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BACHELOR THESIS

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Measures to Increase Safety and Improve National Road Transport Network and Traffic Situation in South Africa.

Through remodeling railway, road, bus and taxi transport networks

Isaai Lawrance Sihlangu

Bachelor Thesis

2013

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V Pardubicích dne 2. 09. 2013 Isaai Lawrance Sihlangu

Foreword

To my illiterate parents, Jacob Anthony Sihlangu and Lucy Agnes Mashele, I will forever be thankful to you as you gave to me opportunity you, yourselves never had: Education, because you believed that with it I can really change the world, well I will start by first and far most changing your world first and eventually changing the world as well. To my siblings: Sipho, Michael, Solly, Glory, and Thomas, thank you for you direct and indirect individual support and contributions. I dedicate this work to my lovely daughter Katekani, who gave me enough courage and strength to finish this Degree.

Isaai Lawrance Sihlangu

Putt's law

Technology is dominated by two people:

Those who understand what they do not manage and those who manage what they do not understand.

Archibald Putt

ACKNOWLEDGEMENT

When I undertook to participace in this National Department of Transport scholarship in partnership with the University of Pardubice (The host institution), University of Pretoria and University of North-west, I wanted to learn all that I could about the field of applied informatics in transport and how acquiring such knowledge could be best implemented in relation to the current South African road transport networks. Our roads had over the years became a death sentence for many road users and, as a result, every year many lives are lost in our roads due to high congestion rate, high usage of minibus taxis and high personal car use due to lack of a safe, reliable, cost-effective and people-oriented transport network.

Although some progress had been made, to some degree, still much needs to be done to better our national road transport networks. Transport networks are currently not safe and needs to be upgraded. After my studies at the University of Pardubice, I now am able to recommend a transport network that will, based on my observations throughout my studies in the Czech Republic, allow the existing transport networks to be revamped. In my thesis, I will suggest how national roads can be intergrated through remodeling. Networks will be proposed which will allow transformation of the current South African transport network.

Remodelling and restructuring of these networks was made possible by the help and guidance of my supervisor, doc. Ing. Josef Volek, CSc. who encouraged me to structure and write it. Lastly but not least, I would like to further extend my gratitude to all applied informatics teachers for their patience with me and their assistance in making this possible, for without their individual help, I wouldn't have done it.

In closing, to the National Department of Transport in South Africa, I will forever be indebted and grateful to you for not only exposing me to a whole new different world but also for their sponsorship in making my coming and staying in the Czech Republic all too possible. So, from the bottom of my heart, thank you all for your direct and indirect individual contributions to making this a success.

Isaai Lawrance Sihlangu Czech Republic, September 2013

ANNOTATION

This work proposes measures to increase the safety of national road transport networks in South Africa by implementing a reliable railway, road, bus and taxi transport network (RRRBTTN). The main focus will be on how to best implement a transport network that will reduce road traffic accidents and the high congestion rate on the South African national roads network. I will use a question-answers approach which will explain in detail the proposed solutions to these problems and a diagnosis of what needs to be implemented to better this dilapidated infrastructure.The how-to structure that can be used in remodeling and upgrading of the current situation.This work will ultimately lead to what successful implementation of it can achieve*:* ***How to minimize road traffic accidents and congestions on the South African roads by maximizing the use of RRRBTTN.***The maximum use of this network will lead to decrease in loss of life.

KEYWORDS

Bus transport networks, road transport network, congestion, integrated transport, location theory, allocation theory, railway transport network.

TITUL

Opatření ke zvýšení bezpečnosti a zlepšení vnitrostátní silniční dopravní sítě a dopravní situace v Jižní Africe

ANOTACE

Tato práce navrhuje zvýšených bezpečnostních opatření na vnitrostátní silniční dopravních sítí v Jižní Africe zavedením spolehlivé železniční, silniční, autobusové a taxi dopravní sítě (RRRBTTN).Hlavní důraz bude kladen na to, jak nejlépe implementovat dopravní síť, která bude schopna snížit počet dopravních nehod na silnicích a vysokou míru přetížení na jihoafrické národní silnice síti. Budu používat otázka-nehlásí přístup, který bude vysvětlovat podrobně navrhovaného řešení Thes problémů a diagnostiku, co je třeba provést, aby lépe tento zchátralý infrastructure. A jak-to struktura, která může být použita v remodelace a modernizace proudu co se práce bude v konečném důsledku vést k provádění úspěšné

dosahuje to možné: ***Jak dopravních nehod a kongescí minimalizované na jihoafrických silnicích maximalizaci využití RRRBTTN***.Uživatel této sítě povede k snížení ztrát na lidských životech na silniční síti.

KLIČOVÁ SLOVA

Autobusová dopravní sítě, silniční dopravní síť, dopravní zácpy, integrovaná doprava, teorie umístění, teorie alokace, železniční dopravní síť

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ACRONYMS AND ABBREVIATIONS

BRT	Bus Rapid Transport
CITIC	Central Integrated Transport Information Centre
CITN	Capetown Integrated Transport Network
CITN	Centralized Integrated Transport Network
CT	Capetown
RTMC	Road Traffic Manangement Corporation
CR	Czech Republic
DBN	Durban
DITN	Durban Integrated Transport Network
DOT	Department of Transport
GP	Gauteng
IRTAD	International Traffic Safety Data and Analysis Group
JHB	Johannesburg
JITN	Johannesburg Integrated Transport Network
NRTN	National Road Transport Network
PITN	Pretoria Integrated Transport Network
PRASA	Passenger Rail Agency of South Africa
PT	Public Transport
PTA	Pretoria
RRRBTTN	Reliable Railway, Bus and Taxi Transport Network
RRT	Rustenburg Rapid Transport Network
RTMC	Road Traffic Management Corporation
RSA	Republic of South Africa
SANRAL	South African National Roads Agency Limited
STATS SA	Statistics South Africa
Taxis	Minibus taxis
UJ	University of Johannesburg

1 INTRODUCTION

The aim of this work is to develop a national transport network model by redesigning and implementating intelligent transport systems on the national level. The network will diagnose the exact problems associated with the current PT system. Examples in this network will integrate and optimize transport systems through an introduction of a reliable railway, road, bus and taxi transport network (RRRBTTN). Practical examples will be graphically presented based on research carried recently out on the state of the national PT. JHB is one of the four major cities this model is suitable for.

In my opinion, economical development of any country lies in its ability to integrate public transportation. I chose JHB, PTA, DBN and CT because they are major economic cities, where this new transport network can be appropriate. This work caters to the public interest of South Africans. Many people choose to use minibus taxi as a preferred mode of transport over rail. This is in part, due to the lack of frequent railway services, lack of transport services in the rural parts regions and lack of passenger safety in rail. The theoretical part of the network focuses on the problems relating to location theory problems and allocation theories. In the practical part there will be graphical representation of places where implementation of this network was successful— at least in my opinion.

RRRBTTN is actually difficult to implement as more research is needed. However with the help of practical examples of the failed networks, I was able to design one that can work. A new central option is proposed with which all four networks are to be interconnected. This is to reinforce network's reliability. Reliability in basic terms is "if the expectation of users is almost always met, and the reliability increases as the frequency and/or consequence of failing to meet user expectations decrease". (*The Network Reliability of Transport ch.1 p2*)

In the final part are the analysis, description and recommendation of this proposed network and its design methods and the limitations this network has and suggestions for further research.

2 REPUBLIC OF SOUTH AFRICA

This chapter provides the reader with geographical facts of the Republic of South Africa, where this network model is designed for. The work is followed by the survey which was carried by the University of Johannesburg in regard to our state of PT. Taxi violence history which inspired the development of this work is also described.

RSA is located at the southern tip of Africa and it is boarded by Namibia, Botswana and Zimbabwe to the North and to the east by Mozambique and Swaziland with Lesotho within:

Figure 1 - National map of the RSA

Source: [1]

RSA has a population of over fifty million people and was divided in nine provinces after the apartheid (people segregation based on colour of their skin) period in 1994.

It has four main capital cities i. e. JHB, PTA, DBN and CT.

Table 1 - List of South African provinces by population

Rank	Province	Population (2011)	Percentage	Population est. (2013)
1	Gauteng	12,272,263	23.7	12,728,400
2	KwaZulu-Natal	10,267,300	19.8	10,456,900
3	Eastern Cape	6,562,053	12.7	6,620,100
4	Western Cape	5,822,734	11.2	6,016,900
5	Limpopo	5,404,868	10.4	5,518,000
6	Mpumalanga	4,039,939	7.8	4,128,000
7	North West	3,509,953	6.8	3,597,600
8	Free State	2,745,590	5.3	2,753,200
9	Northern Cape	1,145,861	2.2	1,162,900
∑	**South Africa**	**51,770,561**	**100.0**	**52,982,000**

Source: [2]

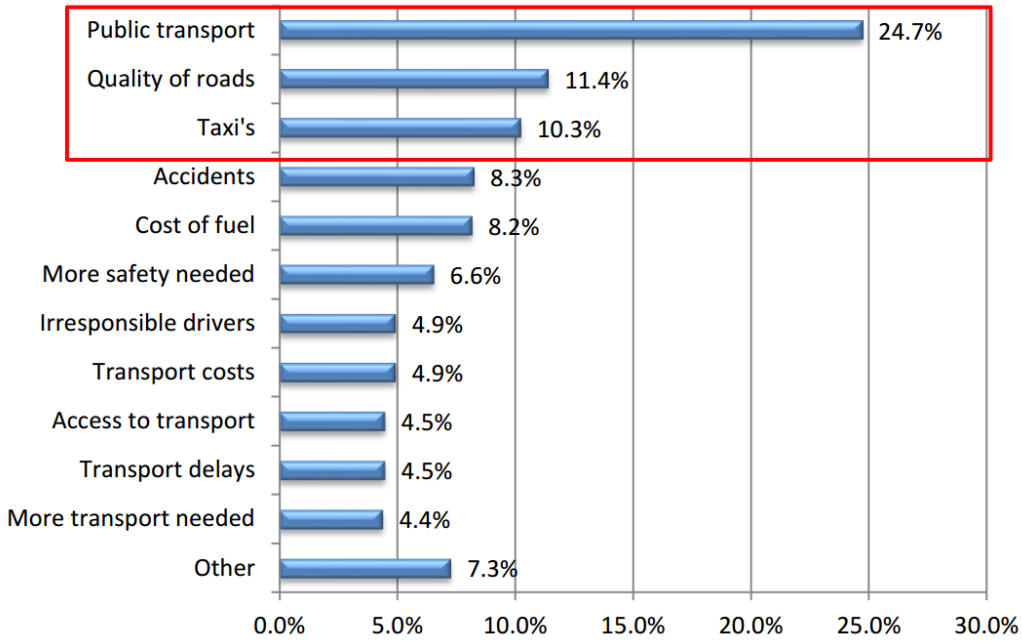
Despite some progress made in bettering the PT network post apartheid by regulating transport, South Africa continues to experience problems. The South African government continues to this day to encounter all sorts of challenges in rolling out plans to implement the BRT System in all four major cities.

2.1 The taxi industry

The taxi industry is historically significant for the economic empowerment of black South Africans. During the apartheid period, the taxi industry played a pivotal role in the South African economy by transporting the black masses to and from their homes to work. And to this day it continues to play such role. Through the years it had produced some wealthy black South Africans and continues to do so. The industry continues to provide many opportunities for small-business creation. They serve as a stepping stone to larger and different businesses. The taxi industry also provides substantial employment and helps in alleviating poverty. The taxi industry provides more security and has a greater accessibility than the PT. It's more convenient and relatively inexpensive and has less waiting time compared to the PT; in addition, it provides people with easy access to their jobs.

The industry is driven by entrepreneurs who are risk takers and identified and served the needs of black commuters for years and while also empowering themselves. They focus on serving the niches such as township tours for tourists. Sixty percent of South African population to date still prefers to use a minibus taxi over rail or buses. [STAT SA]

In the most recent February 2013 survey which was conducted by the University of Johannesburg abouth the state of South Africa's transport problems (currently; in a year's time and in five year's time) under the question: ***highest transport issues in RSA now*** and below were its findings:

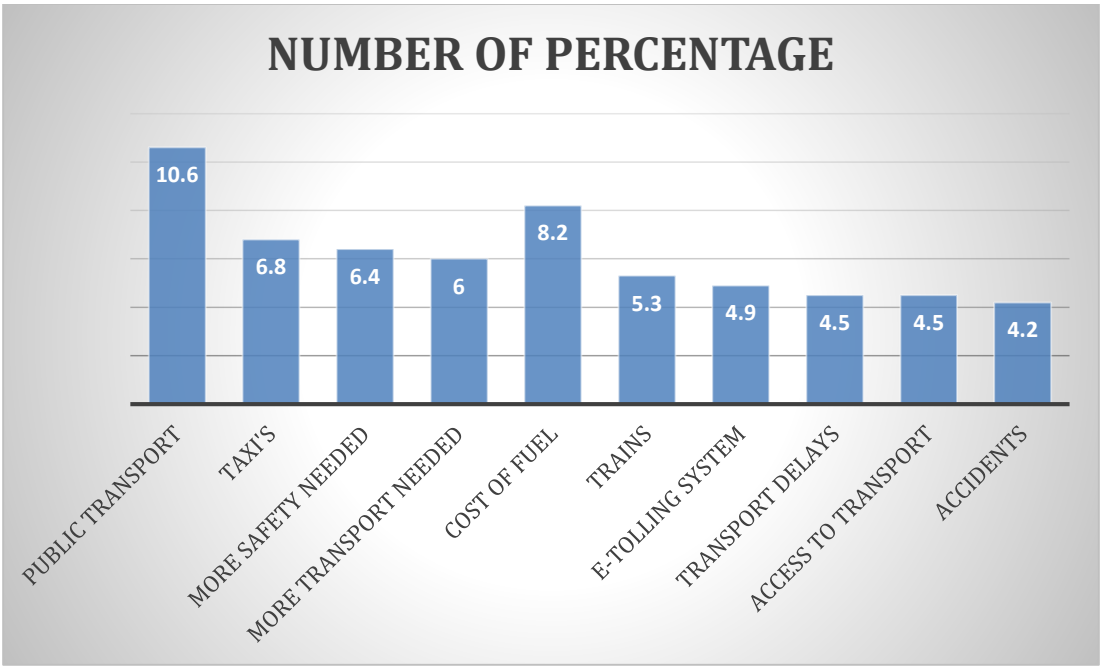


Graph 1 - Findings from the University of Johannesbrg survey

Source: [3]

There are more inclusive survey results which indicate that public transport is by far the **highest priority issue in transport** in RSA. Almost 25% of South Africans highlighted this as an issue. The UJ survey team further conducted a survey under the same topic but more provincial and specific i.e.: ***Gauteng, Limpopo and Mpumalanga***.

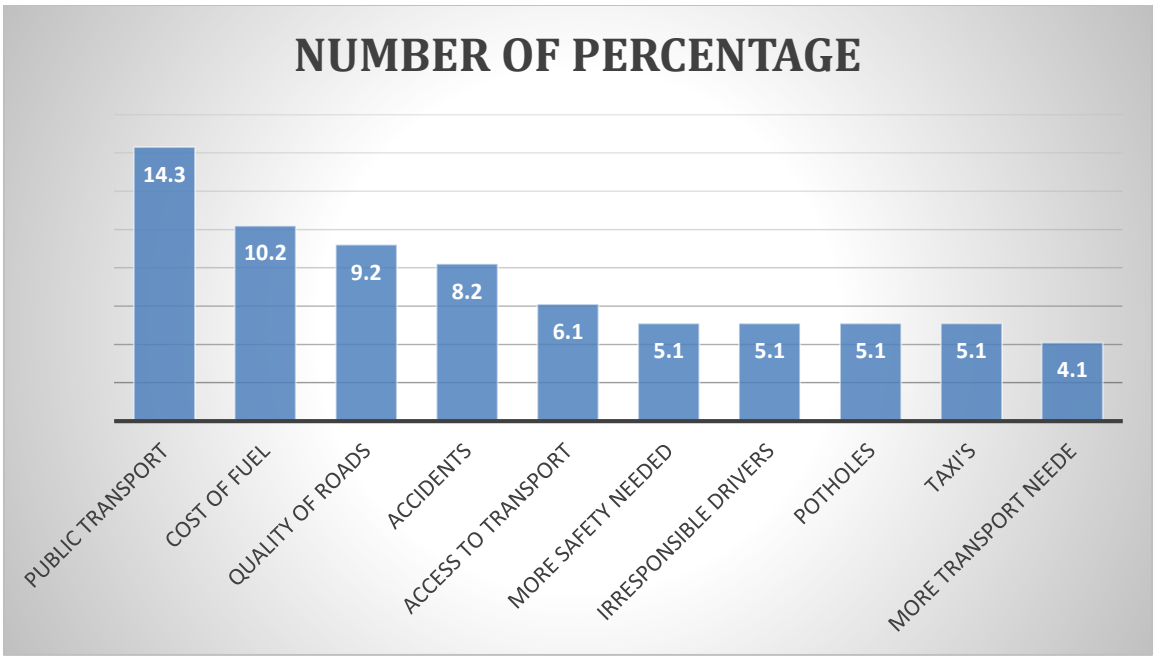
The same question in these provinces was posed and it was noted that transport was the second highest priority after education in these provinces and that Gauteng's public transport was the **highest transport issue**.



Graph 2 - Gauteng survey findings

Source: [3]

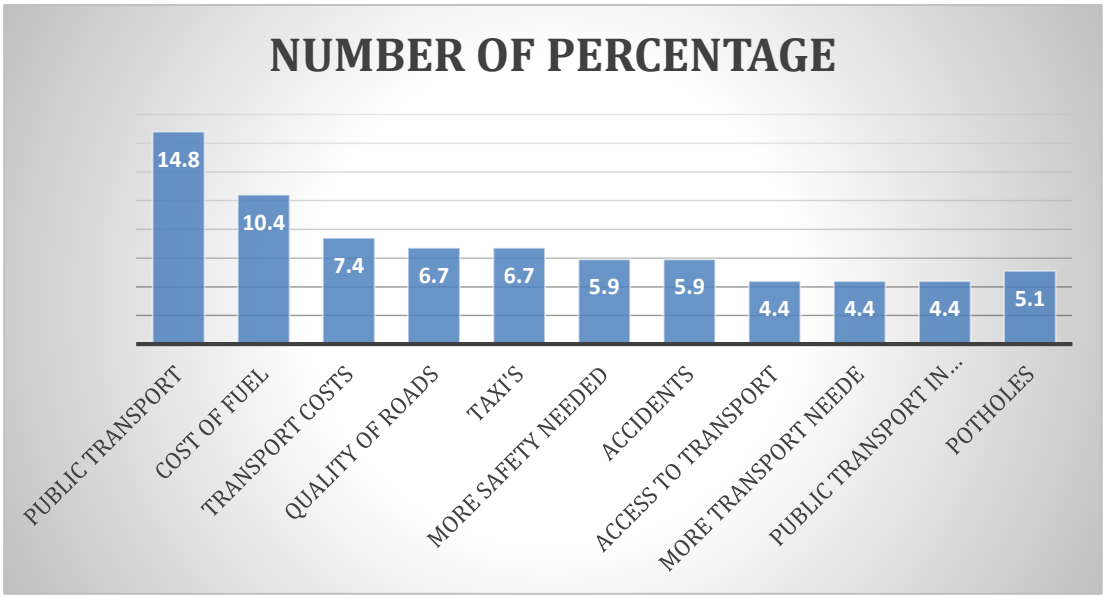
As **graph 2** indicates that PT in Gauteng is the **highest in transport issues** due to amongst other things, the **unreliability of trains**, and **less security.** The worst of all is the upcoming **electronic tolling (e-toll) system** which went live on the third of December 2013 between JHB and PTA. Commuters and private car owners are frustrated and angry as they are now literally forced to pay for the use of the national transport road infrastructure. E-tolling is unfair to many struggling South Africans and further indicates failures by the state in transforming public transport.



Graph 3 - Limpopo survey findings

Source: [3]

In Limpopo as **graph 3** indicates, similar issues in regard to the state of the public transport raised more especially in the most rural parts of the province where **accessibility** and **shortages of transport services.** PT required more attention and funding associated with these shortages were higher due to **multiple commutes** that residents are faced with.

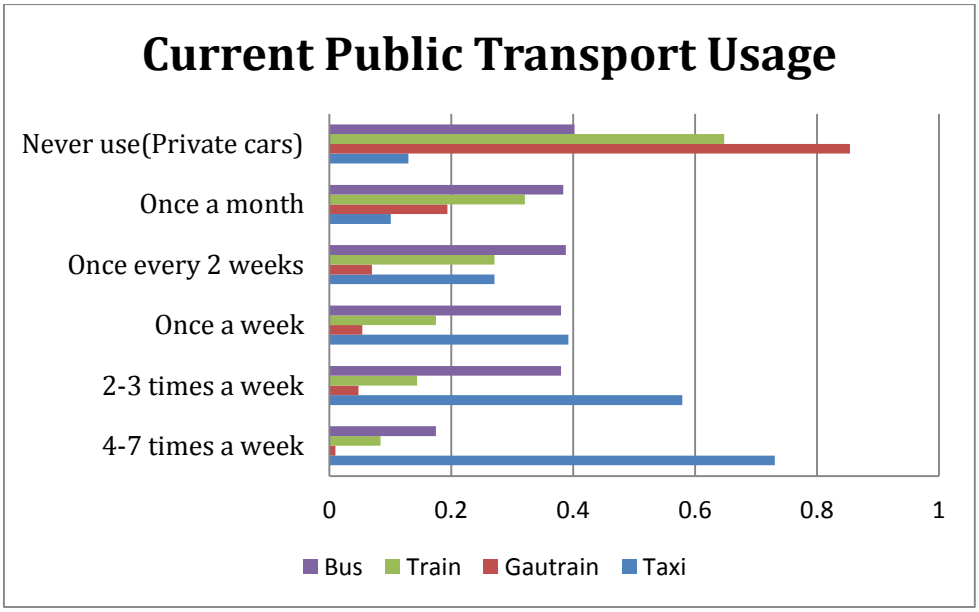


Graph 4 - Mpumalanga survey findings

Source: [3]

Mpumalanga as **graph 4** indicates, echoes the problems of Limpopo residents with **accessibility and shortage in transport services** cited as problems.

Additionally there is the ***quality of the roads*** with ***potholes*** being the predominant factor which is worsens by ***irresponsible drivers.*** The Mpumalanga provincial government still struggles in enforcing the full might of the law against offenders. Questions in regard to whether the current PT state in general was better a year ago; only **32%** felt it was, compared to **50%** those who said very little had changed. South Africans were also quizzed on their optimism whether PT will be better in five years with **57%** believing PT will be better and **RRRBTTN** is the **only** remedy that will determine that optimistic fact.



Graph 5 - Current public transport usage

Source: [3]

Graph 5 is graphical representation of the current PT use and in relation to the regular public transport users (4-7 times a week). Minibuses are **clearly the predominant mode of transport**, followed by **buses**. The same is also true for commuters who use public transport 2-3 times a week. For public transport users that commute less frequently, buses become the dominant mode of choice. Numerous South Africans never use any form of public transport. Nearly **two-thirds** of South Africans **have never used trains**. However, **86%** of South Africans have indicated that they have used taxis as a form of transport the survey had found.

2.2 South African transportation background

2.2.1 Roads

South Africa has the longest road network of any country in Africa. Its national road network currently covers **7,200 km**. The roads include **1,400 km** of *dual* carriageway freeway, **440 km** of *single* carriageway freeway and **5,300 km** of *single carriage main road* with unlimited access. 27 mainline toll plazas service approximately 1,900 km of toll roads. In 2003/04 provincial budgets for infrastructure and road development rose by 7.5% to R5.1 billion. Construction of the N4 Maputo Corridor Toll-Road has been completed, one of the few privately financed cross-border toll-roads in the world.

A road-classification system includes the following categories:

- 9,600 km of surfaced national toll and non-toll roads,
- 56,000 km of surfaced provincial roads,
- 300,000 km of gravel provincial roads,
- 168,000 km of surfaced and un-surfaced urban roads,
- 221,000 km of unclassified roads (predominantly access roads in rural communities and roads in settlements on the urban periphery).

2.2.2 Railroads

Spoornet is the largest division of Transnet, and specialises in freight transport and long-distance passenger services. It also operates the Blue Train, a luxury train service.

Transnet has an annual turnover of R13.1 billion and utilises 30,400 km of track, 2,410 locomotives, 88,000 wagons, and 2,097 passenger coaches. With 80% of Africa's rail infrastructure, Spoornet also connects with other networks in sub-Saharan Africa.

Spoornet plans to invest R1 billion a year in rail transport over the next 15 years.

2.2.3 Other specialist spoornet divisions

- **Coal Line** – Responsible for transporting export coal from Mpumalanga to the Richards Bay Coal Terminal.
- **Ore Line** – This hauls iron ore over the 861 km track from Sishen in the Northern Cape to Saldanha Bay.

- **Shosholoza Meyl** – Which offers daily inter-city passenger services.
- **Metrorail** – This provides commuter rail services in the Witwatersrand, Pretoria, Western Cape, Durban, Port Elizabeth and Cape Town. Metrorail transports two million commuters to and from work daily.

2.2.4 Aviation

The ACSA owns and operates the nine principal airports, including the three major international airports in *Johannesburg, Cape Town and Durban*. The others are domestic airports in Bloemfontein, Port Elizabeth, East London, George, Kimberley and Upington. ACSA's investment in development, the new R750-million domestic terminal at Johannesburg International Airport, will increase its capacity to serve more than 18 million passengers annually.

ACSA has committed R1 billion to the upgrading and development of Cape Town International Airport. A R10-million interim expansion project to extend the domestic terminal was completed in May 2003.

2.2.5 South Africa's international airports

OR Tambo international airport which is located in gauteng is one of the busiest airports in the African continent.

- Johannesburg,
- Cape Town,
- Durban,
- Bloemfontein,
- Port Elizabeth,
- Pilanesberg,
- Lanseria,
- Gateway (Polokwane),
- Nelspruit,
- Upington,
- Kruger Mpumalanga.

2.3 Comparison between RSA and the CR

In a recently released report by the IRTAD, it's evident that South African road safety measures in relation to the rest of the world are yet to be reinforced, as we have one of the highest road fatalities, at 27.6 compared the rest of other countries. :

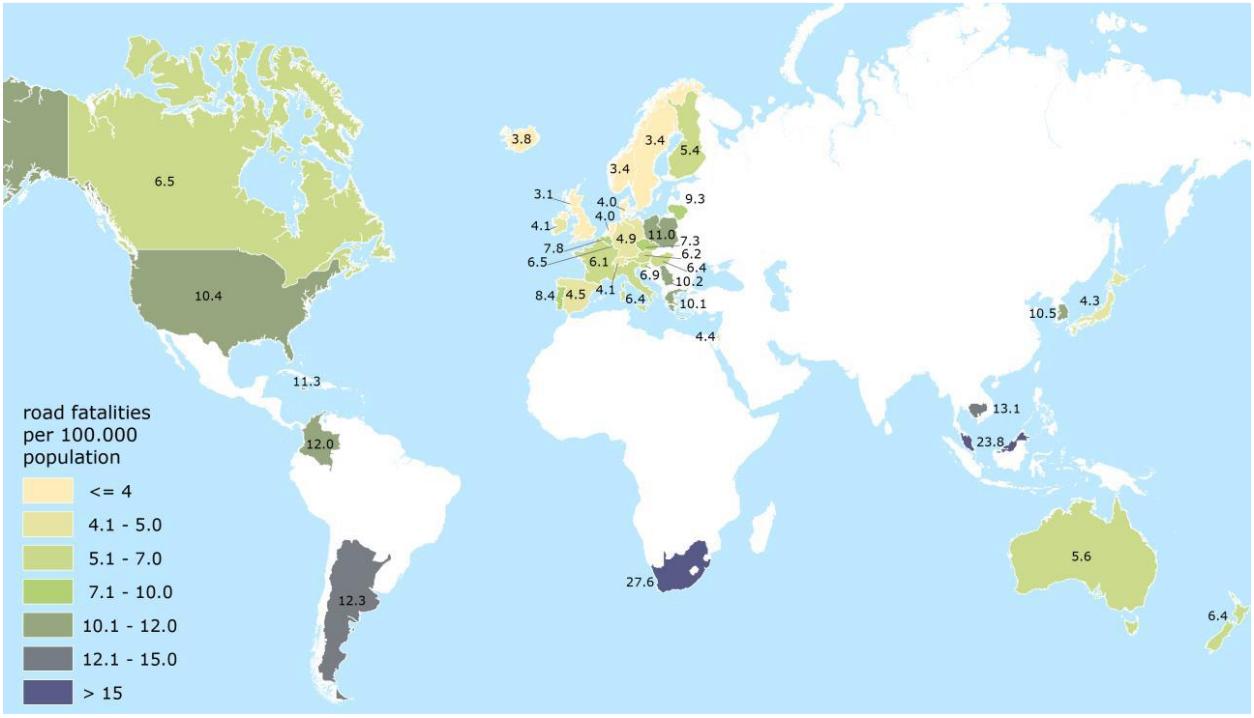


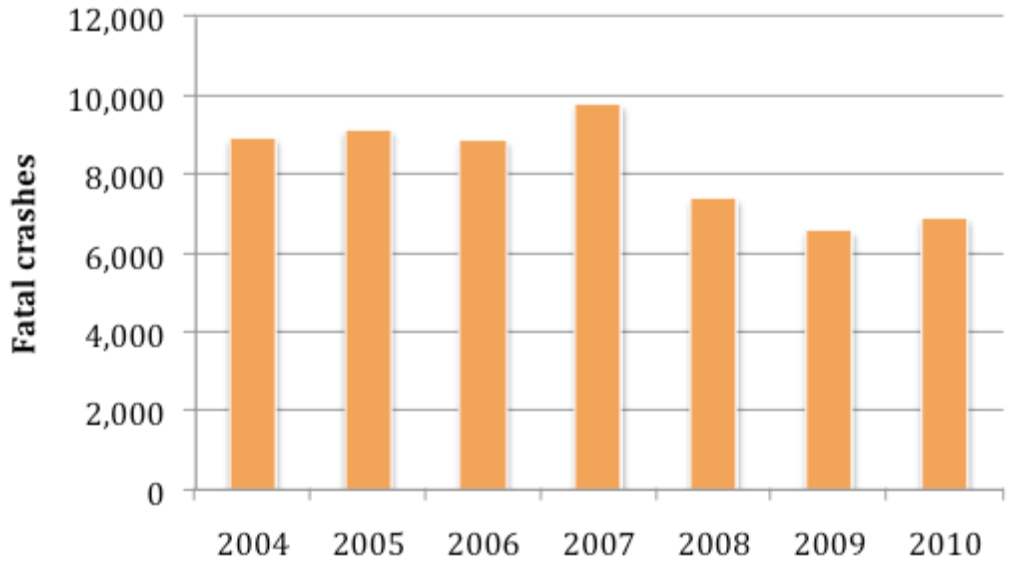
Figure 2 - Road fatalities per 100 000 population in 2011 in IRTAD member and observer countries

Source: [5]

2.3.1 Road accidents

According to the statistics released by the National Department of Transport, there was an increased in the number of **fatal crashed** from **6568** in 2009 to about **6890** in 2010.

Chart 1- Fatal crashes in 2004 to 2010



Source: RTMC

Narrowing it down the comparison between RSA and CR in relation to the road fatalities as **table 2** demostrate how high road fatalities rate in South Africa.:

Table 2 - Comparison between RSA and CR

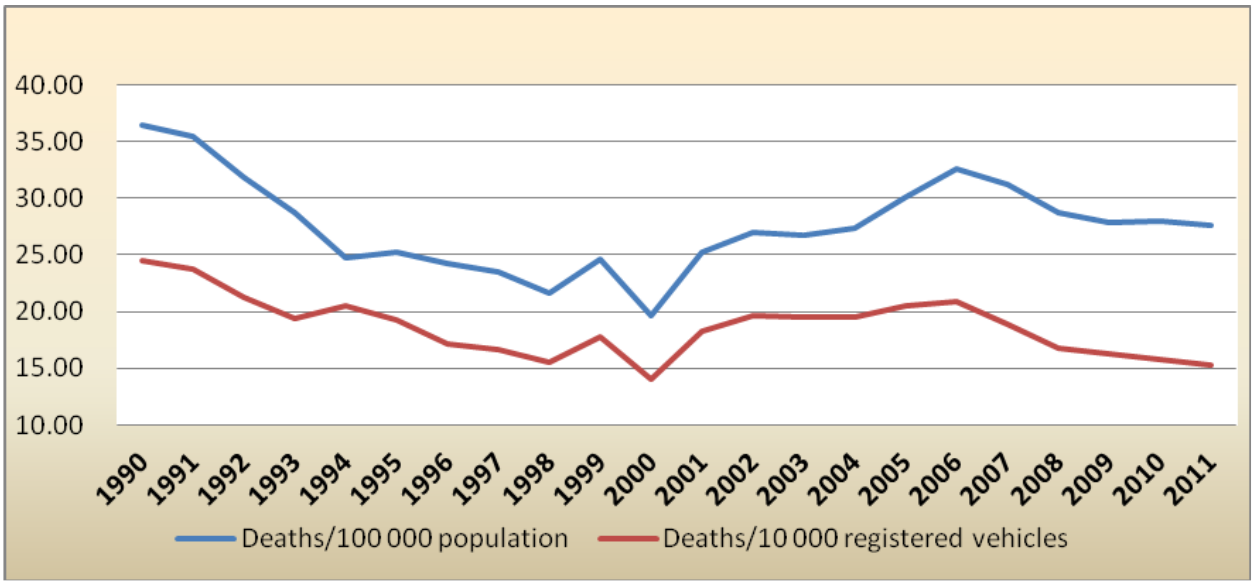
	RSA	**CR**
Inhabitants	51.8 Million	10.5 Million
Vehicles/1 000 inhabitants	N/a*	534
Road fatalities in 2011	13 954	773
Fatalities/ 100 000 inhabitants in 2011	27,6	7,3

Source: [5]

** Denotes not applicable*

Studying **table 2**, it's evident that South African roads are more deadly than the Czech Republic's. In this thesis, I explain what can be done to improve this. The how-to structure that will better the next outcome by offering alternative ways PT can be enhanced in order to reduce the high rate in traffic road fatalities by implementing RRRBTTN.

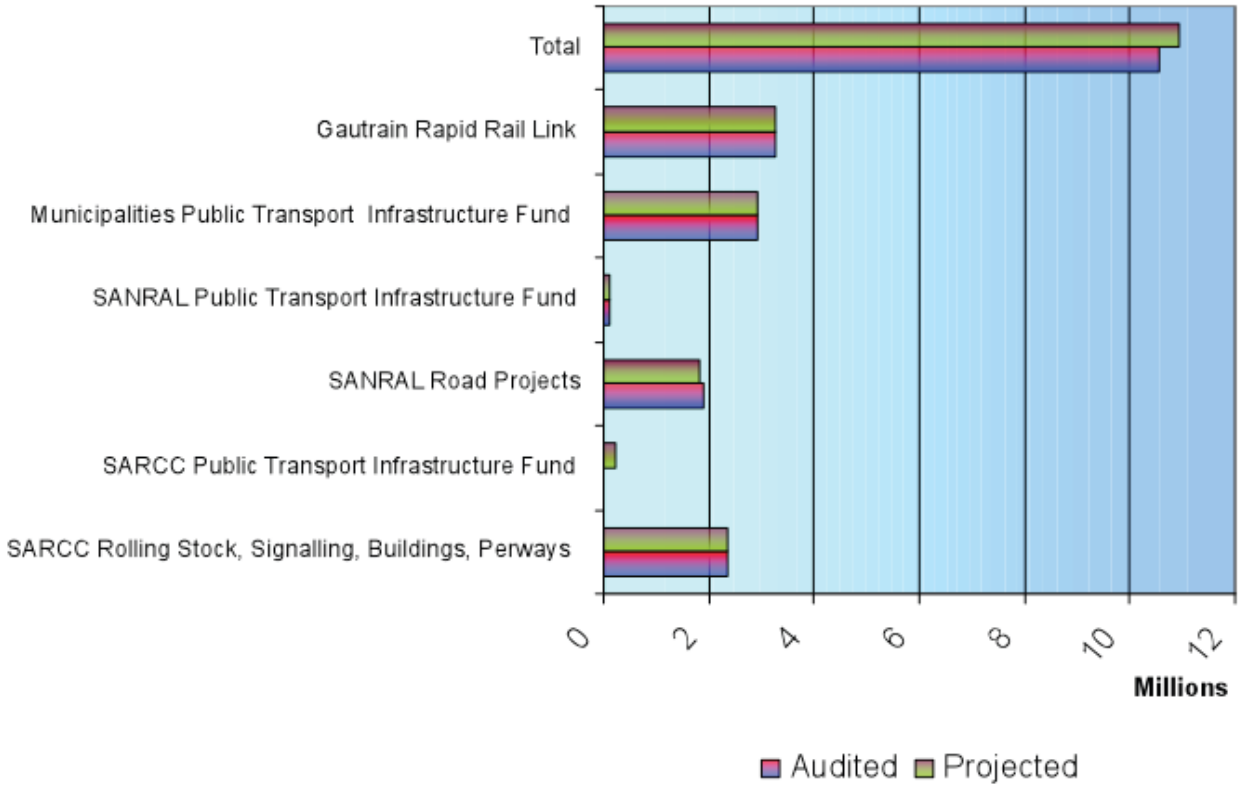
Graph 6 highlights the number of deaths per 100 000 population in the last two decades which has been significantly increasing.



Graph 6 - Evolution in death rates 1990-2011

Source: STAT SA

Chart 2- Summary of Expenditure on Infrastructure, 2005/06-2009/10



Source: Transport statistics bulletin, 2010,*P25.*

2.4 RRRBTTN

The economical prosperity of any country lies in ability to integrate its PT. An affordable public transport network is the heartbeat of any civilized country around the world. A country's success heavily relies in its willingness to integrate PT.Integrated transport networks cater to the ever growing demand of a perfectly integrated transport structure. As RSA is one of the fast emerging countries in Africa and its most developed country, it is in the country's best interest to have a well structured integrated transport network infrastructure in place, with a sophisticated, reliable, secure, integrated and an affordable form of PT. South African roads have increasingly became more deadly to both pedestrains and road users alike due to the high dominance of the sixteen seater minibus taxis's increased recklessness on our roads.

The South African government has over the years been battling and continues to do in trying to regulate and manage the use of minibus taxis. Often their intervention is met with either violence or in most cases loss of life from minibuses taxi owners. This thesis presents a questions-answers approach and diagnosis needed in implementing RRRBTTN in order to finally resolve this continuous long existing strife that the RSA government had been experiencing whenever they wanted to completely get rid of the use of minibuses. This proposed new network will introduce factors that define a reliable, integrated PT network which encorporates buses, rail and minibus taxis with emphasis on rail and bus as a preferred mode of transport. Its successful implementation can be able to finally put to rest these conflicts and subsequent decreases minibus taxis usage and deaths on our roads. This will allow both private and public operators to still be able to economically benefit from its successful implementation.

A ***remodelled integrated, cost effective, reliable, people oriented, and timely*** transport network and RRRBTTN is a solution to fixing these current transport network challenges. JHB has a population of over ten million people which are living and working in and around the JHB metropolitan area. A good and reliable transport network is what all four major cities: PTA, JHB, DBN and CT needs in order to address the challenges identified in the previous surveys such as congestion and lack of transport facilities in some areas.

2.4.1 What is a RRRBTTN

RRRBTTN is *a **timely people-oriented and integrated*** transport network which incorporates rail, bus and taxi with emphasis in **rail and bus** to be able to give South African people a seamless inter-connected mode of transport which comprises of the following:

a) The Network is to be people centered instead of profit driven; profits will still be made as satisfied customers will be regular customers.

b) The Network is to have a centralized control station that will monitor traffic in all four modes of transport, to enforce its reliability and effectiveness.

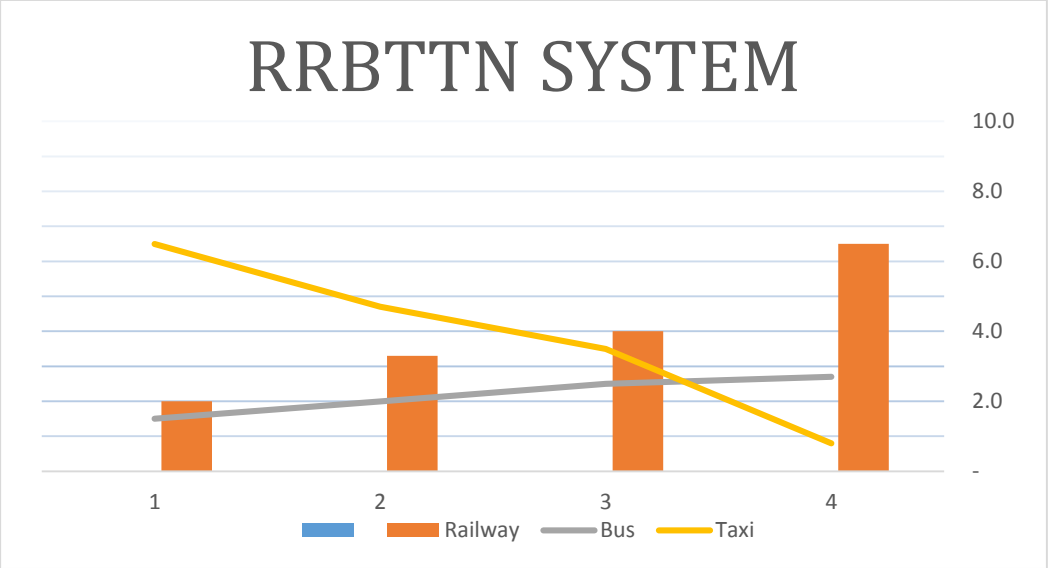
c) Interconnections of the network in the frequency of every ten minutes during peak hours and fifteen to twenty minutes during offpeak hours, this is to intensify and enforce smoothness of the network.

d) The Network to be **affordable, centralized, secure and safe** for the users. This will enforce network's robustness and its usability.

2.4.2 Objectives of the RRRBTTN

The objective of the RRRBTTN is to shift the over sixty percent of passengers from minibus to rail and bus transportation as preferred mode of transport. RRRBTTN will achieve this in four stages. **Graph 7** indicates that, at least **sixty percent** of the South African population currently relies on minibus which RRRBTTN would redress in four stages.

The first phase highlights the number of percentages (for all three modes of transport) summed up (i.e. minibus, bus and rail) which makes a hundred percent respectively. The initial phase represented by number one can be implemented in the first three to four years.



Graph 7– Graphical representation of the RRRBTTN

Source: Author & STAT SA

Advantages of RRRBTTN

- Introducing integrated ticketing system:15min, 30min, 90min, etc,
- Interconnected integrated transport network,
- Enviromentally friendly transport network,
- Reliable and timely at all times,
- Passenger-oriented network design,
- Real time traffic data-sharing through out the entire CITIC network,
- Prioritizing safety, timeliness, affordability and comfortability at all times,
- Data-aide planning: timetables, Liquid-crystal displays (LCDs).

Disadvantages of the RRRBTTN

- Disrupted nodes of the network.
- Network vulnerabilities-undetected network inability to fully function.

2.4.3 Factors that define transport network reliability

Transport network reliability can be defined as network's ability to operate with the minimum disruption as possible. Transport network unrealiability is a huge problem if not

properly addressed. There are many factors that can lead to unrealiability; the following seven are the core factors extensively contributing to the reliability of a network.

- **Terminal reliability**

Terminal reliability is commonly defined as "the probability that nodes are connected, i.e. it is possible to reach the destination", and is the simplest, most fundamental reliability measure. To determine this measure, each link in a network is assigned **a functional probability** denoted by *x* that represents the likelihood that the link will function at any given time. This will be **1** if the link always functions and **0** if it never functions; intermediate values of *x* denote links that function x% of the time.

In order for any single path to function, all of the links in that path must function. Since basic probability theory shows that P (A∩B) =P (A) ×P(B), the probability that a single path will function is the product of the probabilities of all links in that path. In the case where the origin and destination are connected by more than one path, the network will function as long as any one path functions. Since P(A∪B)=P(A)+P(B)-P(A∩B), the probability that the origin and destination (OD) are connected can be calculated after establishing the functional probability of each possible path.

- **Encountered reliability**

Bell and Schocker (2002) defined it to be the probability of not encountering link degradation on the path with least (expected) costs.This measures the likelihood of users encountering a disruption on their preferred route. (*The Network Reliability of Transport, ch1, p8)*

- **Capacity reliability**

Chen et al (1999) defined it as "the probability that the network can accommodate a specific demand level". Although capacity reliability does not take into account restrictions and can therefore overestimate the reliability. It can also be viewed as the probability that a network use will be able to complete a trip without encountering a degraded or over-capacity link. In this sense it is a refinement of terminal reliability, which considers neither link capacity nor user demand and link selection.

- **Travel time reliability**

Travel time reliability is the probability that a trip can be successfully finished within a specified time interval (or less than a specified cost). It is used most often on networks where **travel demand** fluctuations to some degree random, such as **road networks** and other **multi-user networks**.

- **Flow decrement reliability**

Du and Nicholson (1997) proposed measuring reliability using the probability that the reduction in flow (as a result of supply-demand interaction) is not less than a threshold, for both origin-destination (OD) network pairs.

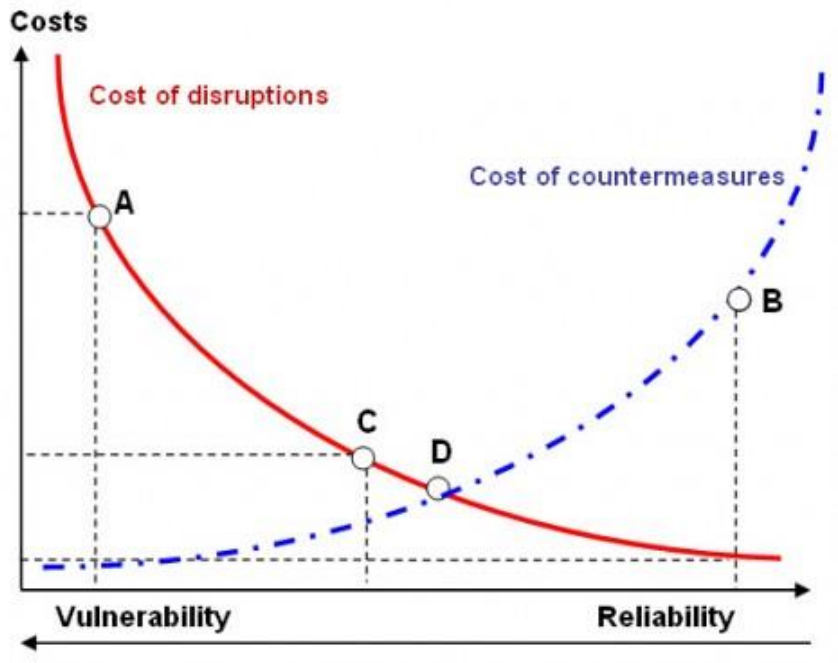
- **Vulnerability**

Vulnerability has been treated with varying degrees of complexity. In its simplest treatment, vulnerability is effectively the inverse of reliability: as a network's reliability decreases, its vulnerability increases and vice versa.

2.4.4 Reliability versus vulnerability

Graph 8 illustrates the relationship between **vulnerability and reliability**. The **investment costs**, and hence the **assumed reliability** thus, increase from left to right (dotted line), **disruptions costs**, and thus **vulnerability**, increase from right to left (solid line). From a strictly economical point of view, the cost of increasing the reliability should not exceed the cost of vulnerability for society to experience a benefit.

Source: [6]



Graph 8 - Vulnerability versus reliability

Source: [7]

What is apparent is that it may be straightforward to quantify the investment costs associated with an effort to increase reliability, the costs of disruptions are much harder to quantify in measurable terms, albeit it can be done. The investment costs are included as a cost in cost-benefit analyses; however, saved disruption costs are not included as a benefit. Consequently, a proposed investment is not valued correctly, if saved disruption costs are not properly accounted for. The question that arises is whether saved disruption costs represent a utility similar to saved travel costs.

2.4.5 Vulnerability and multi-criteria analysis

Elements that project evaluation procedures are taken explicitly into account in order to incorporate considerations of vulnerability:

1. The probability and impact of failure of a given network, link or route-a chosen path, given various external circumstances or strenuous conditions.
2. The probability of those external circumstances occurring.
3. The robustness of the system (i. e., the probability that the system will continue to function even if a threat eventuates at a vulnerable point).

4. How long it will take (and how expensive it will be) to repair the system if the threat occurs and the system fails at its vulnerable point.
5. What the costs are to the general economy of such a failure (i. e., goods and passengers not getting to their destinations, or getting there late, transportation carriers being forced to use expensive detours, etc.).
6. The contribution of a given project to improving the robustness (and hence reliability) of the system.
7. What degree of risk aversion that should be applied in deciding what weight to place on the risk (i. e., level of threat time's vulnerability) that has been identified.

Source: [7]

3 OBJECTIONS OF THE RRRBTTN

The objective of this network proposal is to re-design the current PT by first identifying the problems associated with it.

table 3 indicates identified problems with what could be done to correct them. Transport network that can actually address these adversities with a more **passenger-oriented design approach**, to maximising railway transport usage.

table 3 - Perceived public transport problems and potential solutions

Problems	Service improvement strategy
Crowding on all modes, difficult to get off	Demand responsive operations; computer-aided dispatch; Increased frequency
Long waiting time	Dynamic scheduling planning; improve route structure; traveller info information systems
Inadequate protection form the elements	Data to support planning; public/private partnerships; Customer-orientated
Railways do not adhere to timetable where there's one	GIS or GPS-based vehicle identification; location and monitoring systems; improve network route structure and information dissemination
Uncomfortable seats	Data-aide planning; customer-orientation [increase comfort]
No space for parcels	Data-aide planning; customer-orientation
Long distances to mode	Data-aide planning; GIS-based AccessMap & AccessFlow; Feeder services; fare integration; services coordination
Network modes shortest at times	Demand responsive transit operations; vehicle maintenance & automated reporting
High Fares	Integrating ticketing; electronic ticketing; smart cards; integrated transit management centre
Safety on railways	Improved transit security (emergency access to centre)
Too many transfers	Integrated transit management; data-aide planning; fare integration; timed transfers; tailored schedules
Lack of information and knowledge about services	Information dissemination: bus stop/station information; traveller information centre; computerized and real-time information systems, touch screens technology

Source: Author

3.1 RRRBTTN methodologies and approach

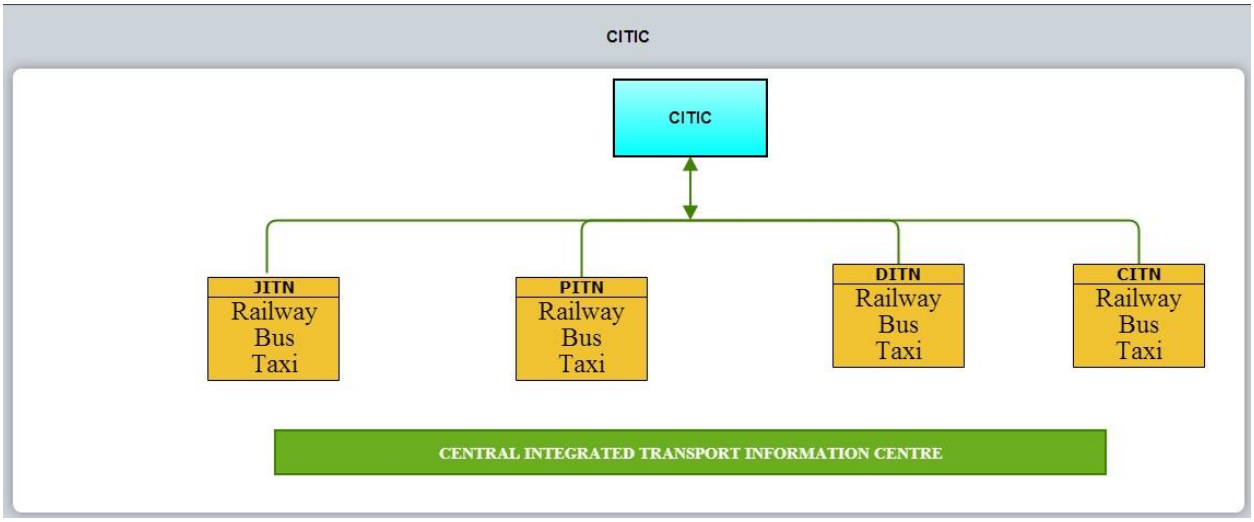
The approach offered in this Thesis is simple, as it seeks to address the need to ***maximise*** railway usage directly propotional with the buses as feeder line providers. Thanks to the already existing railway lines through out the country. The thesis further proposes an introduction of high-speed Pretoria Express (PE) and Durban Express (DE) trains.The Blue, (our "Euro night" train covering PTA-CT routes with feeder buses at either destination stations which is to cater for the areas where railway) has not yet been constructed.

With the introduction of these new high-speed trains, this will be economically beneficial as it'll minimize the travel time between these two cities. This will result in direct traffic congestions reduction on our national road transport networks. Consequently the use of taxis will proportionally decrease as more and more people will be using these new infrastructures. Security and convenience will be offered by the availability of these high-speed trains to and from work. It further will reduce emissions as less and fewer cars will be on our roads which will be beneficial even to the enviroment as more people transfer to rail use.

3.1.1 Central integrated information transport network centre

RRRBTTN will centralize this entire network into one as illustrated in **graph 9** having a central command station that constantly supply real time information synchronically across the entire transport network. This constant information flow is one of the important aspects that minimizes the vulnerability of network and increases its reliability. Currently a lot of agencies are supplying different data which is not accurate or reliable.

RRRBTTN addresses interconnectivity issues by introducing a new design to the existing national transport network. It is more robust, seamless, data-sharing, and realible. Its strenght can easily be measured. See **graph 9** the CITIC interconnects all four major cities i. e. JITN, PITN, DITN and CITN.



Graph 9 - Diagram representation of the RRRBTTN

Source: Author

In my search to prove the significance of this work and to intensify multi-model functionality, Brno main station has a similar transport network and is in my view a perfect example of a truly integrated public transport system. It offers passengers a variety of choices of mode of transportation (tramway, taxis and buses). And they are located right opposite the railway station and this enfources network's reliability. And I am convinced that similar model can work for our national PT network. This can further contribute to a decrease in enviromental pollutions as electric tramway will be used. See **figure 3.**

Figure 3 – Brno main railway station

Source: Author

3.1.2 JITN

The Johannesburg metropolitan region is the economy core of RSA, known as the city of gold with a population of about 12 milion people living and working around it. It is therefore important that PT is properly integrated. This will upgrade it to a city that has a cost-curbing transport system.

3.1.3 Objectives of the RRRBTTN in relation to the JITN

In 2006, South Africa was chosen to host 2010 World cup tournament. Transport infrastructures needed to be upgraded to meet the anticapated huge demand. A massive multi-billion rand infrastructure was rolled out through out the metropolitan regions. Gautrain, the continent's first fast train and the bus rapid system (BRT) were built. The BRT system complement Gautrain's bus transport network system.

Gautrain's implementation was a success as it reduced travelling hours between JHB and PTA. It works the same as SC Pendolina, however it lacks storage facilities.

3.1.4 The Current state of the PT in JHB

The below **figure 4** illustrates the current BRT system routes network which will be fundamental in complementing the proposed remodeling of the integrated transport network, the RRRBTTN.

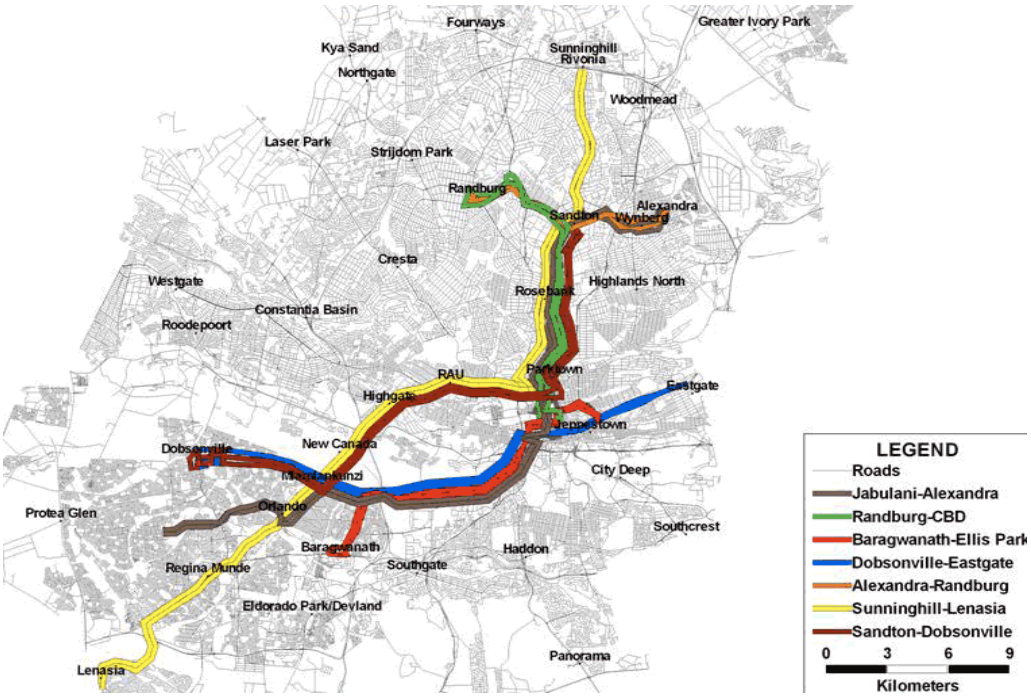


Figure 4 - The current BRT network in and around Johannesburg

Source: [8]

The Johannesburg BRT system consists of 90-seater capacity trunk buses and 32-seater feeder buses, which bring people from outer areas to the trunk routes. Over time, Rea Vaya will cover more than **300 km** of trunk routes across the city, and is expected to transport 430 000 passengers daily. It is expected that business professionals and companies will use the system, moving private vehicles out of the congested roads. The BRT routes are designed to link up with the inner-city distribution system and various other development nodes and residential areas. Various public transport interchange facilities along the routes are expected to provide connection to other road-based public transport services in other areas of the city.

3.1.5 Translux

Translux is one of the many private bus operators that transports commuters across the South African Provinces and plays a central role in rendering services to the passengers throughout RSA. **Figure 5** is the transport network that Translux currently uses and RRRBTTN's effectiveness will seek to encourage the use of rail rather to contribute to climate change.

Figure 5 - Translux network routes

Source: http://www.translux.co.za/routes.aspx

3.1.6 **Intercape**

Intercape is yet another private bus company that offers long distance travelling service across South Africa. RRRBTTN aims at complementing these existing bus feeder lines to increase its reliability as a public transport network. There are several other bus companies which provide transportation in the rural parts of PTA.

Figure 6 - Intercape network routes

Source: http://www.intercape.co.za/route-map/

3.1.7 The rea vaya bus transport network

Figure 7 highlights how the successful integration of the BRT system has optimized travelling in central Johannesburg and, as proposed in my thesis, the same approach should be applied to all other major cities as well.

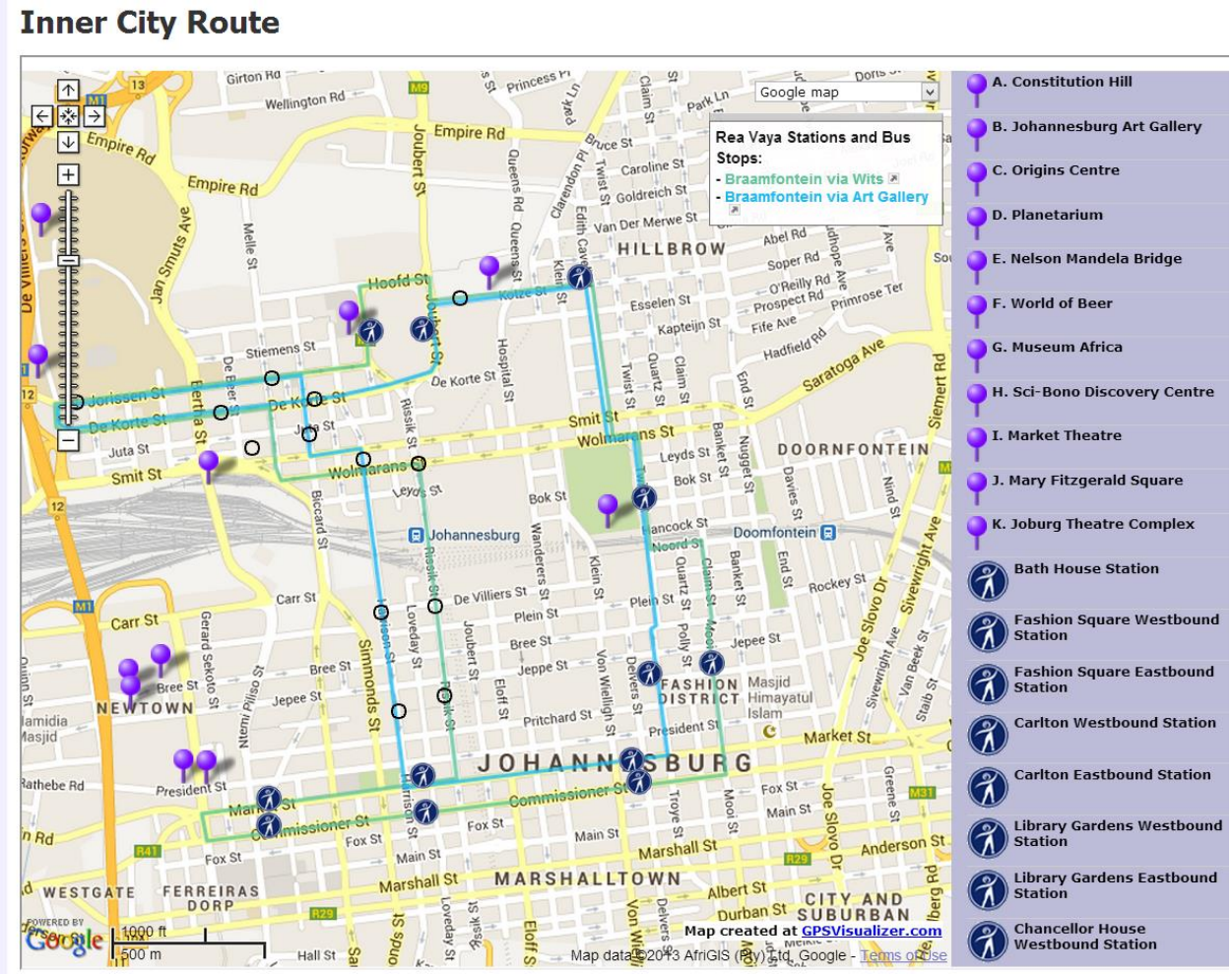


Figure 7 - Rea vaya inner city route

Source: [9]

3.1.8 Jhb and Dbn new transport routes

Figure 8 is a blueprint for the high-speed train that will connect JITN and the DITN. It will be as efficient-effective-reliable as possible and will shorten the travel distance of the current original-destination (O-D) between these two cities by about 44 kilometer. It will also increase of workers between these two cities and this will boast employment as people

can be able to work either in Johannesburg or Durban without having to worry about transportation problems.

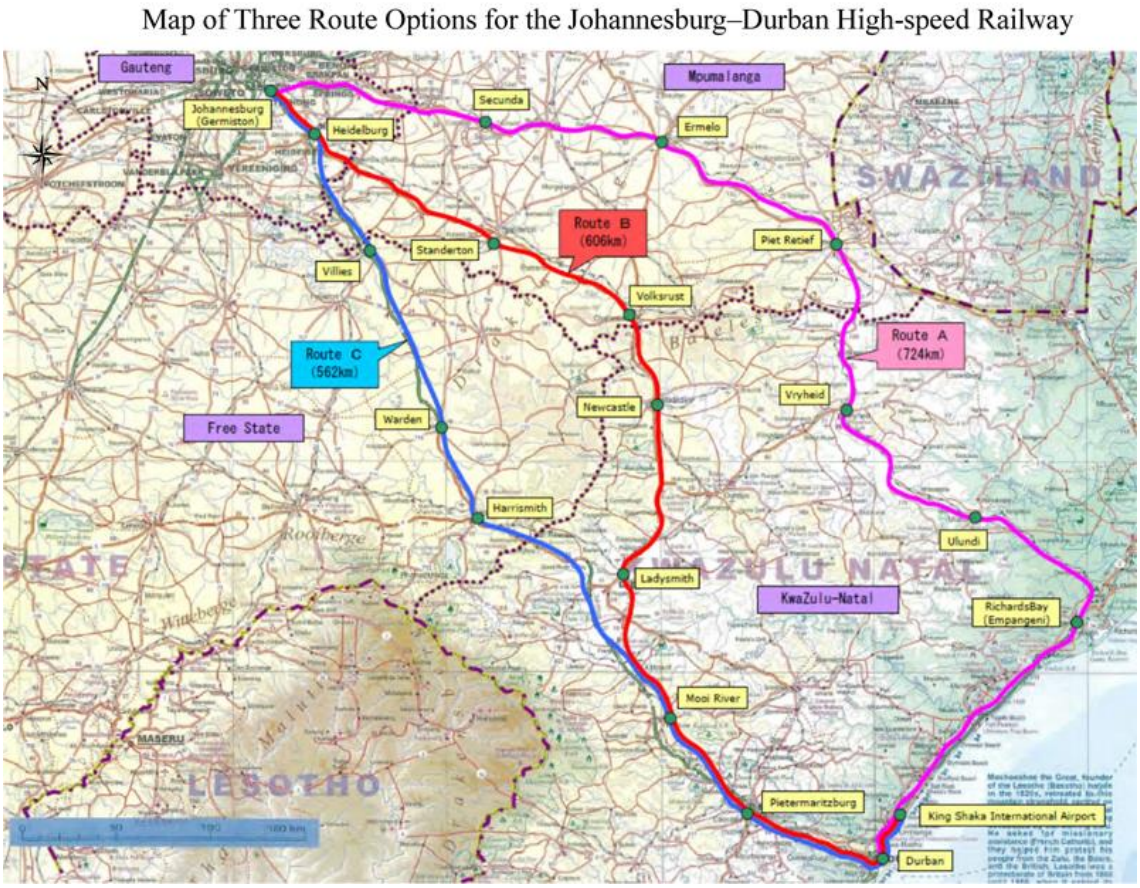


Figure 8 – Feasible studies of the new high-speed train between JHB and DBN

Source: [10]

3.1.9 RRRBTTN methodologies and approach for Gautrain

JITN seeks to integrate the available transport network to make it more seamless through implementation of the proposed Durban Express (DE). DE is a high-speed train that will transport passengers between Durban and Johannesburg at an optimized time yet safely and efficiently. It should run coherently with the buses to reinforce reliability and efficiency of the network.

Part of the railway network is already in place but will require renovation and remodeling towards optimization of the entire RRRBTTN.

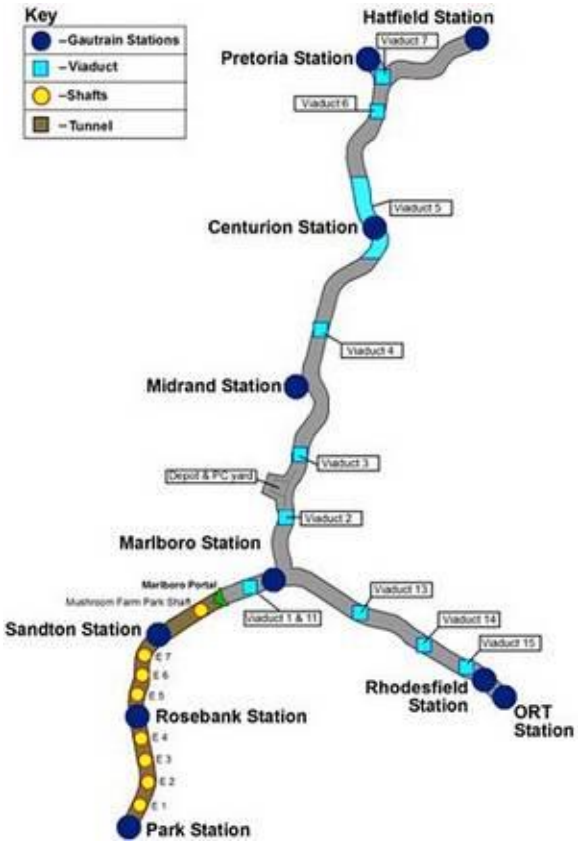


Figure 9 - Gautrain transport network

Source: [11]

The rail network is **80 kilometres** long and integrates other forms of public transport i.e. taxis, buses and the Metrorail public transport system. Commuters can also use several Gautrain buses to destinations within a 15 kilometre radius. Travelling at up to 160 km/h, Gautrain takes 35 minutes to travel between Johannesburg and Pretoria. From Sandton to the OR Tambo International Airport takes 15minutes. Fares on the Johannesburg/Pretoria route are between R20 and R52, depending on distance with feeder bus fares. [12]

Advantages:

- safe and secure,
- convenient and reliable,
- enviromental friendly,
- convenient routes,

- reduces congestion,
- quiet, timely and comfortable.

Disadvantages:

- lack of luggage and desk spaces,
- passengers stands during peak periods,
- expensive.

It can be visibly noted in the above that the Gautrain is by far the greatest investment the government of South Africa had. It has since reduced congestions on our national roads, and continues to do so. There are a visibly more advantages to using Gautrain than disadvantages, and this indicates that rectifying these adversities might result in huge number of commuters' abadoning their cars and into Gautrain. This is a fact with which my thesis seeks to emphasize.

Figure 10 - The gautrain

Source: [13]

Figure 11 is the representation of the routes currently covered by the Gautrain. As you can see, it only covers the urban part between the two cities, which obviously leaves behind the targeted users as not only is it far from the consumers but also increasses travelling costs. It therefore leaves them with no other choice but to settle for the minibus taxi as a result.

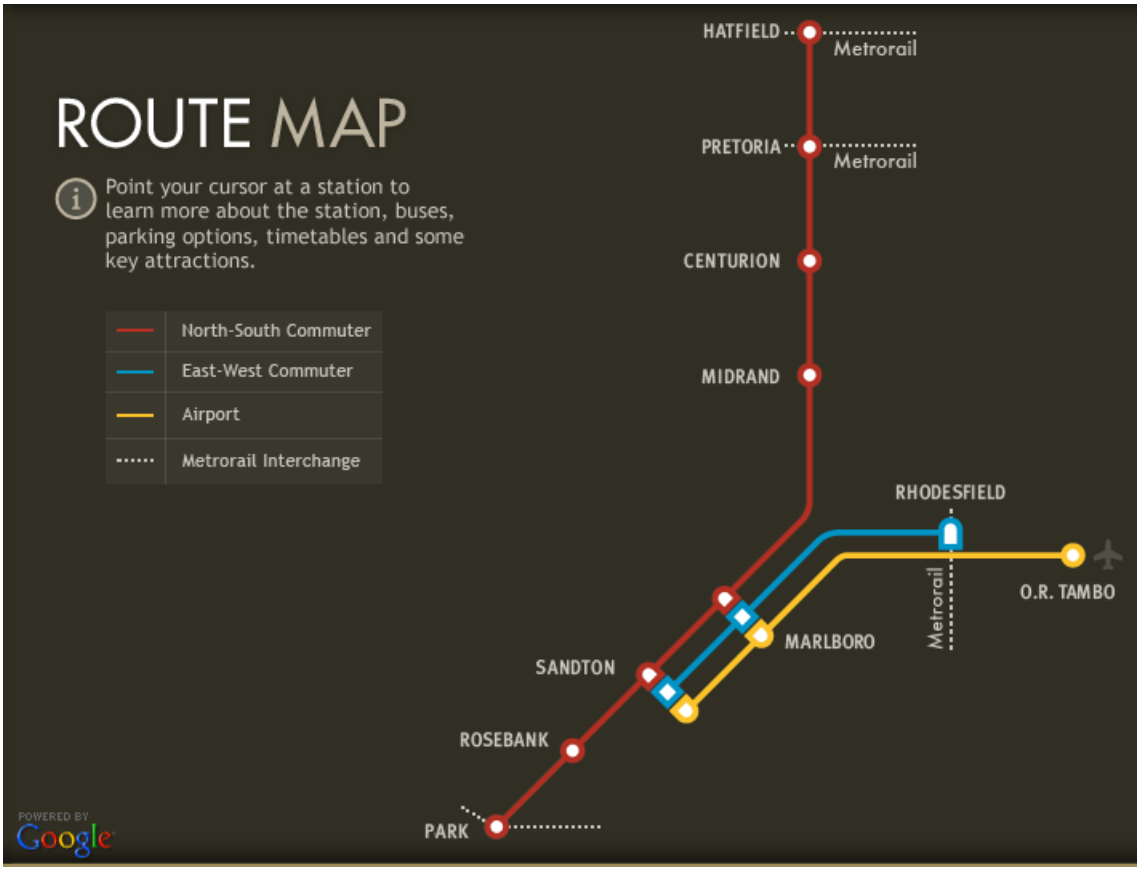


Figure 11 - Gautrain route map with Metrorail Feeds

Source:[14]

In central JHB, there is the option of bus services offered by both the state-owned enterprises (SOEs) and private bus operators. **Figure 5 and figure 6** respectively are just two of the many private owned transport services providers. **Table 4** is a representation of how the current PT is structured; some as stated are state-owned enterprises and others are privately owned ones.

Table 4 - National transport providers

ORGANIZATIONAL	INVESTMENT
Intelligent Transport Systems	Private
Sanral	State Owned Entreprise (SOE)
Gautrain	SOE
Metrobus	SOE
Putco	Private
SARoadlink	Private
Translux	Private
Greyhound	Private
Intercape	Private

Source: Author

The Gauteng Freeway Improvement Project (GFIP) is comprised of different phases in order to **upgrade 560km** of freeway network. The first phase, focuses on the upgrading of **185km** of the most congested freeway has been constructed (a total of 15 work packages). Apart from widening the freeway, the GFIP project will also ensure that bottlenecks at interchanges are resolved. In the first phase of the GFIP, 34 interchanges were significantly upgraded, including infamous interchanges such as the Allandale, Rivonia, William Nicol, Gilloolys and Elands interchanges. Furthermore, median lighting and Intelligent Transport Systems (ITS) as indicated in **Figure 12** were installed throughout the network for billing purposes (electronic-tolling) which in my opinion is a another form of Government rip-off scheme as RRRBTTN indicates, having a reliable railway network can heavily contribute to reducing congestion on our National roads.

Source: SANRAL

Below is one of the many electronic tolling system (e-tolls) installed through out the entire National road transport network between JHB and PTA.

Figure 12- E-tolling system on JHB highway

Source: http://www.engineeringnews.co.za/article/e-toll-courts-extra-financial-burden-sacci-2013-10-17

Figure 13 – Gautrain feeder bus Source[1]: www.timeslive.co.za

[1]http://www.timeslive.co.za/incoming/2012/02/25/gautrain-bus.jpg/ALTERNATES/crop_630x400/gautrain+bus.jpg

Metrobus is a state owned enterprise (SOE) bus operating company owned and opareted by the city of Johannesburg. It operates in central JHB area, covering the Soweto area. **Figure 14** are Metrobuses at Ghandi Square, Braamfontein in central JHB, one of their dedicated bus stop stations.

Figure 14 – Metrobuses in central Johannesburg

Source: www.mediaclubsouthafrica.com

Figure 15 are electronic tag machines placed through out Gautrain route network that uses gold tag cards as per **figure 16** which are billed whenever passengers undertakes their trips. **Figure 17** indicates, passengers are able to recharge their cards with a minimum of R20 cca 40 Czech crowns.

Figure 15 – Electronic gautrain gold tag machines

Source: http://www.turnstar.co.za/wp-content/uploads/2012/07/gautrain-1.jpg

Gautrain gold card gives frequent commuters discounts and convenience and it is easily accessible and available in kiosks within gautrain's stations and other designated outlets.

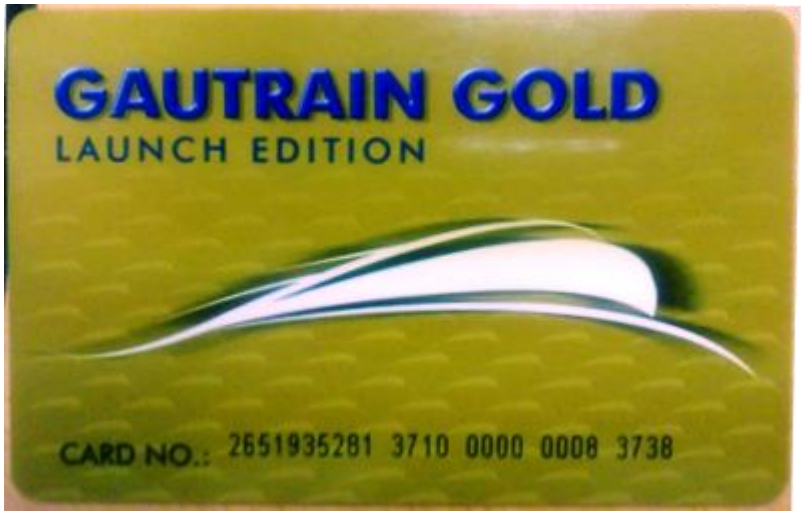


Figure 16 – Gautrain gold card

Source: http://citysearch.yellowpages.co.za/scholarblogs/wp-content/uploads/2010/07/card.png

Figure 17 below is a self-service machine for passengers to reload their gold cards which is easy and convenient.

Figure 17 – Gautrain's gold card recharge machine

Source: http://lillyloompa.files.wordpress.com/2012/02/gautrain1.jpg

The Gautrain project involves a modernization of the state-of-the-art rail connection linking Sandton, Johannesburg, Tshwane and the OR Tambo International Airport (formerly Johannesburg International Airport). [18]

Gautrain is a public private partnership (PPP) project consisting of 80 km of new rapid rail network of which 15 km is underground with 10 stations.

Twenty four trains with four coaches have been provided with 125 buses operating on 430 kilometer of Gautrain bus routes providing a feeder and distribution service.

Figure 18- Gautrain on the move

Source: [17]

In Gauteng area, plans are underway to extend the Gautrain network routes (as **figure 19** below indicates). The plains aim at making it more robust, reliable and more accessible as the new proposed route will have effect in the furthest part of Gauteng.

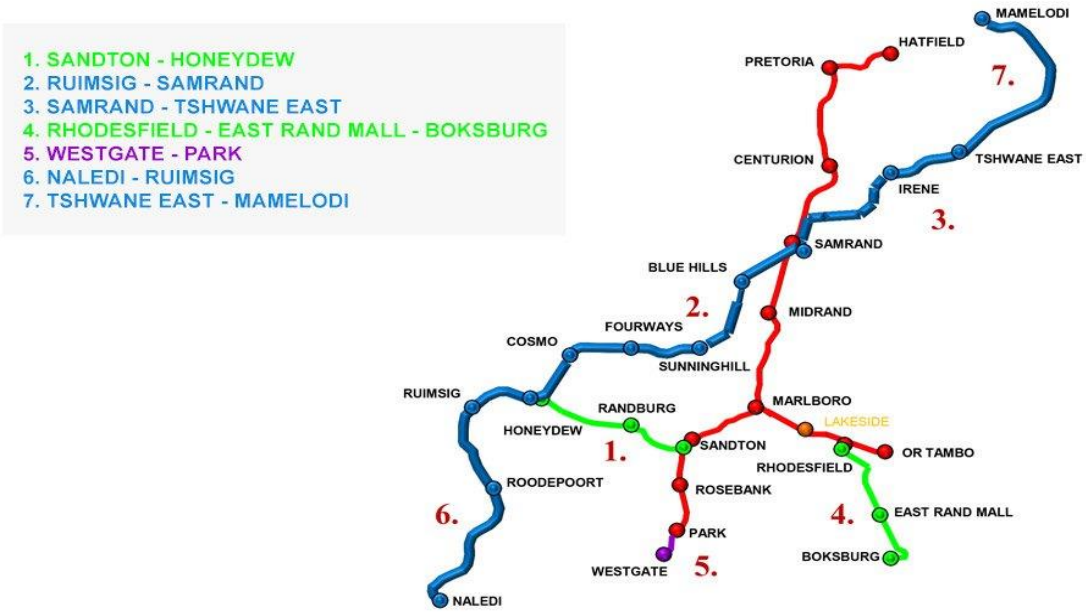


Figure 19 – Gautrain new proposed routes

Source: [15]

RRRBTTN is a model that will be implemented in four phase structure. It should be expected that passengers will initially be skeptical in using Government owned PT due to its reputation of non-reliability. The initial phase of RRRBTTN (refer to **graph 7**) will slowly lure people back to rail transport system, as indicated by the final phase in the graph.

The city of Johannesburg continues to struggle in revamping its PT network and RRRBTTN adaptation would be beneficial to the city. A perfectly integration of PT requires a lot of will power by both the state and businesses alike. Integration of PT will enable employees to be able to get to work on time, and this will increase work productivity.

Gautrain's implementation had done some great justice for the PT, moreespecially between JHB and PTA. It's however, like many form of public transport systems, has its flaws which RRRBTTN not only addressed but offer solution in rectification of these flaws.

From the economically point, successful adoptation of RRRBTTN, will boast our gross domestic products.

Figure 20 below is a perfectly integrated transport network with which the RRRBTTN aims to model to make PT more seamless and robust in enhancing passenger's mobility.

Figure 20 – Perfectly integrated transport network

Source: http://www.ebandla.co.za/uploads/AfricanR2012/PRASA_African_R.pdf

4 PRETORIA INTERGRATED TRANSPORT NETWORK

Pretoria is a city in the northern part of Gauteng Province, South Africa. It is one of the RSA's capital cities which serve as an executive (administrative) center. It has a population of over half a million people living and working there.

PTA, like other major capitals also has a PT problem which RRRBTTN seeks to address by interconnecting the existing PT structures together, to provide effectiveness and reliability of PTA's PT transport network.

4.1 RRRBTTN Objectives for PITN

It is first necessary to identify the current PITN vulnerabilities, which can either be **structure-related** or **nature-related** and **traffic-related**. It is the collective sum of these vulnerabilities that needs to be addressed:

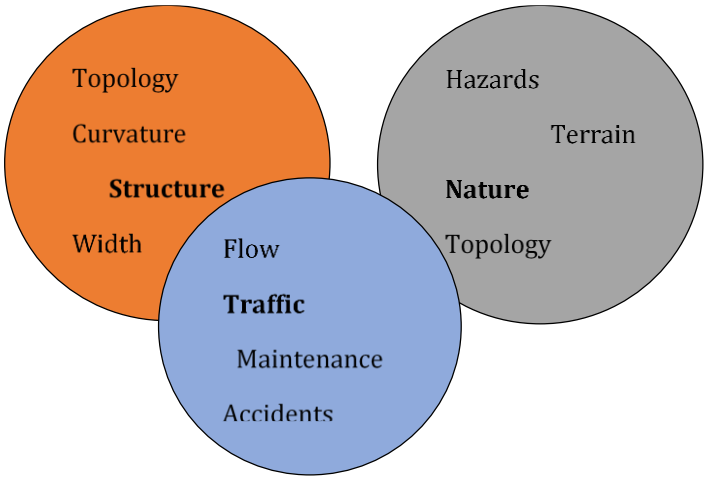


Figure 21 - Road networks are vulnerable to 3 influences

Source: [7]

It can be noted from **figure 21** that network's structure should be a prerequisite in making sure it's robustness is enforced. Traffic is another central factor with nature a central part. PITN will see the introduction in Pretoria Express of a high speed train that is to complement the blue train and reduce the travel time between PTA, DBN and CT.

Gautrain's PTA's main station, which commuters finds to be very efficient and environmentally friendly.

Figure 22 - Gautrain station in PTA

Source: http://media.npr.org/assets/img/2012/11/06/gautrain_toned-69744ea2a2fec4404f571497fde72f3dbd67b9fa.jpg

4.1.1 RRRBTTN methodologies and approach

RRRBTTN proposes a structured approach in PT reinventing which can be implemented in four phases. The ultimate goal will be to restore PT confident by providing frequent railway.

Figure 23 highlights the network routes which are covered by the blue train which runs from PTA to CT. RRRBTTN will integrate with it to make it more reliable. Currently as indicated, there is no proper rail infrastructure integration.

Figure 23 - The blue train route which will complement the proposed Pretoria Express

Source: [16]

4.1.2 Durban Intergrated Transport Network

The garden province of South Africa, KwaZulu-Natal is a subtropical region of lush and well-watered valleys, washed by the warm Indian Ocean. One of the country's most popular tourist destinations, the province stretches from Port Edward in the south to the borders of Swaziland and Mozambique to the north.Its western part is marked by the dramatic Drakensberg mountain range, with several peaks well over 3 000 metres. The range has been awarded World Heritage status for its dramatic natural beauty and the wealth of San Bushman rock art found in its caves – the richest concentration on the continent of Africa.

4.1.3 RRRBTTN methdologies and approach for DITN

Seven most important transport problems the people KwaZulu-Natal are currently experiencing with the current PT network are the following:

- **Affordability**: The cost of Taxis – being too expensive,
- **Public Service ethic**: The rude and reckless taxi drivers,
- **Infrastructure**: The poor condition of roads and potholes and lack of paved roads, with the result that roads are muddy when it rains; broken street lights,
- **Proximity**: That Taxi (and bus) services are too far away to access,
- **Frequency**: The long waits and queues for Taxis,
- **Supply**: Not enough taxis or buses to satisy the demand, or not in their area,
- **Services**: Lack of off-peak, weekend, night services.

No-one is particularly happy or unhappy about the taxi services on offer – it's a 51.1% satisfaction rate with fares being the biggest gripe.

Table 5 - Worker attitudes to the taxi services currently

More than 50% (But less than 58%) satisfied with	More than 50% (But less than 54%) dissatisfied with
Distance from home	Taxi fares
Travel time	Driver behaviour
Distance from work	Facilities at stops
Security in vehicles	Safety from accidents
Crowding in taxis	Punctuality
Roadworthiness	
Peak frequency	
Safety on walk to taxi	

Workers rated bus services at **66.9 %** in terms of satisfaction with stop facilities and off-peak services being the biggest gripe.

Table 6 - Worker attitudes to the bus services currently

Satisfaction rates over 70%	Dissatisfaction over 40%
Security in vehicle	Facilities at stops
Distance from home	Off-peak services
Security on walk	
Security at stop	
Driver behaviour	
Fares	
Distance from work	

Source: Author

Based on these observations; it is, therefore evident that the current PT state is not commuter friendly nor is it reliable as it supposed to be. RRRBTTN adaptation in the KwaZulu -Natal region will greatly help commuters' moreespecially in the rural part of these regions.

5 CAPE TOWN INTERGRATED TRANSPORT NETWORK

Cape Town is home to most of the Western Cape's population and the seat of the South African Parliament. The city is famous for its harbour as well as its natural setting in the Cape floral kingdom, also for such well-known landmarks as Table Mountain and Cape Point. Cape Town is also Africa's most popular tourist destination. Cape Town is the economic centre of the Western Cape Province, South Africa's second main economic centre and Africa's third main economic hub city. It serves as the regional manufacturing centre in the Western Cape. The large government presence in the city – both as the capital of the Western Cape and the seat of the National Parliament – has led to increased revenue and growth in industries that serve the government.

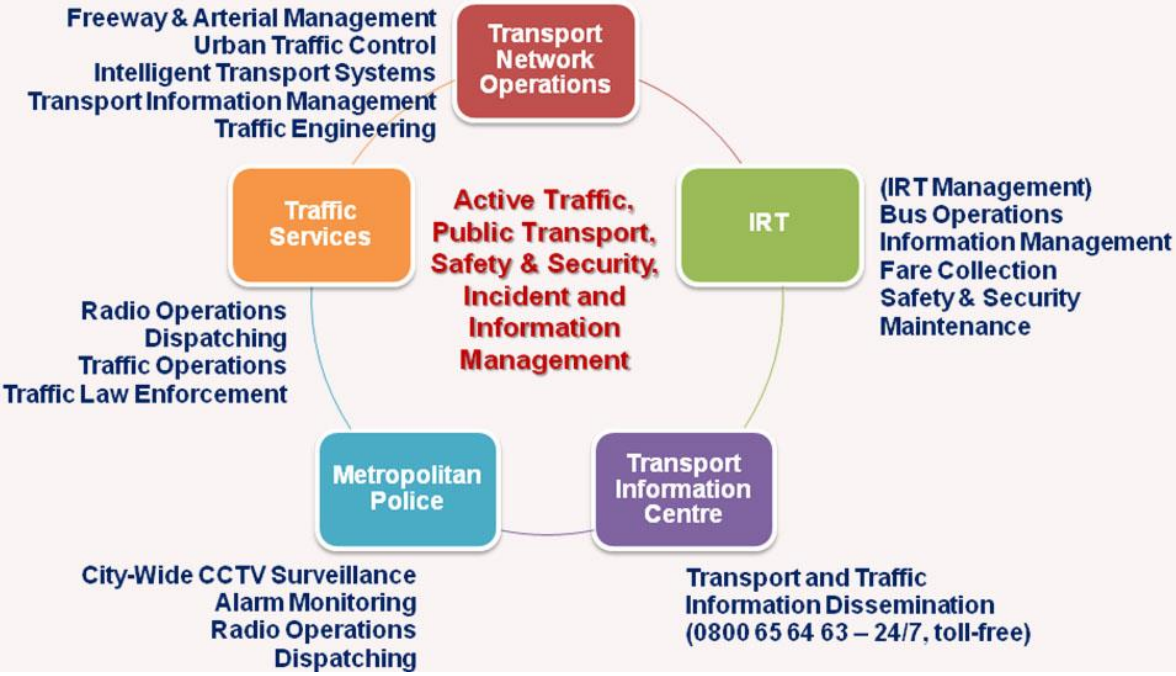


Figure 24 - Current CT transport management centre

Source: TMC

5.1 Objectives of the RRRBTTN in relation to CITN

A liveable Cape Town must have a transport system where multiple ***modes*** are **integrated** to ensure a **seamless travel** experience to all users, whether travelling for work, education, health, recreational or social reasons.

The transport system must operate at a high standard to give confidence to choice users to position themselves around the system in order to derive the many benefits it offers, whether at trunks or feeder routes.

A well designed urban PT environment will allow for shorter trip distances for which non-motorised trips by foot or bicycle will become the preferred way of travel.

Cape Town already had a vision for integrated transport network and RRRBTTN aims at complementing such vision in making sure that the MyCiti's PT network is fully integrated. Moreover, Cape Town has tramway lines which will be very significant in integrating the entire PT. The city also has minibus type of buses which suppliment the use of minibus taxis in the city's center. See below:

6 CONCLUSION

While writing this thesis, I experienced many insights as I learned how a well integrated transport infrastructure is of high importance in the development of any country. Transport is a core element of any well-developed country and this thesis taught me how implementation of a highly integrated transport network requires more planning, funding, resources and willingness.There is many principalities that go into having a truly interconnected public transport network which is reliable, timely, safe, cost-effective and comfortable.

This thesis opened my mind in ways I never imagined. I'd learned that the aspects that goes into making PT effective in the development of major cities is difficult as there are many requirements that needs to be assessed, analysized, studied, researched, hypothesized and then rolled out with as few anticipated problems as possible in ensuring the effectiveness of these new networks infrastructure— which can be detrimental if not well executed.

RRRBTTN is broad as it seeks to make PT inherently linked to each other to enhance its robustness, seamlessness, effectiveness, and strengthens its reliability capabilities. I have learned that when PT is fully integrated, there is huge economical gain that can be achieved. An integrated public transport can further contribute to the drive in curbing environmental emissions which contributes to the global climate change call by making PT seamless, by completely integrating it.

In writing and exploring ways South African's PT can be enhanced, transformed, integrated and improved, RRRBTTN is the answer. The upcoming construction of the High-speed train that will connect JHB and DBN which RRRBTTN will be complementary to this new proposed network if adopted as a mode with which this new transport network can be modelled. Government is to invest more than R149 billion on addressing the road network backlog over the next three years of which RRRBTTN, if implemented as a model, can play a central role in restructuring RSA's national roads infrastructure. [19]

In closing, RRRBTTN is, in my view, the only best solution which will decrease the excessively high rates of both road accidents and congestions our national road networks have been experiencing over the last decade and will enable real transformation of integrated PT.

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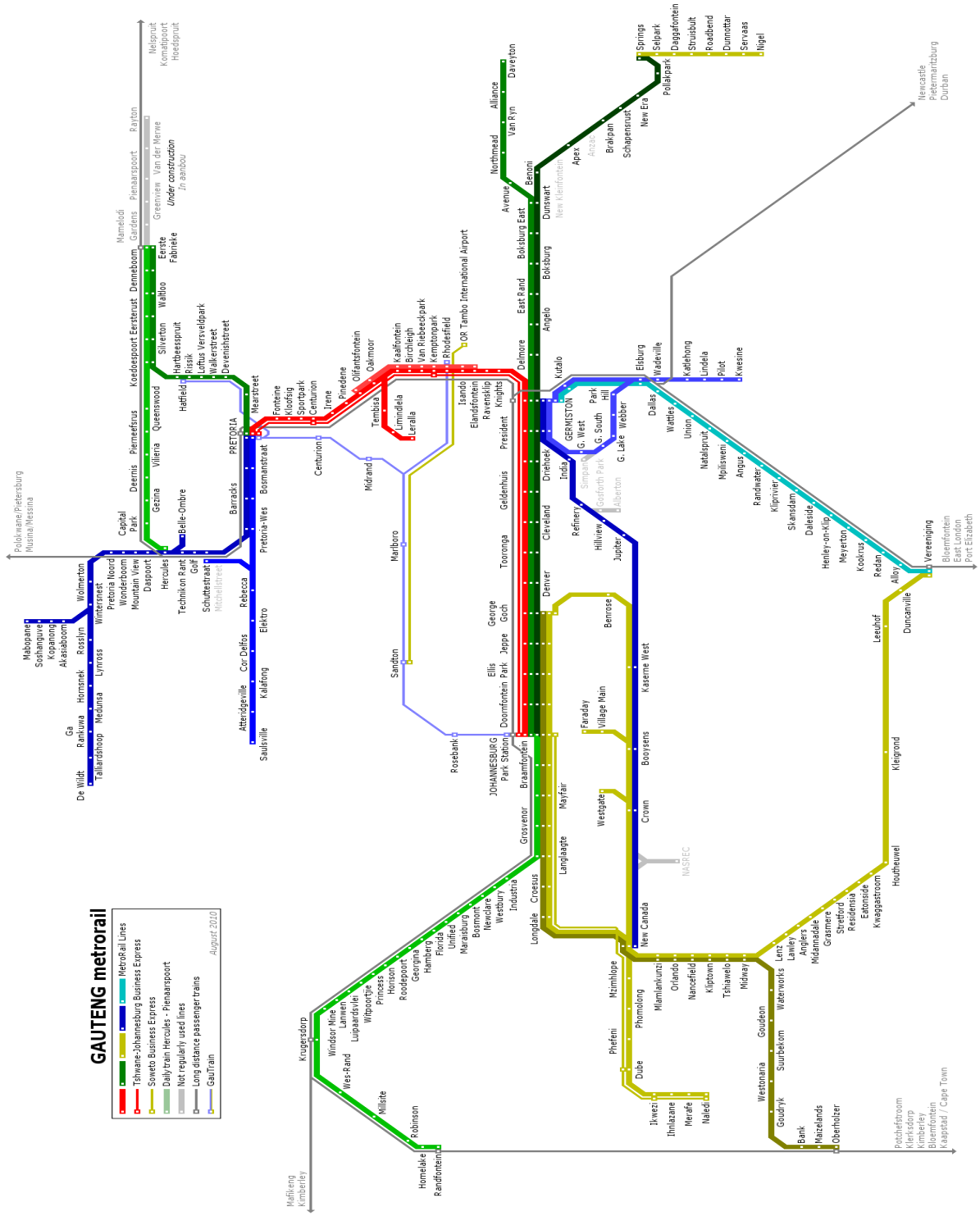
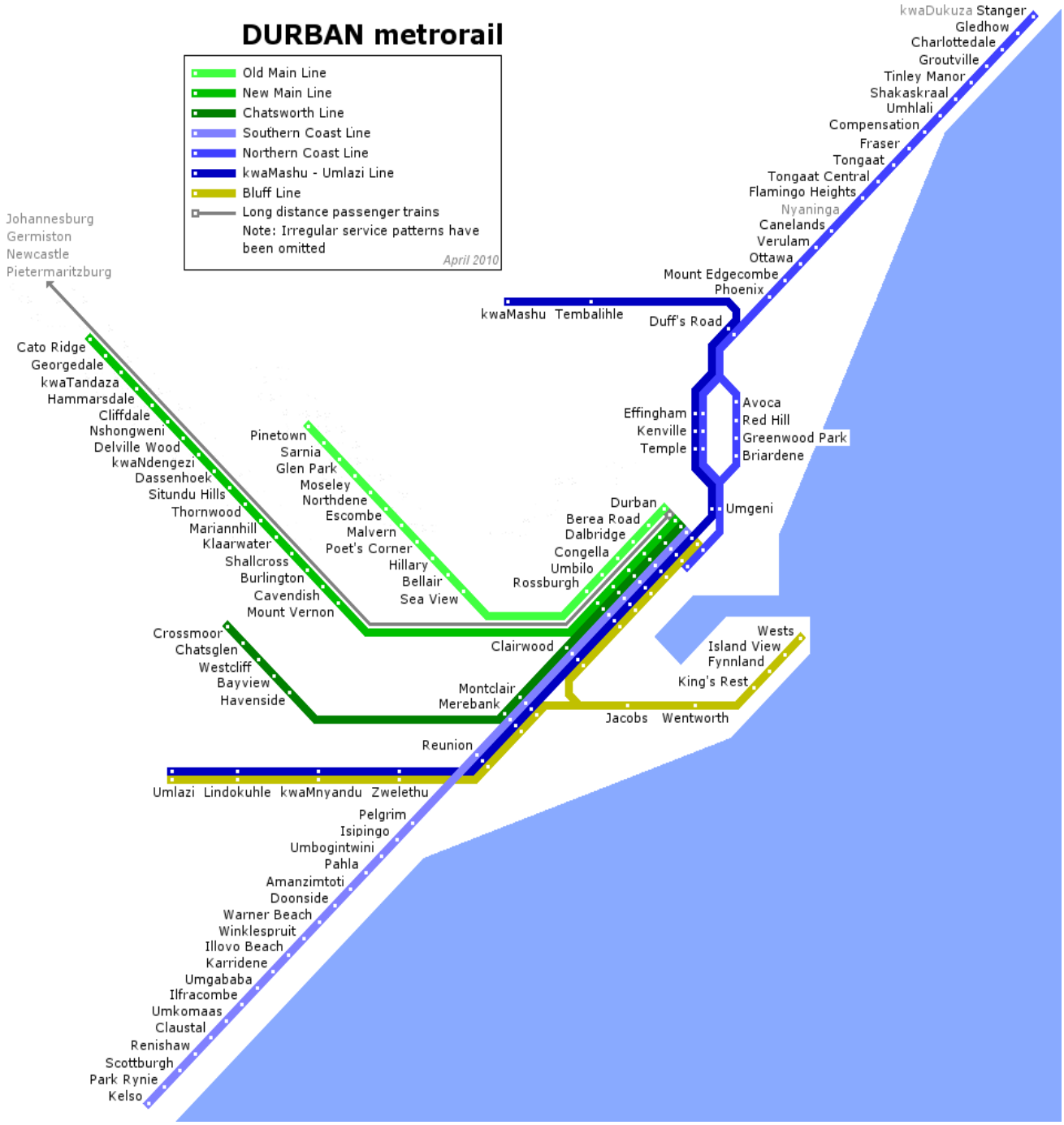
8 APPENDIX A-GAUTENG METRORAIL



9 APPENDIX B- DURBAN METRORAIL



10APPENDIX C- CAPE TOWN & EASTERN METRORAIL