwini Municipal Area (EMA).

An in-depth literature review was conducted in order to determine the most adoptable BRT system amongst median, kerb side and segregated BRT systems, taking into consideration cost implications, safety of the passengers, pedestrian crossing, physically challenged commuters, vehicle option and manoeuvres.

Physical assessment and critical review of the current operating BRT systems in Johannesburg, Cape Town and Port Elizabeth in South Africa was employed in this study as well as a critical comparison among these systems. The pros and cons of the three functional BRT systems in South Africa were stated and a way forward for EMA was recommended.

Lastly, an assessment of the proposed BRT system in EMA was conducted on the existing Phase 1 and the remaining three phases. The review conducted

was based on route inspection, access to property, factors considered in the selection of a BRT system, demand analyses of the routes and the evaluation of Johannesburg, Cape Town and Port Elizabeth BRT systems. Guidelines were also provided for the remaining proposed BRT routes which could be adopted by the eThekwini Transport Authority (ETA) in order to enhance a better performance in EMA over the three functional BRT systems in South Africa using the aforementioned criteria.

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When I look back and it seems nobody is right beside me, I do indeed find some people who are my family and guardian. Nobody is created to be in isolation because “isolation is a dream killer” (Barbara Sher). I am very honoured and privileged not to have experienced isolation and to have had people like Taiye, Kehinde and Femi Adewumi, Doyin Okediji and Mrs Esther Babatunde beside me. Thank you.

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ABBREVIATIONS

AVL – Automatic Vehicle Location

BRT – Bus Rapid Transit

CBD – Central Business District

CCTV – Closed Circuit Television

CITP – Comprehensive Integrated Transport Plan

CMS – Church Missionary Society

CPTR – Current Public Transport Record

CT – Cape Town

DTS – Department of Transportation Service

EC – Eastern Cape

EFP – Electronic Fare Payment

EMA – eThekwini Municipal Area

ETA – eThekwini Transport Authority

FIFA – Federation Internationale de Football Association

FTA – Federal Transportation Authority

HRT – Heavy Rail Transit

IDP – Integrated Development Plans

IRPTN – Integrated Rapid Public Transport Network

IRT – Integrated Rapid Transit

ITP – Integrated Transport Plans

ITS – Intelligent Transportation System

KZN – KwaZulu Natal

LRT – Light Rail Transit

NLTTA – National Land Transport Transition Act

NMBM – Nelson Mandela Bay Municipality

PE – Port Elizabeth

PPHPD – Passengers Per Hour Per Direction

PRASA – Passenger Rail Agency of South Africa

PT – Public Transport

PTISF – Public Transport Infrastructure and System Fund

ROW – Right of Way

PREFACE

Publications/conferences

1. **Adewumi, E.** and Allopi, D. 2014. Determining the best BRT for eThekwini: Part one. *IMIESA*, 38(6): 37-41.

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CHAPTER 1

INTRODUCTION

1.1 Background to the study

Today, both public and private transports all over the world are facing problems due to an increase in vehicle ownership and the suburbanization of both firms and residences. In the past, public transport focused mainly on the central areas of the cities where high population and employment densities enabled frequent services, high occupancy rates and many routes. As growth is reaching the suburbs from the metropolitan areas, the challenge arises to increase public transport services in order to serve commuters better, and to integrate suburban services with metropolitan services (Pucher, Park and Kim 2005: 44).

Hence, public transport has to be made more attractive and user friendly in relation to improved service, travel information, reliability, safety and upgrading of infrastructure like waiting stations. Cost is an imperative element that influences the demand for public transport in relation to the time spent waiting, boarding and alighting from vehicles coupled with the risks and inconveniences involved in those actions. A report prepared for London Transport Marketing (Conquest Research 1997: 217-218) suggests that commuters and business users board the fastest and most direct routes. Besides, according to Page (2004: 134) says “Transport is identified as one of the key elements of the overall tourism product at a destination. Thus, the urban tourism product is made up of a range of goods and services, of which transport is one, and which together form the visitor experience”.

The different forms of Bus Rapid Transit (BRT) systems, namely, kerb side lane, median lane and segregation lane, differ in benefits. Moreover, as the investment in BRT systems increases across the globe, there are also improvements in travel speed and introduction of high quality stations. Bus lanes, indented bus stops, signal priority and regulatory signs are the simplest forms of improvement of the BRT system in the world.

A kerb side lane BRT system (Figure 1) is provided with a dedicated and continuous lane for buses to travel along the kerb edge of the road e.g. Canberra, Australia. The bus stops are designed in such a way that they guarantee easy access to the surrounding streets. However, a problem arises when other vehicles need to cross the dedicated lane into driveways and side streets (Valley Transportation Authority [VTA] Transit Sustainability Policy 2007: 19).

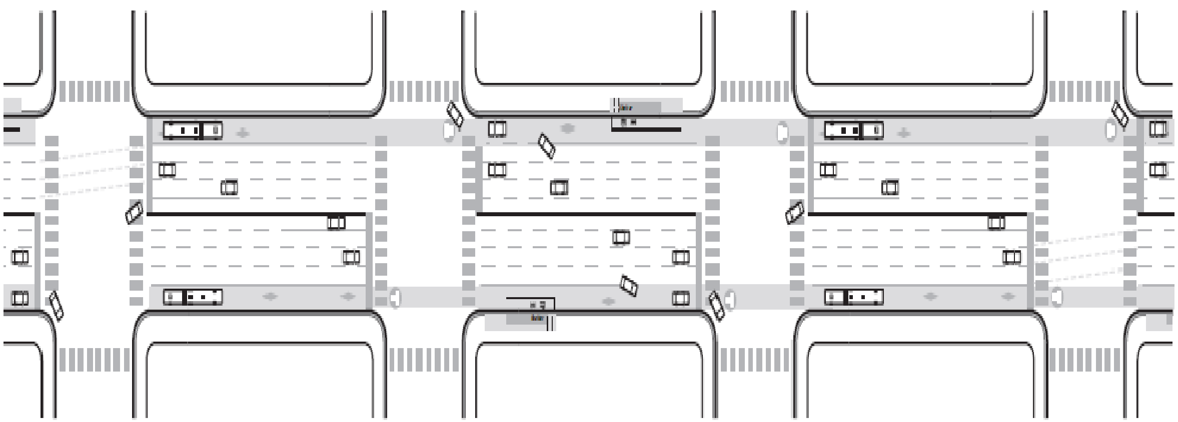


Figure 1 Kerb side BRT concept – typical lane configuration
Source: Valley Transportation Authority Transit Sustainability Policy 2007: 19

A median lane BRT system (Figure 2) is when the lane is situated alongside the median and the median is protected possibly with some physical barriers to keep other vehicles off the lane e.g. Adelaide Avenue, Australia. Bus stations are developed at key locations, which are usually adjacent to the major side streets. Passengers are assisted with pedestrian crossways through traffic signals or overhead walkways. Although an improvement over kerb side, median lane BRT still suffers delays at the intersections, these can be reduced through signal priority measures (VTA Transit Sustainability Policy 2007: 30).

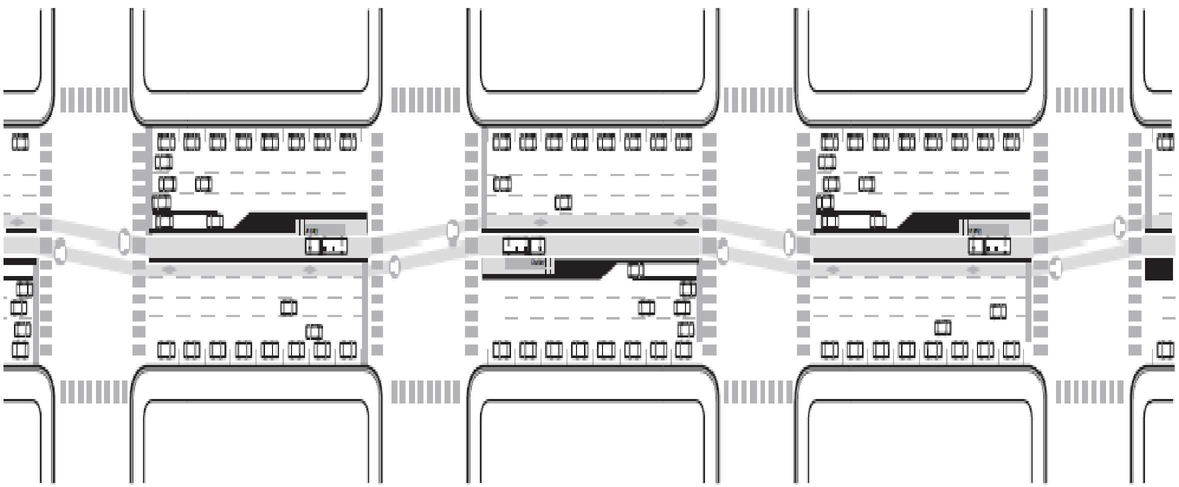


Figure 2 Median BRT system – typical lane configuration
Source: Valley Transportation Authority Transit Sustainability Policy 2007: 30

A segregated lane BRT is fully separated from other traffic either via elevated structures/tunnels e.g. Brisbane and Adelaide in Australia. This offers a fast operating speed when compared with other types of BRT systems and bus services. The main challenge in this kind of BRT system is that it requires a huge financial investment (ACT Government 2012: 1).

1.2 Statement of the problem

Due to increases in population density, traffic congestion and associated pollution and land use intensification there is pressure to seek effective means of moving passengers, reduce travel time, delay time and number of stops. BRT systems have been adopted as an improvement on regular bus services through a combination of features like infrastructure changes and have resulted in better operation speeds and service reliability. Many countries now embark on BRT systems based on the successful implementation of the system by cities like Curitiba (Brazil) and Bogota (Columbia). Government departments are often faced with the challenge of selecting the most suitable BRT system in relation to its transport demands and urban layout.

1.3 What is BRT?

BRT can simply be defined as a rapid mode of transportation that can coalesce the quality of rail transit and flexibility of buses (Thomas 2001: 2). The Transport Research Board (2001) cited in Levinson et al (2002: 2) defined Bus Rapid Transit in a more simplified and understandable way as a flexible, rubber-tired rapid transit mode that combines running way, intelligent transportation system (ITS) elements, stations, vehicles and services into an integrated system with a strong positive image and identity. BRT projects are usually embarked on in phases as funds and opportunity permits because of the flexibility of the service. A BRT system is planned to be appropriate to the place/destination it serves and the physical surroundings. Based on its performance in the implemented areas; the service can be later extended to other environments. Effective and cheap public transport provision aids the growth of a nation in terms of its economy, social and environmental wellbeing, and facilitates the urbanization of cities all over the world in the name of globalization and world economic integration.

1.4 Features of BRT system

BRT features include:

- ✓ Running ways: BRT vehicles ply a fast and easily recognizable dedicated bus lane or traffic lane/exclusive rights-of-way. BRT running ways also operate on abandoned rail lines and highway medians.
- ✓ Stations: These serve as a temporary shelter for passengers waiting to board to their various destinations, which must be conveniently located and integrated along the route which they serve. BRT stations possess specific paint schemes, logos, real-time arrival information and streamlined passenger shelter design.
- ✓ Services: BRT should provide a high frequency service at all time of the day with less waiting time so as to reduce travel time.
- ✓ Intelligent Transportation Systems (ITS): BRT makes use of advanced digital technologies that improve passengers' convenience, speed, safety and reliability. For instance, bus/intersection signal priority, closed circuit television monitoring of operations that makes use of automatic vehicle location (AVL) with the aid of Global Position Systems (GPS).
- ✓ Fare collection: This is collected in a fast and easy way; preferably before passengers get on board the bus that is off-vehicle fare payment.
- ✓ Access and egress: There should be multiple doors for entrance and exit to reduce time.
- ✓ Vehicles: BRT uses rubber tyre, high capacity, multiple double-wide doors, low-floor design and colour-coded vehicles that are very easy to board and convenient to ride with high ridership.

1.5 Justification for the study

The justification for this study is that eThekwini Transport Authority (ETA) is faced with the challenge of selecting the most suitable BRT system in the quest to continue to satisfy commuters regarding the following issues on public transport:

- ✓ The number of stops being experienced in public transport / delay on travelling;
- ✓ Service reliability;
- ✓ Travel time;
- ✓ Poor service conditions;
- ✓ Long waiting time at the stations; and
- ✓ Traffic congestion experienced by public transport and private car users.

1.6 The eThekwini Municipal Area Integrated Rapid Public Transport Network: Current planning and implementation initiative

The users-operators, commuters and the EMA (eThekwini Municipal Area), are the main focus of the Integrated Rapid Public Network (IRPTN). The IRPTN is about implementing a more efficient means of public transport in terms of reducing the cost of travel and trip length. The IRPTN chooses a network structure (BRT corridors) based on population demand. The BRT routes for the proposed BRT system are shown in Figure 3.

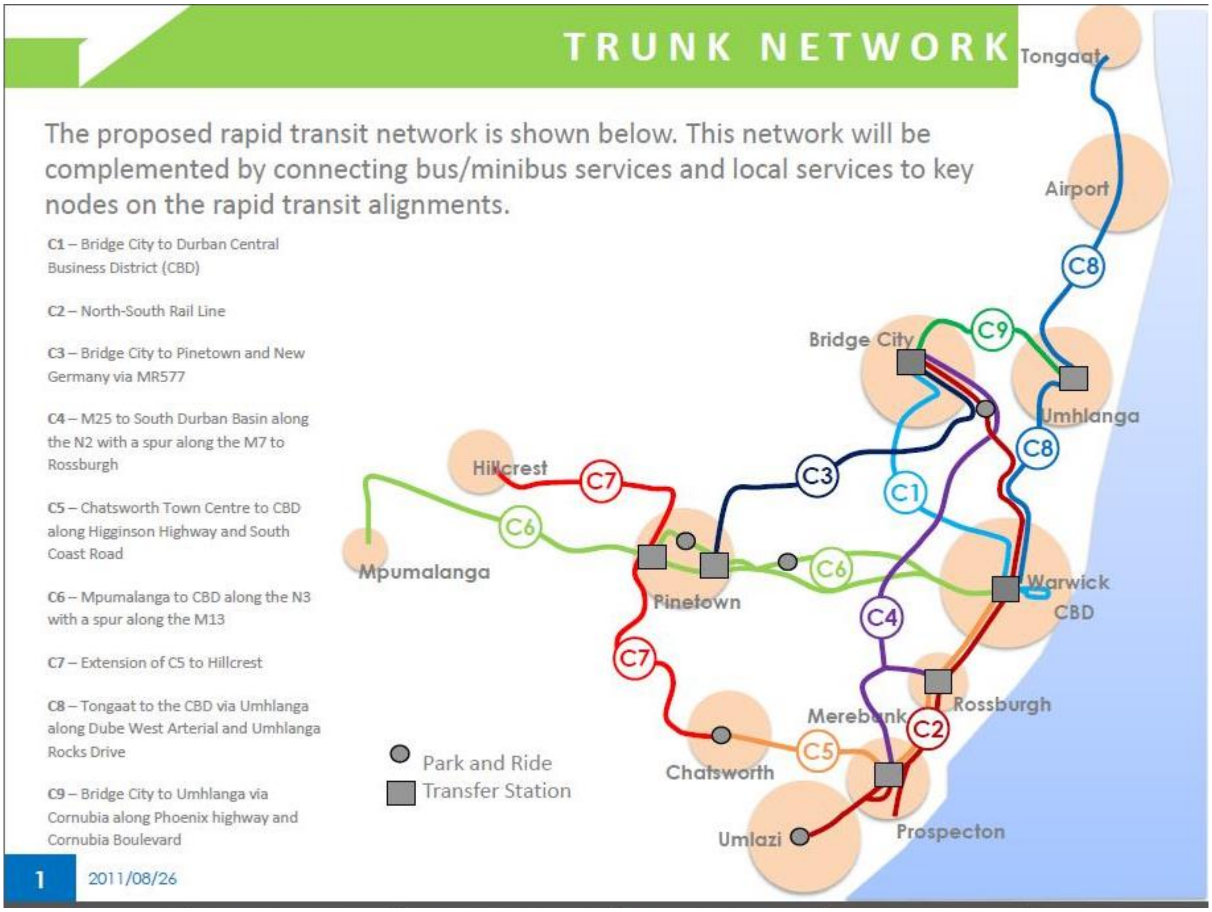


Figure 3 Trunk network of phase 1 of the BRT system in Durban
Source: Moodley et al 2011: 14

1.7 Research aim

The main aim of this study is to evaluate and recommend the most appropriate BRT system in the EMA relative to the unique features of its transport demands and urban layout.

1.8 Research objectives

The research objectives are:

- ✓ To evaluate the various forms of BRT systems implemented throughout the world by means of an in-depth literature study;
- ✓ To undergo a physical assessment and critical review of BRT systems in South Africa; and
- ✓ To document guidelines for the appropriate selection of a BRT system for the EMA based on urban layout, transport needs and other associated factors.

1.9 Scope of the study

This study will focus on the evaluation and recommendation of the most appropriate BRT system given the unique features of the EMA transport demands and urban layout. This will be properly addressed by a theoretical history of the BRT system and by gathering as much information in order to get an in depth knowledge of it across the world, and by means of physical assessment and critical review of the operating BRT systems in South Africa.

1.10 Methodology

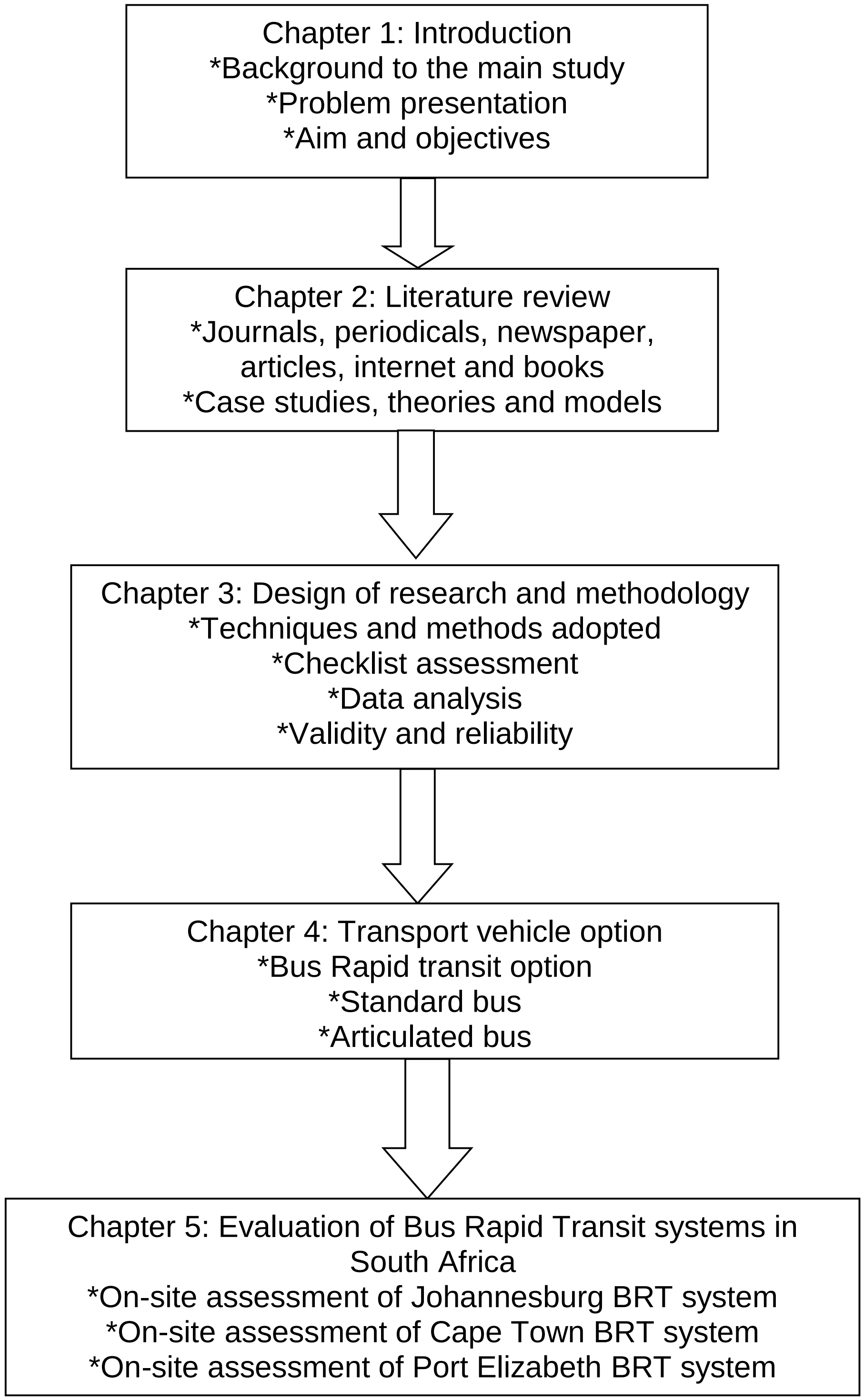
The method that will be employed is as follows:

- ✓ Investigate the theoretical history of BRT systems across the globe by means of an in depth literature study.
- ✓ Compare the kerb side, median and fully segregated BRT systems based on lane configuration. The comparison will be based on the following:
    - o cost implications;
    - o safety of passengers;

    - pedestrian crossing;
    - the physically challenged commuters; and
    - vehicle manoeuvre.
- ✓ Highlight the pros and cons of the various BRT systems.
- ✓ Presentation of the main criteria used in selecting the most appropriate BRT system.
- ✓ Physical assessment and critical review of BRT systems in Johannesburg, Port Elizabeth and Cape Town based on urban layout and transport demands.
- ✓ Presentation of transport vehicle options based on the bus design that is best suitable for EMA.
- ✓ Documentation of guidelines for the appropriate selection of a BRT system for EMA based on urban layout, transport needs and other associated factors.

1.11 Overview of chapters

This dissertation comprises eight chapters (Figure 4). Chapter 1 introduces the research title, provides the background of the study, and highlights the problem statement, objectives and the scope of the study. Chapter 2 reviews the literature on the BRT system. Chapter 3 reviews the methodology employed in this study and Chapter 4 explains transport vehicle option. Chapter 5 presents the evaluation of the BRT systems in South Africa. Chapters 6 and 7 present the proposed BRT system for EMA and data analysis obtained in the course of the research respectively. Finally, Chapter 8 presents conclusions and recommendations based on the results drawn from the study.


Chapter 1: Introduction
*Background to the main study
*Problem presentation
*Aim and objectives
Chapter 2: Literature review
*Journals, periodicals, newspaper, articles, internet and books
*Case studies, theories and models
Chapter 3: Design of research and methodology
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*On-site assessment of Port Elizabeth BRT system

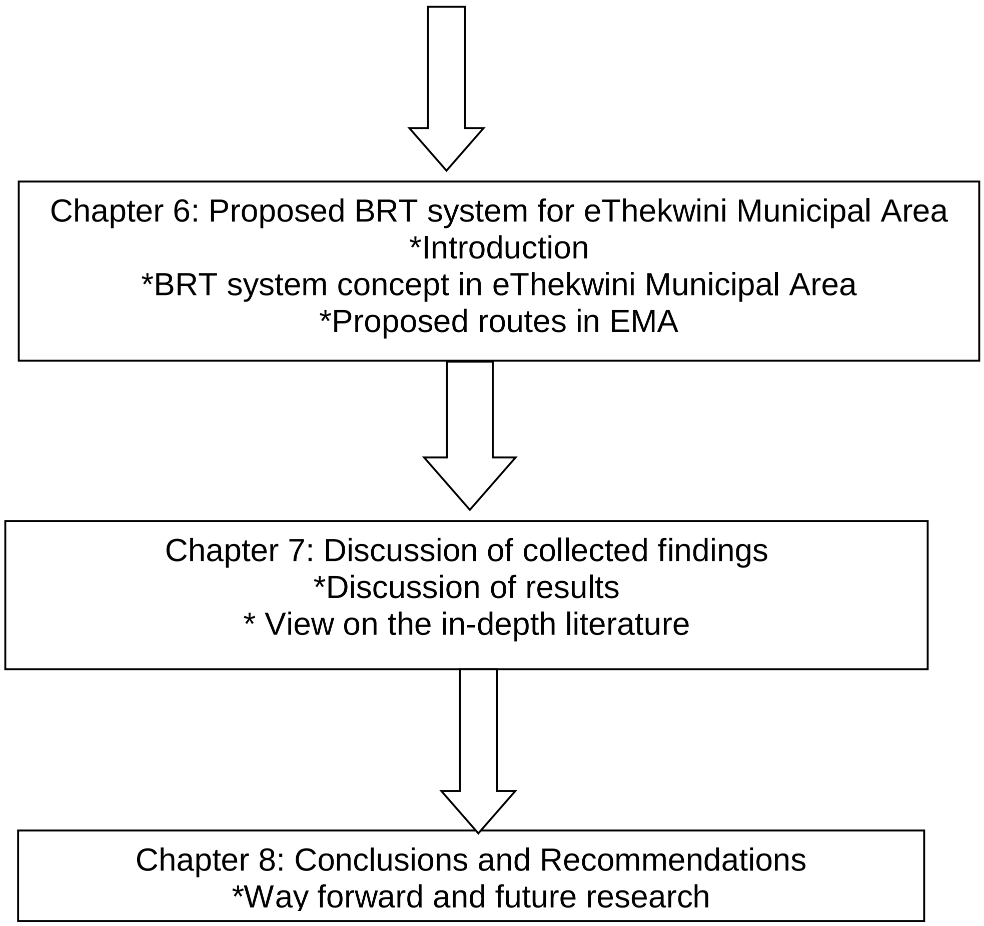

Figure 4 Graphical presentation of research design

1.12 Conclusion

This chapter provided an overview of the chapters that follow. On this basis, the dissertation proceeds to the literature review in which dominant theories that pertain to the study are explored.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Boote and Beile (2005: 1) state that “a literature review is an evaluative report of studies found in the literature related to your selected area and review should describe, summarize, evaluate and clarify the research study.” Hence, this chapter assesses the relevant literature related to this study and presents the overview of BRT across the world to South Africa down to the local level, the review begins with a background to the study and the history of transportation in Africa.

2.2 Background

Leem and Yoon (2004: 347-348) state that customer satisfaction is a broad concept that includes perceived evaluation of product and service. Pucher, Park and Kim (2005: 41) assessed the impact of safety, speed, costs, passenger levels and overall customer satisfaction on public transport in Seoul. The transit industry in U.S.A has developed significant interest in BRT; in 2004 there were about 200 transit agencies considering a BRT system (Miller et al. 2004: 38). BRT is a customer-oriented, high quality transit service that delivers fast, comfortable and cost effective urban mobility (Wright 2003: 11).

2.3 Historical development of BRT systems

The large-scale development of BRTs started in Curitiba (Brazil) in 1974, and before then, there were several smaller-scale projects earlier in its development.

The success of effective BRT in Curitiba inspired many other cities to develop similar systems (Matsumoto 2006: 2). In the 1970s, development of BRT systems was limited to the North and South American continents. In the late 1990s, the replication of the BRT concept gained momentum and BRT systems were opened in Quito, Equador (1996), Los Angeles, USA (1999) and Bogotá, Columbia (2000) (Ernst, 2005: 11). Especially, the TransMilenio project in Bogotá started operation in 2000 and its success drew attention from the world community as an example of the state of the art in BRT systems (Levinson et al 2003: 14). As of 2005, there were up to 70 systems around the world, depending on one's definition of BRT (Wright 2005: 698)

2.4 International BRT operations

2.4.1 Integrated Transport Network (Curitiba, Brazil)

The metro population of Curitiba, Brazil is 2.7 million people and is located in Southern Brazil. The city aimed development in five high-density transit corridors for the latter part of the 20th century. There are now 54km (33.5 miles) of exclusive bus lanes / dedicated lanes in these five corridors. This approach has really proven to be adoptable and doing well with 70 percent of the commuters in the region using the transit system on a daily basis. The number of passengers on the transit is 50 times what it was in the 1970s.

Different from most American transit systems, Curitiba's public transport is operated by 16 private bus companies with 1,900 buses making more than 14,000 trips daily. In order to set right any competition problems, the city pays companies based on the number of miles travelled by the bus rather than the number of passengers served. This method encourages the companies to serve lesser-populated areas. Traffic-signal manipulation and headways as short as

90 seconds have contributed to a successful service. Fares are collected off-board. Curitiba operates five levels of service, namely, conventional, inter-neighbourhood circulators, feeder, express lines and direct lines. The five levels of service operate as one service, but with different branding, marketing and vehicles. No additional costs are involved in transferring from one level of service to another since it is an integrated system and there are minimum wait times between buses (Diaz and Schneck 2000: 110-111).

2.4.2 Transit Way (Ottawa and Ontario, Canada)

The initial leg of Ottawa's transit way was opened in 1983 with 25.8km bus-only roadway, built by the city in phases. In addition, the system has 35.3km of dedicated lanes on the freeways and arterial roads. Ottawa BRT systems operate three routes along a grade-separated roadway and majorly using a railroad right of way. These routes operate 4-8 minute headways during the daytime and 25-30 minute headways during early morning and late night times respectively. BRT vehicles use Intelligent Transportation System (ITS) through vehicle location identification and signal priority at intersections. The transit way is usually two lanes and at stations expands to four lanes to permit express buses to go around the stations. Some stations have real time bus information. Buses have level boarding to make it easy for boarding and alighting of passengers, especially physically challenged passengers and fares are collected off-board.

Conventional buses use part of the transit way as it accommodates the express bus routes, which serve the surrounding residential areas during peak hours. On the average, transit way accommodates 200,000 commuters daily and the buses plying the transit way offer an intermodal link with the light rail, called O-Train. The Province of Ontario funded 75 percent of the construction cost for the transit way, but no further funds were received in the past decade. However, minute system upgrading has been accomplished during that span of time. There are plans to enlarge the transit system to contain a higher ridership, more areas and slot in the use of smart card technology for fare collection (Diaz and Schnek 2000: 112).

2.4.3 North-south corridor (Sydney, Australia)

This is one of Sydney's busiest, which operates a total of 74 bus routes along it. Approximately 9,600 passengers and 210 buses enter the Central Business District from this corridor between the hours of 7am to 10am. This means that 35% of the total buses and 45% of total bus passengers enter the CBD through the Sydney Harbour Bridge. Half of all the services travelling along Military road experience limited stops and express services to the city in the morning. The North-south corridor operates a 24-hour kerb side lane between Mona Vale and Neutral Bay. Some parts of the North-South corridor are operated at the median/centre of the lane. Median BRT system requires a grade-separated pedestrian/cyclist bridge or wait to cross before they can access the centrally located BRT system (NSW Government 2012: 12).

2.4.4 Metro bus (Istanbul, Turkey)

The Istanbul BRT system recently developed its modern bus transit way and is one of the early examples of cities that established bus priority lanes in the 1970s (Vuchic 2002: 74). Originally, the highway had three lanes and Metro bus was designed as a dedicated median lane. During the planning process, the local authorities designed the median lanes without losing any mixed traffic lanes on the main road. Taking advantage of the central reservation, service roads and emergency lanes in spite of some concerns about safety issues, the three lanes per direction were maintained (Alpkokin and Ergun 2012: 60).

2.4.5 BRT system (Beijing, China)

This was the first BRT system implemented in China and commenced commercial operations in December 2004 with only 5.5km in length in the first stage. It was later extended in December 2005 to 15.8km. It is important to note that from proposal to trial operation the time span of BRT implementation was quite short. The route starts at Qian’men (the city centre and multi-modal transport centre) and ends at De’mao’zhuang (a southern residential area) spanning 17 stations, which form part of the main north-south traffic highway of the city. Chinese decision makers have adopted BRT schemes as one of the practicable and affordable plan of public transport from the successful BRT system of Curitiba (Brazil) and Bogota (Colombia) to ease the traffic problems within a fast implementation time. Most lanes are located in the median of the road (Deng and Nelson 2012: 2)

2.4.6 Visakhapatnam BRT system (India)

Visakhapatnam is a fast developing port city on the coast of the Bay of Bengal in India. Ninety percent of the 0.45 million registered vehicles are cars and the travel demand is estimated at 1.2 million person per trips per day, which is projected to grow to 1.6 and 2.8 million trips per day by 2011 and 2012 respectively. The Visakhapatnam BRT project consists of 18.5 and 20km long corridors coupled with 38 traffic junctions and 48 bus stations. The adopted designs for the BRT system include 30m and 36m cross-sections at the mid-block and bus stations respectively (Figures 5 and 6). The dedicated 3.5m BRT lane is along the median side with 3m wide passenger platforms (Ponnaluri 2011: 270).

Figure 5 Design concept at mid-block
Source: Ponnaluri 2011: 271

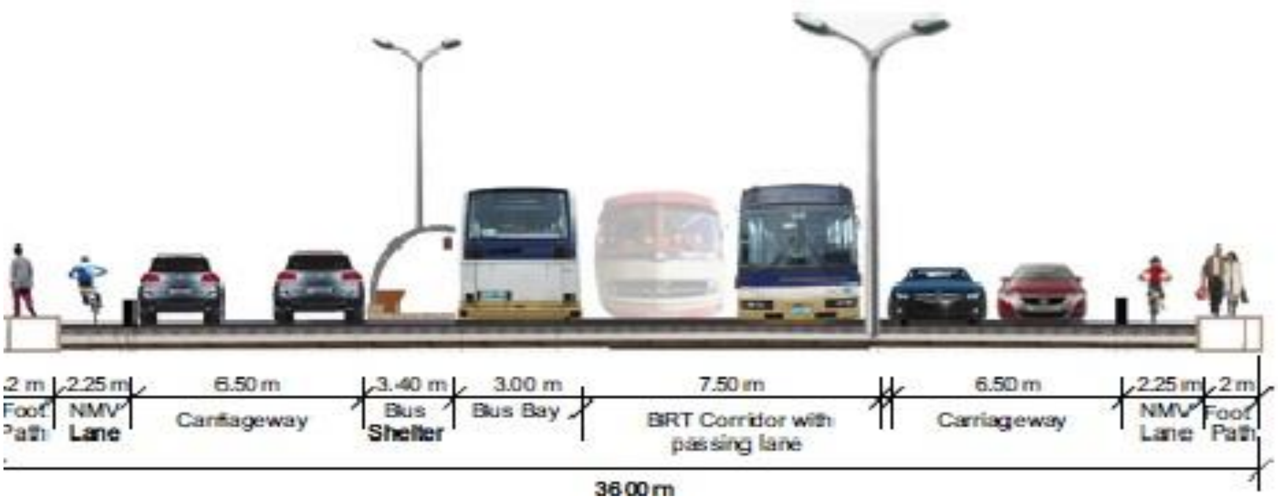

Figure 6 Design concept of bus station
Source: Ponnaluri 2011: 271

2.4.7 Delhi BRT system (India)

Delhi BRT system operates in a dedicated lane separated by a median. It has the ability of being flexible and adaptive to the present bus routes and movement patterns. Bus stops are at an average spacing of 500m at the near side of the intersection setback by 20m. However, if the intersection spacing is more than 500m and points of major boarding/alighting occur in between the intersections, provision is made for mid-block bus stop coupled with signalized pedestrian crossings. Pedestrian holding areas are provided at the kerb side, at each intersection for them to wait before crossing the road (Tiwari and Jain 2012: 89).

2.4.8 Seoul BRT system (South Korea)

Seoul operates both median and kerb side BRT systems. The city reformed its public transit system with the introduction of central-lane BRT coupled with the implementation of integrated fare system, bus-priority signals and real-time information systems in 2004. In 2004, 87.4km of central-lane BRT services were running through 11 corridors. Moreover, the kerb side BRT was installed in 18 metropolitan cities in South Korea, but right-turning and waiting vehicles in the side lanes means the kerb side system has not fulfilled its anticipated travel speed and punctuality. Seoul’s public transit reform not only improves the operational efficiency, but also has a “convenient” fare (Eoma and Schipper 2010: 3605).

2.4.9 South America BRT Systems

The BRT systems installed in Horizonte, Curitiba, and São Paulo, Brazil and that of Quito, Ecuador; and Bogotá in Colombia typically make use of a physically separated median lane along wide multilane arterial roadways. Stations are spaced 365.76-457.2m between major intersections and multidoor articulated (18m) and bi-articulated (24.5m) diesel and trolley buses are used depending on the system. Some of the South America BRT systems offer off-vehicle fare collection. The peak-hour and peak-direction passenger flow range from 10,000 to 20,000 persons per hour (Gordon, Cornwell and Cracknell 1991: 12).

2.4.10 Houston BRT system (United States of America [USA])

This system uses kerb side bus lanes. It is a system of commuter express service through bus/HOV (high occupancy vehicles) with dedicated T access ramps connecting to park-and-ride lots (Levinson et al. 2002: 17).

2.4.11 Boston BRT system (USA)

This consists of both kerb side bus lanes and bus subways and is viewed as the fifth rapid transit corridor using special dual-mode, that is electric trolley and full power diesel with articulated multidoor vehicles. It links the South Station-Red line subway, commuter rail, Amtrak and intercity bus, Financial District with the South Piers and Dudley Square on the MBTA's Orange Subway Line. This will later be extended to the existing Ted Williams tunnel to link Logan International Airport (Levinson et al. 2002: 18).

2.4.12 Seattle BRT system (USA)

This is a bus-only subway that runs via Seattle's CBD with dual-mode articulated buses providing both local and express services to distant areas through freeways and HOV lanes. Some of the buses connect to a busway running south and run an express service through I-5 to the north (Levinson et al. 2002: 18)

2.4.13 Vancouver BRT system (Canada)

The corridor spans from downtown Vancouver and Richmond and uses multi door and low-floor articulated buses. The BRT system uses bus only streets/segregated bus lane coupled with attractive buses and limited stops along Richmond corridor and Vancouver provides a similar service running from east to west (Levinson et al. 2002: 18).

2.4.14 Los Angeles BRT system (USA)

This runs on Wilshire/Whittier (26, 14 miles) and Ventura (16 miles) Boulevards, and are easily recognizable with red coloured low-flow, low-pollution buses with limited stops. The operating speeds and commuters of the Wilshire and Whittier routes have increased by 29 percent and 33 percent respectively. Likewise that of the Ventura Boulevards route has increased in operating speed by 23 percent and commuters by 26 percent. Two-third of the travel time savings was achieved as a result of wider stop spacing (Metropolitan Transportation Authority, 2002: 2-4).

2.4.15 Miami BRT system (USA)

This operates along the abandoned rail line that links the Metro rail line and conveys about 14,000 commuters during weekdays. This is a busway BRT system that provides both local and express services (Levinson et al. 2002: 17).

2.4.16 Montreal BRT system (Canada)

This system has a feeder BRT line through a reversible arterial lane that links to Pie IX Metro rapid transit station. It was operated from 1989 to 2002 and billed to return to service in 2013. During the stoppage period, the lane was used for a regular reserved rush hour lane (Levinson et al. 2002: 17).

2.4.17 Pittsburgh BRT system (USA)

This has three operating busways: South Busway, Martin Luther King East Busway and West Busway. The South Busway commenced operation in 1977, 4 miles in length, nine stations and the buses use a right of way with the light rail vehicles along Mount Washington Tunnel in the Palm Garden Station area. The Martin Luther King East Garden is 6.8 miles in length and was opened in 1983. It is located on an existing right of way with six stations. The West Busway was opened in 2000 and runs on 5 miles of former railroad right of way with six stations. Martin Luther King East and West Busways operate both express and all-stop local services with 28,600 and 8,000 commuters on weekdays respectively, and South Busway has 15,000 commuters on the average (Levinson et al. 2002: 17).

2.4.18 Ottawa BRT system (Canada)

This BRT system was executed in phases since 1982 including 15.5 miles of exclusive busway, 7.5 miles of lanes on roadway and 2 miles of downtown bus only lanes. The stations and park and ride lots located along the transit way and ends of the facility are 22 and approximately 2,200 spaces respectively. Roughly 50 routes offer residents with peak period and transfer-free express services and many of the these routes serve as feeders to all-stop local routes during off peak period. Roughly 200,000 commuters daily, with 10,000 one way in the morning peak hour at the maximum load point (Levinson et al. 2002: 16).

2.4.19 Lagos BRT system (Nigeria)

This system was opened in 2008 and plies Mile 12 passing through Ikorodu Road and Funsho Williams Avenue up to Church Missionary Society (CMS). The 22km Lagos BRT system operates 220 buses on segregated lanes as shown in Figure 7 with 26 stops and 3 terminals. The two operators offering the BRT service to commuters are NURTW Cooperative and LAGBUS which is an asset management company owned by the Lagos state government. The daily ridership exceeds 220,000 with an average load factor of 1000 riders carried per bus per day. The average trip per bus per day, average waiting time, and average journey time are 5, 15 minutes and 55 minutes respectively with over 13 million commuters from inception. The bus terminal at CMS was designed to integrate with rail and ferry modes of transport for future construction by Lagos Metropolitan Area Transport Authority (LAMATA) (Orekoya 2010: 1-20).

Figure 7 Lagos BRT system
Source: Orekoya 2010: 6

2.5 Factors that determine the type of BRT system to be adopted

In determining the type of BRT to be adopted anywhere in the world, there are some factors that need to be put into proper consideration which are the number of passengers to be carried, available road space/land, funding available for the implementation of the BRT system and the time travel benefits that need to be achieved. The implementation of BRT systems is considered to be flexible in the sense that one mode can be adopted and then transition to another seamlessly, just like in Belconnen, which operates different types of BRT systems in one corridor. Secondly, BRT systems can be built gradually if needed without interrupting the operation of the existing bus in such corridor (ACT Government 2012: 1).

2.6 History of transportation in Africa

The main mode of transportation used in the past was walking or the use of animals like horse-drawn carts or ox-drawn carts. Development came to transportation after the European colonization in Africa in 1400s for the first time. There were properly aligned and extensive road networks in the 1600s, which were used to ferry slaves during the trans-Atlantic slave period. During the colonial period in Africa, Europeans preferred rail transport to road as a means of ferrying their raw materials because of the cost of construction and high profit rail transport would bring to them as a result of the slave trade. This caused a lag in the development of road transport (Abuhamoud, Rahmat and Ismail 2011: 51). Until the 1980s, the development of road networks was a low priority. However, roads are now the main means of transportation within each nation in Africa and even in the world (Trans-Africa 2008: 66-68).

2.7 National operating subsidies

Developing a business plan for public transport is difficult for any transport authority unless they know the rate of operating subsidy that will be made available to them. At each metro or functional area, the existing level of subsidy must continue at the levels currently being allocated for bus subsidies. A judgment call will be made by the transport authority to decide which proportion of the subsidy will be allocated to catalytic initiative. In other words, the transport authorities have to plan for zero operating subsidies for the catalytic initiatives as they have no control over the subsidy streams which are currently in place and applied to standard buses and rail (Department of Transport 2007a: 50).

2.8 Current BRT system in South Africa

The commuters of Gauteng province have been using a BRT system called “Rea Vaya”, which means “we are going”. It was the first of its kind in the history of South Africa. Phase one of the BRT system came into effect on August 30, 2009 in Johannesburg, South Africa, along the main routes linking Soweto to the centre of Johannesburg. This conveys 16000 passengers per day. Other functional BRT systems are in Cape Town and Port Elizabeth (Thomas 2010: 1-6).

2.9 Initiatives of commuter bus service in South Africa

The National Land Transport Transition Act of 2000 (NLTTA) authorizes the establishment of Transport Authorities which will deal with the devolution of the rail commuter services and public transport funding functions over the medium to long term. The intention of the NLTTA is also to integrate planning, improve regulation and prepare for full devolution through statutory Integrated

Development Plans (IDP's) and Integrated Transport Plans (ITP's) (Walters 2008: 8).

Before the 2010 world cup, the Department of Transport (DoT) planned a number of strategies to ease transport issues, which are-

- ✓ Refine the Integrated Transport Plan;
- ✓ Improve service information, maps, timetables and marketing;
- ✓ Develop public transport funding to transport authorities in the long term;
- ✓ Put measures in place to recapitalize the bus, taxi and rail systems
- ✓ Introduction BRT systems;
- ✓ Develop Intelligent Transport Systems in support of planning, regulation and enforcement; and
- ✓ Non-motorized and public space network planning.

Plans have been put in place by the DoT to commence the use of BRT systems in metropolitan areas of South Africa using dedicated lanes that have their own right-of-way to bus services that utilize high occupancy vehicle lanes or dedicated freeway with limited bus stops on pre-existing routes. The first phase of BRT started in Johannesburg (2009), and is expected to run through the remaining corridors in South Africa by 2020 (Department of Transport 2007a: 4-10).

2.10 Public transport operators in eThekwini Municipal Area

2.10.1 Bus

There are 400 bus service associations within the EMA, and some of the operators are subsidized operators, although there are numerous corridors that are not subsidized. The large fleet operators vary from Durban Transport to bus owner operators.

The existing bus service consists of 1,400 unidirectional corridors, which is serviced by roughly 200 operators in a mix of subsidized contract and unsubsidized services made available in terms of the operator route permits. At present, there are seven bus contracts covering roughly 70% of the municipal route system. The remaining service of the municipal route system (30%) is operated by 170 unsubsidized bus operators in thirteen (13) associations, alongside with roughly 20 independent operators.

The privatization of Durban Transport which accounts for more than one-third of the bus fleet in the metro area, and which operates roughly half of the bus routes, was terminated. The operators withdrew due to low profitability and subsidy problems. However, this had a striking effect on the commuters that forced them to shift to other modes of transport, but the eThekwini Transport Authority (ETA) soon regrouped and set a new interim contract in place.

Other than the subsidized service contracts, operators suffered a great loss in terms of ridership and profit margin leading to the inability to increase their fleet and struggled to maintain service levels with their ageing coaches. The major issues facing the bus services are that the bus and rail services operate in straight competition and unsubsidized bus services operate with low passenger levels even at peak periods (eThekwini Municipality 2010: 66-88).

2.10.2 Minibus taxi

There are roughly 120 taxi associations serving the municipal area and on completion of the provincial taxi database, a precise figure for the number of the operators will be known. The taxi industry operates in direct competition with the bus and rail services in the metro areas. Some areas indicate that over trading has led to associations operating with split schedules whereby different operators provide the service on different days of the week.

This has resulted in keeping passenger loading at a reasonably high level. Despite the high passenger loads, the unsubsidized taxi industry does not generate profit margins that aid fleet replacement. Most of the fleets are old and break down often so the safety of the passengers is of major concern (eThekwini Municipality, 2010: 66).

2.10.3 Rail operations

There are widespread commuter and freight rail services in eThekwini along the North-South and Port-Inland rail corridors. The Passenger Rail Agency of South Africa (PRASA) operates the North-South Rail corridor and Transnet Freight Rail corridor operates the Port-Inland rail corridor. The needs identified by PRASA are:

- ✓ Increase the number of commuters (preferred mode of choice);
- ✓ Increase funding;
- ✓ Make rail attractive to other users – improve park and ride facilities and security;
- ✓ Flexibility in fare structures for diverse users;
- ✓ Form part of an integrated public transport system;
- ✓ New railway technology to meet the demands of a modern society;
- ✓ Ensure appropriate land uses to make rail mode of transport attractive
- ✓ Better rolling stock/infrastructure/signalling;
- ✓ Generate more revenue to deal with subsidy reduction; and

- ✓ Make entire rail experience on average level with first world travel (access, station facilities, journey, customer service, reliability, punctuality and ticketing) (eThekwini Municipality 2010: 66).

2.11 Transport initiatives in Durban

The Federation Internationale de Football Association (FIFA) World Cup was awarded to South Africa in the year 2010 and Durban was one of the host cities. The world cup was used as a catalyst to ameliorate South Africa's transport system through investment in public transport and road infrastructure, rail upgrades, intermodal facilities, BRT systems, inner-city mobility systems, call centre systems, airport-city links, freight services, passenger safety and intelligent transport systems (eThekwini Transport Authority 2010: 1.2)

Section 6 of eThekwini Transport Authority's Integrated Transport plan update is to implement the Integrated Rapid Public Transport Network (IRPTN) service modes and develop schedules for the rapid movement of passengers at the peak of the service from origin to destination coupled with short travel time and minimum fare-paying transactions (eThekwini Transport Authority 2010: 1.9).

The IRPTN is intended to form an integrated system, where necessary, comprising bus rapid transit/integrated rapid transit (BRT/IRT), light rail transit (LRT) and heavy rail transit (HRT) to meet the current and future demand throughout the urban area on a service/cost effective basis (eThekwini Transport Authority 2010: 4.14).

2.12 Public transport strategy

The pertinent quality of the public Transport Strategy (2007-2020) is the phase extension of the mode based vehicle recapitalisation into IRPTNs. These networks consist of an integrated package of BRT and Rapid Rail priority corridors in major cities.

The Public Transport Strategy has two crucial thrusts: Accelerated Modal Upgrading and IRPTNs. Accelerated Modal Upgrading concentrates on the 3-7 year transitional period with a view to increasing the quality of the public transport fleet and its current operations. The IRPTN concentrates on the 4-20 year period to implement high quality networks of car competitive public transport services that are fully integrated and with dedicated right of way that are fully regulated and managed by the municipal transport department.

Moreover, the main objective of IRPTNs for major cities in South Africa is to advance both the commuter rail, bus and minibus services to Rapid Rail and BRT level of good quality. However, these services will be totally incorporated to form one system no matter what the mode of transport (Department of Transport 2007b: 4-7).

2.13 Phase 1 of Integrated Rapid Public Transport Network package

Phase 1 of the IRPTN package comprises the BRT and Rapid Rail. The action plan suggests that the network implementation consists of a standard basic package that can be embraced by the local city and district conditions. Most especially in the bigger cities, this will require a citywide controlled network of rapid public transport corridors together with a fine-grained feeder system of smaller taxis, buses, park and ride facilities, bicycles, pedestrian access and metered taxis.

IRPTNs make preference for public transport, walking and cycling over private car travel and so dedicate road space to these preferred modes of transport. Below are the core components of the network package:

- ✓ 85% of all the residents within 1km of Rapid Public Transport Network by 2020;
- ✓ Extended hours of operation (16-24hrs);
- ✓ Upgraded modal fleet facilities, stops and stations;
- ✓ Electronic fare integration when making transfers;
- ✓ Integrated feeder services including walking, cycling and taxi networks;
- ✓ Full special needs and wheelchair access;
- ✓ Peak frequencies (5-10min) and off peak frequencies (10-30min);
- ✓ Safe and secure operations monitored by control centre;
- ✓ Car competitive public transport option enabling strict peak period car use management; and
- ✓ Integration with metered taxi services and long distance intercity services.

The critical implementation building block is through the network implementation plan, transport authority control over the network and maximum inclusion of existing operators in the network. The central service vision of 2007 to 2010 is to execute a constant upgrading from the current basic commuter service to an upgraded modal service. In addition, the network will aim to attain maximum accessibility with a target of 85% of the city's residents who live or work within 1km of the network (Department of Transport 2007b: 5-9).

2.14 System performance

The system performance of BRT is based on the following five attributes.

2.14.1 Travel time

One of the main advantages of BRT is its higher operating speed. The overall travel time consists of four components, which are:

- ✓ Running Time – time spent in the vehicle moving from stop to stop;
- ✓ Dwelling Time – time spent when vehicle stopped at a station;
- ✓ Waiting Time – time spent by the passengers initially waiting to board a transit service; and
- ✓ Transfer Time – time spent by the passengers to transfer from one vehicle to another vehicle in order to complete his/her trip (Federal Transit Administration 2006a).

2.14.2 Reliability

Reliability in the service rendered is the ability of the transit operators to offer a dependable level of service and maintain operations as planned. Customers may consider the service undependable when bus arrival times are unpredictable. Operating a dependable service increases customer satisfaction as well as the perception of high-quality service that may increase ridership for the transit operator (Federal Transit Administration 2006a).

2.14.3 Service adherence

Service adherence can be defined as the measure of reliability. In other words, it is the ability of the transit service to wait on schedule at the designated time point, which is designed to be within 0 to 5 minutes of the schedule. The BRT features that help to improve travel times could also help in enhancing schedule adherence by reducing the variability in wait times and in-vehicle travel times. Schedule adherence measures the logical occurrence of divergences from the schedule, for instance the probability of the buses consistently arriving late at the stop.

Service adherence is very pertinent from a customer point of view. Customers may want to use the schedule information to determine the time to arrive at a station in order to start a particular vehicle trip in order to arrive at their destination at the exact time. From the operator point of view, service adherence is used to ensure the efficient running of buses according to the schedule (Federal Transit Administration 2006a).

2.14.4 Service interruption

Service interruption is overseen by the Department of Transportation Services (DTS) to tackle any maintenance related problems like where there are needs for road repair, change of vehicle and return of buses to base. Unpredictable delays and likely increase in travel times affect service reliability (Federal Transit Administration 2006a).

2.14.5 Image and identity

Image and identity mean how the public views the service relative to other transit and transport options available. In this case, the public refers both to commuters and non-commuters. The main aim of BRTs is to introduce an identity and image that is different from the local bus services to ensure the maximum potential of attracting extra commuters (Federal Transit Administration 2006a).

2.15 Safety and security

Accidents are unexpected and unplanned events, often with lack of intention. An accident is usually a negative outcome, which may have been prevented, had the circumstances leading to the accident been recognized and acted upon earlier to its occurrence (Free encyclopaedia 2012:1). Safety and security of BRT systems are measures of the accident rate in a community.

2.16 System capacity

Each BRT bus in USA has a capacity of 160 passengers, transporting 1,596 passengers per day on the average, which is five times more than the average for the local buses (Federal Transit Administration 2006b). Dario Hidalgo (2002 cited in Federal Transit Administration 2006b: 18) suggested the daily km travel per bus has been growing from 216 to 370 (134 to 230 daily miles per bus), which was because of the extended hours of service, a higher number of express services and system expansion. EThekwini Transport Authority (ETA) estimated a maximum capacity of bus and bus way as 2500 and 6000 passengers per hour per direction (pphpd) respectively (Moodley et al 2011: 23). This could be achieved through optimized grade separated intersections and signal prioritization.

2.17 Customer satisfaction

The extent to which an organization is able to satisfy its customer is an indication of its general well-being and prospects for the future (Fornell 1992: 6).

In addition, customer satisfaction can be described as a broad hypothesis that includes perceived evaluation of product and service. Customer satisfaction is based on the maximum utilization of the customer's opinion and information. Failure to implement a customer satisfaction plan may lead to less customers and a slowdown of income for the business. All organizations have come to realize the importance of customer satisfaction. It is less costly and less stressful to keep existing customers than to look for new ones. Customer satisfaction is one of the criteria used to assess the success of many organizations in the public sector (Leem and Yoon 2004: 347-350).

2.18 Service quality

Yang (2001: 26) defines service quality as one of the determinants of a business's failure or success. Service quality is a result of the comparison between the customer's expectation about a service and the customer's perception of how the service is carried out. Fundamentally, service quality constituents are:

- ✓ Tangibles: the appearance of the personnel, equipment and physical facilities;
- ✓ Reliability: the ability to execute the delegated task accurately and dependably;
- ✓ Responsiveness: the willingness to assist customer with the needed and prompt service;
- ✓ Assurance: the knowledge and politeness of the employee coupled with the ability to motivate trust and confidence unto the customers; and
- ✓ Empathy: the individualized attention the company renders its customers (Budiono 2009: 8-9).

2.19 Intelligent Transport Systems (ITS) in public transport

The use of technology within the transport environment is referred to as Intelligent Transport Systems (ITS). ITS can be seen in all modes of transport and incorporates all the elements of the transportation system like the driver, commuters, vehicle and infrastructure interacting with dynamism. The main purpose of ITS is to enhance the operation of the entire transport system. However, ITS is a broad array electronic control and information systems that are engaged to enhance the operation of a transport network. Internationally, these systems are categorized into electronic fee collection, traffic management and operations, public transport management, incident management, transportation data management, disaster management and coordination, freight operations management and others for easy understanding of the extensive application environment (Department of Transport 2007b: 51).

ITS systems are pertinent in public transport for providing the management and control function with the support of IRPTN to ensure a well-organized communications network and operations centre. Public transport can further be made satisfactory through ITS systems by integrating fare collection as well as applying user subsidies, providing real time passenger information shows at stops and stations, giving priority to public transport vehicles to reduce journey times and improving reliability (Department of Transport 2007b: 51).

2.20 Element of ITS implementation in support of IRPTN

The typical elements of an ITS implementation based IRPTN developed through a regional concept of operation (Department of Transport 2007b: 52-53) are listed below.

2.20.1 Public transport operations centre

The management/operation centre forms the backbone of any efficient running of a system. This is the centre where the entire IRPTN system operates on a real time basis and the interfaces between the various elements are controlled through a system integrator contract. Software is used for scheduling, routing, tracking, management and dispatching in public transport operations.

2.20.2 Passenger information signs

Passengers' information shows at stops and key intermodal stations are pertinent elements of guaranteed acceptable user experience in the system.

2.20.3 Communications backbone

A widespread communications network is required to support the spread/ roll out of the system. It is worthwhile to establish a fibre core network that supports wireless systems. Provision should also be made for already established linkages between associated control and operational centres.

2.20.4 Electronic fare payment system

An incorporated electronic fare payment system should be put in place not to only ensure the passengers' satisfaction, but also to provide a platform of information needed to operate and plan these services. The elements needed are the smartcards, fare readers, associated software as well as the distribution network. Greater efficiencies and significant savings can be attained through a national rollout of such a system and through appropriate utilization of banking payment methods when costing the elements needed for an electronic fare payment system.

2.20.5 Traffic detector

Provision of traffic detectors and the associated infrastructure is necessary to ensure that the public transport priority can be implemented at intersections.

2.20.6 Surveillance

Sufficient coverage of the main public transport corridors ought to be provided to ascertain commuters' safety and enhance operational aspects through closed-circuit television (CCTV) with digital video recorders. Surveillance should be operated either from the operations room or from a contracted surveillance operator.

2.20.7 Vehicle tracking

The provision of automatic vehicle location units, cameras, and information signs on board of all vehicles for security reasons. This enables the smooth running of the system from the operation centre through the availability of the necessary information.

The operational and maintenance aspects should also be considered to ensure the effective implementation of the above elements. An operational plan should be developed and the human resource requirement known to ensure that the necessary skill is in place to operate the public transport centre. Maintenance is the key to longevity; a thorough maintenance plan must be put in place to ascertain the reliability of the system upon operation.

2.21 Branding

The ability to adopt branding in transport service is an important effort to encourage and maintain a reliable ridership. A perception survey was referenced in a 2004 report by the Federal Transportation Authority (FTA) which measured public perception of BRT systems. The outcome of the survey indicated that most booming BRT systems were able to accomplish a marked identity and position in their region amidst other transit services (Federal Transportation Authority 2006a; Hess and Bitterman 2008: 22).

2.22 Electronic fare payment

Electronic fare payment allows passengers to pay for public transport services electronically. This system integrates electronic communication, data processing, microcomputer technologies and data storage into the process of revenue collection, record keeping and funds transfer. The process is divided into two: the activities that are being perceived by the end users (commuters) and the hardware options for payment by the commuters. The most widely used methods of payment are smart cards, mobile phones and transponders. The other activities usually include the management of the payment media, transaction processing, account management, revenue management and settlement, reporting, auditing and customer service (Department of Transport 2007b: 55-58).

Electronic fare payment systems are electronic fare collection and information systems implemented as an integrated system to enable the collection of public transport data electronically. The principles underlying these systems in the South African context are as follows:

- ✓ The drive for implementation of these systems needs to be provided by government.
- ✓ Electronic fare collection and information systems are important elements to ensure integration in public transport, fare structures and subsidy policies.
- ✓ The government owns the data generated by the electronic fare collection system.
- ✓ Regional transport databases alongside national public transport data warehouses need to be established and levels of access should be based on the requirements and functions of the various stakeholders.
- ✓ Data structures should be based on international standards adapted to suit local application and implementation.
- ✓ An open system must be specified for the relevant elements of the electronic fare collection and information systems.
- ✓ The electronic fare collection and information systems in public transport is a division of ITS that will be planned and executed holistically to allow integration and associated efficiencies.
- ✓ Duplication of payment, banking infrastructure and its services will be averted where possible through the banking system and its infrastructure.
- ✓ The guiding authority of the Reserve Bank within the payment environment will be valued and its guidelines on electronic money will be properly adhered to.
- ✓ The interest of the end-user must be met in terms of a low value payment product in public transport.
- ✓ The end-user of public transport must be able to use the electronic payment instrument on any mode of transport anywhere in South Africa .

The concept of EFP (Electronic Fund Payment) proposed for national implementation supports a nationwide low value payment instrument such as a smart card, which is good for public transport payment and other non-transport services like telephone, and retailers for fast transactions. Smart cards will be made available from the user's bank, although bank accounts are not a prerequisite since prepaid cards can be obtained. The electronic money risk lies on the banks since they are managing the clearing house function. The circulation network of the banks will be used to make the payment instrument accessible (Department of Transport 2007b: 55-58).

A pertinent aspect of the implementation of EFP is the ability to automatically trigger information every time a transaction takes place, in other words, when a passenger uses a smart card on a public transport vehicle which is enabled to work with a point of sale device. This information is conveyed to a data warehouse which houses both the transport operator and transport authority information. This information is useful for transport operators and authorities for effectual management of their services. The importance of the information obtained is related to public transport management, subsidy management, real time information services and operational planning (Department of Transport 2007b: 55-58).

2.23 Other high-speed transit options

2.23.1 Light rail

Light rail is an electric rail based technology operating either as a single or as multiple cars making use of an exclusive right of way lane at the surface level, on aerial structures, in subways or on streets with overhand electrical connectors. It has the ability to board and alight passengers at station platforms or at street, track and car-floor level. Light rail comprises trams or streetcars and trolleys.

2.24 Impact of public transport on land development

Transport improvement can bring about a positive effect on the likelihood of land development. The areas near transport stations that have high access to rapid transport systems tend to experience a hike in development or new growth if the areas are undeveloped. A good quality transport system can enhance its accessibility to the surrounding area by reducing travel time. However, firms and households are apt to bid high for closeness to the station areas in a viable property market after pondering the profits and dangers of its appreciation. More so, it will be expected that property values will increase with their nearness to the station. Hence, transport improvement eventually leads to accelerated development of land use and property value uplift (Deng and Nelson 2010: 1197).

2.25 Conclusion

This chapter presented the literature review of the study and explores the existing knowledge on the research topic. The literature included information pertaining to BRT systems as a means of public transport to reduce delay; history of public transport in Africa; historical development of BRT systems; and, the necessary transport policy. Each of the subtopics addressed were within the scope of the study. The next chapter explains the methodology underpinning this study.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

“Research is a logical and systematic search for new and useful information on a particular topic. It is an investigation of finding solutions to scientific and social problems through objective and systematic analysis; it is a search for knowledge that is a discovery of hidden truths” (Rajasekar, Philominathan and Chinnathambi 2006: 1). The previous chapters put light on the literature backing the research objectives. This chapter focuses on the manner in which the study was executed, taking into consideration the philosophical study underpinning the study. It is organized into several sections with a framework to describe the research plan. The design adopted for the data collection takes into cognizance the literature review. The research centres on the evaluation of the most appropriate BRT system for EMA based on its urban layout and its transport demand. The approaches employed in this research were research design, data collection method and analysis. This chapter justifies the reason for using in-depth literature (qualitative analysis) and critical assessments in the study.

3.2 Research design

Welman and Kruger (1999: 46) looked at research design as the logical flow of activities undergone to obtain a research output from the collected information in order to draw conclusion relevant to the research problem.

“Research design is related to a situation, which gives a suggestion of the type of study that should be undertaken for an acceptable answer to the research problem.” (Cooper and Schindler 2001: 771). The research design details both the process and product focused on facilitating the construction of sound arguments, i.e. the techniques used to gather and analyse the data, the sampling type that was employed and the manner in which time constraints are dealt with. An argument is the logical structure that gathers the evidence and reasons why that evidence supports some points. A sound argument supports its claim in a way that is credible and useful to the greatest degree of feasibility given the resources available for gathering and analysing evidence in order to support the claims. “Research can be described as a means of using a transparent and systematic approach of conducting studies that answer questions and solve problems by means of claims that are supported well enough to be treated reasonably as knowledge rather than mere statement” (Justice 2008: 75).

Terre Blanche, Durrheim and Painter (2006: 57) state that research design gives the entire plan or structured framework that is meant to execute the research as well as indicate the research pattern, the purpose of the study, the method employed and the situation within the observation takes place.

A research review is a review that recaps relevant past research by attempting to deduce overall conclusions from the studies meant to address a certain topic of interest (Cooper 1989: 4). The basic reason behind a research review is to update the researcher with the latest information on the topic of interest in order to provide new insights that enhance knowledge. A research review can take different dimensions, but the most important one is the ability to observe contradictory studies, meanwhile identifying new ways to interpret research and project future research (Galvan 2006: 73). According to Fink (2005: 5), any work produced by researchers can be categorized into seven steps: selection of the research question; selection of article databases; choosing search terms;

application of practical screening criteria; application of methodological screening criteria, carrying out the review and synthesizing the results. Cooper (1989: 1) divides a research review into five categories, namely: problem formulation/research question; data collection; evaluation of data; analysis and interpretation, and; dissemination of research review results.

3.3 Reasons that justify the review of literature in this research study

"Scientific literature refers to theoretical and research publications in scientific journals, reference books, textbooks, government practice policy statements, and other materials about the theory, practice, and results of scientific inquiry. These materials and publications are produced by individuals or groups in universities, foundations, government research laboratories, and other nonprofit or for-profit organizations" (Garrard 2009: 4). A literature review is a written manuscript that represents a logically debated case founded on the basis of comprehensive understanding of the state-of-the-art knowledge on a topic, which is meant to provide a convincing answer to a research objective or question (Machi and McEvoy 2009: 4). A comprehensive review of literature study relating to the field of the desired research can be expedited in such a way that it shows the relationship between the investigation and the desired research. It helps the researcher to design the desired research due to the awareness of the background knowledge of the field being researched. Hence, it acknowledges past research works, prevents the duplication of research already conducted and validates the need to undertake a certain research topic (Lombard 1992: 41).

This study did not follow a specific analytical technique for the literature review, but all the literature involved, including qualitative, quantitative or mixed research entailed numerous sources of qualitative data (literature review of source articles, conceptual/theoretical frameworks, authors' interpretations and conclusions). Thus, this study is based on qualitative analysis. (Onwuegbuzie, Leech and Collins. 2012: 3).

3.4 Methodology

Research methodology is a logical way to solve an existing or perceived problem, most especially the procedures taken by researchers describing, explaining and predicting phenomena of their work. The various procedures, schemes and algorithms used by the researchers during a research are called research methods (Rajasekar, Philominathan and Chinnathambi 2006: 2). Different research methods such as case study and action research can be critical, or interpretive, or positivist; nevertheless, this distribution is very contentious (Walsham 1995: 76). Mingers, (2001: 241) says research is conducted by undertaking particular activities such as administering and analysing a survey, conducting controlled experiments, doing ethnography or participant observation, or developing root definitions and conceptual models. These basic activities are research methods.

Methodology is the study of procedures used in research to create new ideas (Terre Blanche et al 2006: 561). Cooper and Schindler (2006: 198) further propose that both qualitative and quantitative methods are commonly used to conduct research. Different procedures may be more or less appropriate for particular topics/situations, in the light of this; there should be a relationship between them. Theoretical foundations for research and specific research methods are justified by research aims or purposes. They should not be chosen because they conform to a dominant paradigm or because the researcher believes in their intrinsic value. Theory and method are justified on pragmatic grounds as appropriate tools for accomplishing research aims (Robey 1996: 406).

Danaee Fard et al (2007) cited in Toloie-Eshalaghy et al (2011: 106) state that the disparity between qualitative and quantitative research methods is a huge difference between the natural world phenomena and human, and this disparity is due to the ability of humans to speak. Besides, qualitative research methods are formed to assist researchers to understand human beings and their social and cultural ways.

Qualitative research methods typically serve one or more of the following purposes (Leedy and Ormrod 2005: 134):

- ✓ Evaluation: provides means through which researchers can judge the effectiveness of particular policies or innovations;
- ✓ Interpretation: enables researchers to gain new insights about a particular phenomenon and develops the new concepts or theoretical perspectives about the phenomenon. Alternatively, discovers the problems that exist within the phenomenon;
- ✓ Description: reveals the nature of certain situations, settings, processes, relationships, systems and people; and
- ✓ Verification: allows the researchers to test the validity of certain assumptions, claims, theories and generalization within the real world context.

The researcher questions the subjects and collects their responses by personal or impersonal means. The data collected can be via the following: interview or telephone conversations or self-administered instruments sent through e-mail, left in convenient locations or transmitted electronically or via other means or instruments presented before and after a treatment or stimulus condition in an experiment (Cooper and Schindler 2001: 135).

Quantitative research methods are regularly used to test a theory and focuses on describing, explaining and predicting data with the use of statistical and mathematical methods. However, it is most widely encountered as part of formal or conclusive research and the objective of this technique is to determine the relationship between an independent variable and a dependent or outcome variable in a population (Cooper and Schindler 2006: 198).

Quantitative analysis includes surveys and laboratory work and qualitative analysis uses interviews and organizational documents (Doolen et al. 2008: 637).

3.5 Data collection

Neuman (1997: 7) states that data is obtained using specific tools to either accept or reject theories. Data collection relevant to literature searches rely basically on the following categories as stipulated by Fink (2005: 17):

- ✓ Online public bibliography databases;
- ✓ Online private bibliography databases;
- ✓ Manual searches of references in articles; and
- ✓ Manual searches of references in expert guidance.

The researcher relied heavily on online computer searches in databases available through the university library, search engines on the internet, books, technical documents, government publications, reports and periodicals. Below is a list of the databases and some of the online search engines used:

- ✓ DUT library Summon Search portal;

- ✓ Google scholar;
- ✓ ScienceDirect;
- ✓ Sage Publications;
- ✓ Quick search;
- ✓ SpringerLink;
- ✓ EBSCOhost database;
- ✓ Web of Science; and
- ✓ JSTOR.

Information was gathered to provide in-depth knowledge of BRT systems relating to modes of the system, identify the current challenges being experienced by government and identify the problems related to the systems for the proper selection of the most appropriate BRT system in terms of vehicle design and lane configuration relative to cost implications, safety of the passengers, pedestrian crossings, physically challenged commuters and vehicle manoeuvre. The study depended on the availability of resources available to the researcher which was limited to English language publications. However, the researcher is of the opinion that the study covers a large volume of publications on BRT systems.

3.6 Checklist assessment

A checklist is a mnemonic device that consists of the list of factors, properties, aspects, components, criteria, tasks and dimensions taken to evaluate the performance of a system if there is any shortcoming or to perform a certain task. It incorporates specific knowledge of the item to be evaluated in a prudent way and eases the process of evaluation and contributes to the improvement of the validity, credibility and reliability of an evaluation (Scriven 2005: 1-3). Assessment is the judgment in terms of evaluation about something based on an understanding of the situation (PHS Consulting 2012: 8). Information checklists can be referred to as observations and so be classified as a qualitative research method (Onwuegbuzie, Leech and Collins 2012: 11). Physical assessment and critical review of BRT systems was conducted based on urban layout and transport demands in Johannesburg, Port Elizabeth and Cape Town, South Africa, using checklists (See Appendixes A-C). The main/trunk routes of each functional route were determined and assessed. The pros and cons of each BRT system were identified. Comparison of the three BRT functional systems was done. Solutions were attributed to each of them. An evaluation such as this contributes to the development of guidelines for the proposed BRT system in EMA. Each proposed route in EMA was assessed to be able to suggest suitable guidelines for the implementation of the BRT system.

3.7 Methodology regarding the EMA BRT system

The method employed in the critical review of the EMA BRT system is the collection of secondary data from the ETA. Each route of the EMA BRT system was examined based on the urban layout, traffic counts and features of the routes, then compared with the ETA Phase 1 decision. The remaining unimplemented routes were assessed based on the above features and a guideline was suggested.

3.8 Data analysis

If data analysis of any research study is not done, the data collected is of no use. “Data analysis is a dynamic and creative process. Throughout the analysis, researchers attempt to gain a deeper understanding of what they have studied and to continually refine their interpretations. Researchers also draw on their first-hand experience with settings, informants or documents to interpret data”

(Taylor and Bogdan 1998: 141). Research reviewers are not under any rule to use any standard interpretation or analysis, thus a high level of subjectivity is involved in the interpretation of research (Cooper 1989: 28). A descriptive literature reviewer uses his/her experience and information to evaluate the differences and similarities between the purpose, methods and findings of research (Fink 2005: 7) The research literature was compared according to the challenges being faced in the selection of an appropriate BRT system, and were viewed under the following themes:

- ✓ Vehicle design and lane configuration relative to cost implications;
- ✓ Safety of passengers;
- ✓ Pedestrian crossings;
- ✓ Physically challenged commuter;
- ✓ Transport vehicle options; and
- ✓ Vehicle manoeuvre.

The evaluation of the three functional BRT systems was compared and contrasted under each theme in the checklist and analysed. The lane configuration for each BRT system noted. Proper conclusions were made on this basis.

3.9 Validity and reliability

Validity is the extent to which a question of scale is measuring the concept, attribute or property it says it is. Validity has three important aspects, which are content validity, criterion validity and construct validity. Content validity can be narrowed down to whether or not the content of the manifest variables is right to measure the latent concept being measured. Criterion validity relates to the proposed theory and ability to be able to foresee certain outcomes. Proper knowledge of the theory relating to the concept is a way to establish criterion validity. Another way of establishing criterion validity is conducting statistical analysis measuring the correlation between the dependent variable and independent variables. Construct validity relates to the internal structure of an instrument and the concept it is measuring (Muijs 2004: 63-70).

Reliability is an element that determines the quality of measurement. External reliability refers to the degree to which a measure is consistent over time and internal reliability refers to the degree of internal consistency of a measure. Reliability is needed in research to measure the consistency of a measure.

3.10 Methodological screening criteria

Galvan (2006: 55-60) set up criteria for the methodological screening of a research review in order to ensure the quality of the study:

- ✓ Proof of a rigorous research design: the researcher considered whether the qualitative analysis method used is in sufficient details to clearly explain the type of research design.
- ✓ Validity and reliability of the research: the researcher took into consideration whether the research was conducted by a team or individual. If it is conducted by an individual, the report must state the research process explicitly. Team research tends to increase the validity of a research study.
- ✓ Description of tradition inquiry and research perspectives: the researcher considered whether the theory of knowledge of the research paradigm is defined and connected to the research. This is to help the researcher to be familiar with the tradition he/she is working in and the concepts and terms that are usually used in the tradition.

3.11 Conclusion

This chapter described the methodology and highlighted the various techniques that were employed in this study. Data were collected from the physical assessment and critical review of the functional BRT systems in South Africa and included a critical review of literature on BRT systems. The validity and reliability of the study and analysis of the data were given high precedence because they are crucial for the acceptance of the results and credibility of this study. The next phase of this study presents transport vehicle options that have been chosen by BRT systems across the globe.

CHAPTER 4

TRANSPORT VEHICLE OPTIONS

4.1 Introduction

BRT systems make use of a standard bus with double side doors for alighting and boarding in order to minimize delay. All over the world, buses are the most common type of public transport conveying 80% of passengers. Buses are cost effective and flexible, making it possible to tailor services to the unique characteristics and demands of a particular city. Modern buses can be designed to suit city needs including seat configuration, engine type and door configuration. It is not appropriate for one customized bus type to be adopted throughout the nation, or even all the corridors in a state. The decision should be made with respect to the transport demands of the corridor (ACT Government 2012: 4).

Light rail transit public transport is constructed to suit different kinds of environment, using functioning or non-functioning rail track rights of way, streets, pedestrian malls, highway medians and underground or overhead structures. Its design flexibility is a hallmark of this mode of transport. Light rail transit is “a metropolitan electric railway system characterized by its ability to operate single cars or short trains along exclusive right of way at ground level, on aerial structures, in subways or occasionally, in the street and to board and discharge passengers at the track or car floor level” (Transportation Research Board 2000: 3) (Figure 8).

Figure 8 An Aerial structure of a Baltimore LRT

4.2 Bus options

Buses employed in a BRT system could be standard, standard high capacity, double decker, articulated and bi-articulated or double decker articulated buses.

4.2.1 Standard bus

A standard bus is 12.5m in length with 2-3 doors for boarding and alighting, with a seating capacity of 35-70. A standard high capacity bus shares the same features with a standard bus except for the length, which is 14.5m allowing it to accommodate more passengers when compared to a standard bus. Due to its length, it is difficult to negotiate a very tight corner either to the left or right. A double decker standard, likewise, shares the features of a standard bus except for the number of doors, which is 1-3. This is not used in a place/corridor with height restrictions. It is used for longer distance because of its slow boarding/alighting times and increased number of passengers (ACT Government 2012: 5-6). See Figures 9-11.

Figure 9 Standard and stylised standard buses respectively
Source: ACT Government 2012: 5

Figure 10 Standard and stylised high capacity buses respectively
Source: ACT Government 2012: 5

Figure 11 Standard and stylised double decker standard buses respectively
Source: ACT Government 2012: 5

4.2.2 Articulated bus

An articulated bus is 18.5m in length with 2-5 doors and a seating capacity including the driver of more than 70. The bus consists of more than one rigid section which is permanently interconnected to each other with a jointed section which allows free movement of passenger from one part to the other. The articulated sections can only be disjointed in suitably equipped workshops. Bi-articulated or double decker articulated buses (length: 12.5m per articulated section, number of doors: 3-5, seating capacity including the driver: more than 70) is when there are two articulated sections in a bus (Delhi Transport Cooperation, n.d: 3-5). They tend to consume space because of the length, so are best used in corridor/stops with high passenger demands. Bi-articulated buses are used throughout all the corridors in Port Elizabeth and some parts of Cape Town. See Figures 12-13.

Figure 12 Standard and stylised articulated buses respectively
Source: ACT Government 2012: 5

Figure 13 Standard and stylised bi-articulated buses respectively
Source ACT Government 2012: 5

4.3 Conclusion

This chapter presented the transport vehicles that could be adopted for a BRT system for each corridor based on demand analysis, ranging from the capacity, door type, bus type and length. The next chapter unveils the evaluation of functional BRT systems in South Africa.

CHAPTER 5

EVALUATION OF BRT SYSTEMS IN SOUTH AFRICA

5.1 Introduction

In order to gain first-hand knowledge of BRT systems already operating in South Africa, site assessments and reviews were conducted on the BRT systems in, Johannesburg, Cape Town and Port Elizabeth.

5.2 White Paper on transport for sustainable development

A White Paper is a government guide or an authoritative report, in this case on the transport for sustainable development in South Africa. Lapses had been noticed in the efficient running of the public transport system, which prompted the production of a White Paper on transport for sustainable development. The paper takes into proper consideration the role and responsibility of the Department of Transport in establishing a plan for sustainable development. In order for the Department of Transport mission to be accomplished the White Paper recommends the following: consult all stakeholders; correct the imbalances of the past; promote safe and accessible transport; promote social and economic development; equal opportunities for all and integrated land use and transport. The mission is to "provide, facilitate, develop, regulate, and enhance safe, affordable and reliable multi-modal transport systems which are integrated with land use to ensure optimal mobility of people and goods in support of socio-economic growth and development in South Africa" (Department of Transport 2011: 6-8 and 25).

5.3 Johannesburg BRT system

5.3.1 Johannesburg BRT system operations

Rea Vaya is the name given to the BRT system in Johannesburg, which means "we are going." Each bus has a capacity of up to 90 passengers and travels on designated median lane trunk routes. Complementary buses are able to pick up passengers at Rea Vaya stations on the trunk routes and operates on the kerb side of the lane (Cameron 2010: 4). The South African cabinet adopted public transport in an integrated way in March 2007 (Department of Transport, 2007b: 3). With funding at hand to address the issues of infrastructure and vehicles, DoT embarked on the system to solve the severe traffic congestion and persistent mobility problems of the population, close to 1.5 million transport users in the city. The first corridor spans a 25km trunk line with median lanes, 27 trunk stations and feeder routes that link the CBD and Soweto, which is one of the busiest commuter corridors in the city (Venter 2012: 117). See Appendix F for the route map.

5.3.2 On-site assessment

The method employed by the researcher was an on-site assessment using a checklist system to assess the performance of the system and recognise the possible pros and cons of the system (Appendix A).

Rea Vaya BRT system makes use of a median BRT lane configuration that is located in the middle of the roadway in a two-way direction as an exclusive right-of-way with pavement/lane marking, intersection road marking and stud separators (10cm). The stud separators serve as a separator to the other traffic to avoid vehicle manoeuvres. The system has a distinctive branding/marked identity of vehicle and colour that differentiate it from other public transport. A low-emission vehicle technology standard bus with bi-fold doors at both sides and multiple entrances for boarding and alighting alongside a distinctive identity and image is used.

As the lane is located in the middle, stations are also constructed at the median of the roadway with maps, automatic doors on both sides of the station, elevator for disabled/ wheelchair accessibility, enhanced station environment, full weather protection on all the station platforms, security, telephones, configuration and design, consistent pattern of station location, CCTV and information desk. In some places, the median of the road is decorated with tree planting/grassing and footpaths to enhance the landscape. Stations have temporary streamlined shelters with comfortable seats for the passengers to wait for the next available bus coupled with the installed gadgets, CCTV, maps, specific paint scheme and logo, security and real-time information display. Real time information and CCTV are installed at the station as part of an ITS to improve passengers' convenience, speed, security, safety and system reliability. The system makes use of closed circuit television for monitoring the operations of the buses with the use of Automatic Vehicle Location (AVL) which is connected to the control room that makes use of updated schedules both inside the bus and in the station to inform passengers especially those who do not know the precise station to jump off. It makes use of both card and off board payment, but off board payment is more common due to a flat rate. Pre-board fare collection and verification are exercised for those that are not using a smart card. The pedestrian crossings are controlled by traffic lights at most of the locations. Existing transit signal infrastructure is adopted where it is deemed fit.

5.3.3 Advantages of Johannesburg BRT system

- ✓ It makes use of both smart card and on-board modes of payment which creates flexibility in terms of payment.
- ✓ It has full weather shelters for commuters and staff with security, telephones, CCTV, consistent configuration and design and consistent pattern of station location.
- ✓ The system is safe, clean, accessible, has good intermodal coordination and the ability to meet service demand.
- ✓ There are trained staff to assist the commuters in case of any required help/information.
- ✓ Real time information is displayed at each station and in the bus with the use of AVL.
- ✓ It makes use of standard busses with both sides door for boarding and alighting and distinctive image and identity.
- ✓ Most of the routes are constructed at the median exclusive ROW to ease delays.
- ✓ Automatic entrance and exit doors at each station.

5.3.4 Problems/challenges/disadvantages of Johannesburg BRT system

- ✓ The ability to attract more buy-in customers to use the system, especially the private car users is important.
- ✓ The development of a robust business and financial model for continual maintenance of the existing system is a challenge.
- ✓ Continuous training for the owners and operators with the skills required to maintain the success of the system is necessary.

5.4 Cape Town BRT system

5.4.1 Cape Town BRT system operations

Development has spread to the areas of Cape Town termed low-density areas, which results in movement of people in the pursuit of their daily chores over a long distance. However, a larger percentage of about 3 million residents of Cape Town rely solely on public transport as their means of movement. Considering the topography of Cape Town, there is no more space for the expansion of road or building new roads for private automobiles that might carry one person at a time because it is surrounded by two oceans and the Table Mountain at the centre. Congestion is increasing year by year (Cape Town Transport Integrated Rapid System, 2012).

Besides, studies reveal that building or expansion of road network does not ease congestion because people opt for automobiles instead of using public transport. Hence, there should be great investment in high class public transport in order to encourage private car users to use it and alleviate congestion. This was what prompted the BRT/IRT system in Cape Town named “MyCiTi” (Cape Town Transport Integrated Rapid System, 2012).

The first phase of the Integrated Rapid Transport (IRT) system stretched from the Civic Centre (CBD) to Table View as the trunk route coupled with a series of interim feeder services. Some of the routes are intersected while all the routes are connected to the Civic Centre station (Appendix G)

5.4.2 On-site assessment

The method employed by the researcher was an on-site assessment using a checklist system to assess the performance of the system and recognise the possible pros and cons of the system (Appendix B).

MyCiTi BRT system mainly makes use of a median BRT lane configuration, that is located in the middle of the roadway in a two-way direction as an exclusive right-of-way with pavement/lane marking, intersection road marking and few metres away from the main station (Civic Centre). In some places, its operation is in mixed traffic, at-grade, which does not need a lane markings or separators or a segregated lane. The lane marking serves as a separator to the other traffic to avoid vehicle manoeuvres. It has a fully coloured bus way a few metres away from the Civic Centre to Table View. It has a distinctive branding/marked identity of vehicle and colour that differentiates it from other public transport. Standard and articulated standard low emission vehicle technology buses with bi-fold doors at both sides and multiple entrances for boarding and alighting alongside a distinctive identity and image are used.

As the lane is located in the median, the stations are also constructed at the median of the roadway with maps, automatic doors on both sides of the station, elevator for disabled commuters, enhanced station environment, full weather protection on all the station platforms, security, CCTV, information desk and telephone booth (only at the main station). Consistent pattern of station location and in few places, the existing kerb side bus stop for other public transport systems is adopted. The lane configuration and design are almost the same throughout except in some places where there is mixed traffic (close to Table View and others), and a segregated lane along the Woodstock to Zoarvlei corridor. The median of the road is enhanced with a footpath. It has streamlined shelters with less comfortable seats and real-time information display for the passengers to wait for the next available bus, but it has the following implemented in the station: CCTV, maps, specific paint scheme, logo and security. The destination can be found in the bus, there is a display of the destination in front of the bus and help can be obtained from the staff. The BRT buses are scheduled to operate every 20 minutes from 5h10 to 21h20 during the weekdays and 6h10 to 20h00 over weekends.

They make use of the installed CCTV on the corridors to monitor the buses with regard to theft and performance. Audio announcements and maps inside the BRT buses are used to inform the commuter of both the present and the next bus stop, especially to those who do not know the exact station to alight. It makes use of only smart cards (Figure 14) which is at a flat rate and only the monetary value of the card can be paid back upon the return of the card; the money loaded is not refunded. Fare verification is done in the bus.

Figure 14 MyCiTi smart card
Source:http://www.capetown.gov.za/en/MyCiti/Documents/Media/myciti_west_coast_wrap_03-2012.pdf

5.4.3 Advantages of Cape Town BRT

- ✓ It has a distinctive branding/marked identity of vehicle and colour that differentiates it from other public transport.
- ✓ It makes use of a smart card which makes planning easier.
- ✓ It makes use of both standard and articulated standard low emission vehicle technology buses with bi-fold doors at both sides and multiple entrances for boarding and alighting alongside a distinctive identity and image.
- ✓ It has full weather protection at each station with security, CCTV, and information desk.

- ✓ There is a route map inside each bus showing the destination of each station.
- ✓ At times, public announcements are made to know at which station to alight because Automatic Vehicle Location (AVL) is not installed.
- ✓ Automatic entrance and exit doors at each station.

5.4.4 Problems/challenges/disadvantages of Cape Town BRT system

- ✓ The ability to build more buy-in customers to use the system especially the private car users is important.
- ✓ To develop a robust business and financial model for continual maintenance of the existing system is a challenge.
- ✓ Continuous skills training are required for the owners and operators to maintain the success of the system.
- ✓ There is no AVL which is connected to the control room that helps with updated schedules both inside the bus and station which is essential.
- ✓ Its operation in mixed flow traffic lane is a problem. No provision is made for commuter seating, bicycle and private car lots/parking at the stations.
- ✓ It has no seats for commuters awaiting a BRT bus at both the main and sub-stations.
- ✓ It has a phone booth at the main station only.

5.5 Port Elizabeth BRT system

5.5.1 Port Elizabeth BRT system operation

The Nelson Mandela Bay Municipality (NMBM) area has a population of about 1.1 million with a total area of 1950km^2. 289 000 households are located in the formal areas coupled with 35, 257 informal households and 49 009 backyard shacks also exist within the area. 112 306 out of 289 000 households are classified as indigent and 44% of all households depend on at least one social grant. Table 1 indicates that 66% of the residents receive no income and the remaining residents fall within the low to medium income brackets. This statistic also depicts that a large percentage of the NMBM residents depend solely on public transport (SSI Engineers and Environmental Consultants 2011).

Table 1 Individual monthly income by NMBM population

Income bracket (R)	Percentage of population (%)
No income	66.0
1 – 400	3.3
401 – 800	10.7
801 – 1600	6.1
1601 – 3200	5.7
3201 – 6400	4.7
6401 – 12 800	2.4
12 801 – 25 600	0.8
25 601 – 51 200	0.2
51 201 – 102 400	0.1
102 401 – 204 800	0.01
204 800 or more	0.02
Total	100.0

Libhongolethu is the name given to the BRT system in Port Elizabeth, which means “our pride”, that is, an integrated public transport system that is safe, convenient and reliable. This system brings Nelson Mandela Bay closer to becoming a world-class city and started with seven routes running through Port Elizabeth, Uitenhage and Despatch (Nelson Mandela Bay Tourism, 2012). Within Port Elizabeth city, only four corridors are operated as stated below. Port Elizabeth BRT system was reported a disaster. It was constructed for World Cup 2010 with the initial budget of R1 billion used to create extra lanes and 2 years later the initial lanes were destroyed because it was not properly planned. There were 20 buses lying idle because they did not fit into the original lanes created for them so an extra R30 million was used to make changes (Calls made for inquiry into PE's BRT system, 2012). Due to this, the BRT system in PE was put on hold until it commenced operation in February 2013.

The functioning routes within PE (IPTS zone 1, see appendix H) are listed as follows:

Route 300: PE CBD-Triangle

Start point: Lilian Diedricks building, Govan Mbeki Avenue.

Bus stops: Mostly median stops in dedicated lanes.

Direction of service: Triangle will be operated in both the clockwise and anti-clockwise direction.

Service: It is operated between 06h00-20h00 and 08h00-20h00 with 10 minutes interval in peak hour during the weekdays and weekend respectively.

Route 302: PE CBD-NMMU

Start point: Lilian Diedricks building, Govan Mbeki Avenue.

End point: NMMU (Nelson Mandela Metropolitan University) south campus.

Bus stops: existing kerb side stops.

Service: It is operated between 06h30 -20h00 and 07h00-20h00 with 10 minutes interval in peak hour during the weekdays and weekend respectively.

Route 303: PE CBD-AIRPORT

Start point: Lilian Diedricks building, Govan Mbeki Avenue.

End point: Port Elizabeth International Airport.

Bus stops: existing kerb side stops.

Service: It is operated between 05h30-20h00 and 08h00-20h00 with 20 minutes interval in peak hour during the weekdays and weekend respectively.

Route 304: PE CBD-Greenacres

Start point: Lilian Diedricks building, Govan Mbeki Avenue.

End point: Greenacres.

Bus stops: Median stops on IPTS lanes, existing kerb side stops on loop around Greenacres.

Direction of service: Greenacres loop will be operated anti-clockwise.

Service: It is operated between 06h30-20h00 and 08h00-20h00 during the weekdays and weekend respectively. There are three buses operating at 20 minutes interval during the weekdays.

5.5.2 On-site assessment

The method employed by the researcher was an on-site assessment using a checklist system to assess the performance of the system and recognise the possible pros and cons of the system (Appendix C). Libhongolethu BRT system makes use of a median BRT lane configuration, that is located in the middle of the roadway in a two-way direction as an exclusive right-of-way with pavement/lane marking, intersection road marking and stud separators (10cm). The stud separators serve as a separator to the other traffic to avoid vehicle manoeuvre. It has only four functioning corridors, two corridors (Central Business District – Triangle and Greenacres) operate in median dedicated lanes and the two other corridors (CBD – NMMU and Airport) operate in mixed flow traffic lanes. It has a distinctive branding/marked identity of vehicles and colour that differentiates it from other public transport. Low-emission vehicle technology articulated standard buses with bi-fold doors at both sides and multiple entrances for boarding and alighting alongside a distinctive identity and image are used throughout the corridors in Port Elizabeth.

As the lane is located in the middle, the stations are also constructed at the median of the roadway without a proper shelter – the commuters and staff stand under the sun. The station has a map, security, staff, routine schedule and ramp for disabled commuters. The existing kerb side stations for other public transport systems are adopted in mixed traffic. CCTVs installed on the streets are used to monitor the buses. It makes use of off board payment and fare verification on the bus, which is at a flat rate. The pedestrian crossings are controlled by traffic lights in most of the places. Adoption of existing transit signal infrastructure is in place where it is necessary. The system is safe, clean, accessible and able to meet service demand. Passengers within Zone 1 may be transferred between routes/corridors at no extra cost within 30 minutes of buying a ticket indicating that it is operating as an IPTS.

5.5.3 Advantages of Port Elizabeth BRT system

- ✓ It makes use of articulated standard buses which accommodate more commuters than the standard bus.
- ✓ It has a map and staff to attend to commuters, but these are only at the main station.
- ✓ There is security both at the main station and on the buses.

5.5.4 Problems/challenges/advantages of Port Elizabeth BRT system

- ✓ The ability to build more buy-in customers to use the system, especially the private car users is important.
- ✓ To develop a robust business and financial model for continual maintenance of the existing system is a challenge.
- ✓ Continuous skills training are required for the owners and operators to maintain the success of the system.

- ✓ The intermodal coordination/network is poor.
- ✓ There is no AVL which is connected to a control room that helps with updated schedules both inside the bus and station which is essential.
- ✓ Its operation in a mixed flow traffic lane is a major problem.
- ✓ No provision is made for commuter seating, bicycle and private car lots/parking at each station.
- ✓ Absence of streamlined shelters is noticeable. Collection of fare within the bus makes it more or less like other “standard” public transport.

5.6 Conclusion

This chapter presented the evaluation of the current BRT systems in South Africa. The major trunk routes were considered in the data collected through the use of a checklist assessment. The next chapter presents the proposed bus rapid system for the EMA.

CHAPTER 6

PROPOSED BUS RAPID SYSTEM FOR ETHEKWINI MUNICIPAL AREA

6.1 Introduction

There have been historical disproportions in the South Africa transport system as a result of apartheid city structures. The Public Transport Action Agenda has been set up to continually reform the current transport system to provide accessibility to all passengers. EThekwini's municipal population is about 3.5 million, with 1,679,040 males and 1,763,321 females (census 2011). It is located on the east coast of South Africa in the province of KwaZulu-Natal (KZN). The municipal area is around 2297km^2 and consists of diverse societies facing challenges related to social, environmental, economic and governance issues. The racial diversity consists of Africans (73.8%), Indians (16.7%), Whites (6.6%), Coloureds (2.5%) and other (0.4%). The majority of the population of EMA is in the 15-34 age group.

A Quality of Life survey, which indicates the level of satisfaction of the citizens in that area was established by the eThekwini Municipality over the past years, in order to deduce the areas requiring improvement. Figure 15 shows the satisfaction, neutral and dissatisfaction trends over the years (eThekwini Municipality 2012a: 8).

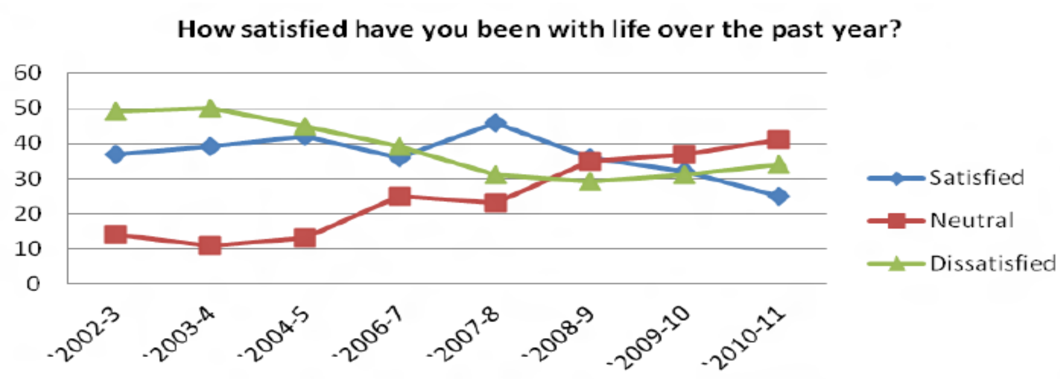

Figure 15 Life satisfaction in eThekwini 2002-2011
Source: EThekwini Municipality 2012a

The main target of the proposed BRT in EMA is the users (commuters, city and operators). The point is not only moving passengers in a comfortable way but to make the city more efficient by reducing the cost of travel, travel length and developing an integrated transport network that incorporates the various modes of transport and technologies available to improve accessibility in a cost effective way. The demand evaluation of eThekwini's IRPTN was conducted in two ways: developing of base year demand matrices and demand forecasting. However, demand is most important when considering restructuring of public transport systems (Moodley et al 2011: 499- 511).

The use of public transport is concentrated in low and middle income areas and most trip movements are served by both bus and minibus taxi and sometimes rail (GOBA 2012: 2).

In order for the ITP objectives to be achieved as stated below, public transport will need to enjoy precedence over private transport. It will also be of great importance to focus on public transport upgrades and budget in some areas at the expense of car users. In line to fulfil these objectives, ETA has developed an IRPTN plan for the whole EMA. The plan defines the desired final public transport for the municipality in the year 2025, allowing for a gradual implementation of the IRPTN. Objectives of the plan are as follows:

- ✓ Impartiality of access to opportunity: every resident of the municipality must enjoy quality access to diverse opportunities like live, work and play within the eThekwini regardless of their income level and disability.
- ✓ Reduction of public transport impact on the environment: there should be a net reduction in the emission of carbon into the environment.
- ✓ Positive impact on the city economy: besides from being operationally efficient, the economic opportunities of the system should also be able to contribute to the economic growth of the city.
- ✓ Spatial structure: IRPTN will solely be behind the major structuring of the eThekwini Municipality. It will help put right the gap created by historic apartheid type of planning practice in respect to integrated transport and land use planning.
- ✓ Acceptable quality of service to the car users: the aim is to make car users use public transport by providing an efficient quality of service after the needs of the public transport users have been catered for.
- ✓ Promotion of a livable city: apart from creating a solution for commuters to travel with no or little delay, the infrastructure of the IRPTN and its surrounding network are to be designed to accommodate non-motorized transport mode and attain urbanity.

  (eThekwini Municipality 2013: 141-143.)

6.2 Current Public Transport Record (CPTR)

The survey of the Current Public Transport Record (CPTR) was conducted in 2004, integrating all bus, rail routes and minibus routes in the EMA. At this time, there were 1730 taxis, 1629 buses and 20 basic rail lines as advised by their operators. The routes were unidirectional with different links distinguished as separate routes. A field survey was carried out at all residential origins and major work zones with significant transfer activity in the morning 3 hour peak period and 3 hour peak afternoon period. Boarding passengers were counted at the origin of all the active routes by vehicle departure time as shown in Table 2. The vehicle destination was known and taken as the destination of the passengers.

Table 2 CPTR 2004 public transport passengers (AM 05h00 – 08h00)

Mode	Passengers
Minibus taxi	161 100
Bus	132 300
Train	5600
Total	349 4000

6.3 BRT system concept in eThekwini Municipal Area

This system is made up of three routes: trunk, feeder and complementary. These are designed to cater for the demand of the existing and projected activity patterns in line with the municipality spatial development plan. The complementary routes are plied by minibus/bus and local services to link to the trunk routes. The system has a different type of infrastructure for bus trunk services ranging from transfer stations, park and ride facilities, communication technologies, and depot and control centres (eThekwini Municipality 2012a: 145).

6.4 IRPTN route structure and description

The main trunk routes of the BRT system within the eThekwini Municipality are shown in Figure 16: There are seven main trunk routes for the BRT system; three of them would be first considered. It is stratified into phases ranging from Phase 0 to Phase 4 in the order of implementation as shown in Table 3.

Regarding Phase 1, the preliminary design has been done, but the final design would take 6 months to 1 years before execution of the work can start. From the Bridge City Terminal Station, the ROW is shared with C3 and C9 through a tunnel up to a junction alongside the M25(W) off-ramp. C1, C3 and C9 are planned to run to median lane configuration except where C1 and C3 share a dedicated ROW from the junction (M25 W) running kerb side along the southern edge of the M25 up to Malandala road. C1 then continues along Malandela road within the centre of the road (eThekwini Municipality 2012b: 12). See Appendix E.

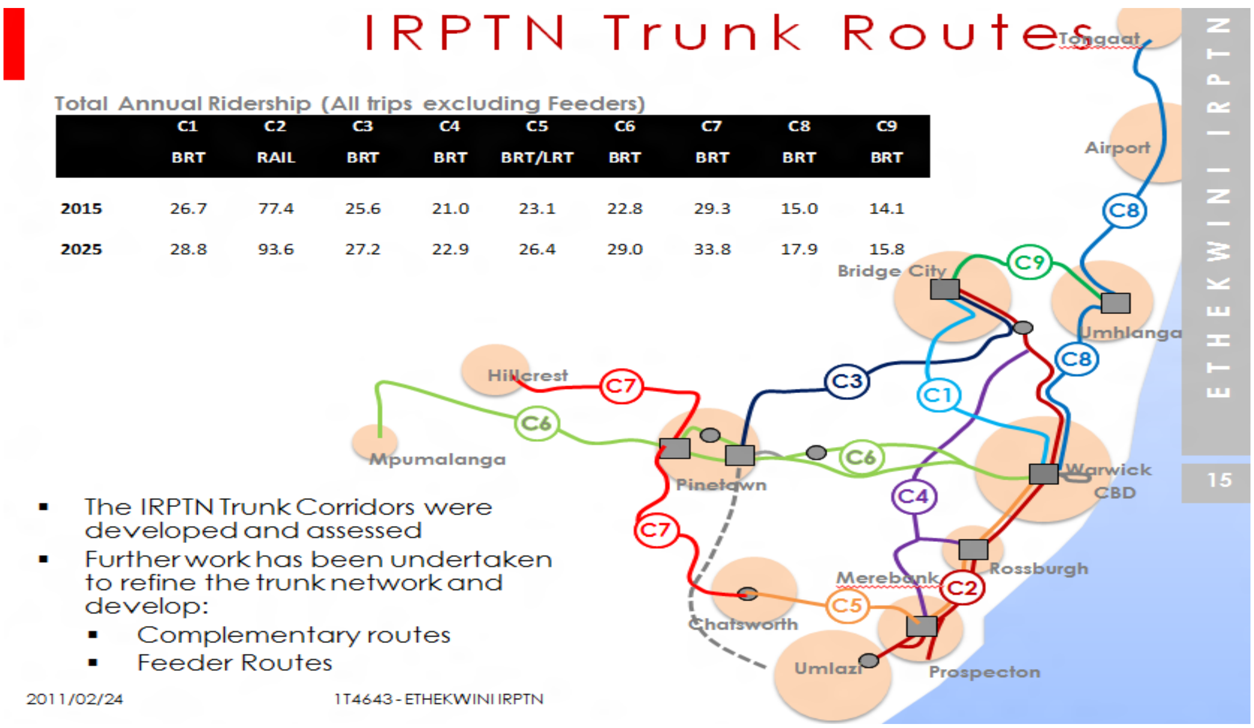

Figure 16 IRPTN trunk routes
Sources: EThekwini Municipality 2011: 15

Table 3 IRPTN phasing plan

Phasing	Corridor	Planned Start Year
Phasing 0	Restructuring of Durban transport	2012
Phase 1	C1, C3, C9	2015
Phase 1 + Rail	C1, C3, C9, C2	2016
Phase 2	C5, C7	2019
Phase 3	C4, C8	2022
Phase 4	C6	2024

Routes C1 to C9 are explained below (eThekwini Municipality 2012a: 131-133).

Route C1: Bridge City to CBD via KwaMashu

This route is a 25.3km BRT corridor that provides connections into the Central Business District to widen access to employment, which provides capacity between two major centres of employment and other activities.

Route C2: Bridge City and KwaMashu through Berea Road to Umlazi and Isipingo

This is an existing rail track that will be upgraded to 60km in length to provide a more reliable, intensive and higher capacity service, linking Umlazi and Isipingo. Many of the stations in place would be serviced by the IRPTN services, enabling integration of the service to other public transport and provide a wide range of job opportunities.

Route C3: Bridge City to Pinetown

This is a 27.5km BRT route that provides connection between two major centres in a route that is highly difficult to navigate at the moment. Interchange opportunities will be made available at Bridge City (C1, C2, C4 and C9) and Pinetown area (C6 and C7).

Route C4: Bridge City to Mobeni and Rossburgh

This is a 34km corridor that provides the opportunity to avoid the need for passenger transfer at Warwick interchange with the route splitting to give access to Rossburgh and Mobeni.

Route C5: Chatsworth to CBD

Route C5 is a 23km corridor that offers direct service from CBD and Warwick to Chatsworth. It will be a combination of BRT and light rail (LRT – Light Rapid Transit) services using former heavy rail alignments, platforms and on-street sections to access Chatsworth town.

Route C6: Hammarsdale and Pinetown to Warwick

This is a 64km corridor linking Pinetown to Warwick interchange and some services would be extended to Hammarsdale as an improved means of accessing Mpumalanga and its rural area with feeder services.

Route C7: Hillcrest to Chatsworth

This route (36km) links Hillcrest with Pinetown (connecting with C6 to Warwick) to Chatsworth. C7 was planned to be part of C5 but it was separated from the network because of the operating distance.

Route C8: Tongaat and Airport to Umhlanga and Warwick

There is a 41km rail service linking Tongaat but the BRT system would provide a service that links Tongaaat and King Shaka Airport to Umhlanga and Warwick. This route is expected to experience increased growth and development and also offer a strong transport service to airport workers and users.

Corridor C9: Bridge City to Umhlanga

This also forms part of the Phase 1 BRT system and links the growth areas of Umhlanga and Bridge City. This corridor is the shortest (13km) as shown in Figure 4.1.

6.5 Trunk corridor demand estimates

The demand for the trunk and feeder network was estimated based on the public transport trip matrices for the projection years 2015 and 2025 as shown in Table 4, supplied by the eThekwini Municipality. The demand was calculated for each corridor based on proportioning demand from matrix zones to trunk network stops. For trips which involve travel within more than one corridor, interchange stops were identified and boardings/alightings were allocated to those stops as appropriate (GOBA 2012: 72).

Table 4 Annual demand and passenger kilometres for trunk services 2015 (millions per annum)

Corridors	Demand (millions per annum)	Passenger (kms)	Average trip length (km)
C1 Bridge City to Warwick/CBD	31.13	301.13	9.7
C2 Bridge City/KwaMashu to Umlazi/Isipingo	103.46	1,218.89	11.8
C3 Bridge City to Pinetwon	20.56	170.65	8.3
C4 Bridge City to Merebank and Rossburgh	11.57	123.87	10.7
C5 Mpumalanga & Pinetown to Warwick	26.27	225.55	8.6
C6 Chatsworth to CBD	16.86	205.64	12.2
C7 Hillcrest & Umhlanga to Durban	25.96	196.50	7.6
C8 Tongaat & Umhlanga to Durban	11.76	106.62	9.1
C9 Bride City to Umhlanga	12.94	86.76	6.7
Total	260.50	2,635.60	10.1

6.6 Right of way

Buses operating on the trunk road network will operate for the most part on the highway. It is intended that the buses will be segregated from other traffic wherever possible by a variety of means, either by a linear separation from other traffic lanes or, on some routes, by placing the right of way off-highway. The high level standard for all trunk corridors is an unguided lane with a width of 3.5m. BRT lanes would also be ideally 3.5m wide, although it should be noted that this could be reduced to 3.0m where vehicle speeds are lower. However, for the options developed within a staggered arrangement this would also reduce the stop platform width and 3.5m has therefore been retained through the station area for such options.

Where a bus lane is mixed with other traffic lanes, 600mm wide separation zones have been assumed. This will accommodate a high kerb to discourage inadvertent entry and use of the busway for general road traffic. The kerb is curved on the busway side and pointed on the highway side. Gaps in the kerbing will need to be left in order to allow buses to ramp over the kerb in case of an emergency, whilst deterring general road traffic from entering the busway (eThekwini Municipality 2012a: 49-50).

6.7 Conclusion

This chapter presented the current situation of the proposed BRT in EMA. The next chapter presents the analysis and interpretation of the data emanating from the research design.

CHAPTER 7
DATA ANALYSIS AND DISCUSSION

7.0 Introduction

This chapter presents a discussion on the data collected from the in-depth review of the literature, the three functional BRT systems in South Africa and the proposed BRT system in EMA. The data are arranged in themes and discussion is based on the checklist and literature review.

7.1 Interpretations in line with the literature review

7.1.1 Cost implications

Cost is an important factor to be put in place during construction or execution of a project. As there are common features attributed to any BRT lane configuration, there are also some forms of structure in one configuration that cannot be implemented in the others. The capital cost is the cost of design, engineering, project management, construction of corridors, stations, purchasing of vehicles and installing of supporting system like security, ITS and fare collection with the exclusion of the maintenance cost and replacement of facilities cost. Kerb side and median lane configurations are less expensive when compared to a segregated BRT system because of the latter's aerial or underground busway. Kerb side BRT systems do not need pedestrian bridges while a median needs pedestrian bridges which are safer than grade pedestrian crossways.

7.1.2 Pedestrian crossings

Among the key components of BRT design and planning is pedestrian safety, convenience and secure access to the facility. If these are not put into proper consideration, commuters will be utterly discouraged using the system. Pedestrian crossings should be controlled by traffic lights which enables both the able and physically challenged passengers to be less at risk when going to the station.

In all the BRT lane configuration discussed in this study, there is also a provision for pedestrian to cross to where the station is situated. It is better to have a pedestrian bridge which is safer than a crosswalk. A crosswalk controlled by traffic light is preferable to one that is not controlled by a traffic light. It is good for a kerb side and median BRT configuration to have a pedestrian bridge for access compared to a crosswalk. For physically challenged commuters, kerb side and segregated BRT systems would provide better access to stations.

7.1.3 Vehicle manoeuvre

In terms of the three modes of BRT system in respect to the lane configurations discussed in this study, vehicle manoeuvre would pose a delay for a kerb side BRT system but the other lane configurations would not have this problem. If a kerb side configuration is adopted, a shoulder lane where automobiles can park and make U-turn to their destination, should be implemented which would improve the system.

7.1.4 Safety

Considering the three lane configurations discussed in this research study, it is safest and most cost effective to board and alight by kerb side.

7.1.5 Lane configuration of cited BRT systems in the literature

A total of 20 BRT systems were reviewed, the authors of the publications reviewed were well versed in the philosophical study of BRT systems. The literature review identified the history, feasibility studies, plans of execution, usefulness and features of BRT systems. Table 5 illustrates that any lane configuration could be adopted based on these factors: available funds, ROW (access to manoeuvre for other activities) and available road space as discussed in the literature.

Table 5 Lane configuration of the cited BRT system in the literature.

Lane configurations	**BRT systems**
Physically separated median lane	Quito BRT system, Columbia
Physically separated median lane	Ecuador BRT system, Columbia
Physically separated median lane	Bogota BRT system, Columbia
Grade-separated roadway and majorly using a railroad right of way.	Ottawa, Canada
24-hr kerb side lane between Mona Vale and Neutral Bay and operates at the median/centre of the lane.	North-South corridor, Sydney
Median	Istanbul BRT system
Median	Beijing southern BRT system, China
Median	Visakhapatnam BRT system, India
Median	Delhi BRT system, India
Both median and kerb side	Seoul BRT system, India
Kerb side	Houston BRT system, USA
Kerb bus lanes and bus subway (Segregated)	Boston BRT system, USA
Subway	Seattle BRT system, USA
Bus only street/segregated	Vancouver BRT, Canada

Kerb side	Lagos BRT system, Nigeria
Abandoned rail line used as the busway	Miami BRT system, USA
Busway	Montreal BRT system, USA
Busway	Pittsburgh BRT system, USA
Busway	Los Angeles BRT system
Median busways longitudinally segregated	Curitiba BRT system, Brazil

7.1.6 Vehicle transport options

To be able to select the appropriate vehicle option for a BRT system for a particular area/corridor, the transport demand, coverage/distance to be covered and length of public transport delay due to general traffic condition must be considered.

If the transport demand and coverage are low, a standard bus could be selected over other modes of bus option and in order to enhance rebranding and marketing strategies a stylised bus could be chosen over others provided the condition is the same as above.

However, if the length of public transport delay experience at a particular suggested corridor or area is low, a standard bus could be appropriate over modes of bus option and to enhance marketing and branding or rebranding, a stylised bus could be selected. Conclusively, the bus BRTs offer is cost effectiveness when compared to light rail transit.

7.2 Interpretations based on the checklist of the three operational BRT systems in South Africa

7.2.1 Running ways

BRT vehicles ply a fast and easily recognizable dedicated bus lane or traffic lane/exclusive rights-of-way. BRT running ways for Rea Vaya in Johannesburg operate highway medians with distinctive pavement markings and studs that serve as a separator to other traffic to avoid vehicle manoeuvres. In some areas of the feeder routes (outer suburbs) that join trunk route at the main station, Rea Vaya operates in mixed traffic. Libhongolethu, the Port Elizabeth BRT system, makes use of a dedicated median lane along Lilian Diedricks station to Triangle (NMB stadium) and Greenacres and the other corridors from Lilian Diedrick station to airport and Nelson Mandela Metropolitan University (NMMU) are operated in a mixed traffic. MyCiTi BRT system in Cape Town makes use of mixed traffic, segregated, at-grade median and median bus ways. In mixed traffic, it operates on the kerb side of the road and a segregated bus way exists from Civic Centre to Table View.

7.2.2 Branding

South African BRT systems are branded differently to distinguish them from other forms of public transport and as a form of public awareness and to please commuters aesthetically.

7.2.3 Stations

Libhongolethu BRT system has no covered station/shelter both for the commuter and staff, but do have security guards at the shelters and on board the buses and there are route maps at the entrance to stations. It makes use of the existing CCTV on the road while Rea Vaya and MyCiTi BRT system have beautified stations and the latter has full weather protection. All the system stations are situated at the median of the highway.

7.2.4 Intelligent Transportation Systems (ITS)

ITS can be referred to as a bus/intersection signal priority, with closed circuit television monitoring of operations that makes use of AVL with the aid of Global Position Systems (GPS). There is real time display of information and place update schedules both in the bus and station, which helps passengers who do not know the exact station to jump off. Rea Vaya BRT system makes use of advanced digital technologies that improve passengers' convenience, speed, safety and reliability, both at the station and in the bus by informing them of the name of each station in transit and also the time of arrival of the next bus at the station. MyCiTi makes use of a public announcement of the next station and a route map on the bus which the commuters can study. Libhongolethu is just a newly rolled out BRT system still in the marketing stage, with no information display either in the bus or in the station, but an informative flyer is given to commuters who can ask the staff questions.

7.2.5 Fare collection

In Rea Vaya, the fare is collected in a fast and easy way before passengers get on board of the bus, which is called off-vehicle fare payment, making use of both multiple entrance for boarding and alighting in order to reduce time. Some passengers make use of smart cards to pay for the fare which is at a flat rate. MyCiTi is strictly by smart card powered by ABSA bank, swiped at the entrance of the bus with money loaded on it beforehand and the fare is a flat rated. Libhongolethu operates an on board mode of payment.

7.2.6 Pedestrian crossings

Among the key component of BRT design and planning is pedestrian safety, including convenient and secure access to the facility. If these are not put into proper consideration, commuters will be utterly discouraged about the system. Pedestrian access of Rea Vaya and MyCiTi are controlled by traffic lights which enable passengers to be less at risk when going to the station to board. Libongolethu, some places are not controlled by a traffic light.

7.2.7 Transport vehicle option

The Rea Vaya system makes use of a standard bus with double side door for alighting and boarding in order to minimize delay as do MyCiTi and Libhongolethu. MyCiTi has a combination of both articulated and standard buses, but the Libhongolethu system makes use of articulated buses throughout.

7.3 Interpretations based on the assessment of the EMA BRT system

It could be deduced that there is pressure on public transport based on the population analysis conducted by CPTR and the demand analyses projection which is discussed in Chapter 6.
The population count shows that the proposed routes will experience passenger demand as listed below in descending order. Note that C2 and C8 are not included below because they are rail tracks:

i. C1 Bridge City to Warwick/CBD;
ii. C5 Mpumalanga & Pinetown to Warwick;
iii. C7 Hillcrest & Umhlanga to Durban;
iv. C3 Bridge City to Pinetown;
v. C6 Mpumalanga & Pinetown to Warwick;
vi. C9 Bride City to Umhlanga; and
vii. C4 Bridge City to Merebank and Rossburgh.

Access to facilities like offices, residents, schools and malls are another factor that is assessed along the routes so as not to create obstruction to other road users because the primary aim of this BRT system is to reduce the travel times experienced by the commuters. Route C1 comprises offices, malls, residences and schools. Route C5 is mainly businesses with companies, schools, malls and residential building. Routes C7, C3, C6 and C4 are roads where commuters travel every day for businesses, schools, shopping, recreational activities and residential houses. Merebank and Rossburgh are suburbs of Durban, commuters living along these places would have the ease of travel to their various destinations. The terrain along routes C1, C3, C4, C5, C6 and C7 is mainly flat although curvy.

7.4 Conclusion

This chapter presented the discussion of the data collected through checklists and in-depth literature review. The last phase of this research presents the conclusions and recommendation of the study.

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

8.1 Introduction

This chapter presents the conclusion and recommendation of the previous chapters regarding the determination of the most appropriate BRT system across EMA.

8.2 Conclusions and recommendations arising from the literature review of international BRT systems

This section gives the conclusions arising from the in-depth literature findings and also satisfies the first objective of this research study.

Kerb side and median lane configurations are less expensive when compared to segregated BRT systems which are more expensive because of their aerial or underground busways. Kerb side BRT systems do not need pedestrian bridges while median systems need pedestrian bridges which are safer than grade pedestrian crossways.

It is better to have a pedestrian bridge which is safer than a crosswalk and a crosswalk controlled by traffic light is preferable to the one that is not controlled by a traffic light. It is good for a kerb side and median BRT configuration to have a pedestrian bridge for access compared to a crosswalk. Also for physically challenged commuters, kerb side and segregated BRT systems would be good for them because of ease of access to stations.

Commuters using a kerb side station/ kerb BRT system tend to be safer when compared to median stations because they do not need to cross traffic to access the service, but segregated BRT lane configuration is safer than both the median and kerb side lane configurations.

Vehicle manoeuvre poses a delay for kerb side BRT systems, but this is not a problem for other lane configurations. kerb side

Conclusively, bus BRT systems offer cost effectiveness when compared to light rail transit.

This research study recommends the following:

- ✓ To be able to select the appropriate vehicle option for a BRT system for a particular area/corridor, the transport demand, coverage/distance to be covered and length of public transport delay due to general traffic conditions must be put into proper consideration.
- ✓ If the transport demand and coverage are low, a standard bus could be selected over other modes of bus option and in order to enhance rebranding and marketing strategies a stylised bus could be picked over others provided the condition is the same as above.
- ✓ If the length of public transport delay/waiting time experienced at a particular corridor or area is low, a standard bus could be appropriate over the modes of bus option and to enhance marketing and branding or rebranding, a stylised bus could best be selected.
- ✓ Any form of BRT system should be considered or implemented because it offers increased levels of mobility, fewer stops and greater accessibility than traditional public transportation. They can also serve as an attractive means to get drivers or car owner to use the system.

- ✓ The introduction of dedicated bus lanes increase reliability and transit speed and have a positive effect on commuters. The level of service of a segregated BRT system is much higher than that of kerb side and median BRT systems. The level of service of a kerb side system can be improved by the provision of a shoulder lane where vehicles can hover or park to execute their task.
- ✓ BRT systems should not be operated in mixed traffic because this results in delays. Only when there is no space for expansion should a BRT system be operated in a mixed traffic since implementation of any mode of BRT system depends on the availability of space.
- ✓ For able and physically challenged pedestrians, a segregated BRT system is preferable. However, cost is a major deciding factor.
- ✓ Segregated and median BRT systems should be considered over kerb side to facilitate vehicle manoeuvre.

8.3 Conclusions and recommendations arising from inspection of the South African BRT systems

This section gives the conclusions and recommendation of the evaluation of the three main functional BRT systems in South Africa and also satisfies the second objective of this research study.

8.3.1 Rea Vaya BRT system, Johannesburg

Using this mode of BRT system poses improvement in travel time, is reliable, safe and fast when compared to other public transport systems because there are no automobiles travelling in mixed flow traffic lanes because they operate on a dedicated bus lane. A separate lane enables the system to have lower headways and accommodate higher peak period loads. When further combined with signal priority, delay is greatly minimized at intersections.

Conclusively, it is commuter/user friendly and cost effective over a long distance when compared to other public transport systems because it operates at a flat rate. In the system, pedestrian safety, convenience and secure access to the facility for physically challenged and able commuters are fully guaranteed, which is encouraging for commuters. The installed ITS helps passengers to know the exact time and place to jump off, especially those who do not know the place of their destinations.

The research study recommends that high maintenance should be the watchword and if there is the need for BRT system diversification in Johannesburg, other lanes should be implemented using other forms of BRT systems. Adopting bicycle and car parking at the main station would enable a complete comparison in terms of service reliability and delay. If there is population intensification, articulated standard buses should be adopted. The use of smart card should be solely adhered to, which will help the commuters to load more than a day fare on it depending on their financial capacity. Another mode of BRT system, especially segregated mode should be employed in case of future BRT intensification. The high cost of such a system can be justified by the high grade of efficiency, reliability and speed.

8.3.2 Myciti BRT system, Cape Town

Use of a dedicated bus lane should be encouraged throughout the routes due to the resulting improvement in travel time, reliability, safety and reduced travel time when compared to other road public transport modes. A separate lane enables the system to have low headways and accommodate higher peak period loads. When further combined with signal priority, delay is greatly minimized at intersections. Use of AVL helps the passengers to know when the bus is due to arrive at the station and the exact place to jump off, especially beneficial for those who do not know the exact location of their destinations. AVL is preferable to audio announcements in the bus. No phone booth and information display system either in the bus or station make it below standard when compared to the expected standard of a BRT station. It was noticeable that segregated lanes were more efficient than median, at-grade median, or mixed traffic lanes.

Conclusively, it is commuter/user friendly and cost effective over a long distance when compared to other road public transport because it operates at a flat rate. In the system, pedestrian safety, convenience and secure access to the facility for the physically challenged and able commuters are fully guaranteed, which is encouraging for commuters.

It is recommended that high maintenance should be the watchword and if there is a need for BRT system diversification in Cape Town, other lanes should be implemented using other forms of BRT systems. Adopting bicycle and car parking lots at the main station would enable a complete comparison in terms of service reliability and delay. Mixed flow traffic lanes should be totally discouraged. Other modes of BRT system, especially segregated modes should be employed in case of future BRT intensification. Phone booths, comfortable seating, bicycle space and Intelligent Transport Systems should be fully installed at the stations.

8.3.3 Libhongolethu BRT system, Port Elizabeth

Use of a dedicated bus lane should be encouraged throughout the routes because there is great improvement in travel time, reliability, safety and reduced travel time with a dedicated BRT system when compared to other road public transport travelling in mixed flow traffic lanes. It makes use of articulated standard buses to accommodate more passengers. The system is far below standard because it has no AVL, information kiosks, phone booths or fully weatherproof shelters.

Conclusively, it is commuter/user friendly and cost effective over a long distance when compared to other public transport because it operates at a flat rate and also commuters can be transferred within 30 minutes of purchasing the ticket within the IPTS Zone 1. In the system, pedestrian safety, convenience and secure access to the facility for physically challenged and able commuters are fully guaranteed, which is encouraging for commuters.

It is highly recommended that proper maintenance should be the watchword and if there is a need for BRT system diversification in Port Elizabeth other lanes should be implemented using other forms of BRT system. Full weather protection streamlined stations should be implemented, adopting bicycle and car parking lots, phone booths, CCTV, AVL, comfortable seating and information maps at each station. Mixed flow traffic lanes should be totally discouraged. Other modes of BRT system, especially segregated mode should be employed in case of future BRT intensification. If there is population intensification, bi-articulated standard buses should be adopted. The use of smart card should be solely adhered to, which will help the commuters to load more than a day fare, depending on their financial capacity.

8.4 Conclusions based on the assessment of the EMA BRT system

This section satisfies the third objectives of this research study that document guidelines that could help the EMA in the selection of an appropriate BRT system.

8.4.1 Decisions made on Phase 1 BRT system for eThekwini Municipal Area

Table 6 shows the decisions taken on Phase 1 of the EMA BRT system, although it has not been executed. Standard buses have been chosen for all the Phase 1 routes, a decision with which this research study concurs. Based on the passenger population route C1 would experience the highest demand. This study suggests articulated buses for C1 and standard high capacity buses for C3 and C9. This suggestion is as a result of commuter demand analyses of the routes coupled with the literature underpinning this research.

The lane configurations and widths were decided bearing in mind access to property such as offices, residences, shopping malls, etc. This research study concurs with the lane configurations and widths stated in Table 6 considering the researcher’s route inspections and factors considered in the selection of BRT systems for Johannesburg, Cape Town and Port Elizabeth.

Funds will be released by the government for consequent phases only if Phase 1 has been implemented and is successful. The system would be executed one phase after the other.

Table 6 Decisions on Phase 1 BRT routes for EMA

Routes	C1: Bridge City to CBD via KwaMashu	C3: Bridge City to Pinetown	C9: Bridge City to Umhlanga
Route length (km)	25.3	27.5	13
Lane configuration	Median Kerb side (where C1 and C3 share a dedicated ROW from the junction (M25 W) running kerb side along the southern edge of the M25 up to Malandala road)	Median (where C1 and C3 share a dedicated ROW from the junction (M25 W) running kerb side along the southern edge of the M25 up to Malandala road)	Median
BRT Lane Width	Single BRT lane width: 3.5m At stations: where passing lanes are provided, the lane alongside the station shall be reduced to 3.0m and 3.5m width has been maintained for the passing lane	Single BRT lane width: 3.5m At stations: where passing lanes are provided, the lane alongside the station shall be reduced to 3.0m and 3.5m width has been maintained for the passing lane	Single BRT lane width: 3.5m At stations: where passing lanes are provided, the lane alongside the station shall be reduced to 3.0m and 3.5m width has been maintained for the passing lane
Vehicle transport option	Standard bus (35-70 capacity, 14.5m length, 2-3 doors for boarding and alighting on both sides)	Standard bus (35-70 capacity, 14.5m length, 2-3 doors for boarding and alighting on both sides)	Standard bus (35-70 capacity, 14.5m length, 2-3 doors for boarding and alighting on both sides)
Demand analysis 2015 (Millions per annum)	31.3	20.56	12.96

Table 7 Guidelines for the remaining proposed BRT routes for EMA

Routes	C4: Bridge City to Mobeni and Rossburgh	C6: Hammarsdale and Pinetown to Warwick	C7: Hillcrest to Chatsworth	C8: Tongaat and Airport to Umhlanga and Warwick
Route length (km)	34	64	36	41
Lane configuration	Fully coloured median lane configuration with median aesthetic bus station.	Fully coloured median lane configuration with median aesthetic bus station.	Fully coloured median lane configuration with median aesthetic bus station.	Segregated lane configuration * Road width extension *Or* Fully kerb side lane configuration and aesthetic kerb station * Provision of shoulder lane
BRT Lane Width	Single BRT lane width: 3.5m At stations: where passing lanes are provided, the lane alongside the station shall be reduced to 3.0m and 3.5m width has been maintained for the passing lane	Single BRT lane width: 3.5m At stations: where passing lanes are provided, the lane alongside the station shall be reduced to 3.0m and 3.5m width has been maintained for the passing lane	Single BRT lane width: 3.5m At stations: where passing lanes are provided, the lane alongside the station shall be reduced to 3.0m and 3.5m width has been maintained for the passing lane	Single BRT lane width: 3.5m At stations: where passing lanes are provided, the lane alongside the station shall be reduced to 3.0m and 3.5m width has been maintained for the passing lane
Vehicle transport option	* Low emission technology vehicle * Standard bus (35-70 capacity, 14.5m	*Low emission vehicle technology * Standard bus (35-70 capacity, 12.5m length, 2-3	*Low emission vehicle technology *low-floor Standard bus (35-70 capacity, 12.5m	* Low emission vehicle technology *Stylish articulated standard bus (≥ 70

	length, 2-3 doors for boarding and alighting on both sides) * Door ramp for the physically challenged commuters * Air conditioner with heater * Emergency exit *Separate comfortable seat with different colour for the aged commuters * Separate comfortable seat with designated colour for the physically challenged commuters	doors for boarding and alighting on both sides) * Door ramp for the physically challenged commuters * Air conditioner with heater * Emergency exit *Separate comfortable seat with different colour for the aged commuters * Separate comfortable seat with a different colour for the physically challenged commuters	length, 2-3 doors for boarding and alighting on both sides) * Door ramp for the physically challenged commuters * Air conditioner with heater * Emergency exit *Separate comfortable seat with different colour for the aged commuters * Separate comfortable seat with designated colour for the physically challenged commuters	capacity, 18.5m length, 2-5 doors for boarding and alighting on both sides) * Door ramp for the physically challenged commuters * Air conditioner with heater * Emergency exit *Separate comfortable seat with different colour for the aged commuters * Separate comfortable seat with designated colour for the physically challenged commuters
Demand analysis 2015 (Millions per annum)	11.5	16.86	25.96	11.76

8.4.2 Guidelines for the remaining proposed BRT routes for eTthekwini Municipal Area

Table 7 shows the remaining proposed BRT routes in EMA yet to be implemented. These decisions are based on access to residential and other activities on the remaining routes, lane widths, urban layouts (as discussed in Section 7.3), evaluations of the three functional BRT systems in South Africa, demand analyses of the routes, factors necessary to be considered when implementing the system and in-depth literature within the scope of the study.

This research study concludes that the documented guidelines, conclusions and recommendations of in-depth literature and the assessment of the three functional BRT systems in South Africa are a good yardstick/blueprint for the implementation of the proposed BRT system in the EMA.

Proper investigations should be carried out after the successful execution of Phase 1 (C1, C3, C3) before implementing the remaining phases.

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APPENDICES

Appendix A: Checklist for the assessment of the Rea Vaya Bus Rapid Transit system

Present	
Lane configuration	
Basic separator cones	
Pavement marking	√
10 cm separator blocks/studs	√
50 cm separator blocks/studs	
Kerb side lane configuration	
Segregated lane configuration	
Median lane configuration	√
Bus colouration/ road markings	
Intersection road marking	√
Lane marking	√
Bus way with fully coloured way	
Distinctive BRT identity and image	√
Distinctive marketing identity for the system	√
Landscaping	
Cycle paths/footpaths	√
Tree planting and grassing	√(but minimal)
Additional park or civic improvement	
Integration with other modes at stations/terminals	
Bicycle parking at stations/terminals	
Formal taxi stands at stations/terminals	
Car parking at stations/terminals	
Intelligent Transportation System (ITS)	
Real-time information display	√
Connection to the control station/room	√
Audio announcements on BRT buses	
Incorporate schedule data into station electronic information systems	√
Place updated schedules and maps at stops	√
Adapting existing transit signal infrastructure	√
Maps and information	
Maps at station	√
Information kiosk	√
Station amenities	

Air conditioning	
Elevator for disabled	√
Automatic doors	√
CCTV/security	√
Enhanced station environment	√
Wheelchair accessible station	√
Full weather protection on all station platforms	√
Telephones	√
Security provision	√
Consistent pattern of station location, configuration, and design	√
Separate BRT, local buses, automobiles, and pedestrian movements in station design.	
Fare collection system	
Smart card	√
On-board fare collection	
Pre-board fare collection and fare verification	√
Flat fare type	√
Zonal fare type	
Distance based type	
Other	
Convenient pedestrian and bicycle access to transit facilities	
Are the bus stops accessible to persons with disabilities?	√
Is there a wheelchair ramp to access the street at crosswalks or mid-blocks?	√
Are these stops accessible by sidewalk or pedestrian paths?	√
Has space been provided for bus stop shelters and/or benches?	√
Is there sufficient lighting?	√
Bus type	
Low –emission vehicle technology	√
One side doorway	
Both sides doorway	√
Standard bus type	√
Articulated bus type	
Bi-articulated bus type	
Double-decker bus type	
Boarding/alighting	
Multiple-door boarding/ alighting	√
Single-door boarding/alighting	
Door with ramp	√
Door type	
Swing door	
Bi-fold door	√

Plug	
Pivot door	
Sliding door	
Others	
Safety	√
Cleanliness	√
Accessibility	√
Reliability	√
Intermodal coordination	√
Urban traffic congestion	Not a problem
Ability to meet service demand	√
Pedestrian crossing controlled by traffic light	√
Excessive bus-to-platform gaps at BRT stations (not a problem)	Not a problem

<u>Appendix B</u>: Checklist for the assessment of Cape Town Bus Rapid Transit system

	Present
Lane configuration	
Basic separator cones	
Pavement marking	√
10 cm separator blocks/studs	
50 cm separator blocks/studs	
Kerb side lane configuration	
Segregated lane configuration	
Median lane configuration	√
Bus colouration/ road markings	
Intersection road marking	√
Lane marking	√
Bus way with fully coloured way	√
Distinctive BRT identity and image	√
Distinctive marketing identity for the system	√
Landscaping	
Cycle paths/footpaths	√
Tree planting and grassing- it is minute	√
Additional park or civic improvement	
Integration with other modes at stations/terminals	
Bicycle parking at stations/terminals	
Formal taxi stands at stations/terminals	
Car parking at stations/terminals	
Intelligent Transportation System (ITS)	
Real-time information display	
Connection to the control station/room	
Audio announcements on BRT buses	√
Incorporate schedule data into station electronic information systems	√
Place updated schedules and [maps at stops] inside the buses	√
Adapting existing transit signal infrastructure	√
Maps and information	
Maps at station	√
Information kiosk	√
Station amenities	
Air conditioning	
Elevator for disabled	√
Automatic doors	√
CCTV/security	√
Enhanced station environment	√

Wheelchair accessible station	√
Full weather protection on all station platforms	√
Telephones	√
Security provision	√
Consistent pattern of station location, configuration, and design	√
Separate BRT, local buses, automobiles, and pedestrian movements in station design.	
Fare collection system	
Smart card	√
On-board fare collection	
Pre-board fare collection	
Fare verification	√
Flat fare type	√
Zonal fare type	
Distance based type	
Other	
Convenient pedestrian and bicycle access to transit facilities	
Are the bus stops accessible to persons with disabilities?	√
Is there a wheelchair ramp to access the street at crosswalks or mid-blocks?	√
Are these stops accessible by sidewalk or pedestrian paths?	√
Has space been provided for bus stop shelters and/or benches?	√
Is there sufficient lighting?	√
Bus type	
Low –emission vehicle technology	√
One side doorway	
Both sides doorway	√
Standard bus type	√
Articulated bus type	√
Bi-articulated bus type	
Double-decker bus type	
Boarding/alighting	
Multiple-door boarding/ alighting	√
Single-door boarding/alighting	
Door with ramp	√
Door type	
Swing door	
Bi-fold door	√
Plug	
Pivot door	
Sliding door	
Others	

Safety	
Cleanliness	
Accessibility	
Reliability	
Lack of intermodal coordination	
Urban traffic congestion	
Inability to meet service demand	
Pedestrian crossing controlled by traffic light	
Excessive bus-to-platform gaps at BRT stations	

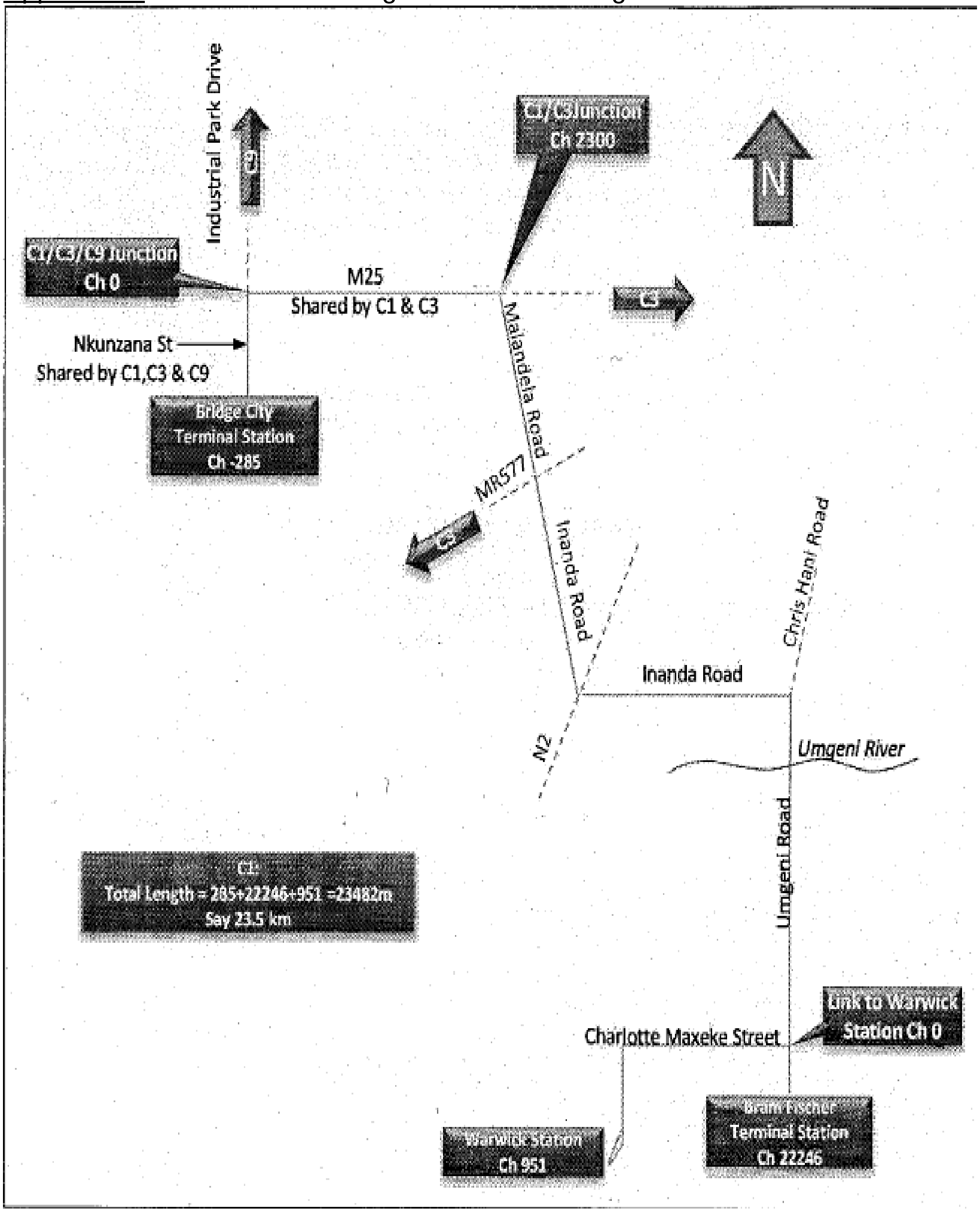
Appendix C: Checklist for the assessment of Port Elizabeth Bus Rapid Transit system

Present	
Lane configuration	
Basic separator cones	
Pavement marking	√
10 cm separator blocks/studs	√
50 cm separator blocks/studs	
Kerb side lane configuration	
Segregated lane configuration	
Median lane configuration	√
Bus colouration/ road markings	
Intersection road marking	√
Lane marking	√
Bus way with fully coloured way	
Distinctive BRT identity and image	√
Distinctive marketing identity for the system	√
Landscaping	
Cycle paths/footpaths	
Tree planting and grassing-	
Additional park or civic improvement	
Integration with other modes at stations/terminals	
Bicycle parking at stations/terminals	
Formal taxi stands at stations/terminals	
Car parking at stations/terminals	
Intelligent Transportation System (ITS)	
Real-time information display	
Connection to the control station/room	
Audio announcements on BRT buses	
Incorporate schedule data into station electronic information systems	
Place updated schedules and maps at stops	
Adapting existing transit signal infrastructure	
Maps and information	
Maps at station	√
Information kiosk/ staff standing without shelter	√
Station amenities	
Air conditioning	
Elevator for disabled/ramp	√
Automatic doors	
CCTV/security	√
Enhanced station environment	√

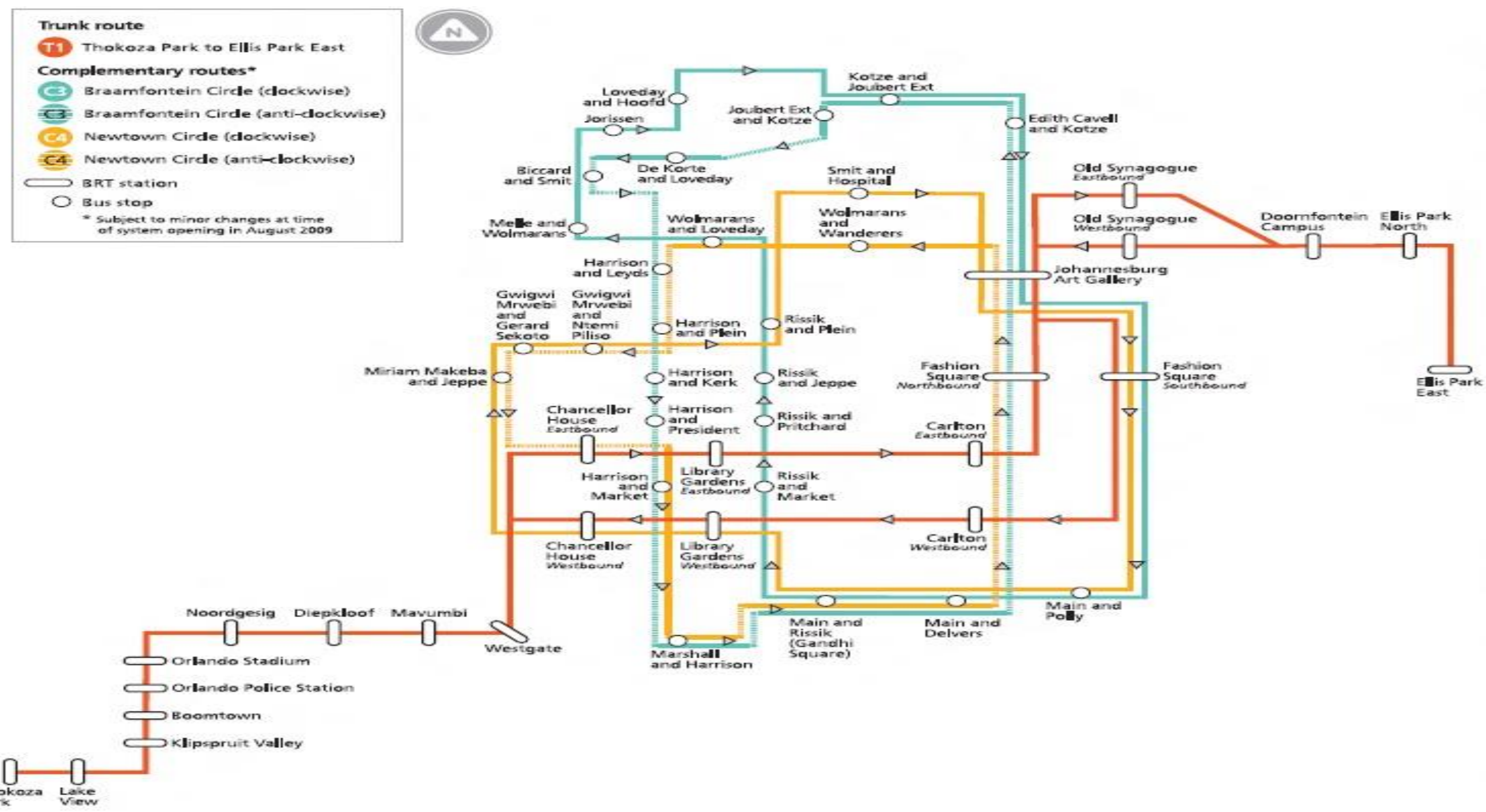
Wheelchair accessible station	√
Full weather protection on all station platforms	
Telephones	√
Security provision	
Consistent pattern of station location, configuration, and design	√
Separate BRT, local buses, automobiles, and pedestrian movements in station design.	
Fare collection system	
Smart card	√
On-board fare collection	
Pre-board fare collection	√
Fare verification	√
Flat fare type	√
Zonal fare type	
Distance based type	
Other	
Convenient pedestrian and bicycle access to transit facilities	
Are the bus stops accessible to persons with disabilities?	√
Is there a wheelchair ramp to access the street at crosswalks or mid-blocks?	√
Are these stops accessible by sidewalk or pedestrian paths?	√
Has space been provided for bus stop shelters and/or benches?	√
Is there sufficient lighting?	√
Bus type	
Low –emission vehicle technology	√
One side doorway	
Both sides doorway	√
Standard bus type	√
Articulated bus type	
Bi-articulated bus type	
Double-decker bus type	
Boarding/alighting	
Multiple-door boarding/ alighting	√
Single-door boarding/alighting	
Door with ramp	√
Door type	
Swing door	
Bi-fold door	√
Plug	
Pivot door	
Sliding door	
Others	

Safety	
Cleanliness	
Accessibility	
Reliability	
Lack of intermodal coordination	√
Urban traffic congestion	
Inability to meet service demand	
Pedestrian crossing controlled by traffic light	
Excessive bus-to-platform gaps at BRT stations	

<u>Appendix D</u>: Route C1 stick diagram and route length



Appendix E: Rea Vaya Route Map

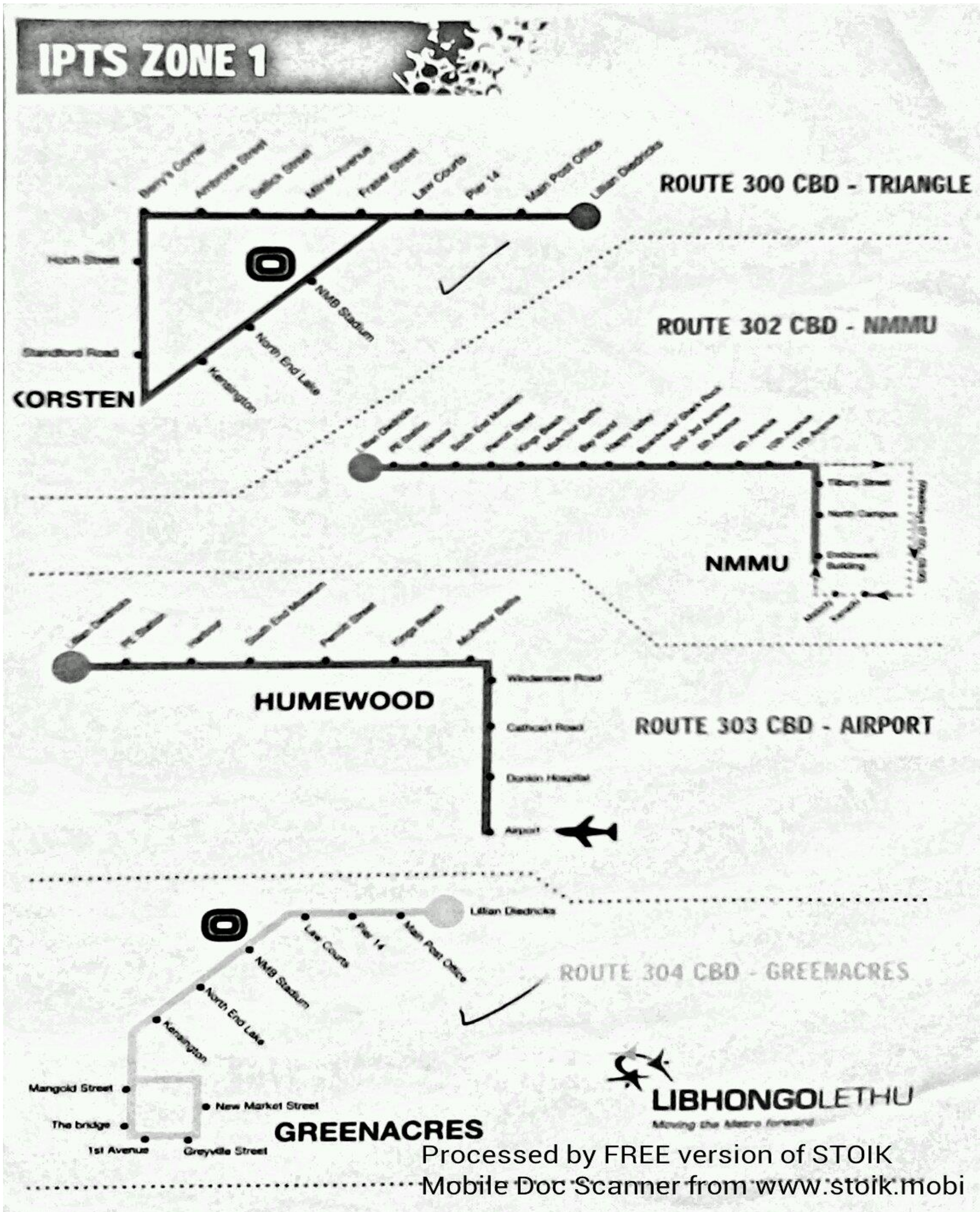


Source: http://www.reavaya.org.za/images/stories/2009pdfs/startermap-27aug09.pdf

Appendix F: MyCiTi Route Map

Partial route map of MyCiTi BRT system
Source: http://www.capetown.gov.za/en/MyCiti/Documents/MyCiTi_System_Map.pdf

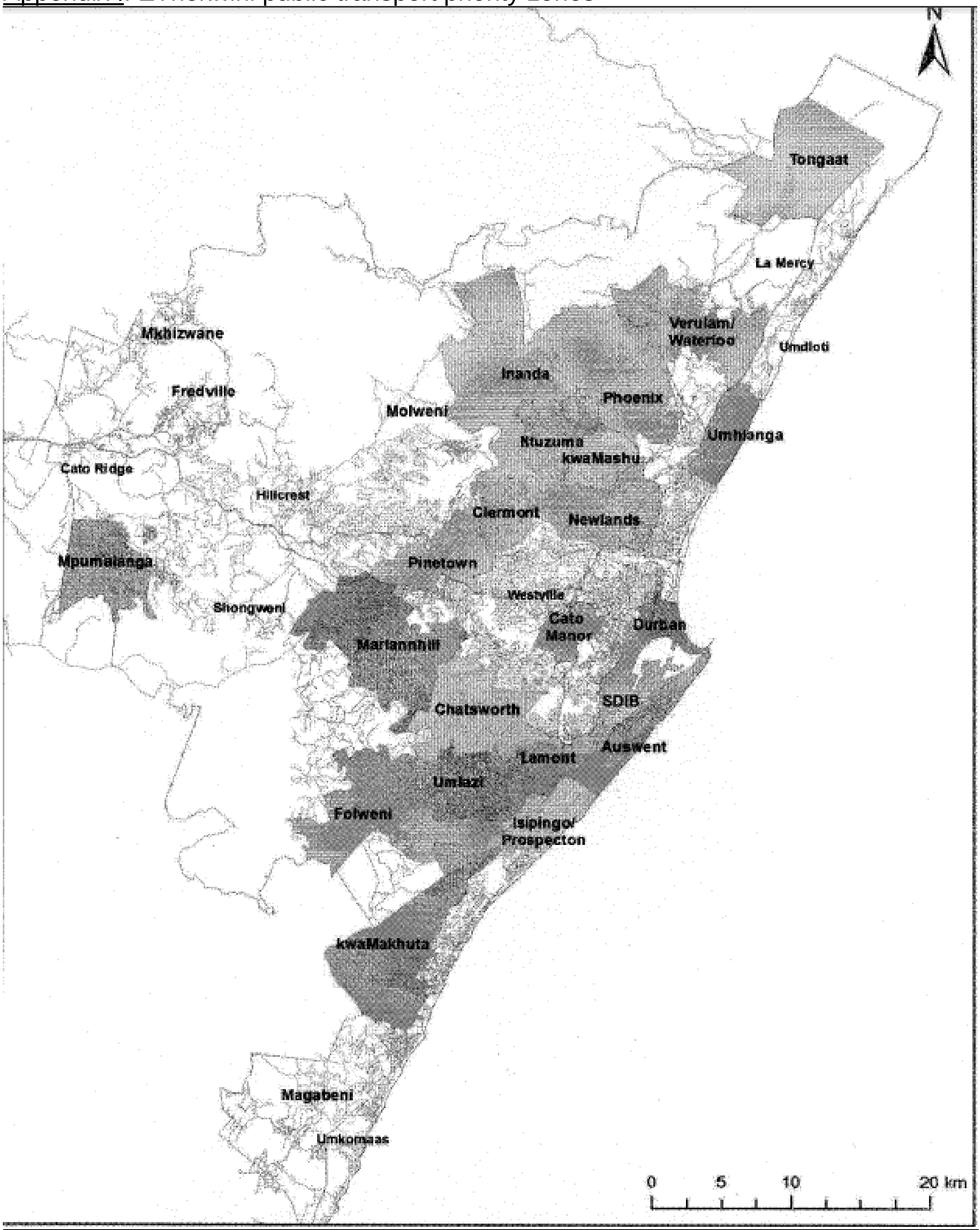
Appendix G: Libhongolethu Route Map



Route map

Appendix H: Existing bus and taxi routes map of EMA

Appendix I: EThekwini public transport priority zones



<u>Appendix J</u>: Critical assessment of Port Elizabeth BRT system

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Research Paper

Critical assessment of Port Elizabeth Bus Rapid Transit system

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ABSTRACT:- Due to increasing pressure on public transport, it has become necessary to seek for a more efficient means of moving passengers, reduce travel time, delay time and numbers of stop. Bus Rapid Transit (BRT) has been adopted as an improvement on regular bus services through the combination of features like infrastructure changes that resulted in better operation speeds and service reliability. The main aim of this study is to check the performance and operationof Libhongolethu BRT system in Port Elizabeth (PE) from inception. Physical assessment and critical review of the operating BRT system was employed in this study. The BRT system in which mixed flow traffic lane is practiced with dedicated lanes and no full weather protection is said to be less effective, even to build more buy-in customers to use the system, especially the private car users.It is cost effective over a long distance when compared to other public transport because it operates at a flat rate. A full weather protection streamlined station should be implemented adopting bicycle and car parking lots, phone booth, CCTV, AVL, comfortable seating and information map/s at each station. Mixed flow traffic lanes should be totally discouraged. Other modes of BRT system, especially segregated mode should be employed in case of future BRT intensification.

Keywords:- Vehicle manoeuvre, commuters, traffic congestion, dedicated lane

I. INTRODUCTION

Today, the public and private transports are facing problems due to increase in vehicle ownership and the suburbanization of both firms and residences in the world. In the past, public transport focused mainly on the central areas of the cities where high population and employment densities enabled frequent services, high occupancy rates and many routes. As growth is reaching suburban from the metropolitan area, imperative challenge crops up in the public transport to increase its service in order to serve the commuters better, and also to integrate suburban service with the metropolitan service(Pucker and Hurth 1996). The main aim of this study is to check the performance and operation of the Port Elizabeth (PE)Bus Rapid Transit (BRT) system from inception. Hence, public transport has to be made more attractive and user friendly in order to have improved service, travel information, reliability, safety and upgrading of infrastructure like waiting stations. Cost is also an imperative element that influences the demand for public transport in relation to the time spent waiting, boarding and alighting from vehicles coupled with the risks and inconveniences involved in those actions. The report (Conquest Research, 1997) also suggested that commuters and business users board the fastest and most direct routes.

What is BRT?

Bus Rapid Transit can simply be defined as a rapid mode of transportation that can coalesce the quality of rail transit and flexibility of a bus(Thomas, 2001). Transport Research Board (2001 cited in (Levinson et al. 2002) defined Bus Rapid Transit in a more simplified and understandable way as a flexible and rubber-tired rapid transit mode that combines running way, intelligent transportation system (ITS) elements, stations, vehicles and services into an integrated system with a strong positive image and identity. Bus Rapid Transit is a project embarked in phases as fund and opportunity permit because of the service flexibility. Bus Rapid Transit application is planned to be appropriate to the place/destination it serves and its physical surrounding. Provided its performance in the implemented areas is successful, the service would be extended to other environments. Effective and cheap public transport provision will aid the growth of the nation in terms of the economy, social and environmental wellbeing leading to the urbanization of cities.

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very few routes exceeding 40km in length.A total number of 65 385 passengers makes use of it daily during 1 410 daily trips (SSI Engineers and environmental Environments, 2011).

Metered taxis

This is another form of transport that focus majorly on tourism market and it remains a system that can not totally fit in as a public transport. This mode is still in the process of setting a strategy of encouraging its use in NMBM. Its operation is mainly around Port Elizabeth airport where there is the opportunity of serving businessmen and tourists. It is not like any other public transport that has a fixed rank station; it operates through a radio cell or cell phone system. These operators rely solely on the contact from advertising brochures at hotels, guesthouses and airport. The operating licensing board and NMBM have little understand of the need for metered taxis, the extent of vehicle fleet and its operation because they are faced with the challenge of transforming other mode of public transport which are more boarded by the commuters, hence, metered taxi is in low profile in NMBM (SSI Engineers and environmental Environments, 2011).

IV. CURRENT SITUATION OF PUBLIC TRANSPORT IN PE

There are roughly 400 standard Algoa buses and 3,200 minibus taxis providing the commuters with transport services on daily basis in NMBM area. Their operations are usually on the same routes; it gives room for competition as their fares are similar. NMBM procured 24 new low-floor articulated buses(Length: 18.5m, number of doors: 2-5, seating capacity including the driver: more than 70) with doors on both sides which were used for 2010 FIFA world Cup in PE. These are now used by the Integrated Public Transport System (IPTS) as BRT buses. These buses are operated by the taxi co-operatives and replaced the existing taxis operating at the median lanes. This is imposed by the operational needs of the new system, which demands the articulated bus with wheel chair accessibility to be operated at these lanes during the peak and off peak times. Hence, the taxi owners were compensated according to their current profits in this regards. Table 2 shows the cost of the proposed transport projects required for further implementation of the Integrated Public Transport System (IPTS) for the next five years. Table 3 shows that a proposal was submitted to the Department of Transport (DoT) for the funding (cost updated to current) of the IPTS project in 2011/2012 financial year. The project in table 3 has been included in Comprehensive Integrated Transport Plan (CITP). The fund shown in table 3 is part of an ongoing funding programme for the implementation of an IPTS in NMBM area. The problem that ravages the current public transport situation is the increasing traffic congestion on the roads leading to city centre, resulting into delay, some drivers become extensively aggressive and drive recklessly which might lead to head-on collisions, injuries and mortalities (SSI Engineers and environmental Environments, 2011).

Port Elizabeth BRT operation

The NMBM area has a population of about 1.1 million with total area of 1950km^2, 289 000 households are located in the formal areas coupled with 35, 257 informal households and 49 009 backyard shacks also exist with the area. 112 306 out of 289 000 households are classified as indigent and 44% of all households depends on, at least, one social grant. In table 4, it indicates that 66% of the residents receive low income and the remaining residents fall within the low to medium income brackets. This statistic also depicts that a large percentage of the NMBM residents depend solely on public transport (SSI Engineers and environmental Environments, 2011).

Libhongolethu is the name given to the BRT system in Port Elizabeth, which means “our pride”, that is, an integrated public transport system that is safe, convenient and reliable. This system brings Nelson Mandela Bay closer to becoming a world-class city and started with seven routes running through Port Elizabeth, Uitenhage and Despatch(Nelson Mandela Bay Tourism, 2012). Within Port Elizabeth city, only four corridors are operated as stated below. Port Elizabeth BRT system was a disaster. The reason is that it was constructed for World Cup 2010 with the initial budget of R 1 billion used to create extra lanes and 2 years later the initial lanes were destroyed because it was not properly planned. There were 20 buses lying idle because they did not fit into the original lanes created for them, so an extra R30 million was used to make changes (Calls made for inquiry into PE's BRT system, 2012). Due to this, the BRT system in PE was put on hold until it commenced operation in February 2013. There are functioning operation of BRT systems in other South African cities like Johannesburg, Cape Town, Pretoria and on-going implementation of such a system in Durban (Thomas, 2010).

The functioning routes within PE (IPTS zone 1, see figure 1) are listed as follow:

1. **Route 300: PE Central Business District (CBD) -Triangle**

Start point: Lilian Diedricks building, Govan Mbeki Avenue
Bus stops: Mostly median stops in dedicated lanes
Direction of service: Triangle will be operated in both the clockwise and anti-clockwise direction

V. CONCLUSION

Use of a dedicated bus lane should be encouraged throughout the routes because there is great improvement in travel time, reliability, safety and fastness with a dedicated BRT system when compared to other road public transport travelling in mixed flow traffic lanes. It makes use of articulated standard buses to accommodate more passengers. The system is far below standard because it has no AVL, information kiosk, phone booth or a full weather-proof shelter

Conclusively, it is cost effective over a long distance when compared to other public transport because it operates at a flat rate and also commuters can be transferred within 30 minutes of purchasing the ticket within the IPTS zone 1. In the system, pedestrian safety, convenient and secure access to the facility for the physically challenged and abled commuters are fully guaranteed, which makes commuters not to be discouraged about the system.

Recommendation

High/future maintenance should be the watchword to keep what is in place at the moment. If there is the need for BRT system diversification in Port Elizabeth,other lane configurations should be implemented especially the segregated type of BRT system. A full weather protection streamlined station should be implemented adopting bicycle and car parking lots or park and ride lots, phone booth, CCTV, AVL, comfortable seating and information map at each station. Mixed flow traffic lanes should be totally discouraged. If there is population intensification, bi-articulated standard buses should be adopted. The use of smart card should be solely adhered to, which will help the commuters to load more than a day fare, depending on their financial capacity, hence, making it more user friendly.

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Appendix K: An appropriate Bus Rapid Transit system

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An Appropriate Bus Rapid Transit System

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ABSTRACT

Bus Rapid Transit (BRT) has been adopted as an improvement on regular bus services through the combination of features like infrastructure changes that resulted in better operation speeds and service reliability. In this regards, it does pose a problem in selecting a BRT that is most suitable for a particular area/region. Hence, this study suggests an appropriate BRT system during in-depth literature review. To be able to select the appropriate vehicle option for a BRT system for a particular area/corridor, the transport demand, coverage/distance to be covered and length of public transport delay due to general traffic condition must be put into proper consideration. In terms of cost implication, median BRT system and kerbside BRT system should be selected over segregated BRT system.

Keywords: *Bus Rapid Transit system, Corridor, Transport demand, Speed*

1. INTRODUCTION

Today, both the public and private transports are facing problems due to increase in vehicle ownership and the suburbanization of both firms and residences in the world. In the past, public transport focused mainly on the central areas of the cities where high population and employment densities enabled frequent services, high occupancy rates and many routes. As growth is reaching suburban from the metropolitan area, imperative challenge crops up in the public transport to increase its service in order to serve the commuters better, and also to integrate suburban service with metropolitan service (Pucker and Hurth, 1996). The main aim of this study is to check the most appropriate BRT system through in-depth literature review. Hence, public transport has to be made more attractive and user friendly in relation to improved service, travel information, reliability, safety and upgrading of infrastructure like waiting stations. Cost is an imperative element that influences the demand for public transport in relation to the time spent waiting, boarding and alighting from vehicles coupled with the risks and inconveniences involved in those actions. The report (Conquest Research, 1997) also suggested that commuters and business users board the fastest and most direct routes.

What is BRT?

Bus Rapid Transit can simply be defined as a rapid mode of transportation that can coalesce the quality of rail transit and flexibility of a bus (Thomas,2001). Transport Research Board (2001 cited in (Levinson et al. 2002) defined Bus Rapid Transit in a more simplified and understandable way as a flexible and rubber-tired rapid transit mode that combines running way, intelligent transportation system (ITS) elements, stations, vehicles and services into an integrated system with a strong positive image and identity. Bus Rapid Transit is a project embarked in phases as fund and opportunity permit because of the service flexibility. Bus Rapid Transit application is planned to be appropriate to the place/destination it serves and its physical surrounding. Provided its performance in the implemented areas is successful, the service would be extended to other environments. Effective and cheap public transport provision will aid the growth of the nation in terms of the economy, social and environmental wellbeing leading to the urbanization of cities.

Historical development of BRT

The large-scale development of the BRTs started in Curitiba (Brazil) in 1974, and before then, there were several smaller-scale projects earlier to its development. After the success of effective BRT in Curitiba, Curitiba's experience inspired other cities to develop similar systems (Matsumoto, 2004). In the 1970s, development of BRT systems was limited to the North and South American continent. In the late 1990s, the replication of the BRT concept gained momentum and BRT systems were opened in Quito, Equador (1996), Los Angeles, USA (1999) and Bogotá, Columbia (2000) (Ernst, 2005:11). Especially, the TransMilenio project in Bogotá started operation in 2000 and its success drew attention from the world community as an example of the state of the art in BRT systems. As of 2005, there may be up to 70 systems around the world, depending on one's definition of BRT (Levinson et al. 2003; Wright, 2005)

System Performance

The system performance of Bus Rapid Transit (BRT) is based on the following five attributes.

Travel Time

One of the main advantages of Bus Rapid Transit is its higher operating speed. The overall travel time consists of four components, which are-

* Running Time-Time spent in the vehicle moving from stop to stop.

*Dwelling Time-Time spent when vehicle stopped at a station.

Vehicle maneuver

In terms of the three mode of BRT system in respect to the lane discussed in this study, vehicle maneuvre would pose a delay for a curbside BRT system but the other lane configurations would be OK. If curbside would be adopted, a shoulder lane-where automobiles can park and make U-turn to their destination, should be implemented which would improve the system.

CONCLUSION

To be able to select the appropriate vehicle option for a BRT system for a particular area/corridor, the transport demand, coverage/distance to be covered and length of public transport delay due to general traffic condition must be put into proper consideration.

If the transport demand and coverage are low, a standard bus could be selected over other modes of bus option and in order to enhance rebranding and marketing strategies a stylised bus could be picked over others provided the condition is the same as above.

However, if the length of public transport delay experience at a particular suggested corridor or area is low, a standard could be appropriate over the modes of bus option and to enhance marketing and branding or rebranding, a stylised bus could be the best to be selected. Conclusively, they offer cost effective when compare to light rail transit.

Using this mode of BRT systems across the nation, there are an improved travel times, more reliable, safer and faster is achieved when compared to buses and automobiles travelling in mixed flow traffic lanes because they operate on a dedicated bus lane. A separate lane enables the system to have lower headways and accommodate higher peak period loads. When further combined with signal priority, delay would be greatly minimized at intersection.

RECOMMENDATION

Any form of BRT system should be implemented in a place of none because it offers increased level of mobility, fewer stops and accessibility than the traditional public transportation. It used also serve as an attractive means to get drivers or car owner to the system.

BRT system should not be operated in a mixed traffic because it poses delay but the introduction of a bus lane would increase reliability and transit speed of such system and has positive effect on the commuters of increased visibility and identity of the system. Level of service of a segregated BRT system is more better than that of curbside and median BRT system. The level of service of a curbside could be improved by the provision of a shoulder lane where vehicle can hover or park to execute their task.

It is only when there is no space for expansion should a BRT system be operated in a mixed traffic because implemented of any mode of BRT system depends on the availability of space in such area and different mode could be practiced based on a single corridor based on available space. For the abled and physically challenged pedestrians, segregated BRT system could be given priority over the rest. Relative to the capital cost, a curbside and median mode could be given plea consideration over segregated mode. Segregated and Median BRT system should be picked over Curbside germane to vehicle maneuver. Segregated is far better of the exclusive right of way. A curbside BRT system could be improved by providing a shoulder lane for parking and maneuver.

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Appendix L: Rea Vaya: South Africa's first bus rapid transit system

Rea Vaya: South Africa's first bus rapid transit system

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Today, both the public and private transport sectors are facing challenges as a result of an increase in vehicle ownership and the suburbanisation of both firms and residences in the world. In the past, public transport was focused mainly on central areas of cities where high population and employment densities enabled frequent services, high occupancy rates and many routes. As growth is spreading to suburban areas from the metropolitan area, imperative challenges arise for public transport: to increase service in order to better serve commuters and to integrate suburban service with metropolitan service.[1] Public transport must be made more attractive and user friendly in relation to improved service, travel information, reliability, safety and the upgrade of infrastructure such as waiting stations. Cost is an important factor that influences the demand for public transport in relation to the time spent waiting, boarding and alighting from vehicles coupled with the risks and inconveniences involved in those actions. It has also been suggested that commuters and business users board the fastest and most direct routes.[2] Here we comment on the performance and maintenance of the Rea Vaya system – South Africa's first bus rapid transit system – since its inception.

Historical development of bus rapid transit

The large-scale development of bus rapid transit (BRT) systems started in Curitiba (Brazil) in 1974, before which there were several smaller-scale projects. After the success of an effective BRT in Curitiba, other cities were inspired to develop similar systems.[3] In the 1970s, development of BRT systems was limited to the North and South American continents. In the late 1990s, the replication of the BRT concept gained momentum and BRT systems were opened in Quito, Ecuador (1996), Los Angeles, USA (1999) and Bogotá, Columbia (2000).[4] The TransMilenio project in Bogotá started operation in 2000 and its success as a state-of-the-art BRT system drew attention from around the world. As of 2005, there were 70 such systems around the world, based on one definition of BRT.[5,6]

National operating subsidies

Developing a business plan for a public transport system is difficult for any transport authority unless they know the rate of the operating subsidy that will be made available to them. At each metro or functional area, the existing level of subsidy should continue at the level currently allocated for bus subsidies. A judgement call must be made by the transport authority on which proportion of the subsidy will be allocated to catalytic initiative. In other words, the authority must plan for zero operating subsidy for the catalytic initiative as they have no control over the subsidy streams, which are in place because they applied to standard buses and rail.[7]

Bus rapid transit systems in South Africa

Commuters in the Gauteng Province have been using the BRT system called 'Rea Vaya', which means 'we are going'. It is the first of its kind in South Africa. Phase 1 of the BRT system, which linked Soweto to the centre of Johannesburg, came into effect on 30 August 2009. There are also functioning BRT systems in Cape Town, Port Elizabeth and Pretoria, and on-going implementation of such a system in Durban.[8]

Johannesburg's bus rapid transit operation

Rea Vaya has a capacity of up to 90 passengers on designated median lane trunk routes and currently conveys 16 000 passengers per day. Complementary buses collect passengers at Rea Vaya stations on the trunk routes and operate on the kerbside of the lane.[9]

The South African cabinet appropriated public transport in an integrated way in March 2007.[10] With funding at hand to address the issues of infrastructure and vehicles, they embarked on a solution for the severe traffic congestion and persistent mobility problems of the nearly 1.5 million transport users in the city. The first corridor spans through a 25-km trunk line with median lanes, 27 trunk stations and feeder routes that link the CBD and Soweto, which is one of the busiest commuter corridors in the city.[11] (For the route map see http://www.reavaya.org.za/images/stories/2009pdfs/startermap-27aug09.pdf)

On-site assessment

We assessed the performance of the system and its possible pros and cons on-site using a checklist (Table 1). The Rea Vaya BRT system makes use of a median bidirectional BRT lane configuration which is located in the middle of the roadway, as an exclusive right-of-way with pavement and lane markings, intersection road markings and stud separators (10 cm). The stud separators serve to separate the other traffic to avoid vehicle manoeuvre. It has distinctive branding in the form of markings on the vehicle that differentiate it from other public transport systems. The standard bus is fitted with low-emission technology, bi-fold doors at both sides and multiple entrances for boarding and alighting.

As the lane is located in the middle of the roadway, the stations are also constructed at the median of the roadway. Each station has maps, automatic doors on both sides of the station, an elevator for wheelchair accessibility, an enhanced environment, full weather protection on all platforms, telephones, security, CCTV and an information desk. The stations have a uniform configuration and design. In some places, the median of the road is decorated by planting of trees or grass and a footpath. The stations have branded temporary streamlined shelters with comfortable seats for the passengers to wait for the next available bus, CCTV, maps, security and real-time information displays. Real-time information displays and CCTV are installed at the stations as part of the Intelligent Transportation System (ITS) to improve passengers' convenience, speed, security and safety, and system reliability. The system makes use of CCTV for monitoring the operations of the buses using Automatic Vehicle Location, which is connected to the control room, and enables the update of schedules, both inside the bus and at the stations. Both smart card and off-board payments are accepted, but off-board payments, which are a flat rate, are more common. Pre-board fare collection and verification are exercised for those that are not using a smart card. The pedestrian crossings are controlled by traffic lights in most places. Existing transit signal infrastructure has been adopted where deemed suitable. The system is reportedly safe, clean, accessible, well coordinated between modes and able to meet service demand.

Problems and challenges

The ability to attract more customers, especially private car users, is important. The development of a robust business and financial model for continual maintenance of the existing system is a challenge. Continuous training for the owners and operators in the skills required to maintain the success of the system is necessary.

Conclusion

The median configuration of the Rea Vaya BRT system, which operates on a dedicated bus lane, offers improvement in travel time, reliability, safety and speed compared with other public transport systems and automobiles travelling in mixed-flow traffic lanes. A separate lane enables the system to have lower headways and accommodate higher peak period loads. When further combined with signal priority, delay is greatly minimised at intersections.

The BRT system is commuter friendly and cost effective over a long distance, compared with other public transport systems because it operates at a flat rate. Pedestrian safety, convenience and secure access to the facility for both the physically challenged and able commuters are provided. The installed ITS ensures passengers know the exact time and place to disembark, which is especially useful for those who are not familiar with their destination station.

Recommendations

To maintain a successful system, frequent maintenance is imperative. Should the need arise for BRT system diversification in Johannesburg, other lanes should be implemented using other forms of the BRT system and bicycle and car parking should be adopted at the main station. If there is further population intensification, articulated standard buses should be adopted. Smart cards should be used exclusively and will enable commuters to load more than a day's fare, depending on their financial capacity. Other modes of BRT, especially the segregated mode, should be employed for future BRT implementation. Although cost effective, the cost of the BRT system is justified by the high levels of efficiency, reliability and speed.

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Appendix M: Critical analysis of Cape Town BRT system

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Critical Assessment of Cape Town BRT System

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Abstract*— Due to increasing pressure on public transport, it has become necessary to seek for a more efficient means of moving passengers, reduce travel time, delay time and numbers of stop. Bus Rapid Transit (BRT) has been adopted as an improvement on regular bus services through the combination of features like infrastructure changes that resulted in better operation speeds and service reliability. The main aim of this study is to check the performance and maintenance from the inception of the Myciti BRT system in Cape Town (CT). Physical assessment and critical review of the operating BRT system was employed in this study. The lane configuration and design are almost the same all through the routes except in some places where there are mixed traffic, at-grade median, median and segregated lanes. There is no Automatic Vehicle Location (AVL) which is connected to the control room that helps with updated schedules both inside the bus and station. Also, no comfortable seats, phone booths, bicycle and private car lots/parking is provided at the stations. High maintenance should be the watchword and if there is the need for BRT system diversification in Cape Town, other lanes should be implemented using other forms of BRT system adopting bicycle and car parking facilities at the main station which will enable a complete comparison in terms of service reliability and delay.

***Index Terms*— Vehicle manoeuvre, commuters, traffic congestion, dedicated lane.**

I. INTRODUCTION

Today, both the public and private transports are facing problems due to increase in vehicle ownership and the suburbanization of both firms and residences in the world. In the past, public transport focused mainly on the central areas of the cities where high population and employment densities enabled frequent services, high occupancy rates and many routes. As growth is reaching suburban from the metropolitan area, imperative challenge crops up in the public transport to increase its service in order to serve the commuters better, and also to integrate suburban service with metropolitan service (Pucker and Hurth 1996).

The main aim of this study is to check the performance and maintenance from the inception of the Myciti BRT system. Hence, public transport has to be made more attractive and user friendly in relation to improved service, travel information, reliability, safety and upgrading of infrastructure like waiting stations. Cost is an imperative element that influences the demand for public transport in relation to the time spent waiting, boarding and alighting from vehicles coupled with the risks and inconveniences involved in those actions. The report (Conquest Research, 1997) also suggested that commuters and business users board the fastest and most direct routes.

II. HISTORICAL DEVELOPMENT OF BRT

The large-scale development of the BRTs started in Curitiba (Brazil) in 1974, and before then, there were several smaller-scale projects earlier in its development. After the success of an effective BRT in Curitiba, its experience inspired other cities to develop similar systems (Matsumoto, 2004). In the 1970s, development of BRT systems was limited to the North and South American continent. In the late 1990s, the replication of the BRT concept gained momentum and BRT systems were opened in Quito, Equador (1996), Los Angeles, USA (1999) and Bogotá, Columbia in the year 2000 (Ernst, 2005). Especially, the TransMilenio project in Bogotá started operation in 2000 and its success drew attention from the world community as an example of the state of the art in BRT systems. As of 2005, there may be up to 70 systems around the world, depending on one's definition of BRT (Levinson et al. 2003; Wright, 2005).

III. NATIONAL OPERATING SUBSIDIES

Developing a business plan for public transport is somehow difficult for any transport authority unless they know the rate of operating subsidy that will be made available to them. At each metro or functional area, the existing level of subsidy must continue at the levels currently being allocated for bus subsidies. A judgment call will be made by the transport authority to decide which proportion of the subsidy will be allocated to catalytic initiative. In other words, it means that they have to plan for zero operating subsidies for the catalytic initiatives as they have no control over the subsidy streams, which are in place because it applied to standard buses and rail (DoT,2007a).

IV. CAPE TOWN BRT OPERATIONS

Development has spread to the peninsula area of Cape Town termed as a low-density area, which depict that there would be movement of people in the pursuit of their daily chores over a long distance. However, a larger percentage of about 3 million residents of Cape Town rely solely on public transport as their means of movement. Considering the topography of CT, there is no more space for the expansion of road or building new roads for private automobiles that might carry one person per time because it is surrounded by two oceans and table mountain range at the centre. Congestion is increasing year after year. Besides, international studies reveal that building or expansion of road network should not ease the congestion because people opt for automobile instead of using public transport. Hence, there should be great investment on public transport to classy taste in order to

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encourage private car users to use it and alleviate congestion. This was what prompted the BRT/IRT system in Cape Town named "Myciti" (System, 2012).

The South African cabinet appropriated public transport in an integrated way in March 2007 (DoT, 2007b). The first phase of the Integrated Rapid Transport (IRT) system span through Civic Centre (CBD) to Table View as the trunk route coupled with a series of interim feeder services. Some of the routes are intersected while all the routes are connected to the Civic Centre station (Figure 1)

There are functioning operation of BRT systems in other South African cities like Johannesburg, Port Elizabeth, Pretoria and on-going implementation of such a system in Durban (Thomas, 2010).

V. On-site Assessment

The method employed was an on-site assessment using a checklist system to assess the performance of the system and subject the possible pros and cons of the system (annexure 1). Myciti BRT system majorly makes use of median BRT lane configuration, that is, it is located in the middle of the roadway in a two-way direction as an exclusive right-of-way with pavement/lane marking, intersection road marking and few metres away from the main station (Civic Centre). It some places, it operates in mixed traffic, at-grade BRT system which does not need a lane marking or separator and segregated lane. The lane marking serves as a separator to the other traffic to avoid vehicle manoeuvre. It has a fully colored bus way some metres away from the Civic Centre to Table View. It has a distinctive branding/marked identity of vehicle and color that differentiates it from other public transport. Standard and articulated standard low emission vehicle technology buses with bi-fold doors at both sides and multiple entrances for boarding and alighting alongside a distinctive identity and image are used.

As the lane is located at the middle, the station is also constructed at the median of the roadway with maps, automatic doors on both sides of the station, elevator for disabled/ wheelchair accessibility, enhanced station environment, full weather protection on all the station platform, security, CCTV, information desk and telephone booth (only at the main station). Consistent pattern of station location and in few places, the existing kerb side bus stop for other public transport is adopted.

The lane configuration and design are almost the same all through except in some places where there is mixed traffic (close to Table View and others), and segregated lane along Woodstock to Zoarvlei corridor. The median of the road is enhanced with a footpath. It has streamlined shelters with no comfortable seats and real-time information display for the passengers to wait for the next available bus, but it has the following implemented in the station: CCTV, maps, specific paint scheme, logo and security. The destination could be found in the bus, there is a display of the destination in front of the bus and help could be got from the staff. The BRT buses are scheduled to operate every 20 minutes from 5h10 to 21h20 during the weekdays and 6h10 to 20h00 over weekends.

They make use of the installed CCTV on the corridors to monitor the buses in regard to theft and performance. Audio announcement and map sticks to the side of the BRT buses are used to inform the commuter of both the present and next bus stop especially to those who do not know the exact station to jump off. It makes use of only smart card (Figure 2) which is at a flat rate and only the monetary value of the card can be paid back upon the return of the card; the money loaded is not refunded. Fare verification is done in the bus.

VI. Problems/Challenges

The ability to build more buy-in customers to use the system especially the private car users is important. To develop a robust business and financial model for continual maintenance of the existing system is a challenge. Continuous skills training are required for the owners and operators to maintain the success of the system. There is no Automatic Vehicle Location (AVL) which is connected to the control room that helps with updated schedules both inside the bus and station which is essential. Its operation in mixed flow traffic lane is a promising problem. No provision is made for commuter seating, bicycle and private car lots/parking at the stations.

VII. Conclusion

Use of a dedicated bus lane should be encouraged throughout the routes due to its improvement in travel time, reliability, safety and fastness when compared to other road public transport modes. A separate lane enables the system to have lower headways and accommodate higher peak period loads. When further combined with signal priority, delay is greatly minimized at intersections. Use of Automatic Vehicle Location (AVL) helps the passengers to know when the bus would arrive at the station and the exact place to jump off, especially to those who do not know the exact location of their destinations. AVL is more preferable to audio announcement in the bus. No phone booth and information display system either in the bus or station makes it below standard when compared to the standard of a BRT station. It could be noticed that where segregated lane is used, it is more efficient than the median, at-grade median, or mixed traffic lane.

Conclusively, it is commuter/user friendly and cost effective over a long distance when compared to other road public transport because it operates at a flat rate. In the system, pedestrian safety, convenient and secure access to the facility for the physically challenged and abled commuters are fully guaranteed, which makes commuters not to be discouraged about the system.

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lanes should be implemented using other forms of BRT system adopting bicycle and car parking lot at the main station which will enable a complete comparison in terms of service reliability and delay. Mixed flow traffic lanes should be totally discouraged. Other modes of BRT system especially segregated mode to be employed in case of future BRT intensification. Phone booth, comfortable seating, bicycle space and Intelligent Transport System should be fully installed at the station.

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Appendix N: Study of drivers' response time in traffic streams

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Study of Drivers' Response Time in Traffic Streams

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Abstract ***-Reaction times of drivers responding to traffic wardens' signals are important for the design and safe operations of roads. The increased number of road users and pedestrians lead to increasing demands on the facilities and eventual inconvenience and delays. This study evaluated the response time of drivers on the minor leg of Challenge Intersection in Ilorin because of the significance of the minor traffic stream on the capacity analysis or design of traffic merging at the major leg. The method employed was basically manual whereby stopwatches were used to measure the response time of drivers who were unaware of being monitored The response time of each driver in a traffic stream queue was taken in relation to respective positions in the queue. The average response time for the first and consecutive vehicles in stop and move signal are shown in tables 1.0 and 1.1 respectively. It can be deduced that those far behind do not have to see the warden signals before they respond because the brake light of the preceding vehicle will dictate the signal***

Index Term: **Traffic Warden, Perception-Reaction Time, Minor Leg, Queue, Intersection.**

I. INTRODUCTION

The increase in the number of road users and pedestrians lead to increasing demand on the facilities and eventual distresses or inconveniences and delays. The proper way of studying traffic streams or flows should be adopted at intersections and most especially in areas where stopped delays are more pronounced. This leads to traffic characteristics like poor headways, forced flows, delays and queues [1]. The main aim of this paper was to study the response time of drivers to traffic wardens' signals at Challenge urban intersection. An intersection to a great extent can be used to determine the efficiency, safety, speed, cost of operation and capacity of a highway relative to its design. An intersection could be explained as an area where two or more arteries cross including the roadside and roadway facilities branching out from the intersection, which form the intersection leg [2].

II. DRIVER'S REACTION TIME

Reaction/perception-reaction time means the speed at which a person responses to an action. Reaction time is the key to account for liability. It is classified to be complex in behavior because it is not determined by a single character that applies globally but it is governed by a large number of variables[3].[4]stated the diverse component affecting driver's reaction time as follow:

A. Mental Process Time

It is the time taken for the responder to observe that a signal has ensued and to decide upon it a quick response. For instance, the time required for a driver to notice that a pedestrian is crossing the roadway directly ahead especially when the pedestrian crossway is not controlled by traffic light and decide to apply brake to halt the automobile. Mental processing time can further be split into four categories as explained below.

B. Sensation

It is the time taken to notice the sensory input from an object, for instance, there is a shape of an object on the road. Reaction time tends to decrease as the signal intensity-brightness, contrast, size and loudness, increases and increased visibility conditions. When comparing the auditory signal to visual signal, the former has best reaction time.

C. Perception/Recognition

It can be referred to as the time required to recognize the meaning of sensation, which is aided by the interpretation of information from the memory to the sensory input.

D. Situational Awareness

It is the ability in form of time required to notice the seen object and its layout on the road; depict its meaning and relay it to the future. For instance, once a driver recognizes a pedestrian on the road, and perceives his own speed and distance, he must realize what is happening and what will happen next.

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$$\text{Mean } (\overline{\mathrm{X}}) = \sum \frac{X}{N} \quad (1)$$

$$\text{Variance}(\sigma^2) = \left(\frac{\Sigma(\mathrm{X} - \overline{\mathrm{X}})^2}{\mathrm{N} - 1}\right) \text{ and Standard deviation } = \sqrt{Var\ (\sigma^2)} \quad (2)$$

Where:

Σ is called Sigma, means sum up

$\overline{\mathrm{X}}$ = Mean

X = Response of each vehicle

N = Total number of vehicles per run

A. Graphical representation

Figures 2- 8 and tables 1 and 2 show the graphical relationship of the driver's response time to stop and move and average response times respectively.

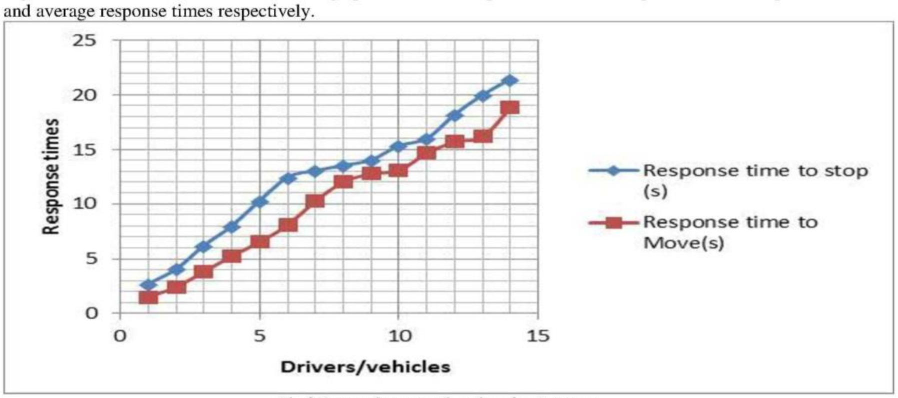

Fig 2 Perception- reaction time for day one

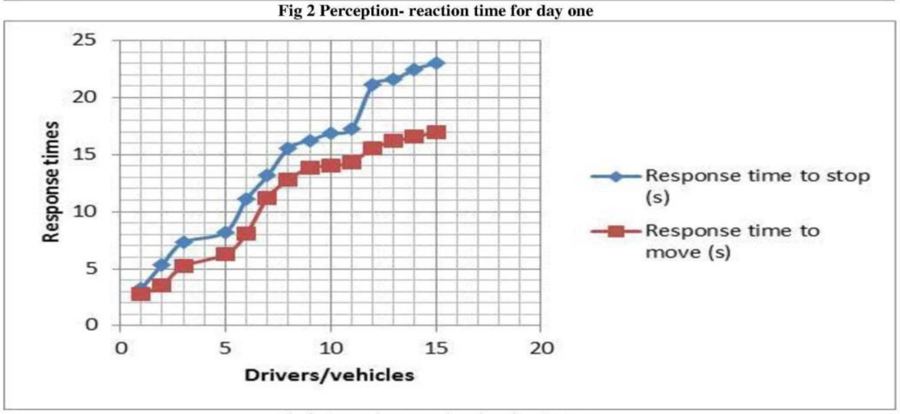

Fig 3 Perception- reaction time for day two

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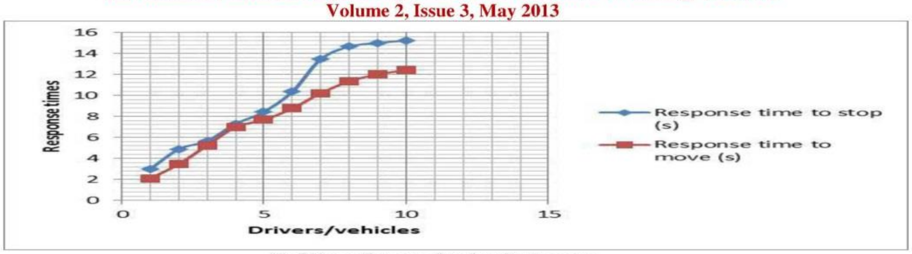

Fig 8 Perception- reaction time for day seven

Table 1.The average response time for each participate (driver) for stop signal.

Driver	1	2	3	4	5	6	7	8	9
Mean	2.72	4.65	5.98	7.99	9.63	11.96	14.53	15.28	15.97
STDEV	0.59	0.72	0.84	1.39	1.45	3.85	2.41	2.32	2.67

Driver	10	11	12	13	14	15
Mean	16.85	17.56	18.67	19.90	21.65	22.08
STDEV	2.45	2.61	2.78	2.80	2.88	3.00

Table 2The average response time for each participate (driver) for move signal

Driver	1	2	3	4	5	6	7	8	9
Mean	1.63	2.51	3.37	5.31	7.30	8.59	10.02	11.42	12.68
STDEV	0.28	0.58	0.89	1.57	1.25	1.15	1.75	1.81	1.34

Driver	10	11	12	13	14	15
Mean	13.29	14.71	15.20	16.81	17.87	19.10
STDEV	1.99	2.67	1.92	2.21	2.34	2.56

VI. DISCUSSION OF RESULTS

From tables 1.0 and 1.1, the average response time for green signal is faster than the average response time for red signal. Fifteen (15) was the highest number of vehicles served at the intersection in a single queue at any given time for a week and 889 vehicles were served per run in a week. From the graphs of response time against drivers, it was deduced that those far behind do not have to see the warden signals before they response because the brake light of the preceding vehicle will dictate a signal to him. They do not need to see the traffic signal before they stop.

VII. CONCLUSION AND RECOMMENDATION

The morning peak periods vary between 8:00am and 10:00am while the morning lull period is between 11:00am and 12noon.The afternoon peak periods vary between 2:00 pm and 4:00pm and the afternoon lull period is between 6:00pm and 7:00pm. It could be deduced from the tables 1.0 and 1.1 that the average response time to stop is more than the average response to move. The average response times for the first vehicle to stop and move were 2.72secs and 1.63 secs respectively. A comparative analysis can only be done once a signalized intersection is installed and similar study be conducted using the same case study. Hence, one will be able to determine the most efficient and effective mode of traffic control between signalized and unsignalised intersection.

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Appendix O: Analysis of headway in traffic streams on the minor leg of an intersection

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Analysis of Headway in Traffic Streams on the Minor Leg of an Intersection

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Abstract: *An increase in the number of road users and pedestrians lead to increasing demand on the facilities and eventual inconvenience and delays. This study evaluated the response time of drivers on the minor leg of the Challenge Intersection in Ilorin because of the significance of the minor traffic stream on the capacity analysis or design of traffic merging at the major leg.The method employed was basically manual whereby stopwatches were used to measure the response time of drivers. The response time of each driver in a traffic stream was taken in relation to theirrespective positions in the queue from which the headways were calculated.The headway for a car to stop is more than the headway to move as indicated in tables 1.0 and 1.1. The mean and the standard deviation for the headway to stop and move were also determined.*
Keywords: Traffic warden, perception-reaction time, minor leg, traffic stream, intersection

Submitted date 14 May 2013 **Accepted Date: 18 May 2013**

I. Introduction

An increase in the number of road users and pedestrians lead to increasing demand on the facilities and eventual inconvenience and delays. The proper way of studying traffic streams or flows should be adopted at intersections and most especially in areas where stopped delays are more pronounced. Thisleads to traffic characteristics like poor headways, forced flows, delays and queues (Garber and Hoel, 1999)

The main aim of this paper was to determine the headway based on the response time of the drivers to stop and move to the traffic warden's signal at Challenge urban intersection. An intersection is the general area where two or more highways join or cross; including the roadway and roadside facilities for traffic movements within each highway radiating from an intersection, forming part of it is an intersection leg. Intersections differ in complexity from a simple intersection which has only two roads crossing angle to each other, to a more complex intersection where three or more roads cross within the same area. It can be in the form of grade separated without ramps, grade separated with ramps (commonly known as interchanges) and at grade intersection (AASHTO, 2001).

II. Traffic Stream Characteristics

Traffic volume is the number of pedestrians or vehicles passing a point on a lane, roadway or other traffic way during some time interval, often one hour, expressed in vehicles, bicycles or persons per hour. On a roadway, the volume of traffic fluctuations widens with time. Flow is the movement of traffic; it may be in terms of pedestrians and vehicles (Smith, 2002).

Time headway is the time usually in minutes between the passing of the front ends of successive transit units moving along the same lane or track in the same direction (Hobbs, 1994). A queue is a line of vehicles, bicycles or pedestrians waiting to be served by the system in which flow rate from the front of the queue are usually considered part of the queue(Akcelik, 1999).

Movement Time

Once a response is selected, the responder must perform the required muscle movement. For example, it takes time to lift the foot off the accelerator pedal, move it laterally to the brake and then to depress the pedal. Several factors affect movement times. In general, the more complex the movements, the longer the movement time it takes. Finally, Yerkes-Dodson Law states that high emotional arousal, which may be created by emergency, speeds or gross motor movements and pairs fine detailed movements(Vonk, 2007). Mechanical devices take time to actuate, even after the responder has acted. For example, a driver stepping on the brake pedal does not stop the car immediately. Instead, the stopping is a function of physical forces, gravity and friction(Wright and Norman, 1976).

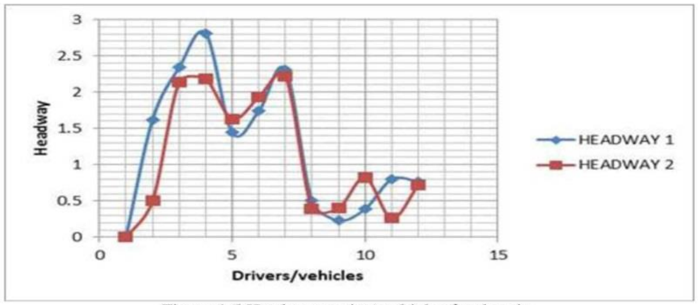

Figure 1.6 Headway against vehicles for day six

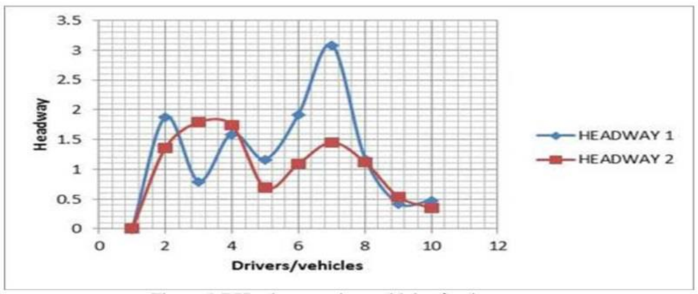

Figure 1.7 Headway against vehicles for day seven

Table 1.0 Average headway for the car to stop (minutes)

Mean	1.372143	1.076923	1.389286	1.561429	1.555714	1.245833	1.256753
Standard deviation	0.733822	0.688602	1.157288	1.137817	1.137106	0.929129	0.906387

Table 1.1 Average headway for the car to move (minutes)

Mean	1.237857	1.203077	1.014286	1.291429	1.298571	1.099167	1.013675
Standard deviation	0.724528	0.899337	0.837585	0.767512	0.728105	0.850919	0.60137

V. Discussion Of Results

In figures 1.1 to 1.7, fifteen (15) was the highest number of vehicles served at the intersection in a single queue at any given time for a week and 889 vehicles were served per run in a week. The graphs of headway against vehicles were sinusoidal graphs. Towards the end of the graph, the signal has little response on those vehicles far behind. They do not need to see the traffic signal before they stop.

VI. Conclusion And Recommendation

The morning peak periods vary between 8:00am and 10:00am while the morning lull period is between 11:00am and 12noon.The afternoon peak periods vary between 2:00 pm and 4:00pm and the afternoon lull period is between 6:00pm and 7:00pm.

The headway for a car to stop is more than the headway to move as shown in tables 1.0 and 1.1. The mean and the standard deviation for the headway to stop are 1.37 minutes and 0.73 minutes respectively. The values 1.23 minutes and 0.72 minutes are the mean and standard deviation for cars to move.

A comparative analysis can only be done once a signalized intersection is installed and a similar study be conducted using the same case study. Hence, one will be able to determine the most efficient and effective mode of traffic control between signalized and unsignalised intersection.

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