TECHNICAL PAPER

JOURNAL OF THE SOUTH AFRICAN INSTITUTION OF CIVIL ENGINEERING

Vol 49 No 3, 2007, Pages 2–10, Paper 633

Forecasting household car ownership in South Africa: alternative models and future trends

M Mokonyama, C Venter

The paper investigates the use of an alternative household car ownership modelling approach for South African urban areas, particularly the metropolitan areas, that moves away from existing race-based classifications, but instead uses household income and spatial attributes of an area captured in terms of dwelling unit types. The model has been successfully calibrated for the City of Johannesburg, and tested for other Gauteng areas. The paper also provides limited benchmarking of South African household car ownership against published literature, in which it is illustrated and concluded that localised research on behavioural market responses is critical. Topical issues such as development density and lifestyle choices within the context of the emerging nature of household car ownership in South Africa are also investigated, although the transitional nature of the South African economy presents some analytical challenges. Finally, the paper illustrates the model's application in the urban development planning context. The model results, supported by other qualitative considerations, point to a potentially explosive growth in car ownership to be expected in historically disadvantaged areas of South African cities as middle-class incomes grow. Thematic areas for further research in the field are also identified.

MATHETHA MOKONYAMA is a senior researcher at the Council for Scientific and Industrial Research (CSIR). His current research interest lies in the design and delivery of passenger transport services in relation to end user satisfaction-related dynamics. He graduated from the University of the Witwatersrand in 1999 with a BSc in Civil Engineering. He also holds honours and master's degrees in Transportation Engineering from Pretoria University, where he has recently commenced with his doctoral studies. He has previously worked for the City of Johannesburg and in consultancy for the firm LTE Consulting, both in the area of transportation modelling.

Contact details:
Built Environment Unit
CSIR
PO Box 395
Pretoria, 0001
T +27-12-841-4732
mmokonyama@csir.co.za

CHRISTO VENTER is an associate professor in the Department of Civil and Biosystems Engineering at the University of Pretoria, where his work focuses on transport planning and engineering. He graduated from the universities of Stellenbosch (1991, 1993) and California (Berkeley) (1998), where, in his PhD work, he looked at travel behaviour among disabled and elderly transport users. Current research interests include the links between urban form and transport, public transport planning, and transport's contribution to achieving sustainable livelihoods among marginalised people. He also undertakes consulting work in transport engineering. He is a member of the US Transportation Research Board's Committee on Accessible Transportation and Mobility.

Contact details:
Department of Civil and Biosystems Engineering
University of Pretoria
Pretoria, 0002
T +27-12-420-2184
christo.venter@up.ac.za

Keywords: car ownership, transport modelling

INTRODUCTION

Around the world, household car ownership modelling and forecasting have been significantly researched. Such a focus has historically been warranted by the relatively high investments in the provision of transport infrastructure by governments to accommodate changes in travel demand due to changes in household car ownership. In South Africa, car ownership studies were undertaken, notably by Marks (1979) and Sweet (1988), before the 1994 democratic elections and the adoption of the new constitution in 1996. In an attempt to minimise data aggregation errors as a result of differing economic profiles of the population groups, past South African car ownership modelling studies made a distinction between the different population groups. Racial distinctions made it easier to model average trip generation rates within the respective areas allocated to different population groups by apartheid planning policies. Growing spatial and economic integration amidst fundamentally changing market conditions as a result of the democratisation of the country are rendering the use of racial distinctions in transportation modelling exercises difficult and increasingly irrelevant.

Despite currently low overall levels of household car ownership in South Africa – 74 % of all households did not own cars in 2003 (DOT 2005) – growth in car ownership is accelerating, especially in metropolitan areas, where competition for road space is resulting in increasing congestion and environmental costs. Local vehicle manufacturers reported record growth in car sales of almost 30 % in 2004 and 2005 (*Business Day* 2005a). The forecasted South African gross car population growth by DOT (1997) of 64 % between 1996 and 2020, resulting in 8,7 million cars by 2020 or 160 cars per 1 000 human population, which still appears valid, is also indicative of a relatively high future growth potential in car-based travel demand. In view of the evident impact of motorised transport on fiscal resources and the environment, car ownership studies should continue to be an integral part of development planning.

The primary purpose of this research is to explore a household car ownership modelling approach that is not reliant on the classification of the population into race groups and is relevant to the market profile of an area. Secondary to this is to profile the nature of household car ownership in a typical urban area in South Africa and to show the application of the proposed modelling approach in a typical planning exercise. The research uses the City of Johannesburg Metropolitan Municipality and Gauteng Province as case studies. Such a model would typically be used by a local authority in estimating both existing and future car ownership in its planning area. Owing to the limited financial resources of gov-

ernment, the model needs to be relatively affordable to maintain and use.

In addition to providing the necessary inputs to trip generation estimation, a car ownership model needs to provide useful insight into other pertinent strategic transport planning options. Foremost among these is the need to accurately reflect the potential impact on car ownership of interventions aimed at reducing travel demand or shifting mode use, such as public transport improvements and travel demand management (TDM) type actions. At present, unfortunately, neither the data nor the theoretical knowledge is locally available to allow inclusion of such capabilities in car ownership models. The paper considers recent evidence on the influence of service quality on car ownership and highlights other contextual factors to be considered such as developmental trajectories. The paper examines only household car ownership as opposed to household car use, although implications for car use are briefly discussed.

PREVIOUS CAR OWNERSHIP MODELLING EFFORTS

Ortuzar and Willumsen (2001) report that traditionally vehicle ownership models have been used for three general purposes, namely market research studies, estimation of future infrastructure needs and policy-oriented transportation studies. These models have always been limited by the availability of relevant data, and the cost of collecting the data, noted as a major constraint, resulting in a widened gap between theory and practice.

Bunch (2000) distinguishes between static and dynamic car ownership models. Static models estimate car population at a given point in time and the dynamic ones model car transactions over time. Generally static models have lower data requirements than dynamic models, hence their popularity with practitioners. Static car ownership models can further be classified as either time series models or cross-sectional models. Time series models, also referred to as extrapolation models, are calibrated using historical data of car ownership, under the assumption that trends of the past continue into the future in line with a predetermined time series function (Button *et al* 1982). Cross-sectional models – also referred to as causal models – are calibrated using data collected at a given point in time and attempt to link car ownership to selected explanatory variables for which forecasts can be made. The latest developments include the application of stated preference modelling techniques in car ownership studies, for example the testing of the market viability of low-emission vehicles in Japan for environmental planning purposes (Zhang *et al* 2004).

Time series models assume that time can be used as a surrogate variable for factors affecting car ownership levels over the period under investigation. The archetypal time series model is in the form of a sigmoid curve in which car ownership is assumed to follow a typical product consumption pattern lifecycle, where the use of the product ultimately reaches a saturation value at which the rate of consumption equals the rate of replacement (Button *et al* 1982). The car ownership saturation value is then used as an indication of the ultimate demand for road infrastructure demand in the study area. Button *et al* (1982) reported that the sigmoid curve approach attracted many critics who believed that, owing to its self-fulfilling nature, it was relevant only in the era when the building of roads needed to be continuously justified.

As an example, the time series model of car ownership developed by the Central Witwatersrand Regional Services Council in 1994 (CWRSC 1994) illustrates the difficulty with previous modelling attempts in South Africa. Car ownership saturation values estimated for each population group varied widely between 830 cars per 1 000 people for whites, 44 cars per 1 000 for blacks, and other groups somewhere in between, while no theoretical argument could be forwarded why such discrepancies should exist. Such race-based designations are also increasingly inaccurate, as the economic growth trajectories of population groups are very different from what they were a decade ago.

Cross-sectional models, on the other hand, attempt to relate car ownership directly to variables that are postulated to influence car ownership. Accordingly, cross-sectional models require a more in-depth understanding of explanatory variables other than time. However, they can be much more policy relevant, as the variables may be more easily related to levers that government has some control over.

Two popular analytical approaches used for car ownership modelling exist, namely regression analysis and category analysis. Whereas regression analysis formulates a parametric relationship between an independent variable, or a combination of independent variables, and a dependent variable, category analysis segments the independent variables into different classes and calculates a representative value for the dependent variable for each combination of classes. Unlike regression analysis, category analysis does not have a standard statistical goodness of fit measure and therefore closeness to the observed data cannot be evaluated, although statistical tests can be performed to evaluate the significance of the differences between alternative category values. Furthermore, category analysis does not permit extrapolation beyond its calibrated strata. It is, however, easy to use and understand, especially by non-technical decision-makers. Some other advantages of category analysis are the following (Mekky 1996):

- It does not make assumptions about the shape of the response surface
- It allows the relationship between the dependent variable and each stratum of the independent variable to be different from any other stratum
- It can deal easily with qualitative data

In addition, calibration of regression models often suffers from high collinearity between many of the relevant household attributes, for example the number of employed persons per household, the number of household members at a driving age, and household income (Button *et al* 1982), forcing the analyst to omit many of these variables. Category analysis, by contrast, allows all relevant variables to be used to extract maximum information from the data.

Sweet (1988) investigated the use of a cross-sectional logistic function to estimate the probability of household car ownership in South Africa for different population groups, with income as the explanatory variable. The function is defined by the following equation:

$$p = \frac{s}{1 + \exp(-a - bI)} \qquad (1)$$

Where:

p = probability of household car ownership at income level I

s = saturation value

a and b are model parameters obtained through regression

The model used by Sweet (1988) has been successfully calibrated elsewhere in the world. However, the need to specify saturation values is problematic. In South Africa it would be difficult to derive a single representative saturation value as a result of entrenched disparities within the population; yet it is increasingly difficult, both technically and politically, to specify a different value for each population group.

Ortuzar and Willumsen (2001) report on an improvement to the basic category analysis model to overcome some of its disadvantages such as cells with too few or no sample observations and the lack of statistical goodness of fit measures. In multiple classification analysis, cell values are based on a grand mean derived from the entire data set as well as means derived from classes of data sets. The method is essentially based on analysis of variance and therefore provides a structured procedure for choosing among alternative independent variables and alternative groupings of the values of each independent variable (Mekky 1996). The application of the approach in South Africa is proposed to be a subject for further research.

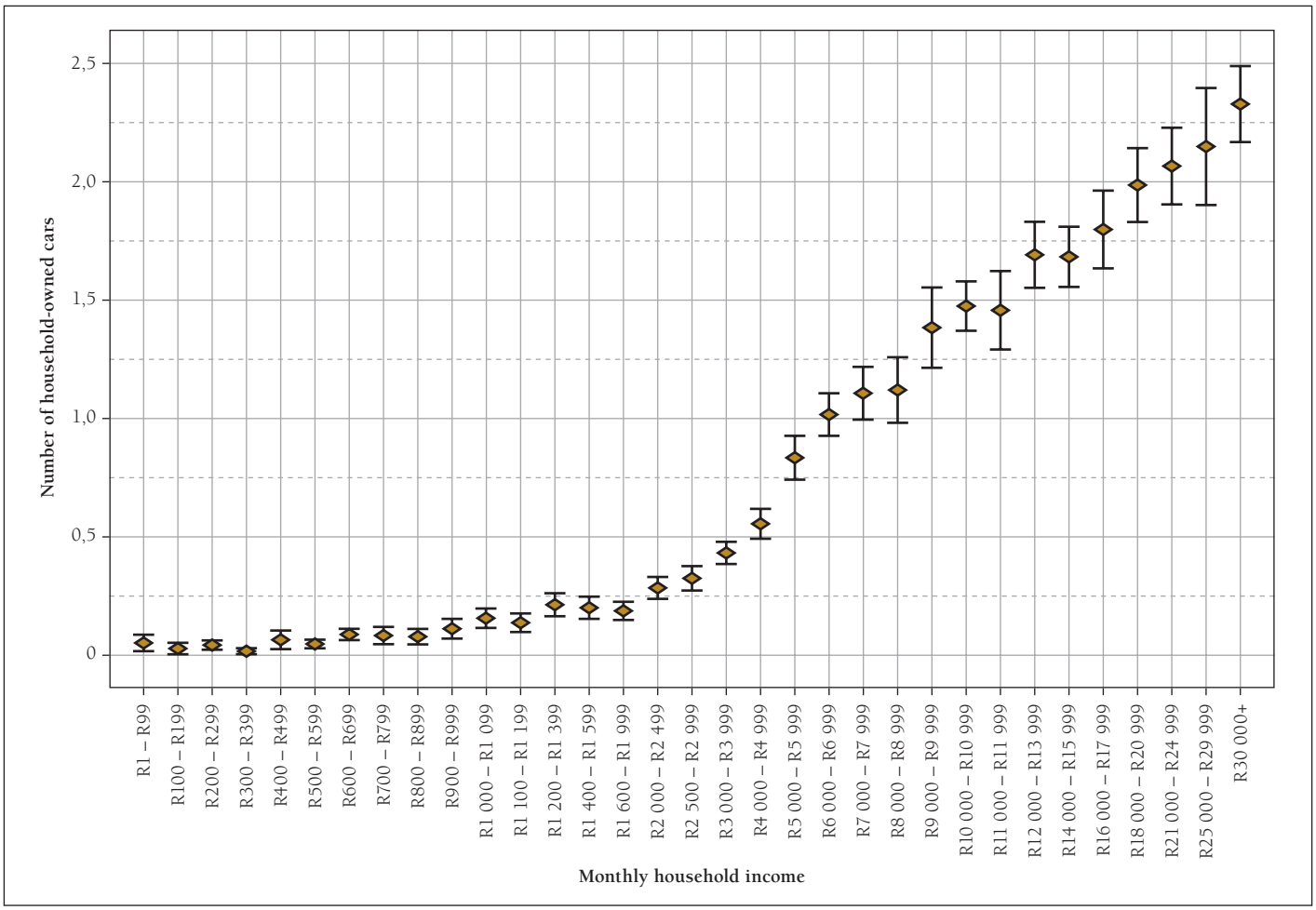

Figure 1 Car ownership and household income in Gauteng (source: Gautrans 2003)

The model tested in this study is cross-sectional and based on category analysis. The fact that this method does not impose a continuous (and linear) functional relationship between the variables makes it more attractive than the regression model, given current uncertainty about the nature of the underlying relationships in the fast-changing South African environment.

VARIABLES INFLUENCING HOUSEHOLD CAR OWNERSHIP

This section reports on some of the variables reported in literature to have a major influence on household car ownership. In order to contextualise them within the South African experience, they are further compared with trends from areas within South Africa. The comparison highlights some of the stark contrasts between literature findings and the situation in South Africa, further emphasising the need for localised research in development planning while at the same time providing more detailed historical research perspectives.

Household income

As early as the initial developments of car ownership models in the 1960s, household income has been found to be the most significant explanatory variable in household car ownership models. Button *et al* (1982) report that the use of income as an explanatory variable has been widely supported, due to the important role of income in econometric studies of consumer behaviour. This is consistent with the consumption of car travel as a 'luxury good', where the increasing value of time that accompanies income growth makes the time-saving (and other) benefits of private vehicle travel increasingly attractive. Dargay and Gately (1999) confirmed the relationship between countries' gross domestic products (GDPs) and car ownership levels across a range of developed and transitional countries, where higher GDPs are strongly associated with higher car ownership levels. Dargay and Gately (1999) estimate the ultimate common car ownership saturation values for all countries at around 0,62 cars per capita (or 0,85 vehicles per capita, including both light and heavy vehicles). Ngoe *et al* (1993), from the analysis of low-income countries' car ownership data, noted that as low-income countries become more prosperous, there is an inevitable and rapid rise in their car ownership and use.

Figure 1 confirms the above relationship between car ownership and household monthly income in Gauteng Province. The figure was derived from the 2002 Gauteng household travel surveys data (Gautrans 2003), with a 95 % confidence interval. Figure 1 shows that household car ownership starts increasing substantially at a monthly household income of about R4 000 to R6 000 (2002 rand value), which is the 80th percentile household income.

Car purchase and running costs

Dargay and Gately (1999) report elasticity of car ownership with respect to running costs at –0,5 and to purchase cost at –0,3. Button *et al* (1982) argue that increases in fuel prices are more likely to influence the type of car owned in terms of fuel consumption than car ownership. This argument was further supported by the inverse relationship found between fuel prices and average car engine sizes. In South Africa the elasticity of car use with respect to a rise in fuel prices is reported as between –0,027 (Smit *et al* 2003) and –0,22 (Naudé 2002), indicating a relatively inelastic relationship. Furthermore, as shown in figure 2, the relationship between car engine sizes and the sale of new cars in Gauteng Province has generally remained stable between 2000 and 2004, amidst the rapid rise in fuel prices which increased by an average of 32 % in the same period, further illustrating the rather inelastic relationship between car ownership and car running costs in South Africa. Local fuel prices are likely to rise over the longer term due to global energy supply factors, and consumers may become more price-sensitive. The long-term impact of rising energy costs on car

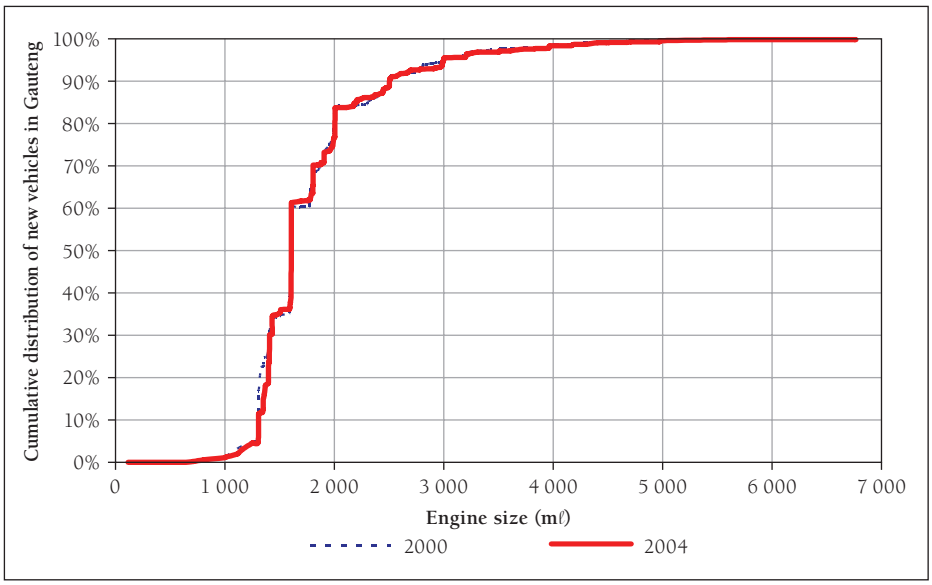

Figure 2 New car sales and engine sizes in Gauteng Province (source: NaTIS, 2000–2004)

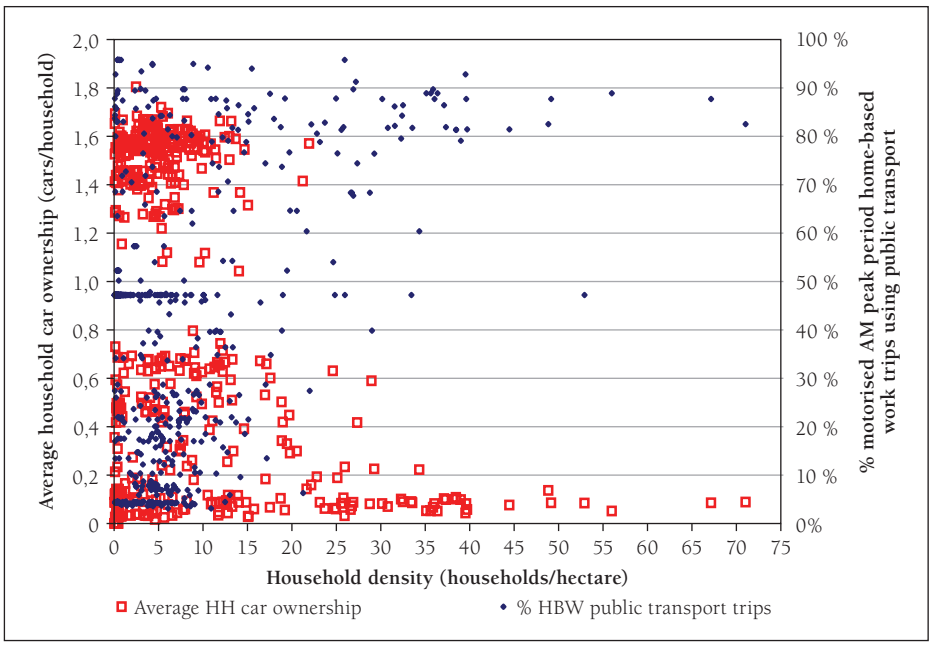

Figure 3 Household density in relation to household car ownership and public transport use (source: Joburg 2004a)

ownership and use is admittedly unknown, and warrants serious consideration. The potentially important effect of changes in car purchase prices is discussed further below.

Road density

Investment in road infrastructure is often thought to be perpetuating increases in household car ownership. Dargay and Gately (1999), however, found that for a given level of car ownership, there was a wide range of road densities, especially for higher income countries. Iingram and Liu (1998) argue, through examination of data from selected countries, that investment in roads is strongly associated with economic growth and not car ownership *per se*. The increase in road network capacity in South Africa has remained marginal compared to the rise in car ownership. It is not clear that any further road infrastructure investment will noticeably affect car ownership.

Population density and the availability and level of service of public transport

Dargay and Gately (1999) report that it is often observed around the world that in densely populated urban areas with good public transport systems, the vehicle/population ratio is lower than expected given the high levels of per capita income. Button *et al* (1981) attribute the inverse relationship between car ownership and population density to shorter travel distances between activity centres, higher generalised costs of using cars, and greater efficiency of public transport in higher density areas.

As indicated above with population density, public transport usage is reported to have an inverse relationship with car ownership, especially in areas with good public transport systems. Bates *et al* (1981), however, argue using data from travel survey and performance of bus operators, that the relationship is two way, that is, increasing car ownership affects the demand for public transport and hence the viability of public transport over time.

Data for South Africa do not reveal a simple relationship between density and car ownership. Figure 3 shows the relationship between residential density on a transport zone level, average household car ownership, and public transport use in terms of motorised home-based work trips in the morning peak period (to 9:00) for the City of Johannesburg. The relationship between household car ownership and household density reveals what appears to be three distinct clusters of household groups. The first cluster is a combination of low density and high average car ownership corresponding largely to historically affluent suburbs. The second cluster is a combination of low density and lower car ownership corresponding largely to areas found on the periphery of the city, most of them informal settlements, while the third cluster is a combination of higher densities above about 25 households per hectare and low car ownership corresponding to inner city areas like Hillbrow and Alexandra, as well as traditional townships like Soweto. Of the theoretically purported continuous inverse relationship between density and car ownership there is no evidence, due to the fractured and bipolar nature of the urban social and economic landscape. What is more, within each cluster there appears to be no relationship between car ownership and density as reported in literature.

Similarly, the relationship between public transport use and household density is not well defined. At densities below about 25 households per hectare, there is no relation between car use and density (figure 3), while the higher public transport mode share apparent among high-density households may simply reflect captive behaviour among low income households, rather than any density effect per se. All these observations caution against the simplistic use of density as an explanatory variable in a car ownership model, especially if its results are used for mode-specific trip generation estimation.

With regard to the impact of the quality of public transport available, conflicting evidence exists. Some evidence in the City of Johannesburg suggests that household car use has a strong positive relationship with car ownership, irrespective of the level of supply of public transport (Joburg 2004a). However, a recent analysis of country-wide household-level data from the National Household Travel Survey (NHTS) (DOT 2005) indicates a noticeable tendency of households with access to minibus-taxi service within 30 minutes' walk from the home, to own fewer (or no) cars, even controlling for income and rural/urban differences (Venter 2006). It is clearly attractive for policy reasons to include sensitivity to

Table 1 Household car ownership probabilities, City of Johannesburg

Dwelling unit type	Zonal income group	Car ownership probability (%)			
		0 car/hh	1 car/hh	2+ cars/hh	Total
House	High	12	26	62	100
	Medium	57	32	11	100
	Low	84	11	5	100
Flat	High	20	54	26	100
	Medium	75	23	2	100
	Low	89	11	0	100
Townhouse	High	5	44	51	100
	Medium	29	55	16	100
	Low	59	31	10	100
Other	High	82	14	4	100
	Medium	81	19	0	100
	Low	97	3	0	100

public transport options in a model of car ownership. However, further research is needed to shed more light on the nature and magnitude of such a sensitivity, and on the best way of treating it analytically.

Family legacy and social standing

Bjoner and Leth-Petersen (2004), from a panel household dataset in Denmark, report on the apparent ratchet effect due to increased dependency on car ownership. From the data it was observed that when single people got married, the car ownership of the couple tends to increase, and also that married couples who later separate and become singles have higher levels of car ownership than singles who never got married. Within the South African context Burger *et al* (2004) argue that because affluent blacks have urbanised more recently than their White counterparts, they have not yet accumulated assets (such as houses) of a commensurate value, which leads to systematically different spending patterns. This suggests the possibility that consumer decisions, such as the purchase of one asset (a car), may be systematically linked to the characteristics of other assets owned or used by the household, such as housing.

With regard to social class, respondents in a household survey into the lifestyles of the newly-emerging middle class in Gauteng Province (Ungerer 1999) agreed with the statement that a person's status is reflected by the products he or she uses. A car was chosen overwhelmingly as the single most important product imparting the most status. The pool of potentially status-conscious consumers is growing fast: higher education graduates, for instance, have shown an average annual increase of 7 % between 1998 and 2001, dropping to 3 % between 2001 and 2002 (CHE 2004). The picture that emerges is one of a growing pool of car-aspirant urbanites with legacy and consumer issues that are not yet well understood, which makes modelling efforts more difficult.

Distance of a household from essential amenities

Kalenoja (2001) calibrated a car ownership model for Tampere, Finland, based on the availability of local services in a traffic zone by six types of areas. It was found that car ownership was highest in the low service level suburbs and also in sparsely populated areas but lowest in the central business district and surrounding areas. In South Africa similar spatial patterns exist to some extent. Apartheid spatial and economic planning has left historically black townships/suburbs with low levels of retail and other services, which would tend to increase the perceived need for private transport and thus car ownership.

FUNCTIONAL FORM AND CALIBRATION OF THE PROPOSED MODEL

The model proposed is an aggregate cross-sectional model based on category analysis. The variables tested during model development were dwelling unit type, household income and location of households relative to the inner city. Dwelling type was classified as houses, flats, townhouses and 'other' (including informal dwellings, backyard shacks and rented rooms). The use of this variable rested on the hypothesis that a household's dwelling asset (whether owned or rented) expressed something about its lifestyle choice, which in turn may be related to vehicle ownership. Dwelling type is further related to residential density where for example flats and 'other' dwellings typically occupy higher density areas than townhouses and houses and would therefore capture some of the effect of density on car ownership. However, dwelling type is far easier to use as an estimation variable than density, as data on dwellings are routinely collected in transport surveys (such as the National Household Travel Survey – DOT 2005) and census surveys. Density, by contrast, can only be estimated from relatively complete geospatial databases not accurately available everywhere.

The model was calibrated for the City of Johannesburg using data from the 2002 Gauteng Household Travel Survey (Gautrans 2003), 2001 Census (StasSA 2001), and land use data in the form of City of Johannesburg transport zones (Joburg 2004b). Transport zones were subdivided into three monthly income groups, namely low (<R1 999), medium (R2 000 – R6 999) and high (R7 000+). A zone was classified into each income category depending on the proportion of the households in the income category residing in the zone. For example, if a zone had a higher proportion of households in the low-income category, the zone would be classified as a low-income zone.

In order to evaluate the influence of the location of the dwelling units relative to the city centre, a further distinction was made between households residing within the N1–N3–N12 Johannesburg freeway ring-road and households residing outside the ring road. The ring road was chosen as a functional boundary because of its historical role in by-passing what was regarded as the centre of Johannesburg (Mitchell *et al* 1990). The largest proportion of the land within the ring road, in contrast to the land outside the ring road, was formerly declared white (Tomlinson *et al* 2003). So, for example, low-income households in the ring road could be pensioners who have assets different from low-income households living outside the ring road, especially on the periphery.

However, calibration efforts showed the location of households in relation to the ring-road to be irrelevant: there was no statistically significant difference, at 95 % significance, between the car ownership of households within and outside the ring road, controlling for income group and dwelling unit type.

The resulting model is indicated in table 1. From table 1 the following is noted:

- The categories as defined produce an efficient classification scheme. Statistical tests of the differences indicated significant differences between the category variable at 95 % significance, as shown in table 2
- The dwelling unit category 'other' has the lowest household car ownership. This is in line with the association of these dwelling unit types with low-income households, for example those in informal settlements and backyard units
- Townhouses have the greatest probability of owning a car, followed by houses,

*Table 2 Chi-square values for table 1**

Dwelling unit type 1	Dwelling unit type 2	Zonal income category	Number of cars per household		
			0	1	2+
House	Flat	High	2,00	9,80	14,73
		Medium	2,46	1,47	6,23
		Low	0,15	0,00	5,00
	Townhouse	High	2,88	4,62	1,07
		Medium	9,12	6,08	0,93
		Low	4,37	9,52	1,67
	Other	High	52,12	3,60	50,967
		Medium	4,17	3,31	11,00
		Low	0,93	4,57	5,00
Flat	Townhouse	High	9,00	1,02	8,12
		Medium	20,35	13,13	10,89
		Low	6,08	9,52	10,00
	Other	High	37,69	23,53	16,13
		Medium	0,23	0,38	2,00
		Low	0,34	4,57	N/A
Townhouse	Other	High	68,15	15,52	40,16
		Medium	24,58	17,51	16,00
		Low	9,26	23,06	10,00

* Significant difference exists at 95 % confidence level when the Chi square > 3,841

Table 3 Johannesburg and Tshwane municipalities household profiles, 2002

Metropolitan municipality	Total number of households	% Households in income categories			% Households in dwelling unit types			
		High	Med	Low	House	Flat	Town-house	Other
City of Johannesburg	1 006 744	24	10	65	78	12	6	4
City of Tshwane	562 556	27	17	56	83	9	5	3

Table 4 Comparison between modelled and actual car population

Metropolitan municipality	Total number of registered cars in 2002	Modelled number of household owned cars	% Predicted (modelled/actual ratio)
City of Johannesburg	645 417	552 276	86 %
City of Tshwane	411 117	338 352	82 %

flats and the 'other' category, in that order. This suggests a departure from the typical density-car ownership relationship: although townhouses are typically *denser* than houses, they also occupy the topmost position in terms of car ownership propensity. This observation can be related to the style and layout trends in modern townhouse developments, where security and lifestyle considerations have created a demand for housing in security estates that is almost entirely car dependent. As the number of these developments has mushroomed in recent years in South African cities, this is a significant trend that may shape transport needs for many years to come

MODEL VALIDATION

The proposed model, developed using data for the City of Johannesburg, was validated in two ways, firstly using global vehicle registration data in the City of Johannesburg and secondly by comparing the raw sample survey observations to the modelled values. Validation of the model at a zonal level requires independent data on household car ownership at that level, which is not readily available.

On a global scale, the total number of modelled household owned cars made up 86 % of the total number of cars registered in the City of Johannesburg (NaTIS data). This is close to a figure of 89 % found by the CSIR (2002) to be the proportion of cars registered by household formations in Gauteng Province. The registered car population is also inflated by households that reside outside Gauteng Province but register household owned cars in the province.

The proposed model was further validated against the raw sample of Gauteng zonal household travel survey data (Gautrans 2003) obtained in the City of Johannesburg, which comprised 6 581 households. The differences between modelled and sampled car ownership values in low-income zones were marginal, in the order of 3 % across all dwelling unit types. Medium-income zones had larger relative differences between modelled and sample values, in the order of 10 % to 15 %. These differences are especially observed in 2+ cars per household for houses, 0 cars per household for flats, 1 car per household for townhouses and 0 and 1 car per household for the 'other' income category. Closer inspection of these high deviations revealed relatively small sample sizes in these categories, implying that the overall forecasting error due to calibration problems may be quite limited.

TRANSFERABILITY OF THE MODEL

The spatial transferability of the model was investigated for the City of Tshwane in Gauteng Province. The test made use of land use and household data for transport zones contained in the Gauteng Department of Public Transport, Roads and Works strategic transportation model. The drawback in this regard is the larger size of the transport zones of the provincial model compared to the City of Johannesburg zones. The household profiles for the cities of Johannesburg and Tshwane are shown in table 3, indicating the extent to which low-income housing dominates the property market in both cities.

Table 4 shows a comparison between the modelled and actual aggregate car populations in each city. In order to estimate the number of cars owned in the 2+ cars per household category, the number of households in the relevant category is multiplied by a factor of 2,25 obtained from the analysis of empirical data. In the aggregate, the model performs almost as well in Tshwane as in Johannesburg, predicting 82 % of the actual vehicle fleet. As before, the difference is explained by the number of cars owned by non-household formations and non-residents.

TREATMENT OF CAR PRICE ELASTICITY

As discussed before, it can theoretically be argued that a car ownership model should be sensitive to changes in car prices relative to household incomes. Therefore changes in the market, particularly the arrival of highly affordable cars aimed at entry-level car buy-

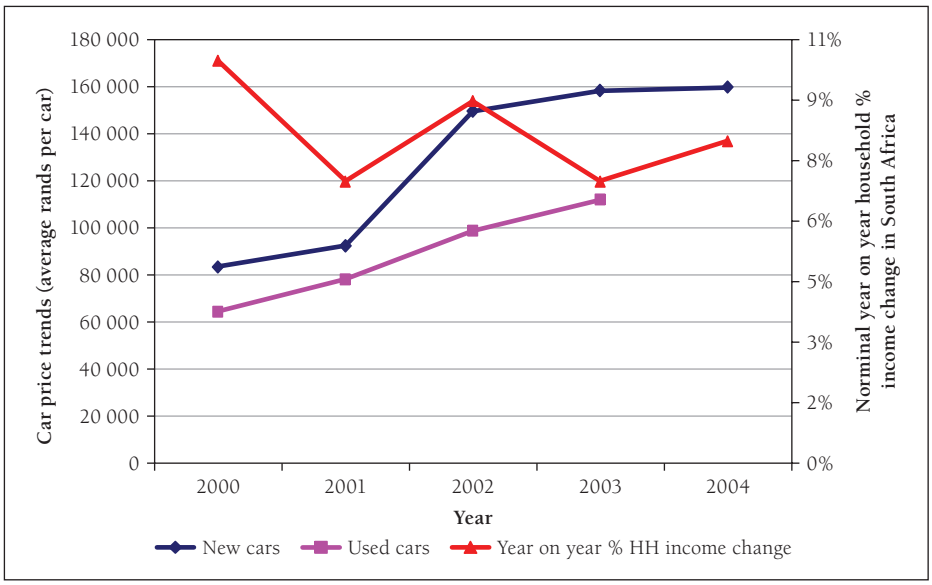

Figure 4 Car price and household income trends in South Africa (source: NAAMSA 2005; Du Toit 2005b)

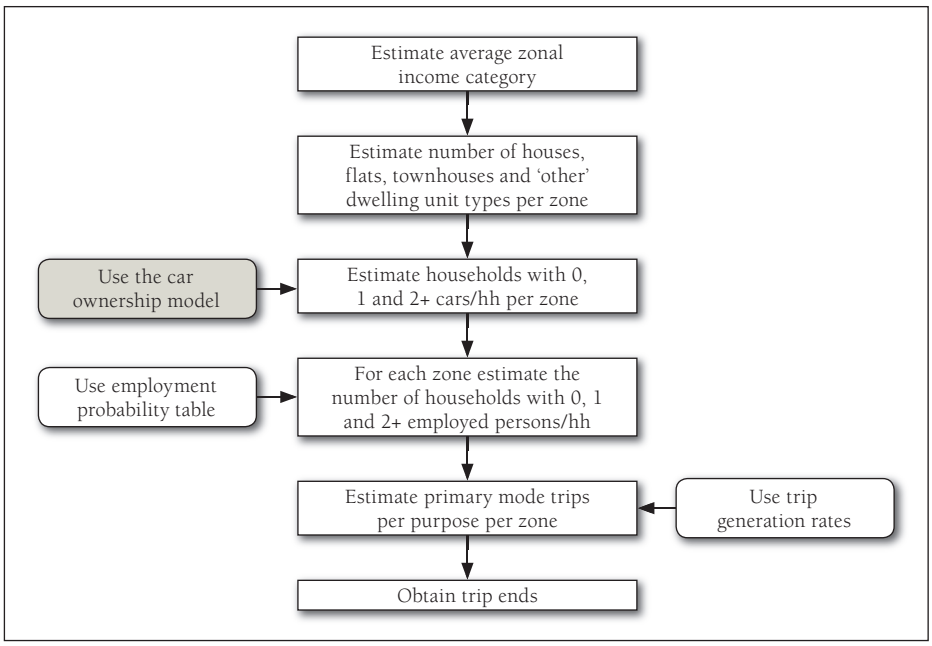

Figure 5 Application of the car ownership model in a typical trip generation exercise

ers, could significantly alter the situation. At least one vehicle manufacturer has mooted the possibility of developing a very low-cost car priced at under R20 000 (*Business Day* 2005b). A 2005 study has identified a potential 1,5 million new car buyers among 'emerging black consumers' (*Business Day* 2005c) should innovative financing and pricing make vehicles more affordable.

Some previous car ownership models have attempted to accommodate the effect of car price changes by using a measure of income deflated by an index of car price (DOT 1982). However, this index was dropped from the UK model when it was found to underpredict the rise in car ownership during the 1976-1978 period, when car prices rose more rapidly than real incomes (Salter 1990) but people continued to buy new cars.

In general, it is not clear what the best way is to incorporate a car price variable into a car ownership model. The authors could identify no readily available local data to help quantify the price elasticity of household car purchases. However, the available evidence suggests that it is primarily amongst the lower and medium income groups that the largest behavioural shift would occur if car prices were to be lowered dramatically:

- A significant proportion of the growth in car ownership recently has come from first-time car buyers, rather than from households that already own cars. The number of households in Johannesburg has been growing at an average rate of 6,5 % per annum between 1996 and 2001, and at an average rate of 6,1 % per annum in Gauteng Province over the same period (Joburg 2004b). Between 2000 and 2004 the rate of growth in car registrations in Gauteng exceeded this household growth rate, implying that more households own cars than before. First-time buyers are more likely to opt for competitively priced entry-level vehicles
- First-time buyers are most likely to be found in the medium-income categories. NHTS data shows that car ownership rates rise most steeply among households in the R2 000 to R6 000 monthly income range (Venter 2006). Car payments would constitute a significant proportion of household expenses at these modest income levels. The introduction of more affordable cars will thus have a disproportional effect on low and medium income households, by lowering the apparent income threshold at which a car becomes affordable (currently around R4 000 to R6 000 per month – 2002 rands), as shown in figure 1
- Car prices have been decreasing relative to household incomes, making cars more affordable. The car price trends for both new and used vehicles, shown in figure 4, show car prices increasing substantially up to 2002, but flattening drastically in the latter years for new vehicles. This in turn will result in the flattening of used car prices. At the same time car sales have rocketed: in Gauteng alone new car sales per annum have in recent years been in the order of 100 000 to 150 000 cars, while used car sales is usually 15 % to 20 % more than new car sales in Gauteng (NAAMSA 2005)

THE APPLICATION OF THE MODEL IN A TYPICAL PLANNING EXERCISE

The model as proposed is most suitable to scenario planning exercises. Such planning exercises could extend to the following:

- Input of car ownership forecasts into a trip generation model
- Impact assessment of different types of developments
- Assessment of transport policies such as parking policies or travel demand management measures
- Input into a behavioural based development planning cost:benefit model
- Benchmarking studies

Figure 5 illustrates a stepwise procedure of how the model can be used in a typical strategic transportation model trip generation exercise. The illustration is customised to the home-based work trip generation model structure of the City of Johannesburg (Joburg 2004b). In this particular cross-classification trip generation model, explanatory variables are the number of employed persons per household, car ownership per household and the household income category. In order to estimate trip ends for the model (split further in terms of primary modal split), the number of households in each category needs to be estimated. One way of accomplishing this, as in the City of Johannesburg, is to establish statistical rela-

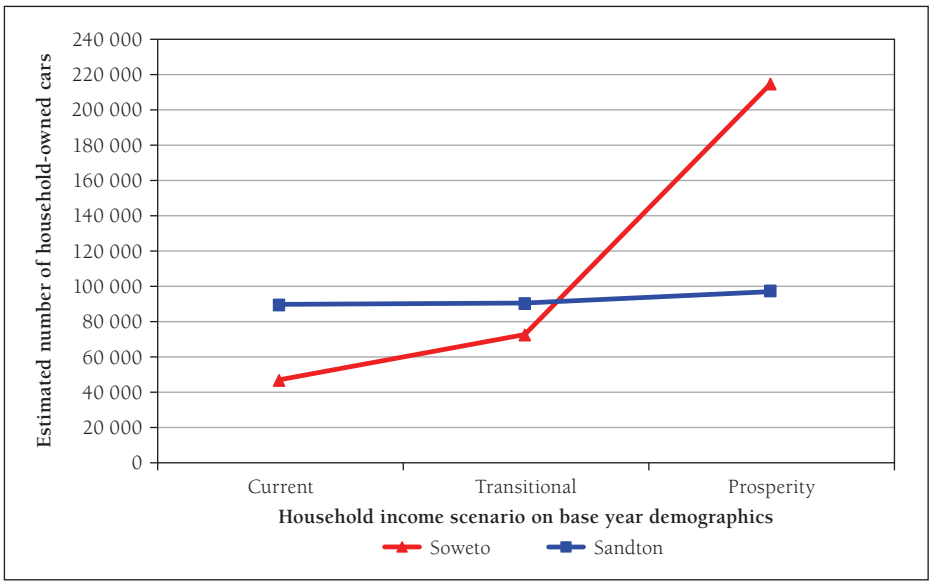

Figure 6 Household car ownership scenario contrast between historically affluent and historically disadvantaged areas

tionships between metro-wide demographic variables, such as cohort survivals, together with metro-wide economic variables, such as gross geographic product (GGO), and the modelled explanatory variables. In the forecast mode, the transportation model would then borrow relevant future estimates of metro-wide variables from economists and demographers.

Figure 6 illustrates notional scenario-based ranges under which household car ownership changes could take place by contrasting the Greater Sandton and Greater Soweto areas in the City of Johannesburg. The Greater Sandton area is historically affluent while the Greater Soweto is a historically disadvantaged township area. Using the 2002 base year household structure, population and dwelling unit types, the household income is varied from the base year distribution referred to as 'current', to 'transitional', in which all low-income transport zones become medium income, and finally 'prosperity', in which all transport zones become high income. The latter is an extreme scenario to illustrate a boundary result. The 'transitional' scenario is supported, however, by findings of a survey that indicated that a significant proportion of 'emerging middle-class' cohorts who realise rising incomes choose to reside in the townships and have no intention of leaving (*Sunday Times* 2006). From the figure it can be seen that the effect of income change on household car ownership is bound to have a larger relative impact in historically disadvantaged areas than in the historically affluent areas. The figure shows that, relative to the base year, car ownership in Soweto could increase as much as 55 % and 360 % using the incremental income scenarios described, in contrast to only 1 % and 9 % in Sandton for the same scenarios.

In the forecasting mode, future housing development trends would need to be estimated. For example, Du Toit (2005a) reports on a year on year increase in 2005 of house plans of greater than 80 m^2 of 11,3 % and that of flats and townhouses of 29,2 %. In Gauteng alone new houses of greater than 80 m^2 have recently been in the order of 5 000 to 6 000 units per annum and new flats and townhouses combined in the order of 5 000 to 9 000 per annum, all representing about 50 % of the new formal residential developments (Du Toit 2005a). Most of these were in high income areas with limited (if any) public transport supply, due to developers' inclination to build in such areas for profitability purposes. Using the City of Johannesburg trip generation model (Joburg 2004a), this would directly translate into 17 000 household cars and a corresponding 9 400 additional morning person trips to work to be accommodated on the province's already congested road network.

CONCLUSIONS AND RECOMMENDATIONS

The following can be concluded from the paper.

- Although socio-economic disparities within the various population groups may still be prevalent, analytical models of household car ownership do not have to rely on racial groupings for effective forecasting. The present model uses income and, for the first time, dwelling type variables, to indirectly represent the household's asset base and lifestyle choices in relation to its car ownership likelihood
- Transport planning practitioners in South Africa need to treat imported behavioural research conclusions with circumspection prior to making major decisions. This further calls for increased investment in localised travel behavioural research
- The proposed approach, validated for metropolitan areas in Gauteng Province, can be used as input to trip generation models in scenario-based planning exercises. However, further validation is required at a zonal level, for instance using residential area cordon traffic counts

While making advances in household car ownership modelling, the approach should be seen as transitional, given the uncertainties around the changing nature of consumer behaviour in South Africa at present, and perhaps used with caution over long forecast horizons. It is recommended in particular that further work be conducted on the effects of rising energy prices, expanded household access to credit, and the introduction of more affordable cars on households' car purchasing patterns, especially among the lower to medium income strata. Further research is needed on the relationship between households' residential and lifestyle choices, and their vehicle ownership and use patterns, in order to broaden our understanding of the long-term behavioural implications of transport policy implementation such as travel demand management, public transport improvements, and perhaps the development of more innovative models for providing access to private vehicle use such as flexible or on-demand car-sharing schemes.

ACKNOWLEDGEMENT

The City of Johannesburg is gratefully acknowledged for allowing the use of the cty's datasets. The views expressed in the paper, however, are those of the authors.

REFERENCES

Bates, J, Roberts, M, Lowe, S and Richards, P 1981. *The factors affecting household car ownership*. Aldershot: Gower.

Bjoner, T B and Leth-Petersen, S 2004. *The effect of car ownership on changes in household size and location – descriptive analyses based on panel household* data, Institute of Local Government Studies, Denmark [online]. Available at http://www.akf.dk [accessed 20 September 2004].

Bunch, D S 2000. Automobile demand and type choice. In D A Hensher and K Button (eds), *Transportation modelling handbook*. 1st ed. Amsterdam: Pergamon.

Button, K J, Pearman, A D and Fowkes, A S 1982. *Car ownership modelling and forecasting*. Aldershot: Gower.

Burger, R, Van der Berg, S and Nieftagodien, S 2004. *Consumption patterns of South Africa's rising black middle class – correcting for measurement errors*. Department of Economics, Stellenbosch University.

Business Day 2005a. Study shows 1,5-million black buyers in car market, 2 August.

Business Day 2005b. 'Stronger, richer economy' gets vehicle makers going, 11 November.

Business Day 2005c. With a bit of 'lakh' a car for the masses may soon be a reality on SA's roads, 22 December.

CHE (Council on Higher Education) 2004. South African higher education in the first decade of democracy. Council on Higher Education, Pretoria.

CSIR (Council for Science and Industrial Research) 2002. Strategic overview and analysis of vehicle ownership trends in South Africa. Unpublished research, Pretoria.

CWRSC (Central Witwatersrand Regional Services Council) 1994. Car ownership forecasting for the

Central Witwatersrand Regional Services Council. Johannesburg.

Dargay, J and Gately, D 1999. Income's effect on car and vehicle ownership worldwide: 1960–2015. *Transportation Research Part A: Policy and Practice*, 33(2):101–138.

DOT (Department of Transport) 1982. *Traffic appraisal manual*. London.

DOT 1997. *Moving South Africa: urban passenger module*. Pretoria.

DOT 2005. *National Household Travel Survey 2003 – technical report*. Pretoria.

Du Toit, J 2005a. *Building statistics still strong in certain market segments*, Absa Group Economic Research, Johannesburg.

Du Toit, J 2005b. *Residential property perspective – housing at regional level: affordability and potential market size*. Absa Group Economic Research, Johannesburg.

Gautrans 2003. *The 2002 Gauteng Household Travel Survey*. Gauteng Department of Public Transport Roads and Works, Johannesburg.

Iingram, G K and Liiu, Z 1998. Motorisation and road provision in countries and cities [online]. Available at http://www.worldbank.org/dec/publications/workpapers/wps-1880series/wps1842.pdf [accessed 15 September 2004].

Joburg 2004a. The City of Johannesburg Emme/2 transportation model. Johannesburg.

Joburg 2004b. The City of Johannesburg strategic transportation model land use and socio-economic report. Johannesburg.

Kalenoja, H 2001. *Car ownership effects on the availability of local service*. The Nordic Research Network on modelling transport, land use and environment, Finland [online]. Available at www.infra.kth.se/tla/tlenet/meet5/papers/kalenoja.pdf [accessed 15 September 2004].

Marks, A P 1979. Car ownership forecasting in South Africa. MSc thesis, University of the Witwatersrand, Johannesburg.

Mekky, A 1996. *Transportation planning models*. 2nd ed. University of Toronto, Canada.

Mitchell, M F, Lucykx, L M and Stanway, R A 1990. The Johannesburg ring road. In *Proceedings* of the International Conference on Orbital Motorways. London: Institution of Civil Engineers.

NAAMSA (National Association of Automobile Manufacturers of South Africa) 2005. *The National Association of Automobile Manufacturers of South Africa 2005 Annual Report*. Pretoria: NAAMSA.

NaTIS (National Traffic Information System) 2000–2004. Vehicle registration database maintained by the Department of Transport.

Naudé, C M 2002. Investigation into the impact of a petrol-diesel price differential on the South African economy. Contract Report CR 2002/70. Pretoria: CSIR.

Ngoe, N, Button, K and Hine, J 1993. Modelling vehicle ownership and use in low income countries. *Journal of Transport Economics and Policy*, XXVI:51–67.

Ortuzar, J and Willumsen, L G 2001. *Modelling transport*. 3rd ed. Chichester: Wiley.

Salter, R J 1990. *Highway traffic analysis and design*. 2nd ed. London: Macmillan.

Smit, B, Van der Berg, S, Kruger, D, Adams, I, Ellis, L, Gutuza, T, Loots, L, Mbangeleli, K, Murray, C, Pienaar, W, Ramuhulu, L, Saller, K, Scholtz, A and Sheraton, M 2003. *The feasibility of a fuel tax levy in the Western Cape*. Bureau for Economic Research, Stellenbosch University.

StasSA (Statistics South Africa) 2001. *The Republic of South Africa 2001 census*. Pretoria: Statistics South Africa.

Sweet, R J 1988. A causal car ownership model. MSc thesis, University of the Witwatersrand, Johannesburg.

Sunday Times 2006. Western tastes, black values, 5 March.

Tomlinson, R, Beauregard, R A, Bremner, L and Mangcu, X 2003. *Emerging Johannesburg – perspectives on the post-apartheid city*. New York: Routledge.

Ungerer, L M 1999. *Activities, lifestyles and status products of the newly-emerging middle class in Gauteng*. Bureau of Market Research, University of South Africa.

Venter, C J 2006. Analysis of 2003 National Household Travel Survey data: car ownership and use in South Africa. Unpublished working paper, University of Pretoria, Pretoria.

Zhang, J, Fujiwara, A and Kuwano, M 2004. *Analysis of car ownership behaviour in local Japanese cities from environmental perspective,* Conference on Social Capacity Development for Environmental Management and International Cooperation in Developing Countries, Hiroshima University, Japan.