26th Australasian Transport Research Forum
Wellington
New Zealand
1-3 October 2003

# GREATER WELLINGTON'S TRIP GENERATION AND CAR OWNERSHIP: A PERSON BASED APPROACH AND ITS IMPLICATIONS.

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## 1. THE WELLINGTON MODEL UPDATE PROJECT

In 2000 Wellington Regional Council commissioned a major update of their regional transport model (the current model as described in Booz Allen & Hamilton, 2000), the Wellington Transport Strategy Model (WTSM). This multi-modal, emme/2-based model encompasses the entire Greater Wellington Region.

The project commenced with an extensive survey programme (including household, intercept and count surveys) which, once these data had been processed, was followed by model recalibration, implementation and validation and the production of base forecasts.

This paper describes two components of the model update: the car ownership and trip production model calibrations. As will become apparent in later sections, in order to ensure the most effective use of resources and time available, we carefully planned in advance and in detail each stage of the project. Wherever feasible, we made in principle decisions on the model specification in advance of calibration, based on our knowledge of the local context and experience of models nationally and internationally.

### 1.1 THE HOUSEHOLD SURVEY

Travel data for model recalibration has primarily been based on the household survey data, which we designed with the assistance of Tony Richardson from The Urban Transport Institute. Indeed the travel data on which the production models have been based has come exclusively from this survey.

The household survey returned approximately 2500 households and 7000 persons across the Wellington Region, stratified by Territorial Authority to ensure adequate coverage throughout the region, and was conducted between October 2001 and February 2002 with a break over the Christmas holiday period between 18th December and 27th January.

The structure of the questionnaires was conventional, but designed specifically to address Wellington’s requirements. Each household answered a series of questions pertaining to the household and its occupants, with those household members aged five or over asked to complete a full day travel diary encompassing all trips undertaken on their nominated travel day. While each household was allocated one weekday for their travel day to ensure a complete coverage of the working week, those households whose day was Monday or Friday were also requested to complete an adjacent weekend day travel diary.

While all household travel was collected as trip stage information, these trip segments (41,011) have been linked to create 36,144 trips upon which all modelling has been based.

## 1.2 PERSON AND HOUSEHOLD SEGMENTATIONS

With linked models there is a need for some consistency between the segmentations adopted in each sub-model, and it must be feasible to estimate the population distributions for the chosen segmentations. Compatible with our general approach to model development, we pre-defined the major segments based on the existing model, international best practice and analysis of local survey data.

The trip purposes were chosen based on the client's objectives, the expected proportions of trips for each purpose and behavioural differences between purposes, and recognising the constraint of the size of the survey sample on which the model was to be estimated. These trip purposes were selected after examination of the travel survey data and are shown in Table 1.

**Table 1 Trip Purpose Segmentation**

| Purpose | | Trips |
|---|---|---|
| HBW | Home Based Work | 255,000 |
| HBEd | Home Based Education | 183,000 |
| HBSh | Home Based Shopping (including personal business) | 300,000 |
| HBO | Home Based Other (including social, recreation and other) | 366,000 |
| NHBO | Non Home Based Other | 480,000 |
| BU | Home and Non Home Based Business Travel | 152,000 |

The general principle of splitting the market by car availability for mode choice modelling used in the present model has been retained, the classification below being adopted. We also considered replacing adults either by employed persons or by licensed drivers; these alternatives were equally acceptable and effective but adults was more convenient for implementation. The car availability segmentation is shown in Table 2.

**Table 2 Car Availability Segmentation**

| | |
|---|---|
| Captive | Trips by residents of non car owning households |
| Competition | Trips by residents of households where no. of cars < no. of adults |
| Choice | Trips by residents of households where no. of cars ≥ no. of adults |

Both person and family characteristics affect the car ownership and trip end sub-models. Following reviews of the most recent international practice (notably in London), we decided to base the trip production model on person trip rates in preference to household trip rates, according to the following person (and household) types, with further refinement for specific purposes. A 3+ car segment was considered but it was too small (11%) to justify the cost of an additional segment. These segmentations are detailed in Table 3.

**Table 3 Person and Household Segmentation**

| |
|---|
| Person types:<br>- Infant (<5)<br>- Child (5-16)<br>- Young adult (17-25) unemployed<br>- Young adult (17-25) employed<br>- Adult (26-65) unemployed<br>- Adult (26-65) employed by:<br>- "retired" (>65) |
| Household types:<br>- car ownership: 0, 1, 2+<br>- other characteristics which emerged as significant in the calibration |

Similarly the car ownership model was segmented (Table 4) by the following household characteristics. While other parameters such as presence of employed persons and children in the household have also been included in other models internationally, this seemed a demanding refinement for the database available to us.

**Table 4 Car Ownership Model Segmentation**

| |
|---|
| Non-retired household: |
| 1 adult |
| 2 adults |
| 3+ adults |
| Retired household: |
| 1 adult |
| 2+adults |

# 2. PERSON TRIP GENERATION MODELS

## 2.1 STATISTICAL APPROACH

The trip production models have been calibrated using linear regression software, and evaluated using model fit statistics such as t-statistics, standard errors, r-squared values and sum of residual values. The fit statistics have then been used to compare alternative models and parameter values.

However in the final selection of a model, behavioural sensibility may override the choice of model when the statistics are either ambiguous (i.e. r-squared and residual sum of squares suggest alternative models), or the statistical tests indicate only a marginal improvement in performance.

## 2.2 HBW MODEL

The model uses trip rates by employer type and work arrangement as illustrated below in Table 5. The trip rates (Tables 6 and 7) vary sensibly: part-time employees have lower trip rates, as do those who do not have fixed employment arrangements. A number of additional variables were tested but were found to be insignificant, including household size and location (eg rural/urban) and the number of household vehicles.

**Table 5 Model Segmentation**

| **Work Arrangement** |
|---|
| Fixed hours |
| Flexible hours |
| Rostered shifts |
| Works from home |
| **Employment Type** |
| Paid employee |
| Self employed – no others employed |
| Self employed and employer of people |
| Family business |

**n Table 6 Full-Time Worker Trip Rates (trips per day)**

| | Paid Employee | Self Employed, Family Business and Employer of Others |
|---|---|---|
| Fixed Hours | 1.51 | 1.30 |
| Flexible Hours and Rostered Shifts | 1.27 | 1.06 |
| Works from Home | 0.78 | 0.58 |

**n Table 7 Part-Time Worker Trip Rates (trips per day)**

| | Paid Employee | Self Employed, Family Business and Employer of Others |
|---|---|---|
| Fixed Hours | 0.97 | 0.76 |
| Flexible Hours and Rostered Shifts | 0.73 | 0.52 |
| Works from Home | 0.24 | 0.03 |

## 2.3 HBED MODEL

In this model, escort education trips (by parents) are associated with the child who generates the trips). The trip rates (Table 8) vary by age group, because escort trips and the probability of a person being in education both reduce with age. A number of additional variables were tested but were found to be insignificant: household location (eg rural/urban) and number of household vehicles.

**n Table 8 Person Education Trip Rates (trips per day)**

| Age Group | Trip Rate |
|---|---|
| 5-10 Years | 2.269 |
| 11-16 years | 1.748 |
| 17-25 Year | 0.337 |
| 26+ Years | 0.014 |

## 2.4 HBSH MODEL

Trip rates for home based shopping vary with age and employment status. Table 9 illustrates that trip rates increase with age, and also for those not full time employed. Household size, location (rural/urban), car ownership and household income were all found to be insignificant in determining the trip rates.

**n Table 9 Person Shopping Trip Rates (trips per day)**

| Heading | Full Time Employed | Other |
|---|---|---|
| Children (6-16 Years) | | 0.35 |
| Young Adults (17-25 Years) | 0.41 | 0.74 |
| Adults (26-65 Years) | 0.54 | 1.22 |
| Older Adults (66+ Years) | 0.81 | 1.29 |

## 2.5 HBO MODEL

The calibration of the home based other model concluded with a large number of significant person and household characteristics that influenced trip rates. Table 10 details these trip rates.

Significantly, we found that trip rates for adults were dependent on the number of children in the household. Additionally, the trip rates are a function of household size, car ownership, household income and person characteristics such as age and employment status.

**Table 10 Person Home Based Other Trip Rates (trips per day)**

| Person Type | With No Children | | With 1 Child | | With 2+ Children | |
|---|---|---|---|---|---|---|
| | Full Time Employed | Other | Full Time Employed | Other | Full Time Employed | Other |
| Children (6-16 Years) | | | | 0.57 | | 0.57 |
| Young Adults (17-25 Years) | 0.361 | 0.726 | 0.595 | 0.96 | 0.829 | 1.194 |
| Adults (26-65 Years) | | 0.975 | | 1.209 | | 1.443 |
| Older Adults (66+ Years) | 0.207 | 0.748 | 0.207 | 0.748 | 0.207 | 0.748 |
| | | | | | | |
| **Additional Parameters (adjustments to trip rates above)** | | | | | | |
| With 1 Vehicle | +0.304 | | | | | |
| With 2+ Vehicles | +0.411 | | | | | |
| Household Size 2+ | -0.198 | | | | | |
| Household Income (000's) | +0.001 times income | | | | | |

## 2.6 NHBO MODEL

The non-home based other trip rates are shown below in Table 11. These rates were found to vary primarily with employment status, with those persons in part time employment having the highest trip rates. The trip rates for children and older adults not employed full time are significantly lower.

Trip rates also vary with location for those in Porirua, Lower Hutt and Upper Hutt and also for those persons in a household with 1 or more cars. We found that trip rates did not vary with household income or the presence of children in the household.

**Table 11 Person Non Home Based Other Trip Rates (trips per day)**

| Person Type | Full Time Employed | Part Time Employed | Other |
|---|---|---|---|
| Children (6-16 Years) | | | 0.582 |
| Young Adults (17-25 Years) | 1.157 | 1.544 | 1.110 |
| Adults (26-65 Years) | | | |
| Older Adults (66+ Years) | | 0.762 | |
| | | | |
| **Additional Parameters (adjustments to trip rates above)** | | | |
| Locations in Porirua, Lower Hutt, Upper Hutt | | -0.187 | |
| With 1 or more vehicles | | +0.287 | |

## 2.7 BU MODEL

The worker disaggregation for employers business was as that for the home based work model. The calibrated trip rates are shown in Tables 12 to 14.

**Table 12 Full-Time Worker Employers Business Trip Rates (trips per day)**

| | Paid Employee | Self Employed, Family Business and Employer of Others |
|---|---|---|
| Fixed Hours | 0.277 | 1.779 |
| Flexible Hours | 0.704 | 1.722 |
| Rostered Shifts | 0.094 | |
| Works from Home | 1.093 | |

**n Table 13 Part-Time Worker Employers Business Trip Rates (trips per day)**

| | All Workers |
|---|---|
| Part Time Workers | 0.094 |

**n Table 14 Additional Person Trip Rates (trips per day)**

| | All Workers |
|---|---|
| Employees in 1 car households | 0.158 |
| Employees in 1 car households | 0.316 |

The highest trip rates for employer's business trips are for those employees with fixed and flexible hours that are either self employed, working in a family business or an employer of others. Not suprisingly those employees who work rostered shifts (usually in the manufacturing or related industries) and part time workers have the lowest trip rates.

# 3. CAR OWNERSHIP MODELS

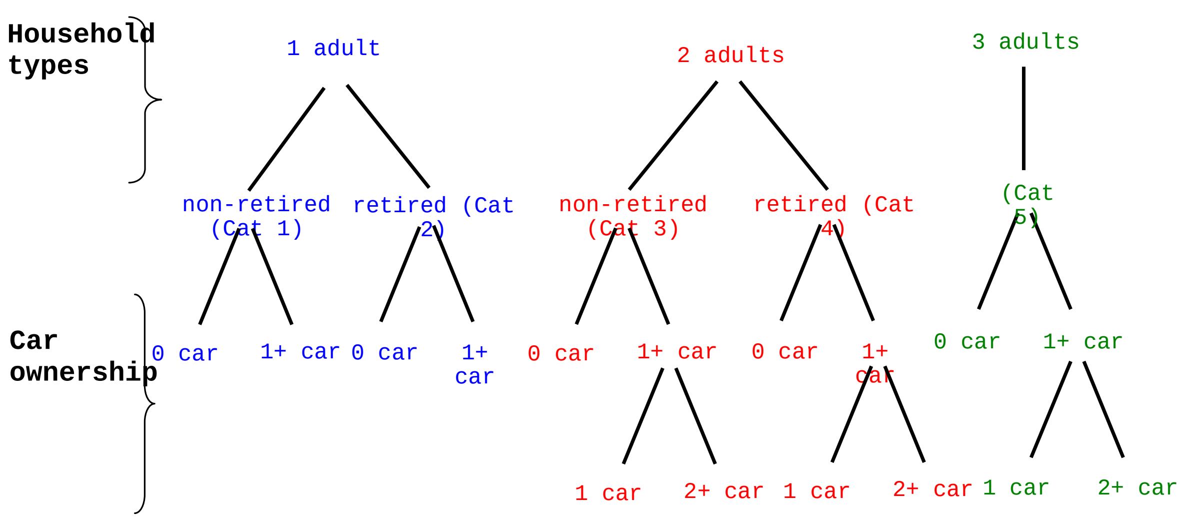
## 3.1 STRUCTURE

The car ownership model has three components:

- A disaggregate model of household car ownership;
- A process of applying the disaggregate model at zonal level and matching the base year estimates to zonal car ownership values derived from the 2001 census;
- A time series model to which the disaggregate model forecasts are controlled at a regional level.

Each component is described below, the model development benefiting greatly from the advice of John Bates and the Car Ownership Studies as part of LTS (MVA et al 1997). The structure of the disaggregate household model is illustrated in Figure 1.

**n Figure 1 Car Ownership Model Structure**



The mathematical structure is as follows:

$$P_{mhzy} = \frac{S_{mh}}{\left(1 + e^{LP_{mhzy}}\right)}$$

where:

$P_{mhzy}$ is the car ownership probability for an individual household in model *m*, household category *h*, zone *z* and year *y*; m=1 refers to the probability of owning 1 or more cars; m=2 refers to the probability owning 2 or more cars for the group of households owning at least 1 car;

$S_{mh}$ is the saturation level for each model which can be a function of the household type h,

and LP is called the linear predictor.

and:

$$LP_{mhzy} = \alpha_{mh}.f(I) + \delta_{mh} + \lambda_{hmz} + \gamma_{year}$$

where:

$\alpha$ is the coefficient of some function of household income I (either income, log income or square root of income – established through statistical analysis),

$\delta$ is a calibrated constant varying for each model and each household type,

$\lambda$ is a constant varying for each model, household type and zone that is calibrated from the second, census fitting procedure, and

$\gamma$ is a constant varying for each year that is calibrated from the third stage in the procedure, the time series model,

The $\alpha$ and $\delta$ parameters in the linear predictor have been estimated, using the maximum likelihood estimator in Limdep, on the data collected in the household survey, while the parameters $\lambda$ and $\gamma$ are externally derived.

## 3.2 1+ CAR MODELS

The 1+ car model has a saturation level of 1 and a log form of the income function. The income constant $\delta$ was held fixed across all household categories, with $\alpha$, the income parameter varying across each household category. Alternative assumptions with regards to the saturation levels and income function were tested, as was a full disaggregation of the income constant, however these calibrations were not preferred. The final calibrated parameters are shown in Table 15. There is a general trend for sensitivity to income to be higher as household size increases and also for those households with at least one employed adult (categories 1 and 3).

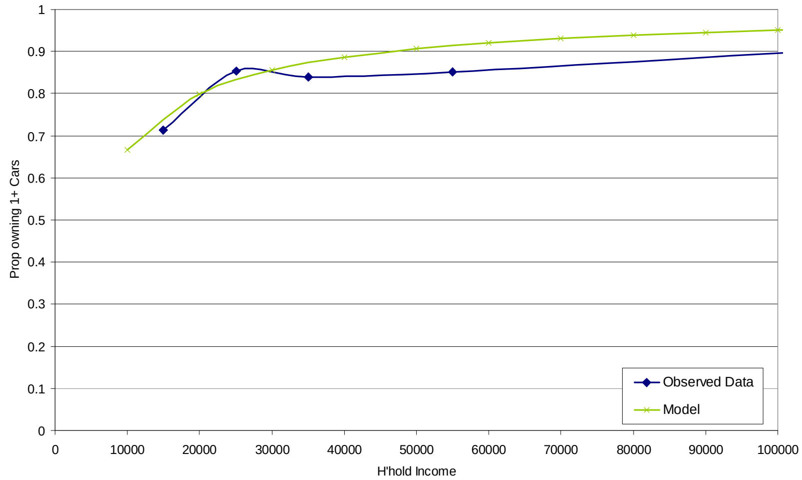
**n Table 15 1+ Car Model Limdep Calibration Results**

| | |
|---|---|
| $\alpha_1$ | -0.990(-6.23) |
| $\alpha_2$ | -0.830(-4.15) |
| $\alpha_3$ | -1.359(-9.13) |
| $\alpha_4$ | -1.307(-6.26) |
| $\alpha_5$ | -1.438(-7.28) |
| $\delta$ | 1.591(3.14) |

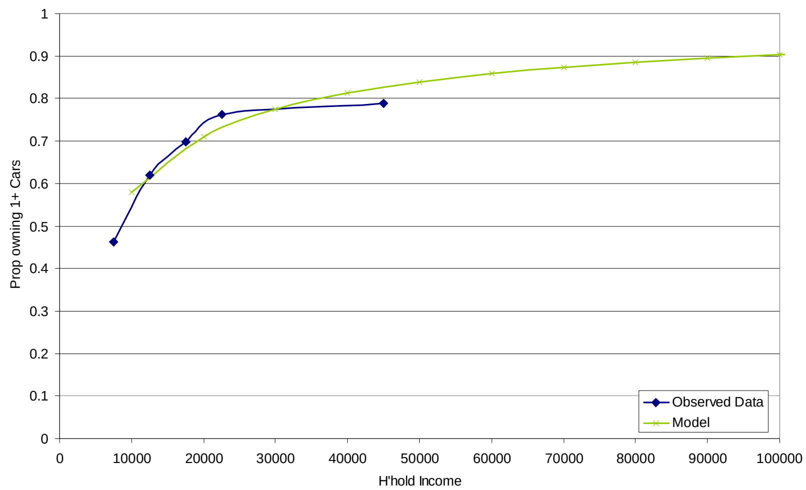
Note: Figures in brackets refer to the t-statistics from the Limdep calibration.

The fit of the model is illustrated below for each household category

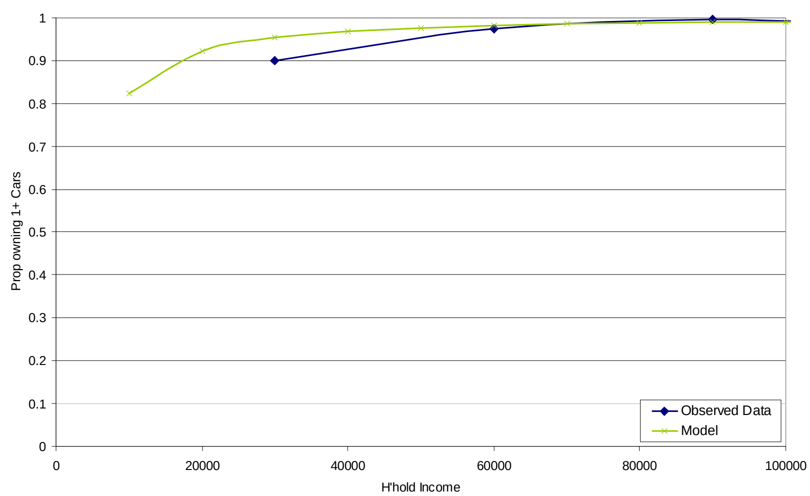
## n Figure 2 Full Models for Household Category 1



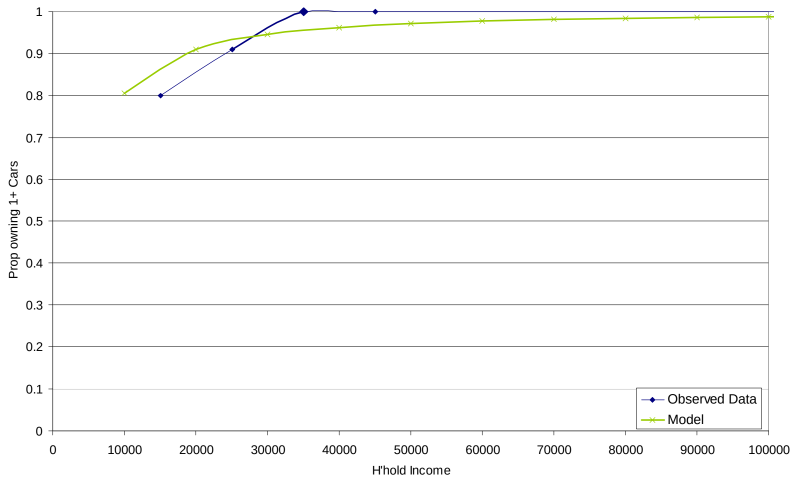

## n Figure 3 Full Models for Household Category 2



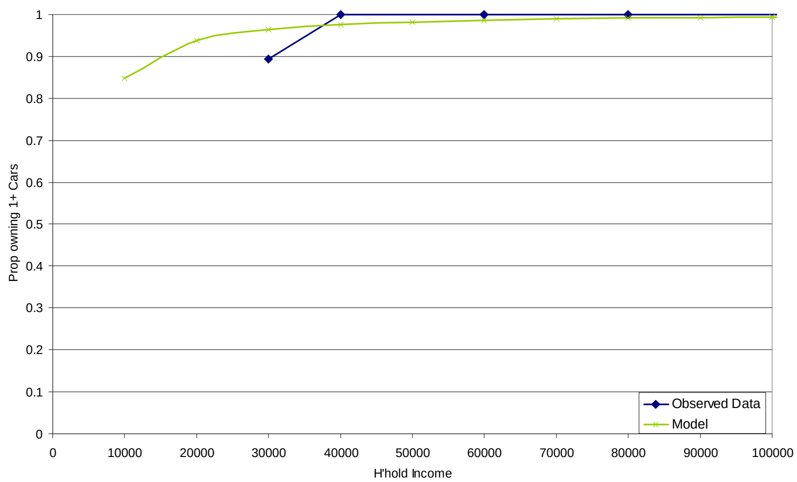

## n Figure 4 Full Models for Household Category 3



n **Figure 5 Full Models for Household Category 4**




n **Figure 6 Full Models for Household Category 5**




## 3.3 2+CAR MODELS

The choice between 1 or 2+ cars was calibrated for those households with 2 or more adults. Various saturation levels were tested for the 2+ car model, with 0.95 being adopted. For this model the linear function of income was preferred (F[I] = Income / 1000). The calibrated income parameters and constants are shown below in Table 16. The sensitivity to income is greatly reduced for category 4 (households with 2 adults, neither employed), with this parameter being not statistically significant. 3+ adult households demonstrate the highest sensitivity to income.

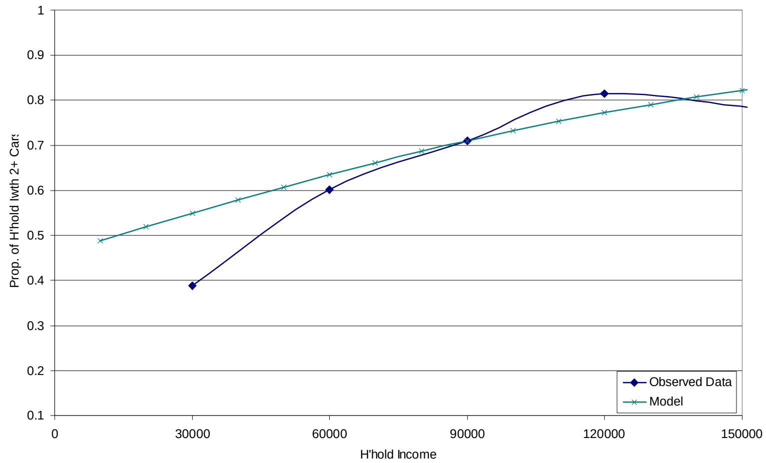
n **Table 16 2+ Car Model Limdep Calibration Results**

| | |
|---|---|
| $\delta_3$ | 0.0723(0.40) |
| $\delta_4$ | 1.0261(3.29) |
| $\delta_5$ | 1.0538(2.01) |
| $\alpha_3$ | -0.0129(-5.26) |
| $\alpha_4$ | -0.0027(-0.34) |
| $\alpha_5$ | -0.0390(-4.12) |

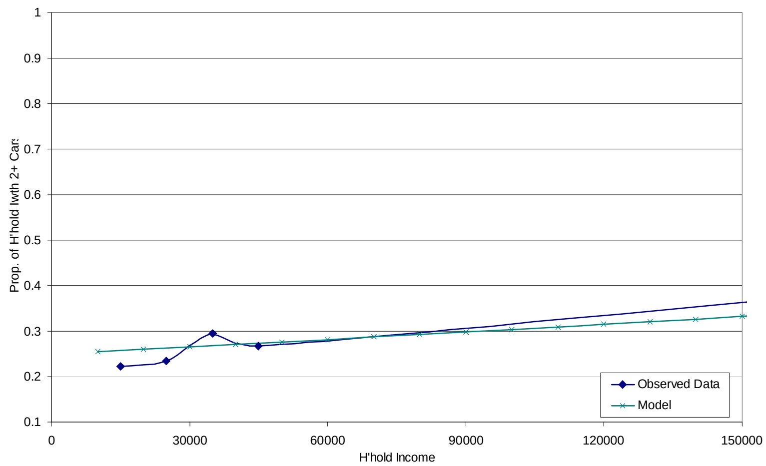
Note: Figures in brackets refer to the t-statistics from the Limdep calibration.

The model fit is illustrated below.

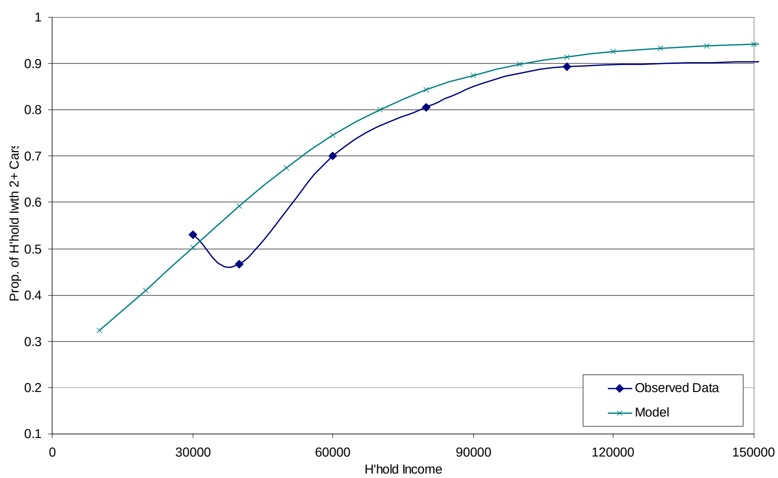
- **Figure 7 2+ Car Model for Household Category 3**




- **Figure 8 2+ Car Model for Household Category 4**




- **Figure 9 2+ Car Model for Household Category 5**



## 3.4 CENSUS FITTING

The disaggregate models detailed above were calibrated using the data collected in the household survey. Zones were classified into 50 bands according to their level of car ownership (from the census), separately for each household category and for each of the models. Within each category/model, the relevant household sample obtained in the survey was used to be a representative sample, and the census adjustment constant λ was set for each of the 50 bands such that when the car ownership model was run on the household sample it reproduced the car ownership level for the band. This process enabled the disaggregate model to be applied to produce zonal car ownership figures compatible with census (and was also the basis of the forecasting).

## 3.5 TIME SERIES MODEL

In order to develop car ownership forecasts, the linear predictor detailed above is adjusted for each forecast year in such a manner that the overall level of car ownership growth in the Wellington Region matches that predicted by a nationwide time series model (the regional average car ownership is identical to the national value). This time series model was developed in Systat, and is a function of GDP growth, car price growth and a general time trend that saturates with time (this is an update of the national model developed by Booz Allen & Hamilton, 1997). The form of this function is shown below.

$$\Delta C = \Delta GDP^{a} \cdot \Delta P^{b} \cdot (1 + g - t \cdot h)$$

where:

Δ refers to year on year change
C is cars/person
GDP is GDP/person
P is car price
t is the number of years from the start of the period
α, β are elasticites
γ, η are the time trends and incremental reductions to this time trend respectively – note that the term γ-t.η is set to 0 for all negative values.

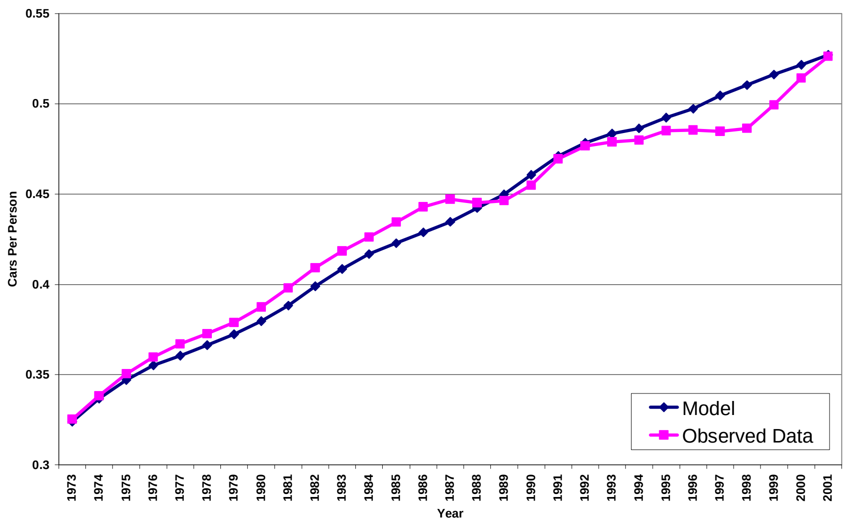
The calibration results are shown below in Table 17.

**Table 17 Time Series Model Calibration Results**

| Parameter | Value | T-Stat |
|---|---|---|
| α | 0.309 | 2.009 |
| β | -0.158 | -2.710 |
| γ | 0.0274 | 7.086 |
| η | -0.00108 | -4.299 |

The performance of this model is shown in Figure 10.

- **Figure 10 Modelled Car Ownership Levels v Observed Levels**




- Note: The plot is based upon 3 year moving averages

### 3.6 TIME SERIES AND CROSS SECTIONAL MODEL FORECASTS

The time series forecasts are used to set the $\gamma_{year}$ parameter in the linear predictor function. We found that the car ownership growth forecast by the cross-sectional model actually matched very closely the growth as predicted by the time series model. This led to very small adjustment factors for the linear predictor function in each forecast year.

### 3.7 FAMILY STRUCTURE MODEL

The trip production models are person-based, yet stratified in many cases by household characteristics such as household size, employment status and car ownership status. Hence we have developed a family structure model to transform the planning forecasts of persons by person type and households by household type to the full cross-classification required by the models. The model follows work by MVA in Scotland (MVA 1998).

## 4. CONCLUSIONS

The 2500 sample household survey has provided sufficient data (as planned) to support the statistical calibration of trip generation and car ownership models with quite detailed segmentations.

While the model is designed to accord with international good practice and, as such reflects the findings of past international research, the success of a number of innovations is worth noting.

The trip generation model is on a person basis, and significant variations in trip rates are apparent by person type in all the models. In general, after allowing for these person-type variations, there were no residual trip rate variations that were explained by household characteristics. The notable exception to this were the home based other models in which household car ownership, family size, income and the number of children in the household were also important. Car ownership is also a factor in the non home based other model.

This last characteristic should perhaps be noted: we found that persons in households with 2 or more children made more HBO trips, which does not seem very surprising.

The variations in work and business trip rates by the different types of employment and work arrangement are also noteworthy – investigating these variations was a regional council objective.

Finally, although there has not been space to dwell of it in this paper, the detailed household and person segmentations required by this model are forecast using planning data provided by MERA and a family structure model. The latter model estimates the cross-distributions of person and households in each zone, a feature missing from some NZ models of this type.

## 5. REFERENCES

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