ALTERNATIVE MULTIMODAL ROAD PLANNING PROCESSES FOR THE DEVELOPING WORLD – A CASE STUDY IN CAPE TOWN, SOUTH AFRICA

Edward Andrew Beukes, Dept. of Civil Engineering, University of Cape Town, Rondebosch, South Africa - ebeukes@ero-engineers.co.za

Mark Zuidgeest, Dept. of Urban and Regional Planning, ITC, Enschede, The Netherlands - zuidgeest@itc.nl

ABSTRACT

Road planning practice relies almost exclusively on parameters related to traffic factors, such as private vehicle speeds and volumes. In many developing countries the requirements for public transport and non-motorised transport are not explicitly integrated into the planning process, despite the fact that these form the primary mode of transport for the majority of the population. This exclusion of the main modes affects the mobility opportunities for various sectors of the population and contributes to poor road safety, especially with regards to pedestrians.

The research outlined in the paper posits that, in order to assess the usage and needs of the road holistically, other factors related to the adjacent land uses, socio-economic characteristics of the population the road serves and the environmental context within which the road is located, factors heavily in how the road is used and should, therefore, be considered within the planning process.

The paper outlines the development of a methodology to include these factors in the planning process of roads. The method under development attempts to prioritise amongst the four primary road based modes (bus, car, walking and cycling) based upon a combination of traffic and non-traffic factors. The method employed uses a geographic information system (GIS) based spatial multi-criteria evaluation (SMCE) model with inputs from widely available data sources such as census, household travel surveys, land use and environmental data to arrive at solutions for modal priorities. The paper demonstrates the validity of this alternative planning process through the application of the method for a major arterial route in Cape Town. The results of this analysis are contrasted with results from a multimodal level of service analysis done in accordance with NCHRP guidelines.

Keywords: Multimodal Road Planning, Spatial Multicriteria Evaluation, Level of Service

1. INTRODUCTION

1.1. Road planning in South Africa

In developing countries such as South Africa, mode choice is very often dictated by income. Specifically, lower income people are often captive to public transport (PT) and non-motorised modes (NMT), and higher income people are more likely to use private motorised transport (NDoT, 2003). Furthermore, even in metropolitan areas the overall levels of car ownership are low relative to developed countries, which is symptomatic of the high proportion of low income earners and the high numbers of unemployed (Dargay, 2001). Figure 1 illustrates the reliance on walking and public transport in South Africa.

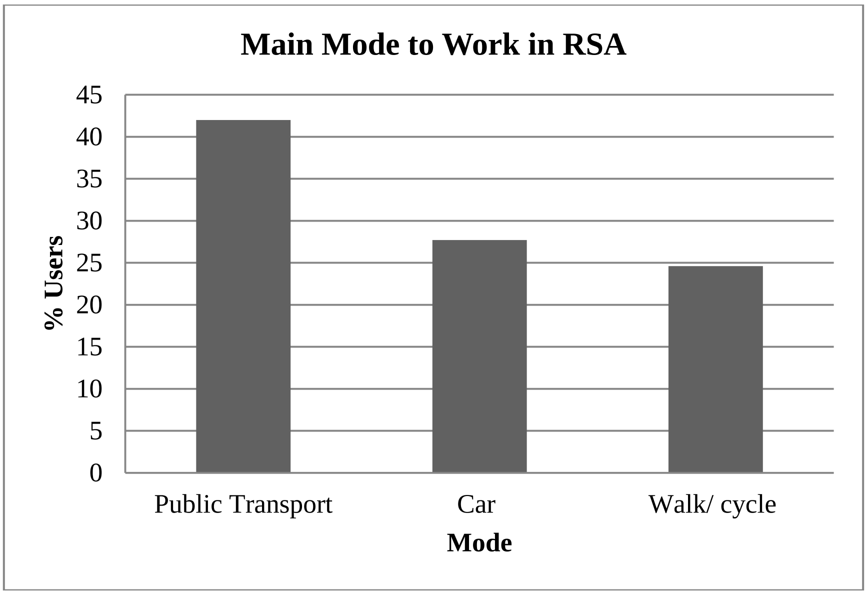

Figure 1: Modes of travel used to work (Source: Adapted from NDoT 2003)

In this context, it would be fair to assume that road planning practice would be sensitive to the demand for facilities for NMT and PT. However, this is not the case. There is a lack of infrastructure and facilities that inhibits NMT use and PT and NMT is not successfully integrated in all aspects of planning (CoCT, 2005a). This is despite legislation and policy documents calling for PT to be given higher priority in planning and infrastructure provision and for NMT to be promoted as the preferred mode over appropriate distances (NDoT, 2006).

The authors contend that one of the primary reasons for this continuing in planning practice is that many of the guidelines commonly used by planners and designers are outdated, and were not developed to comply with the current policies (CUTA, 1989). Guidelines are fragmented between modes and road categories, and so consequently fail to provide the planner with a modally integrated perspective on the needs of all road users who may use the facility being planned. In most instances there is very little, if any, explicit guidance given on infrastructure provision for mixed use roads, despite more recent literature defining these as constituting the majority of urban streets (CSIR, 2000).

Despite guidelines specifically stating that they do not preclude the use of innovative engineering practices (CSIR, 2000), professional liability concerns may deter planners from deviating from their recommendations. It is therefore unsurprising that road planning practice in South Africa continues to produce infrastructure that is biased towards the needs of private motorised transport.

1.2. Cost of road accidents in South Africa

Road accidents cost developing countries' economies severely and prevent them from investing more in other sectors, where the funds are needed to improve living standards in the country. South Africa, despite being accepted as having a higher level of development than most African countries, is no exception to road accident trends and their cost implications. Table 1 compares some costs of road accidents over the last 5 years in the country.

Table 1 – Costs due to fatal crashes, pedestrians killed and speed related crashes (converted to USD) for the whole of South Africa. Source: Road Traffic and Fatal Crash Statistics 2003-2004; RTMC Road Traffic Report-2008

Year	**Total Fatal crashes**	**Pedestrians & Hit and Run**	**Speed related**
2004*	$ 1.196 bn	$ 0.584 bn	$ 0.312 bn
2006-2007**	$ 1.866 bn	$ 0.867 bn	$ 0.556 bn
2007-2008***	$ 1.804 bn	$ 0.807 bn	$ 0.583 bn

The figures shown give an indication of just how serious road accidents are and how they affect the country economically. Pedestrian and speed related crashes are the two types of crashes that make up the majority of these costs (total fatal crashes).

1.3. Location of pedestrian accidents

A striking statistic is that in the Cape Town metropolitan area in 2005, nearly 52% of all pedestrian fatalities occurred along the top five most dangerous roads for pedestrians (CoCT, 2005b), and four of these top five roads are freeways that are officially off limits to pedestrians. Table 2 illustrates:

Table 2 – Worst five roads in Cape Town for pedestrian accidents. Source: Adapted from 2005 Traffic Accident Report; City of Cape Town

Road	**Suburb**	**Fatal**	**Injuries**
National Road 1	Cape Town	19	17
Kuils River Freeway (R300)	Delft	12	31
Lansdowne Road	Lansdowne	10	208
National Road 2	Cape Town	10	51
National Road 7	Cape Town	7	45

Freeways are clearly not safe routes for pedestrians to use, this is why these roads are officially restricted to pedestrians, but the number of casualties that occur on these roads indicates that there must be a significant number of pedestrians walking along these roads. In addition, the figures speak to a failure of integrated urban and transportation planning and, more importantly in the context of this paper, a failure to adequately plan for or respond to the needs of multiple modes.

The data also alludes to some of the particular problems associated with planning road infrastructure in a developing world context. As was mentioned previously, the majority of people in South Africa are reliant upon walking, cycling and public transport for their mobility needs (although cycling remains a relatively minor mode). However, a significant minority of people (approximately 25%) use private vehicles as their primary mode of transport (NDoT, 2003). This leads to competition amongst modes for road space, and sets up conditions on the roads that encourage accidents. In this context, the need for considered multimodal planning becomes critical, especially in light of the high social and economic costs associated with accidents.

Of particular interest in the data presented in Table 2 is Lansdowne Road. Whereas all the other roads in the top five are freeways, Lansdowne Road is an arterial route with no restrictions to any mode.

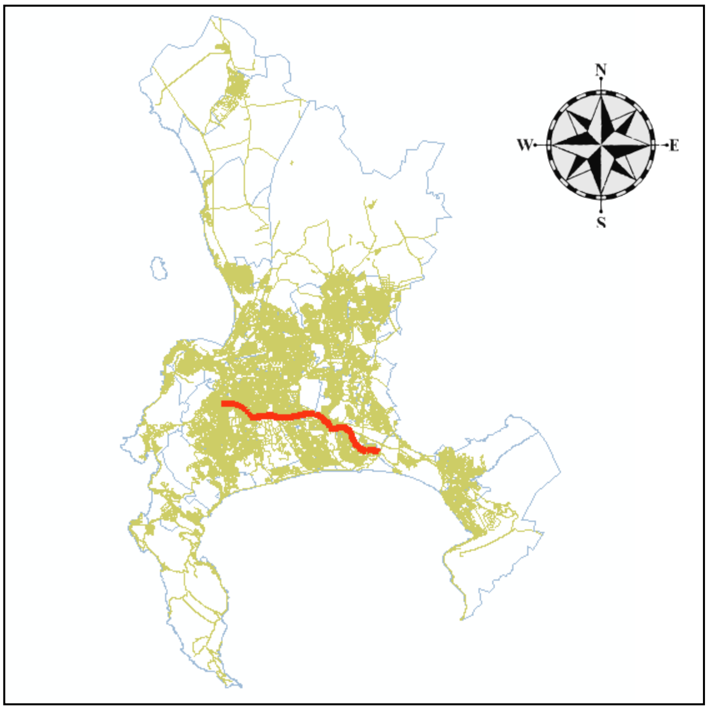

Figure 2: Lansdowne Road locality plan

This makes it an interesting case study to try to understand the features that lead to high accident rates and to identify possible interventions to limit the number of accidents that occur in these multimodal environments in the developing world context.

2. METHODOLOGY

Locations along Lansdowne Road with abnormally high accident rates were identified along the route and one was selected for further investigation. A site inspection was conducted and the data required to conduct a Level of Service (LOS) analysis was collected.

Multimodal levels of service (MMLOS) were then calculated for this location using recently developed analysis methods. MMLOS analysis methods improve upon the existing Highway Capacity Manual (HCM) (TRB, 2000) LOS analysis methods in that the relationships between modes using a corridor are incorporated into the analysis. There is a recognition that improving service levels for one mode will impact upon service levels for another mode using the corridor. The first method comprises a set of manual calculations developed by the National Cooperative Highway Research Programme (NCHRP).

The next step involved analysing the route using a Geographic Information System (GIS) based Spatial Multicriteria Evaluation (SMCE) method currently being tested by the authors. The method assesses the relative importance of one mode over another in terms of a number of contextual or environmental criteria. The method employs a multi-criteria evaluation using the four main road based modes (private vehicles, pedestrian, public transport and bicycle) as alternatives. The criteria used to assess these alternative modes are drawn from the aspects of the locational context. The output from the evaluation is a ranking or score for each mode.

The results from the SMCE analysis are then compared to the results from the level of service calculations. The SMCE results provide an indication of what the ideal configuration should be based upon the criteria selected and MMLOS results describe the status quo. Where there are significant discrepancies between these two sets of results, further on site investigations are conducted to identify possible interventions.

3. ANALYSIS METHODS

3.1. NCHRP method

The LOS calculations for Auto, Transit, Bicycle and pedestrian modes, as developed by the National Cooperative Highway Research Program (Dowling, 2008), are presented below.

3.1.1. Auto LOS

The Auto Level of Service is related to the average speed travelled on the study segment length and the number of stops. A lower LOS is obtained where many stops per kilometre occur. The auto LOS is given by the following formula:

$$Auto\ LOS = \sum_{j=1}^{6}(\mathrm{Pr}(\mathrm{LOS} = \mathrm{J}) * \mathrm{Wj}) \qquad (1)$$

Table 3: Auto LOS variable description (Source: Dowling, 2008)

Variable	**Description**	**Computation / value**
J	Level of service letter grade	A, B, C, D, E or F
Wj	Numerical value of LOS grade	A=1,B=2,C=3,D=4, E= 5, F =6
Pr (LOS = J)	Probability of an LOS rating equal to J	Pr ($LOS = J$) = Pr($LOS \leq J$) – Pr($LOS \leq J - 1$)

The probability that a person will rate a given facility as LOS J or worse is given by the ordered cumulative logit model as shown below:

$$Pr(LOS \leq J) = \frac{1}{1+exp(-\alpha_{(J)}-\sum_k \beta_k x_k)} \qquad (2)$$

Where:

Pr(LOS<=J) = Probability that an individual will respond with level of service grade of J or worse.
J = A, B, C, D, E, or F
exp = Exponential function.
α_k = Alpha, Maximum numerical threshold for LOS grade .J. (see Table 4).
β_k= Beta, Calibration parameters for attributes (see Table 4).
x_k = Attributes (k) of the facility (see Table 4).

Table 4: Alpha and Beta Parameters for Auto LOS Model

Parameter Value	**Alpha Values**
Intercept LOS E =	-3.8044
Intercept LOS D =	-2.7047
Intercept LOS C =	-1.7389
Intercept LOS B =	-0.6234
Intercept LOS A =	1.1614
Beta Values	
X(1) = Stops/Mile=	0.253
X(2) = Proportion of Intersections with Left Turn Lanes =	-0.3434

3.1.2. Transit LOS

The transit level of service refers to the quality of service experienced for transit vehicles such as busses. It is related to the speed of the transit vehicle, waiting time, amenities at bus stop and pedestrian accessibility.

$$Transit\ LOS\ Score = 6.0 - 1.50 * \text{TransitWaitRideScore} + 0.15 * \text{PedLOS} \qquad (3)$$

Table 5: Transit LOS variable description

Variable	**Description**

TransitWaitRideScore	Rating for the waiting time and bus ride. Related to perceived travel time rate and average bus headway.
PedLOS	Numerical value for the pedestrian level of service in the direction of facility (i.e. bus) A=1,B=2,C=3,D=4, E= 5, F =6

The overall facility LOS (directional) is computed by the addition of the segment LOS in that direction, using:

$$\mathit{LOS\ (facility)} = \Sigma\ \mathrm{LOS\ (i)} * \mathrm{L(i)}\ /\ \Sigma\mathrm{L(i)} \qquad (4)$$

Where:
LOS (i) = LOS for each segment (directional)
L (i) = Segment length

3.1.3. Bicycle Level of Service

Bicycle LOS is dependent on:
- Perceived separation between motor vehicle traffic and cyclist
- Parked vehicle interference
- Pavement quality

There exists an inverse relationship between this perceived separation and vehicle (light and heavy) volumes and speeds.

$$\mathit{Bicycle\ LOS} = 0.160*(\mathrm{ABSeg}) + 0.011*(\exp\ (\mathrm{ABInt})) + 0.035*(\mathrm{Cflt}) + 2.85 \qquad (5)$$

Table 6: Bicycle LOS variable description

Variable	**Description**
ABSeg	Length weighted average segment bicycle score
Exp	Exponential function
ABInt	Average intersection bicycle score
Cflt	Number of unsignalised conflicts / km = sum of unsignalised intersections and driveways / km

The overall facility LOS (directional) is computed by the addition of the segment LOS in that direction, using:

$$\mathit{LOS\ (facility)} = \Sigma\ \mathrm{LOS\ (i)} * \mathrm{L\ (i)}\ /\ \Sigma\mathrm{L\ (i)} \qquad (6)$$

Where:
LOS (i) = LOS for each segment (directional)
L (i) = Segment length

3.1.4. Pedestrian Level of Service

The pedestrian LOS is a function of the perceived separation between the pedestrian and vehicular traffic. The greater the vehicle volume and speed are, the smaller the perceived separation. The final Pedestrian LOS is the taken as the worse or poorer value between DPLOS and NDPLOS:

$$PLOS = \text{Worse of (DPLOS, NDPLOS)} \qquad (7)$$

Table 7: Pedestrian LOS variable description

Variable	**Description**
DPLOS	Letter grade LOS for sidewalks, walkways and street corners based on density
NDPLOS	Letter grade LOS for the urban street based on factors other than density

The overall facility LOS is given by:

$$LOS\ (facility) = \Sigma\ \text{LOS (i)} * \text{L (i)} \ / \ \Sigma\text{L (i)} \qquad (8)$$

Where:
LOS (i) = LOS for each segment (directional)
L (i) = Segment length

3.2. Spatial Multiple Criteria Evaluation

The open source software ILWIS v3.31 developed at the Institute for Earth Observation and Geosciences (ITC) in Enschede in The Netherlands was used to conduct the analysis. The GIS software has a module specifically developed for conducting Spatial Multiple Criteria Evaluations (SMCE) on raster datasets. Spatial datasets were constructed using the available data sources and converted to raster images to conduct the SMCE. ILWIS outputs the results of the analysis as a raster image. A uniform weighting regime was used to test the viability of the method without introducing any biases. Each mode was evaluated individually, thereby producing a set of four preference or suitability maps. Image processing techniques were then used to aggregate the results along the route centreline for each map. This information was exported to a spreadsheet programme for further analysis.

Data sources used included data from the 2001 National Census, the 2003 National Household Travel Survey (NDoT, 2003), and data acquired from the City of Cape Town's Corporate GIS department.

3.2.1. Criteria selection

In order to assess the context of the road, a number of variables must be considered. These can be classified into the various categories that define the reality of the area in general and the specific locality under consideration in particular. Each locality is defined by these variables. It is reasonable to assume that this contextual reality will vary from place to place and possibly will change with time as well.

The variables that are considered relate specifically to the what, who and how questions that can be asked of any locality. What are the characteristics that define the locality? Who are the people using the locality? How are these people using the locality?

It is from within this framework of information that the locational context within which the road exists emerges. The locational context comprehensively defines the access function of the road. Roads, however, serve more than just to provide access; they also have a very important mobility function. They provide connectivity between locations. From these two ideas stems the dichotomy between location specific traffic and through traffic (AASHTO, 2001).

Traditionally, service levels have been skewed towards the mobility perspective, that is, how easy is it to get from point A to point B via a given route? In an automobile centric planning environment this has been come to mean how easy is it to get from point A to point B by car? Optimising mobility may be appropriate under certain circumstances, where the locational context allows for this, but in many urban settings this is not the case. Other factors, such as the safety of other road users, or the ease of access to the adjacent land uses, or simply maintaining the dignity of a location (CoCT, 2009) may override the mobility needs.

How are these principles captured in traditional road design? Traditionally, this has been the role of road classification, where, given a roads location in the network, a range of appropriate design parameters can be assigned to it. However, the characteristics of the urban setting does not always conform to the ideals of the classification scheme, and so much is left up to the discretion of the designer. Furthermore, these locational contexts also change over time. Usually, this leads to one of two design reactions, either try to meet the demand by allocating additional space, or try to refocus the demand by restricting or confining flows using traffic calming. Only in the latter instance is any explicit consideration given to the context, and in South Africa, traffic calming is almost always restricted to residential roads, and also often does nothing to promote one mode over another, instead focussing only on limiting the mobility of vehicles.

So instead, the approach adopted by this methodology is to integrate locational contextual information into the planning process, along with traditional traffic related variables to arrive at a holistic view of the circumstances. The question now becomes, what are the criteria that should be used to assess the alternatives? To answer this question we frame the decision problem as: based upon the context within which the infrastructure is to be developed, what should the order of priority of the various modes be?

Given a certain location, what are the factors that distinguish it from other locations? As mentioned previously, these factors cover a range of issues relating to what is unique about the location, who uses the location and how is the location used. The factors can be categorised into information describing the location (land use, density etc) and information describing the users (age, income levels, etc).

Multi criteria analysis methodologies require that criteria be standardised in order to be evaluated. Standardisation involves reducing the variables to a common base (usually 1) so that arithmetic operations can be performed on it. This presents a challenge because some variables can be described as being continuous (such as densities, incomes) while others are presented in discreet categories (land uses, environmental sensitivity). Furthermore, variables must be evaluated as being either a cost or a benefit. As will be seen, this is often dependent upon the evaluator's viewpoint. The case of land uses (discreet categories) and household densities (continuous) are used to illustrate the approach adopted.

Land use: Various land uses have differing characteristics in the type and volume of traffic that they generate, the time of day and day of the week that peak volumes are generated, and the traffic needs specific to the land use (NDoT, 1995). Consequently, when planning infrastructure to service any particular land use, these differences need to be considered and the design altered as required. By considering land use as an explicit variable in the criteria tree, we want to capture these differences, and the costs or benefits attributed to each mode as a result of them.

These costs and benefits can vary according to viewpoint. For example, in an industrial area it is not unreasonable to expect high volumes of heavy vehicles. In fact, the businesses in these areas depend upon the ease of access afforded to these vehicles. From this viewpoint, maximising the ease of mobility for heavy vehicles (and in fact all motorised vehicles) is important. However, these areas may also see high levels of non-motorised traffic (workers walking to work etc). The conflicts between non-motorised road users and vehicles factor as a significant cost from their perspective.

The question centres around the values we impose on the evaluation. These values are translated into impacts or modal priorities through value statements. In the example given above we could use the following statement to interpret our values from the perspective of NMT road users:

"We want to maximise the safety of all road users"

In order to maximise safety, we need to afford the most vulnerable road users priority, limit vehicle speeds and minimise potential conflict points. Maximising safety is a benefit function, and the safety of each mode is expressed qualitatively in terms of vulnerability and travel speed. This yields an impact vector as shown in Table 8:

Table 8: Safety maximisation impact vector

Mode	**Private Vehicle**	**Public Transport**	**Pedestrian**	**Bicycle**
Impact	+	++	++++	+++

Alternatively, we could take the position, since we are considering an industrial area, that mobility and access for delivery vehicles is of paramount importance. Our value statement could be expressed as:

"We want to maximise the mobility of delivery vehicles"

In order to maximise mobility for delivery vehicles we must give highest priority to speed, in which case our impact vector will look as follows, with the fastest mode receiving the highest preference:

Table 9: Mobility maximisation impact vector

Mode	**Private Vehicle**	**Public Transport**	**Pedestrian**	**Bicycle**
Impact	++++	+++	+	++

It becomes clear that with each land use, multiple value positions could be taken that would each yield different impact vectors. Furthermore, since the concerns around traffic vary across land uses (the concerns in a commercial district are different to that of a residential district) (NDoT, 1995), it is not possible to assume one value position for all land uses. Instead, the impact vector must be individually defined for all land uses. This yields what can best be described as a value matrix. Each land use option is assessed from the value position that is perceived to be best suited to it. This yields an ordinal scale of benefits as seen in Table 10.

In Table 10, different value statements (to be read as: "We want to maximise [value] by giving priority to the mode with the [indicator]") are used to express priorities varying between safety, access and mobility. In this case only two indicators, speed of mode and volumes by mode are used to distinguish between alternatives in terms of the value statement. Different impacts can be developed for different land use options despite the fact that the same indicator is used.

The reason for adopting an ordinal, rather than cardinal scale is that the primary objective of the evaluation is to derive a modal priority or modal preference ranking for each segment. The disadvantage of the ordinal scale approach is that the extent of preference is lost. Also, it is not possible to confer the same rank to different alternatives (in this case these are modes). In order to assign weights, the preference rankings must be standardised to preference scores. In the example above the highest preferred mode gets 1 point and the lowest gets 0.

Table 10: Land use value matrix

Criteria	Option	Value	Indicator	Car	Public Transport	Pedestrian	Bicycle
Land Use	Residential	Safety for NMT	Lowest Speed	0	0.33	1	0.67
	Commercial	Access for patrons	Highest Volume	0	0.67	1	0.33
	Industrial	Mobility for vehicles	Highest Speed	1	0.67	0.33	0
	Education	Safety for learners	Lowest Speed	0	0.33	1	0.67
	Sports and recreation	Access for spectators	Highest Volume	0	0.33	1	0.67
	Vacant Land	Mobility for passersby	Highest Speed	1	0.67	0	0.33
	Medical	Access for patients	Highest Volume	0.33	1	0.67	0
	Office	Access for workers	Highest Volume	0	1	0.33	0.67

Importantly, the impacts reflect not what the final modal split is expected to be but instead what it is desired to be. This is especially apparent when volume is used as an indicator. For an office environment, it is desired that workers access the area by highest volume according to the split defined by the vector given in Table 11.

Table 11: Modal preference expressed using an impact vector

Mode	**Private Vehicle**	**Public Transport**	**Pedestrian**	**Bicycle**
Impact	0	1	0.33	0.67

This characteristic differentiates the evaluation in that it now reveals the desired outcomes as informed by the context instead of the expected outcomes.

Household density: Higher density areas are better suited to a more intense activity mix, and can support better quality public transport (CoCT, 2009). Density is often cited as an indicator of trip frequency and trip length (Chen, C et al, 2007; Chatman, D. G., 2006). Density is also an indicator of modal split, in that in less dense regions, with a higher uniformity of land uses, trips are more often made using motorised modes that are better suited to longer trips, whereas in high density areas with a higher mix of land uses, trips can be shorter, and so better suited to public transport and non-motorised modes (Limtanakool N. et al, 2006; Kockelman, K, 1996; Zhao, F. et al, 2002).

Density is therefore important in defining the character of a location in relation to which mode should receive a higher priority. In low density residential environments, it is not unreasonable to assume that many trips will be made using private vehicles, especially when trip attractors such as shops or work places are far away, and especially when public transport facilities are unavailable. So, although mobility may not be the overriding concern in that context, if density were the only evaluation criteria the lower density gives justification to considering the needs of the private automobile as primary.

Returning to the value statements we used to identify indicators for our criteria, if density is assumed to be a continuum of some range of values from high to low, then in higher density areas, a higher preference is given to NMT and PT and in lower density areas a higher preference is given to private vehicles. The value statement can be stated as:

“We want to maximise the mobility of the majority of road users”

So, in high density areas where the majority of road users can be expected to be either pedestrian, cyclist or public transport users, they should receive priority, whereas in low density areas where most people could be expected to be driving, private automobiles should receive priority.

The relationship between density and modal priority can be modelled as a simple linear function. Each mode is modelled in terms of its preferred modal priority given a certain density. Figure 3 illustrates how modal priorities shift with increasing densities, and the specific modal priority values selected are a reflection of the subjective values imposed on the evaluation by the decision maker. The only caveat is that the summation of the priority values be equal at all given density values (in this case 100 was chosen – but the actual number is not significant since it is the relationships between the modes themselves that are of interest).

If as discussed, density were defined as being a continuum between a measureable low and high value, as can be derived from census data, the relationships defined above can be applied to each location to determine the appropriate modal mix in terms of the value function as expressed by the chart.

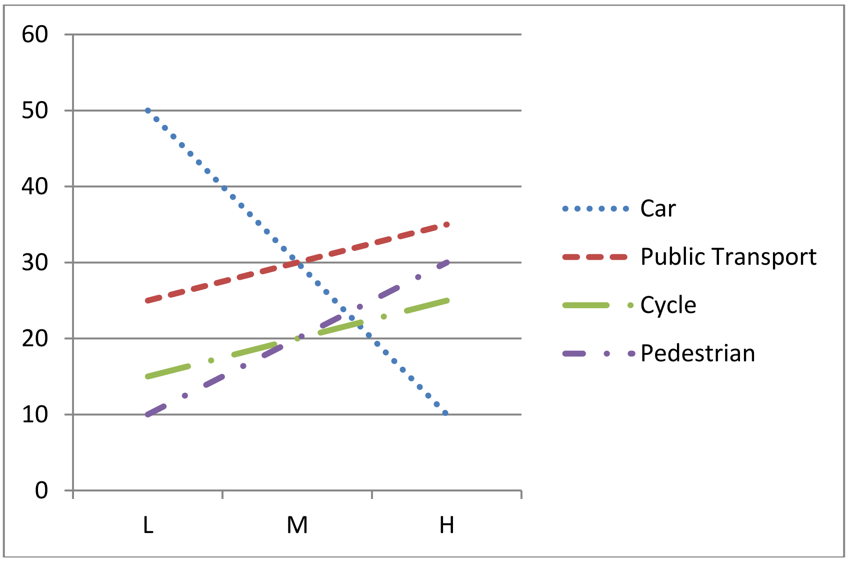

Figure 3: Modal preference in relation to density

Similar methods as described above were used to identify and standardise the remaining factors. Care was taken to avoid including highly correlated criteria wherever possible, without losing important contextual detail, so as to avoid biasing one mode over another. The model development does not at this stage include a transportation category, but this will be included as soon as this data becomes available. The remaining factors are described below:

Property value: The relationship between property value and accessibility, as well as between liveability and property value is well established. In general, where access in the form of proximity to public transport facilities and access to highways is improved, property values tend to be higher (Litman, 2003; Song et al, 2003; Srour et al, 2002). Liveability has also been found to be positively correlated to property values (Gemzøe et al, 1996). Since good public transport facilities and improved liveability are commonly associated with high levels of pedestrian activity, this suggests that high levels of pedestrian activity would be associated with high property values. However, MacIntyre (2006) comments that badly designed, poorly maintained pedestrian areas are often associated with decreases in property value.

Vulnerable road users: Although all pedestrians and cyclists are vulnerable road users, the presence of children, people with disabilities and the elderly would suggest that extra consideration be given to the infrastructural needs of this grouping. In South Africa the overwhelming majority of school goers walk to school (NDoT, 2003). Although the majority of pedestrian accidents involve people over school going age, a significant proportion (20%) involves people under the age of 18. Figures 4 and 5 illustrate.

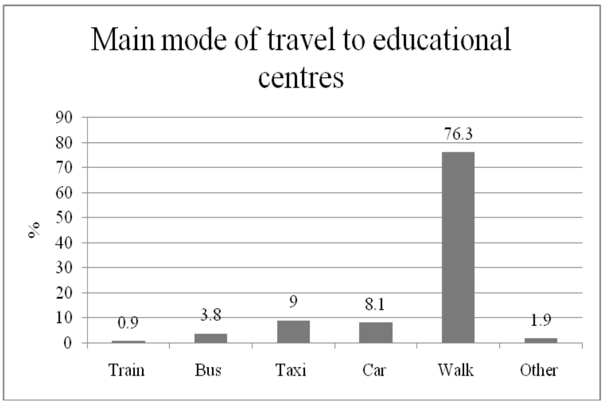

Figure 4: Main mode to educational centres (Source: NDoT, 2003)

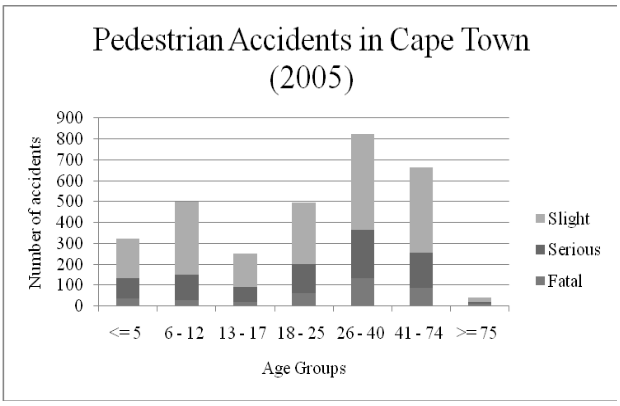

Figure 5: Pedestrian accidents in Cape Town (Source: CoCT, 2005b)

Income (Education level): Income is very closely associated with modal split, especially in the South African context. Table 5 gives an overview of modal split in relation to income in South Africa. It can be seen that dependence on taxi's, busses and trains are highest in the lower income bands, whereas private car use is highest for the high income bands.

Table 12: Income versus modal split (Source: NDoT, 2003)

Monthly household income	**Percentage of all people**												
	Train	**Bus**	**Metered taxi**	**Minibus taxi**	**Sedan taxi**	**Bakkie taxi**	**Car**	**Truck**	**Motor cycle**	**Cycle**	**Animal transport**	**Air**	**Other**
Up to R500	1.5	4.4	1	18.9	0.7	1.7	2.3	0.4	0.1	0.8	0.4	0	1.6
R501 - R1000	1.6	5	0.8	19.8	0.7	2.1	3.3	0.6	0.1	0.7	0.2	0.1	1.2
R1001 - R3000	3.2	6.6	1.3	26.3	0.9	1.6	8	0.8	0.1	0.8	0.2	0.1	1.3
R3000 – R6000	3.5	7.5	1.7	28.7	1.1	1.8	25.6	0.7	0.2	1.1	0.2	0.1	1.5
> R6000	2.1	4.6	1	15.3	0.8	2.8	60.2	0.5	0.6	2.1	0.1	0.2	0.7

Income is therefore critical in determining the context in terms of predicting the probable modal split and therefore, the appropriate infrastructure needed to accommodate mobility. However, it proved difficult to gather income data at an acceptable level of aggregation. A proxy dataset describing levels of education was used instead after a correlation analysis showed that incomes and education levels had a high degree of correlation.

Heritage sites: The City of Cape Town has stated that it wants to enhance the value of heritage resources for the people of Cape Town (CoCT, 2009). In order to achieve this it has developed the following policies:

- Provide access to, and information about, public heritage resources (P66).

- Consider the relevance of social and landscape contexts when making planning and development decisions that affect heritage resources (P67).
- Ensure that buildings and sites of historical and architectural significance make a positive contribution to the economy and quality of urban life, and create an enabling environment for urban regeneration (P68).

These policies clearly identify the importance of heritage sites in assessing the context within which infrastructure is developed, and requires that such infrastructure be developed in a way that is sensitive to the importance of the site, and that facilitates access to the site. The city has identified sites that are of cultural or historic value, and these are used to inform the analysis as to the heritage value of a particular location.

Wetlands and ecologically important sites: In compliance with the requirements of the National Environmental Management Act (NDoEAT, 1998) the city has developed extensive policies that govern use and access to wetlands and environmentally sensitive areas (CoCT, 2009). The protection of the valuable natural heritage resources to be found in the city is a key strategic goal of both social and economic importance to the city, and consequently infrastructure that passes through or abuts these areas must include them as key considerations in the plans. Consequently, these areas are included as criteria in the assessment of a location.
These criteria were selected as the key factors that need to be assessed in order to develop a holistic view of the context within which a road is located and functions. An overview of the criteria and standardisation used to test the evaluation procedure is provided in Table 13.

Table 13: Criteria, value statements, indicators and standardisations

Criteria	Option	Value	Indicator	Car	Public Transport	Bicycle	Pedestrian
Density	Low	Mobility of majority	Highest Volume	0.5	0.25	0.15	0.1
	Medium			0.3	0.3	0.2	0.2
	High			0.1	0.35	0.25	0.3
Property Value	Low	Mobility of majority	Highest Volume	0.05	0.3	0.15	0.5
	Medium			0.25	0.3	0.15	0.3
	High			0.5	0.3	0.15	0.05
Vulnerable road users	Low	Safety of vulnerable road users	Lowest Speed	0.55	0.25	0.1	0.1
	Medium			0.3	0.2	0.175	0.325
	High			0.05	0.15	0.25	0.55
Education level	Low	Mobility of majority	Highest Volume	0.05	0.25	0.3	0.4
	Medium			0.275	0.175	0.25	0.3
	High			0.5	0.1	0.2	0.2
Heritage	No	Access	Lowest	0.5	0.3	0.1	0.1

	Yes		Speed	0.05	0.35	0.15	0.45
Wetlands	No	Minimise impact	Lowest Speed	0.5	0.3	0.1	0.1
	Yes			0.05	0.35	0.15	0.45
Eco sensitive areas	No	Minimise impact	Lowest Speed	0.5	0.3	0.1	0.1
	Yes			0.05	0.35	0.15	0.45

4. STUDY SECTION

Road sections with intersections where a high number of accidents occur, termed “worst known intersections” were used as selection criteria. Figure 6 gives a listing of the worst known intersections along Lansdowne Road. Lansdowne Road was selected for the analysis due to its poor accident record. As guided by the NCHRP MMLOS manual, a section of Lansdowne Road was selected for evaluation. This is called the study length. Two ‘worst known intersections’ are contained in the study length. These are Lansdowne-Palmyra and Lansdowne-Chichester-Cook intersections. The study length is 1.3km and runs from the Lansdowne-Palmyra intersection to the Lansdowne-Belvedere intersection. Figure 7 shows the study length, with the intersections of interest highlighted.

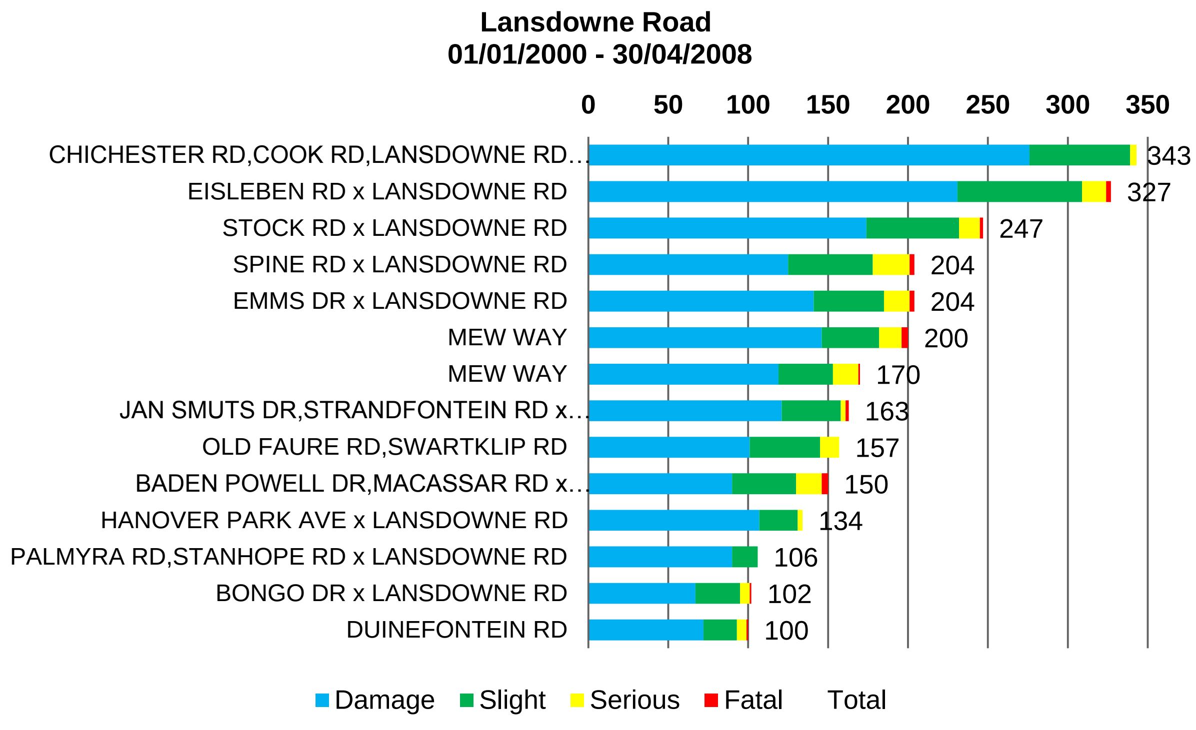

Figure 6: Worst known intersections with Lansdowne Road - Source: Seeger (2008)

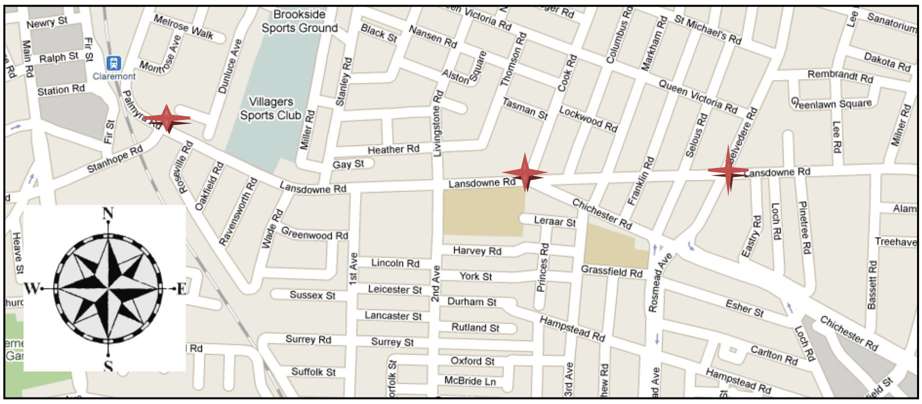

Figure 7: Lansdowne Road study length in relation to surrounding roads-Source: Google maps

The study length is segmented such that the street geometry, vehicle and pedestrian demand and intersection control, are uniform within each segment. Each segment is contained between two intersections.

5. SMCE RESULTS

The SMCE analysis process conducted in ILWIS as described in section 4.2 produced the following results. The software outputs the results as raster images. These raster cell values are represented on a colour spectrum of green to red, with green being the highest and red being the lowest. A higher cell value (greener shading) represents a higher preference or score for the mode being analysed.

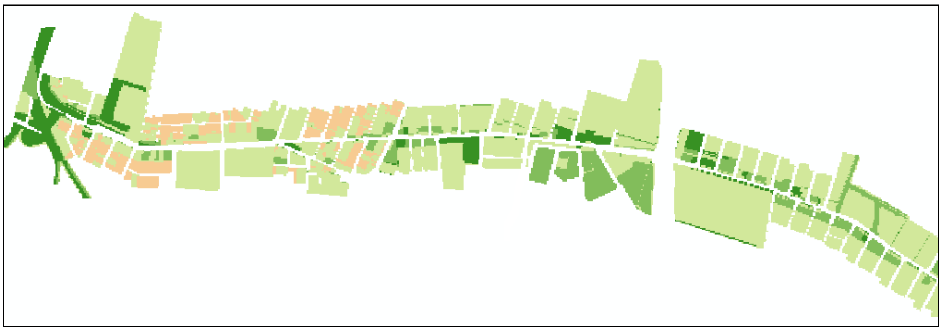

Figure 13: Raster modal preference map for car mode

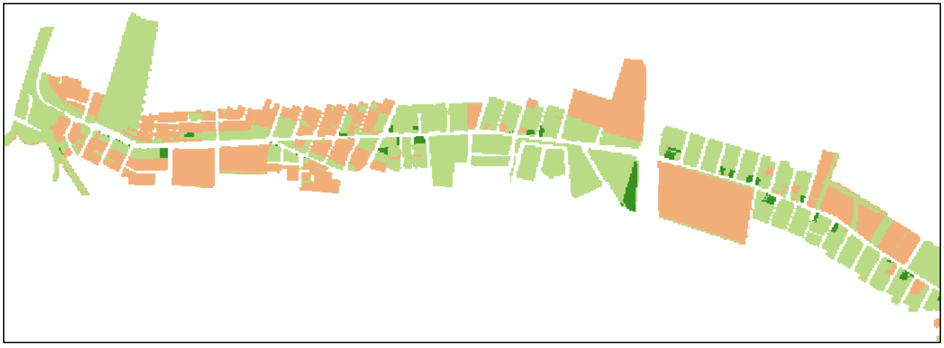

Figure 14: Raster modal preference map for bus mode

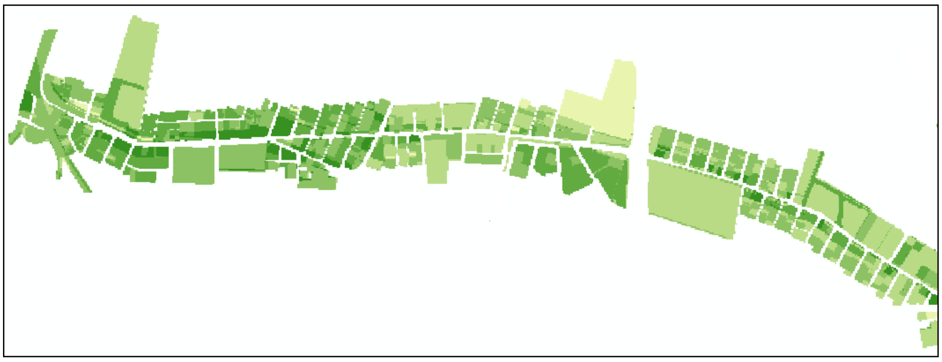

Figure 15: Raster modal preference map for pedestrian mode

Figure 16: Raster modal preference map for bicycle mode

The raster images were then processed by taking the neighbourhood average’s for each cell. The neighbourhood was defined as being within a 50m radius (10 cells at 5m) around each cells centroid. 50m was selected as the appropriate radius because this is the average plot depth away from the road centreline. The cell values along the road centreline were then extracted from the resultant averaged image, and these were then imported into a spreadsheet for further analysis. The data for each mode was then collated and the results are plotted in Figure 17.

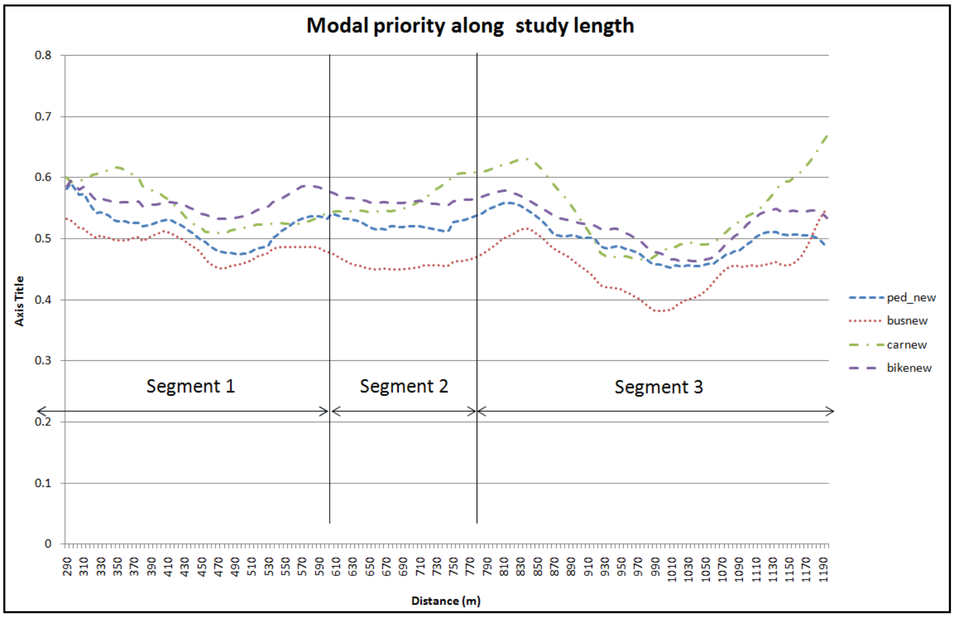

Figure 17: Modal priority ranking for study length

The data presented in Table 15 represents the average SMCE score per mode per segment. This information is used to get a segment wide ranking for each mode.

Table 15: Average SMCE priority score per mode per segment

Segment	Car	Bus	Pedestrian	Bicycle
1	0.603	0.507	0.490	0.523
2	0.571	0.457	0.524	0.561
3	0.553	0.454	0.504	0.533

6. DISCUSSION AND COMPARISON

Table 16 provides a summary of the analysis results. The results for the NCHRP method are based on calculations performed using the formulas given in section 4.1.

Table 16: Summation of analysis results

Mode		NCHRP method		SMCE model
Segment	Mode	Eastbound	Westbound	
1	Car	B	B	1
	Bus	A	A	3
	Pedestrian	B	B	4
	Bicycle	E	E	2
2	Car	C	C	1
	Bus	B	A	4
	Pedestrian	C	C	3
	Bicycle	E	E	2
3	Car	F	D	1
	Bus	A	A	4
	Pedestrian	C	C	3
	Bicycle	E	E	2

The SMCE results provide an indication of the recommended priority rank of each mode for each road segment, whereas the NCHRP results give the existing LOS afforded to each mode per segment. This provides an interesting perspective on the ideal functional requirements (based upon the selected analysis criteria) and hence infrastructural requirements for each mode in each segment, in relation to what is currently in place.

A direct comparison between the two sets of results would not be valid; hence the SMCE results are labelled in numerical rank order so as to avoid confusion. However, clearly, one can begin to draw conclusions about deficiencies in the existing street configuration that could be addressed to bring the LOS's of each mode more into line with what is recommended by the SMCE analysis results.

In doing this, it is important to take cognisance of the inputs for each analysis, and the reasons for why the results are as they are. For example, the SMCE results suggest that public transport should be the least important mode along the last two segments, whereas the LOS analysis findings are that this mode enjoys a high service level across the entire study length.

Recall, however, that the LOS score for public transport is a function of the speed of the transit vehicle, waiting time, amenities at the bus stop and pedestrian accessibility. Since the study section enjoys a high service frequency and pedestrian accessibility is reasonable to good, this improves the overall quality of service, and consequently the LOS score. Additionally, a closer inspection of Figure 17 shows that although the bus mode consistently scores lowest, the overall spread of the scores amongst the modes is relatively small. So a conclusion could be that it may not be necessary to make any further improvements to the service along this stretch of the route, since the quality of service here is already quite good.

However, cycling receives a very low level of service, whereas the SMCE analysis indicates that given the context, it should actually be quite important along this section of the route. The low LOS score is clearly a reflection of the fact that there are no dedicated facilities for cyclists along the route. This coupled with relatively dense traffic and a high proportion of public transport vehicles is what is driving the score down. The inclusion of cycling facilities would do much to rectify this situation.

Improvements in signal timing and flow conditions would do much to improve the LOS for the car mode, but care should be taken that this does not to impact the service levels of the other modes.

7. CONCLUSIONS

The study demonstrates the potential value of conducting a spatial multicriteria evaluation in conjunction with a multimodal level of service analysis to identify deficiencies in road infrastructure and possible interventions to improve the quality of service along a corridor. The method examined in the study could be used to great effect during preliminary planning processes to streamline further investigations.

The method also allows for a much larger range of factors to be considered at the initial phases of infrastructure planning activities. It is unfortunate that often times in South Africa social, economic, environmental and heritage concerns are not as thoroughly evaluated as traffic issues when planning road infrastructure. The SMCE methodology allows for these issues to be systematically included at an early stage of the project.

The method therefore develops a systematic method for existing infrastructure and current infrastructure plans to be evaluated against stated policy priorities and objectives in relation to these contextual factors. In this study, accident data was only used to identify problematic road sections. Detailed information regarding the precise locations of accidents is not available in South Africa. However, with more accurate accident data, the precise locations of accidents could be assessed against the MMLOS and SMCE results, to try and understand whether the disjuncture between the existing levels of service and the recommended modal priorities reveal any correlation with accidents.

The SMCE method is still being evaluated for sensitivity to criteria and input variation and applicability to road types other than arterials. Possibilities for area wide assessments are also being investigated.

8. ACKNOWLEDGEMENTS

This research is part of the scientific output of the Cycling Academic Network (CAN) and is partly based on a financial contribution by the Dutch Minister of Development Cooperation through the Bicycle Partnership Program (BPP) of Interface for Cycling Expertise (I-CE), co-funded by ITC and UT.

The research work is partly based on work carried out and submitted during 2009 by Ms Mwamba Kayonga in partial fulfilment of the requirements for the degree of Bachelor of Science in Civil Engineering at the University of Cape Town, Cape Town, South Africa.
The authors would like to express their appreciation to Ass. Prof. Marianne Vanderschuren at the University of Cape Town, Cape Town, South Africa for her valued assistance.

9. REFERENCES

American Association Of State Highway And Transportation Officials (AASHTO) (2001). "A Policy On Geometric Design Of Highways And Streets".Washington, Dc

Chatman, D. G., (2006). "Deconstructing Development Density: Quality, Quantity And Price Effects On Household Non-Work Travel". Transportation Research Part A 42 (2008) 1008–1030.

Chen, C., Gong, H., Paaswell, R. (2007). "Role Of The Built Environment On Mode Choice Decisions: Additional Evidence On The Impact Of Density". Transportation (2008) 35:285–299.

City Of Cape Town (Coct) (2005a). "Nmt Policy And Strategy, Volume 2: Policy Framework".City Of Cape Town Directorate: Transport, Cape Town.

City Of Cape Town (Coct) (2005b). "Traffic Accident Report". City Of Cape Town Transport Roads And Stormwater, Cape Town.

City Of Cape Town (Coct) (2009). "Cape Town Spatial Development Framework: Technical Report (Draft For Comment)".City Of Cape Town Spatial Planning And Urban Design Department.

Committee Of Urban Transport Authorities (Cuta) (1985 - 1991). "Draft Urban Trasport Guidelines Series". Director General, Department Of Transport, Pretoria.

CSIR (2000). "Guidelines For Human Settlement Planning And Design". Compiled By Boutek, CSIR For The Department Of Housing, Pretoria.

Dargay, Joyce (2001). "The Effect Of Income On Car Ownership: Evidence Of Asymmetry". Transportation Research, Part A. 35:807-821.

Dowling, R. (2008). "Multimodal Level of Service Analysis for Urban Streets: Users Guide". Oakland

Gemzøe L., Gehl, J. (1996). Public Spaces Public Life. The Danish Architectural Press, Copenhagen.

Kockelman, K. M., (1996). "Travel Behavior As A Function Of Accessibility, Land Use Mixing, And Land Use Balance: Evidence From The San Francisco Bay Area". Thesis Submitted In Partial Satisfaction Of The Requirements For The Degree Of Master Of City Planning In City And Regional Planning, University Of California, Berkeley.

Limtanakool, N., Dijst, M., Schwanen, T. (2006). "The Influence Of Socioeconomic Characteristics, Land Use And Travel Time Considerations On Mode Choice For Medium- And Longer-Distance Trips". Journal Of Transport Geography 14 (2006) 327–341.

Litman, T. (2003). "Evaluating Criticism Of Smart Growth". Victoria Transport Policy Institute. Victoria, Bc, Canada.

Macintyre, S. J., (2006). "Evaluating Bicycle Accessibility And Bike-Bus Integration Infrastructure: Saskatoon, Saskatoon, Sk, 2006". A Thesis Submitted For The Degree Of Master Of Arts To The Department Of Geography, University Of Saskatchewan.

National Department Of Environmental Affairs And Tourism (NDoEAT) (1998). "National Environmental Management Act, 1998 (Act No. 107 Of 1998)". The Minister Of Environmental Affairs And Tourism, Pretoria.

National Department Of Transport (NDoT) (1995). "South African Trip Generation Rates: 2nd Edition". Prepared On Behalf Of The South African Road Board, Pretoria.

National Department Of Transport (NDoT) (2003). "The First South African National Household Travel Survey 2003 Technical Report". Director General, Department Of Transport, Pretoria.

National Department Of Transport (NDoT) (2006). "Draft strategy to accelerate public transport implementation via a win-win-win partnership between government, existing operators and labour". Director General, Department Of Transport, Pretoria.

Road Traffic Management Corporation of South Africa (RTMC) (2008). "Road Traffic Report-2008". Pretoria

Seeger, T. (2008). "Road Safety and Black Spot Analysis in the Mother City, Cape Town". Submitted In Partial Satisfaction Of The Requirements For The Degree Of Batchelor Of Science in Civil engineering, University of Cape Town, Cape Town

Song, Y., Knaap, G. (2003). "New Urbanism And Housing Values: A Disaggregate Assessment". Journal Of Urban Economics 54 (2003) 218–238.

Srour, I. M., Kockelman, K. M., Dunn, T. P., "Accessibility Indices: A Connection To Residential Land Prices And Location Choices". Paper Presented At The 81st Annual Meeting Of The Transportation Research Board.

Transportation Research Board (TRB). (2000). "HC Manual". National Research Council, Washington, DC

Zhao, F., Li, M., Chow, L., Gan, A., Shen, L. D. (2002). "FSUTMS Mode Choice Modeling: Factors Affecting Transit Use And Access". Report Prepared For The National Center For Transit Research (Nctr), University Of South Florida Tampa, Florida.