CALIBRATING MICROSCOPIC SIMULATION MODELS

Dr M. Vanderschuren

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

South African government, public and private organisations are investigating the potential benefits of the application of Intelligent Transport Systems (ITS) in South Africa. It has become clear that microscopic simulation models are required to estimate the impact of ITS measures. Nevertheless, no specific South African microscopic simulation models have been developed and the question needs to be asked if it is appropriate to use developed world models in the South African context?

An extensive analysis of existing models has lead to the application of the microscopic simulation model Paramics. Micro-simulation models allow assigning and simulating the movement of individual vehicles, on the roads and intersections within a local area network in order to design and evaluate traffic management and control strategies.

The Paramics model is calibrated on UK driving behaviour. The driver behaviour and driving conditions in South Africa can be found to be very different to those of the developed world. It was found that no research has been carried out in South Africa with regards to driving behaviour. Moreover, traffic flow data that can assist during the calibration process, is often not available.

This paper describes the investigation of available models, as well as the calibration process undertaken. Moreover, the importance of the calibration process is discussed, comparing results of calculations using default settings and calibrated parameter settings. In this study two corridors (the Ben Schoeman Highway (BSH) and the N2 near Cape Town) were investigated. It appears that calibrated parameter settings for both corridors are significantly different from the default setting!

1. INTRODUCTION

Literature suggests that driving behaviour of South Africans might be quite different from that of Europeans and Americans. In a recent study (Sukhai, 2006) it was found that South Africans are the most aggressive drivers among ten researched countries. However, no comprehensive study has been conducted that can assist in the calibration of transport models.

In a comparative study of general behavioural differences between various cultures/countries Hofstede (1991) shows that South Africans score high for masculinism and individualism, and average for uncertainty avoidance. He also concludes that masculinism and uncertainty avoidance are dominant indicators for ‘aggressive’ driving behaviour.

South Africa has a triple heritage, from African society, Europe and Asia. It is, therefore, problematic to compare the South African average score with other countries. In another study (Trompenaars Hampden-Turner, 1998) eight cultural groups within South Africa were analysed. In this study it was concluded that behavioural differences between these groups are large. It indicates that differences in driving behaviour in South Africa are probably larger than in Europe and the USA.

The findings in the literature demonstrate the need to do a thorough calibration of models for the South African situation. As a first step, a suitable model needed to be found.

2. LEVEL OF DETAIL OF THE MODELS

Road users make different types of choices (strategic, tactical and operational) at various moments in time. Strategic choices, such as purchasing a vehicle or making a trip, are made (long) before the road user enters the public space. Tactical decisions, such as the departure time or route choice, are generally made as the trip starts. Some tactical decisions, such as the route choice, may be changed during the trip due to information that becomes available (i.e. congestion). Operational choices, such as accelerating, decelerating, lane changes etc., are constantly made during the trip.

Decision makers operate on different levels. Traditionally, middle- to long-term decision making was required. Based on that planning horizon, the four-step model (the traditional macroscopic model) was developed. Over the years, the planning horizon of decision makers changed; more strategic decisions (like changing fuel levies) were required.

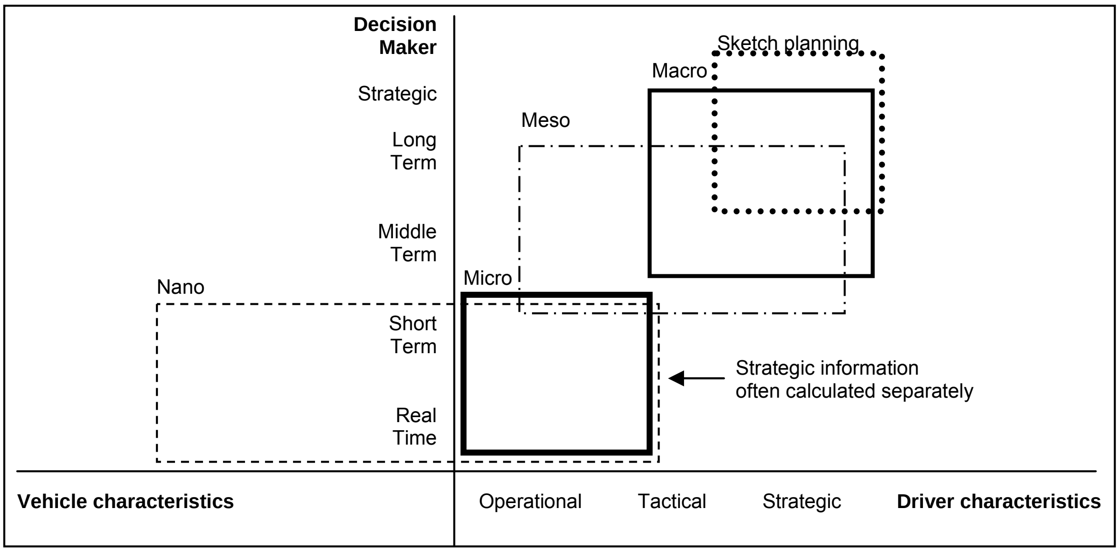

Figure 1 Trade-offs between the decision horizon and model characteristics
Source: Vanderschuren, 2006

Tailor-made sketch planning models have been developed for that purpose. On the other hand, there has been an increasing awareness that the predict-and-provide philosophy is not sustainable. Ways to utilise existing capacity in a better manner is one of the new aims. ITS systems are one of the types of measures that were explored, needing real-time or short-term models. Figure 1 provides an overview of the type of models available.

Based on the flow and traffic dynamics representation, transport models can be divided into five types:

- **Sketch planning models** are, although based on the four-step transport model theory, tailor made for specific questions. In general, a higher aggregation level is chosen. Moreover, often one or more steps, of the traditional four step model, are eliminated.
- **Macroscopic models** are based on the four-step transport model. Individual vehicles are not recognised in macroscopic models. The network representation is based on links, notes and attributes.
- **Mesoscopic models** include a representation of individual vehicles (or small 'packages' of vehicles with similar characteristics). Traffic dynamics are based on fluid approximation and queuing theories. The network representation is link and lane based (often for a corridor). Traffic control systems are detailed models based on aggregated capacity equivalents.
- **Microscopic models** include a representation of individual vehicles and traffic dynamics through vehicle interaction and movement. Driver behaviour is included in a more detailed way (often via driver classes). Departure times of vehicles are available for every one to five minutes. During every calculation time step (e.g. 0.1 sec), the position of all vehicles in the network is calculated.
- **Nanoscopic models** are micro-simulation models that also include vehicle dynamics, such as turning radius and acceleration power. Nanoscopic models are developed for situations where microscopic models are not detailed enough. Many nanoscopic models are tailor made by car manufacturers.

Due to the specific features, the models mentioned are often used for different geographical scales. Sketch-planning models have been developed to calculate national, provincial or metropole-wide changes. Macroscopic models were developed for main road networks (highway systems and other primary roads). Mesoscopic models are mostly used for corridors and include, as mentioned, traffic controller calculations, as well as secondary roads. Microscopic and nanoscopic models are generally used for any type of road or corridor where knowledge of the interaction of vehicles is needed. Generally, the research area will be smaller than for macroscopic and mesoscopic models.

In a traffic simulation study, it is essential that the simulation model replicates real behaviour of drivers (Bonsall et al, 2005). To be able to analyse the changes due to the introduction of ITS measures, every detail of the traffic flows, vehicle interaction and driver choices need to be known. It can, therefore, be concluded that meso-, micro- or nanoscopic transport models are needed to model ITS measures. Nevertheless, it appears that nanoscopic models often include non required detail (for the purpose of ITS measure analysis) and are not commercially available.

3. COMPARISON OF COMMERCIALLY AVAILABLE MODELS

Mesoscopic and microscopic simulation models, in which the dynamic behaviour of individual agents is explicitly simulated over both time and space to generate aggregate system behaviour, have been applied with increasing frequency over the past decade or more in the field of transportation systems analysis. Perhaps the best developed application is in the area of transportation network simulation models, in which a number of operational (and often commercially supplied) software packages exist, which model second-by-second operations of individual road and/or transit vehicles over very high fidelity representations of urban transportation networks (Miller et al, 2004).

An extensive analysis of available transport models was carried out. An overview of the models included is provided in Table 1.

The original aim was to use two models during this study. To investigate a wider range of models, it was decided to use a mesoscopic and a microscopic transport model. The focus area of investigated nanoscopic transport models appeared to be too narrow. After a broad investigation of models, taking modelling as well as financial restrictions into account, it was decided to purchase the mesoscopic transport model DynaMIT from MIT in Boston (United States) and Paramics from Quadstone in Edinburgh (United Kingdom). The added advantage of selecting these two models is the fact that one is based on US principles and the other on European principles. Unfortunately, it was impossible to make DynaMIT operational. After 10 months the original intent to include this model was abandoned. All modelling results in the paper are, therefore, based on Paramics.

4. COMMON PARAMETER SETTINGS IN MICROSCOPIC SIMULATION MODELS

Young (Young et al, 1998) pointed out that most of the parameters used in microscopic simulation models have implications for safety – even a parameter as seemingly neutral as the simulation interval will have an impact on safety if, as is commonly the case, it effectively defines the driver's reaction time.

Table 1 List of investigated simulation models

Model	Type of model	Organisation	Country
AIMSUN 2	Micro, transport, combined	Universitat Politècnica de Catalunya, Barcelona	Spain
ANATOLL	Micro, transport, other	ISIS and Centre d'Etudes Techniques de l'Equipement	France
ARTEMIS	Micro, transport	University of New Wales, School of Civil Engineering	Australia
ARTIST	Micro, transport	Bosch	Germany
AUTOBAHN	Nano, transport, motorway	Benz Consult - GmbH	Germany
CASIMIR*	Micro, transport, urban	Institut National de Recherche sur les Transports et la Sécurité	France
CONTRAM	Meso, transport, combined	TRRL	UK
CORSIM	Micro, transport, combined	Federal Highway Administration	USA
DYNAMIT	Meso, transport, combined	Massachusetts Institute of Technology	USA
DYNASMART	Meso, transport, combined	Federal Highway Administration (developed by: H. Mahmassani)	USA
DYNDART	Meso, transport, combined	Netherlands Organisation for Applied Scientific Research - TNO	Netherlands
DYNEMO	Meso, transport, combined	PTV System Software and Consulting GMBH	Germany
DRACULA	Micro, transport, urban	Institute for Transport Studies, University of Leeds	UK
DTASQ	Meso, transport	Centre for Research on Transportation (CRT), Montreal University	Canada
FLEXSYT II	Micro, transport, combined	Ministry of Transport	Netherlands
FREEVU	Micro, transport, motorway	University of Waterloo, Department of Civil Engineering	Canada
FRESIM	Micro, transport, motorway	Federal Highway Administration	USA
HUTSIM	Micro, transport, urban	Helsinki University of Technology	Finland
INTEGRATION	Micro, transport, combined	Queen's University, Transportation Research Group	Canada
MELROSE	Micro, transport, combined	Mitsubishi Electric Corporation	Japan
METROPOLIS	Meso, transport	University of Berkley	USA
MEZZO	Meso, transport	Royal Institute of Technology (KTH) and the Swedish National Road and Transport Research Institute (VTI)	Sweden
MICROSIM	Micro, transport, combined	Centre of parallel computing (ZPR), University of Cologne	Germany
MICSTRAN	Micro, transport, urban	National Research Institute of Police Science	Japan
MITSIM	Micro, transport, combined	Massachusetts Institute of Technology	USA
MIXIC	Nano, transport, motorway	Netherlands Organisation for Applied Scientific Research - TNO	Netherlands
NEMIS	Micro, transport, urban	Mizar Automazione, Turin	Italy
PADSIM	Micro, transport, urban	Nottingham Trent University - NTU	UK
PARAMICS	Micro, transport, combined	The Edinburgh Parallel Computing Centre and Quadstone Ltd	UK
PHAROS	Micro, transport, other	Institute for simulation and training	USA
PLANSIM-T	Micro, transport combined	Centre of parallel computing (ZPR), University of Cologne	Germany
REAMACS	Nano, transport	Ford	USA
RORSIM	Nano, transport, accidents	Battele	USA
SHIVA	Micro, transport, other	Robotics Institute - CMU	USA
SIGSIM	Micro, transport, urban	University of Newcastle	UK
SIMDAC	Micro, transport, other	ONERA - Centre d'Etudes et de Recherche de Toulouse	France
SIMNET	Micro, transport, urban	Technical University Berlin	Germany
SISTM	Micro, transport, motorway	Transport Research Laboratory, Crowthorne	UK
SITRA-B+	Micro, transport, urban	ONERA - Centre d'Etudes et de Recherche de Toulouse	France
SITRAS	Micro, transport, urban	University of New South Wales, School of Civil Engineering	Australia
Smart AHS	Nano, transport,	California PATH	USA
THOREAU	Micro, transport, urban	The MITRE Corporation	USA
TRANSIMS	Micro, transport, combined	Los Alamos National Laboratory	USA
TRAF-NETSIM	Micro, transport, urban	Federal Highway Administration	USA
VISSIM	Micro, transport, combined	PTV System Software and Consulting GMBH	Germany

* Note: no longer maintained by INRETS. Sources included: Smartest, 1997, Koutsopoulos, 2004 and Vanderschuren 2006

Most of the listed parameters (Table 2) in traffic simulation models appear in sub-models representing car-following, gap-acceptance and lane-changing behaviour. Typical values for different parameters in the sub-models are provided by Bonsall (Bonsall et al, 2005). Parameters in simulation models should, therefore, preferably be calibrated for each different setting.

Table 2 Parameters commonly included in microscopic simulation models

Parameter	Type	Notes	Typical value
Desired speed	Behavioural and political	Generally link-specific, should reflect the speed limit, the road layout and frontage and the amount of pedestrian activity	Legal speed limit; Speed of vehicles that have headways >6s
Desired headway	Behavioural	May be expressed in units of time or distance	1.5–2.5s; 2.12s (s.d. of 0.86) 5.96s for truck; 6.5m
Reaction time (s)	Physiological	May not be explicitly represented (may be inherent in the simulation interval)	0.57-3.0
Rate of acceleration (m/s^2)	Behavioural (constrained by vehicle performance)	May distinguish between normal rate of acceleration and maximum rate of acceleration, may differ depending on vehicle type	1.5-3.6 (max); 0.9-1.5 (normal) 1.2-1.6 (buses)
Rate of deceleration (m/s^2)	Behavioural (constrained by vehicle performance)	May distinguish between normal deceleration and emergency braking, may differ by vehicle type	1.5-2.4 (emergency) 0.9-1.5 (normal) 3.0 (theoretical)
Critical gap (s)	Behavioural	From the back of one vehicle in the target stream to the front of the following vehicle in that stream	3.5-8.5
Stimulus required to induce use of the reduced gap	Behavioural	Time spent waiting for acceptable gap or number of rejected gaps	Various
Minimum gap (s)	Behavioural		1.0
Willingness to create gaps to assist other vehicles to merge, cross or change lanes	Behavioural	May be expressed as a percentage of the priority traffic stream who stop accelerating or even start decelerating once they “see” a vehicle attempting to merge, cross or enter the lane	20% if the other vehicle is a car 70% if the other vehicle is a bus
Rules for mandatory lane change	Behavioural and political	May simply reflect traffic regulations but may vary depending on enforcement policy	Various
How far ahead the driver anticipates the need to change lanes	Behavioural and political	The behavioural element may be constrained by sight lines, etc.	1 to 2 links or 500m
Minimum acceptable gap when changing lanes	Behavioural	As in gap-acceptance model	As gap acceptance model
Willingness to create gaps to assist other vehicles to change lanes	Behavioural	May be expressed as a percentage of the traffic in the target lane who stop accelerating/start decelerating once they “see” a vehicle attempting to enter the lane	20% if the other vehicle is a car 70% if the other vehicle is a bus
Level of compliance	Behavioural and political	May vary for different types of regulation. Should vary depending on enforcement policy	50-100%
Distribution of aggressiveness	Behavioural	The proportion of drivers of several preset categories	n.a.

Source: based on Bonsall et al, 2005

Note: Bonsall based the information in this table on a wide range of sources

5. DRIVING BEHAVIOUR PARAMETERS IN PARAMICS

Although transportation models are based on the same theory, every model is unique with regards to the details. Paramics does not include a parameter for desired speed, for example. Desired speed of a vehicle is based on the maximum speed and the vehicle age. All gap related parameters (i.e. minimum, critical, creation) are included in the Mean Target Headway (MTH) and Mean Reaction Time (MRT). Moreover, the level of compliance is included in the aggression and awareness of drivers.

The only two parameters identified by Young (Young et al, 1989) that are not included in the Paramics model are “rules for mandatory lane change” and “how far ahead the driver anticipates the need to change lanes” (see Table 6.2). Users of Paramics could program these parameters themselves. Nevertheless, this would be changing the model that is commercially available.

In short, when in Paramics a vehicle catches up with another vehicle or reaches an obstacle, such as a junction or bottleneck, a car following and lane changing algorithm takes effect. Several algorithms determine how the (trailing) vehicle will respond to the current circumstances. The vehicle path is also controlled by a dynamic cost finding algorithm depending on time, distance and toll coefficients.

The three implemented individual vehicle movement models in Paramics (vehicle following, gap acceptance and lane changing) are strongly influenced by two key user specified parameters (Gardes et al, 2002): the Mean Target Headway and Mean Reaction Time. Moreover, based on the experience of Paramics users, the model includes the parameters awareness and aggressiveness (on which Paramics distinguishes itself from other models).

6. APPLICABILITY OF PARAMICS PARAMETERS

Conventionally, driving behaviour was researched, measuring speeds and headways on the road. In South Africa, this type of research is completely lacking. In a study conducted in 2005 (Sukhai, 2006), a comparison of 10 countries, including South Africa, was carried out. South Africa appeared to have the highest aggression levels. Unfortunately, these results only became available after the completion of the described study and calibration. Nevertheless, results are in line with this finding.

It was concluded that the seed value, target headway (MTH), reaction time (MRT), aggression and awareness need to be investigated during the calibration process. This further investigation was conducted in the following manner:

Seed value: every setting of parameters was run for three different seed values.

MTH: based on previous work by Innovative Traffic Solutions (unpublished) and Vreeswijk (2004) it was concluded that the MTH, for the South African situation, will be close to 0.5. The trial and error approach to fit the MTH, therefore, used 0.5 seconds as a starting point.

MRT: based on previous work by Innovative Traffic Solutions (unpublished) and Vreeswijk (2004) it was concluded that the MRT should be 0.35.

Aggression and awareness: can have a normal distribution (the majority of people will act in an average manner) or a squared distribution (25% of people are not aggressive or alert at all, 25% of people are slightly aggressive or aware, 25% of people are quite aggressive or aware and 25% of people are very aggressive or aware). All combinations of normal/squared distributions for aggression and awareness were tested.

It needs to be mentioned that Paramics provides the possibility to change the ‘steepness’ (the standard deviation σ) of the normal distribution. This is done using a multiplier. A single multiplier is used for the normal distribution, while a multiplier of two or four leads to ‘steep’ distributions. In this study, all settings (over 50 different ones) were tested. With regards to the multiplier, it was concluded that the normal setting (single multiplier) performed best. Similar results were found in the literature (Jansen, 2005) where speed limit differences for the different multipliers were not significant.

It was concluded that either the normal (with single multiplier) or squared distribution best represents South African driving behaviour. Table 3 provides a selection of the results for these settings. To be complete, a default run with default settings (run: default) for MTH, MRT, aggression and awareness was calculated. The results show that the volume and lane distribution are very different from the actual measured values. It was, therefore, concluded that it is not appropriate to accept the default settings, neither for the BSH nor for the N2.

During the calibration process, it was found that a normal distribution for aggression and a squared distribution for awareness are most appropriate for the BSH. For the N2, a squared distribution for aggression, as well as awareness, proved to be better.

The literature indicates that there are large behavioural differences in South Africa. It is, therefore, not surprising that a squared distribution was found for awareness. South Africans from different cultural backgrounds score differently with regards to awareness.

A squared distribution for aggression represents the large variance in driver behaviour and experience (based on expert analysis, as well as the fact that one out of five licences are fake[1]) as well as the large variance in vehicle quality (about 10% of all accidents are caused by vehicle factors (NDoT, 2003)). It is striking that the results for the BSH show that a normal distribution best represents local driving behaviour, while a squared distribution performs best for the N2. This confirms the difference between drivers from the Gauteng province and Cape Town drivers often communicated by the general public. Moreover, the representation of drivers with different cultural backgrounds is not equally distributed. There are differences between Gauteng and Cape Town as well as between the urban wealthy and the urban poor.

Several analyses with regards to traffic flow information were carried out as well. As an example, the changes in volume over time are compared with the average volumes (seed average) for the base case. The results for the BSH are included in Figure 2.

It can be concluded that the modelling results follow the actual measurements very well, especially for the first two hours. Thereafter, the modelling results alternate quite a bit. Unfortunately, this is typical for microscopic simulation results in congested conditions. The results were, therefore, accepted.

A travel time analysis shows that the build up of traffic in the model is slower than it actually happens on the N2 (Figure 3). Moreover, during the peak period, travel times are about 10 minutes less than measured. The lack of accurate lane changing behaviour is probably responsible for these findings. In addition, minibus taxis abuse on and off ramps, causing disturbances of the traffic flow that the model will not include.

---

[1] www.wheels24.co.za/News/

During the tail of the peak period, the model calculates travel times that are slightly higher than measured. Nevertheless, the maximum difference is five minutes, which is acceptable. It can be concluded that the modelling results follow the actual measurements very well.

Table 3 Volume and lane distribution calibration

Input								Output			
CASE	RUN	SEED	OD-MATRIX	TARGET HEADWAY	REACTION TIME	AGGRESSION	AWARENESS	VOLUME	LANE DISTRIBUTION (percentages)		
									Lane 1	Lane 2	Lane 3
BSH	Actual		2001 2002					16 916 17 437	28.6 30.7	35.3 33.6	36.1 35.7
	Default		100%	1.0	1.0	N	N	15 572	33.2	36.6	30.3
	OD8A OD8B OD8C	1111 2222 3333	100%	0.50	0.35	N	Sq	18 128 17 940 18 418	30.1 30.0 30.5	35.4 35.8 35.8	34.5 34.1 33.7
	OD9A OD9B OD9C	1111 2222 3333	100%	0.55	0.35	N	Sq	17 673 18 015 18 086	31.0 30.6 30.5	35.1 35.9 35.7	34.0 33.5 33.7
	OD10A OD10B OD10C	1111 2222 3333	100%	0.60	0.35	N	Sq	19.800 18.081 18.353	30.5 30.5 30.7	35.4 35.7 35.6	34.0 33.8 33.7
N2	Actual	Loop 3 Loop 4	2004					15 190 14 510	31.6 31.9	34.9 35.5	33.5 32.6
	Default	1111 2222 3333	100%	1.0	1.0	N	N	12 166 12 038 11 823			
	JL3A JL4A	Loop 3 Loop 4	100%	0.50	0.35	Sq	Sq	15 305 14 725	31.4 30.8	40.8 40.5	27.7 28.7
	KL3A KL4A	Loop 3 Loop 4	100%	0.55	0.35	Sq	Sq	15 299 14 781	31.4 30.7	40.6 40.7	28.0 28.6
	LL3A LL4A	Loop 3 Loop 4	100%	0.60	0.35	Sq	Sq	15 223 14 661	31.2 30.3	41.0 41.0	27.8 29.6

Note: The grey background indicates that the results were not accepted based on that parameter
Source: Vanderschuren, 2006

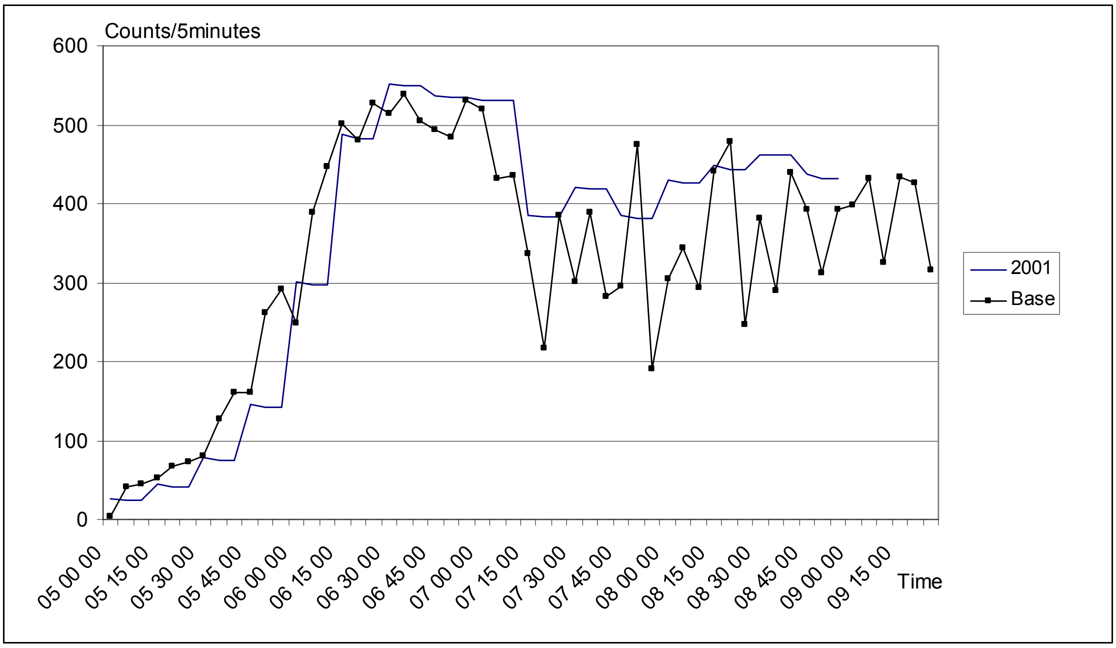

Figure 2 Comparison of actual and modelled volumes over time for the BSH
Source: Vanderschuren, 2006

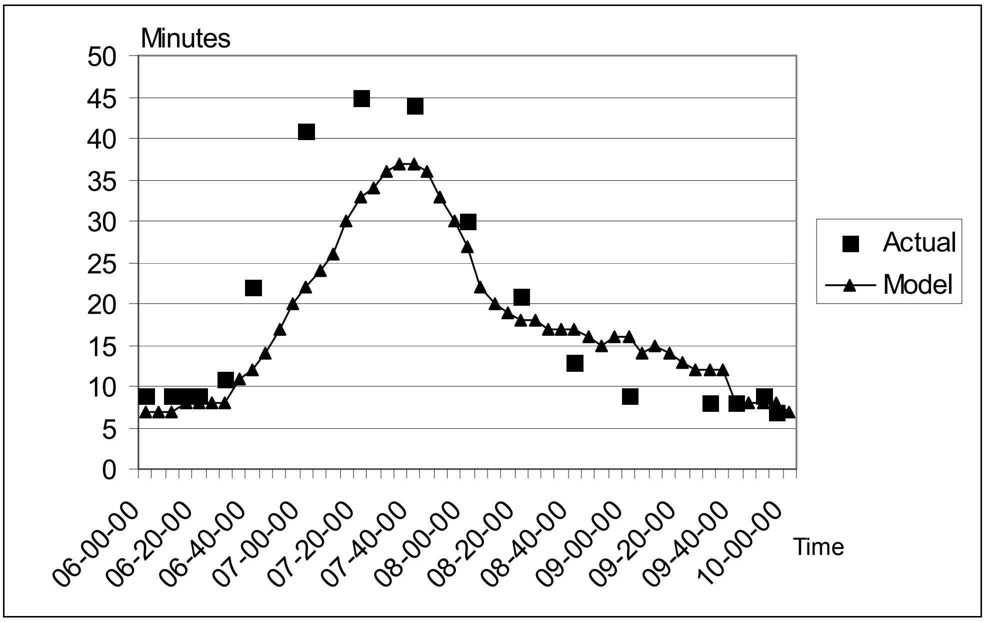

Figure 3 Travel time comparison for the N2
Source: Vanderschuren, 2006

7. CONCLUSIONS

Within microscopic simulation models, an attempt is made to include driving behaviour via driver classes. No research is available with regards to the reliability of this approach, as well as whether the error included using this approach is acceptable.

In a Driver Anger Scale (DAS) based study comparing 10 countries, it appeared that South African drivers were most aggressive (Sukhai, 2006). Based on the knowledge gathered from the literature, it was concluded that the Paramics parameters of aggression and awareness need to be tested. Many settings were investigated. Based on Trompenaars (Trompenaars and Hampden-Turner, 1998), who found severe differences in South African cultural groups, an argument was made to test a squared distribution (large variance in driver behaviour/experience).

With regards to the Mean Target Headway and Mean Reaction Time, it was found that the parameter settings are much lower than the default setting, which is based on driving behaviour in the United Kingdom.

Although the changed parameters Mean Target Headway and Mean Reaction Time appear to be the same for both investigated corridors, aggression and awareness show different settings for the two corridors. For the Ben Schoeman Highway, a normal distribution for aggression and a squared distribution for awareness appeared to represent the measurements best. For the N2, a squared distribution for both aggression and awareness provides the closest fit to the data.

8. ACKNOWLEDGEMENTS

The described work is based on my PhD work. I would like to thank my supervisor for his never ending support. I would also like to express my gratitude to all South African Institutions for their assistance during the data collection phase (AGMAC Consulting, Mikros, ITS, SANRAL and the city of Cape Town).

9. REFERENCES

[1] Bonsall, P, Lui, R and Young, W (2005). Modelling safety-related driving behaviour – impact of parameter values. Transportation Research, Part A, Issue 39, Pages 425-444

[2] Gardes, Y, May, D, Dahlgren, J and Skabardonis, A (2002). Freeway Calibration and Application of the Paramics model. 81st Annual Meeting Transport Research Board, Washington D.C., January 2002

[3] Hofstede, G (1991). Cultures and Organizations, Software of the Mind. McGraw-Hill, London (UK), ISBN 90-254-6913-2

[4] Jansen, M (2005). Modellering van in-car systemen voor snelheidsondersteuning met behulp van het microsimulatie pakket Paramics 2000. Research Report, Stichting Wetenschappelijk Onderzoek Verkeersveiligheid SWOV, Leidschendam (NL) (Dutch)

[5] Koutsopoulos, HN (2004). Traffic performance models I: Traffic flow theory and simulation approaches. MIT Summer Professional Program 1.10S, Modeling and simulation for Dynamic Transportation Systems, Boston (US), August 2004

[6] Miller, EJ, Hunt, ND, Abraham, JE and Salvini, PA (2004). Microsimulating urban systems. Computers, Environment and Urban Systems, Volume 28, Issue 1, Pages, 9-44

[7] National Department of Transport (NDoT) (2003). Festive season report on road accidents. Pretoria (SA)

[8] Smartest (1997). Review of Micro-Simulation Models, Appendix D. SMARTEST Project Deliverable D3, European Commission 4th Framework Programme under the RTD Programme, June 1997

[9] Sukhai, A (2006). SA drivers most aggressive in 10 countries polled. 8th World Conference on Injury Prevention and Safety Promotion, Durban, 31 March – 1 April 2006 Durban (SA), South Africa

[10] Trompenaars, F and Hampden-Turner, C (1998). Riding the Waves of Culture, Understanding the Cultural Diversity of Business. Nicholas Brealey Publishing, London (UK), ISBN 1-85788-176-1

[11] Vreeswijk J (2004). The applicability of the microscopic simulation model Paramics in the South African Context. University of Twente (NL) in collaboration with the University of Cape Town (SA), October 2004 (Undergraduate thesis)

[12] Young, W, Taylor, MAP and Gipps, PG (1989). Microcomputers in traffic engineering. Research Studies Press, Taunton

[13] Vanderschuren, MJWA (2006). Intelligent Transport Systems in South Africa – Impact assessment through microscopic simulation in the South African context. PhD thesis University of Twente, TRAIL Thesis Series T2006/4, The Netherlands TRAIL Research School.