

MODELLING AND PROFILING HOUSEHOLD CAR OWNERSHIP IN THE POST-APARTHEID SOUTH AFRICA

M MOKONYAMA¹ and C VENTER²

¹City of Johannesburg Metropolitan Municipality, PO Box 30733, Braamfontein, 2017.

²Pretoria University, Department of Civil and Biosystems Engineering, Pretoria, 0002.

ABSTRACT

Data representation and interpretation found in transportation planning literature tends to overlook the role of influences such as political systems and related history in travel behaviour. This could be as a result of the mature nature of the democracies of the countries from which transportation research is mostly published. The importance of localised research in social sciences such as transportation planning therefore cannot be overemphasised, especially in South Africa where the socio-economic landscape is ever-changing, inherently related to the recent democratisation of the country.

In line with the ever-changing socio-economic landscape of South Africa, the paper investigates an alternative household car ownership modelling approach for use in strategic transportation modelling exercises, founded on the spatial attributes of a typical South African city. Furthermore, the model is applied to critically review some of the spatial variables mooted in literature to have influence on household car ownership. The City of Johannesburg is used as a case study within the context of South African development planning paradigm.

The findings of the research can be used in trip generation sub-models using household car ownership as a variable, and also in spatial planning exercises aimed at managing travel demand in an urban area.

1. INTRODUCTION

The research work in this paper was undertaken to investigate car ownership profiles in the Post-Apartheid South Africa and associated suitable car ownership modelling parameters. The basic premise of the research is that the South African car ownership models developed in the era when South Africa was still under the influence of provision of Apartheid policies would increasingly become difficult to implement in transportation modelling exercises. Such models were characterised by the segmentation of population into the four traditional population groups i.e. Black, White, Coloured and Indian and calibrated accordingly, warranted by the previous legislated spatial segregation of the population groups. In contrast to this historical backdrop, spatial integration of the different population groups is increasingly taking place, especially in the former White areas. Moreover, through the interventions such as Broad Based Black Economic Empowerment strategy of the government, whose fundamental goal is to increase meaningful participation of Black persons in the economy, an ever increasing household income prospect in the Black households would be expected to be the norm. Such changes would imply trip making patterns fundamentally different from those observed under the influence of the provisions of Apartheid policies.

The paper aims to contribute to the discipline of transportation planning in the following ways:

- To illustrate an alternative way of modelling household car ownership based on spatial attributes of a city.
- To apply the proposed model and provide some context into some of the variables currently mooted as fundamentally explanatory in sustainable development planning within the South African metropolitan areas.

The results of the study would be of primary interest to transportation planners involved in development planning and strategic transportation modelling in metropolitan areas. The results could also provide useful input to land use planning exercises relating to the residential areas. Also, the results of the study, used in conjunction with some other spatial attributes, would provide some fundamental understanding of the nature of household car ownership and thus put in perspective the National government's long-term target of the ratio between public transport to car usage at 80:20 (RSA, 1996a).

The study uses the City of Johannesburg Metropolitan Municipality as a case study, however, within the context of conditions in Gauteng Province and South Africa. Furthermore, only household car ownership as opposed to household car use is examined in detail, although implications on car use are briefly discussed. Although the original research identified issues, inherently related to government development policy, that are likely to influence the future profile of household car ownership in South Africa, these are also not covered in the paper.

2. BACKGROUND

Household car ownership modelling and forecasting has been significantly researched around the world. Such a focus has historically been warranted by the relatively high investments related to the provision of transport infrastructure by government to accommodate changes in travel demand due to changes in household car ownership. Some of these models, however, have always been limited by the availability of relevant data and the cost of collecting the data often resulting in what Ortuzar and Willumsen (2001) describe as the source of widening gap between theory and practice. In South Africa similar studies were undertaken, although mostly in a period when Apartheid policies shaped the country's legislature, before the 1994 democratic elections and also the adoption of the new Constitution in 1996 (RSA, 1996b). Furthermore, in an attempt to minimise data aggregation errors due to differing economic profiles of the population groups, the past South African car ownership modelling studies made a distinction between the different population groups. Such a distinction made it easier to establish aspects such as average trip generation rates within the respective areas allocated to different population groups, due to legislative spatial separation of the population groups. Continued distinction of the population groups would render transportation modelling exercises difficult and increasingly irrelevant. The fundamental difference in the Post-Apartheid South Africa being the Bill of Rights contained in the new Constitution, that has broken down the past racial spatial barriers and thus introduced a new development planning paradigm.

The primary purpose of this research is to explore an alternative household car ownership model that is not reliant on the classification of the population into race groups and is relevant to the development history of an area. The research uses the City of Johannesburg Metropolitan Municipality as a case study. Such a model would typically be used by a local authority in estimating both existing and future car ownership in its area of jurisdiction, for its transportation model that uses household car ownership as one of the explanatory trip generation variables. Due to the limited financial resources of government, the model needs to be relatively affordable to maintain and use. In addition to providing necessary data for trip generation estimations, the model needs to provide some useful insight into other pertinent strategic transportation planning exercises as opposed to solely being focused on road space provision. Although not covered in this paper, the original research study also examined the relevance of some of the factors that could continue to redefine the nature of car ownership in the Post-Apartheid South Africa, inherently related to the democratisation of the country through various government policies, with more emphasis, however, on the City of Johannesburg.

3. VARIABLES INFLUENCING HOUSEHOLD CAR OWNERSHIP

Static and dynamic car ownership models, described in detail by Bunch (2000) have fundamentally different modelling parameters, where static models estimate car population at a given point in time and the dynamic ones model car transactions over time. Generally static models have lesser data requirements than dynamic models hence their popularity with practitioners. Static car ownership models have further been classified as either timeseries models or cross-sectional models. Timeseries 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 (Button et al, 1982). Cross-sectional models, also referred to as causal models, are calibrated using data collected at a given pointing in time and attempt to link car ownership to selected explanatory variables for which forecasts can be made. Time series models assume that time can be used as a surrogate variable for factors affecting car ownership levels over the period under investigation. Cross-sectional models on the other hand attempt to relate car ownership directly with variables that are postulated to influence car ownership. Accordingly, cross-sectional models require more in-depth understanding of explanatory variables. Latest developments include the application of stated preference modelling techniques in car ownership studies, e.g. the testing of the market viability of low emission vehicle in Japan for environmental planning purposes (Zhang et al, 2004).

As early as the initial developments of car ownership models in the 1960's, household income has been found to be a significant explanatory variable in household car ownership models. Button et al (1982) report that the use of income as an explanatory variable has been fundamentally supported, due to the important role of income in econometric studies of consumer behaviour. Dargay and Gately (1999) further confirmed the relationship between Gross Domestic Products (GDPs) of Organisation for Economic Cooperation and Development (OECD) countries and their car ownership levels, where countries with higher GDPs generally had higher car ownership levels. The relationship so confirmed described a sigmoid curve. Dargay and Gately (1999), however, note that the income elasticity of car ownership was significantly higher in developing countries in the period 1960 to 1992. Through this approach, Dargay and Gately (1999) estimate the ultimate common car ownership saturation values for all countries at 0.62 cars/capita and 0.85 vehicles/capita. 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 abovementioned relationship between car ownership and household monthly income in Gauteng Province. The relationship was calculated from the 2002 Gauteng household travel surveys data (Gautrans, 2003), with 95% confidence interval. Figure 1 shows that household car ownership starts increasing substantially at a monthly household income of at least R6 000.

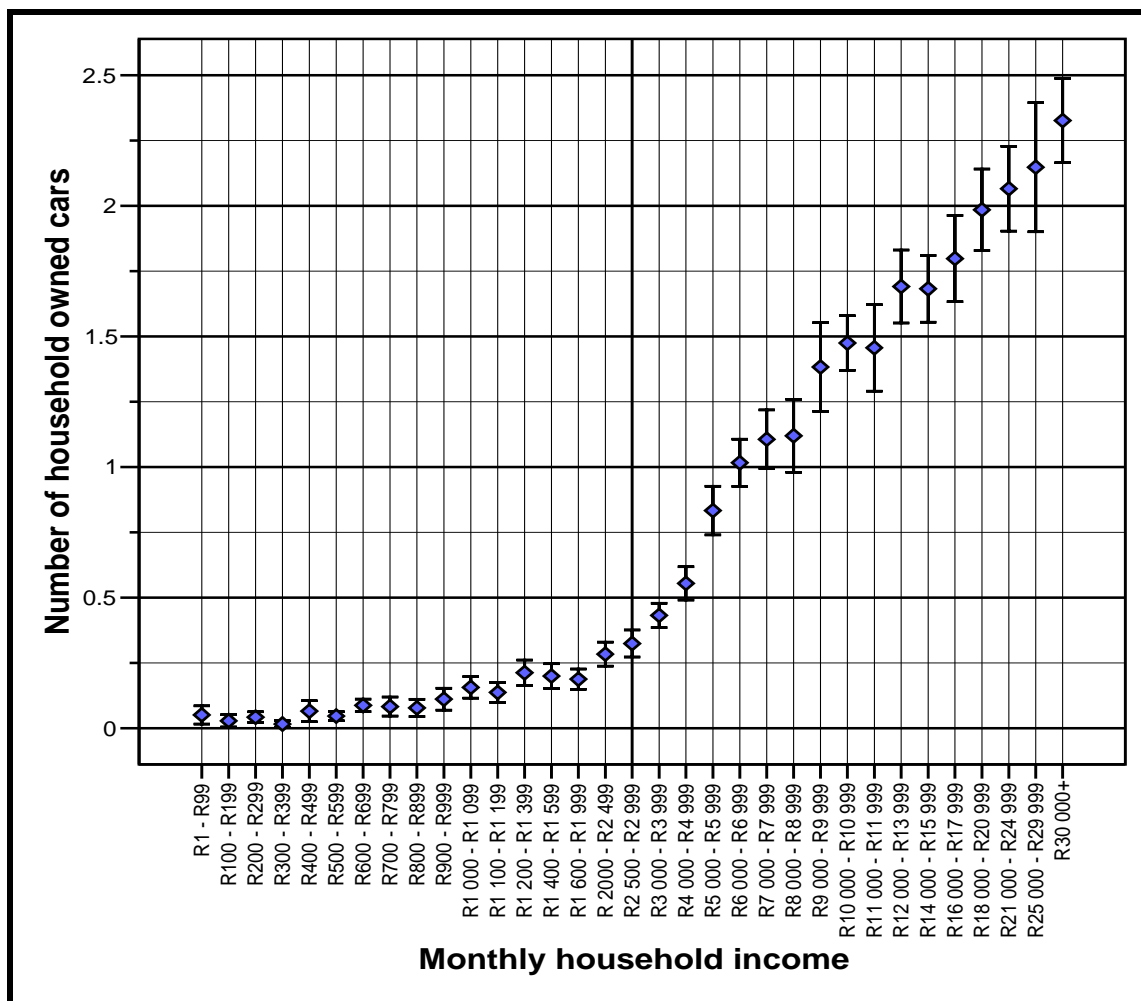


Figure 1. Car ownership and household income in Gauteng.

A significant positive relationship has also been found in literature between household car ownership and household attributes such as the number of employed persons per household, the number of household members at a driving age and the level of education. However, Button et al (1982) caution against the high collinearity between many of these household structure attributes and household income.

Some of the variables influencing car ownership reported in literature from a transportation planning perspective are as follows:

- **Car running costs:** Dargay and Gately (1998) report elasticity of car ownership with respect to running costs at -0.5 and to purchase cost estimated 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. However, this relationship would further be influenced by household income.

- **Road density:** Investment in road infrastructure is often thought to be perpetuating increase in household car ownership. Dargay and Gately (1998), however, found that for a given level of car ownership, there was a wide range of road densities, especially for higher income countries. Ingram 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.
- **Population Density:** Dargay and Gately (1998) 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 (1982) attribute the inverse relationship between car ownership and population density to shorter travel distance between activity centres in high density areas, higher generalised costs of using cars in higher density areas and also efficiency of public transport in higher density areas.
- **Availability and level of service of public transport:** As indicated under population density, public transport, 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 i.e. increasing car ownership affects the demand for public transport and hence the viability of public transport over time.
- **Family legacy:** 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 noted that married couples who later separate and become singles have higher levels of car ownership than singles who never got married. Within the context of South Africa, Burger et al (2004) argue that although affluent Blacks have urbanised more recently than their White counterparts, they have not yet accumulated assets (e.g. houses) of a commensurate value, which leads to systematically different spending patterns and this remains the major hindrance towards middle class consumption patterns by Black people.
- **Location 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.

4. FUNCTIONAL FORM AND CALIBRATION OF THE PROPOSED MODEL

The model proposed in this study is an aggregate cross-sectional and based on category analysis. It was decided from the onset to produce a modelling framework that is related to spatial attributes of a former Apartheid city that would require relatively little resources for data collection.

The variables tested were: dwelling unit type, household income and location of households relative to the inner city. Dwelling unit type has been chosen as a variable due to its potential role in showing the preference profile of households in respect of important decision such as type of home environment. The location of residential areas relative to the inner city was chosen due to the unique history of former Apartheid cities where cities were defined spatially in terms of race and development privileges. The relevance of the variables for inclusion in the model was tested in the model calibration stage.

The main sources of data used for constructing the model were the 2001 Census (StatsSA, 2001), 2002 Gauteng household travel survey (Gautrans, 2003) and the City of Johannesburg land use data using 2001/2002 (Joburg, 2004a) as the base year. Census

data is collected in five-year intervals by Statistics South Africa, the official statistics provider in South Africa. The Gauteng household travel survey was conducted in October 2002. A stratified random sample of 15 000 households in Gauteng Province was obtained, using the Gauteng Province traffic zones as the strata. From the study, weighting factors were prepared for each traffic zone based on the total number of households per income group. Three monthly household income groups, namely, low (<R1 999), medium (R2 000 – R6 999) and high (R7 000+), consistent with the provincial transport model classification, were used. The weighting was also completed for the number of persons residing in the traffic zones within these monthly income groups. In the cases where households did not disclose their income, an assumption was made that the missing values were spread proportionately over all the income groups (Gautrans, 2003). The land use data of the City of Johannesburg are organised in terms of the traffic zones, where population and employment at work place related data are stored. The City of Johannesburg traffic zones, although much smaller in size than the Gauteng Province traffic zones, are completely compatible with the Gauteng Province traffic zones according to which the Gauteng household travel survey data were stratified.

The results of the Gauteng household travel surveys were used to derive the relationship between car ownership and the type of dwelling unit for the Gauteng traffic zones located in the City of Johannesburg. The City of Johannesburg traffic zones were further disaggregated 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. Moreover, in order to evaluate the influence of the location of the dwelling units relative to the city centre, a further disaggregation was made between households residing within the N1-N3-N12 Johannesburg freeway ring-road and household residing outside the ring-road due to the historical development of the City e.g. low income households in the ring road could be pensioners who have assets different from low income households living outside the ring road, especially the periphery. The ring road was also chosen as a boundary due to its historical role in by-passing what was regarded as the centre of Johannesburg (Mitchell et al, 1990). Moreover, the largest proportion of the land within the ring road, in contrast to the land outside the ring road, was formerly declared White. Non-residential zones were identified accordingly and no calculations were performed for them. Zones that had less than 100 dwelling units were also classified as non-residential zones. The number of dwelling unit types for each zone was identified, providing a further dimension in the disaggregation process.

5. RESULTS AND FINDINGS

The detailed empirical relationships were obtained between the dwelling unit types and car ownership, indicating the probability of household car ownership per zone for the three income groups. For transportation modelling purposes, however, it is desirable to limit the model to the most relevant variables.

The following model simplification process was therefore followed:

- Household car ownership was limited to three categories, namely, 0, 1 and 2 or more cars per household, and the data were grouped accordingly.

- Only four dwelling unit types were included, namely, house, flats, townhouses and “other”. The “other” category includes backyard shacks, informal settlements, room in house, backyard room, garage and hostel. This grouping was regarded as relevant firstly due to the insufficient sample size obtained from some of the dwelling unit types, e.g. garages, and also due to the temporary nature of these dwelling arrangements.
- The influence of the location of the households in relation to the traditional Central Business District (CBD) was tested in terms of evaluating the significance of the difference between household car ownership within and outside the ring road through the Chi-square test. The comparison revealed that there is no statistically significant difference, at 95% significance, between household car ownership of households within and outside the ring road belonging to the same income group and residing in the same dwelling unit types.
- Table 1 represents the final household car ownership probability values to be used for modelling purposes. At 95% significance, the Chi-square tests generally revealed significant differences between the different categories. The following can further be noted from the data in Table 1:
- The category “other” has the lowest household car ownership. This is in line with the association of these dwelling unit types with low income households.
- Flats, which can be associated with high density development, generally have households with lesser cars than the other formal development i.e. townhouses and houses.
- Townhouses have the greatest probability of owning a car, followed by houses, flats and the “other” category in that order.

Table 1. Household car ownership probabilities per zone.

| 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 |

The car ownership values derived in Table 1 can be used as part of a transportation modelling exercise that uses car ownership as an explanatory variable in trip generation, to estimate trips in line with the requirements of a specific trip generation model. In a forecasting mode, the modeller would need to estimate the dwelling units of a specific type within a traffic zone to be able to forecast household car ownership.

The proposed model was validated in two ways, firstly using global vehicle registration data in the City of Johannesburg and secondly using the raw sample survey observations and comparing them to the modelled values.

Using the model, the total number of household owned cars calculated for the City of Johannesburg was 495 463 for 2002. A comparison between the total modelled and the total registered number of cars in the City of Johannesburg revealed that modelled household cars account for close to 80% of the total cars registered in the City (JMPD, 2003). The remainder of the cars could possibly be business registered cars and also cars belonging to households not residing in Johannesburg but choosing to register their cars in the City, in addition to estimation errors.

In the absence of independent datasets on the geographical distribution of household car ownership in the City of Johannesburg, the proposed model was further validated against the raw sample of Gauteng household travel survey data (Gautrans, 2003) obtained in the City of Johannesburg, which comprised of 6 581 households.

The following was noted from the second validation exercise:

- There was an average difference of 6.5% between modelled and sample values across all the dwelling type units and income categories. The differences were especially high in the high income “other” dwelling unit category where the differences were as high as 25%. In the medium income category the differences were especially high in 2+ cars/hh for houses (11%), 0 cars/hh for flats (16%), 1 car/hh for townhouses (17%) and 0 and 1 car/hh for the “other” income category (10% and 11% respectively). The comparisons in the low income categories revealed very close match between actual and modelled values with an overall average deviation of 3% across all the car ownership categories.
- Closer inspection on the higher deviations, however, revealed that sample sizes in these categories were relatively small.

The performance of the proposed model would be acceptable for the purpose of a strategic transportation model. An independent validation test is recommended to compare the modelled values with the actual household car ownership values. This could be partly achieved by conducting cordon traffic counts in selected residential areas, segmented in accordance with the proposed model.

6. SOME APPLICATION OF THE MODEL

Figure 2 shows the relationship between residential density on a zonal level, in terms of households per hectare; average household car ownership, for residential densities up to 75 households per hectare (although higher densities do exist); as well as public transport use in terms of motorised home based work trips in the morning peak period for the City of Johannesburg. The morning peak period includes all the home based work trips that take place before 09:00 in the morning.

The following can be gathered from the figure:

- There appears to be three distinct clusters of household groups in terms of the relationship between household car ownership and household density, where the first cluster is a combination of low density and high average car ownership, the second cluster is a combination of low density and lower car ownership and the third cluster is a combination of relatively high density and low car ownership. Within each cluster there appears to be no relationship between car ownership and density. Taken in isolation each cluster shows that household car ownership in the City of Johannesburg does not necessarily decrease with increase in residential density as reported in literature. Historically, high density residential development in the City of Johannesburg, for example, can be associated with the legacy of an Apartheid city, e.g. overcrowded conditions.

- Generally, however, households with high car ownership tend to reside in residential densities of up to 10 households per hectare, followed by moderate car owning households in densities of up to 20 households per hectare and lastly low car owning households in densities as high as 70 households per hectare.
- Similarly the relationship between public transport use and household density is not well defined. However, car use in this context dominates up to densities of 15 households/hectare. This may further illustrate the nature of captive transport markets in the City.

Further evidence suggests also that in the City of Johannesburg, household car use has a strong positive relationship with car ownership, irrespective of the level of supply of public transport.

It should however be noted that in general the development density in the City of Johannesburg is largely relatively low and that the new urban form mooted in the Spatial Development Framework (Joburg, 2004b) might change the future patterns.

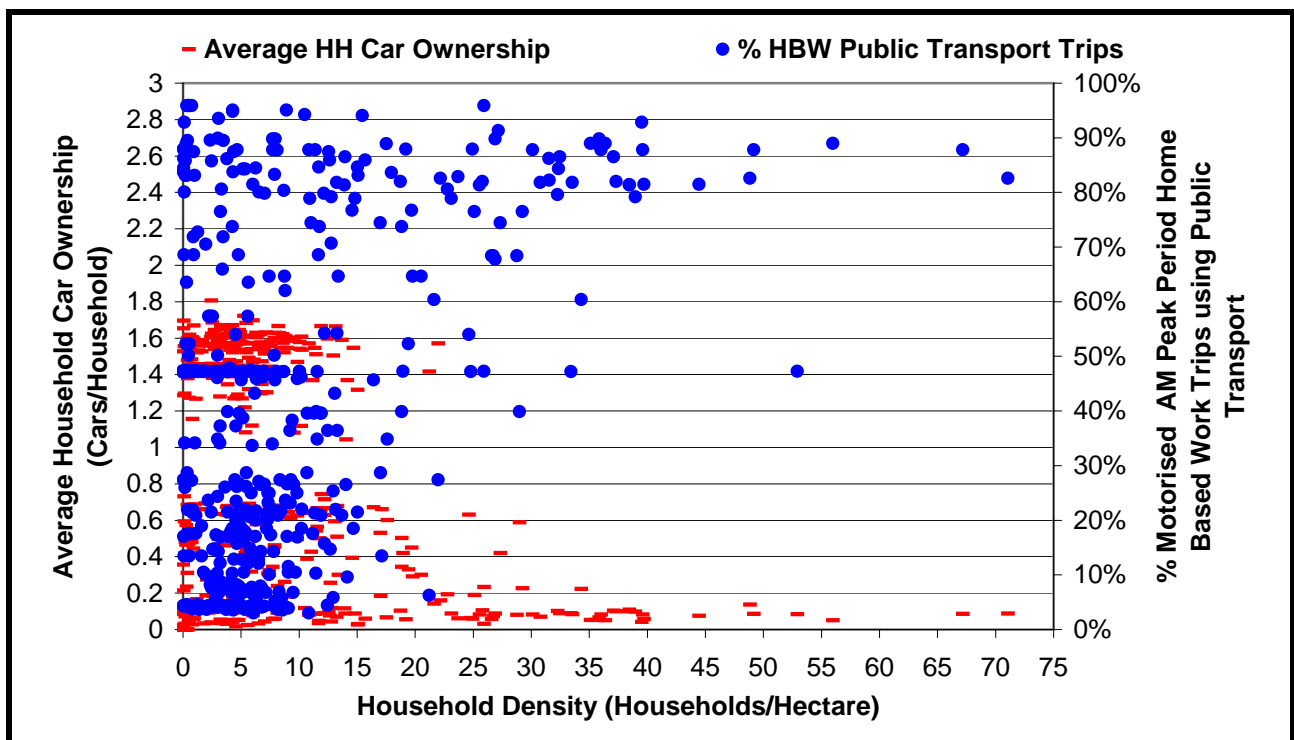


Figure 2. The relationship between household density, household car ownership and public transport use in the city of Johannesburg.

Through GIS spatial queries, more informative trends pertaining to the spatial distribution of household car ownership in relation to other spatial variables in the City of Johannesburg were obtained.

7. CONCLUSIONS AND RECOMMENDATIONS

In contrast to the previous car ownership models in South Africa, for use in transportation modelling, the following stand out as some of the main features of the proposed model:

- The proposed model facilitates spatial analyses readily.

- Although there are still major economic disparities between the different population groups, the model does not explicitly differentiate between the population groups. Spatial distribution of wealth is used instead across the entire population.
- The model is empirical in nature and therefore multi-car ownership statistics could be easily obtained.

In developing the modelling procedure, the often limited resources of local government were taken into account hence the simplicity of the proposed model.

The dependence of the model on spatial separation of income groups, however, may not be politically acceptable. The reality is nevertheless that market forces will always create such separations, especially in the property market.

It is recommended that the findings of the paper be applied to urban strategic development planning proposals, where the relationship between car ownership and use has been estimated. It is also recommended that the findings be tested in other metropolitan areas for spatial stability.

8. REFERENCES

- [1] Bates, J. Roberts, M. Lowe, S. Richards, P. 1981. *The factors affecting household car ownership*. Gower publishing company limited, England.
- [2] Bjoner, T.B. 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. <http://www.akf.dk>, Sourced 20 September 2004.
- [3] Bunch, D.S. 2000. Automobile demand and type choice. *Transportation modelling handbook*. Edited by Hensher, D.A. Button K.J. 1st edition. Pergamon publishing, Amsterdam. pp 463-479.
- [4] Button, K.J. Pearman, A.D. Fowkes, A.S. 1982. *Car ownership modelling and forecasting*. Gower Publishing Company Limited, England.
- [5] Burger R., Van Der Berg S., Nieftagodien S., 2004, *Consumption patterns of South Africa's Rising Black Middle Class – Correcting for measurement errors*, Department of Economics, Stellenbosch University, South Africa.
- [6] Gautrans, 2003, *The 2002 Gauteng Household Travel Survey*, Gauteng Department of Public Transport Roads and Works, Johannesburg.
- [7] Ingram. G.K. Liiu, Z. 1998. *Motorisation and road provision in countries and cities*. <http://www.worldbank.org/dec/publications/workpapers/wps1880series/wps1842.pdf>, sourced 15 September 2004.
- [8] JMPD. 2003. The City of Johannesburg Metropolitan Police Department vehicle registration data, Johannesburg.
- [9] Joburg. 2004a. The City of Johannesburg strategic transportation model land use and socio-economic report. Johannesburg.
- [10] Joburg. 2004b. The City of Johannesburg Spatial Development Framework. Johannesburg.
- [11] Kalenoja, H. 2001. *Car ownership effects on the availability of local service*. The Nordic Research Network on modelling transport, land use and environment, Finland, www.infra.kth.se/tla/tlenet/meet5/papers/kalenoja.pdf sourced 15 September 2004.

- [12] Mitchell, M.F. Lucykx, L.M. Stanway, R..A. 1990. The Johannesburg ring road, *Proceedings of the international conference on orbital motorways*. Institution of civil engineers, London, pp. 123-141.
- [13] Ngoe, N. Button, K. Hine, J. 1992. *Modelling vehicle ownership and use in low income countries*. Journal of transport economics and policy, Volume XXVI, pp 51 -67.
- [14] Ortuzar, J. Willumsen, L.G. 2001. *Modelling transport*. 3rd edition. John Wiley & sons Ltd, England.
- [15] Republic of South Africa, 1996a, *White Paper on National Transport Policy*, Government printers, Pretoria.
- [16] Republic of South Africa. 1996b. The Constitution of the Republic of South Africa, Act 7 of 1996. Government printers, Pretoria.
- [17] StatsSA. 2001. *The Republic of South Africa 2001 Census*. Statistics South Africa. Pretoria.
- [18] Venter, C. Bierman, S. Van Ryneveld, M. 2004. *Low-cost housing location in South African cities: Empirical findings on costs and benefits*. Paper delivered at the South African Transport Conference, Pretoria.
- [19] Zhang, J. Fujiwara, A. 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.