MODELLING TOLL IMPACTS USING CONGESTED HIGHWAY ASSIGNMENT SOFTWARE – A CASE STUDY OF THE PROPOSED N2 - R72 LINK ROAD IN EAST LONDON, SOUTH AFRICA

By

FEZEKILE DUZE (DZXFEZ001)

A 60 CREDIT M ENG DISSERTATION

University of Cape Town

Faculty of Engineering & the Built Environment
Centre for Transport Studies

Thesis presented in partial fulfilment of the requirement for the degree Master of Engineering – Transport Studies in the Faculty of Engineering and Built Environment at University of Cape Town

Supervisor: Prof. Mark Zuidgeest

October 2019

PLAGIARISM DECLARATION

- I know that plagiarism is wrong. Plagiarism is to use another's work and to pretend that it is one's own.
- I have used the Harvard convention for citation and referencing. Each significant contribution to and quotation in this report from the work or works of other people has been attributed and has been cited and referenced.
- This report is my own work. The work done by others is mentioned and properly recognized under Acknowledgements and Chapters 1 and 4.
- I have not allowed and will not allow anyone to copy my work with the intention of passing it off as his/her own work.

FEZEKILE DUZE (DZXFEZ001)

Signed by candidate

SIGNATURE

2019-01-31

DATE

ACKNOWLEDGEMENTS

Firstly, I thank God, the most merciful, for allowing me to get through all the difficulties I encountered throughout my studies. I am experiencing your guidance every day of my life. It is only by your permission, I am able to finish my degree. I will always trust you for anything concerning my future. Thank you Lord.

My sincere gratitude goes to my supervisor, Prof. Mark Zuidgeest, who has nurtured me with his guidance, encouragement and advice throughout my time as his student. I am extremely favoured to have a supervisor who cherish my work, and who responded to my challenges and queries swiftly. My gratitude also goes to Prof. Roger Behrens and Ms Rowen Geswindt.

I relay my appreciation to my parents and siblings for their continued support and encouragement. Special thanks to Mrs Janet Blignaut for her support by proofreading the English grammar, language and her inclination to proofread numerous pages of transport modelling and road tolling articles.

The completion of this work would not have been possible if not for the support and friendship shown by the staff of Atkins (Epsom, UK) and PTV (Karlsure, Germany) and I am indebted to them for their warm reception and support. Mr Dirk van Vliet (Atkins – UK) answered all my queries and responded to all questions about SATURN software.

I am thanking the South African National Roads Agency Limited (SANRAL), not only for the provision of funding to undertake this postgraduate study, but also for opportunities given to attend conferences and meet people in academics and industry. Mr Alan Robinson for criss-crossing Europe with me, Dr Mathetha Mokonyama for his invaluable criticism and advice and Mr Gary Hayes (CSIR, now UP) for providing transport modelling insights and literature. I am taking this opportunity to thank you. Mr Dewalt Lotter, Mr Altus Moolman and Mr Kerson Naidoo, all from Toll Industry (private sector), thank you very much.

I also want to appreciate and again thank Mr Alan Robinson for allowing me to work on the model he built whilst he was with Goba Engineers, and for always responding to my queries whenever I need him.

ABSTRACT

Traffic congestion has become a growing burden on society. Various approaches to model transportation do not scale efficiently due to its complex nature. The estimate of the locality and quantity of traffic that passes through, leaves or enters a study area are arrived at by assumption. There could be an increase in congestion if investments in infrastructure are done based on inaccurate transport modelling. Furthermore, outside the study area, the effects of changes in infrastructure are unknown. Hence, it is necessary to model transportation networks at a larger scale than previously required.

Governments all over the world are faced with continual challenges of providing infrastructures with basic amenities to their citizens. In every financial year, government budgets are always overstretched, which leaves very little for infrastructure maintenance, especially in less developed countries such as South Africa. Tolling road is one option to overcome this challenge. This thesis, therefore, studies toll road modelling options for the proposed N2-R72 link road in East London, South Africa.

The proposed N2/R72 Link Road is approximately eight kilometres long and includes a long-span bridge across the Buffalo River as well as a number of interchanges/intersections within an urban environment. Tolling in urban areas is not uncommon in South Africa and is typically associated with mainline plazas supported by several ramp plazas. The strategy presumably for the N2/R72 Link Road involves a mainline plaza constructed on the N2/R72 Link Road just before or after the Buffalo River Bridge. Traffic will be attracted from the existing roads depending on the benefits and toll on the proposed link.

The research problem addressed in this thesis arose from the fact that TomTom Traffic Index in South Africa identified East London as the third most congested city in South Africa. The morning and evening commuters experience a massive increase in travel times. Globally, it has been shown that congestion level does not necessarily get reduced as a result of an increase in road capacity.

At the same time, there is a need for a possible of diversion to the proposed link road, which can be a choice of a road user's willingness to pay toll fees. The challenge that arises is that diversions can result in gains and losses in terms of revenue for toll agencies if travellers' chose alternative, lower class, existing routes.

Now, based on the above the Buffalo City Metropolitan Municipality (BCMM) approached SANRAL to construct a new link with a bridge. In order to finance that (with the benefit of managing traffic as well) the idea is to toll the new link. Knowing that the road user preferences are different. especially there is a need to understand the impact of tolling on traffic flows in the area.

The main research question is *What the impact of tolling is on the use of the upgraded link knowing that there is heterogeneity amongst users in terms of sensitivity to user costs for transport? The effect of tolling on the proposed N2-R72 link roads is being tested using the* congested highway assignment software called SATURN. The way the problem is although preferably VISSUM as a 'proper' micro model in that they model on a real-time, behavioural level. EMME models on a macro level and could have been used to accommodate all four steps in conventional models. It is tricky to use SATURN on a meso and micro level, as the micro level can distort the trip assignment if only a small (but key) part of the network is simulated (i.e. the assignment results in trips diverting around the simulation by using the buffer network). SATURN as employed in this study can operate at the meso level (buffer networks)

with the junction simulation component operating at the micro level (somewhat). This report cautions against confusing the concepts of micro, meso and macro traffic models.

In order to understand how the transport network may react to the proposed changes, a modelling approach is proposed. To achieve this, a traffic model was developed to represent the existing situation. This model provides the benchmark against which any proposal will be compared. This study will compare results between the existing and proposed situation in order for an informed decision can be taken on whether to proceed with the proposal based on the impact it will have on the existing network. In transport planning, various transport models are used to forecast impacts and evaluate options.

This study investigates and reports on the impact of tolling should SANRAL construct a new road linking two national roads knowing that there is heterogeneity amongst users in terms of sensitivity to user costs for transport. To undertake this study a congested highway assignment model will be used based on a known case study and available old model.

The literature review illustrates that with a growth of Public-Private Partnership (PPP) projects, toll roads would increase incessantly. Route choice by users is greatly influenced by toll and can sometimes also have effects on trip departure time and choice of mode. To model toll roads, users' willingness to pay (WTP) or Value of Time (VOT) has an important role, and generally, worker's wages is considered to be equivalent to VOT.

This study also acknowledges that there is a distinguished difference between urban toll schemes and congestion pricing. The GFIP e-toll scheme is not congestion pricing, but rather a way to generate revenues for road upgrading and network expansion. It is not meant to suppress trip demand; in fact, it has the opposite effect when upgrades are made, and the network is expanded.

The "user-pay" principle is viewed as a traffic demand measure, not as a means by which to raise funds for road building. The obvious questions are: What is the "user-pays" principle? How is the amount that the user must pay determined?

Congestion pricing is meant to reduce congestion by suppressing demand. The objectives of congestion pricing are to reduce congestion, to reduce the environmental impact of vehicles by reducing harmful exhaust emission, and to improve the space for public and Non-Motorised Transport (NMT) modes. Revenue from congestion pricing should be used for public transport provision and not upgrading and/or building new roads.

The results of the model analysis show that, since traffic growth on toll roads is increasing somewhere in the range of 2% and 6%, the impact on income cannot be negative. There is, notwithstanding, a risk of heightening maintenance charges if heavy vehicles continue to increase at an expense twice that of light vehicles. While not a single verification utilized in sight in the literature that toll roads in South Africa are looking to alleviate clog, it very well may be presumed that growth of light vehicle (Class 1) exacerbate congestion.

It is the research candidate's view that research on the perception of Value of Time (VOT) by road-user needs to be found and on toll diversion, being able to classify and predict future traffic and volumes will be essential for the national roads agency and other provincial road authorities on roads they are in control for.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

GLOSSARY OF TECHNICAL TERMS AND ACRONYMS

It is recognised that the terminology for transport modelling may differ between different jurisdictions. As such, a glossary of technical terms is provided below:

Links	Individual sections of the transport network (i.e. section of road, rail or waterway) in a transport model, and which contains all relevant information on the characteristics of that link.
Transport Zones	A geographical area within a transport model where transport activity may start or finish.
Zone Connectors	The mechanisms for connecting zones to links in the transport network.
Origin Destination (OD) Matrix	A means of representing individual trips between origin and destination zones in a transport model. The total of all cells in an Origin Destination Matrix will be equal to the number of trips undertaken in a transport system.
Generalised Cost	A means of representing the "cost" of travel between two points, which incorporates the value of travel time, including time in and out of vehicles and waiting/inconvenience time, along with fares/tolls, all converted into a single comparable trip cost. Used as the basis for the assignment of trips to destinations, routes and modes. In simple cases, it is often reduced to travel time or distance.
Do-Minimum	A term used to describe a future situation whereby only committed projects are assumed to occur, and against which a with-project scenario.
Trip Generation	The method of deriving the total number of trips generated by a transport zone.
Trip Distribution	The method of allocating trips to an OD matrix.
Mode Share Calculation	The splitting of trips between modes for each OD relation, based on probability models reflecting the generalised cost of relation per mode.
Traffic Assignment	The method of allocating network routes for trips between transport zones.
Static Demand	Models that do not assume any change in the quantum of travel demand because of transport infrastructure or policy interventions.
Variable Demand	Models that measure a change in the quantum of travel demand because of transport infrastructure or policy interventions.
Prior Matrix	The demand matrix that is developed using data from surveys and other sources, but prior to undertaking calibration.
Calibration	The process of adjusting the various elements of a base-year transport model so that it will fit in sufficiently with observed data.
Validation	The process of comparing a calibrated year transport model with independent observed data to understand if it sufficiently reflects reality.
User Classes	Categories of journey purpose, normally including commuting, business, leisure and freight as a minimum.
Vehicle Classes	Categories of vehicle type.
Matrix Estimation	The process of manipulating a matrix such that the output is consistent with observed data.
Matrix Factoring	The application of global factors to increase or decrease a demand matrix.
Matrix Infilling	The process of adding data to a demand matrix where there are gaps in the data within the matrix.
Synthetic Matrices	Matrices constructed using theoretical relationships, with limited reliance on survey data.

1. BACKGROUND

1.1 Research Introduction

Economic activities in South Africa during the past decades have caused, inter alia, road traffic congestion to accelerate annually and road infrastructure to deteriorate rapidly. As such, congestion, especially in the metropolitan municipalities, has reached unacceptable levels during peak hour periods. This has necessitated the construction of new roads, and the upgrading and continual maintenance of existing roads and other national roads. The financial burden of upgrading and maintaining road infrastructure is enormous and although the South African government makes contributions, income from road users is necessary to sustain quality (Swarts, 2017).

Transport is fundamental to both infrastructure development and economic growth. This means without access to health care, education, employment and other basic services, the quality of life do not improve; without physical access to markets and resources, growth declines, and poverty reduction cannot be sustained (World Bank, 1999).

The demand for transport cannot be measured in the same light as the demand for goods as it is a service and the benefits of transport are different for different user typologies. The demand for products and services is greatly influenced by change in generalized transport cost. Pricing and laws in transport coincide with the important elements of society and cannot be left absolutely to the free-market system. The pricing of transport possibly will no longer be market-related.

The South African National Roads Agency Limited (SANRAL), established in 1998, has been assigned by government to provide, manage, control and maintain a world-class, sustainable road network as cost-effective as possible, to enhance economic growth and improve quality of life of all South Africans (SANRAL, 2015). The toll impact investigated in this research will be on the national roads.

Due to non-availabilty of sufficient allocation of the fuel-levy, it becomes apparent that, for the national road agency to successfully meet its objectives, exploring alternative source of funding such as a road user pay principle is warranted. Hence, SANRAL explored prospects to lessen its reliance on tax-based incomes, subsequently soughting after an alternative sources of finance for road infrastructure .

The user-pay (tolling) policy was developed in the early 1980s. The first modern toll plaza in South Africa was opened for traffic in the mid-80s on the national route N2 in Tsitsikama, Eastern Cape. The advantanges of tolling includes the following:

- It provides an avenue for SANRAL for prompt provision of roads unlike depending on traditional tax-based revenues for funding of roads. i.e. dedicated funding for maintenance of the road.
- Introduction of Tolls enables quick delivering of the much-needed infrastructure.

In the case of this study the tolling discussed can either take place in one of the following types:

- Traditional Toll Collection – This applies where a Toll Plaza is built on the road as an obstruction to free flow of traffic. Motorist must pay a toll fee to pass the Toll plaza in order to continue with their trip.
- Open Road Tolling (ORT) – This is a method where toll is collected electronically along a road or road network. This method of payment does not allow obstruction of free traffic flow as motorist pays for toll without physically stopping at a Toll Plaza. Motorists can drive along their route without stopping, as all billing are electronic. Overhead gantries for an example are situated approximately every 10km (or between interchanges) along the Gauteng road network.

The Eastern Cape operates as the Southern Region (one of four SANRAL regions) and is responsible for a total road length of 4 900km as of 22 June 2016 (i.e. approximately 20% of the national road network).

This case study aims to investigate and report on the impact of tolling should SANRAL construct a new road linking two national roads knowing that there is heterogeneity amongst users in terms of sensitivity to user costs for transport. To undertake this study a congested highway assignment model will be used based from a known, available but old model.

Development of road infrastructure can be achieved using a user-based funding mechanism such as tolling. It enables the mobilisation of substantial capital funds upfront, usually through debt equity, for the construction of infrastructure such as freeways. The introduction of tolls road by regimes of the so called third world and developing countries and countries in transition is becoming an appealing one because of the following reasons:

- *It enables infrastructure to be executed as fast as possible to trigger the much needed economic growth.*
- *It does not require the government to make available additional funding from their current revenue base for these projects.*
- *Funds can be spent on other crucial services like health and education.*

Toll financing has the distinct advantage of accelerating the availability of initial funding for construction as compared to traditional tax-supported highway finance. The initial capital cost for a project can therefore be financed over a shorter period than through limited tax based budgets. As a result, the benefit of increased roadway capacity is available to the public sooner. Therefore, tolling is an equitable way of implementing the user-pays principle and does not compromise fiscal integrity.

The cost associated with the provision, maintenance and refurbishing of a specific road is used to calculate the toll fees or the road user charges for that specific road. The benefit such as saving in vehicle operating cost and reduced travel times, which road users experienced when using toll roads are bigger than the toll fees charged for using those specific roads. Toll fees may enhance economic efficiency, transparency and accountability. In contradiction,when there are no tolls, costs associated with roads would have to be payed by all people paying taxes, regardless of the level of benefits individuals derive from specific road capacity improvement and upkeep thereof. Unlike a user charge, a tax does not confer a direct benefit for the payment made.

1.2 Research Background

The South African National Roads Agency Ltd (SANRAL) manages the South African national road network, which forges the arteries of the nation by connecting major cities, town, and developing villages in the country. The benefits of the national road network range from economic growth, tourism, social development to the creation of economic opportunities.

SANRAL Southern Region based in the Eastern Cape, together with other authorities wants to construct a new link with a bridge. In order to finance that (with the benefit of managing traffic as well) the idea is to toll the new link. Knowing that user's typologies are very different in the context of SA especially there is a need to understand the impact of tolling on traffic flows in the area.

As mentioned under section 1.1, a modelling approach is proposed because they are developed to understand the reaction of the transport network to the proposed changes. For this to be achieved, a traffic model which replicates the current situation is developed. This model offers the foundation towards which any concept will be compared. Comparison of the results gives rise to an informed decision to be taken regarding if the proposed situation should be implemented based on its effect on the existing network. Various transport models are used to predict impacts and evaluate options for transport planning.

High congestion levels are necessitating the need for transport models to motivate for new developments and upgrades. Where previously individual intersection analyses were considered sufficient, high levels of congestion requires new developments and upgrades to consider the effects on the wider road network.

Network familiarisation and data acquisition need to completed first before a traffic model can be developed. Development of a traffic model normally follows a described sequence to set up a common audit trail between model versions. Generally, an preliminary skeleton model is sophisticated till completely calibrated and validated to produce an audited base model which is ultimately developed into a proposed model. However, it is the duty of the model developer to generate a strong methodology that generates a correct and fit for purpose model.

When a new road is to be constructed, a transport model is usually built to forecast the number of vehicles the road will carry. This is the required input for the design of the road, i.e. how many lanes should there be, where to place the road intersections and interchanges etc. Many governments want to build roads which will give them the best value for money in economic terms. Alternative road schemes are ranked so as to give the best value for public money. Model outputs using the current "do-nothing" scenario is compare to each of the network improvement alternatives to calculate the economic metrics for comparison including Internal Rates of Return (IRR), Benefit Cost Ratios (BCR), Net Present Value (NPR) and in the case of privately funded projects the Loan Supported by Revenue (LSR) and Debt Service Cover Ratios (DSCR).

1.2.1 Research Location

Figure 2 illustrate that there is currently one practical crossing for the Buffalo River and the construction of a new bridge crossing is essential to provide future access across the river. The new route will provide a more direct link for a new trunk bus route operating from the Mdantsane Highway Central Business District (CBD) Rank to the Indudrial Development Zone (IDZ) and the West Bank industrial area and also to alleviate congestion through the CBD area. The Buffalo City Metropolitan Municipality (BCMM) network analysis indicated that the implementation of the complete route from N2 (north) and R72 (south) would have a significant effect on the reduction of the average travel times for the entire BCMM road network.

The feasibility study conducted in 1998 proposed a phased construction approach. The initial phase would consist of the construction of a two-lane single carriageway from R72 to the Ziphunzana interchange. The second construction phase would involve the upgrade of the single carriageway to a two-lane dual carriageway along the entire length, including additional associated interchanges. The following road authorities are potential funding sources for this project:

- BCMM;
- SANRAL and
- Eastern Cape Department of Roads and Public Works (ECDRPW)

Within the Buffalo City Metropolitan area, the N2 follows an east-west alignment passing through the northern suburbs of the city, this east-west route being located some five kilometers north of the city's central business district (CBD). On the other hand, the R72 approaches the city's CBD area from the south west and whilst this route continues through the city's CBD area by way of Settlers Way, Fleet Street, Fitzpatrick Road and Valley Road, its intersection with the N2 only occurs at the N2/R72 Interchange, this interchange being located some six kilometers north north-east of the CBD area. On its route through the CBD, the R72 first crosses the Buffalo River by way of the Biko Bridge, this bridge providing an extremely important access link between those developments of the city which are located north and south of the Buffalo River.

Because of the alignment characteristics of the N2 and the R72, traffic wishing to access the N2 from the R72 (or vice versa), is essentially required to pass through the CBD area. In this respect it is true that traffic between the N2 and the R72 can also use the M5 Buffalo Pass crossing of the Buffalo River, this negating the need to pass through the CBD area. The Buffalo Pass route is however of poor standard and is meandering and circuitous in nature and hence use of this alternative option is somewhat limited.

North of the Buffalo River one not only finds the CBD but also just about nearly the entire city's residential areas. South of the river, this area often being referred to as the West Bank, the dominant features are the employment areas of Gately and Woodbrook and of course the East London Airport.

In terms of the city's ongoing expansion and development, the West Bank is considered as a priority development area. To unlock the development potential of this area, it is however recognized that access links across the Buffalo River need to be improved, this being necessary to facilitate access to new work activities, to improve linkages to markets and to also relieve the traffic pressures prevailing on the CBD area.

With the aim of fulfilling the above objectives, it has been proposed that a new link across the Buffalo River needs to be developed and so that it link the R72 in the south toward the N2 in the north and follow the alignment denoted in Figures 1, 2 and 3. This study is therefore concerned not only with appropriate investigations into the upgrading and development of the N2 and R72 corridors but also similar work in relation to the development of the proposed Buffalo City N2/R72 link. Refer to figures 1 and 3.

In terms of upgrading the N2 and R72 corridors and developing the proposed N2/R72 link it is presently proposed that these two routes and the link be developed as tolled facilities.

Consequently, a further requirement of the study work undertaken for the N2 and R72 and detailed herein, is to determine the financial feasibility and the degree to which the tolling of these two routes can be expected to contribute to the upgrading and development costs of these two routes.

In March 1998, a report titled, *"Proposed Buffalo River Bridge and Arterial Road Link between N2 and R72 – Part B – Business and Financial Plan"*, prepared by Ninham Shand Consulting Engineers for the then East London Metropolitan Transport Advisory Board was published.

This research will also investigate the appropriate toll impacts of upgrading of the N2 and R72 corridors and on the development of the proposed Buffalo City N2/R72 link and will evaluate the extent to which road users are sensitive to tolling.

Figure 1: Locality Layout

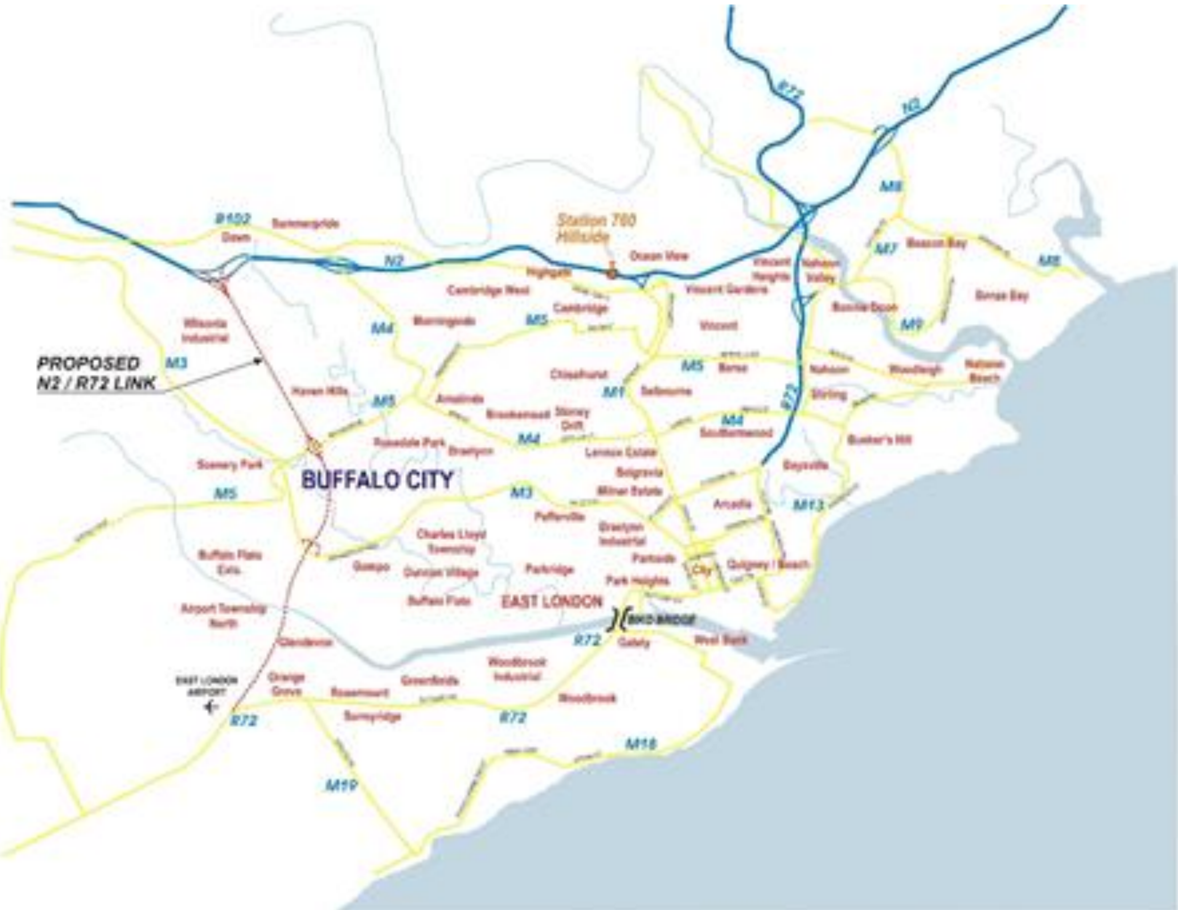


Figure 2: Proposed N2/R72 Link Road

There was no further planning and implementation progress from the planning authority between 1998 and 2007. In April 2007, SANRAL appointed Tolplan (Pty) Ltd and Goba (Pty) Ltd in a joint venture to undertake a feasibility study of tolling for the N2 and/or R72 routes between Port Elizabeth and East London. The study is a macro-simulation project considering that the distance between Port Elizabeth and East London is approximately 285km.

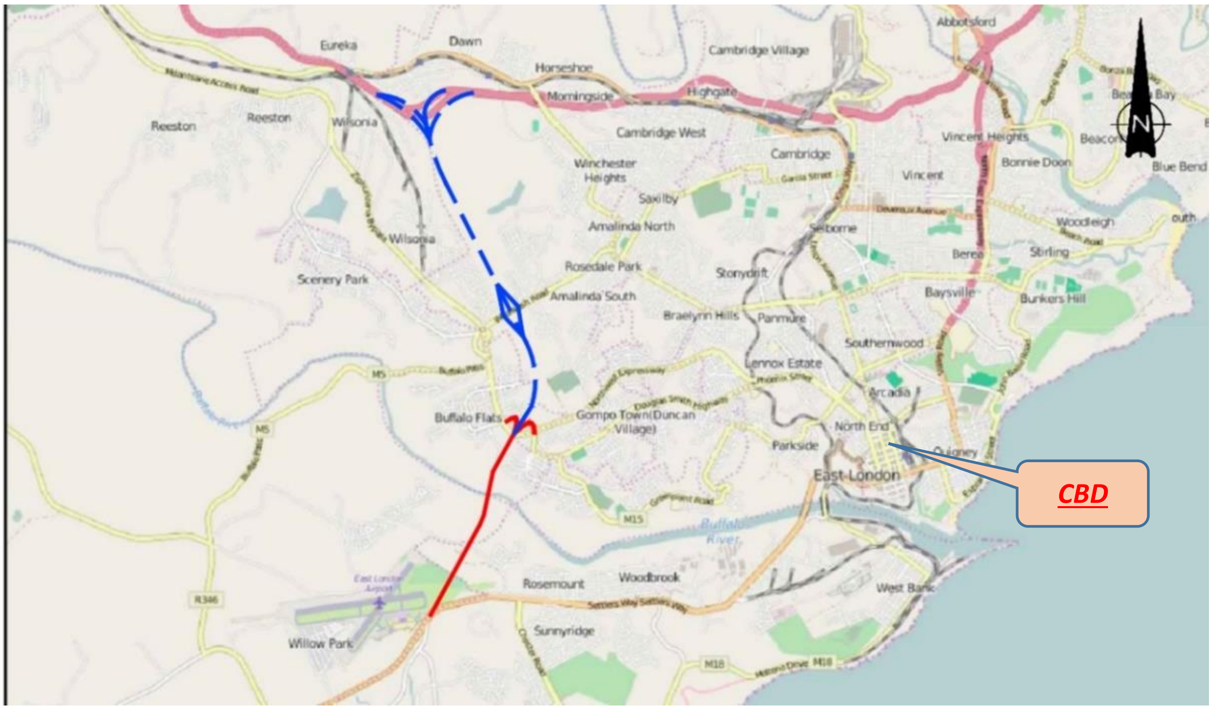


Figure 3: Proposed N2/R72 Link Road Implementation Phase

1.3 Research Problem

The 2016 TomTom Traffic Index in South Africa recognized East London as the third most congested city in South Africa. Their data shows that morning and evening commuters experience an average of 55% and 50% respective increase in travel times (TomTom Traffic Index, 2014 and 2016).

When a specific route is congested, the time cost associated with using such a route is too high for some individuals, leading them to choose an alternative route (Duranton and Turner, 2011). Most commuters choose their mode of transportation and route by considering their opportunity cost – they evaluate and compare each alternative.

The time and value associated with a congested route is too excessive for some individuals, leading them to select an alternative route (Centre for Economics and Business Research, 2014). This route may be longer, but the journey time might be shorter, or the free-flow would possibly make the route more attractive.

Theoretically, if traffic was a closed system with constant demand, increasing the network capacity (the supply) to meet this demand would be an effective solution. However, a road network does not fulfil either of these requirements. If the capacity of the previously congested route were to increase, it attracts more traffic to itself, away from other latent demand congested routes. Individuals can also change their mode of transportation. A person carpooling to reduce costs could go back to driving oneself because they value their time more than the increased cost (of fuel) of driving to work alone. It is therefore assumed that all individuals travel on the route that has the lowest cost according to their own criteria (Swarts, 2017). This is termed Wardrope's principle.

Another method of reducing congestion is to increase the price of travelling on a specific road through toll fees. The demand for the route is then controlled by the cost of the fare. Concessionaires can determine a price structure by requesting stakeholders to participate in a survey. This, however, does not decrease the demand for the total network. The congestion could once again spread to other parts of the network as individuals seek to minimise their travel costs (Duranton and Turner, 2011).

1.3.1 Research Question

The central research question may be summarised thus: *What the impact of tolling is on the use of the upgraded link knowing that there is heterogeneity amongst users in terms of sensitivity to user costs for transport?*

The two main economic drivers for road user charging are either to increase financial efficiency or to maximise returns for reinvestments into the roads. The latter is because some toll road sections are constructed on greenfields to improve the flow of traffic on existing roads. The impact of the toll pricing on the anticipated traffic diversion to decongest the CBD would be subject to a transport model.

In the case of this research, there is a possibility of diversions, which can be caused by the travellers' willingness to pay toll fees. The challenge with diversions is, they may lead to revenue loss for toll agencies if travellers' choose alternative, lower class, and existing routes.

The results of this research are valuable in understanding the extent of the growth of traffic in the toll section that came as a result of toll fee introduction and later increases. This proof will then make a contribution in optimising a transport corridor productivities when future toll roads are planned.

1.4 Research objectives

The main objective of this research is to work on a transport model that illustrates the impact of tolling the link road that seeks to divert the traffic from the East London CBD. East London was identified as the third most traffic jammed city in South Africa and congestion is a result of traffic from the western region of East London (towards Port Elizabeth). The methodology adopted for this research is outlined below:

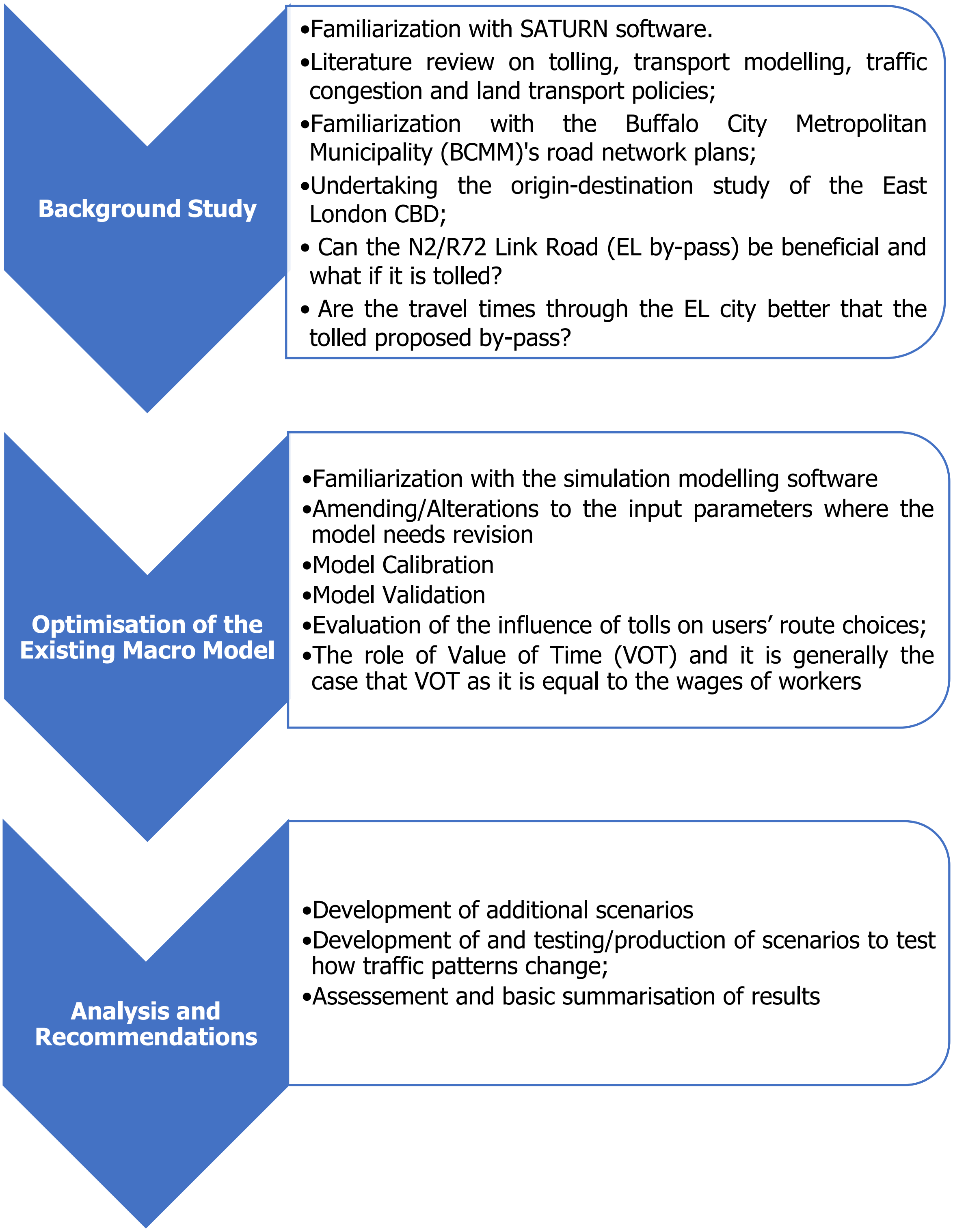
a) Literature review of existing road tolling methodologies; transportation modelling; road pricing; background on the tolling in South Africa and the world; and traffic diversion away from non-toll to toll and *vice versa*. The relation of diversion and price and, very briefly, the impact of diversion on revenue.
b) Modelling and testing and to;
   i.) review and adopt a modelling approach using macroscopic techniques for appropriate modelling of a Green Field Road in East London, Eastern Cape. This is carried out utilising the software package named Simulation and Assignment of Traffic to Urban Road Networks (SATURN).
   ii.) develop a modelling framework for constructing a macroscopic model with parameters and an approach to derive a demand matrix, to replicate actual traffic route operations.
   iii.) choose an appropriate calibration and validation technique process.
c) Provide an overview of the traffic patterns into East London originating the western region (east-bound traffic). i.e. when toll is not applied (do-nothing) and after charged (scenarios).

The following parameters are critical in evaluating the benefits of investment into transportation infrastructure and rule-making initiatives, but they will be briefly discussed:

- The Value of Time (VOT) in the reduction of delay in passenger transportation is a major objective for investments.
- The other vital derivative is the Value of Travel Time Saving (VTTS), which is the economic price a traveler is inclined to pay to save a specific quantity of time.

1.4.1 Research Design

The figure below illustrates the process that this research followed.



1.4.2 Introduction of SATURN as a Congested Highway Assignment Software

Van Vliet (2015) describes the Simulation and Assignment of Traffic to Urban Road Networks (SATURN) software as a suite of flexible network analysis programs developed at the Institute for Transport Studies, University of Leeds and distributed by Atkins Limited since 1982. It has the following basic functions*:*

- *As a combined traffic simulation and assignment model for the analysis of road-investment schemes ranging from traffic management schemes over relatively localized networks (typically of the order of 100 to 200 nodes) through to major infrastructure improvements where models with over 1000 junctions are not infrequent;*
- *As a "conventional" traffic assignment model for the analysis of much larger networks (e.g., up to 7 500 links in the smallest standard PC version, 200 000 in the largest);*
- *As a simulation model of individual junction;*
- *As a network editor, data base and analysis system;*
- *As a matrix manipulation package to produce, e.g., trip matrices*
- *As a trip matrix demand model covering the basic elements of trip distribution, modal split etc.*

As a combined simulation and assignment model – its original function – SATURN is most suitable for the analysis of relatively minor network changes such as the introduction of one-way streets, changes to junction controls, bus-only streets, etc. (which can loosely be categorized as *"traffic management measures")* and whose evaluation required a detailed analysis of traffic behavior at junctions (Van Vliet, 2015).

With both simulation and conventional network representations SATURN provides a wide range of assignment options such as generalized cost, all-or nothing, Wardrop equilibrium, Burrell multiple-route assignment (SUE) and, more recently, demand-responsive (elastic) assignment to deal with induced traffic All these are founded on theoretically consistent modeling frameworks and convergent algorithms reflecting the academic background of SATURN's development.

Using the modelling theory, a strategic network was built and on and this exercise reviewed on the SATURN, 2015 version 11.3.10 modelling software. The software has these features:

- *fully interactive analysis of results, including on-line help files, optimum green splits for traffic signals, traffic signal co-ordination modelled, lane structure of intersections* *and choice of lane modelled, the growth and decay of queues modelled quasi – dynamically, facilities to "skim", e.g., inter-zonal time, distance, etc. Matrices, bus routes, bus-only roads and bus-only lanes included explicitly, both left-hand and right-hand drive accepted, selected link analysis, multiple User Class Assignment differentiating between (e.g., cars, taxis, HGV's, etc.), full analysis of O-D routes generated by the assignment and modelling tolls or road charges on specified links.*

The impact of several interventions was observed, and the result were analysed. However, it is important to highlight that there are limimations as mention in sections 1.5 and 2.

1.5 Challenges and Constraints

This research is limited to two road portions of national routes. i.e. N2 sections 12 to 15, R72 sections 1 to 4 and the proposed N2/R72 arterial link road. The proposed N2/R72 arterial road links section 4 of the R72 and section 15 of the N2, both in East London, Eastern Cape. However, the approach to be presented may be utilised for other roads in South Africa.

To evaluate the existing and future traffic demands along the N2 and R72 corridors, as well as those demands that could be expected to use the proposed N2/R72 link, and to determine the potential impact that the proposed tolling of the above corridors would have on traffic patterns, a traffic and (thereafter) a toll modelling study procedure will be presented later in this dissertation, but without the public transport in terms of modal split.

Since the N2 and R72 are *predominantly* rural routes, and since the N2/R72 link (if developed) would essentially form part of an urban road network designed to accommodate more diverse urban traffic patterns, the modelling work in this research will look at the following as a base:

- Developing a rural N2/R72 corridor model using the SATURN suite of programs.
- The following sub-sections describe the modelling processes and pertinent results with respect to:
  - *The base-year model development and calibration.*
  - *Traffic forecasting.*

The use of the models for the testing of Toll Strategies will be presented in this minor dissertation. There were various limitations to this study which are summarised below:

- A significant amount of time went into revision and interrogating the base-year model (existing, 2007). This exercise is carried out to the best of the candidate's ability, given the time limitations.
- The access to the models was limited to SATURN in this study. Other micro and macro simulation packages could have been used. E.g. PTV-VISUM and VISSIM and EMME.
- The SATURN program was used as is, hence no option to do a mode choice modelling exercise was carried out. The macroscopic modelling focussed only on private vehicle distribution.
- The other corridors that experienced challenges when the proposed route was introduced as a bypass. This was not within the scope of this dissertation.

1.6 Research Ethics

The base model used for this research was issued by means of Mr Alan Robinson (of SANRAL) without any confidentiality provision. The candidate, however, understood that it was provided only for use on research only, and cannot be shared to other parties. The other information, like toll fee charges per vehicle class, income and expenditures, was once posted information on SANRAL website. Ethics form was completed and submitted to to the Centre for Transport Studies during the research proposal stage and was approved.

1.7 Dissertation Layout

This dissertation consists of eight chapters. The current chapter explores background and the problems being investigated and outlines the main objectives of the study. Chaper 1 also serves as an introduction to the concepts of traffic congestion, modelling and road tolling.

Chapter 2 reviews literature about toll policy and associated objectives and how it impacts on generalized costs, and how it has been modelled in previous studies. It deals with Value of Travel Time Saving (VTTS), Value of Time (VOT) and Generalised Cost (GC) through choice modelling.

Chapter 3 describes the structure and the generic steps of how a transport model is developed and designed, i.e. scoping, data collection, base-year transport model, model calibration and validation, future year transport model and scheme testing. This chapter also explains the different types of models and its functions.

Chapter 4 describes the origins of tolling as a "user pay" principle policy and briefly unpacks SANRAL's Act 7 of 1998. The chapter also discusses the characteristics of the study area, the data required to setup a model and the relevant data that has been collected and processed is highlighted.

Chapter 5 puts forth that the data described in the previous chapter serves to explain how to build a transport model framework as defined in Chapter 3. The model described in the previous paragraph (chapter 4) are then calibrated and validated in this chapter.

Chapter 6 discusses the transport modelling and toll scenarios and results. This chapter also demonstrates the candidate's understanding and ability to use the SATURN software. The dissertation discusses the key findings as it concludes and recommends in Chapter 7.

2. LITERATURE REVIEW

This chapter contains a review of available literature in the South African legislation, toll policy, transport modelling, some critical engineering concepts related to traffic management on freeways as well as project finance.

2.1 Toll Road Objectives

The main purpose of toll roads is really to secure funding from the private sector and / or facility earlier road construction. The secondary objectives of toll roads include reducing vehicle operational costs and travel time as well as maximising socio-economic benefits. It will assist in the public acceptance of toll payment if level of service (LOS) requirements related to toll plaza and road capacity, minimum posted speed limits, the provision of on-road services, etc. can be offered and, in some instances, be "guaranteed" to road users (SANRAL, 2015).

2.2 Toll Road Diversions

According to Rubuluza (2013), the diverted traffic is the flow of vehicles that changes from another route to the subject project road, but still travels between the same origin and destination. For the purpose and of importance to this research, diverted traffic is the traffic that diverts from an un-tolled to a tolled road. This sub-section discusses the elasticity of the price literature and the income effects of such diversions.

a) Reasons for and extent of Diverting

It is a strong possibility that tolls can be introduced to an existing (with or without road upgrading) or a newly constructed road. In both cases, there is usually a parallel road that exists as a choice for road users to utilise. Travelling through this corridor would not alter the traveller's origin and destination.

In 1988, the Transport and Road Research Laboratory stated that where such parallels roads exist in one corridor, traffic will usually travel on the quickest and cheapest route. Stock (2004) attributes the decision of which route is more cost efficient to emotions and perceptions. He goes on to state that such emotions and perceptions outweigh the benefit of using a tolled road. The price, emotions and perceptions result in a high proportion of motorists diverting to the alternative routes.

Lave (1994) stated that *"demand is a function of price and speed, as drivers will pay more for a high-speed journey than a congested one. Toll roads are fast and expensive, whereas un-tolled roads are usually slow but cheaper to the user"* (Lave, 1994). The degree of diverted traffic rest on on the accessibility of convenient, alternative road links that are toll-free. Swan and Belzer (2010) on the other hand argued for the elasticity of demand for tolled roads as a basis for the extent to which traffic is divert.

Acccording to Rubuluza, 2013, when tolls are assumed to be costly, like in Hungary, massive diversion of traffic to parallel roads occurs. Tolls need to be set at affordable levels to circumvent excessive diversion of traffic to other un-tolled route. Rubuluza (2013) argues that the optimal economic solution is to set toll tariffs such that the cost of the journey is equal to the average marginal cost of vehicle trips (Rubuluza, 2013).

b) Impact on Toll Revenue

On a typical toll road, trucks form 10% of toll transaction, but can account for more than 25% of toll road revenue (Prozzi, Rutzen, Robertson and Walton, 2009). It is therefore important to understand their reaction to toll increases. In 2007, Vadali, Gupta, Womack and Pappu argued that there was limited information with respect to the route choice decision of the truckers, especially as it pertained to toll road usage. According to Stock (2004), to obtain marginal economic efficiency, the pavement damage incurred by a vehicle should be equivalent to the toll paid by such a vehicle. Stock (2004) accepted that it is not possible to have a toll fee of relative magnitude to charge for such damage (Rubuluza, 2013).

2.2.1 Road User Charges (Tolls) as a Traffic and Environmental Management Tool

An objective of road user charging is for road users to internalise the external costs of their travel and travel behaviour. Utilising private vehicles has both an impact on congestion and the associated costs to continuously improve and expand infrastructure, as well as the environment (noise, emissions, etc.).

Travel Demand Management (TDM) measures are implemented across the world to encourage ridesharing, public transport use and to consider the time when trips are made. In its most direct application, as it relates to charging road users, congestion pricing levies a fee to a user based on the costs imposed on all travellers as it pertains to the trip being made. These levies are charged without making any improvements to the road network. The income generated is utilised to improve other transport services, such as public transport or non-motorised transport (NMT). Heavily congested areas, such as the CBD, are thereby made less attractive for private vehicle usage.

In terms of conventional tolling, where the toll revenue is used to upgrade road infrastructure, many of the travel demand management objectives are still achieved as follows:

- Modal Shift - rebates or discounts for transit (public transport vehicles). The use of transit is thereby supported.
- Ride sharing – sharing trips reduces the direct costs of travelling to road users, including toll charges. Ride sharing reduces road capacity needs and congestion.
- Time when trips are made – time of day discounts, whereby a substantial discount on the toll tariff for different vehicle classes are applied, can change road user behaviour, reducing road capacity needs and congestion.

a) Emission Pricing

Emission Pricing is a mechanism whereby more emission friendly vehicles are charged tolls, in addition to other road user charges. This may not be palatable in South Africa due to the ownership and average age of the vehicle fleet. However, an emissions levy has been introduced on new vehicle sales in South Africa. Irrespective of the implementation of a specific emission charge, the question remains, does tolling in especially congested urban areas contribute to changing road user behaviour such that it has a positive impact on the environment?

b) Congestion Charging

Congestion charging refers to an amount of money that road users have to pay whenever they enter into a city centre. The amount is charged to reduce traffic entering that particular area, thereby reducing congestion. A congestion charge is different from normal tolling since the charges are not used to provide improved levels of service and road infrastructure for private and commercial vehicles. The funds collected from a congestion charge are mostly used to improve facilities and infrastructure of other modes of transport, including public transport, cycling and walking.

2.3 Generalised Costs and the Value of Time as a Method of Patronage

Anticipating the support of a new public transport facility is of significance in the money saving advantage examinations. The accuracy of such forecasts has been criticised in earlier reports, and overly optimistic forecasts have led to the reduction in public funding for new tramway and other public transport projects in the UK (Lesley, 2009).

Partialy, the explanation behind erroneous forecasting is that there are a few observed techniques dependent on time series investigations. These once in a while have demonstrated circumstances and logical results connections, despite the fact that exceptionally factual connection verifies the connections to be non-arbitrary (Lesley, 2009).

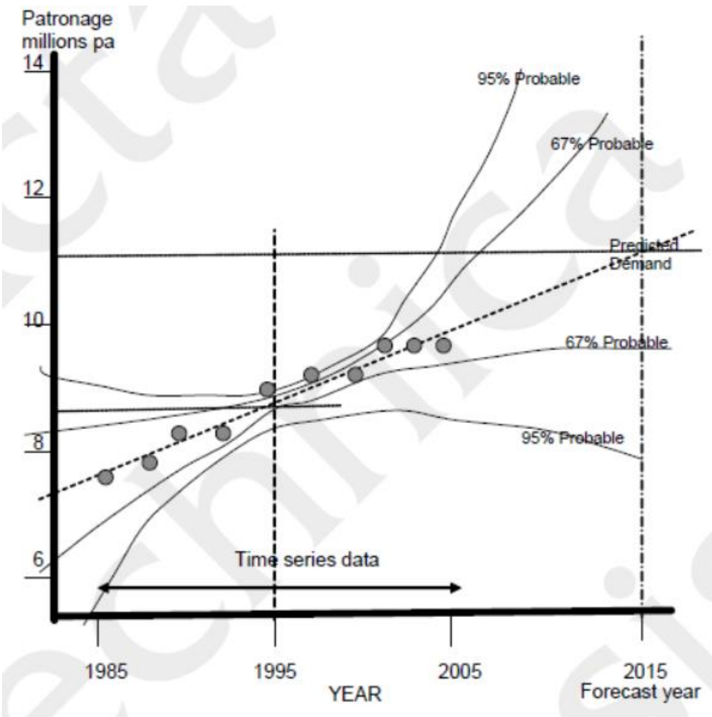


Figure 4: Time Series Analysis (Source: Lesley, 2009)

The economic theory states a well known fact that there is an opposite relationship between demand and cost, the demand curve (see Figure 5). Where, n oe 1/C and so n =k.1/C, where k =a constant.

Regrettably, where the monetary transport cost is replaced into this relationship, there is weak correlation and naturally the elasticity of demand (E) is low.

E = dn/Dc is < zero (0)

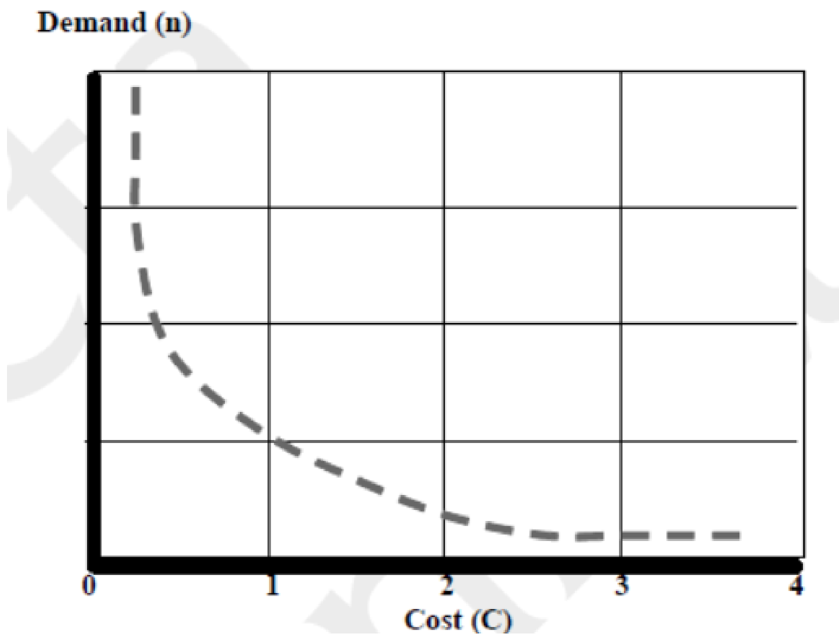


Figure 5: Economic Demand (n)/Cost Curve (C) (Source: Lesley, 2009)

The Generalised Costs (GC) provide a causal model, linking the cost of using a service and the demand created. Considerable research over the last 30 years has shown that the choice of public transport modes includes measures of the quality, as well monetary costs for using the service. GC then can be converted to standard units of measurement by a conversion factor: the VOT. This is sensitive to the purpose of journey and the economic value afforded to passengers. Journeys for work are valued at about the rate of the hourly pay.

GC can be expressed in units of money or time (equivalent minutes). There are generous favorable circumstances in utilizing a time sensitive measure, since this permits noteworthy and universal information to be legitimately thought about. GC measured in equivalent minutes provides an inverse relationship with demand, directly equivalent to the classical economic demand curve. Another explanation is, it makes support projections plausible utilizing pair-wise likelihood investigation, it permits contrasting the GC of a current and that of the new mode. GC can be beneficial adjusted to watch the affectability of the precision of the information, and the effect on the yield conjectures.

GC have been used over several decades for many real transport projects. A recent case study in Galway, Ireland showed how promoters of the new tramway could evaluate the financial viability of a new tramway network. Crucial patronage and revenue forecasts were calculated from expected GC values, splitting the existing and known traffic demand in the corridors served.

To be sensitive to the separation between the origin and the destination, we need a measure of this *"separation".* It needs to take account of the transport system, wherein it is not just distance that is important but other variables, too, the most common being: travel time (usually termed in-vehicle time or IVT), fare, waiting time, walking time, whether the traveler should inter-change, petrol cost, parking charge and toll.

The idea of GC was embraced in financial matters to fuse every one of these factors. GC is fundamentally the weighted aggregate of every one of these factors, so the GC of going from origin to destination would be the weighted entirety of these factors for the subject cause to goal zone pair. These factors can be taken from the systems utilized in the task procedure. They can be *"skimmed"* from the systems as a matrix. i.e. not of outings this time yet where every cell speaks to the estimation of a variable. In like manner, the in-vehicle time skim would include the time spent in going from each zone to different zones, the passage skim would involve the expense of movement from each cause zone to each goal zone, etc for all factors. These skim grids can be joined into one by and large proportion of the *"separation"* between each pair of zones by weighting every lattice and including them all together.

However, GC is not the same as trip utility. The question then is: *how does one determine the weightings associated with the components of GC?* For example:

- High income motorists will perceive the trip time component to be of more value than the trip cost and would thus be more willing to pay tolls to save travel time *(vice versa* for low income motorists).
- How is the VTTS determined if one does not have a discrete choice model based on random utility theory?

The above means that one cannot just use a linear sum of unweighted times and costs (converted to minutes using VTTS) in trip assignment to determine route choice. It is much more complicated than this. It should be kept in mind that trip costs are usually the out-of-pocket costs only, such as petrol, tolls and parking. Lastly, motorists in urban areas have different VTTS for different levels of service (VTTS increases in congested conditions and decreases in free flow conditions). One suspects that because of the rural nature of the N2 and R72 routes and the N2/R72 link road, VTTS for Class 1 car users will be low.

2.4 Tolling as Traffic Management Toll (Transport Policy)

2.4.1 Tariff Objectives

Toll road tariffs must be based on user willingness to pay (WTP) for savings in time and costs. WTP is the foundation for these schemes, urban and inter-urban. Too often toll road structures are based on the financial requirements of the scheme, i.e. time-period to pay back capital (CAPEX) and operational (OPEX) needs. Tariffs are estimated based on meeting financial needs, not WTP. The SANRAL's Gauteng Freeway Infrastructure Project (GFIP) is a good example of this kind of failure.

2.4.2 Road User Charges as a Traffic Management Tool

Urban tolls have as their objective the revenue for expanding and upgrading the road system. There may be initial reductions in travel times, costs and emissions but, over time, the new roads and upgrades will attract more car users and the congestion levels will increase until new roads are built, or upgrades are implemented. Mode share objectives will not be met as building new roads (even if tolled) will not induce a significant mode shift. Adding capacity results in car travel time and cost savings that negate the use of public transport.

Congestion pricing has as its objective the permanent reduction of travel demand, mode shift and reduction of emissions. Congestion pricing revenues are designated for improving public transport, not building new roads. Congestion pricing is a traffic demand management measure based on the user pays principle.

It is very important to differentiate between urban toll schemes and congestion pricing. The GFIP e-toll scheme is not congestion pricing, but rather a way to generate revenue for road upgrading and network expansion. It is not meant to suppress trip demand; in fact, it has the opposite effect when upgrades are made, and the network is expanded. It reduces congestion (if temporarily) through infrastructure improvements and increases demand (which in turn reduces the congestion benefits). It could be argued that tolling adopts the user pays principle, although this is a misunderstood statement. The South Africa national governments user-pay policy was reiterated in the 2017 Draft White Paper on National Transport Policy as follows: "A National Road Transport **Demand Management** Guideline will be developed considering the following principles: Adopt the 'user pays' principle where appropriate, on the understanding that it will **not be universally applied** and the **impact on vulnerable sectors of society will be considered in its design**."

The main purpose of congestion charging is to internalise the external cost of congestion, i.e. the cost imposed on other road users of the additional vehicle. Seconary to that, congestion pricing, is meant to reduce congestion by suppressing demand. Lastly, congestion pricing are to reduce congestion, to reduce the environmental impact of vehicles by reducing harmful exhaust emission, and to improve the space for public and NMT modes. Revenue from congestion pricing can be used for public transport provision and not for upgrading and/or building new roads.

2.5 Traffic Modelling of Urban Toll Corridors – A South African Practice Applied in the Gauteng Freeway Improvement Project (GFIP)

More recently, road construction budgets have decreased substantially at national, provincial and local levels. At a national level, this resulted in the emergence of the Build Operate Transfer (BOT) projects, whereby new road construction projects are financed via toll revenue, with toll concessions being granted to privately owned companies or consortia.

The focal point of the cost demonstrating exercise was to decide the impacts of different situations of Gautrans Toll Road Strategy (GTRS) on traffic conditions on the proposed cost streets and supporting street organize, and to convey transportation-related contribution for broad possibility investigations of the cost system. The components of this were as per the following:

- *Traffic development depended on the land-use gauges for future years. The base-year was 2000.*
- *Two road network circumstances were investigated. for example business as usual and base case future traffic .*
    - *the business as usual system adjusted with different system advancements.*

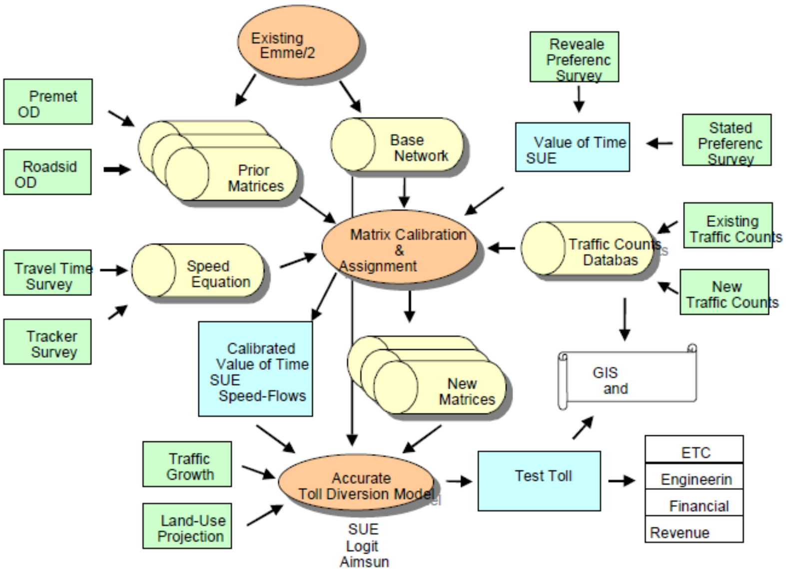


Figure 6: Gautrans Model Desing (Source: Van Zyl, Oberholzer and Chen, 2001)

The GFIP model is not a good example of best practice in urban toll modelling because of some of the reasons given above. It is also because it simply assumes that all motorists are willing to pay the toll. It is safe to say that very few toll roads projects in South Africa have estimated proper discrete route choice models and willingness to pay tolls for travel time and cost savings (Van Zyl, Oberholzer and Chen, 2001).

It is noted that for dense road networks in urban areas, the high number of alternative routes can make the estimation of route utility complicated, especially if there is correlation between the routes, i.e. route overlaps. These require the application of specific logit models that have not been applied in South Africa before.

2.6 Estimation of Value of Time From Stated Preferences Studies and Their Use in Toll Roads Models – A World Practice Applied in Gauteng Freeway Improvement Project (GFIP)

The decision of route conduct for likely toll route users and their expected VOT, which controls their choice of route, are significant in demonstrating the cost-pay stream of a toll road being referred to. This is fundamental in assessing the financial risks of the financiers of the toll road investment.

Van Zyl, Oberholzer and Chen (2001) clarify the discrete decision models as exceptionally mainstream universally to reproduce the decision conduct of transport clients for movement guaging and approach testing purposes. Generally, a large number of these models were made for mode decision considers. With the international trends to finance new high order roads by means of tolling, route choice studies have become more popular. Discrete decision models are explicitly used to gauge the VOT of road users as the models precisely catch the fundamental decision conduct of the particular objective market of the planned toll road. The models additionally permit the effect of any factor impacting the VOT to be evaluated, for example, reason for the trip, salary, road standards, and so forth.

The VOT is assessed from the detailing of the logit discrete decision model. Consider the basic course decision circumstance between a toll road and its other option, or equal, non-tolled street. The utility that the road user gets from each route can be defined as far as toll fee and travel time:

- $U_{toll} = {}_{c}\, Ct + {}_{t}T_{t} + M_{t}$.. Equation 1
- $U_{alt} = {}_{c}\, C_{a} + {}_{t}T_{a}$.. Equation 2

Where:

- U_{toll} and U_{alt} are the utilities of the toll and alternative road respectively.
- C_{t} and T_{t} are the user cost of the travel time on the toll route respectively.
- C_{a} and T_{a} are the cost and time on the alternative route.
- C_{a} and t are the cost coefficients, which are estimated on survey data of road users' perceived travel times and costs by means of special logit model calibration programs.
- M_{t} is the constant, attached to the utility of the toll road, which then captures any factor not related to the variables in the model, cost and time in this case, which may relative to the safety and convenience of using the toll road relative to that of the alternative road.

The VOT is the pace of progress of utility comparative to the rate of change in travel time, isolated by the pace of progress in utility comparative with the pace of progress in the expense. For direct utility capacity, for example, Equations 1 and 2 over, the VOT is just the proportion of the time coefficient to the cost coefficient:

VOT = t/c...Equation 3

On the off chance that time was estimated in minutes and cost in cents, the VOT is given in cents per minute. Any factor in the utility capacity can be communicated as far as fiscal qualities by taking the proportion of that variable's coefficient to the cost effective. By taking the proportion of the cost street steady M_t t to the cost coefficient, one arrives at the value of the safety and convenience that road users attach to the toll road. This is often referred to as the motorway bonus in international literature.

By making the utility capacities increasingly intricate, one can get more data from the model. The surveyed information can likewise be portioned by trip reason and additionally pay level to evaluate the VOT for various outing purposes and pay levels. For instance, by separating the cost variable into running and cost charge costs, one can appraise the VOT identified with running and cost expenses. Louviere and Hensher (2000) determined a VOT work by bringing quadratic and increase cost and time terms in the utility capacity. Right now, could evaluate how the VOT would contrast by the degree of the cost expense and travel time.

VOT's governing of route choice behaviour in road users was found to be much higher than the average income per working hour that is normally used in economic evaluation studies. For the toll road feasibility studies, it is therefore important that VOT is estimated for each toll road context.

Various factors that significantly impact on the VOT were quantified: *the degree of traffic blockage experienced, pay and financial status, trip reason and the standard of the roads* (Hensher and Goodwin, 2004:11).

2.7 Using Values of Travel Time Savings (VTTS) for Toll Roads

For most of the post-war period, the evaluation of travel time savings has been an important public policy issue. In the UK, for example, travel time savings account for around 80% of the monetised benefits within the cost-benefit analysis of major road schemes. A few questions arise: Why do we care about travel time savings? Why do we attach a value to it? Is it because we do not like travelling? Or is it because we would like to be doing something more pleasurable instead. The answer to these apparently simple questions covers and amalgamates many areas in economic thought, from the theory of labour supply, to home production and transport (Mackie, Jara and Fowkes, 2003).

According to Hensher and Goodwin , there are countless experiential studies on the estimation of values of time savings (VTTS), with varying grades of relevance and rigour. These are mainly on observation that travellers are willing to spend money to save time. These values are applied both for the estimation of social benefit of such savings and to forecasting the effects of speed changes on practices so as to figure the worth for-cash of spending open assets on transport ventures. The wellsprings of exact data on such qualities are not in every case well-coordinated with the models and programming inside which the outcomes are utilized.

Barely any years back, an undeniably significant application has been used to decide the potential income from tolled roads, and systems with user charges, which offer high speeds at a more significant expense. In this case, critical point is not hypothetical eagerness/willingness to pay (WTP), yet the genuine cash that will be given over. This progressions the concentration from theoretical to bankable VTTS.

It has been indicated that some basic practices risk generous mistake in estimation, influencing the sharing of risks among public and private sectors. Especially significant is the point at which a normal worth is taken as illustrative of a slanted dissemination of qualities. In these conditions, there will be an inclination to overestimate the income, and disparage the traffic effect of a charge. This is on the grounds that, for a given mean VTTS, there will be fewer people who are set up to pay the cost. To address this inclination, the fundamental assignments are: *setting up an important arrangement of excursion reason explicit VTTS conveyances and choosing a method for taking care of the dispersions in support guaging; developing VTTS through time; treating the VTTS of vehicle travelers; and building up a proper arrangement of rules for changing over disaggregated (or heterogeneous) segments of movement time esteems into a solitary outing esteem fitting to the venture being assessed*. Other related issues of the utilization estimations of time identify with the suppositions that these qualities develop in relation to salary.

One problematic feature is that all of the problems deliberated tend to produce biases in the same direction, namely *the risk of overestimating revenue in the short and long term*. This produces a tendency towards appraisal bias, which can misrepresent the contractual confidence between partners. Overall, it is likely that current assumptions are underestimating the degree of toll-avoiding behaviour, thus overestimating the financial viability of projects.

According to South Africa's Hayes and Venter (2016), Random Utility Maximisation (RUM) econometric hypothesis depending on the weighted straight extra of property vectors has been used in worker trip decision models since the mid 2000s. The utilization of this hypothesis acknowledges objective decision properties and their relative weightings, just as the determination of the arbitrary (mistake) segment of the utility condition. Hayes et al. went on to say that the important derivative of this approach is the VTTS, i.e. money a traveller is eager to to pay to save a specific amount of travel time. The VTTS is a WTP measure, *characterized as a money related worth a suburbanite is willing to expense for a particular savings in at their travel time*. VTTS is commonly applied in road and public transport pricing and transport related economic analyses (Hayes and Venter, 2016).

The following observations were made from a survey of the VTTS gauges got from a few transit and toll road projects in the province of Gauteng since 2000:

i.) The variety of the VTTS for commuters is important for:
   - *cars users, between R 16.98/hour (Ekurhuleni) and R 126.00/hour for the normal non-business vehicle user for the 2004 Gautrain study in the off-peak time frame.*
   - *transit users, between R 4.16/hour (low salary) and R 41.58/hour (high pay).*

ii.) Studies finished since 2010, for example the Ekurhuleni, Johannesburg and Tshwane SP studies have found lower VTTS than in past examinations.

iii.) There have been quite a few efforts to categorise the values by income and by mode, depending on the nature of project under consideration.

This is additionally upheld by the UK Division for Transport who distributed rules for VTTS application in monetary examinations, for both business and non-business-related outings (UK Office for Transport, 2015). These amended qualities depended on 11 500 SP overviews and were indicated by mode for business-related outings.

As a final note on VTTS for toll roads in urban areas, recent research (Rose, John M., Hensher, D.A., 2013) in Sydney has shown that not only is WTP an issue, but ability to pay is also an important consideration. This is particularly important in the case of cumulative tolls, i.e. tolls that are incurred every day, twice a day, over a working month or year. Even with toll caps on the GFIP, for example, it can be expected that there are some motorists who cannot afford to pay the monthly toll fee. In Sydney, this was found to dramatically reduce the VTTS for those motorists. Also, research in New Zealand found that commuters did not value travel time savings of eight minutes or less. So, if a new road saved five minutes in travel time, motorists would not perceive any benefit, i.e. VTTS = 0.00. No research has been done in South Africa on this issue.

a) Application to the Gauteng Freeway Improvement Project (GFIP)

The main obstacle to acceptance of the GFIP scheme by motorists has been SANRAL's inability to show that the tolls were nothing more than a *"revenue grab".* Battered by high personal taxes and the high price of fuel, many motorists have little ability to pay. Also, research done for SANRAL into express toll lanes on the freeways in Gauteng in 2004 as part of the super-highway's consortium showed that there was a very low WTP for urban tolls. This should have rung alarm bells (Hayes, 2016).

2.8 Price Elasticity of Toll Road Demand

In 2016, Odeck and Brathen characterized the cost value flexibility as communicating the adjustment in movement request actuated by an adjustment in cost rates. They likewise referenced two kinds of versatility: short-run and since a long time ago run flexibility. They characterize short-run flexibility as the impact on request happening inside one year of an adjustment in the free factors. They proceeded to recognize since quite a while ago run flexibility as a complete reaction on request to change on autonomous factors over periods longer than a year. This sub-area manages writing on versatility of cost request comparable to expanding cost charges.

The profit-maximising toll rates should be set at a point at which elasticity of demands equals one (Gronau, 1999). As per Alvarez et al. (2007), the Road Economic Decision (RED) model, which is an immediate interest model, likewise expect a value versatility of interest for transport of 1.0 for all vehicles. This implies a 1% decline in transport costs yields a 1% increase in generated traffic, because of a decrease in transport costs. Notwithstanding, as per Matas and Raymond (2003), the agreement is that, all things considered, transportation request is inelastic as for cost. They went further, citing that empirical evidence confirming toll elasticity most frequently indicated values around - 0.2 and - 0.3 with a range of – 0.03 to – 0.50. Low elasticity thus implies relatively ineffective levers for influencing demand and revenue. Results in a Spanish study showed that the sensitivity of demand to price depends on both the characteristics of the tolled motorways and those of the alternative free road.

Swan and Belzer (2010) refer to Oum, Pindeyck and Rubinfeld (1998) as utilizing a direct interest model for this non-consistent versatility. The straight cost value versatility is characterized as relative change in movement request, partitioned by relative change in cost. To represent this experimentally, an ideal evaluating outline for transport request (Burris, 2003) is utilized in Figure 7 beneath. This examination is mostly intrigued by what impact on traffic volume (q1 to q2) the expansion in cost value (t) has. The slope of the line with coordinates (q1,p1)(p2,q2) characterizes the direct and linear toll value versatility.

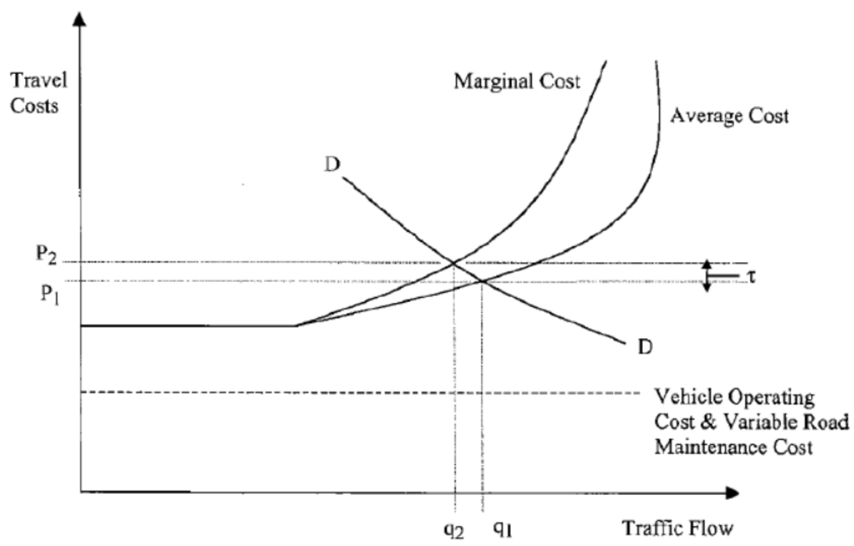


Figure 7: Optimal Pricing of Transport Demand (Source: Burris, 2003)

Equation 4 below illustrates the relationship in percentage form. According to Hirschman et al. (1995), *"the 'shrinkage' ratio compares the traffic on the facility before and after a toll change. In this technique, the toll elasticity is estimated by computing the ratio of the percentage change in traffic to the percentage change in the toll, using the initial traffic and toll levels as the bases of the calculations".*

Hirschman et al. (1995) discourage the use of this ratio, as it yields distorted results. They proceed to state that it does not speak to the effect of value changes in different factors, similar to fuel cost and business. It was, in any case, registered in their examination as a legitimacy check for the strategy that was utilized. Since the examination to some degree predicts, various relapse investigation was utilized. Different relapse investigation permits the investigator to join factors other than the cost into the model. This numerous relapse examination likewise disconnects the impacts of toll charges by measurably holding steady different effects on movement volumes.

$$\textbf{Elasticity (Shrinkage Ratio)} = \frac{\frac{q2-q1}{q1}}{\frac{p2-p1}{p1}}$$ .... Equation 4

Where: q = demand (traffic volumes) and p = price (toll free)

In any case, it was found by Odeck and Brathen (2008) that a linear relationship does not perfectly reflect reality in the transport field. They incline toward the utilization of circular segment flexibility, which yields a convex demand function. It merits referencing that it is typically information constraints that powers investigators to utilize circular segment flexibility, as it tends to be assessed from as not many as two information points. This perception is predictable with Dwijono (1997), who utilized the shrinkage proportion for approving the Arc-Elasticity strategy. Dwijono (1997) proceeds to state that shrinkage proportion is typically littler than bend flexibility because of the idea of condition. Parkin, Powell and Matthews (2012) express that, independent of the sign, versatility of somewhere in the range of 0 and 1 is said to be have an inelastic interest. To acquire this curved interest, Odec and Brathen (2008) utilized Equation 5 underneath to communicate circular segment flexibility.

$$\textbf{Arc Elasticity} = \frac{\Delta \ln \textbf{Demand}}{\Delta \ln \textbf{Toll Price}}$$ ....Equation 5

Whichever method is used, as demand becomes less elastic, revenue-maximising tolling becomes less efficient. Bowerman (2007) points out that demand become inelastic as accessible substitutes become less. As indicated by Verhoef et al. (1996), this all prompts wastefulness if incredibly more responsible option costs are charged. This is affirmed by Standish and van Zyl (2003), who likewise state that high tolls that lead to substantial vehicle redirection to minor streets may decrease proficiency (Rubuluza, 2013)

2.9 Modelling Road User Charges in SATURN

The drivers nowadays are being approached to pay straightforwardly for them to drive along or a particular area or explicit routes. The location and scale of these charges are planning issues. Tolls emerge in various circumstances, as fixed tolls to utilize a segment of a roadway, tolls imposed to enter a region of a city (regardless of whether gathered legitimately at a cost point or in a roundabout way by means of electronic strategies) or section to-leave motorway tolls or to cross a bridge (Van Vliet, SATURN Manual, 2015).

Tolls are defined as (monetary) charges per "link" *(including, in this context, simulation turns, centroid connectors etc., as well as buffer/simulation roads)* per user class, so that – in the context of a route over a succession of links – they are additive. Thus, the software precludes the possibility of directly modelling non-additive tolls (the situation that commonly arises with entry-to-exit tolls on motorways whereby to toll from A to C is different from the sum of the toll from A to B plus B to C).

The strategy where tolls influence decisions inside SATURN is moderately basic and direct, they are essentially one additional segment in the meaning of Generalised Cost (GC). they influence route choice within the assignment, as well as the minimum O-D costs used within elastic or variable demand assignment.

In this way, inside SATURN demand models, there are no direct facilities for "multi-criteria" modelling. For example, it is not possible to define a demand function in *SATALL/SATEASY* that is a function of time, distance and monetary tolls separately; they are all subsumed within generalised cost. It would be feasible for users to define such complex demand functions using the facilities within *MX*, since it is quite possible to skim distinct matrices of time, distance and tolls from an assignment (Van Vliet, SATURN Manual, 2015).

2.10 Simulation Models and Levels

Broadly speaking, vehicle/passenger modelling methodologies fall into three categories:

- Macrosimulation models: *For assignment, these models calculate the cost of using different routes on the basis of an aggregate calculation of journey time on each section of the network as a function of the traffic flow using that network. They provide good visual representations of demand across a network for a defined period. Modern macrosimulation models also encompass the Trip Generation, Distribution, Mode Share and Assignment stages, therefore covering all processes within the Four Stage Model*. (Jaspers 2014).

- Microsimulation models: *which tend to undertake assignment modelling only. The assignment model operates on the basis of individual vehicles/pedestrians, measuring the behaviour of vehicles/pedestrians on the basis of vehicles/pedestrians around them. The condition of the network is then measured by effectively undertaking 'surveys' of the network within the model. They provide a good visual tool to understand network* *operation in real time and are suitable for accurate modelling of delay build-up in road networks or pedestrian movements, particularly for singular or groups of congested junctions;* and (Jaspers, 2014).

- Mesoscopic models: *These fill the gap between microscopic and macroscopic models, by representing the choices of individual drivers at a probabilistic level, but limiting the level of detail on driving behaviours.* i.e. provide a functionality mid-way between Microsimulation and macrosimulation models, although these are not common (Ferrara et. al, 2018).

c) Discussion

Although Macrosimulation models can be time and resource consuming, they allow numerous *"what-if"* scenarios to be tested during a project preparation or strategy development exercise. In addition, they provide outputs that are compatible with the requirements of a traffic and environmental impact assessment, as well as economic and financial appraisal (Jaspers 2014).

Microsimulation Models are most appropriate for the assessment of road networks in urban areas, or where the nature of the road layout makes the modelling of conflicts difficult using Macrosimulation Models (e.g. merges, weaving, complex junctions). Microsimulation models can also be used to a wider scale e.g. on motorways in order to model users' response to traffic management and users' information strategies and systems (ITS). More advanced techniques also permit to use Microsimulation models for road safety analyses. Where Microsimulation models are used, the method of generating outputs for the CBA should be considered in advance. The use of Microsimulation models for interurban road projects and for large complex urban networks can be problematic and can be very consuming in terms of computing capacities. City-wide Microsimulation for large cities or complex motorways networks is an extremely challenging task and is generally not recommended.

The aim of travelling is move to from one destination to another. Travel is typically planned for in macroscopic models (Zuidgeest, 2014a). Macroscopic transport models, such as SATURN attempts to replicate the land use and transportation interaction. The planning of transportation of cities the location of humans' activities, such as living, working, shopping, education or leisure, determine the spatial interaction or trips in transportation system. This is the basic rationale of macroscopic traffic models. (Wegner, 2011).

Transport planners use macroscopic transport models in determining where future road upgrades are required and where new links will help ease congestion in the overall network (Montero et all, 1998).

It is worth mentioning that, SATURN does not replicate the land use transport interaction. Only land use transport simulation (LUTS) platforms simulate this effect as described earlier. Four-step models are very poor at simulating this relationship. For example, residential location choice is affected by, amongst others, the transport network. There is no evidence found to confirming if the land use planners use the transport networks to estimate zonal land use data. It is done very poorly in South Africa and accounts for a large chunk of the forecasting error.

In macrosimulation models, the models calculate the cost of using different routes based on an aggregate calculation of journey time on each section of the network as a function of the traffic flow using the network. They provide good visual representation of demand across a network for a defined period. Modern macrosimulation models also encompass the trip generation, trip distribution, mode share and assignment stages, therefore covering all processes within the FSM. (Jaspers 2014). Also, macrosimulation models can be time and resources consuming, they allow numerous "what-if" scenarios to be tested during a project preparation or strategy development exercise. In addition, they provide outputs that are compatible with the requirements of a traffic and environmental impact assessment, as well as economic and financial appraisal.

In any traffic model, the model estimates the cost of a trip by using modeler specified inputs (e.g. petrol cost, car fuel consumption, parking fees, toll fees) and a rule-based assignment method. In transport (road and public transport) economic appraisal, time savings benefits normally make up the biggest chuck of economic benefits."

2.11 Conclusion

From the existing literature explored above, the following can be concluded:

- Whilst there are various forms of road pricing, literature shows that congestion pricing and revenue maximisation are the most dominant forms South Africa uses in a revenuegeneration model, with the purpose of funding the ongoing maintenance costs.

- Heavy vehicles are significant contributors of revenue, but they also cause exponential damage compared to cars. However, it is possible to have a toll fee of relative magnitude to charge for such damage.
- The cost increments can possibly redirect traffic away from the tolled to the un-tolled roads or the other way around. The occupying can be demonstrated by establishing the value versatility of cost street request. This redirection likewise, thusly, negatively affects the incomes for the road authority or tolling offices.
- Road pricing as a form of generating revenue for reinvestment in road infrastructure is on the increase globally. This increase is a product of growing economies not being able to fully fund such investments. Literature also shows that governments are progressively seeking the involvement of the private sector in this function.

Based on this literature, it is important to quantify the extent of diversion on the tolled network in East London, South Africa. It is also important to understand how price is the demand for toll road use. It is believed that having such understanding will help the agency in understanding the revenue growth risks and determining optimum tolls that will maximise revenue even in future projects.

3. STRUCTURE OF MODEL DEVELOPMENT

Regardless of the functionality and method of modelling choses, the procedure for developing a transport model is relatively consistent. The steps to be followed in model development are presented below and should be followed in this sequence during the development of any transport modelling tool.

3.1 Steps in Model Development

Prior to undertaking any transport modelling exercise, it is necessary to completely know the requirements and functions of that model. This will ensure that the model delivers output that is relevant to the project and enables a good project appraisal. The scoping stage of a modelling exercise examines the type of model that is required, the level of detail that will be inputted, and the method for undertaking the calculations.

Other critical parts of a model scoping exercise are the determination of the type of data that is required to develop the model; the time period to be modelled; and appropriate modelling platform to be used. The model design must drive the data needs, not the other way around.

Following the scoping, the data collection stages involve the collection of all the necessary data as outlined in the scoping report. Because of the number of movements and the complexity of a transport network, it is not possible to measure every transport movement for inclusion in a transport model. As such, the data collection stage also allows the necessary data to be collected for the calibration and validation stages, and the future year model development stages.

The base-year transport model involves the expansion of the data collected into a full data set of transport movements using aggregate indicators. This demand is then loaded onto a transport network and transport services (in the case of public transport), which is also constructed as part of this stage, using an initial set of mathematical algorithms.

The development of the base-year requires the execution of the four-step process. The models basically consist of three data sets: the supply side (the road network and its capacity and the public transport services and routes, if modelled); the demand side – the vehicle (or passenger) demand data; and the parameters that control the supply-demand relationship (speed flow curves, trips costs etc.).

The calibration and validation process seek to ensure that the synthesised data-set matches observed conditions on the transport network. It provides an opportunity for the practitioner to modify the transport network, transport services, transport demand and mathematical algorithms such that the model outputs better reflect existing observed transport activity on the network (journey times, traffic flows at individual locations, observed mode share on selected corridors etc.). This stage also provides an opportunity to correct any errors in the model development that may become clear.

The first challenge that model developers and users must get-rid of are the acceptance of a standard set of terminology to describe verification, calibration and validation in Step 4. Presently, the terms verification, calibration and validation are frequently misused, misunderstood by traffic modellers. The point of this section is to give clear definitions of these procedures and furthermore to address the abuse of these wordings.

a) Model verification is the way toward deciding whether the rationale that depicts the basic mechanics of the model, as determined by the model designer, is really caught by the computer code. Model verification decides whether, free of the legitimacy of the rationale or the hypothesis from which the rationale is inferred, the comparing computer program creates the ideal yields. i.e. extent, precision and direction. For example on the off chance that the model originator indicates that A = B + C, at that point model check decides whether the computer code registers A as the sum of B and C. Model verification does not attempt to make sense of whether this relationship sufficiently catches reality, or if A ought to be equivalent to an option that is other than the total of B and C
b) Model calibration is the process of defining to what degree the model user can modify the default input parameter values that defines the underlying mechanics, in order to replicate the observed local traffic conditions being modelled.
c) Model validation is the process of finding out the amount the model's underlying essential rules and relationships can sufficiently capture the targeted growing behaviour. i.e. as specified within the relevant theory, and as demonstrated by field data. To streamline the above it implies, *can the lane changing, car following rules, gap-acceptance, vehicle keeping rules used by the model produce the relating limits, line sizes, speed dispersions and weaving impacts?*

Following this stage, future year forecasts of the transport model are developed that incorporate changes to the network and to the factors driving transport demand (e.g.

population, employment, car ownership, economic activity). This provides a picture of the future year transport conditions that will exist in defined years and represents the background against which a project is evaluated.

Finally, transport infrastructure and policy and/or land-use interventions are tested in future-year versions of the transport models. This allows impacts and benefits to be assessed for the future-year in question and forms the input to design and the subsequent project appraisal. This is outlined in Figure 8 below.

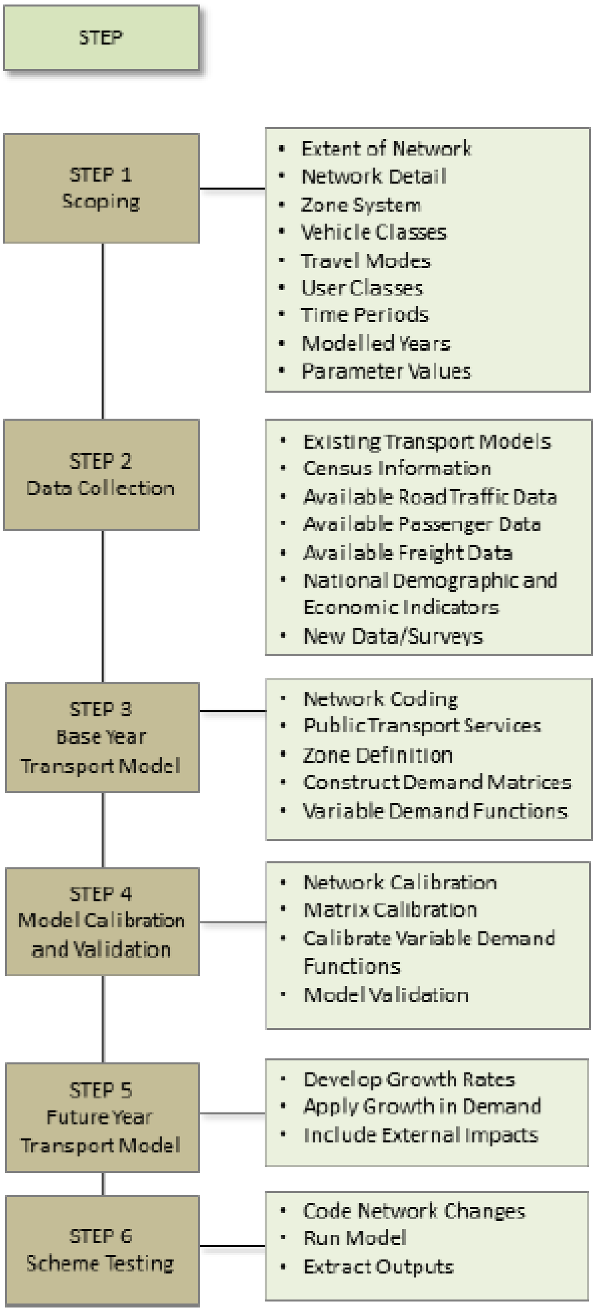


Figure 8: Structure of Model Development (Source: Jaspers, 2014)

3.2 The Functionality of Models

For each of the four modelling stages described of the Four-Step, there is often a requirement to include a range of feedback loops into the modelling process. Feedback loops recognise the interdependency of the various stages of the modelling process and the subsequent need to apply calculation methods. The functionality of a model is defined by the presence of such feedback loops, which increase the ability of a model to forecast real outcomes. The varying levels of functionality are Simple Models, Assignment Models, Mode Share Models and Variable Demand Models. These are described in Table 1 below.

Simple Models	Assignment Models	Mode Share Models	Variable Demand Models
SHORT RUN TIMES NO ROUTE CHOICE NO NETWORK EFFECTS NO MODE SHARE RESPONSES NO DEMAND RESPONSES	LONGER RUN TIMES INCLUDES ROUTE CHOICE INCLUDES NETWORK EFFECTS NO MODE SHARE RESPONSES NO DEMAND RESPONSES	LONGER RUN TIMES ROUTE CHOICE RESPONSES MODE SHARE RESPONSES NO DEMAND RESPONSES	LONGEST RUN TIMES ROUTE CHOICE RESPONSES MODE SHARE RESPONSES INCLUDES DEMAND RESPONSES
• Capacity analysis of single or multiple junctions with no route-switching. • Analysis of road sections or small networks for Accident Forecasting where no change in demand, mode share or route switching is anticipated. • Application of growth rates to forecast future transport demand on a transport link or from a transport zone. • Can often be done without network modelling software	• Small Network Changes where mode share effects are not expected. • Impact of new and upgraded roads in areas with Limited Public Transport or potential for variable demand responses • Rerouting impact of service changes in a public transport model where no mode share responses are expected. • Needs network modelling software	• Small Network Changes where mode share changes are likely to occur. • Mode share and assignment impacts of service changes in an overall transport model where mode share responses are expected between public transport and road. • Mode share and assignment impacts of service changes in a public transport model where complex mode share responses are expected between different public transport modes with qualitatively different characteristics or where mode share changes need to be economically analysed. • Needs network modelling software	• Major Network Improvements which lead to significant changes in travel time and/or accessibility. • Major urban areas where congestion exists, or will exist within the study period. • Areas where population and/or employment patterns are expected to result from changes to the transport network. • Significant Public Transport Service Changes. • Analysis of Impact of Policy on Network Condition. • Strategic Planning models. • Needs network modelling software

Table 1: Summary of Model Functionality and Applications (Source: Jaspers Guidelines, 2014)

For this research the functionality used is the Variable Demand Models. This is described overleaf.

Variable Demand Models represent a broad functionality of transport models. Usually, in addition to Assignment and Mode Share modelling, they also include the Trip Generation, Trip Distribution modules of the Four-Stage Models as part of the modelling process, with feedback loops into those stages. Variable Demand Models can therefore model the following responses:

- Changes in overall transport demand, including the assessment of transport volume induced by the assessed project in terms of the impact of cheaper travel.
- Changes in trip patterns.
- Changes in the timing of travel.

Variable Demand Models are therefore driven by the land use pattern, socio-economic profile and network condition within the study area. They can thus allow the responses to change in these properties to be understood. Typical scenarios requiring Variable Demand Modelling include larger towns and cities with congested networks; scenarios of substantial change in travel time or cost and/or in the structure of land use and of the related economic activities; or regions that have traditionally suffered from poor transport accessibility.

Variable Demand Modelling is a powerful tool in the assessment of the impacts of transport/environmental policy or changing economic circumstances on travel. Examples that are not otherwise quantifiable through assignment or mode choice models include:

- fuel price changes
- road-user charging
- public transport fare changes
- parking levies
- new population/development patterns
- major traffic management schemes

In these cases, the Variable Demand response is a fundamental element in the valuation of a project. As such, the relevant demand responses need to be captured to understand the impact of the project. Variable Demand Models can require a very high level of computing capacity for big network models where variable demand, mode choice and route choice equilibrium are being sought simultaneously. However, Simple Models that examine individual elements of Variable Demand can be developed. For example, elasticities or logit functions can be used to determine transport demand effects for a single zone or region.

Nevertheless, this information is usually combined with network information to run the final mode share and/or assignment. Hence most Variable Demand Models used for appraisal of or planning of transport infrastructure are correctly built using network models.

4. STUDY AREA, DATA AND AVAILABLE MODELS

4.1 Tolling roads in South Africa

According to Aureco (2011), the history of toll roads in South African can be summarised as follows:

- In the late 1970s, the dedicated fuel levy as a mechanism of raising funds for road repairs proved to be ineffective (due to fuel crises in 1974 and a decrease in fuel consumption in later years).
- In 1981, toll financing was identified as the most likely mechanism to supplement road funding.
- In 1982, a Parliamentary Select Committee recommended that toll financing of roads be introduced in South Africa to supplement the fuel levies.
- In 1984, the first toll road in South Africa started operating (the Tsitsikamma toll road on the N2).

South Africa has two main types of toll roads, namely concessions contract and state-owned or so-called CTROM (Comprehensive Toll Road Operations and Maintenance) contracts. South Africa currently has three contracts: N4 Maputo Development Corridor, operated by Trans-African Concessions (TRAC), N1/N4 Platinum Corridor, operated by Bakwena Concessions, and N3 Toll Concession, operated by the N3 Toll Concessionaire (operated as N3TC). They represent a total network of about 1 250km and contain about 31 toll plazas (of which about 16 plazas are ramp plazas). Further concession contrasts are being planned. The traffic through selected plazas on the three concession contracts during initial years (i.e. shortly after commencement) is indicated in Figure 9.

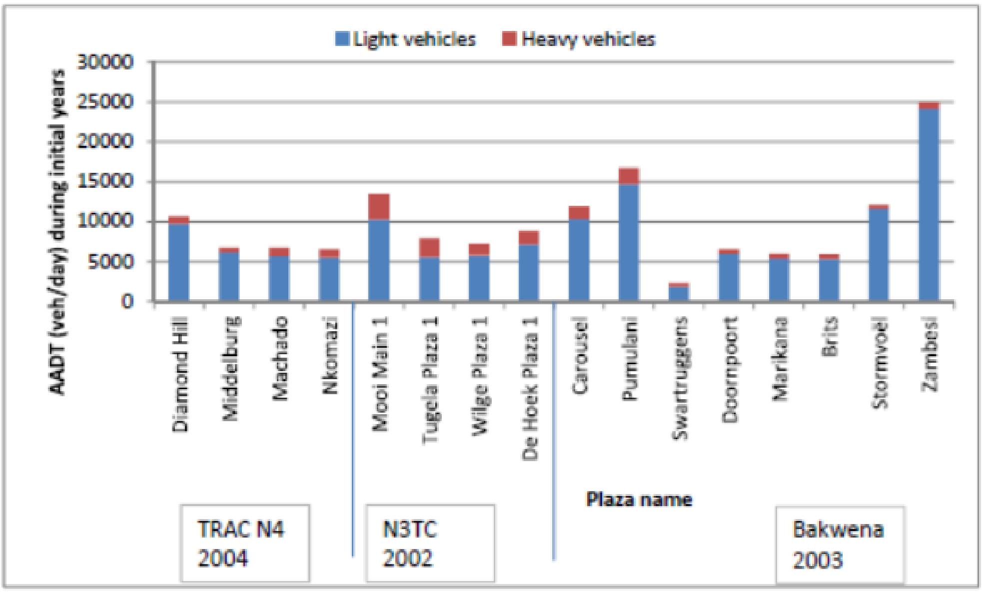


Figure 9: Traffic Through Selected Plazas (Source: Aurecon, 2011)

About 1 750km of toll roads in South Africa are owned by the state and operated under CTROM contracts. Under these contracts, an operator is appointed for a long term (five to eight years), and performs tasks of operation, maintenance and toll system development and installation. The operator also assumes some operational risks. The typical organisational setup for a CTROM contract is indicated in Figure 10.

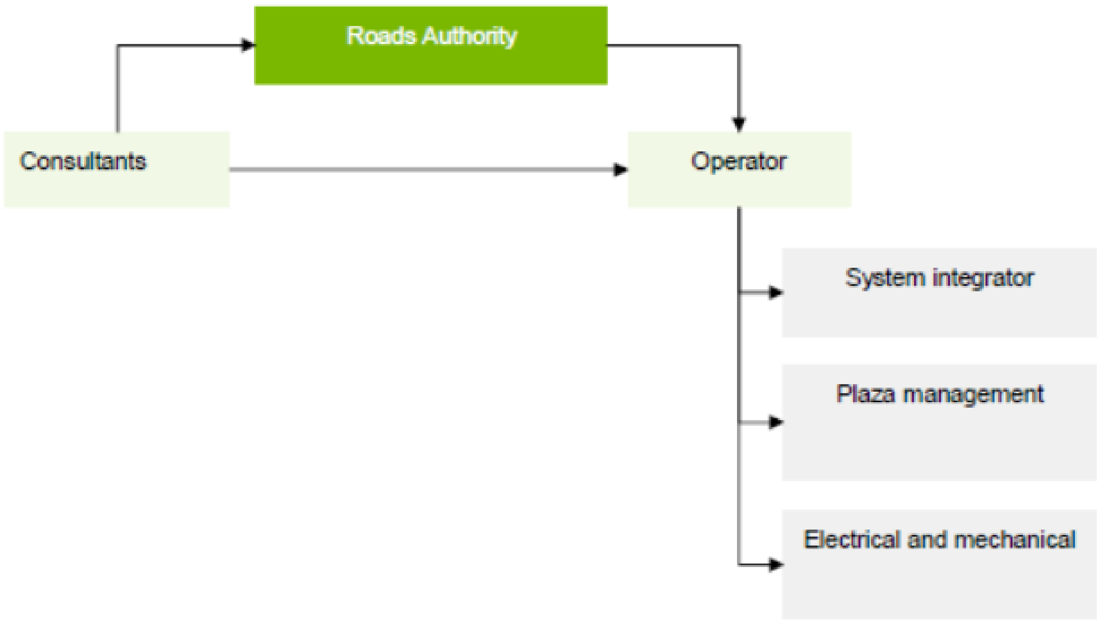


Figure 10: Organisational Structure for CTROM Contracts (Source: Aurecon, 2011)

Since the opening of the first modern toll plaza on the N2 Tsitsikamma, the toll road network in SA has been further developed and currently comprises up to 3120km of the national road network.

Currently, there is only high-level toll policy with legislative requirements. The current road funding policy considerations are contained in the "Transport White Paper" of 1996 published by RSA's National Department of Transport, "National Development Plan" of August 2012 and "Moving South Africa Action Agenda (1999) ". From a legislative perspective, the SANRAL Act (Act 7 of 1998) and the National Land Transport Act of 2009 are considered when toll roads are implemented.

4.2 Toll Legislation

Only two authorities in South Africa have legislation that enables the implementation of toll roads in South Africa. For national roads, the SANRAL Act (1998) determines the mandate for SANRAL to implement toll roads and furthermore describes the way in which toll roads should be declared and operated. Apart from one toll road in South Africa, all toll roads were implemented and are operated on national roads under SANRAL jurisdiction.

The Western Cape Province also has applicable legislation that allows the implementation of toll roads in the province. To a large extent, this legislation mirrors the original SANRAL toll legislation. The Western Cape Province implemented and operates one toll project, the Chapman's Peak toll road.

4.3 SANRAL's Mandate and Role

SANRAL is an agency accounting to the Department of Transport (DOT) and acts as implementer of government policies. SANRAL is mandated in terms of the SANRAL Act to implement and operate toll roads on National Routes. The current toll road network encompasses the key road corridors in South Africa:

- N1 (Bloemfontein to Musina; Huguenot Tunnel
- N2 (KZN north and south coast)
- N3 (Durban to Gauteng)
- N4 (Botswana to Mozambique)
- N17 (Johannesburg to Ermelo)

- The GFIP freeway network in Gauteng

Section 28 of the SANRAL Act enables SANRAL to allow the *"operation of toll roads and levying of tolls by authorised persons".* Accordingly, SANRAL may enter into agreements with the private companies to fund, construct (build), operate and transfer toll roads in South Africa through Public Private Partnership (PPP) projects. Approximately 50% of the South African toll route network is operated in terms of toll concession contracts.

4.4 Data required to set up the model

The updated model is a strategic travel demand estimation and link-based route assignment model, covering the complete metropolitan area. This section focuses on the development, calibration, validation results of the demand and route assignment models. The 2007 VISUM, 2007 SATURN for N2 and R72 roads, 2007 travel demand survey data was used as a basis for the building of the base-year 2017 model (this dissertation).

The figure below illustrates the creation of the toll traffic model for the toll impact study of the N2 and R72 routes between Port Elizabeth and East London.

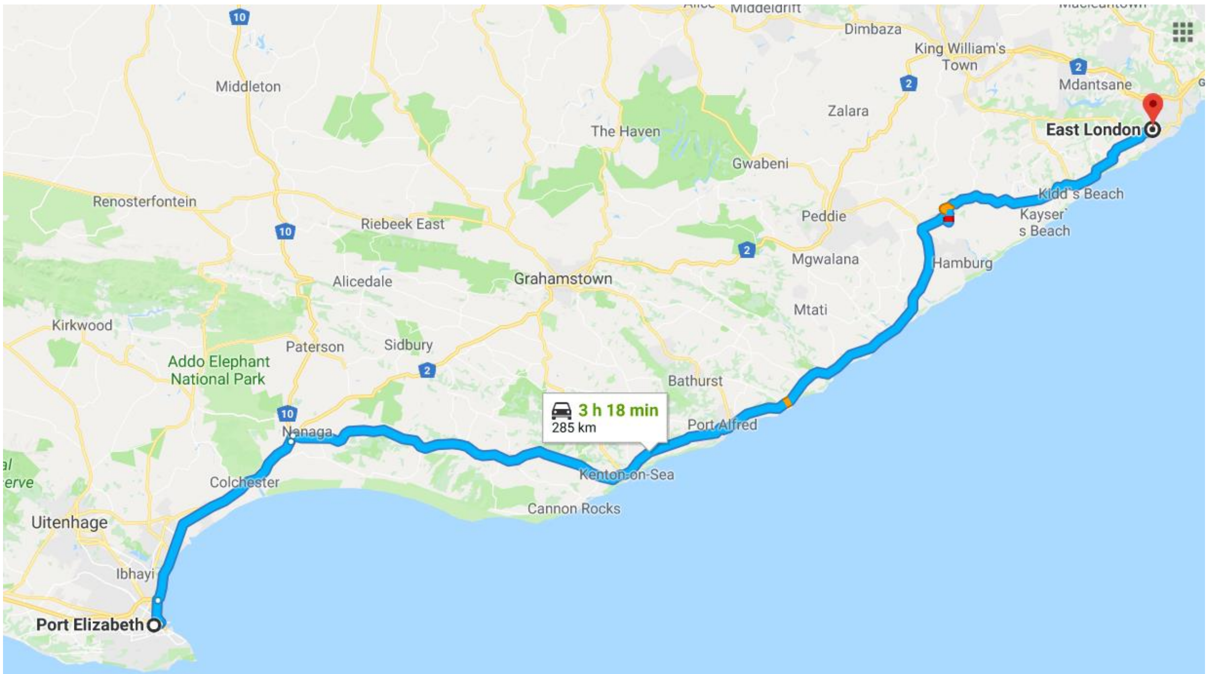


Figure 11: National Route R72 between Port Elizabeth and East London

This dissertation was conducted based on the data and model already gathered and developed by Robinson (2007). Nevertheless, this chapter will briefly discuss the data that is required to setup a model, as well as how the data was collected, collated and the final data used to update the model used in this dissertation.

Robinson’s model was a strategic model developed for public transport demand estimation, as for ITP, as well as evaluation of road projects in the (C)ITP. Therefore, its focus was on major movements along corridors, which did not include tolling scenarios; the scope of this dissertation. The update included land-use data, classified cordon counts, improved alignment with GIS data and alignment with the latest Spatial Development Framework (SDF) information.

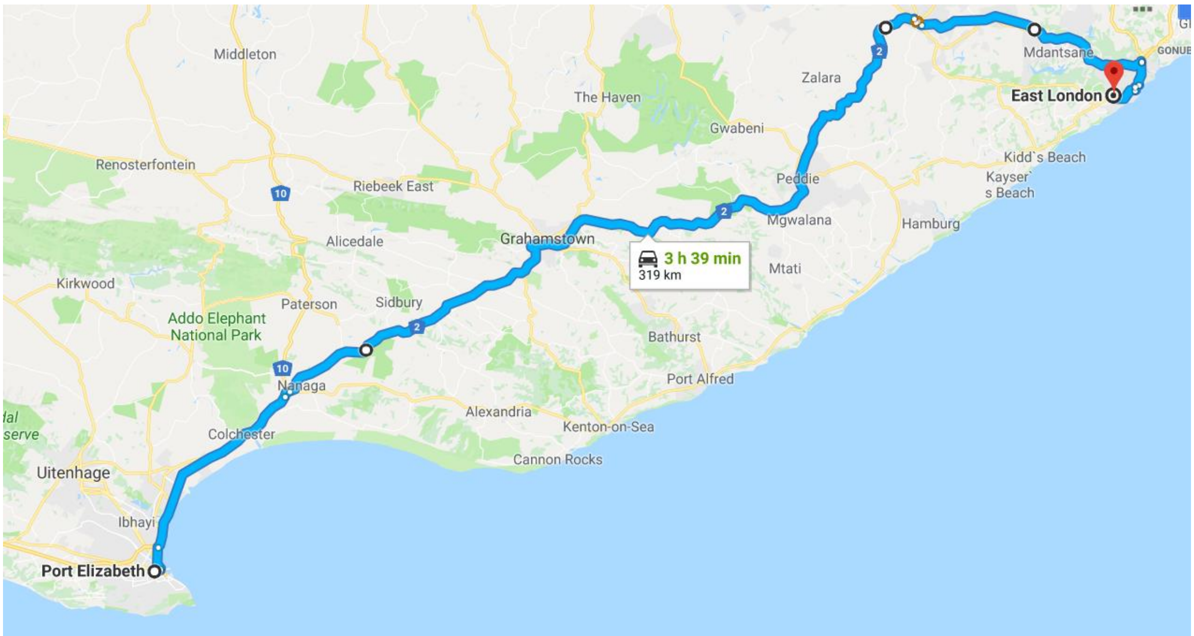


Figure 12: National Route N2 between Port Elizabeth and East London

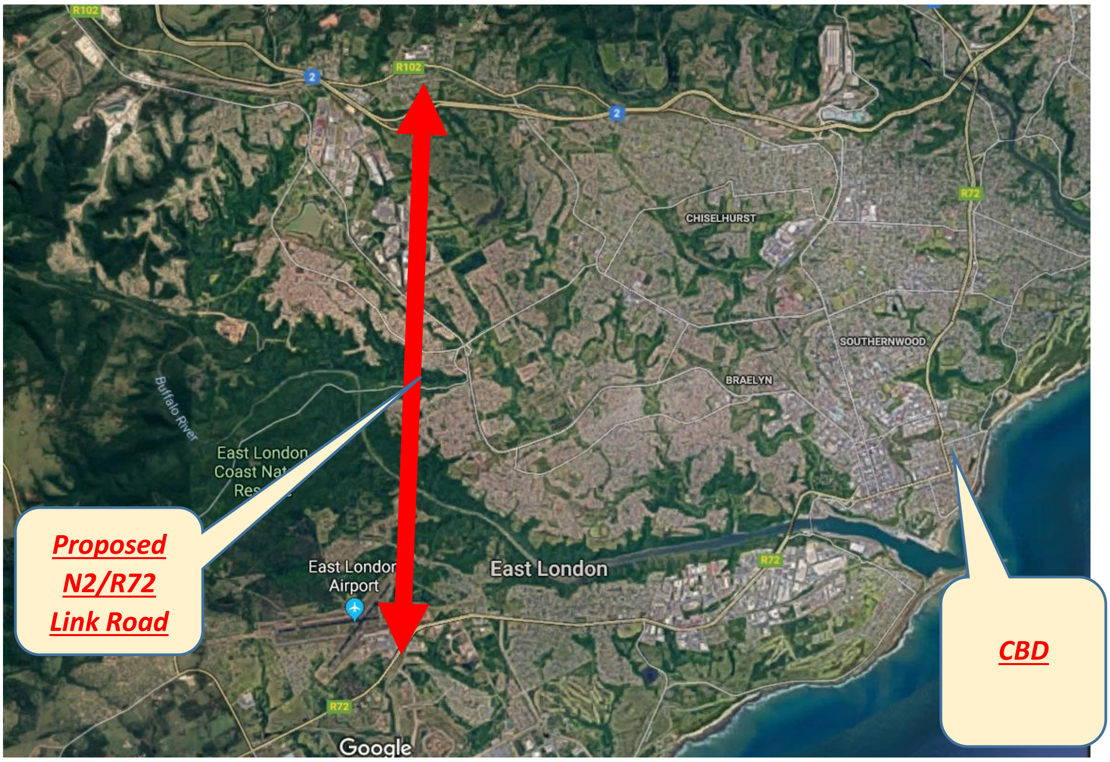


Figure 13: East London CBD

The updated travel demand estimation and route assignment model had a dual purpose:

- The model was used to test and prioritise various network alternatives for the updating of the arterial road network plan with a direct link, with spatial planning, user preferences, and modal and network characteristics.
- To act as an updated transport model for planning purposes. The model could, for instance, act as a base for the updating and development of an integrated public transport strategy and serve as a base to test operational aspects of strategic development networks and other purposes.

4.5 Model Design

This model was designed as a link-based volume-delay model. Impedances at nodes are indirectly accounted for in the link characteristics and link volume-delay, not on a turn, node, intersection capacity analysis or simulated delay. The model makes use of equilibrium and stochastic assignment techniques for private vehicle.

A private vehicle equilibrium is an iterative assignment procedure whereby private vehicles are assigned and redistributed among numerous possible alternative routes between two zones, until the perceived travel costs (usually travel time) are equal among all the possible alternative routes (Wardrope's First Principle, 1952).

Furthermore, the following design allowed for the following elements:

- Demand strata based on typical home and non-home-based trip purposes, in combination with low-, medium- and high-income persons. The traffic demand was segmented on this basis.
- Morning and afternoon peak period, with a strong focus on morning peak hour.
- Private, public, non-motorised demand matrices.

The study area, zone map and modelled road network is shown in Figure 14 below.

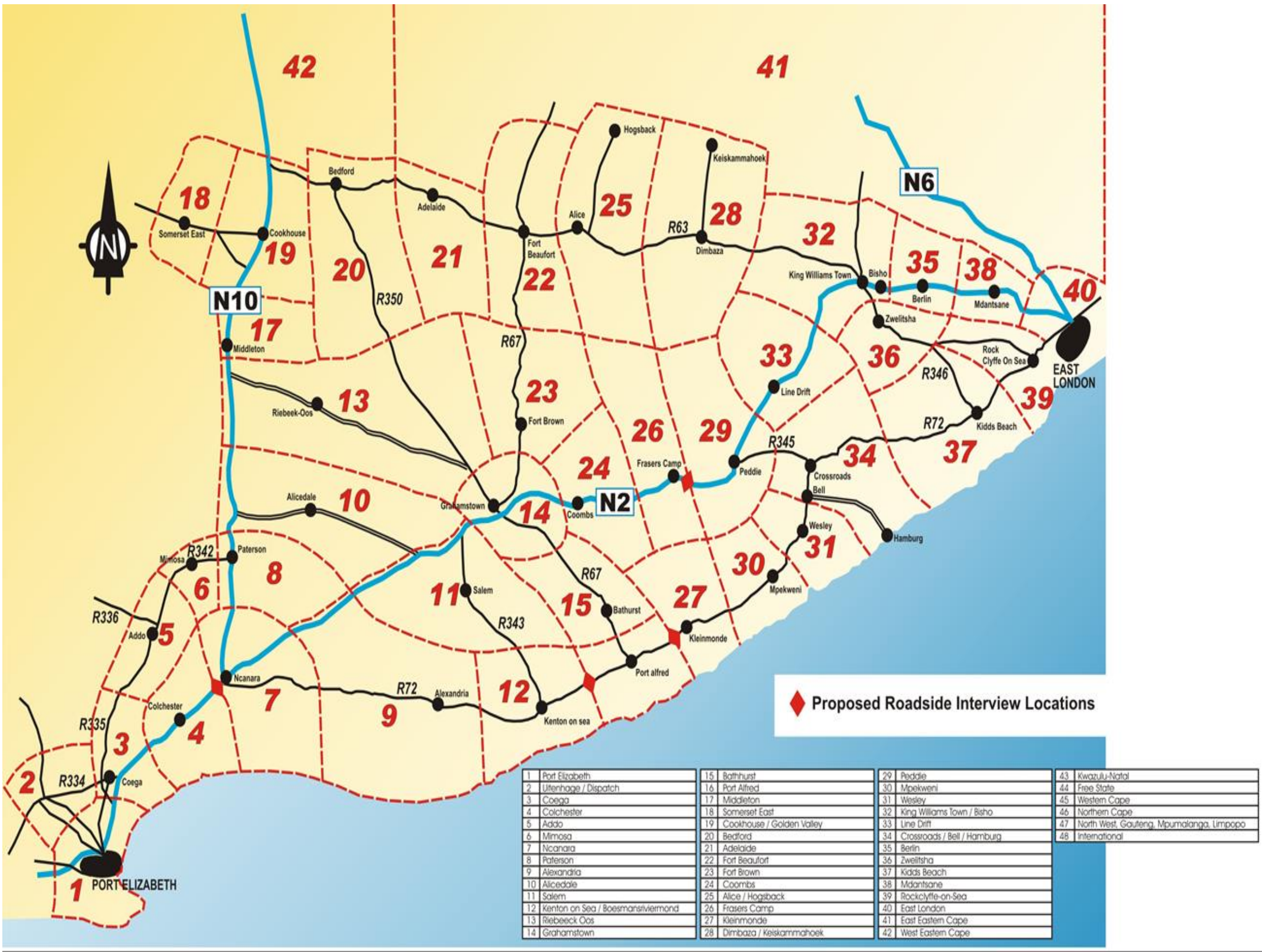


Figure 14: Study Area, Zone Map and Modelled Road Network

4.5.1 Network

The current road network has been sourced from BCMM and SANRAL road centre line database, which was used as a base network. The network attributes (which include Link ID, Name, From and to Descriptions, Link Lengths and Road Types/Class) have been updated to include fields for speed limits, number of lanes, single/dual carriageways, road direction (if one-way) and lane capacity per hour.

A network model speaking to the transport system portrays the spatial and temporal structure of the transport supply. Thus, the network model comprises of a few system objects, which contain applicable relavant data about connection links. The most significant system object types are are zones, nodes, links, turns and connectors. Each system is depicted by its characteristics. Traits can be sub-partitioned as follows:

- Input traits, for example, interface (link) lengths or connection numbers.
- Computed attributed (yield properties). I.e. the quantity of assigned vehicles. These are just decided during estimation strategy.

The initial rural road network was coded using a map as a background. Other data used in the coding of the network included:

i) Information obtained from the field trip along the R72 and N2, which included distance and speed limits along these two routes.

ii) Travel time surveys along the following alternative routes, undertaken in October 2007:
   - The R102 from East London to Berlin
   - The R63 from King William's Town to the N6
   - The N6 from the R63 (to Bisho) to East London
   - The N10 from the N2 to Paterson
   - The R342 and R335 from Paterson to Coega via Addo
   - The R102 from Coega to Colchester

iii) Daily road capacity values for each road type, so that the model can be used to model daily traffic volumes. i.e. from the data obtained from Comprehensive Traffic Observation (CTO) and Electronic Traffic Monitoring Stations (ETMS).

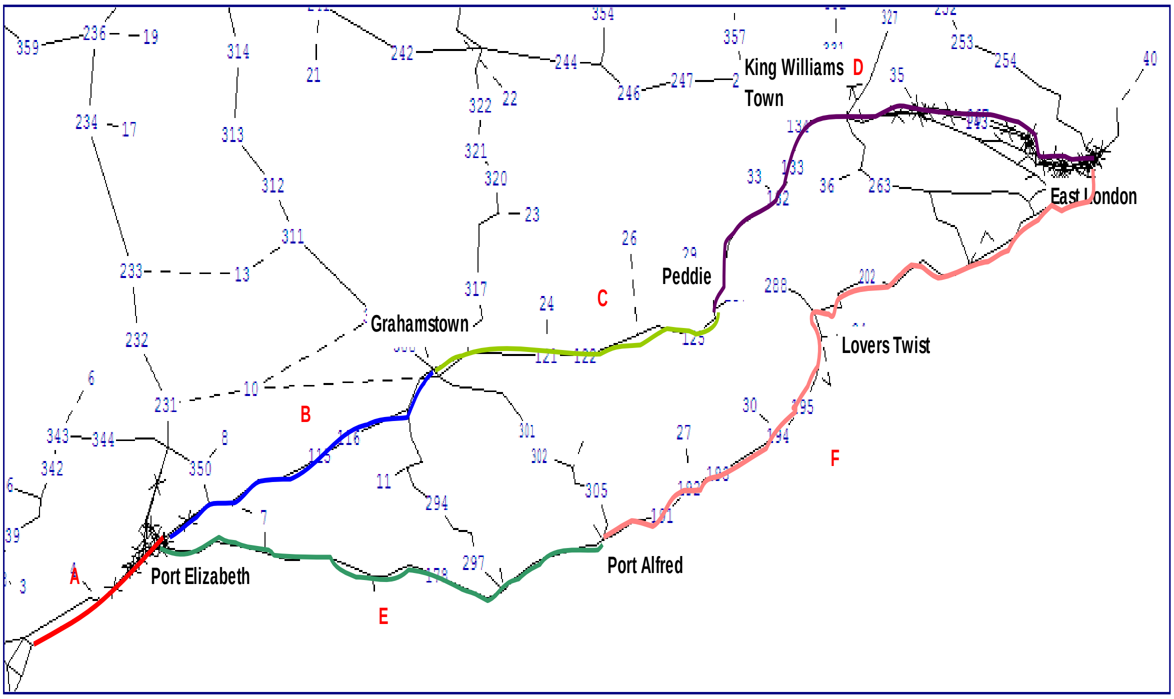


Figure 15: SATURN Network and Nodes

Instead of updating the current base-year network, the entire network was re-coded to produce a new base-year. This model update provided an opportunity to correct some spatial inaccuracies and other network errors that were inherited from original models.

a) Traffic Zones

Traffic Zones define areas with land use and their position in the network. They are the origin and destination of trips within the transport network. The zoning system of the existing model was used as a point of departure. Many zone boundaries were adjusted according to the Sustainable Community Units boundaries of Nelson Mandela Bay Municipality (NMBM) and BCMM. All population and land-use data were captured according to this zoning system.

b) Nodes

Nodes are objects that define the position of intersections in the link network and of switches in the railway network. They are starting or terminating elements of links. The updated base-year network consists of many nodes. These nodes were generating automatically when the GIS road centerline layer was imported as "shapefiles". Some nodes had to be manually connected to the rest of the network.

c) Links

Connections connect nodes and therefore portray the road instrastructure. A connection has a bearing, so the contrary connection speaks to a different network object. The model includes strategic major roads and local distributors in BCMM. The rest of the network is represented as connectors from the model zones to the model network. Where the zoning system required it, the model network was refined. For the rest of the model refinement was not done because it is a strategic model, and the link network should correspond with the zoning system.

The network was classified according to the following link types with associated attributes:

Type	Description	Speed (km/h)	Carriage-way Types	Capacity per lane (pcu's/l/h)
10-12	Suburban Freeway	120	single	2,000
13-15	Suburban Dual Freeway	120	dual	2,000
16	Non free-flowing off	40	single	1,000
17	On ramps & free-flow	60	single	1,500
18	Tight loops	40	single	1,450
20-22	Suburban single carriageway	100	single	1,400
23-25	Suburban dual carriageway	100	dual	1,800
30-32	Suburban single carriageway	80	single	1,100
33-35	Suburban dual carriageway	80	dual	1,400
40-42	Suburban single carriageway	70	single	1,100
43-45	Suburban dual carriageway	70	dual	1,400
50-52	Urban single carriageway	60	single	1,100
53-55	Urban dual carriageway	60	dual	1,400
60-62	Urban single carriageway	50	single	1,000
63-65	Urban dual carriageway	50	dual	1,000
99	Rail	50	N/A	N/A

Table 2: Link Type Qualitative Description of Operating Conditions

d) Turns

Turns demonstrate which turning developments are allowed at a node and store the turning time penalty. Certain turns are not permitted by default, these include U-turns and turns into oncoming traffic. The dual carriageways are represented as separate links, one for each direction. However, these were not factored into this model.

e) Connectors

Connectors interface zones to the connection network. They indicate to the the distance covered between a zone's focal point of gravity and/stops of the network. Areas with little or no development required long connectors. The models required connectivity, even if they were areas with limited development.

4.5.2 O-D Matrix Development Overview

The demand model contains the travel demand data. This provides vital information about travel demand within the planning area required for the analysis of transportation networks. Traffic demand matrices can only be partially determined by surveys. For this reason, mathematical models are used to model the real demand ratios, which calculate traffic flows between planning area zones based on the population structure and behaviour data, the spatial utilisation structures and the transport system.

The trip matrices were derived from the survey data obtained from eight RSI sites. The RSI trip OD data by the seven vehicle types was saved in the .csv format for input into SATURN.

Traffic models have inherent errors since they are generally based on incomplete data sets (it is impractical to survey every link between all towns; samples do not include weekend traffic patterns etc.). In models with relatively low flows on an hourly basis, future estimates are based on factoring up from the hourly to daily volumes. Using this approach, a small discrepancy between modelled and actual traffic volumes is exacerbated in the factoring up process. By modelling the daily volumes, the possible percentage error in the model volumes may be similar, but no factoring is necessary. It was therefore deemed appropriate to model daily (24 hour) traffic for this study.

Each vehicle class was factored up to a prior vehicle class 24-hour matrix using the following formula:

Class (24hr) = SurveyClass x % sample of 12hr count x 1.15

This was done for each data set from the various survey locations.

4.5.3 Combination of RSI Matrices

The RSI sites were located along the N2 and R72. As the sites along each of the routes were in series, there was the potential for double counting, thus they could not merely be added together. The N2 and R72 are, however, in parallel, therefore, combining the data from the routes could be done by addition. The RSI on the N2 west of the N10 is in series, with both the N2 and R72 survey stations thus creating another double-counting situation. The base assumptions for the combination of the RSI trip matrices are:

a) At any one RSI, the maximum amount of trips between an origin and destination would be recorded.

b) The above would apply to either the N2 or the R72, with the exclusion of the RSI on the N2 west of the N10, which would be included in both routes.

The methodology of combining the survey matrices is as follows:

i) Combine the N2 matrices between the N10 and East London, that is, the N2 west of Peddie and N2 East of the R102, by taking the maximum value of each OD pair.

ii) Combine the three R72 matrices, that is, west of Port Alfred, east of Port Alfred and west of the M5, by taking the maximum value of each OD pair.

iii) Add these matrices together to combine the parallel routes.

iv) Combine the two days of N2 west of the N10 data by averaging the OD pairs.

v) Combine the N2 west of N10 data to the matrix from iii) above by taking the maximum value of each OD pair.

If it is necessary to separate the R72 traffic as a separate user-class to improve the assignment, this can be done at a later stage by subtracting the R72 matrices from the overall matrix.

The matrices from the four classes of vehicle are combined (stacked) for assignment purposes.

4.6 Review of Existing Information

The following existing data sources were used to update the current year SATURN model:

- Previous BCMM VISUM model
- Previous BCMM SATURN model
- June 2007 BCMM Demand Modelling Report and Arterial Road Network Plan
- 2014 manual one-day intersections count
- Internet sources for various modes and operators
- Open Street Maps (http://openstreetmaps.org) – "shapefiles"

Each of the four steps in the conventional four-step process will now be addressed in more detail in the following section.

a) <u>Production and attraction data generation</u>

Production data was generated as follows:

- Production data was derived from "2011 Census" data. However, due to the census data being available on a ward and sub-place level only (VISUM model was based on transport zones) the census sub-place data was converted to a zonal structure on a spatial level.
- According to the 2014 socio-economic profile of Buffalo City undertaken by ECSECC, the annual rate of population growth since 2005 has been 0.8%.
- Specific area growth based on SDFs as it was found that all housing projects are informal settlement upgrades or relocations, which have a minimal impact.
- Transport zones not covered by the sub-place areas were resolved manually, based on assumptions/previous data.

An up-to-date base-year land use data will improve the trip distribution assumptions. Previous model versions, described above, relied on outdated land-use data, which was supplemented by observations from outdated aerial photographs. For modelling purposes, all population and land-use data needed to be allocated to the traffic zones. The manipulation of land-use and population data are discussed in the following graphics:

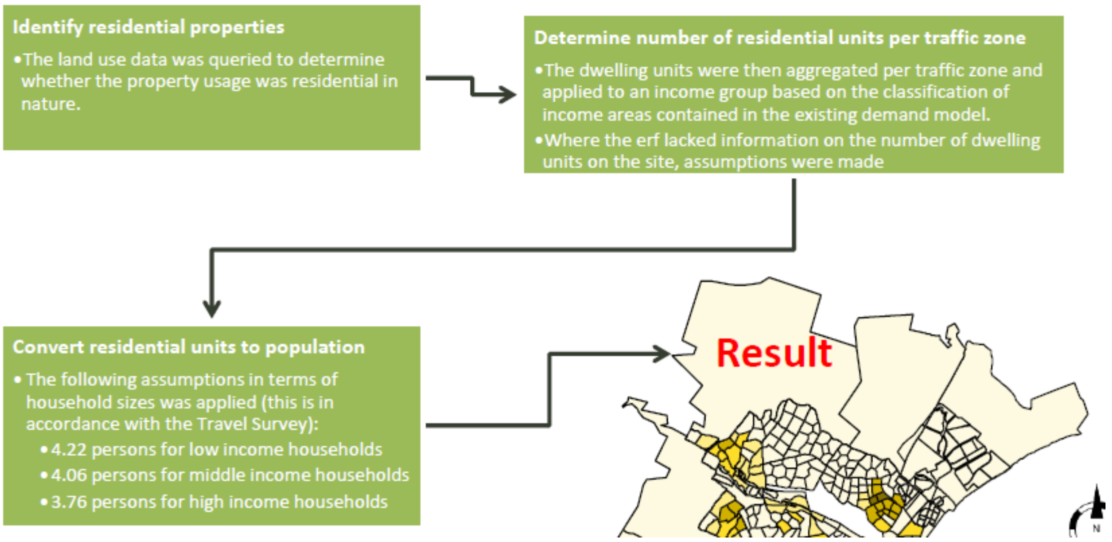


Figure 16: Land-Use Population

Data was obtained from Urban Econ, who conducted a detailed empirical study in the Gauteng area. The following rates per unit area were provided by Urban Econ and were assumed for this study:

- Office – 1 employee per $27.5m^2$ (0.0364 employees per m^2)
- Retail – 1 employee per $26.5m^2$ for area < $100m^2$ (0.0377employees per m^2)
- Retail – 1 employee per $31.5m^2$ for area > $100m^2$ (0.0323employees per m^2)
- Industrial – 1 employee per $35m^2$ for area (0.02857 employees per m^2)

The number of employees per erf was determined for each relevant employee category by applying the above employee rates for erf area and erf coverage and/or floor space ratio where applicable. The data was then cross-checked with the actual and surveyed data, which was sourced and adjusted where necessary, before it was aggravated into traffic zones.

4.6.1 Traffic Count Information

With respect to the N2 and R72 road corridors, SANRAL's Comprehensive Traffic Observations (CTO) traffic database includes 14 counting stations of relevance. This will be used for analysing the number of vehicles versus the capacity of the road. These stations and their locations are shown in Figure 17.

Traffic count surveys are typically carried out to determine baseline traffic flows, which are used in transport studies or the calibration of traffic models. In view of the previously mentioned surveys, baseline demand of the transport network is estimated. The verifiable includes are likewise utilized in deciding rush hour gridlock evelopment rates inside an examination territory. The growth rates are utilized to evaluate the future traffic request guaging, utilizing a mix of develop and development and strategies.

Notwithstanding, it is imperative to note that there are normal contrasts in rush hour gridlock stream that can seriously affect the consequences of the examinations and street plans dependent on the gathered traffic check information. These distinctions can be for the afternoon, week, regular or yearly. Notwithstanding the normal varieties, there are estimation blunders that are human in nature in manual tallies and gear/constraints in the event of programmed checks. This kind of varieties is regularly underestimated in most rush hour gridlock contemplates, as inadequate information is acquired to appropriately evaluate them. On the off chance that the varieties or mistakes are not appropriately considered in the beginning times of transport contemplates, it is lilkely going to be spread in downstream investigation and basic leadership. The UK's Department for Transport provides guidance on 95% confidence intervals for various types of count surveys (Department for Transport (UK), 2014 (1)). The inclusion of these limits illustrates that different survey methods have some degree of inherent measurement errors, which need to be considered early on in a transport study.

Some of the CTO stations (there are seven) are Permanent Stations, with the remainder being Secondary Stations. Several of the Secondary Stations have not been in operation since 2003, one has not been in operation since 2001 and two are operated by the Eastern Cape Department of Transport (EC DoT). The CTO Permanent Stations provide information on total traffic volumes (sub-divided into light and heavy vehicle volumes) 24 hours a day, 7 days a week, 365 days a year. The CTO Secondary Stations are generally only in operation for a limited time in any given year (in many cases for two to three weeks), but for this period they provide identical information to that supplied by the Permanent Stations.

Buffalo City has an extensive traffic count database that covers East London, King William's Town, Bisho, Berlin and Mdantsane.

Figure 17: CTO Traffic Count Information

The seven CTO counting stations understood to be Permanent Stations, and which were assumed operational during the survey period, were the following:

- Station 3013 - Coega Weigh-in Motion (WIM) on N2.
- Station 3075 - Kinkelbos Eastbound WIM operated by EC DoT (now by SANRAL since 2013) on N2.
- Station 3076 - Kinkelbos Westbound (WIM) operated by EC DoT (now by SANRAL since 2013) on N2.
- Station 1181 - Nanaga North Piezo on N10.
- Station 1182 - Nanaga East Piezo on R72.
- Station 336 - Grahamstown West Piezo on N2.
- Station 760 - Hillside Piezo on N6.

The remaining seven stations are Secondary Stations. If it was not possible to have these stations operational during the survey period, the request was made that the following stations be made operational, so as to fulfill the study requirements:

- Station 755 - Grahamstown on N2.
- Station 1047 - King William's Town on N2.
- Station 759 - Amalinda on N2.
- Station 104 - Port Alfred on R72.

Figure 18: Roadside Interviews

The remaining traffic count requirements were dependent upon what could be arranged in respect of making the above four Secondary Stations operational, as well as the data that would be forthcoming from Buffalo City. Bearing in mind that the roadside interview surveys would, in terms of standard practice, also incorporate classified counts (this being obligatory to determine sample sizes), the minimum and maximum additional requirements in terms of counting, were seen to be as follows:

a) Rural Road Sections – Minimum Requirement:

- Undertaking classified counts on the R72 between Crossroads and the R346.
- Undertaking classified turning movement counts at the R72/R345 intersection in Crossroads.
- Undertaking classified turning movement counts at the N2/R343 intersection west of Grahamstown.

(Note: It was proposed that the above counts be of a 12-hour duration.)

b) Rural Road Sections – Maximum Requirement:

As above, but also conducting classified 12-hour counts at the three "rural" Secondary Stations outlined above (i.e. Grahamstown, King William's Town and Port Alfred), in the event that it was not possible to make these counting stations operational over the survey period.

c) East London Area – Minimum Requirement:

- Undertaking classified counts on the three bridges (Buffalo, Biko and Buffalo Pass Bridges) over the Buffalo River, assuming that such data was not available from Buffalo City.
- Conducting classified interchange turning movement counts at the N2 Main Road/Amalinda interchange and at the adjacent Main Road/Voortrekker Road intersection.
- Conducting classified interchange/intersection turning movement counts at the junction of the M5/M3 (Mdantsane Access Road/Buffalo Pass).

(Note: It was also proposed that the above counts be of 12-hour duration.)

d) East London Area – Maximum Requirement:

As above, but also conducting a classified 12-hour count at the remaining Secondary Station outlined above (Amalinda), if it was not possible to make this counting station operational over the survey period.

As highlighted previously, Figures 17 and 18 summarise the survey work for the Rural Road Sections and the East London Area respectively.

4.6.2 Travel Time Survey

The need to undertake travel time surveys along the rural road sections was not foreseen. Within the Buffalo City Metropolitan area, however, use of the proposed N2/R72 link will be dependent upon the origin and destination of the trip being undertaken and the perceived benefit (the saving in distance and time) attained because of using the link. For this reason, and to ensure that the Buffalo City/East London model accurately reflected and was also calibrated in terms of journey times, it was recommended that travel time surveys be undertaken during the morning peak period along the routes shown in Figure 18.

Figure 19: Travel Time Surveys

4.6.3 Data on Traffic Characteristics

Whilst BCMM obviously has some data on traffic characteristics "housed" within the ambit of its metropolitan traffic model (e.g. information on trip origin/destination movements in the morning peak hour in the Buffalo City area), there was found to be no such data in respect of the traffic using the greater part of the N2 and R72 from Coega to East London. To fulfil the objectives of the study, the lack of information on the characteristics of the traffic utilising these two road corridors was therefore deemed to be one area requiring attention.

4.6.4 East London Traffic

To determine the amount of traffic that would use the proposed N2/R72 link, and to determine the feasibility of this link, further surveys were conducted in and around the East London area. Discussions with the Buffalo City Metropolitan Authority revealed that a transportation model for the metropolitan area had been developed; it was available and could be utilised to investigate the links feasibility. Whilst this model was deemed to be invaluable, particularly in terms of determining to what extent the N2/R72 link would be used when undertaking intra-metropolitan trips, it was concluded that additional surveys were needed to more accurately determine or clarify the "through" traffic demands (i.e. N2 to R72 and *vice versa*) that would use the N2/R72 link.

Because of the above, it was therefore proposed that four RSI surveys be conducted at the following locations (refer to Figure 17):

- On the N2 west of the future interchange between the N2 and the N2/R72 link.
- On the M3 just north-west of the M5/M3 (Mdantsane Access Road/Woolwash Road) crossing.
- On the R102 just west of the R102/M4 (Voortrekker Road/Main Road) intersection.
- On the R72 west of the future interchange between the R72 and the N2/R72 link.

4.7 Base-Year Traffic Characteristics

The traffic data available from existing sources, as well as that obtained from the traffic surveys, provided all the necessary information to undertake the required traffic and toll modelling work. However, to create greater awareness and understanding prior to engaging in the modelling work, it was advantageous to summarise and highlight the salient traffic features contained in this traffic database. This information is provided below.

4.7.1 Daily Volumes

The traffic demands denoted in terms of the Average Daily Traffic (ADT) on each link of the N2 and R72 are shown in Figure 20. Based on this information, it can be concluded that:

Figure 20: Daily Traffic Volumes

- The highest traffic demands along the N2 occur between King William's Town and East London, the daily volumes being some 10000 vehicles/day in the vicinity of King William's Town, and some 12800 veh/day in the vicinity of East London. However, at approximately the mid-point of the route between King William's Town and East London, the daily volume drops to some 8500 veh/day.
- The second highest traffic demand along the N2 occurs west of the junction between the N2, the R72 and the N10, where the daily volume just west of the N2/N10 Nanaga Interchange is some 7400 veh/day, increasing to some 9100 veh/day in the vicinity of Coega.
- Along the remainder of the N2, daily volumes range from being some 4100 veh/day between Nanaga Interchange and Grahamstown, some 1950 veh/day between Grahamstown and Peddie, and some 3700 veh/day between Peddie and King William's Town. Of note here is the increase between the latter two daily volumes, and the fact that a significant amount of traffic from Peddie, Fish River, Kleinemonde, Port Alfred and Kenton-on-Sea (via the R72 and R345 corridors) is generated onto the N2 Peddie to King William's Town section.
- Along the R72 corridor, the daily volumes are more consistent, generally ranging from just under 2200 veh/day between Fish River and Crossroads, to just over 3300 veh/day between Kenton-on-Sea and Port Alfred. On its approach to East London, the daily volumes do naturally increase such that on entering the Buffalo City Metropolitan area, the daily volume increases to some 5120 veh/day.

4.7.2 Hourly Volumes

Since the N2 and R72 project routes are essentially rural roads, the critical hourly flow from a design point of view is the 30 Highest Hourly Flow (30HHF).

Only from the SANRAL's CTO counting stations is one able to obtain information on the 30HHF. Using the information from these stations and applying the relationship between the 30HHF and the daily volume at these stations to those other sections of the routes where no information on the 30HHF is available, enables one to obtain a realistic picture of the 30HHF on all sections of both routes. By applying this procedure, the 30HHF along the various sections of the N2 and R72 were determined. The results obtained are shown in Table 3 below. **Note:** The 30HHF shown above are the two-way flows.

Route/Section	2007 (2015)	2007 (2015) 30HHF
N2 Coega – East London		
Coega – Colchester	9095 (12836)	1237 (1746)
Colchester – Nanaga	7950 (11220)	1113 (1571)
Nanaga – R343	3556 (5019)	544 (768)
R343 – Grahamstown	4115 (5807)	621 (876)
Grahamstown – Peddie	2100 (2964)	320 (452)
Peddie – King William's Town	3698 (5219)	560 (790)
King William's Town – East London		
• Station 756 Berlin	10013 (14131)	900 (1270)
• Station 757 Mdantsane	9308 (13136)	874 (1233)
• Station 758 Nahoon Dam	8484 (11973)	822 (1160)
• Station 759 Amalinda	11003 (15529)	1099 (1551)
• Station 760 Hillside	12795 (18058)	1319 (1862)
R72 Nanaga – East London		
Nanaga – Alexandria	2819 (3978)	444 (627)
Alexandria – Kenton-on-Sea	3072 (4336)	484 (683)
Kenton-on-Sea – Port Alfred	3319 (4684)	523 (738)
Port Alfred – Kleinmonde	3070 (4333)	484 (683)
Kleinmonde – Fish River	2632 (3715)	415 (586)
Fish river – Crossroads (R345)	2181 (3078)	344 (485)
Crossroads (R345) – R346	2253 (3180)	355 (501)
R346 – East London	5120 (7226)	807 (1139)

Table 3: Hourly Volumes 2007 (2015)

5. TRANSPORT MODELLING METHODOLOGY

The conventional FSM process is used below to review and update the model.

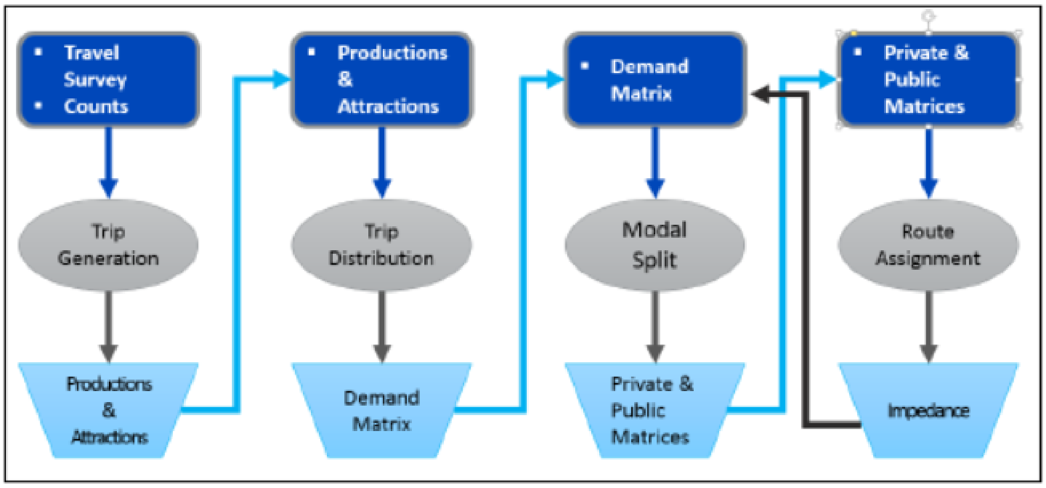


Figure 21: Four Step Model Process (Source: BCMM, 2015)

5.1 Derivation of Base-Year Trip Matrices

The base-year (2007) trip matrices were derived from the Roadside Interviews (RSI) data from the eight sites. Separate origin-destination (OD) trip matrices from each RSI site were derived for the four typical toll classes:

- Class 1 – Light vehicles, including LDV and minibus taxis
- Class 2 – Heavy vehicles with 2 axles, including buses
- Class 3 – Heavy vehicles with 3 or 4 axles
- Class 4 – Heavy vehicles with 5 or more axles

Special care had to be taken in the process of combining the vehicle class matrices to ensure that there was no "double counting" of OD trips, especially from survey sites that were in series (i.e. along the same route). The process of matrix combination was therefore achieved as follows:

i.) The OD data for each vehicle class and at each RSI site was factored up to the control 12-hour counts undertaken at the time of the surveys.

ii.) Based on the CTO data for the permanent counting stations, the OD matrices were factored up to 24-hour (daily) volumes. This factor was determined to be 1.15.

iii.) OD matrices from the sites in series were combined by taking the maximum OD (cell) value. For the N2, the RSI sites included those located west of Peddie and west of the R102 on the outskirts of East London. The RSI sites along the R72 included those to the east and west of Port Alfred and to the west of the M5 on the outskirts of East London.

iv.) The two sets of matrices from iii.) above represented the combined OD's of the trips on the parallel sections of the N2 and the R72. The corresponding user-class matrices were then added together to provide a single set of user-class matrices for the N2 and R72 between the Nanaga Interchange and East London.

v.) Finally, the matrices derived in iv.) above were combined with the matrices from the RSI site on the N2 to the west of the N10 Nanaga Interchange as per the process in iii.) above.

The above process resulted in a combined OD matrix from the RSI surveys, this incorporated four individual base-year user-class trip matrices. These matrices were, however, only partial matrices since they did not account for trips of shorter distance on the road network that did not pass through the RSI locations. By assigning the RSI prior matrix to the network and comparing the resultant assignment results to the traffic counts, the probable short-distance trips were identified and added to the matrices. In this way, the assignments from the model were developed to provide assignments that were relatively like the traffic counts.

5.2 Traffic Forecasting

The derivation of the future OD matrices was based on the historic traffic growth rates as determined from the N2 and R72 historic traffic growth obtained from SANRAL's CTO counting stations. A salient point in these results is the different growth rates between the N2 and R72 corridors. These different growth rates indicated that it would not be correct to apply a global growth rate to the overall trip matrices. Instead, it would be best to identify the specific OD's within the matrices that make up the traffic on the two routes and thereafter to apply the different growth rates to the respective trips. It was also important to note that there are splits in the route choice between the N2 and R72 for individual OD pairs, which need to be considered in the "factoring up" process. The methodology adopted to derive the design year matrices was therefore as follows:

a) Determining the proportion of trips within each OD pair of the user-class matrices that use the N2 and R72 routes. This effectively provided three sets of data:

   i) The proportion of trips within each OD pair that use the N2

   ii) The proportion of trips within each OD pair that use the R72

   iii) The OD pairs that do not use the N2 or R72

b) Applying the differential growth rates to the proportion of the OD pairs determined in i) and ii) above for the trips on the N2 and R72 respectively.

c) Applying an average growth rate to the remainder of the trips in the OD matrices.

d) Combining the three sets of data from steps a) to c) above to provide the design year matrices.

The above method produced future matrices that would be reactive to any possible future road capacity implications. In other words, in the case that any section of a route was to start approaching its capacity, the model would ensure that ever increasing use was made of the residual or spare capacity available on the alternative route. Using the above methodology, design year OD matrices were developed for 2015, 2025 and 2035. Salient traffic growth rate features of these matrices are provided in Table 4 below.

Year	**N2 Corridor**		**R72 Corridor**		**Background Traffic**		**Overall Matrix Growth**	
From / To	Light	Heavy	Light	Heavy	Light	Heavy	Light	Heavy
2007 – 2015	5.0%	6.5%	2.0%	4.5%	4.0%	5.5%	4.4%	5.6%

Table 4: Traffic Growth Rates

5.3 Traffic Assignment

For the model to accurately assign vehicles and persons to the public transport and private vehicle transport network, the modelled networks were updated. Before assignment, the private vehicle person trips needed to be recalculated to present vehicle trips. Vehicle occupancies per trip purpose and income group (according to the travel surveys) were applied to the private person trip matrix. The public vehicles were assigned together with private vehicles.

This model uses the equilibrium assignment procedure for private transport. The equilibrium procedure distributes demand according to Wardrop's first principle: "every individual road user chooses his route in such a way that his trip takes the same time on all alternative routes and that switching routes would only increase personal journey time". The state of equilibrium is reached by multi-successive iterations, based on an incremental assignment as a starting solution. In the inner iteration step, two routes of a relation are brought into a state of equilibrium by shifting vehicles. The outer iteration step checks if new routes with lower impedance can be found as a result of the current network state.

5.3.1 Modelled Network

The road network included in the rural traffic model is depicted in Figures 1-2 and 13-14.

In addition to the N2 and R72, the second-order road network included the provincial linkage roads between the N2 and R72 (this toll study), as well as alternative links between the N2 and N10 and the N2 and N6. The model zones correspond to the main populated areas and external roads. The route speeds were derived from on-site inspections and relate to the posted speed limits along each section of the roads.

Traffic models are usually based on a typical hour. This is because speed-flow relationships are based on the hourly road capacity. In this case, the hourly traffic volumes on the rural road sections were relatively low, therefore the link capacities were coded in terms of daily capacities for each road cross-section. The reason for taking this approach was to minimise the potential for modelling errors that would otherwise be amplified in the "factoring up" of hourly flows to daily traffic volumes.

The original models were not geo-referenced. The websites were used to determine the appropriate spatial coordinate systems. The private vehicle network was updated using openstreetmaps. Road shape files for the entire model area was downloaded from openstreetmaps and were imported as "shapefiles" to SATURN. The new base-year SATURN model was then compared to the "shapefiles" and the necessary corrections were applied to the SATURN base-year model. After the initial review, it was subjected to the latest satellite images. The original link types and associated free-flow speed and capacities were utilised and only deviated from if necessary, for instance, where there were large differences between the link flow speeds and the posted speed limits.

During the route assignment, vehicles are distributed as delay increase (due to link saturation) and vehicles are redistributed among different route choices until their travel delay (generalised cost) is equal among all available paths between specific origins and destinations. The model increases the travel time using the volume delay function specified in the equilibrium assignment.

A traffic and toll modelling study procedure was adopted to evaluate the existing and future traffic demands along the N2 and R72 corridors. This was with regards to those demands that could be expected to use the proposed N2/R72 link, as well as to determine the potential impact that the proposed tolling of the above corridors would have on traffic patterns.

Since the N2 and R72 are predominantly rural routes and since the N2/R72 link, if developed, would essentially form part of an urban road network designed to accommodate urban and more diverse traffic patterns, it was concluded that the modelling work should comprise two components:

- Developing a rural N2/R72 corridor model using the SATURN suite of programs.
- Obtaining the Buffalo City VISSUM model, updating this model with the new traffic survey data and, thereafter, using this updated model to test and evaluate the benefits of the N2/R72 Buffalo River link.

5.3.2 Model Calibration/Validation

The calibration of the base-year model was undertaken by adopting the following methodology:

- Assigning the combined prior trip matrices derived from the survey data.
- Comparing the assigned traffic volumes (per vehicle class) to the observed traffic volumes.
- Manually adding short-distance trips to the matrices between towns/settlements/ major intersections to "make up" traffic volumes along sections that were not recorded at any of the RSI sites. This process updated the prior matrices such that the assignments produced flows that were as close as possible to the traffic counts.
- Running multi-user class matrix estimation on the prior matrices to calibrate the model.

The model validation is based on the correlation between the assigned traffic volumes and the traffic count data. The R^2 and GEH statistics were used for this purpose and the pertinent results were as follows:

- The overall results showed good correlations between the modelled and observed traffic volumes.
- There is a wider spread in the heavy vehicle results, predominantly due to the low volumes. However, the GEH statistics for all counts are below 5, being the acceptable norm.

The following graphs represent the validation of the base-year model.

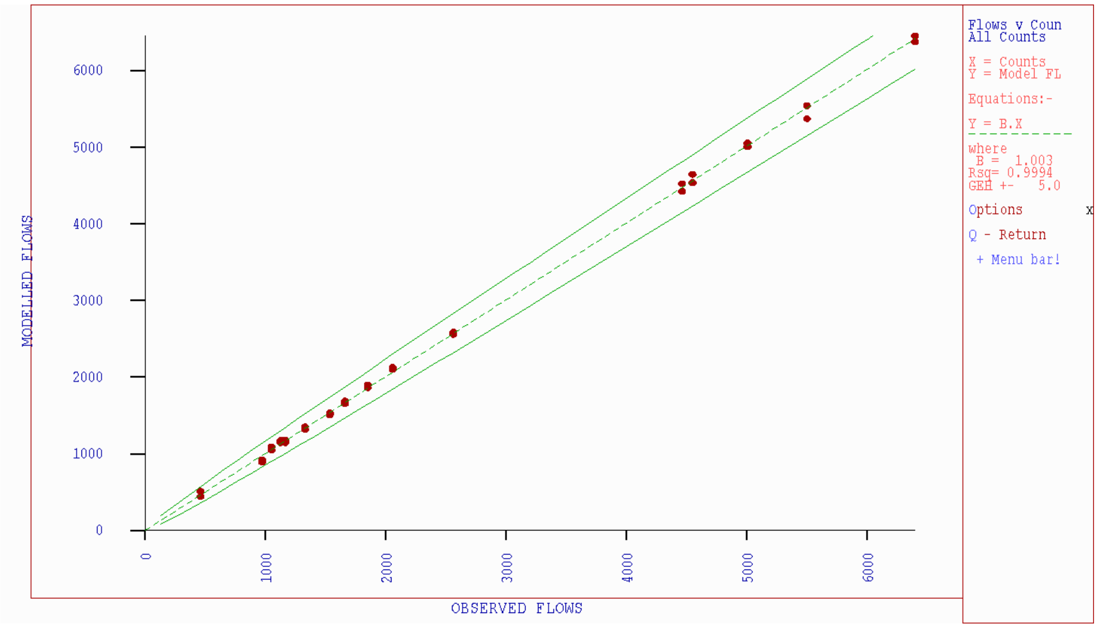


Figure 22: Validation - All Vehicles

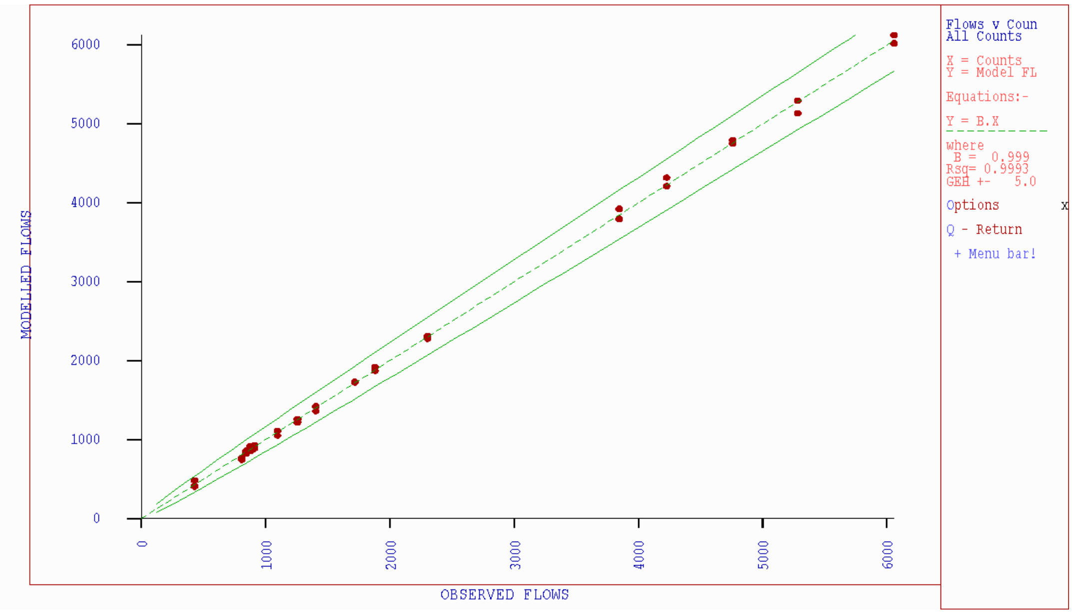


Figure 23: Validation - User Class 1 - Light

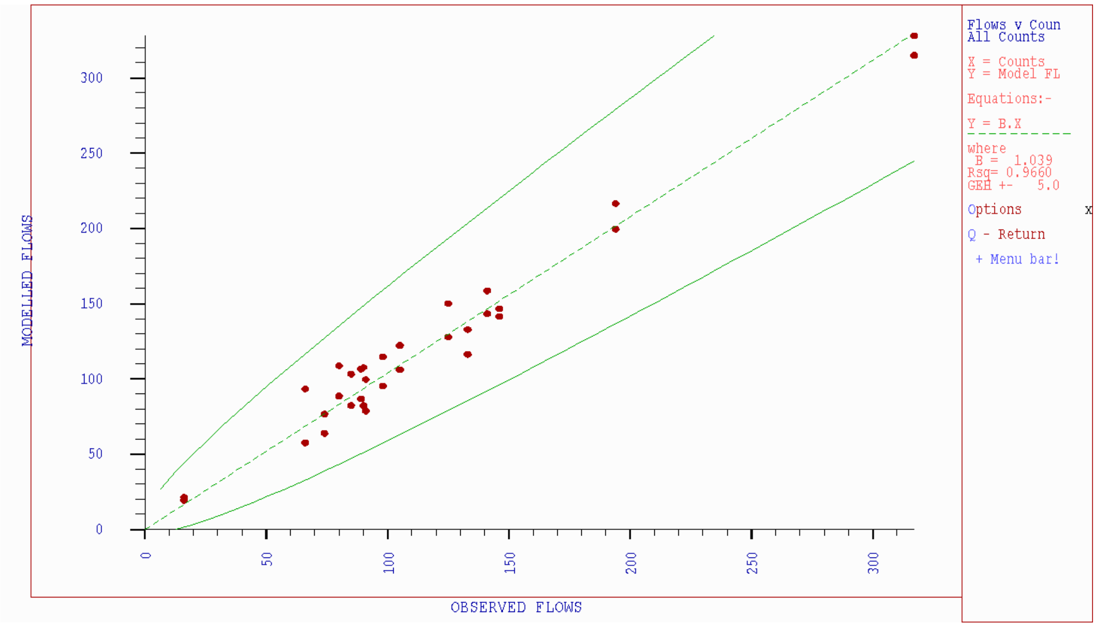


Figure 24: Validation - User Class 2 - Heavy 2-Axle

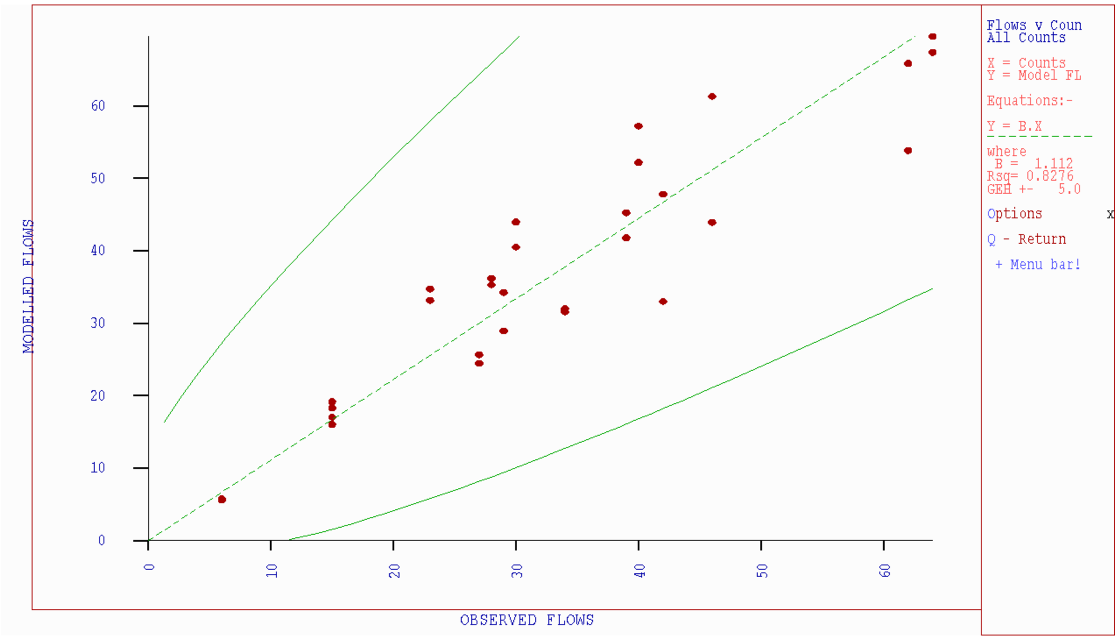


Figure 25: Validation - User Class 3 - Heavely 3 & 4 Axle

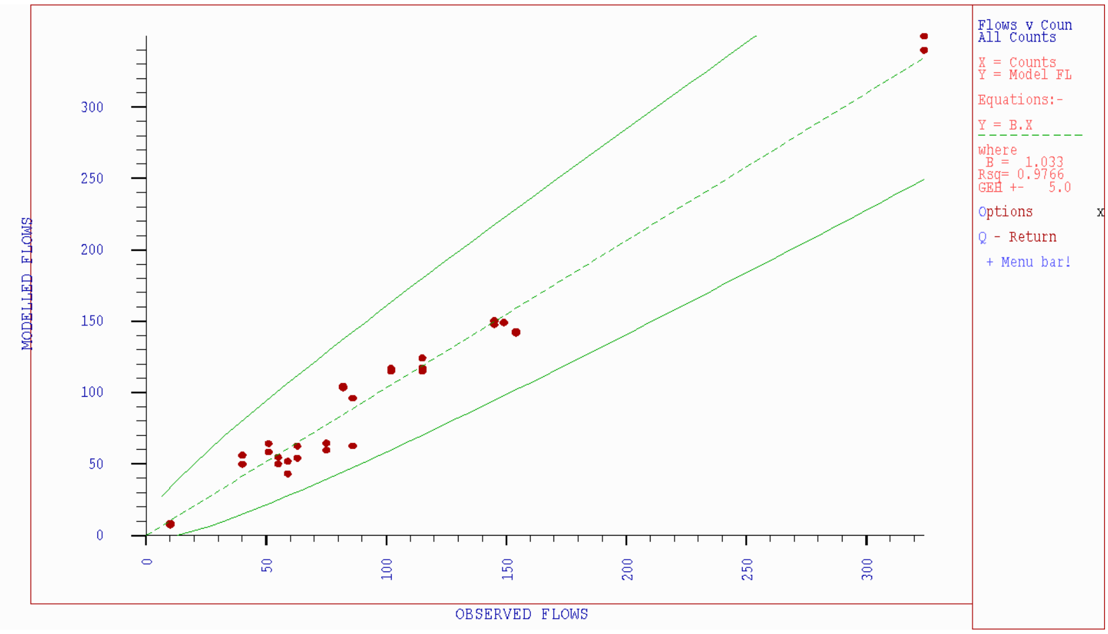


Figure 26: User Class 4 - Heavy 5+ Axle

The final step in the model calibration process was to run a multi-user class matrix estimation process to balance the matrices and assignments with the daily traffic counts.

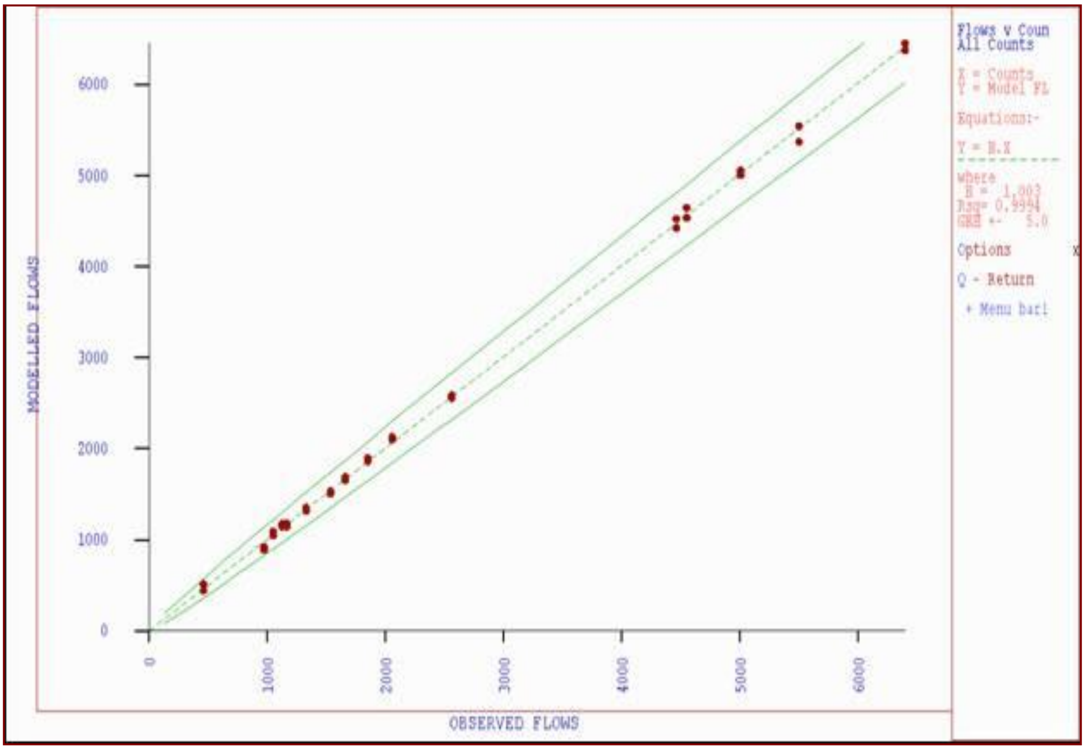


Figure 27: Correlation of assigned traffic volumes & traffic counts

The model validation was based on the correlation between the assigned traffic volumes and the traffic counts. The graph to the above shows the correlation between the assigned traffic volumes and the traffic counts. The statistics used for the validation of the model were in accordance with the internationally accepted British DMRB standards. These standards and the results from this model were as follows:

MODELLED v COUNTS SATISFYING THE DMRB RULES:

(IN ALL FOUR TESTS THE OK % SHOULD BE > 85%)

FLOW < 700: MODELLED WITHIN +-100 OF OBSERVED	=	100.00% -	2 OUT OF 2
700<FLOW<2700: MODELLED WITHIN 15% OF OBSERVED	=	100.00% -	20 OUT OF 20
FLOW > 2700: MODELLED WITHIN 400 OF OBSERVED	=	100.00% -	10 OUT OF 10
COMPLIANCE SUMMED OVER ALL FLOW RANGES	=	100.00% -	32 OUT OF 32
ALL LINKS - GEH STATISTIC < 5.0	=	100.00% -	32 OUT OF 32

Based on the above results from the rural traffic model, the following can be concluded:

- The overall model results correlate very well with the observed daily traffic volumes.
- The rural traffic model can be used with confidence for the forecasting of traffic on the rural sections of the N2 and R72 corridors and, subsequently, to test any changes in traffic patterns brought about because of the imposition of various toll strategies along these two corridors.

When the cordon volumes were compared with the counted volumes per direction, the goodness of fit was very good with an R = 0.99 for a combined vehicle traffic.

A model plot of the base-year (2007) traffic assignment is provided in Figure 28 below.

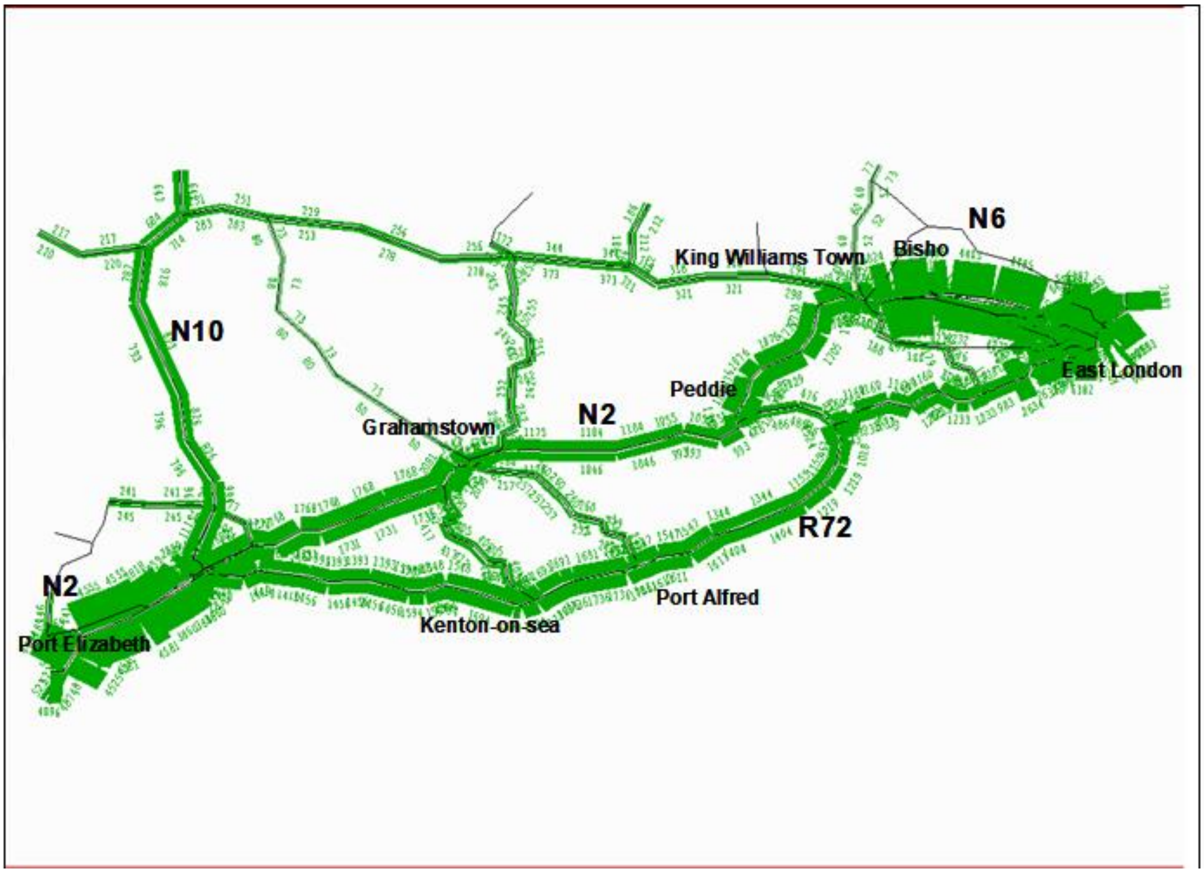


Figure 28: N2 R72 Rural Daily Traffic Volumes

6. TRANSPORT MODELLING SCENARIOS AND RESULTS

The rural traffic model was used to assess the impact of various toll strategies, as well as the tolling of only the N2 or R72. Furthermore, the impact of the construction of the proposed Buffalo River Bridge and freeway section between the N2 and R72 was assessed in terms of the traffic on the rural road sections.

The network was evaluated in terms of operating conditions. The network operating conditions were assessed in terms of Level of Service. The measure used to provide an estimate Level of Service (LOS) here was V/C. Table 5 provides the qualitative description of the various service levels. During evaluation, required upgrades could be determined. The matrices were then assigned to the base-year.

LOS	Qualitative description
A	Free flow; individual drivers are virtually unaffected by the presence of other vehicles on the road.
B	A region of stable traffic flow but the presence of other vehicles on the road begins to be noticeable.
C	A region of stable flow; individual drivers begin to be significantly affected by other vehicles.
D	The onset of unstable flow; the two opposing directions of traffic begin to operate separately as overtaking becomes extremely difficult.
E	Operating conditions are at/or near the capacity level.
F	Unacceptable to drivers, traffic volumes greater than the available capacity, operations characterised by stop-and-start waves.

Table 5: Qualitative description of operating conditions (Source: NMBM, 2011)

It was perceived that the addition of this bridge would encourage more traffic on the R72, as it would provide an effective route between the R72 and N2 without the need to travel through the East London CBD. The traffic impact of each toll scenario below was measured in terms of the diversion of traffic from the current traffic patterns.

For each toll scenario, the rural traffic model was updated to include the tolls on each link. The generalised cost function and distribution function, together with the Skim Matrix and Gravity Model print screen, were incorporated to distribute the trips between the macro zones referred to above.

a) Generalised Cost Equation:

The parameters at the below PPM and PPK (see Chapter 6 and 7 of SATURN manual) were specified as follows:

- *Value of Time (VOT) is the same as PPM. pence per minute – used to change over distance into generalised costs.*
- *Vehicle Operating Cost (VOC) is the same as PPK. pence per kilometre – converts times into generalised costs.*

As can be seen below, the VOT is R128.4/minute (i.e. 1284c/minute) and VOC is given as R0.70/km (i.e. 70c/km), applicable to vehicle Class 1 only. In this exercise, only the relative differences are important, but it is best to convert them into cents/minute and cents/kilometre as per the manual.

Finally, using the volume averaging script, a user equilibrium assignment method was utilised to assign the trips to each link. The only difference is that on N2/R72 link, a toll was applied using the 444 cards as a penalty on a link. Toll is expressed in cents, preceded by the $ sign, e.g. $505 for a R50.50 and $4310 for R431.00 for Class 1 and 4 tolls respectively.

Alternatively, the toll could be expressed in seconds (as an equivalent time penalty). The Toll Time Penalty (hr) = Toll (R)/VOT (R/hr). When expressing it in seconds, one does not add the $ sign.

i.) VOT = R0.7/min
ii.) VOT = R42/hr
iii.) Toll = R50.5
iv.) Toll Time Penalty (hr) = 1.11hr
v.) Toll Time Penalty (s) = 3996s

The effect on the traffic volume was analysed. Scenarios were performed by using job scripts that were different from the ones used previously for the skim matrix and the volume averaging function. The toll value was assumed to start at R50.50 for Class 1. Figures 28 to 31 below show the volume of traffic and v/c ratios along Directions 1 and 2 of the N2, R72 and N2/R72 link road where applicable. Where a model had more than one user-class (e.g. light and heavy vehicles), it was best to code different values for each class. In this case, one would have had to do it in the 888 cards (as per SATURN manual).

b) Generalised Cost Assignment: Time and Distance

All assignment techniques inside SATURN programming accept that every driver try to limit their movement cost, with *"travel cost"* being clarified in one of the accompanying three distinct ways under ordinary use:

- As pure time
- As pure distance
- As "generalised cost" (this is most common). This is a linear combination of distance, time and monetary charges (e.g. tolls) defined by:

  $C = PPM * T + PPK * D + M$ *(Source: Van Vliet, 2015)*

Where:

- C is the cost in units of pence
- T is time in units of minutes (including any 44444-time penalties)
- D is distance in units of kilometres
- M is monetary charge in units of pence
- PPM is a user-defined parameter specifying "Pence Per Minute"
- PPK specifies "Pence Per Kilometre".

A trip length distribution (TLD) computes the number of trips from one matrix within length bands defined by another matrix. *"Length"* in this case is any one property, such as time, generalised cost and distance etc., and should correctly be referred to by the generic title *"cost".* Thus if "length" or "cost" is a time matrix, then the TLD lists the number of ij trips in the time band 0-20 seconds, 20-40 seconds, etc., where the "width" of each band is user-set.

Within SATURN, the tolls were input in terms of the monetary value, which is converted to a toll penalty (in terms of the user class value of time) in seconds. For each toll strategy, these were applied to the road section (model links) where the toll plazas would be located.

As stated above, the toll penalty is calculated in accordance with the VOT for each user-class. The values of time (VOT) and vehicle operating costs (VOC) incorporated into the model were derived from previous toll road studies carried our by SANRAL in Gauteng and Western Cape provinces for light vehicles and a comprehensive evaluation thereof. These are as follows:

Vehicle Class	VOC (R/km)	VOT (R/hr)
1	R 0.70	R 128.40
2	R 1.17	R 198.00
3	R 2.36	R 297.00
4	R 3.20	R 380.40

Table 6: Operational Cost vs Value of Time per vehicle class

The following is a basic description of the scenarios currently under investigation:

i.) Do-nothing.
ii.) The R72 is constructed to toll road standards using the quantum of available provincial funds for the project, with the remainder being funded from loans repaid by toll revenues. The toll tariff ratio to be applied to the R72 is: 1:2:3,5:5. The N2 remains as is and is un-tolled.

The above forms the base scenario for three additional scenarios:

iii.) Minimal upgrading is applied to the N2, which is then tolled at the following toll tariff ratio: 1:2:4:7. The high rate applied to the Class 4 heavy vehicles, when compared to the R72, would divert heavy vehicle traffic from the N2 onto the R72, the R72 also having shorter travel times.
iv.) As per iii.) above, but the Buffalo Bridge link is constructed and left un-tolled.
v.) The Buffalo Bridge link is constructed and tolled.

It should be noted that a local user discount of R 12.50 for class 1 (SANRAL – Tsitsikamma Plaza, 2019)has been applied on the N2 between King William's Town and East London only, and nowhere else on the network (as per earlier model runs). Discounts offered at specific toll plazas for frequent users, as well as qualifying local users, still apply. Applications for discounts can be made at the toll plaza offices.

The impact of several interventions was observed, and the results were analysed. However, it is important to highlight, that there are limitations of this assignment: a uni-model (not only cars) was built, thus rendering Step 3 of the modelling process rather insignificant.

VOT by vehicle class is joined in task parameters, however not used. The VOTs for heavy vehicles are vague. This is on the grounds that VOTs are constrained to trip purposes, this propose extra VOTs would should be determined or surveyed for the extra alloted demand portions, (for example, truck and external trips) that do not fall into one of the fundamental reason for the trip classifications, if a assignement decision income model were to be executed.

The model database contains a fixed link toll fields yet does not give off an impression of being utilized or to shift by class. It would be normal that not all toll kinds of vehicles would pay a similar cost, if one somehow happened to be actualized.

In sensitivilty examination, anticipating presumptions are shifted each in turn and the subsequent changes in anticipated results (e.g. traffic forecast) are accounted for as needs be. In this case study the sensitivity and scenario examination are explored. The expression *"sensitivity analysis"* is the point at which different determining suspicions and model parameters are changed at the same time.

The vulnerability in the estimation of traffic determinant and other info variables (e.g. increase in population and change in pay).

6.1 No Tolling (N2 or R72)

The simulations in this regard were undertaken to determine the traffic implications before any upgrading and tolling . i.e. on both the N2 and R72. The results in this respect are shown in Figures 29.

6.2 Tolling One Route Only (N2 or R72)

The simulations in this regard were undertaken to determine the traffic implications of upgrading and subsequently tolling only one route, that is, the N2 or the R72. The results in this respect are shown in Figures 30 and 31. The salient points that emerge are:

- In the event of tolling only the N2, and depending upon the section in question, some 700 to 1200 veh/day will divert from the N2 to the R72.
- In the event of tolling only the R72, and again depending upon the section in question, some 1000 to 1200 veh/day will divert from the R72 to the N2.
- Based on the above, and whilst it is accepted that the upgrading and tolling of only one route will essentially halve the projects capital and operating costs, it is evident that:
  - Although the upgrading and tolling of one route has the potential to improve the traffic operating conditions of those motorists whose trip movements are directly accommodated by the upgraded and tolled route, there will be no improved operating conditions or benefits for those motorists presently accommodated on the other route.
  - The improved traffic operating conditions and benefits offered by the upgraded and tolled route are obviously significantly reduced because of the traffic diversion highlighted above. Not only does this reduce the project's economic benefits, but it results in an outcome whereby the upgraded and tolled route will be carrying less traffic than the other, non-upgraded route.

- For the above reasons, it is concluded that the alternative, which involves the tolling of one route only, does not really represent an optimum outcome. Moreover, since the two routes accommodate, for the greater part, different trip demands, every effort should be made to pursue the objective whereby both routes are upgraded and rehabilitated.

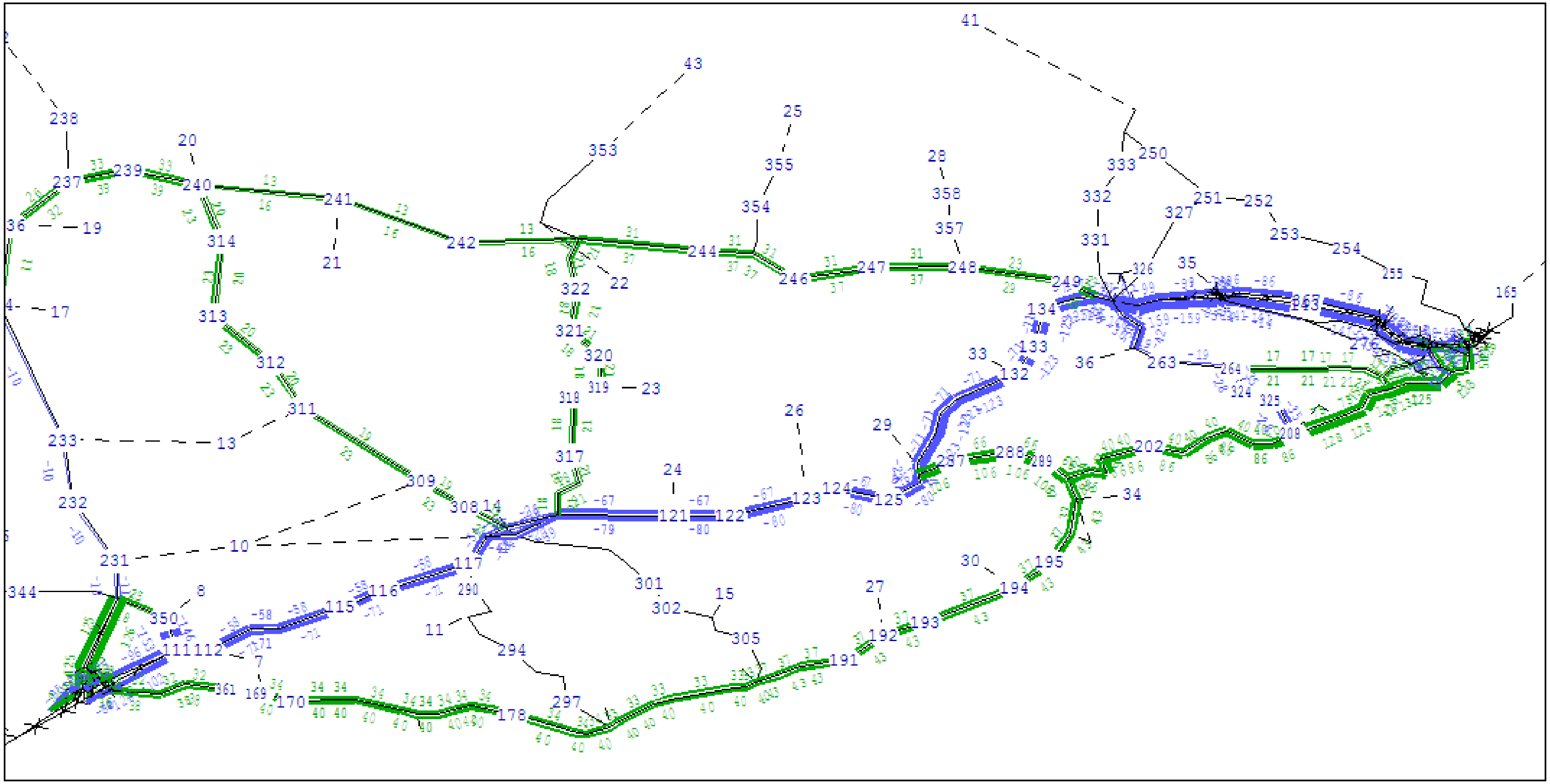


Figure 29: Scenario 1 – No Tolling Option

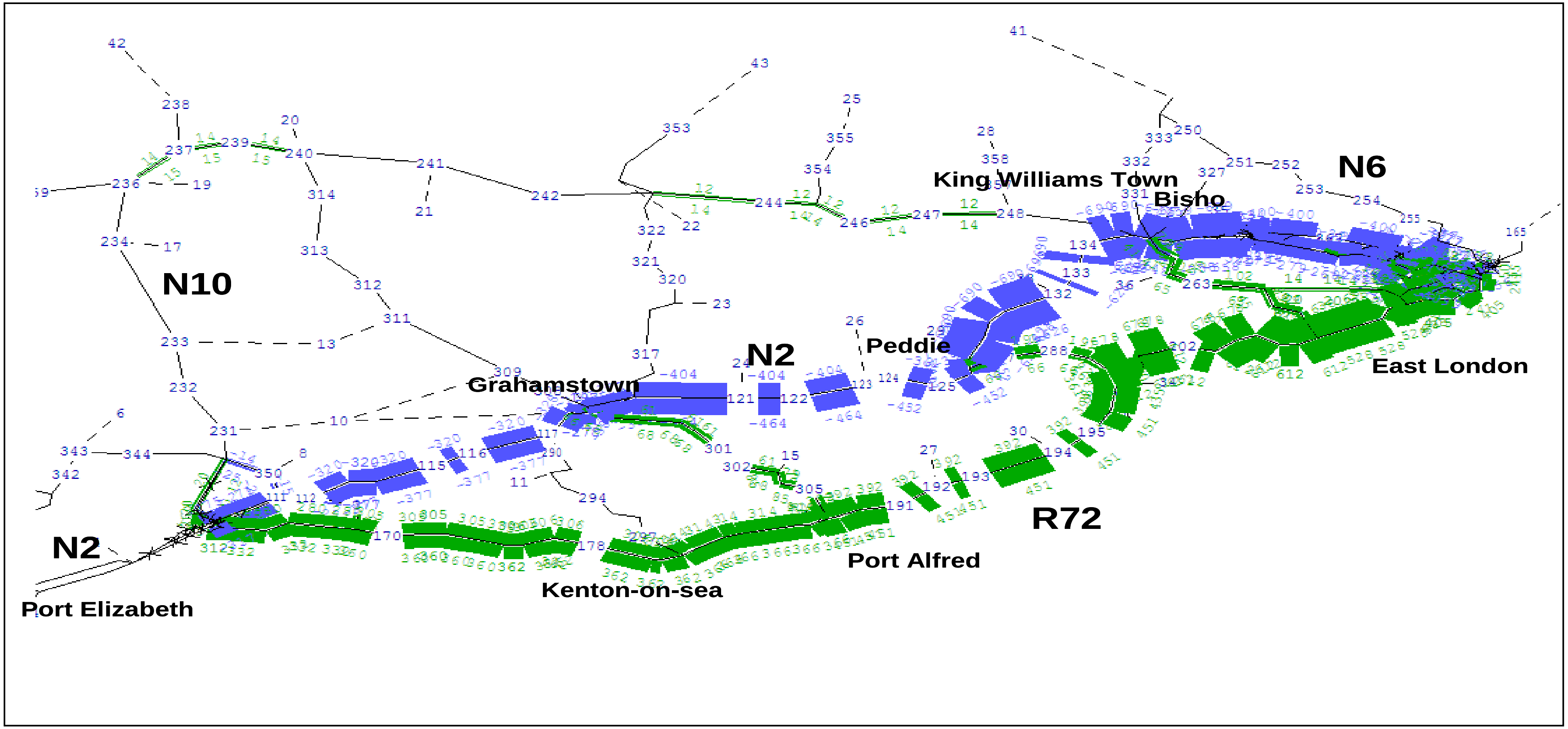


Figure 30: Scenario 2 - Tolling One Route Only - N2

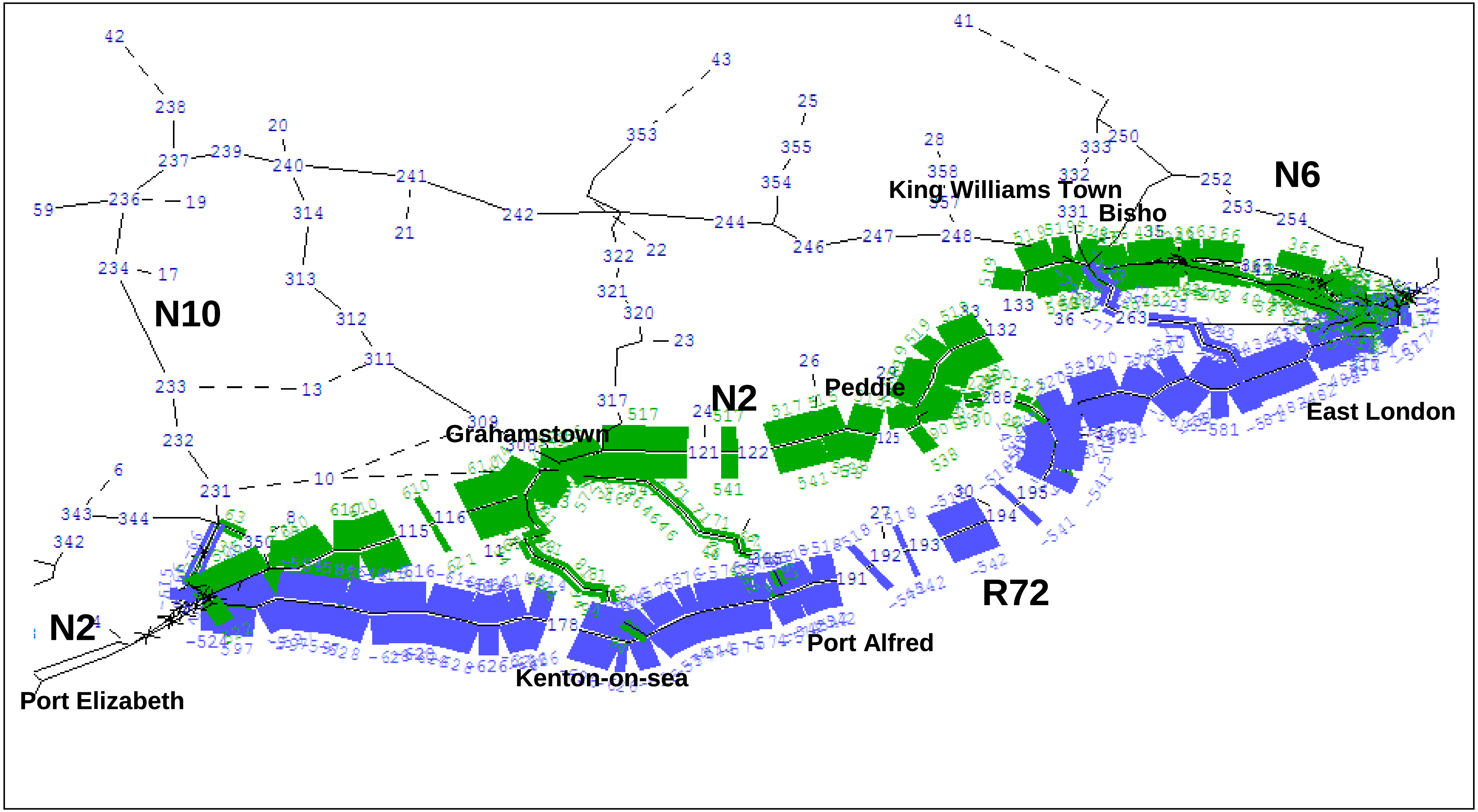


Figure 31: Scenario 2 - Tolling One Route Only – R72

6.3 Minimal upgrading is applied to the N2, which is then tolled.

In a scenario in which both N2 and R72 are tolled, albeit with marginal improvements to the N2, the revenue is considerably higher. It should be noted that the N2 earns a greater average revenue per road user in comparison to the R72. This is due to the higher tolls (due to the greater travel distance) and the higher toll tariff ratio per vehicle class on the N2.

The latter is reflected in the analysis of Scenarios 2 and 3, i.e. improving network connectivity for road users, particularly those on the R72, with the construction of additional links (the Buffalo Bridge link). This results in the R72 being an even more attractive route to road users and shifts traffic from the N2, a higher yielding route in terms of toll revenue returns, to the R72. This explains the unexpected drop in revenue with the construction of the un-tolled Buffalo Bridge link.

Results obtained from testing the alternative strategies in this scenario and can be summarised as follows (refer also to Figure 30):

- A comparison of the "after-toll" traffic volumes along the N2 from the Nanaga Interchange to Peddie and along the R72 from the Nanaga Interchange to Crossroads generally shows a small amount of traffic (50 to 100 veh/day) diverting from the R72 to the N2.
- There is diversion (some 200 veh/day) from the R72 between Crossroads and East London to the R345 between Crossroads and Peddie, then onto the N2 between Peddie and King William's Town and then onto the R346 route which links King William's Town and East London via Potsdam. This diversion is also evident, but is confined to one direction only because of the incorporated one-way tolling philosophy.
- There is significant diversion (some 550 veh/day) from the N2 between King William's Town and East London to the R346 and the N6. Once again, this diversion has a directional bias. As a result of the toll imposed on the eastern ramps of the N2 Mdantsane Interchange, the traffic on these eastern ramps reduces, some motorists preferring not to pay a toll but rather to utilise the R102 for their trip on to East London.

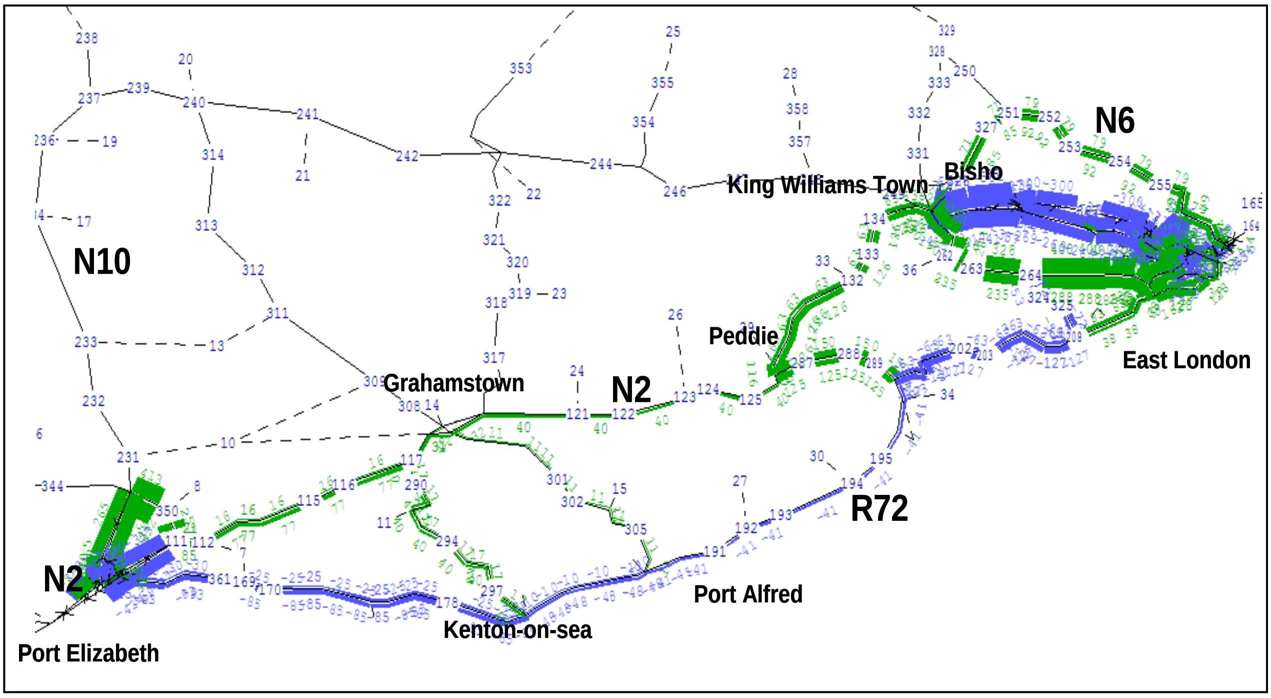


Figure 30: Scenario 3 - Tolling the R72 and N2/R72 Link Road (Buffalo Bridge)

6.4 Tolling the N2/R72 Link Road Only (Buffalo Bridge)

The impact of the proposed Buffalo River Bridge on the rural road sections was modelled by inserting links between the R72 and N2 to represent the bridge and associated roads to/from the bridge and the R72 and N2. In this assessment, the rural road sections were assumed to be tolled, but the no tolls were applied to the bridge, thus showing the maximum potential diversion between the N2 and R72. Obviously, should the bridge/bridges over the Buffalo River be tolled, the diversion to the R72 would be reduced.

Figure 33 below illustrates the changes in the number of trips between the N2 and R72.

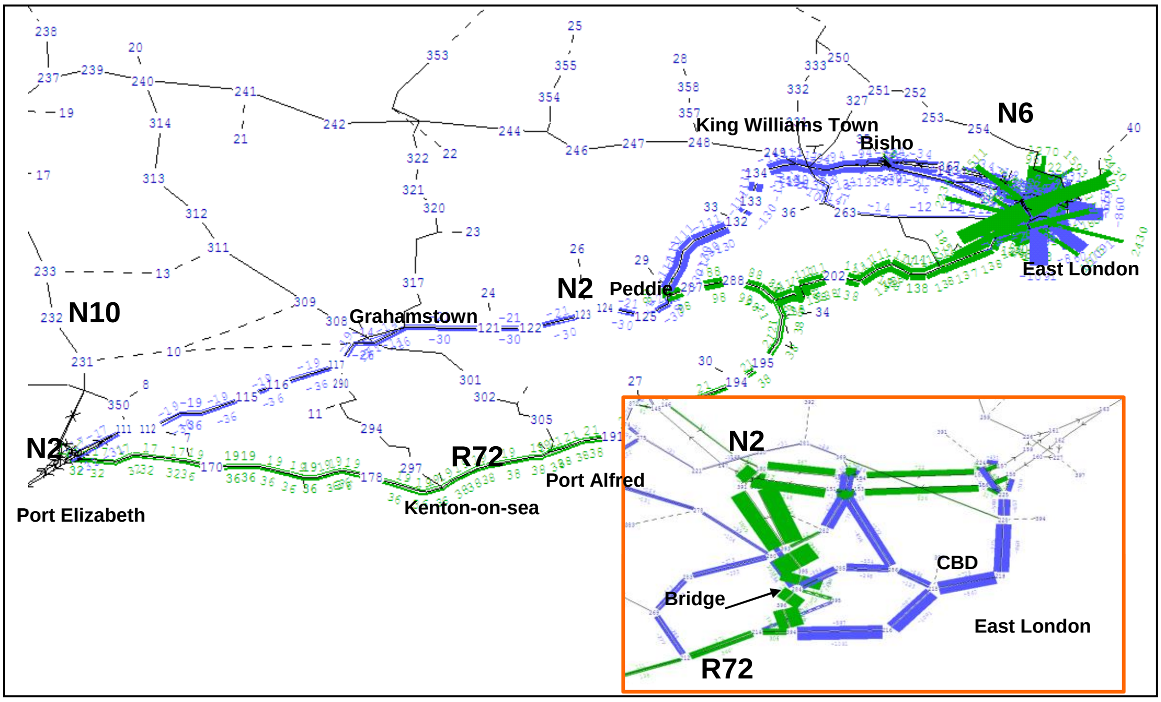


Figure 33: Scenario 3 - Tolling the N2/R72 Link Road Only (Buffalo Bridge)

This diagram indicates the diversion between the N2 and R72. On the N2 between Nanaga and Peddie and the R72 between Nanaga and Crossroads, the variation in daily traffic flows would be ranging between 20-30 vehicles per day. However, on the eastern portion of the corridors, the diversion towards the R72 could increase by 110-140 vehicles per day. In the inset in the above figure of the East London area, the model indicates that the Buffalo River Bridge would provide an alternative route between the R72 and N2 that would relieve the congestion through the CBD.

This scenario reflects the revenue that can be earned from tolling the Buffalo Bridge (toll set at R55,00 for user-class 1). The revenue for the N2/R72 alone would increase, implying that the toll on the bridge would serve as a minor constraint to traffic shifting away from the N2.

Scenario	Trips Deviation
1.Tolling One Route Only (N2 or R72)	-
2.Tolling One Route Only (N2 or R72)	700 to 1200 veh/day (N2) 1000 to 1200 veh/day (R72)
3. Minimal upgrading is applied to the N2, which is then tolled.	200 to 500 veh/day
4. Tolling the N2/R72 Link Road Only (Buffalo Bridge)	110 to 140 vehicles per day

Table 7: Comparison of Scenarios

7. RESEARCH CONCLUSION

7.1 Tolled Modelling Results

From the research, conclusions were drawn to answer the research question. On the extent of diverting from toll roads, only usage of alternative roads could be established. It is concluded than alternative roads in rural sections carry less than half of the traffic on the tolled section. There is no other economic or social activity; *the proportion using the alternative route can be as low as 1%.* The conclusion is that where the origin and destinations are constant, the use of diversion is less than 10%.

A conclusion can be drawn that toll roads are not flexible (elastic). This is in accordance with with literature in chapter 2, which says that the inelasticity of transport demand. From the Section 5 and 6 above, the tolling of the R72 alone yields rather low returns, even though a considerable benefit was applied to the model to attract road users to the upgraded R72. Traffic simply shifts onto the N2, which is un-tolled.

In Scenario 2, where both routes are tolled, albeit with marginal improvements to the N2, the revenue is considerably higher. It should be noted that the N2 earns a greater average revenue per road user compared to the R72. This is due to the higher tolls (due to the greater travel distance) and the higher toll tariff ratio per vehicle class on the N2.

The latter is reflected in the analysis of Scenarios 3, i.e. improving network connectivity for road users, particularly those on the R72, with the construction of additional links (the Buffalo Bridge link). This results in the R72 being an even more attractive route to road users and shifts traffic from the N2, a higher yielding route in terms of toll revenue returns, to the R72. This explains the unexpected drop in revenue with the construction of the un-tolled Buffalo Bridge link.

Scenario 4 reflects the revenue that can be earned from tolling the Buffalo Bridge (toll set at R50,50 for user-class 1). The revenue for the N2/R72 alone has increased, implying that the toll on the bridge serves as a minor constraint to traffic shifting away from the N2.

The following occurs:

- If the N2 is not tolled, traffic diverts from the R72 to the N2.
- If the N2 is tolled, traffic on the R72 increases.
- The more attractive the R72 becomes in relation to the N2, the increase in toll revenue from the R72 is less than the reduction in revenue from the N2, thus the slight reduction in overall revenue from these two rural roads.

Since toll road traffic is increasing somewhere in the range of 2% and 6%, the impact on income cannot be unwanted. There is a danger of ever-expanding maintenance costs if heavy vehicles keep on increasing at double the pace of light vehicles. While no evidence was found in previous writings that toll roads in South Africa try to ease tracffic congestion, it very well may be settled that an expansion in light vehicles (Class 1) exacerbates the level of service. The SANRAL Act does not make provision for SANRAL to play a role in managing congestion.

As urban regions like East London develop, so does traffic congestion. The upgrades in framework have up-and downstream impacts, some of which cannot be completely represented, because of the constrained extent of the obsolete transportation demonstrating strategies. To dodge horrible infrastructure investment or policy choices, their impacts should be surveyed on a bigger scale than was already important, because of the expansion in urban populace density.

The structure of the national road network infrastructure market in South Africa has the characteristics of a public monopoly because, among other things, prices imperfectly reflect the interaction between supply and demand. Since the market is constrained by a state owned company, to be specific SANRAL, it is commonly expected that the prosperity of residents will be a top need to at last *"improve the personal satisfaction for all South African individuals".*

The essential capital required for road project and its upkeep can be significant, and this is risky on the grounds that the assessments recouped by methods for a general fuel levy and ordinary provincial licenses are not distributed in full by the National Treasury to SANRAL for road speculation and support. A road-pricing estimating approach, explicitly the improvement of toll roads, related with a road-user rule, was created by the National Department of Transport (DOT) - Roads Division (now SANRAL) to make up for the deficiency where important. There has been a critique that SANRAL does not argue and persuade to counter the under-funding by National Treasury but instead resorts quickly to tolling the roads. The economic efficiency, territorial, horizontal and vertical equity were not considered when SANRAL developed a road user-pay pricing approach. This may be because this approach was developed in the 80s, prior the democratic dispensation in the mid-90s. Accordingly, the outcomes can be seen in the GFIP, when monetarily burdened residents since the equity between the road users and suppliers of infrastructure (SANRAL) (and, along these lines, disparity among clients and shoppers) might be in danger. In the GFIP, the client pay rule (user-pay principle) did not think about financial effectiveness, regional, flat and vertical equity. The rebate rates for neighborhood clients (local users) do not recognize the diverse salary groups and accordingly neglect to be viewed as vertical equity consideration

The complete weight of financing national road infrastructure has more than completely become that of the road users, despite the way that the commitment of roads to the nation's monetary welfare is vital and that all residents, not just the road user-payers, share right now. Public confidence in a toll system is a pivotal component in a period where the *'client is top dog'* and service levels are estimated dependent on consumer satisfaction levels. So far, the focal point of the toll framework has been progressively about how it benefits the organizations dealing with the roads than how they will improve roads for the individuals. The plan and usage of the toll system demonstrates a need to fill the coffers of the road agency and provincial authorities. The design and implementation of the toll system indicates a need to fill the coffers of the road authorities. Presumably, a decision will be made when the money is available. While this may sound prudent, it exposes the *"new money"* to more pressing demands that may crop up in a situation when the government desperately needs funds

The toll system totals all incomes from the individual toll gates. This move will sponsor the less fortunate performing toll gates and occupy income away from the busiest roads. Besides, by apportioning incomes from toll roads to local authorities, probabilities are extremely high that incomes will be utilized to keep up roads that are not being tolled. This will overstretch the limit that restricted incomes can accomplish, bringing about not exactly extensive fix and upkeep of strategic roads.

There is no uncertainty that the tolling framework is contributing gigantically towards raising the truly necessary income. Without pre-decided income focuses on, any income accomplished is a significant improvement. The way that the tolling framework is producing the most elevated measure of income contrasted with different sources shows its potential over the long haul. Despite the specialized, technical and authoritative difficulties experienced in the usage of the tolling framework, the mediation should be praised as an intense advance towards a far reaching procedure that will achieve an increasingly supportable road upkeep program.

Taking into consideration the funding, transportation, as well as the toll authority procedures, it is recommended that the following toll policy principles be stated as part of the new roads policy:

i.) Toll is a mechanism/enabler to expedite the improvement and/or implementation of new roads *to address congestion, road safety, the need for access and mobility to stimulate economic growth and to address socio-economic matters.*

ii.) Toll is a mechanism to change user behaviour *whereby private vehicle users internalise the external cost of infrastructure provision. User charges discourage the use of alternative modes of transport, ridesharing, less trip making and urban sprawl. It therefore indirectly reduces the amount of carbon emissions and has a positive environmental impact.*

iii.) Toll as a funding mechanism can be viably implemented, *taking into consideration traffic, economic, social and environmental studies that show an overall benefit to road users, society and the environment. Toll viability can be achieved by means of hybrid funding options, as discussed under "Tolling – Funding Policy".*

iv.) Toll as a funding option can only be implemented following a proper stakeholder engagement and participation process. *This process should spell out toll tariff setting and adjustment principles, based on the maximum tariff that can be implemented for new toll roads, or a national standard tariff in the event of tolling an existing road. Maximum annual toll tariff adjustments will be based on Consumer Price Index (CPI) for the preceding financial year.*

v.) Toll project implementation should differentiate and address the spatial context and associated road-user requirements *in respect of different categories (new and existing), as well as types (rural, commuter, bridge, and tunnel) of toll roads. The different categories and types of toll roads require a consistent approach with respect to the positioning and spacing of toll points, determination of toll tariffs and discounts/rebates.*

vi.) Toll tariffs, once determined, are to remain consistent in real terms, *implying that tariffs will only be adjusted annually in accordance with the CPI.*

7.2 Recommendation for Further Research

The utilization of bigger scale transportation demonstrating, in light of a Dynamic Traffic Assignment (DTA) approach, is recommended as a significant apparatus to support experts. It gave a solid system the potential positive and negative effects of huge street framework speculations, or to control strategy leaders in regards to transportation, which can be assessed. What's more, since transportation displaying is dependant on information, it is prescribed that:

- Transportation authorities ought to keep up a nitty gritty spatial database of all transportation framework. A focal database containing the physical properties of the transportation organize and other related information will encourage the usage of increasingly precise transportation demonstrating.
- Practitioners should avoid a one-size-fits all or "black box" approach to transportation modelling. A fundamental understanding of the transportation modelling techniques, their limitations and data requirements should inform the selection of a suitable transportation modelling methodology.
- Researchers should further investigate and refine larger scale transportation modelling techniques. Urban population density is forecast to increase, which will compound the up- and downstream effects of changes to infrastructure or policy. Effective techniques should be available to evaluate these impacts.
- This thesis illustrates that the traditional modelling framework, as it is implemented (and in this dissertation), is not sufficient to evaluate policy decisions or infrastructure investment, as it only incorporates people travelling to work during the morning peak hours. To measure the effect of increased public transportation, all instances of travel should be incorporated into the framework. This includes commercial vehicles (heavy and light), scholars/students travelling to school/academic institutions, as well as travel related to recreational purposes. Bus stops and taxi ranks should also be incorporated in to a TAZ connector selection .

This research could be further expanded to a full costing exercise, as well as an environmental air pollution exercise, which could be developed from each mode with the use of emissions in the Advanced Interactive Microscopic Simulator for Urban and Non-Urban Networks (AIMSUN). The latest data from research on fuel usage and emissions captured into the model could be used. This emission could be calibrated, and the determination of which mode could be most environmentally friendly could be investigated.

The distributed work on South African road is insufficient in contrast with worldwide guidelines. The acknowledgment of the user-pay system in future as one of the methods for cost recuperation in South Africa stays sad. It is the examination up-and-comer's view that the following exploration can be considered:

- Perception of Value of Time (VOT) by road client should be set up. The special urban and rustic cases need assessment from the present cost arrange. The significance of getting a handle on VOT observations is that SANRAL can modify cost utilization openings.
- On cost preoccupation, it would be basic for SANRAL and other roads authorities and specialists to have a capacity to extend volumes and clasify future traffic on the streets they are answerable for.
- The 'dynamic assignment' models in some micro-simulation packages are behaviourally-based, hence the assignment equilibrium concept is irrelevant. There is no evidence of any research that has been done on the proper calibration of the behavioural factors for use in micro-simulation models in South Africa, although there is proof and awareness of people using the software.
- There is a concern about the theoretical soundness of the approach of this research, especially with generalised cost equations. Whenever there is modelling uncertainty, sensitivity testing is necessary to assess the risk. A relationship between trip utility and generalised cost relationships needs to be undertaken.

8. REFERENCES

Alvarez, O, Cantos, P & Garcia L, 2007. The Value of Time and Transport Policies in a Parallel Road Network. Transport Policy, 14(5), 366-376.

Britton, H, 1994, *The Real Issues Concerning Lee's Requiem*, Journal of the American Planning Association.

Burris, M, 2003, The Toll-price Component of Travel Demand elasticity. International Journal of Transport Economics. available from https://ceprofs.civil.tamu.edu/mburris/Papers/Toll Price Component of Travels Demand Elasticity.pdf.

Carpintero, S, 2010, Toll Roads in Central and Eastern Europe: Promises and Performance. Transport Reviews, 30(3), 337-359.

Centre for Economics and Business Research, 2014, *The future economic and environmental costs of gridlock in 2030*, (online), (cited 2018-05-16), available from https://www.ibtta.org/sites/default/files/documents/MAF/Costs-of-Congestion-INRIX-Cebr-Report%20(3).pdf

Davidson P and T, Transport Modelling, *Your Primary Source for Transport Modelling, available from* http://www.transportmodeller.com/index.html

De Palma, A & Lindsey, R, 2011. Traffic Congestion Pricing Methodologies and Technologies. *Transportation Research Part C Emerging Technologies, 19(6),* 1377-1399.

Depolo, V and Jovic, J, 2011*, The Role of Trip Generation Models in Sustainable Transportation Planning in South East Europe, Transport*.

Duranton, G and Turner, MA, 2011, *The Fundamental LAW OF Road Congestion: Evidence from US Cities*, American Economic Review.

Ferrara A., Sacone S., Siri S. (2018) Microscopic and Mesoscopic Traffic Models. In: *Freeway Traffic Modelling and Control. Advances in Industrial Control.* Springer, Cham. https://doi.org/10.1007/978-3-319-75961-6_5

Grounau, R, 1999, The Economics of a Single Toll Road in a Toll-free Environment. Journal of Transport Economics and Policy.163-172.

Hayes, G and Venter C, *Trip Utility and the Value of Travel Time Savings (VTTS) for Commuter Trips: Critique and Recent Advances,* 26th SATC, South Africa 16 – 20 July 2016.
HCM, 2000. Highways Chapter 12. Highway Capacity Manual 2000.

Helbing, D, Hennecke, A, Shvetsov V and Treiber, M, 2002, *Micro – and Macro-Simulation of Freeway Traffic. Mathematical and Computer Modelling,* 35 (2002) 517-547.

Hensher, DA and Goodwin, P, *Using Values of Travel Times Savings for Toll Roads: Avoiding Some Errors*, Transport Policy, 2003 Elsevier Ltd 171-181.

Hirschman, I., Mcknight, C, Pucher, J., Paaswell, R.E, & Berechman, J., 1995. Bridge and Tunnel Toll Elasticities in New York: Some Recent Evidence. *Transportation, 22:2, 97-113.*

Jaspers Appraisal Guidance (Transport), *The Use of Transport Models in Transport Planning and Project Appraisal* – August 2014.

Koomen E and Borsboom-van Beurden, J, *Land-Use Modelling in Planning Practice by GeoJournal Library 101*

Kennedy, R, Kennedy R and Schaefer, W, *Inside the Blackbox: Making Transportation Models work for Livable Communities,* Citizens for a Better Environment and The Environmental Défense Fund – Funded by a Grant from Joyce Foundation, 2002.

Lave, C., 1994. The Demand Curve Under Road Pricing and the Problem of Political Feasibility. *Transportation Research Part A: Policy and Practice, 28A(No.2), 83-91.* from https://escholarship.org/cu/item/5165m7jr.

Lesley, L: *Generalised Costs and the Value of Time as a Method of Patronage Forecasting, by Acta Technica Jaurinensis.*

Odeck, J & Brathen, S, 2008. Travel Demand Elasticities and Users Attitudes: A Case Study of Norwegian Toll Projects. *Transportation Research Part A: Policy and Practice, 42(1), 77-94.*

Mackie, PJ, Wardman, M, Fowkes, AS, Whelan, G, Nellthorp, J & Bates J*, Value of Travel Time Savings in the UK,* Working Paper 567, White Rose, University of Leeds.

Mackie, PJ, Jara, S & Fowkes, AS*, The Value of Travel Time Savings in Evaluation*, Final Version.
Mathew, TV & Krishna Rao, KV, *Introduction to Transportation Engineering, NPTEL, May 2007*

McCallum, G and Fox, K, *Models United: Using SATURN and TRANSYT within an AIMSUM micro-simulation environment*, Halrow Group.

Mikros Traffic Monitoring (Pty) Ltd, 2016, SANRAL Traffic Count Information for Count Stations.

Milne, DS, May, AD, Van Vliet, D, 1993: *Modelling the Network Effects of Road User Charging: Results from a SATURN Study,* ITS Working Paper 411, University of Leeds – Institute for Transport Studies, ISSN 0142-8942.

NDOT, 2009, National Land Transport Act 5 of 2009, National Department of Transport, Pretoria, South Africa.

Oberholzer, J DE V, Van Zyl, NJW, Anderson SJ, *Traffic Modelling of Urban Toll Corridors – A review of current South African practice, as applied within the Johannesburg Pretoria toll corridor,* 20th SATC, South Africa 16 – 20 July 2001.

Ortuzar, JDD and Willumsen, LG, 2011*, Modelling Transport*, Edition, Wiley Chichester West Sussex United Kingdom.

Rose, John M., Hensher, D.A., 2013, Toll Roads are only Part of the Overall Trip: *the error of our ways in past willingness to pay studies, Institute of Transport and Logistics Studies (ITLS) The University of Sydney Business School: The University of Sydney NSW Australia 2006.*

Rubuluza, B., 2013. Toll Roads and Traffic Diversions in South Africa

SATURN, *Version 11.3 Manual – January 2015: Version 11.3.10, University of Leeds,* Atkins, Dirk van Vliet.

Swarts, S. J, 2017: Modelling South African Traffic for Large Network – An extension of the Gravity Model for Traffic Demand Models.

The South African National Roads Agency Limited *Act 7, 1998* – South African Government, Pretoria, South Africa.

The South African National Roads Agency Limited, *Annual Reports 2015 & 2016* – South African Government, Pretoria, South Africa.

TomTom, 2014, TomTom Traffic Index (online), (cited 2018-05-16), Available from https://www.tomtom.com/en_gb/trafficindex/.

TPO Consulting (Pty) Ltd, Roux E & Jones A, (June, 2016) *Buffalo City Metropolitan Municipality Arterial Road Network Development Plan, Report on BCMM VISUM Transport Model Development, Calibration and Validation*.

Transportation Research Board of the National Academies, *Transportation Research Circulation E-C153 – Dynamic Traffic Assignment: A Primer,* 2011.

Wegner, M, 2011, *From Macro to Micro – How Much Micro is too Much*? Transport Reviews, 31:2, 166-177.

Van Vliet, D, *Simulation and Assignment of Traffic to Urban Road Networks (SATURN), Manual (2015)* – Version 11.3.10, ITS, Atkins.

Van Zyl, NJW, Oberholzer, J DE V and Chen, YS, *South African experience within Estimation of Values of Time from Stated Preferences Studies and their Use in Toll Road Models,* 20th SATC, South Africa 16 – 20 July 2001.

Victoria Transport Policy Institute, 2017, *Transportation Cost and Benefit Analysis II – Travel Time Costs,* (online), Available from https://www.vti.org/tca0502.pdf.

Wardrope, JG, 1952, *Some Theoretical aspects of road traffic research*, Proceedings of the ICE – Civil Engineering: Engineering Divisions.

Zuidgeest, M, *Transport Models,* University of Cape Town, Faculty of Engineering & Built, Centre for Transport Studies – Transport Modelling (END5048Z) Lecture Notes on 27 January 2016.

12134 **EC_N002_15_8.2**

	TRAFFIC HIGHLIGHTS OF SITE 12134			
1.1	Site Identifier			12134
1.2	Site Name			EC_N002_15_8.2
1.3	Site Description			Between King Williamstown and East London
1.4	Road Description			Route : N002 Road : N002 Section : 15 Distance : 8.2km
1.5	GPS Position			27.427610E -32.8892218
1.6	Number of Lanes			4
1.7	Station Type			Secondary (Temp)
1.8	Requested Period			2017/01/01 - 2017/12/31
1.9	Length of record requested (hours)			8760
1.10	Actual First & Last Dates			2017/09/06 - 2017/09/21
1.11	Actual available good data (hours)			371
1.12	Percentage good data available for requested period			4.2
		To East London	To King Williamstown	Total
2.1a	Total number of vehicles (counted)	100057	99167	199224
2.1b	Total number of vehicles (projected for period)	2358264	2337288	4695552
2.2	Average daily traffic (ADT)	6461	6404	12865
2.3	Average daily truck traffic (ADTT)	433	417	850
2.4	Percentage of trucks	6.7	6.5	6.6
2.5	Truck split % (short:medium:long)	59 : 15 : 26	59 : 17 : 24	59 : 16 : 25
2.6	Percentage of night traffic (20:00 - 06:00)	7.8	7.6	7.7
3.1	Speed limit (km/hr)			60
3.2	Average speed (km/hr)	91.9	97.6	94.7
3.3	Average speed - light vehicles (km/hr)	93.3	99.0	96.2
3.4	Average speed - heavy vehicles (km/hr)	72.7	76.8	74.7
3.5	Average night speed (km/hr)	88.4	93.8	91.1
3.6	15th centile speed (km/hr)	73.7	81.6	77.7
3.7	85th centile speed (km/hr)	111.9	113.9	113.9
3.8	Percentage vehicles in excess of speed limit	95.7	97.8	96.7
4.1	Percentage vehicles in flows over 600 vehicles/hr	20.9	18.8	83.7
4.2	Highest volume on the road (vehicles/hr)		2017/09/15 17:00:00	1536
4.3	Highest volume in the East (vehs/hr)		2017/09/15 17:00:00	880
4.4	Highest volume in the West (vehs/hr)		2017/09/15 08:00:00	918
4.5	Highest volume in a lane (vehicles/hr)		2017/09/15 08:00:00	521
4.6	15th highest volume on the road (vehicles/hr)		2017/09/19 08:00:00	1293
4.7	15th highest volume in the East direction (vehs/hr)		2017/09/13 17:00:00	729
4.8	15th highest volume in the West direction (vehs/hr)		2017/09/15 09:00:00	653
4.9	30th highest volume on the road (vehicles/hr)		2017/09/14 17:00:00	1205
4.10	30th highest volume in the East direction (vehs/hr)		2017/09/08 14:00:00	590
4.11	30th highest volume in the West direction (vehs/hr)		2017/09/08 15:00:00	550
5.1	Percentage of vehicles less than 2s behind vehicle ahead	7.3	7.4	7.3
6.1	Total number of heavy vehicles (projected for period)	158126	152163	310289
6.2	Estimated average number of axles per truck	0.2	0.2	0.2
6.3	Estimated truck mass (Ton/truck)	0.9	0.9	0.9
6.4	Estimated average E80/truck	0.1	0.1	0.1
6.5	Estimated daily E80 on the road			1225
6.6	Estimated daily E80 in the East direction			620
6.7	Estimated daily E80 in the West direction			605
6.8	Estimated daily E80 in the worst East lane			564
6.9	Estimated daily E80 in the worst West lane			569
6.10	ASSUMPTION on Axles/Truck (Short:Medium:Long)			(2.0 : 5.0 : 7.0)
6.11	ASSUMPTION on Mass/Truck (Short:Medium:Long)			(10.9 : 31.5 : 39.8)
6.12	ASSUMPTION on E80s/Truck (Short:Medium:Long)			(0.5 : 3.9 : 2.1)

MIKROS TRAFFIC MONITORING

Mikros Traffic Monitoring (Pty) Ltd (012) 943 3600 12134 - 2

	TRAFFIC HIGHLIGHTS OF SITE 763			
1.1	Site Identifier			763
1.2	Site Name			Gonubie North I/C
1.3	Site Description			Inside Gonubie I/C
1.4	Road Description			Route : N002 Road : N002 Section : 16 Distance : 20.3km
1.5	GPS Position			27.952030E -32.9380308
1.6	Number of Lanes			4
1.7	Station Type			Permanent
1.8	Requested Period			2016-01-01 - 2016-12-31
1.9	Length of record requested (hours)			8784
1.10	Actual First & Last Dates			2016-04-08 - 2016-04-25
1.11	Actual available good data (hours)			417
1.12	Percentage good data available for requested period			4.8
		To Mthatha	To King William's Town	Total
2.1a	Total number of vehicles (counted)	80414	90694	171108
2.1b	Total number of vehicles (projected for period)	1692271	1908608	3600878
2.2	Average daily traffic (ADT)	4624	5215	9838
2.3	Average daily truck traffic (ADTT)	436	485	921
2.4	Percentage of trucks	9.4	9.3	9.4
2.5	Truck split % (short:medium:long)	49 : 15 : 36	56 : 13 : 31	52 : 14 : 34
2.6	Percentage of night traffic (20:00 - 06:00)	10.1	10.2	10.2
3.1	Speed limit (km/hr)			120
3.2	Average speed (km/hr)	95.1	102.4	98.9
3.3	Average speed - light vehicles (km/hr)	98.1	104.3	101.4
3.4	Average speed - heavy vehicles (km/hr)	65.6	83.5	75.0
3.5	Average night speed (km/hr)	87.4	96.2	92.1
3.6	15th centile speed (km/hr)	77.7	83.7	81.7
3.7	85th centile speed (km/hr)	113.9	119.9	117.9
3.8	Percentage vehicles in excess of speed limit	6.3	14.7	10.7
4.1	Percentage vehicles in flows over 600 vehicles/hr	4.8	7.3	59.0
4.2	Highest volume on the road (vehicles/hr)		2016-04-08 18:00:00	1128
4.3	Highest volume in the East (vehs/hr)		2016-04-13 18:00:00	695
4.4	Highest volume in the West (vehs/hr)		2016-04-25 08:00:00	735
4.5	Highest volume in a lane (vehicles/hr)		2016-04-25 08:00:00	427
4.6	15th highest volume on the road (vehicles/hr)		2016-04-14 08:00:00	985
4.7	15th highest volume in the East direction (vehs/hr)		2016-04-08 16:00:00	528
4.8	15th highest volume in the West direction (vehs/hr)		2016-04-22 15:00:00	490
4.9	30th highest volume on the road (vehicles/hr)		2016-04-19 17:00:00	903
4.10	30th highest volume in the East direction (vehs/hr)		2016-04-22 15:00:00	427
4.11	30th highest volume in the West direction (vehs/hr)		2016-04-15 18:00:00	420
5.1	Percentage of vehicles less than 2s behind vehicle ahead	5.6	11.8	8.9
6.1	Total number of heavy vehicles (projected for period)	159728	177468	337196
6.2	Estimated average number of axles per truck	4.3	4.0	4.1
6.3	Estimated truck mass (Ton/truck)	24.4	22.6	23.5
6.4	Estimated average E80/truck	1.6	1.4	1.5
6.5	Estimated daily E80 on the road			1380
6.6	Estimated daily E80 in the East direction			686
6.7	Estimated daily E80 in the West direction			694
6.8	Estimated daily E80 in the worst East lane			655
6.9	Estimated daily E80 in the worst West lane			643
6.10	ASSUMPTION on Axles/Truck (Short:Medium:Long)			(2.0 : 5.0 : 7.0)
6.11	ASSUMPTION on Mass/Truck (Short:Medium:Long)			(10.9 : 31.5 : 39.8)
6.12	ASSUMPTION on E80s/Truck (Short:Medium:Long)			(0.5 : 3.9 : 2.1)

MIKROS TRAFFIC MONITORING

Mikros Traffic Monitoring (Pty) Ltd (012) 943 3600 763 - 3

	TRAFFIC HIGHLIGHTS OF SITE 12136			
1.1	Site Identifier			12136
1.2	Site Name			EC_R072_04_49.4
1.3	Site Description			Between East London and Port Alfred
1.4	Road Description			Route : R072 Road : R072 Section : 04 Distance : 49.4km
1.5	GPS Position			27.751028E -33.0946398
1.6	Number of Lanes			2
1.7	Station Type			Secondary (Temp)
1.8	Requested Period			2016-01-01 - 2016-12-31
1.9	Length of record requested (hours)			8784
1.10	Actual First & Last Dates			2016-09-21 - 2016-09-30
1.11	Actual available good data (hours)			203
1.12	Percentage good data available for requested period			2.3
		To East London	To Port Alfred	Total
2.1a	Total number of vehicles (counted)	26032	26718	52750
2.1b	Total number of vehicles (projected for period)	1125978	1155650	2281627
2.2	Average daily traffic (ADT)	3076	3158	6234
2.3	Average daily truck traffic (ADTT)	360	356	716
2.4	Percentage of trucks	11.7	11.3	11.5
2.5	Truck split % (short:medium:long)	34 : 22 : 44	35 : 23 : 42	35 : 22 : 43
2.6	Percentage of night traffic (20:00 - 06:00)	11.7	10.6	11.1
3.1	Speed limit (km/hr)			100
3.2	Average speed (km/hr)	100.0	97.2	98.6
3.3	Average speed - light vehicles (km/hr)	102.9	99.0	100.9
3.4	Average speed - heavy vehicles (km/hr)	78.3	82.4	80.3
3.5	Average night speed (km/hr)	93.3	96.1	94.6
3.6	15th centile speed (km/hr)	79.8	79.7	79.7
3.7	85th centile speed (km/hr)	120.0	113.9	117.9
3.8	Percentage vehicles in excess of speed limit	50.6	42.7	46.6
4.1	Percentage vehicles in flows over 600 vehicles/hr	0.0	0.0	3.7
4.2	Highest volume on the road (vehicles/hr)		2016-09-23 16:00:00	675
4.3	Highest volume in the East (vehs/hr)		2016-09-26 07:00:00	401
4.4	Highest volume in the West (vehs/hr)		2016-09-23 16:00:00	429
4.5	Highest volume in a lane (vehicles/hr)		2016-09-23 16:00:00	429
4.6	15th highest volume on the road (vehicles/hr)		2016-09-22 18:00:00	511
4.7	15th highest volume in the East direction (vehs/hr)		2016-09-24 10:00:00	276
4.8	15th highest volume in the West direction (vehs/hr)		2016-09-22 16:00:00	293
4.9	30th highest volume on the road (vehicles/hr)		2016-09-23 07:00:00	473
4.10	30th highest volume in the East direction (vehs/hr)		2016-09-22 09:00:00	225
4.11	30th highest volume in the West direction (vehs/hr)		2016-09-29 14:00:00	243
5.1	Percentage of vehicles less than 2s behind vehicle ahead	15.5	22.3	18.9
6.1	Total number of heavy vehicles (projected for period)	131707	130280	261987
6.2	Estimated average number of axles per truck	4.9	4.8	4.8
6.3	Estimated truck mass (Ton/truck)	28.2	27.8	28.0
6.4	Estimated average E80/truck	1.9	1.9	1.9
6.5	Estimated daily E80 on the road			1394
6.6	Estimated daily E80 in the East direction			701
6.7	Estimated daily E80 in the West direction			693
6.8	Estimated daily E80 in the worst East lane			701
6.9	Estimated daily E80 in the worst West lane			693
6.10	ASSUMPTION on Axles/Truck (Short:Medium:Long)			(2.0 : 5.0 : 7.0)
6.11	ASSUMPTION on Mass/Truck (Short:Medium:Long)			(10.9 : 31.5 : 39.8)
6.12	ASSUMPTION on E80s/Truck (Short:Medium:Long)			(0.5 : 3.9 : 2.1)

MIKROS TRAFFIC MONITORING

Mikros Traffic Monitoring (Pty) Ltd (012) 943 3600 12136 - 2

ANNEXURE B

B.1 Toll Road Categories

The way in which toll tariffs and discounts are determined is associated with the high-level categories of toll roads:

B.1.1 Category 1 – Greenfield toll roads

The route should be a completely newly constructed road to be categorised as a Category 1 Toll Road. Alternatively, if sections of an existing route are incorporated into a new route, the points at which the obligation to pay toll (toll plaza or toll gantry) is recorded will only be positioned on the newly constructed sections of the toll route. Road users may still exit or enter the existing route at intersections or interchanges positioned before and after the newly constructed sections of the toll route.

B.1.2 Category 2 – Converting existing routes into toll roads

This category of toll route comprises the upgrading and the tolling of an existing road section. The point/s at which the obligation to pay toll (toll plaza or toll gantry) is recorded is/are positioned on an existing road.

B.2 Differentiation Between Types of Toll Roads

The different categories of toll roads are further defined in accordance with the following "types" of toll roads:

a) Rural toll roads: A toll road in a rural environment that predominantly carries long distance non-commuter traffic. A route will be classified as a rural toll road if less than 10% of the Class 1/Class A traffic utilises the route to commute to and from work more than three times per week.
b) Rural and commute toll road: A toll road in a rural environment that predominantly carries long distance non-commuter traffic, but also carries more than 10% of the Class 1/Class A traffic that utilises the route to commute to and from work more than three times per week.
c) Urban/network toll road: A toll road that is in an urban environment or forms part of a network of toll roads that is predominantly carrying urban and commuter traffic. A route will be classified as an urban/network toll road if more than 60% of the traffic utilising the route during a normal weekday enters or exits the route or network of toll

routes at an on-ramp/access or off-ramp/exit within the toll road or network of toll roads.

d) Tunnel/bridge: These types of toll roads refer to the tolling of very specific and high capital cost infrastructure associated with bridges longer than 500m or road tunnels.

B.3 Standardised Methodology for Determination of Toll Tariffs for Different Vehicle Classes

Two vehicle class classification systems are in use in South Africa, axle-based and volumetric systems. The axle-based classification system defines four vehicle classes:

- Class 1 (light vehicles and motorcycles)
- Class 2 (small heavy vehicles)
- Class 3 (medium heavy vehicles)
- Class 4 (large heavy vehicles)

The volumetric classification system defines three vehicle classes:

- Class A (light vehicles).
  Class A is broken down into two sub-categories:
    - *Class A1 (motorcycles)*
    - *Class A2 (light vehicles and small commercial vehicles)*
- Class B (medium heavy vehicles)
- Class C (large heavy vehicles)

The way in which toll tariffs are determined are standardised for the different categories and types of toll roads, as well as vehicle classes.

For **Category 1** toll roads (Greenfields), the toll tariffs for the different types of toll are determined as follows:

a) **Urban/Network:** Maximum of 75% of the net benefits derived for users for each different vehicle class, based on vehicle cost and time savings. The maximum ratio between different classes are:

- Class 1: Class 2 – 1:2
- Class 1: Class 3 – 1:3,5
- Class 1: Class 4 – 1:4,75
    - *Class A: Class B – 1:2,5*
    - *Class A: Class C – 1:5*

For **Category 2** toll roads (tolling existing roads), the toll tariffs for the different types of toll are determined as follows:

a) **Urban/Network:** Maximum of 75% of the net benefits derived for users for each different vehicle class, based on vehicle cost and time savings or 35c/km (2018 base date) (for Class 1/A vehicles) – whichever of the two is lowest. The maximum ratio between different classes are:

- Class 1: Class 2 – 1:2
- Class 1: Class 3 – 1:3
- Class 1: Class 4 – 1:4
  - *Class A: Class B – 1:2,25*
  - *Class A: Class C – 1:4*

B.4 Toll Strategy and Plaza Spacing

By determining the toll strategy and maximum spacing of toll points/plazas, the maximum tariff is also determined. By defining the maximum toll plaza spacing, the maximum toll tariff payable (given the principles of "standardised methodology for determination of toll tariffs for different vehicle classes") can be determined. If the section of toll road for which a single toll plaza is provided is longer than the maximum recommended spacing, only the per kilometre tariff in accordance with the maximum spacing will be payable. For a "closed toll strategy", the plaza spacing will be determined by the on-entrance and exit points to the toll road. No maximum toll plaza/point spacing is therefore applicable.

In the event of an "open toll strategy", a maximum spacing for different categories and types of toll roads are defined as follows:

Category 1 (Greenfields toll roads)

a) Rural: 100km

b) Rural/Commute: 100km

c) Urban/Network: 30km

d) Tunnel/Bridge: Will depend on the specific facility that is tolled.

Category 2 (tolling existing route)

a) Rural: 80km

b) Rural/Commute: 60km

c) Urban/Network: 20km

d) Tunnel/Bridge: Will depend on the specific facility that is tolled.