THE ROLE OF MICROSCOPIC SIMULATION MODELLING IN THE PLANNING OF TRANSPORT CORRIDORS: AN APPLICATION OF PARAMICS TO KLIPFONTEIN CORRIDOR

H Ntoi And M Vanderschuren*

MSc Student, University of Cape Town, Employed at Ninham Shand, 81 Church street, Cape town 8001, ✆ +27 (76) 117 7772, ☎ +27 (21) 481 2400, +27 (21) 424 5588, ✉ Hopolang.Ntoi@shands.co.za

*University of Cape Town, Department of Civil Engineering, Private Bag X3, Rondebosch 7701, ✆ +27 (83) 444 4530, ☎ +27 (21) 650 2593/2584, +27 (27) 689 7471, ✉ marianne.vanderschuren@uct.ac.za

ABSTRACT

Corridor development has become the focal point of many municipal spatial development frameworks in South Africa, à la the City of Cape Town's *Mobility Strategy, 2003*. The Mobility Strategy consists of a mobility plan whose core target is a "city-wide multidisciplinary roll-out of public transport corridors" on a number of designated routes. The widely documented *Klipfontein Corridor* represents Phase One of the Mobility Strategy. The unique context of the Klipfontein Corridor project poses numerous challenges with regard to its planning, financing and implementation. A literature review revealed that the use of microscopic simulation modelling would most probably provide a vast amount of necessary information to assist the planning process. This study aimed to demonstrate how microscopic simulation modelling can assist during the planning of corridors. This was achieved through a modelling exercise of Klipfontein Corridor using the microscopic simulation package, Paramics. Due to the demonstrative nature of this project, the results demonstrate the output possibilities, rather than final figures for the Klipfontein Corridor.

1. INTRODUCTION

The widely documented *Klipfontein Corridor* represents Phase One of the City of Cape Town's Mobility Strategy (2003), whose core objective is to tackle the city's spatial inequities and the deficiencies associated with the incumbent public transport service. Klipfontein Road, the centrepiece of this corridor development, linking Khayelitsha to the Cape Town CBD, traverses a number of low and middle-income communities that would greatly benefit from an efficient transport service and the associated commercial and recreational facilities that would accompany the project.

The project is of a vast and highly complex nature, consisting of numerous elements, parameters and stakeholders. In order to fulfil all the stakeholders' objectives and incorporate all relevant features of the corridor, transport planners require a tool that is flexible and equipped to deal with highly complex, dynamic systems in a detailed. Microscopic simulation models provide this flexibility.

This study undertakes a microsimulation modelling exercise of the Klipfontein Corridor using the dynamic software package, Paramics. The aim is to demonstrate the features of microsimulation modelling and comment on its role in the planning of transport corridors.

Proceedings of the 26th Southern African Transport Conference (SATC 2007)
ISBN Number: 1-920-01702-X
Produced by: Document Transformation Technologies cc

9 - 12 July 2007
Pretoria, South Africa
Conference organised by: Conference Planners

2. PROBLEM STATEMENT

A large segment of the Cape Town population remains socially and economically marginalised, without the benefit of an effective public transport (PT) service. This has had serious effects on poor communities' ability to improve their quality of life and empower themselves economically.

It has been cited that the average length of a bus trip in the morning peak period from Khayelitsha to the Cape Town CBD is 99 minutes and costs a significant proportion of the commuters' average monthly income, which, for the majority of residents within the study area, is less than the household subsistence level of R1 600 (TTPT, 2004). The current transport system has caused commuter trips to commence very early and terminate after dark in the evenings. This poses safety risks for travellers, exacerbated by the lack of lighting and security at interchange facilities.

Furthermore, there is a lack of integration between the three main PT modes, namely rail, bus and minibus taxi (MBT). The result is a very cumbersome process of passenger transfers between modes, which further lengthens trips and threatens the security of travellers.

In addition, transport system design has traditionally given priority to the private car over PT and non-motorised transport (NMT) modes. This has resulted in long walking distances without adequate provision of safe and convenient paths and crossings for pedestrians and cyclists (CCT, 2003). It has also resulted in transport infrastructure that does not facilitate the required high mobility for PT vehicles. Currently, buses and MBTs compete for road space with private cars, which is a source of much frustration on the part of users of both private and PT modes, especially during peak periods.

Added to this, travel demand is strongly concentrated within the morning (AM) and evening (PM) peak periods, which, in combination with the Cape Town CBD's location relative to the main areas of residence, has resulted in a poor temporal and directional distribution of traffic.

On an institutional level, the MBT (which boasts the highest daily road-based PT ridership in the Western Cape) is largely unregulated and bears the characteristics of paratransit. It offers an informal service with haphazard stops and no adherence to a schedule. This lack of operational planning has resulted in an over-supply of vehicles and reckless competition among operators. It has been a source of recurring disputes and violence within the MBT industry. The situation is neither desirable legally, socially, operationally nor economically, and has provided more impetus for transport authorities to seek an alternative as a matter of urgency.

3. PROPOSED ACTION

The plan of action is a 30 km corridor with a dedicated public transport lane linking Khayelitsha, Crossroads, Gugulethu, Gatesville and Athlone via Mowbray, to the Cape Town CBD. The Corridor intends to invite commercial, housing and open space/ recreational developments along its edges, and provide an integrated MBT and bus system offering 24-hour feeder and corridor express services *(Figure 1)*.

Figure 1 Proposed PT Network (Klipfontein Corridor highlighted in green)
Source: TTPT, 2004

The Corridor will have Klipfontein Road as its centrepiece (running from Gugulethu to Mowbray) but also includes Steve Biko Road (running from Khayelitsha CBD), Lansdowne Road (from Khayelitsha to Nyanga) and connecting to New Eisleben Road. The actual route from Mowbray to Cape Town CBD is still to be selected from a number of alternatives.

The plan in the project's year of inception, 2003/4, was to implement the proposed improvements in a number of phases over time. It is envisaged that the new PT services will be operational by the time South Africa hosts the FIFA World Cup in 2010, and the total cost of the project has been estimated at R450 million.

4. THE KLIPFONTEIN CORRIDOR

Owing to the sheer size and complexity of the Klipfontein Corridor Project, attempting to acquire exhaustive background data would prove to be a mammoth task (even for the Klipfontein Project Team, whom it has taken over a year to set up the model), and well beyond the realm of this particular study. The focus of the study is on the process and role of microsimulation in the planning of transport corridors. Therefore, due to the demonstrative nature hereof, the results demonstrate the output possibilities, rather than final figures for the Klipfontein Corridor.

4.1 Data collection

Ninham Shand Consulting Services (one of the engineering firms making up the Klipfontein Project Team consortium) provided processed traffic data, which then formed input to the Paramics model. Although the Klipfontein Project Team had not completed their detailed transport model at the time of writing, significant updates had been made to the City of Cape Town's (CCT) existing EMME/2 model. Klipfontein Corridor falls within the area covered by the CCT EMME/2 model. For this reason, the trip generation and distribution data in the city-wide model became the basis for the travel demand patterns specified in the Paramics model.

The information provided, therefore, relates mainly to the EMME/2 model inputs and focuses on the entire Cape Metropolitan Area (CMA). Data collection for the development of the EMME/2 model was not the work of the author but of the Klipfontein Project Team throughout 2005.

4.2 Study area

The section of Klipfontein Corridor, which is modelled in Paramics as part of this study, represents the 12 km segment of Klipfontein Road between the Klipfontein and Milner Roads intersection in Mowbray, and the New Eisleben and Lansdowne Roads intersection in Crossroads.

4.3 Population

The spatial distribution of the various population groups in Cape Town is a result of historic apartheid social engineering, which actively drove Black, Coloured and Indian people to the city’s peripheries. The Klipfontein Corridor study area chiefly comprises these population groups.

Research data reflects a likelihood that the population of previously disadvantaged groups in Cape Town will increase significantly by 2011 (LATP&UE, 2005). The data also projects a steep increase of medium and high-income household bands within the study area, accompanied by a steadily declining low household income growth rate. The low-income band consists of households whose annual income is below the R38 400 margin, the medium income band falls between R38 400 and R76 800, and the high-income band earns more than R76 800.

However, despite the overall growth-rate decline in the low-income household category, there is still a growth, in absolute terms, from 518 000 in 2006 to 534 000 in 2011; therefore, the expected result is still a marked growth in the Klipfontein Corridor travel demand. The significance of the household size and income level is that low-income groups typically consist mainly of ‘captive’ PT users.

4.4 Land use

Bulk gross land-use area (GLA) quantities that can be accommodated in various nodes within the study area, have been determined (NMAPD, 2005). 17 nodes of opportunity were identified in Khayelitsha, Mitchell’s Plain, Philippi, Nyanga, Greater Athlone and Cape Town *(Figure 2)*. A generic breakdown was applied to these nodes so that in each case, 50% of the land was assigned to residential land use, 10% to commercial/ industrial, 10% to institutional, 15% to public open space, and 15% to roads; excepting the Philippi node, where the split between commercial/ industrial and institutional was 15%:5%. Node 16: Culemborg and Node 17: District Six were not considered to be of direct impact to the modelled section of Klipfontein Corridor.

4.5 Traffic zones

The City of Cape Town: Cape Town Administration Zoning Scheme, used to set up the CCT EMME/2 model, consists of 819 zones throughout the CMA and 6 Metro Local Councils (MLCs). The gravity model concept was used in the production/ attraction and distribution of trips, where zones of higher residential capacity produce more trips and zones of higher activity levels attract more trips.

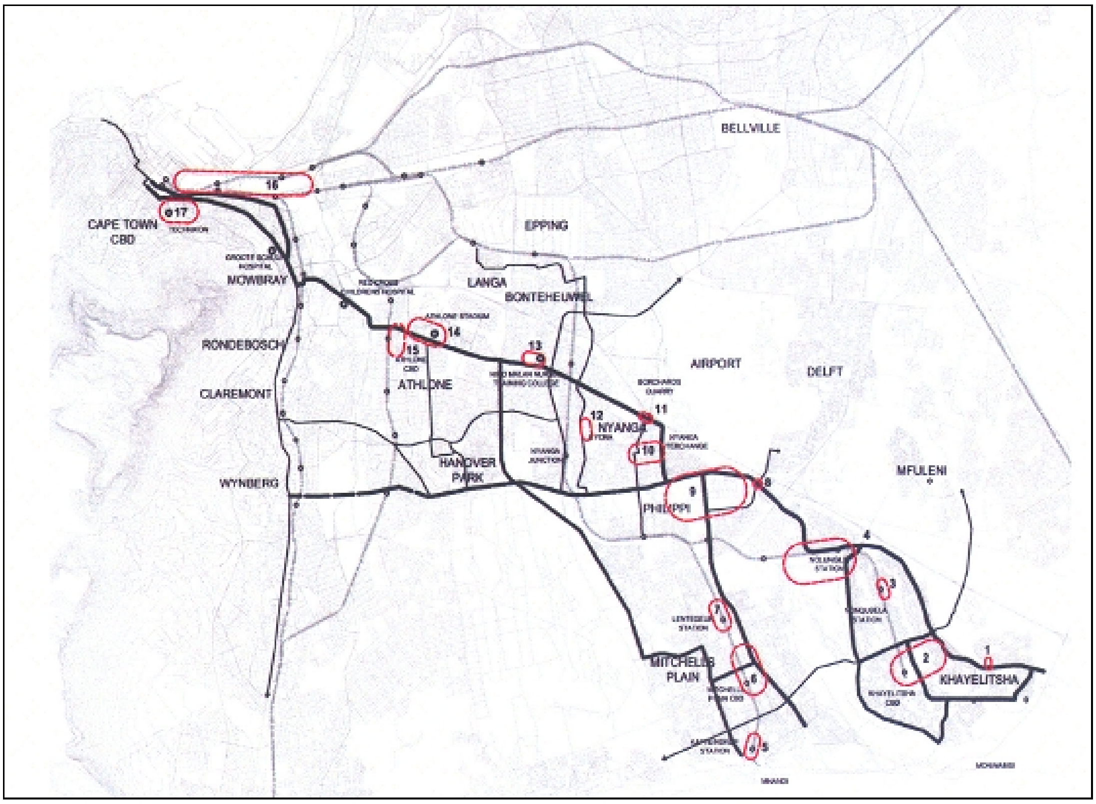

Figure 2 Identified Nodes of Opportunity along Klipfontein Corridor
Source: NM & Associates, 2005

4.6 Road network and transport conditions

The Klipfontein Corridor road network consists predominantly of Class 3 road links (based on the CCT road classification scheme), except New Eisleben Road between Klipfontein Road and Lansdowne Road, classified as a Class 2 (TTPT, 2004). The Klipfontein Corridor road links are, for the most part, severely congested during peak times, especially in the AM peak period when demand is the highest. In addition to an improved PT service, the road cross-sections and alignment, in some cases, will also require upgrading. The intention is to introduce PT priority measures which would include exclusive bus and minibus taxi (BMT) lanes, PT signage, shelters, street furniture and dedicated stops and PT interchange facilities with improved safety and security, such as lighting and closed circuit television surveillance.

The modelled section of the corridor consists of over 50 intersections. Traffic count surveys were conducted at most of these intersections, mainly the signalised ones with the higher traffic flows, as part of the *Klipfontein Corridor Public Transport Feasibility Study* (TTPT, 2004) and more recently by Arup Consulting Engineers (Arup, 2005).

Historical traffic volume trends reveal an average annual traffic growth of about two to five percent along Klipfontein Corridor from 1990 – 1995, thereafter beginning to plateau. It is likely that the low traffic growth rate is due to capacity constraints at the intersections (TTPT, 2004). However, with improved levels of service, more traffic may be attracted from the adjacent N2.

The Current Public Transport Record (CPTR) summary document of 2004/5 provides detailed PT modal split information for the AM peak (06:00–09:00), inter-peak (09:00–16:00) and PM peak periods (16:00–19:00), as shown in *Figure 3*.

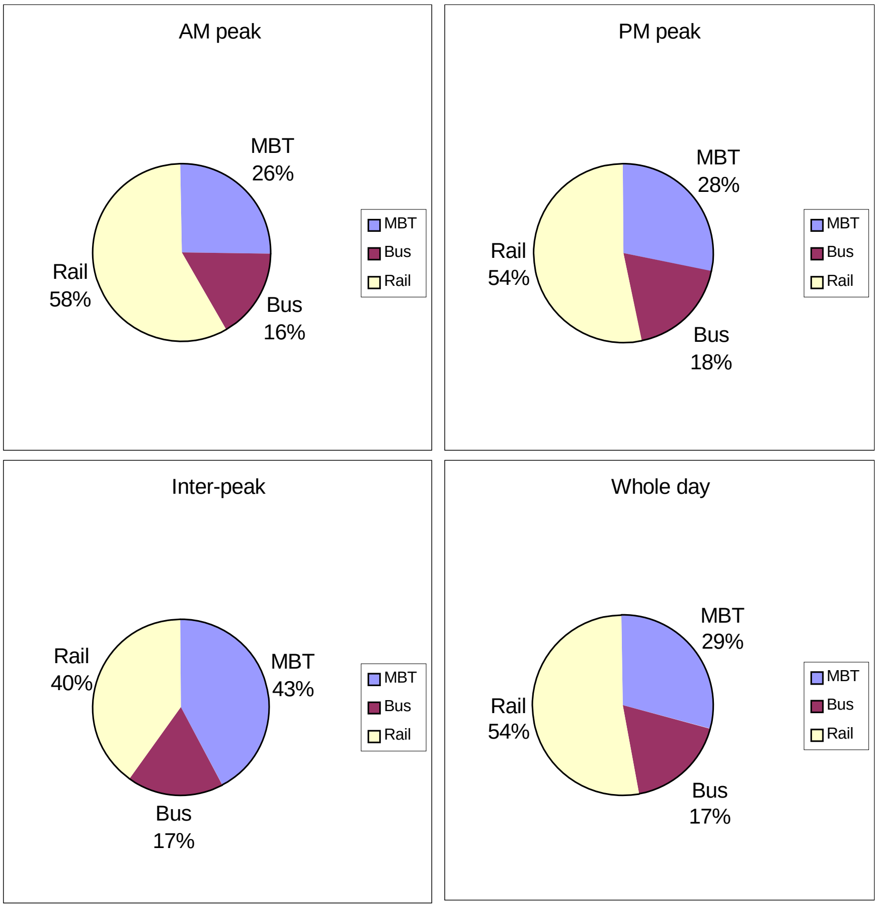

Figure 3 Public transport modal split
Source: CCT, 2005

The proportion of PT in the Klipfontein Corridor and N2 traffic is relatively high. Based on the 2001 Census, PT is the main travel mode for the low household income bracket, making up 57% of all work trips, and also with 49% of all PT work trips being made by persons belonging to the low-income category. The road-based PT mode trips, bus and MBT, together make up the majority of PT trips made for most of the day.

The bus utilisation rate is fairly fixed throughout the day, with a narrow range of 16%–18%. The rail mode is more dominant during the AM and PM peak periods, making up 58% and 54% respectively, of the PT trips, but falls to a ridership of 40% during the inter-peak period. This decline corresponds to a similar increase in MBT ridership for the same period, suggesting that passengers find the MBT mode more attractive during the lower demand periods of the day. An explanation for this could be the road congestion levels during peak periods, which lead to excessive delays. It is therefore reasonable to assume that improved road-based PT levels of service may attract some rail passengers.

4.7 Travel Demand

From the CPTR 2004/5 information, it is apparent that the weekday AM peak period represents the highest demand for PT services. For this reason, this is the period upon which the EMME/2 model and, therefore, the Paramics model, have been based.

5. THE PARAMICS MODEL

Paramics is classified as a *dynamic microsimulation* modelling tool while EMME/2 falls under the category of *static macro analytical* models. In other words, Paramics is capable of conducting more detailed microscopic analysis than EMME/2 whose modelling capabilities do not extend far beyond a coarse area-wide trip assignment procedure. The O/D matrix informing the EMME/2 model consists of 819 zones throughout the CMA, which had to be considerably simplified for the purposes of this study.

The overall trip assignment for the corridor had already been conducted in EMME/2 so traffic volume estimates were available for all links. These link volumes were used to amalgamate the Klipfontein Corridor trips from/to external zones by summing up the totals on links entering/exiting the section of the corridor intended for modelling. This resulted in a traversal matrix representing only the Klipfontein Corridor trips between the Klipfontein/ Milner Roads intersection in Mowbray and the New Eisleben/ Lansdowne Roads intersection in Crossroads. The centroidal nodes were used to cordon off the area of interest, and are themselves used as the trip origin/destination zones.

The cordon does not include the parallel N2 freeway. It does, however, take into account the trips currently entering the corridor from the N2 and vice versa; though not any increased/reduced tendency for traffic to interchange between the two once the Klipfontein Corridor road network has been modified. Based on the purpose of this study, the simplification of the problem inherent in the Paramics model and the decided level of significance, it was reasoned that the N2's inclusion was not of paramount importance.

The Paramics model seeks to comparatively assess the impacts of the proposed bus priority on the corridor's performance. This is achieved by way of 3 hypothetical scenarios each representing different traffic conditions:

- Scenario 1: Base Case – Existing Traffic, Existing Network (2006)
- Scenario 2: Do Nothing – Future Traffic, Existing Network (2010)
- Scenario 3: PT Priority – Future Traffic, Future Network (2010).

2010 was chosen as the analysis year because of government's stated intention to have effective transport systems in place by the time South Africa hosts the 2010 FIFA World Cup. It is assumed that the Klipfontein Corridor project will be complete and that the new PT system will be fully operational by this time.

In addition to the EMME/2 link volumes, Arup Consulting Engineers had conducted a series of SIDRA analyses of most of the corridor intersections, for which results were available. The two independent sets of results could be used as a template of existing traffic flows along the corridor to ensure that the traffic volumes reflected by Paramics were reasonable.

However, a detailed model calibration, using the least squares regression equations and associated r^2 statistic, was not undertaken due to the fact that the Klipfontein Corridor network is represented as a singular route in the model. This means that multiple route options are not available and all trips (from the reduced matrix drawn from the CCT EMME/2 model) are assigned to the corridor itself. It was not deemed to be of paramount importance to reflect figures identical to reality, provided the values were not so inaccurate as to misrepresent the general prevailing traffic conditions. The most important consideration was that the base case model configuration and parameters remained unchanged between the different scenarios, with the given scenario's system of interest (travel demand and/or road network) being the only changing aspect. This would provide an opportunity to compare the corridor's performance in each scenario, and assess the impact of any changes to the traffic demand and/or the road network.

6. RESULTS

The overall performance of Klipfontein Corridor is summarised in Table 1.

Table 1 Comparison of network performance for various scenarios

Scenario	Mode	Average Journey Time (m:s)	Average Delay* (s)	Average Queue Length (pcu)
1. Base Case	General Traffic	32:41	80.8	6.4
	Bus	37:32	93.7	6.4
2. Do Nothing	General Traffic	39:26	82.6	8.3
	Bus	49.22	112.3	8.3
3. PT Priority	General Traffic	36:13	85.3	9.1
	Bus	20:29	19.4	3.3

* Delay excludes passenger loading time at stops

In each of the three scenarios, the road network performance is measured in terms of journey times, delays and queue lengths. The average values of journey time given are for all trips in the network, regardless of the length of the trip. Therefore, the values combine journey time data of a very wide range, and cannot be blindly compared with the bus journey times of *Scenario 3*, which occur on a fixed route traversing the entire length of the modelled section of the corridor. The delay and average queue length parameters are more appropriate measures for comparison.

It is to be noted that in *Scenarios 1* and *2*, PT routes were not coded and as such, PT-specific average journey time and delay data could not be extracted. Instead, the maximum journey time and delay data was taken as that which represents PT modes, specifically buses. The average bus queue length values were however maintained at similar values to those representing the general traffic, as this aspect describes lane characteristics, and lanes are shared by all modes in the first two scenarios. The average journey times, delays and queue lengths reflected under *Scenario 3*, on the other hand, are actual values obtained from the Paramics outputs.

The numeric results reveal that the benefits of the PT priority measures apply more to PT operations than to the general traffic. As the overarching objective for the initiative is to enhance the performance of PT operations, this result is plausible. In future studies, it is recommended that a closer look be taken to the effect of the improvements to road-based PT operations, on the mode choice of the users of other modes (rail and private vehicles). It is the opinion of the author that significant improvements to the bus service would attract more and more users, requiring an upscale of the service to accommodate all the new users, on an ongoing basis. Microsimulation modelling lends itself to the process of iterative adjustments of the model inputs, and enables the user to see the effects of these adjustments on the performance of the network, immediately.

Once business initiatives start taking off along Klipfontein Corridor in response to the improved transport system, the corridor will itself become a highly attractive economic development and employment zone. This may result in the alleviation of the directional bias, in the long run, as explained earlier. For this reason, the initial PT operational design considerations would change and some modifications to the route scheduling would become necessary. Through microsimulation modelling packages, such as Paramics, these adjustments can be explored.

7. CONCLUSION AND RECOMMENDATIONS

The level of service of current public transport is poor in most South African cases, including the Klipfontein corridor. Many interventions are needed to make public transport more appealing to choice passengers. Public transport priority at intersections is one of the possibilities to improve the level of service and image of the system.

Calculations reveal that the average travel time in public transport reduces by more than 15 minutes due to the priority system, while average travel time for the general traffic increases by three to four minutes. In this study it was, therefore assumed that, due to this intervention, mobility growth (5% per annum) in the corridor would occur in public transport.

The Authors are of the opinion that a major shift towards public transport will only occur if multiple interventions to improve public transport occur. A major shift was therefore not assumed.

Although the modelling approach taken in this study was exploratory, it can be concluded that microsimulation models are suited to estimate the impacts of public transport priority systems.

Transport planning is an ever-evolving discipline, whose areas of interest are subject to multiple and complex changes over time. In order to best represent and deal with these systems, it is recommended that transport planners make use of the technology available. Microsimulation is the ‘state of the art’ in transport modelling.

8. REFERENCES

[1] BKS Consulting Engineers, November 2005. N2/Klipfontein Corridor Extension.

[2] City of Cape Town, 2003. City of Cape Town Mobility Strategy.

[3] City of Cape Town, 2005. 2004/5 Current Public Transport Record.

[4] de Beer, L., Mayaba, Z, Mokonyama, M, 2005. The Use of DRACULA Microsimulation Modelling in the Evaluation of Public Transport Priority Measures on the SOWETO to Parktown Corridor. 24th Annual South African Transport Conference.

[5] Kacir, K, Krogscheepers, C, 2001. Latest Trends in Micro Simulation: An Application of the Paramics Model. 20th Annual South African Transport Conference.

[6] Kingma, R, Williams, RM, 2002. Cape Town’s Strategic Public Transport Network, 21st Annual South African Transport Conference.

[7] Klipfontein Corridor Technical Transport Planning Team, June 2004. Public Transport Feasibility Study – Stage 1: Alternatives Analysis (draft).

[8] Larry Aberman Town Planning & Urban Economics, June 2005. Macro Demographic and Employment Analysis and Forecasts.

[9] NM & Associates Planners and Designers, December 2005. Klipfontein Corridor Assessment of Potential Land Use for Transport Impact Assessment Purposes (draft).

[10] Provincial Administration: Western Cape, May 2005. Western Cape Taxi Recap Socio Economic Study.