

Use of the Auckland Land-Use Modelling Survey in Calibrating Household Location Model

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Abstract This paper reports on the Auckland Land-Use Modelling Survey (ALUMS) which was conducted as part of the Auckland Transport Models (ATM2) project. The component models within the ATM2 project are the Auckland Strategic Planning Model ASP3, run on DELTA software, and the Auckland Regional Transport Model ART3, run on EMME software. The models are strategic in nature: they model the entire Auckland Region at a relatively high level to assess regional impacts, rather than local issues. ALUMS was a Computer-Assisted Telephone Interview (CATI) survey carried out in order to collect data on actual moves and preference which could be used to calibrate the household location model which is one of the main models of ASP3. The estimated parameters include values on the number of bedrooms, accessibility, travel time to desired destinations, area quality, and rent or price of housing. Despite the limitations of the sample size and the range of variables collected, the fact that it was possible to obtain some significant coefficients of the expected signs provides some modest endorsement of the approach taken.

1. Introduction

In this introduction we explain briefly the context of the Auckland Land-Use Modelling Survey (ALUMS). The following sections describe the household location model to which it relates, the survey itself and the use of the data it yielded, and some of the results obtained from the eventual working model system.

ALUMS was carried out as part of the Auckland Transport Models (ATM2) project to develop new transportation and land use models for the Auckland Regional Council (ARC). The ATM2 project (see Feldman et al. 2009) is the first integrated model in New Zealand that incorporates land use and transport interactions in a dynamic manner over a fifty-year time period. The land-use component is known as ASP3 and the transport com-

ponent as ART3. The ATM2 project was carried out by Sinclair Knight Merz (SKM), Beca Infrastructure and David Simmonds Consultancy (DSC), with SKM as overall project managers, SKM and Beca jointly developing the transport model and DSC the land-use model.

ASP3 is a land-use model which has been developed as an application of the urban components of the DELTA package (see Simmonds 1999, Copley et al. 2000, Simmonds and Feldman 2007, Feldman et al. 2008). Its purpose can be summarized as being to forecast the pattern of land-use across the Auckland region by:

- taking account of given economic and demographic scenarios, which determine the total numbers and types of households, residents and jobs across the region;
- taking account of planning policies which determine what can be built where within the region; and
- interacting over time with the transport model, so that the pattern of land-use largely determines travel patterns and the patterns of accessibility or congestion (calculated in the transport model) influence subsequent land-uses.

The ART3 model is a transportation demand model run on the EMME package and can broadly be described as an extended, aggregate, traditional four step model. ART3 iterates until the transport supply (congestion) and demand elements converge.

The models are strategic in nature: they model the entire Auckland Region plus two small towns just to the south of the region at a relatively high (spatially aggregate) level to assess regional impacts, rather than local issues. ASP3 models the land use activities throughout the area, whilst ART3 models all trips made in an average weekday within the main urban areas, and for the remaining largely rural area models only those trips between these areas and the urban areas. Additionally, ART3 has 5 external links to the north and south of the Auckland Region. The ATM2 models' base year is 2006. Data from the 2001 and 2006 Censuses and from specially commissioned surveys conducted in 2006 were used in their development.

The objectives of ALUMS were to help to calibrate the modelling of household choices about whether to move and where to move, and to a lesser extent to inform the modelling of individual choices about whether and where to work. The central purpose of ALUMS was therefore to col-

lect data on actual and firmly planned¹ future moves which could be used to calibrate the ASP3 household location model.

A widely recognized problem in the calibration of this kind of model is the correlation between the independent variables - in particular, the best dwellings tend to be found in the most attractive areas and command the highest prices. This poses major problems in the estimation process. We adopted the standard solution to this, which is to supplement Revealed Preference (RP) data (observed choices) with Stated Preference (SP) experiments in which respondents are asked to state what choice they would make between hypothetical choices (in this case alternative locations or dwellings), the hypothetical alternatives being constructed so that the critical factors vary independently.

2. Household Location Modelling in ASP3

2.1 Modelled area

The ART2 models the entire Auckland Region which is one of the sixteen regions of New Zealand, centred on the New Zealand's largest city – Auckland. The region is the most prosperous and populous region of New Zealand, with a population of 1,414,800 (June 2008 estimate), which is about 33% of the country's population. The Auckland Region is under the jurisdiction of the Auckland Regional Council and of the seven Territorial Local Authorities, four cities (Auckland City, Manukau City, North Shore City and Waitakere City) and three districts (Rodney, Papakura and the northern half of the Franklin District). The zone system consists of 512 internal zones, see Fig.1.

¹ “Firmly planned” meaning that the interviewee could provide details, including price or rent, of the specific dwelling to which his/her household would be moving.

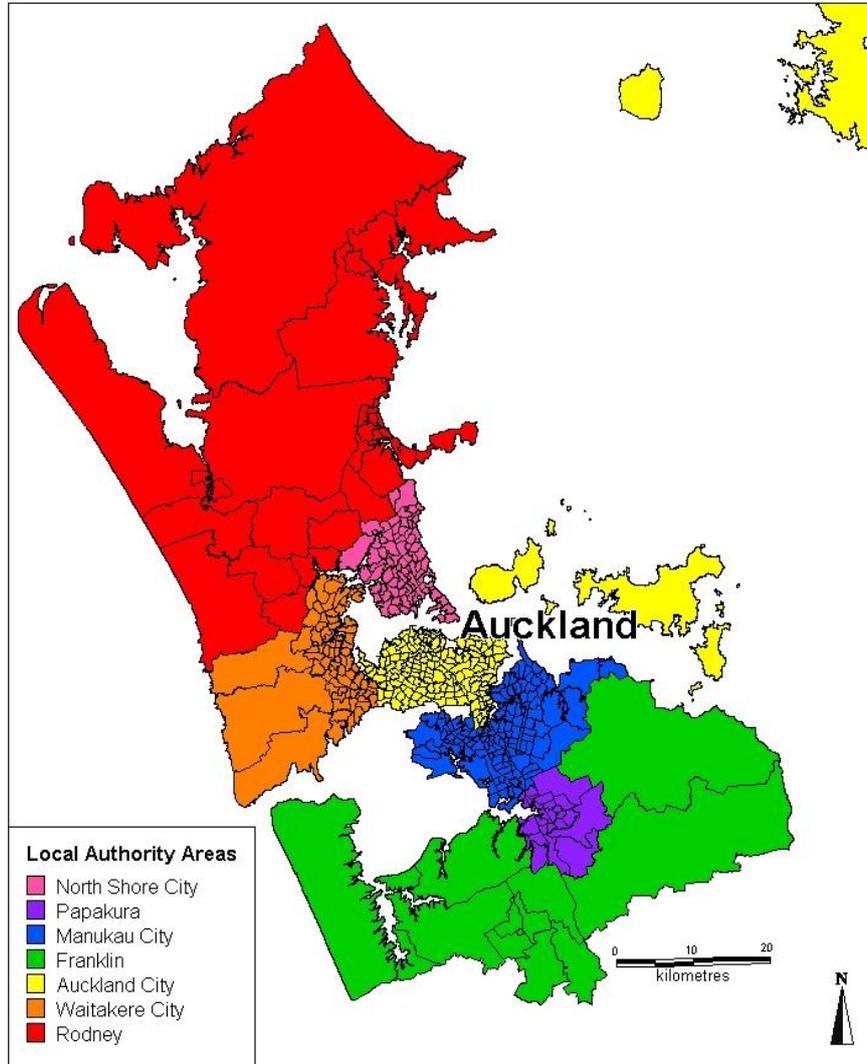


Fig. 1. ART2 zones and Local Authority Areas (approximate).

2.2 Overview of the ASP3 Land-Use Model

The ASP3 model consists of the original five urban (or zonal) sub-models of the DELTA package, namely, the transition and growth sub-model (dealing with demographic change and employment growth), the employment status and commuting sub-model, the development sub-model, the area quality sub-model, and the location and property market sub-model

which deals with the interaction of space and activities. The main linkages between the sub-models within a one-year period are shown in Fig 2.

The modelling of households and their members is based on the approach of modelling the different kinds of choices that they make which are of concern in forecasting urban and transport change. The modelling also recognizes the importance of some effects which are not choices at all (ageing being the prime example) and that other actors' choices have impacts on households (such as losing jobs because employment has declined or moved away).

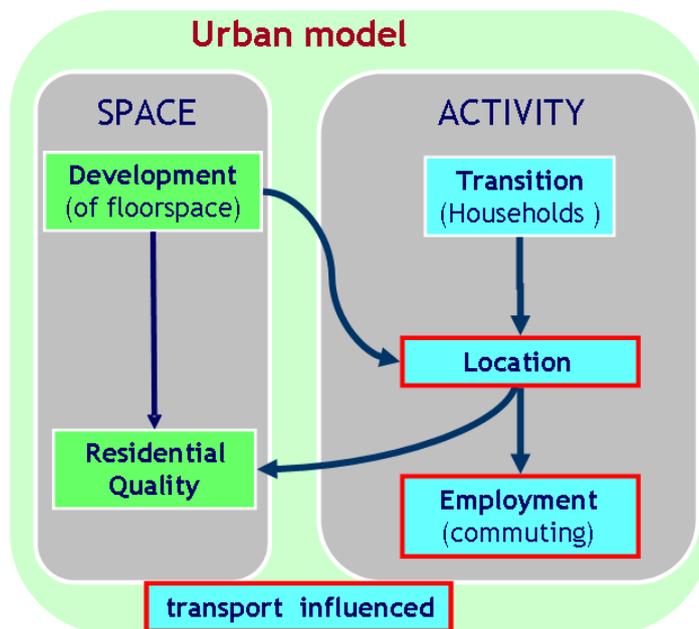


Fig. 2. Linkage of DELTA submodels in one year of ASP3.

The transition sub-model forecasts household changes over time (each year) between the modelled household types. The rates of change are fixed as part of the process of setting up the demographic scenario. This part of the model also deals with migration to and from the modelled area and forecasts how many households are considering moving, how many have to locate anew (new arrivals and new households), and how many are not moving at all.

The location model allocates households to housing and jobs to employment floorspace. The household location sub-model forecasts where

households which have to locate, or are looking to relocate, will move to. This model is discussed in more detail in the next section.

The employment status and commuting sub-model adjusts how many of the household members are in work and where they work to reflect the changing patterns of labour demand and of accessibility to work. In order to maintain consistency with the exogenously specified economic scenario, the model ensures that all jobs are filled. A separate sub-model adjusts the commuting pattern in response to changes in generalised costs of travel.

ASP3 also includes zonal data on persons who are not in households. Their numbers change over time, but the model does not attempt to represent any choices they make.

ASP3 does not explicitly represent firms: it represents employment in sectors and treats the Auckland Region as a single local economy. The treatment of employment consists of the application of growth rates, derived from the overall scenario, to the employment in each sector in the region, and the employment location sub-model, which is broadly similar to that for households.

All of these sub-models are run in each year. Note that only the employment status/commuting model involves an instantaneous response to the employment location modelling (because it is assumed that the number of workers going to work must match the jobs available in each year); all other responses to employment location are gradual and time-lagged ones.

The model of development is a top-down one which assumes that total amount of development of each type of floorspace varies in response to recent demand, and that the development sector collectively seeks to build this quantity of floorspace where rents are attractive and where planning policy allows. The demand and rent information is endogenous to the model and derived from the outputs of the household and employment location models. There are time lags from when development is modelled as “starting” to when it is “complete” and available to activities (households, employment) to occupy. Planning policy is assumed to exercise very strong control: development of the type permitted can take place up to the quantity permitted, but no more.

There is also a model of changes in housing quality which reflects the way in which the occupiers of housing can influence its qualities. The hypothesis is that high-income occupiers will tend to improve housing and the immediate environment, whilst low-income occupiers will tend to let it decline (if only from lack of money for maintenance). These changes then affect the willingness of movers to move into different areas, tending to create a virtuous circle in areas that are getting better and a vicious circle in those that are declining.

2.3 ASP3 Dimensions

The model's level of complexity and the segmentation of the region's activities are illustrated in Table 1.

Four person-types - children, working adults, non-working non-retired adults, and retired adults - are modeled. The split between working and not-working for non-retired adults is directly related to the demand for labour. Households are classified by composition, socio-economic group, age (in some cases, mainly to identify those most likely to produce children), and number of workers. The 11 household composition categories were defined on the basis of the information available from the New Zealand 2001 Census. These are:

- persons sharing – this category tries to identify groups of people who are sharing but have no other relationship;
- younger singles – persons aged under 45 who may go on to become younger couples or single parents,;
- younger couples – typically male + female, aged under 45;
- couples with children;
- single parents, i.e. one adult with one or more dependent children;
- 3+ adults with dependent children – typically couples with mixture of “grown up” and dependent children;
- 3+ adults – including couples with children who are all grown up (i.e. not dependent);
- older couples – both aged 45 or over and not retired, also including non-couple two-person households both over 45 and both not retired, not elsewhere specified;
- older singles – aged 45 and over and do not fit the definition for retired single person;
- retired couples – both household members fit the person type definition of being retired, also includes non-couple two person households who are both retired;
- retired singles – person type definition is retired.

Table 1. ATM2 dimensions

Dimension	Number	Description
Zones	512	Common system in ATM2
Household socio-economic groups (SEG)	4	Professional, technicians, clerks/sales, production
Worker socio-economic groups (SEG)	4	As above
Person types	4	Child, worker, non-worker, retired
Car ownership levels	4	0, 1, 2, 3+ cars per household

Modes	3	Car, Public Transport, Walk
Accessibility types in the land-use model	3	HBW, HBO, EB
Household composition types	11	E.g. Persons sharing, retired
Total household type combinations	136	Composition x SEG x workers per household
Employment activities	17	E.g. Retail trade, hospitals
Floor space categories	11	E.g. Housing, retail, office

2.4 Household Location Model: Design

The household location model only operates on those households which are defined as “mobile” or “pool” by the transition model. The majority of households are immobile in any one year. The ‘pool’ households are those that do not have a previous location (i.e. they are newly formed households or new in-migrants to the area), the ‘mobile’ households are moving households with a previous location within the area. The location model calculations are slightly different for these two groups

The pool households are located by the formula:

$$H(LP)_{pi}^h = H(P)_{pa}^h \cdot \frac{H(XA)_{pi}^h \cdot \exp(\Delta V_{pi}^h)}{\sum_i H(XA)_{pi}^h \cdot \exp(\Delta V_{pi}^h)},$$

where $H(LP)_{pi}^h$ are the “pool” households of type h locating at i in period p ; $H(P)_{pa}^h$ are the “pool” of households type h to be located in area a in period p (resulting from the transition model); $H(XA)_{pi}^h$ is the “expected” number of households of zone i in available housing (new, vacant or vacated-by-mobile-households) during period p in zone i ; ΔV_{pi}^h is the change (over a number of previous years) in the utility of location of zone i influencing households type h locating in period p .

The “expected” number of households is calculated from the available housing space and serves as a sophisticated form of “size” term. Mobile households are located by a very similar formula, the difference being that in the absence of change, mobile households will tend to remain where they are, whilst pool households will tend to locate where households of the same type were previously located:

$$H(LM)_{pi}^h = \left[\sum_i H(M)_{pi}^h \right] \left\{ \frac{H(XA)_{pi}^h \cdot \exp(\Delta V_{pi}^h)}{\sum_i H(XA)_{pi}^h \cdot \exp(\Delta V_{pi}^h)} \right\},$$

where

- $H(LM)_{pi}^h$ are “mobile” households of type h locating at i in period p ;
- $H(M)_{pi}^h$ are “mobile” households type h initially located in zone i ;
- $H(XA)_{pi}^h$ is the “expected” number of households of zone i in available housing (new, vacant or vacated-by-mobile-households) during period p in zone i ;
- ΔV_{pi}^h is the change in the utility of location of zone I for households type h locating in period p , as for pool households.

The change in utility of location is calculated as the weighted sum of changes over time in five different variables, as follows (the timelags are explained below):

$$\Delta V_{pi}^h = \theta_p^{hC} (a_{pi}^{hH} \cdot r_{pi}^H - a_{(tB(U))i}^{hH} \cdot r_{(tB(U))i}^H) + \theta_p^{hF} (a_{pi}^{hH} - a_{(tB(U))i}^{hH}) \\ + \theta_p^{hA} (A_{(tA(A))i}^h - A_{(tB(A))i}^h) + \theta_p^{hQ} (Q_{(tA(Q))i}^h - Q_{(tB(Q))i}^H) + \theta_p^{hR} (R_{(tA(R))i}^h - R_{(tB(R))i}^h)$$

where:

- ΔV_{pi}^h is change in utility of locating at i affecting location of households h during period p ;
- θ_p^{hF} is a coefficient on floorspace per household for households type h in period p ;
- θ_p^{hC} is a coefficient on cost of location consumption for households type h in period p ;
- θ_p^{hA} is a coefficient on Accessibility for households type h in period p ;
- θ_p^{hQ} is a coefficient on Quality for households type h in period p ;
- θ_p^{hR} is a coefficient on environment for households type h in period p ;
- r_{pi}^H is cost of location for households type h locating in zone i in period p (calculated from rent and floorspace per household in current period, and revised as rent is adjusted in iterating the model)
- $r_{(tB(U))i}^H$ is cost of location for households type h locating in zone i at time $(tB(U))$;

- a_{pi}^{hH} is floorspace per household type h locating in zone i in period p (function of rent in the period);
 $a_{(tB(U))i}^{hH}$ is floorspace per household type h locating in zone i at time $(tB(U))$;
 $A_{(tA(A))i}^h$ is accessibility of zone i for households type h at time $(tA(A))$;
 $A_{(tB(A))i}^h$ accessibility of zone i for households type h at time $(tB(A))$;
 $Q_{(tA(Q))i}^H$ is quality of housing areas in zone i at time $(tA(Q))$;
 $Q_{(tB(Q))i}^H$ is quality of housing areas in zone i at time $(tB(Q))$;
 $R_{(tA(R))i}^h$ is transport-related environmental quality as perceived by households type h in zone i at time $(tA(R))$;

The cost of location is the rent r_{pi}^H multiplied by the space a_{pi}^{hH} per unit activity: $c_{pi}^h = a_{pi}^{hH} \cdot r_{pi}^H$, where the space per household is in turn calculated by

$$a_{pi}^{hH} = q_i^{hH} \left[b_p^{hH} + \frac{\alpha_p^{hH} (y_p^h - b_p^{hH} \cdot r_{pi}^H - b_p^{hO})}{r_{pi}^H} \right]$$

Where

- q_i^{hH} is an adjustment factor, reconciling densities and rents in the base period;
 y_p^h is income of households type h during period p ;
 r_{pi}^H is rent per unit of housing floorspace.

2.4 Household Location Model: Coefficients

The inputs to the household location model consist of

- household incomes, which are part of the economic/demographic scenario (and are also used in the car-ownership model);
- utility of consumption coefficients (the minimum floorspace per household and the proportions of remaining income spent on floorspace or on other goods and services);
- utility of location coefficients (coefficients on rent, accessibility,

housing quality, environment and floorspace).

The mobility rates have been calibrated so that, together with households which are mobile because they are newly-formed, newly-arrived (from outside the Modelled Area), have changed composition or changed employment status, approximately 25 percent of households are mobile in each year. In addition to this we have calibrated the model such that the general trends of single, young and sharer households being more mobile and couples with children households being least mobile are reflected in the model.

For the utility of consumption variable, the change to which households respond is from N years ago to the present (so that the change is affected by the current rent values, which are found within the location model); for all other variables, the change is from N+1 years ago to the previous year (ie the database at the beginning of the present period).

The coefficients in the household utility of location function are used to scale changes in the modelled variables. These changes are measured over a number of years related to the typical movement frequencies of different kinds of households. The coefficients were informed, though not finally determined, by the analysis of the ALUMS survey, commissioned by ARC specifically to inform the calibration of ASP3. That analysis is described in the following chapter.

3. Auckland Land-Use Modelling Survey

3.1 Objectives

The objectives of the survey work in relation to location choices were originally defined as being to identify the most appropriate measures of some of the variables used in the location model, particularly the measures of accessibility and of quality, and to estimate the importance of each of the variables in the location/relocation model. Part of the objective was therefore to obtain data for a sample large enough to support some segmentation, though it was recognized from the outset that it would be unrealistic to attempt to obtain separately estimated coefficients for anything like all 136 ASP3 household activities.

3.2 Survey Data and Executions

ALUMS was a Computer-Assisted Telephone Interview (CATI) survey, designed by TUTI and carried out by the I-view Head Office in Melbourne, Australia. It was intended as a follow-up to the 2006 Auckland Household Travel Survey (AHTS), the main target population being AHTS respondents who had either

- recently moved house,
- had indicated an intention to move house in the next 12 months, or
- had indicated an intention to change job location in the next 12 months.

In addition, a number of households with “non-movers” were selected from the AHTS respondents, to provide a control sample.

The Auckland Household Travel Survey is a survey of a day-to-day travel being conducted in the Greater Auckland Region over a two-month period May to June 2006, and a small Pilot Survey was also carried out in April 2006. AHTS obtained responses from 6000 households. The main ALUMS fieldwork ran from 7 December through 19 December 2006. Because there was a substantial the delay between the AHTS fieldwork and the ALUMS fieldwork many intending movers identified in AHTS were lost from the ALUMS sample because they had moved as planned. Additional respondents were recruited by random telephone calls in regions of the Study Area that had been shown in the AHTS survey to have a higher probability of household or job movers.

In total 15,133 phone numbers were attempted, and of the 4106 respondents, 2605 completed one or more sections of the questionnaire. There were 688 recent movers and 313 planning to move respondents. 1001 people answered the Stated Preference section of the survey. Given that the survey was a CATI survey, all coding was done online at the time of the interview, using the SurveyCraft software system.

3.3 Data Received

The data sets were provided as Excel spreadsheets. The following data was collected:

- household size (number of people);
- number of people in full-time, part-time, casual work, homemaker, unemployed, retired or other activities; number of children in not yet in school, in primary and secondary education; number of people in full and part time tertiary and other education; some

people indicated more than one activity and therefore quite often the total number of household members involved in different types of work or educational activities appeared greater than the household size;

- car ownership (number of vehicles in a household);
- their current suburb (coded only in terms of eleven areas: Rodney, North Shore North, North Shore South, Auckland Central, Waitakere North, Waitakere South, Howick, Flat Bush, Mangere, Papakura and Franklin);
- for households who had moved, their previous suburb; for households planning to move, their future suburb (likewise only to eleven sectors);
- number of rooms and bedrooms for old and new locations;
- perceptions of dwelling suitability, area quality, accessibility on a range 0 to 11 for the current and previous locations;
- price or rent for both locations and in case of rent, rental period (per week, per month, etc) for the new location (note that the money rents were not always plausible for the periods reported, and it was not always possible to assume that those periods were applicable to the previous locations, also there were lots of cases when households moved from renters to owners and therefore the rental periods were not specified).

The major problem of the ALUMS survey was that addresses of “previous dwelling” and “intended future dwelling” were not recorded in full and hence these locations (and the current location) could not be converted into ASP3/ART3 zones. This in turn meant that it was impossible to attach ART3-estimated data to the records, and limited the analysis to using the data collected directly from the survey itself.

4. ALUMS Analysis

4.1 *Stated Preference (SP) Analysis*

Stated preference (SP) analysis generally makes it possible to obtain very much more information from each respondent, including multiple responses to different choice situations and reactions to combinations of attributes that are unobserved in revealed preference data. The following trade-offs were offered in the SP part of ALUMS:

- one more/less bedroom but the average time to go to places you want is higher/lower (by 5 or 10 min);

- one more/less bedroom but the purchase price is higher/lower (by 10, 000\$; 20,000\$ or 30,000\$).

The model tested in SP exercise was a simple binary logit model of household choices between the desired – choice location and the alternative one. This model was run in BIOGEME² separately for owners and renters for full sets of data and for the data subsets. It uses a dataset of 2496 observations for owners and 1200 for renters; the sizes of the subsets vary a lot. For each household, a number of bedrooms, rent and time for a “chosen” and a “rejected” dwelling are collected.

The explanatory variables for the model, and the deterministic utility specifications for owners are:

$$V_{choice} = \beta_{bedroom} \cdot Bedroom_{choice} + \beta_{time} \cdot Time_{choice} + \beta_{cost} \cdot Cost_{choice}$$

$$V_{alt} = \beta_{bedroom} \cdot Bedroom_{alt} + \beta_{time} \cdot Time_{alt} + \beta_{cost} \cdot Cost_{alt}$$

And for renters:

$$V_{choice} = \beta_{bedroom} \cdot Bedroom_{choice} + \beta_{time} \cdot Time_{choice} + \beta_{cost} \cdot Rent_{choice}$$

$$V_{alt} = \beta_{bedroom} \cdot Bedroom_{alt} + \beta_{time} \cdot Time_{alt} + \beta_{cost} \cdot Rent_{alt}$$

An example of the data file is given in Fig.3 where the first three and the last three rows of the complete file are shown.

Case	Choice	ChoiceBedrooms	ChoiceTime	ChoiceCost	AlternativeBedrooms	AlternativeTime	AlternativeCost
20	1	1	5	0	-1	-5	0
20	1	-1	0	-30000	1	0	30000
20	1	0	10	-20000	0	-10	20000
6069	1	-1	-5	0	1	5	0
6069	1	1	0	10000	-1	0	-10000
6069	1	0	-5	30000	0	5	-30000

Fig. 3. Examples of data file

Each row in the data file after the header line corresponds to one observation. The first column *case* contains a unique identifier of the household. The column name *Choice* shows which alternative has been chosen, it is always 1 in these tests – the chosen alternative. The other six columns con-

² BIOGEME (Bierlaire's Optimization Toolbox for GEV Model Estimation) is an object-oriented open source software package designed by Prof. M. Bierlaire for the maximum likelihood estimation of Generalized Extreme Value (GEV) models.

tain the values of the alternative attributes: bedrooms (1 means one more bedroom, -1 – one less and 0 – this question was not asked), time (5 or 10 minutes more if positive or less if negative of travel to the desired destinations, 0 if the question was not asked) and cost (or rent for renters) (10 000\$, 20 000\$ or 30 000\$ more or less).

The following tests were completed for owners and renters separately:

- Full data set;
- Households with children only;
- Households without children;
- Single person households with and without children;
- Couples with and without children;
- 3+ adults with and without children;
- Single person households with and without children 0 workers, 1 worker;
- Couples with and without children 0 workers, 1 worker, 2 workers;
- 3+ adults with and without children, 1 worker (no data for renters without children), 2 workers, 3+ workers; no tests were set up for 3+ adults with and without children with 0 workers as either no or very few cases were available.

The total number of tests we set up was 50. Unfortunately for quite a number of tests some or all estimation results were statistically insignificant or did not look plausible. Therefore only results for renters all, with and without children were used in the location model calibration. The estimation results for these three tests are presented in Table 2 to Table 4.

Table 2. Estimation results: renters all, 1200 observations

Name	Value	Standard error	t-test	p-value
$\beta_{bedroom}$	0.854	0.0835	10.23	0.00
β_{cost}	-0.0243	0.00355	-6.84	0.00
β_{time}	-0.0583	0.0102	-5.70	0.00

Table 3. Estimation results: renters with children, 600 observations

Name	Value	Standard error	t-test	p-value
$\beta_{bedroom}$	1.05	0.126	8.36	0.00
β_{cost}	-0.0326	0.00517	-6.30	0.00
β_{time}	-0.0705	0.0152	-4.64	0.00

Table 4. Estimation results: renters without children, 600 observations

Name	Value	Standard error	t-test	p-value
$\beta_{bedroom}$	0.667	0.113	5.93	0.00
β_{cost}	-0.0159	0.00500	-3.18	0.00
β_{time}	-0.0462	0.0140	-3.30	0.00

4.2 Revealed Preference (RP) Analysis – Samples of Alternatives

We have done a set of tests with revealed preference data by drawing a sample of alternatives in addition to the chosen alternative. It would seem that a simple random sample is not necessary for an efficient scheme because, for any given decision maker with a large choice set, the majority of the alternative may have very small choice probabilities. It may be more efficient to design a sample of alternatives in which the most likely to be chosen by the decision maker have a higher probability of being selected.

Therefore, in the ALUMS analysis we tested the following alternatives sets separately for owners and renters, in all of which the first alternative was the chosen alternative:

- 10 random alternatives;
- 10 alternatives selected by the households of the same size;
- 5 alternatives selected by households from the same suburb;
- 5 alternatives of a 10% price or rent range from the chosen alternative.

In different tests the chosen variables were rooms or room stress (defined as the number of people per room), price or rent, accessibility and area quality.

A multinomial logit model was built and estimated using BIOGEME software. The analysis of the RP data was done as a first step and not used in the model calibration, and later the SP and RP data sets were combined.

4.3 Joint SP/RP Analysis

This analysis deals with the simultaneous estimation of a nested logit model with 2 nests from revealed and stated preference data. The structure of the model is shown in Fig.4. Chosen and rejected stated preference alterna-

tives are both assigned to the same nest and the revealed preference alternatives still in the multinomial logit model structure.

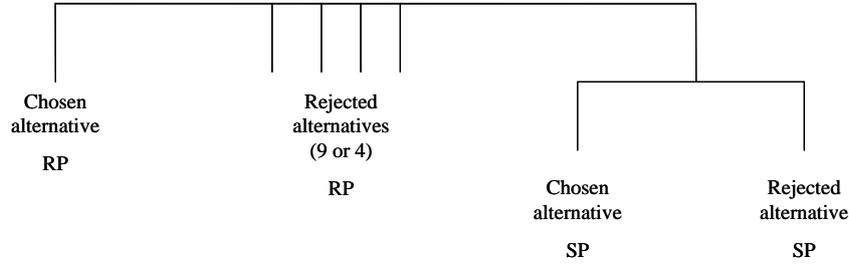


Fig. 4. Structure of the SP/RP model

The tests which were carried out with the combined SP and RP data are similar to those described in the previous section. The best results are found with the RP alternatives selected from the alternatives by households of the same size (10 alternatives).

The expressions of the synthetic utility functions for each alternative used in this model specification are

$$V_1 = \beta_{bedroom} \cdot Room_1 + \beta_{access} \cdot Acc1 + \beta_{area_quality} \cdot AreaQ1 + \beta_{rent} \cdot Rent1$$

...

$$V_{10} = \beta_{bedroom} \cdot Room10 + \beta_{access} \cdot Acc10 + \beta_{area_quality} \cdot AreaQ10 + \beta_{rent} \cdot Rent10$$

$$V_{11} = \beta_{bedroom} \cdot Bedroom_{choice} + \beta_{time} \cdot Time_{choice} + \beta_{rent} \cdot Rent_{choice}$$

$$V_{12} = \beta_{bedroom} \cdot Bedroom_{alt} + \beta_{time} \cdot Time_{alt} + \beta_{rent} \cdot Rent_{alt}$$

The estimated parameters including the nest parameter $SPnest$ are shown in Table 5. All the estimated coefficients have the expected sign, namely positive for accessibility, area quality and floor space (extra room for RP or bedroom for SP questions) indicating that the better the accessibility, area quality or the more spacious the house is, the higher the utility, and negative for cost of floor space and time of travel to the desired destinations indicating that the higher the cost or time, the lower the utility. Finally, the scale parameter of the random term associated with the SP nest has been estimated as $SPnest = 146$. The t -statistic with respect to 1 is also output from BIOGEME and is equal to 3.31, which indicates that $SPnest$ is significantly different from 1.

Table 5. Estimation results: all renters, SP and RP alternatives for households of the same size, 2076 observations

Name	Value	Standard error	t-test	p-value
β_{access}	0.0572	0.0192	2.99	0.00
$\beta_{area_quality}$	0.0923	0.0184	5.03	0.00
β_{rent}	-0.000163	4.35e-005	-3.75	0.00
$\beta_{bedroom}$	0.00564	0.00156	3.61	0.00
β_{time}	-0.000385	0.000110	-3.5	0.00
SPnest	146	44	3.31	0.00

4.4 Conclusion on Joint SP/RP Analysis

Despite the limitations of the sample size and the range of variables collected, the fact that it was possible to obtain some significant coefficients of the expected signs provides some modest endorsement of the approach taken.

Nevertheless the fact that the useable results were obtained only from a small part of the sample, and that these results implied implausible levels of insensitivity to change when tested in the working model, meant that significant adjustments were required, as discussed below.

4.5 Adjustments and Other Coefficients

The results of the RP tests for all renters, renters with children and renters without children as well as the results of the combined SP/RP test for all renters with alternatives based on those selected by households of the same size were used setting initial values for the location model cost and floor-space coefficients.

To estimate the coefficients for the 136 households activity types we

- used the activities incomes as weights: for each activity the thetas from the combined SP/RP test were scaled to the ratio of the activity income as a proportion to the average household income;
- adjusted the new thetas so that the average thetas weighted by the total number of households in each activity are equal to the SP/RP thetas;
- scaled the floorspace thetas obtained above by with/without children weights obtained from the SP analysis. The following weights were used: 1.225426 for households with children, 0.763445 for

households without children, 1 for older couples as they have significant number of children. The weights were calculated as the ratios of β_{rent} parameters estimated for SP tests renters with and without children to the beta cost parameter estimated for SP test all renters (see Table 1- Table 3).

However, the resulting values tended to produce implausible non-responsive results to transport change when tested in the model, and a limited amount of adjustment was undertaken to scale the theta values to obtain more reasonable results. The coefficients for quality and environment were added by reference to the implied willingness-to-pay per unit of these variables.

5. Scenario Assumptions and Future Planning Inputs

5.1 Economic and Demographic Scenarios

The economic scenario is defined mainly in terms of employment growth by sector. This is input to the model as an overall growth rate for each sector in each year; the resulting totals of employment for the whole modelled area are shown in Figure 5. It can be seen that steady and substantial growth of total employment is assumed, almost exactly doubling the numbers of jobs (+99%) over the forecast period. The other key input defining the economic scenario is that of household income growth, which is set at +1% per year for all household types. This is real growth in net incomes (after taxes or subsidies).

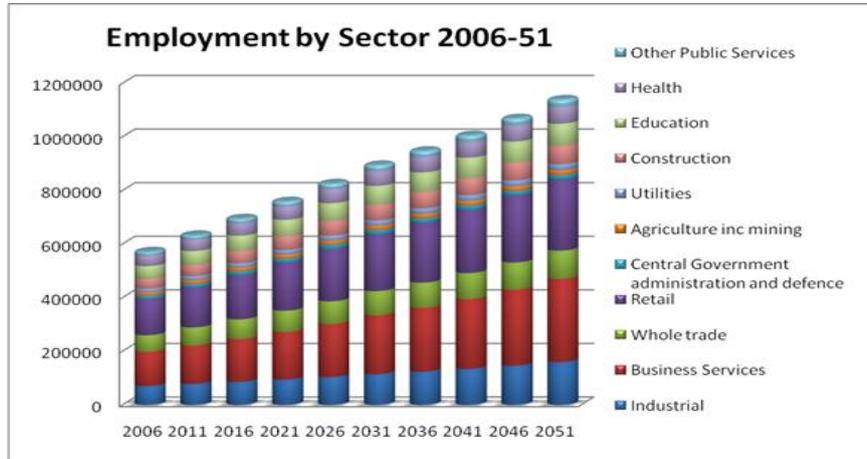


Fig. 5. Employment by employment sector

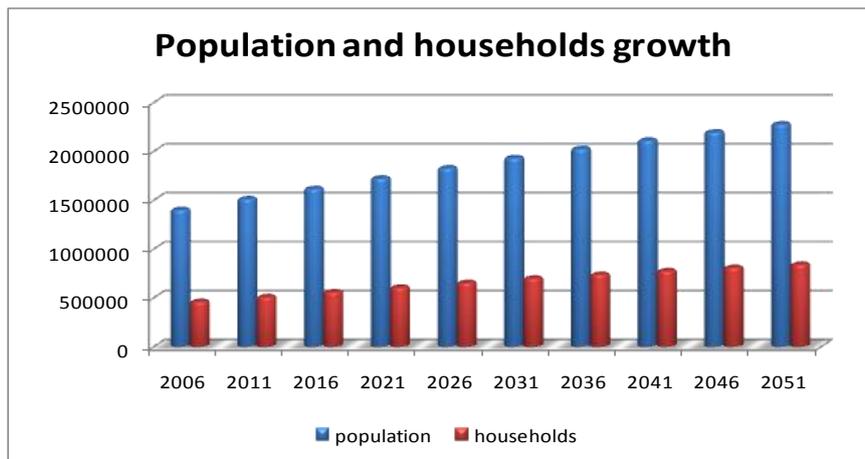


Fig. 6. Population and households growth

The demographic scenario is implemented in the model by a fairly complex process of modelling household changes; this is necessary to provide both the numbers of new and existing households by composition, socio-economic status etc, which influence mobility and residential preferences in the household location process, and the numbers of persons as input to the travel demand modelling. These inputs have been implemented so as to reproduce, as closely as practical, the Medium-Growth scenario

defined by ARC. The output numbers of persons and households are shown in Figure 6. (Note that the values are shown only at five-year intervals, but are calculated for each year.) The numbers of children increase (in the model output) by 29%, working-age persons by 49% and retired persons by 229%. The differences in growth between children, working-age and retired are a feature of the target scenario that the model was calibrated to match.

5.2 Land use Planning Policy Inputs

Land-use planning policy is input to the model mainly in terms of the amounts of development by type permitted in each zone at any time; construction is forecast by the model itself. These “permissible development” inputs define how much floorspace the modelled development processes can build. Permissible development that is input but not immediately used is carried forward to the next year and remains available until used. The permissible development figures are assumed to represent absolute controls that the modelled quantity of development should not exceed.

Permissible development was estimated from information about local authority policies for residential, retail, office, industrial and warehouse floorspace types. Residential development is split into two categories: “typical density” development (with an average size of a dwelling of 198m²) and “higher density” development (with an average size of a dwelling of 95 m²). For other types of development (preschool and primary education, secondary education, tertiary education, hospitals, medical practices, and public service/other floorspace), the development processes are not modelled; instead increases in floorspace supply are directly input to the model. Changes in primary and secondary education floorspace up to 2012 were based on information supplied by the Ministry of Education. Beyond 2012, and for the other floorspace types listed above, the total growth in floorspace was assumed proportional to the growth in employment, and this growth was distributed to zones in proportion to the existing stock.

6. ASP3 Forecasting Results

In looking at a single test, especially one where the underlying scenarios involve very substantial growth, the future location patterns of households and jobs within one urban area are likely to be most strongly influenced by

the availability of housing and of the various types of non-residential floorspace. We therefore consider

- housing development and the distribution of households;
- non-residential development and the distribution of employment,
- and then, in this particular case, the levels of accessibility resulting from these patterns of location together with the transport supply.

The changes in the distributions of households and jobs are strongly influenced by the location of new floorspace, which in turn is (in the long run) wholly constrained by the planning policy. The general pattern of location is that the majority of the growth is accommodated within or very close to the existing urban area though in some zones of the more rural parts of the region there is a high relative level of growth.

A general point to note about the development processes is that practically all of the permissible development is built, and the rates of development vary enormously, from no new development at all to the very high rates of development (mainly in zones which have very little housing at present). There are very substantial amounts of additional housing in the Central Isthmus, particularly in and around the Auckland CBD, with a higher proportion of the remainder in the existing areas immediately south and north/west of the Isthmus. There are also some significant quantities of new housing further afield, particularly to the north, but in general the pattern of changes in housing supply is consistent with moves to resist further sprawl of the Auckland urban area. As one would expect, housing development is not entirely prevented in the largely rural zones, and some of them (including a large block of zones to the north, and those in the south-west and south-east extremities of the modelled area) are shown to have housing supply more than doubling over the 45 years, but it these represent a very small proportion of the overall increase forecast.

As for housing, the relative increases in total employment floorspace show a range of values from tens to thousands of percent increase on the 2006 stock; some of the rural zones show very substantial increases (up to a six-fold increase in employment floorspace) but the vast majority of the additional floorspace is forecast to be provided within the existing built-up areas.

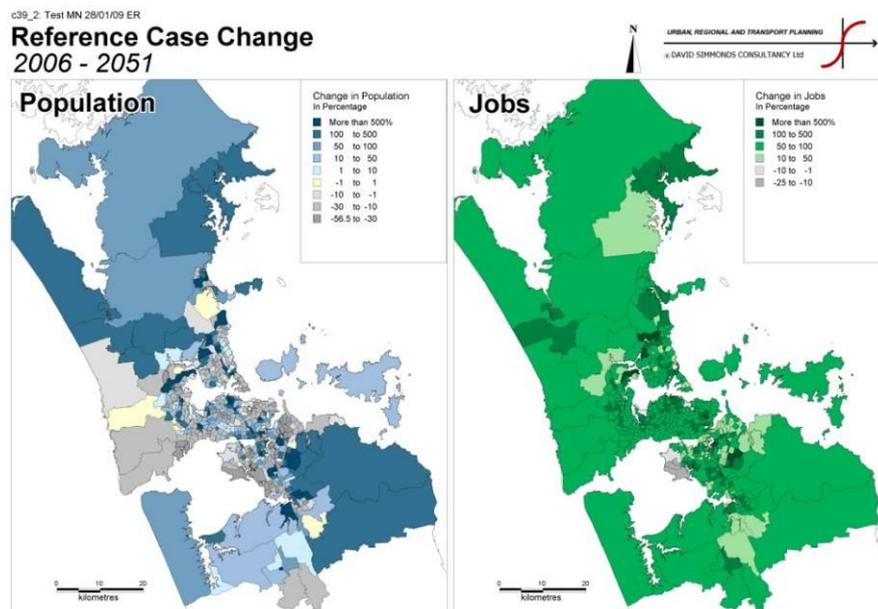


Fig. 7. Population and employment changes 2006-2051

The first map of Figure 7 shows the percentage change in population over the forty five year modeled period. The pattern of population change is to a large extent a result of the pattern of permitted development, with substantial volumes of housing development occurring in particular places at different times. Some rural zones show very large relative increases in population however these increases are small in absolute terms and the bulk of the total population increase occurs in existing urban areas. Household changes are closely but not perfectly correlated with population changes with the differences reflecting differences in the types of households moving into or out of different zones. The changes in jobs over the 45 year modeled period are shown in the second map of Figure 7. There are small percentage decreases in the number of jobs in a few zones but the majority of zones show increases of between 50 and 100 percent, broadly in line with the overall scenario. Figure 8 to Figure 11 summarise the forecast growth of population and employment by Territorial Local Authority, both absolute values and percentage changes relative to their 2006 numbers are shown.

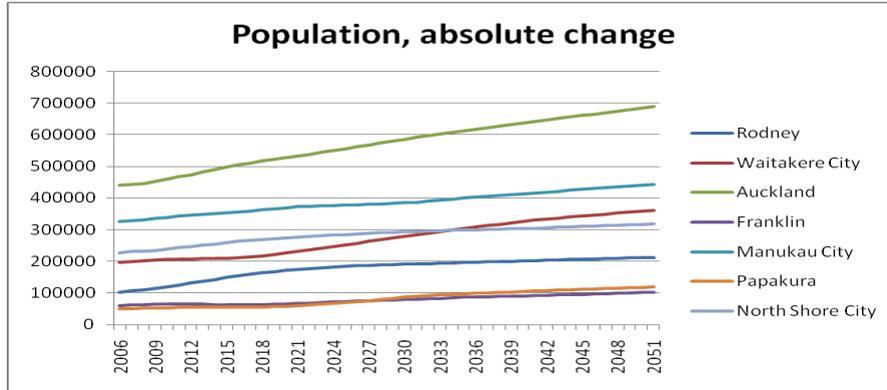


Fig. 8. Population dynamic 2006-2051 by Territorial Local Authority, total people

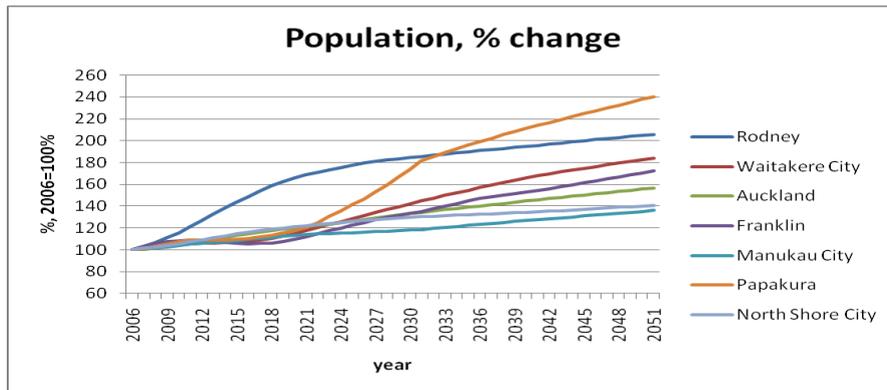


Fig. 9. Population dynamics 2006-2051 by Territorial Local Authority, percentage changes relative to their 2006 numbers

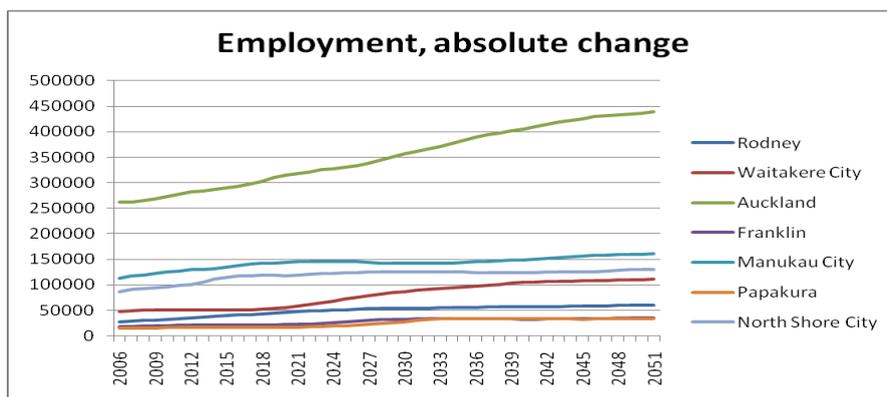


Fig. 10. Employment dynamic 2006-2051 by Territorial Local Authority, total jobs

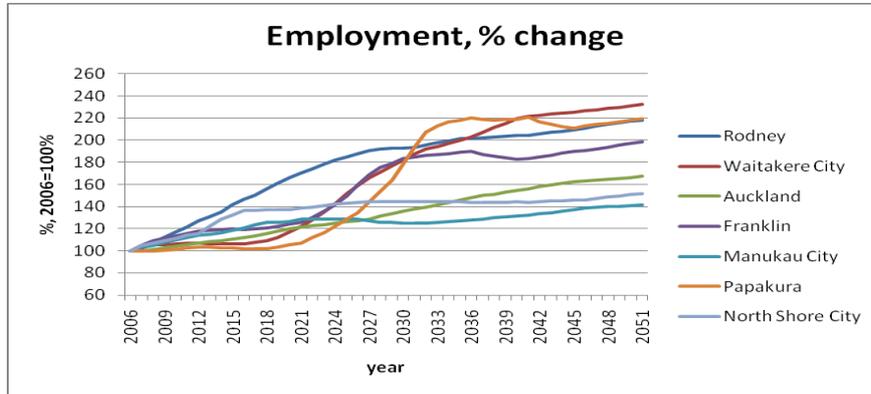


Fig. 9. Employment dynamics 2006-2051 by Territorial Local Authority, 2006 = 100%, percentage changes relative to their 2006 numbers

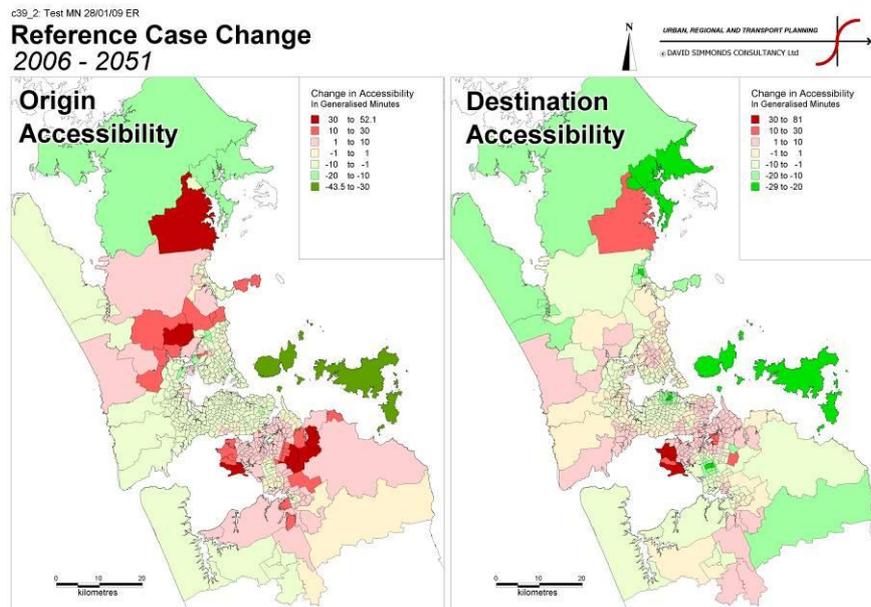


Fig. 10. Origin and destination accessibility changes 2006-2051

The final comment on the results is to consider the resulting patterns of accessibilities. These are of course both output (from the distribution of

land-uses and the generalised costs of travel at one point in time) and input (as an influence on land-use change subsequent to that point in time). Two types of accessibility are modeled: origin accessibility which is a measure of how easily residents can get to destinations such as work opportunities, and destination accessibility which is a measure how easily destinations can be reached, for example by members of a potential workforce. Accessibilities are measured in generalised minutes, so negative changes indicate improvements in accessibility whilst positive changes indicate worsening accessibility. The first map of Figure 10 shows that accessibilities to work are generally improving in the Central Isthmus with some worsening to the north and south of the fully modeled area. The improvements in the central zones are likely to be the result of increased investment in the transport network whilst the worsening suggests that increasing congestion is outpacing any investment in the transport networks. Note that accessibilities to work will generally tend to improve as a result of the overall increases in job numbers, and hence that worsening in accessibility implies that increases in congestion (or other costs) are more than sufficiently severe to outweigh the increases in the number of opportunities.

The change in destination accessibility (the ease with which job opportunities can be reached in each zone) is shown in the second map of Figure 10. The pattern of change shows noticeable “hotspots” of improvement centred on the CBD, Manukau and Orewa. These appear to result largely from very substantial population growth (improvement in labour supply) close to these locations and partly from improvements in the transport links to these areas.

7. Conclusion

The ATM2 model system brings together and operationalises a wide range of theory about individual, household and business behaviour to provide a practical tool for forecasting, and in particular for the assessment of the impacts of alternative long-term strategies for the development of the Auckland region and for the provision of appropriate future transport systems. In the nature of such an exercise, the performance of the model has largely to be judged on the reasonableness of its results in relation to our understanding of the urban system and how it may change in future. The results discussed here (and the much larger volume of detailed results behind them) suggest that the model is working as intended to provide such a forecasting system, with results that make good sense in terms of the high growth scenario assumed and of the pattern of permissible development that is assumed in these particular tests.

The results also demonstrate the scale of the issues that have to be addressed in relation to the demands for mobility that will tend to arise from the continuing growth in population and in incomes. The model itself, by taking into account a wide range of the interactions between different components of land-use and between land-use and transport, should provide a powerful tool for ongoing use in urban planning and urban management.

8. Acknowledgements

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