AN INTEGRATED SYSTEM OF TRANSPORT AND LAND-USE MODELS FOR AUCKLAND AND ITS APPLICATION

Olga Feldman[1], John Davies[2], David Simmonds,
David Young, Emma Richmond, Jojo Valero

Abstract: This paper describes the development and use of an integrated system of new regional transport and land use models for Auckland, New Zealand, known as 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. The ATM2 models are intensively used by Auckland Regional Council to forecast land use and transport demands in the region to assist planners and decision makers in developing efficient and effective strategies to guide regional development. They are tools that quantify and compare options relating to land use development and associated transport systems. The ATM2 models are able to respond to a wide range of policy and other decisions. The results of two scenario tests are presented.

Keywords: Auckland, interaction model, land use, transport, policy

1. INTRODUCTION

Land-use/transportation interaction modelling draws from a number of different approaches including urban economics, spatial interaction (gravity) models, and discrete choice models. Urban economics (notably Alonso, 1964) focuses on understanding the general, aggregate behaviour of a city in terms of location of citizens of different types and the prices or rents they pay for landetc, often in a highly abstract context. The second tradition, that of spatial interaction models, came from the need of practitioners to be able to make at least crude forecasts of traffic flows, trade patterns etc These were often based initially on simple physical analogies, but were later elaborated into the entropy-maximising approach (see in particular Wilson, 1974). The third approach is the theory of discrete choice based on random utility theory (McFadden, 1974), within which the nested multinomial logit model is a special but important case. The combination of these approaches provided by basis for two widely-used packages, MEPLAN (Echenique et al., 1988) and TRANUS (de la Barra, 1989). A further step was to focus land-use models upon processes of change, in contrast with the preceding models which have generally assumed the existence of equilibrium conditions at modelled points in time. The pioneer in this was Wegener (1985), whose example has been followed in the design of DELTA (Simmonds, 1999; Simmonds and Feldman, 2007, Feldman et al, 2008) and UrbanSim (Waddell, 2001).

This paper describes a new transport and land use model for the Auckland region, known the Auckland Transport Models (ATM2) project. The ATM2 project is the first integrated model in New Zealand that incorporates land use and transport interactions in a dynamic manner over an extended time period (fifty years). The land-use component is known as

[1] David Simmonds Consultancy, Suite 14, Millers Yard, Mill Lane, Cambridge CB2 1RQ England, tel: (+44) 1223-316098; Email: olga.feldman@davidsimmonds.com
[2] Auckland Regional Council, 21 Pitt St, Private Bag 92012, Auckland, NZ, Tel: (+64) 9 366 2000 x 8024, E-mail: john.davies@arc.govt.nz

ASP3 and the transport component as ART3.

ASP3 is a land-use model which has been developed as an application of the urban components of the DELTA package. Its purpose can be summarised 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. The zone system is common to the two models and consists of 512 internal zones. 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.

This paper covers the overall design of the Auckland land-use and transport interaction model, data used and the first application of the model.

2. OVERALL MODEL STRUCTURE

2.1 Land-use model ASP3

The ASP3 model consists of the original five sub-models of the DELTA package. Two of these deal exclusively with activities:

- the transition and growth sub-model, dealing with demographic change and employment growth (i.e. implementing the demographic and economic scenarios within the model);
- the employment status and commuting sub-model;

two focus on the spaces occupied by activities:

- the development sub-model;
- the area quality sub-model;

and one critical sub-model:

- the location and property market sub-model, deals with the interaction of space and activities.

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).

The **transition** sub-model forecasts household changes over time (each year) between the modelled household types. The rates of change here 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. For newly-locating households there is a general tendency that they will locate where similar households are already located. For moving households, the tendency is that they will tend to stay where they are. The factors which drive the changes in location and modify these inherent tendencies are

- changes in the quantity of housing supply (from the development model or exogenously specified by the model user);
- changes in accessibility to work and services (using accessibility measures based on other land-use forecasts and the outputs of the transport model);
- changes in the quality of housing (from the quality model);
- changes in the quality of the environment due to changes in traffic volumes (output from the transport model);
- changes in rent, which are endogenous to the model.

The location model is also a form of "housing market" model. Households are modelled as competing for the available space, given their budgets, which depend on their household type and employment status. The changes in rent result from the changing competition for housing. If demand falls in particular areas, rents there will fall and housing may be left vacant. The location model ensures that all households are located. It assumes that household compositions are fixed and that households will occupy housing at higher or lower densities so as to fit themselves into the available stock. ASP3 assumes that households rent housing, and does not attempt to model owner occupation explicitly.

The final stage in modelling households and their members in each year is the **employment status and commuting** sub-model, which 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 begins with the application of growth rates, derived from the overall scenario (supplied by ARC). The growth rates determine the number of jobs locating in the **employment location** (and non-residential property) sub-model assumes that employment of each activity will tend to locate where that activity has previously located, but that these patterns of location will be modified by

- changes in the quantity of appropriate floorspace in each zone,
- changes in accessibility (different measures for different types of employment, reflecting other land-uses (eg the supply of labour) and the transport system),
- changes in rent, which reflect the changing balance of supply and demand .

The model adjusts rents until all employment is accommodated. Space per worker can vary, as can the location of jobs and the floorspace left vacant. Like the household location model, the employment location model is affected to some extent by most other parts of the model system.

The final stage in the modelling of employment is to convert employment by zone and activity into employment by zone and socio-economic group. This determines the demand for labour, which is then filled from households (hence changing the employment status as household members gain/lose jobs). A small number of jobs is filled by persons not in 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 modelling (because it is assumed that the number of workers going to work must match the jobs available in each year); all other responses are gradual and time-lagged ones.

The model of development is a top-down one which assumes that

- the total amount of development of each type of floorspace varies in response to recent demand (and hence, largely, in response to the economic sector and past levels of development);
- 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 no mechanism within the model for developers to build contrary to the policy inputs, and no mechanism for the policy inputs to respond to development pressure. Any such response has to be introduced by the user after analysis of the model results. The development models run in each year; they involve both a time-lagged response to changing demand conditions and time-lags until the resulting development is complete.

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.

2.2 Transport model ART3

The ART3 model is a transportation demand model incorporating trip generation, distribution, mode choice, time-of-day choice and assignment. Generalised costs (a combination of travel time, distance, vehicle operating cost, fares or tolls.) are the main driver of transport decisions and are used particularly in the distribution, mode split and time of day sub-models.

The model is segmented into groups of travellers that exhibit similar travel characteristics (based on observed data). Thus, we model eight person types (by age and working status), eight household types (by numbers of adults and working status), three car ownership levels, and six trip purposes. The final trip matrices represent the travel between all origin and destination zones in the region aggregated across these different segments.

Trip purposes represent different activities that people need to or wish to carry out that require some form of travel. ART3 includes the following trip purposes: Home-based work (HBW), Home-based education (HBE), Home-based shopping (HBSh), Home-based other (HBO), Employers business (EB), and Non-home-based other (NHBO). The types, or modes, of transport included in the model, and the way they are grouped, are based on those that currently have a reasonable amount of use at the strategic regional level:

- Light vehicles (called cars); persons in cars, car driver and car passenger combined, are forecast in the demand models and then converted into vehicle trips prior to assignment (routes) on the transport network. This mode includes light delivery vehicles;

- Passenger transport (PT); all PT mode trips are combined in the demand models and then split into bus, rail and ferry when they are routed onto services;
- Active modes; walk and cycle trips combined, only the total number of trips that are produced in each zone are modelled;
- Medium and heavy commercial vehicles (called HCVs).

Car and PT modes are referred to as mechanised modes in the demand models. HCVs are estimated using an alternative process based on observed matrices.

The trip generation and distribution-mode split are 24-hour models. These trips are then split into five periods by the time-of-day choice model: Morning (AM) peak: 7am to 9am, Interpeak (IP): 9am to 3pm, School peak (SP): 3pm to 4pm, Afternoon (PM) peak: 4pm to 6pm, and Offpeak (OP): 6pm to 7am. Vehicle and PT assignment of trips between zones onto transport networks occurs in only three of these periods: AM peak, Interpeak, PM peak (each are 2-hour periods).

The car ownership model determines the number of persons by person type and household type that own either 0, 1, or 2 or more cars. This element has only a minor role in the amount and mode of travel people choose due to the high car ownership levels in Auckland.

The model estimates the total number of trips that are generated by activities in the region on an average weekday. Employment, households and education rolls, and persons (by type and car ownership) are used in the trip end models for home-base purposes to determine the number of person trips (excluding HCVs) by purpose in each zone. Trip productions are by all-modes and active modes and are fixed rates. Mechanised-mode productions are the difference between all-modes and active mode productions. Trip attractions are for mechanised modes only. Active mode trips are produced at the “home” zone and are not distributed. This approach was adopted as the model is regional in nature and the networks are not sufficiently detailed to usefully assess active trips. The effect is that all active trips are assumed to be short trips that occur within their “home” zone. There is a sub-model that adjusts the level of active trips according to the amount of “mixed use” within a zone (and correspondingly adjust mechanised trips).

The mechanised-mode home-based trip productions and attractions are input into the distribution-mode split (DMS) and time-of-day (ToD) choice models. This links the trips ends that are produced and attracted to each zone into trips from one zone to another, creating a pattern of origin to destination (OD) trip-making in the region. Person trips by car are also converted into vehicle trips for the three assignment time periods. EB and NHBO trip ends are generated from the home-based trip attractions by mechanised mode (car and PT), and are then input into the distribution and time of day choice models. Separate HCV trip matrices are estimated for the three assignment time periods.

Vehicle trips are calculated by summing car vehicles + HCVs + vehicle trips external to the region + vehicle trips to/from the airport associated with flights. Once OD matrices of trips between zones have been developed (representing the demand for travel) they need to choose a route between the origin and destination zones along the transport network (the supply of transport). This trip assignment process is dependent upon the generalised cost of travelling along different parts on the network. As the network is loaded with trips the performance of the network changes, for example a trip’s shortest route may be highly congested and thus be more “costly” in terms of travel time than some other longer route. For car, trip routes are adjusted in an iterative process until the entire system is in balance, or equilibrium, and no single trip can use a less costly route without increasing the total cost of the system.

2.3 Land-use/transport interaction

The ATM2 modelling system is run for all modelled time periods and years using a batch file. This file calls both models sequentially with the land use and transport scenarios to be used specified as inputs. The ASP3 and ART3 models are run sequentially from 2007 until 2051 with information passed between them in both directions. ASP3 (land use) is run in each year beginning with year 2007, and ART3 (transport) is run in every fifth year beginning in 2011. Transport costs, car ownership and environmental data are passed from ART3 to ASP3 following each ART3 model run, and land use planning data (persons, households, employment, education rolls) are passed from ASP3 to ART3 prior to each ART3 model run.

3. CREATION AND CALIBRATION OF MODELS

3.1 ASP3 dimensions and model development

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. There are 11 main household compositions in the model. They are split into four socio-economic groups and by the number of workers per household (0, 1, 2, 3+) making total of 136 household types. Households with unidentifiable household composition in Census were redistributed pro-rata over the other categories.

Employment is measured in terms of numbers of workers counted at their reported place of work. The employment types are based on aggregating the Australian and New Zealand Standard Industrial Classification categories into 14 sectors, then splitting some of these into "production" and "administration" according to the socio-economic group of the workers to have a total of 17 employment types.

The model implementation process started with using 2001 Census data (for each zone) to assemble

- the household database (households by activity);
- the persons-in-households database (persons by person type and household activity);
- the employment database (workers by employment activity and socio-economic group); and
- the travel-to-work matrices (in terms of persons).

Additional information on housing, housing rents, and commercial floorspace was then added using Census and other information. The main source for commercial floorspace and rent data was the 2006 rating and property database held by the ARC. Accessibility values, which cannot be observed, had to be calculated.

The full household dataset exists in the 2001 Census records; the problem is that the model requires substantially more detail than was released by Statistics New Zealand. A further complication was that in order to obtain Census data at all it was necessary to amalgamate some of the small zones when requesting data. Therefore most of the processing was done on the amalgamated zones and then they were split into ATM2 zones using simple proportions. The synthesis involved taking a detailed cross-classification of households by composition, number of workers and socio-economic group, which was obtained for the whole region, and adjusting this so as to be consistent with the zonal data, which was obtained (without cross-classification) on households by composition, by number of workers and by socio-economic group. In addition, the data on the number of children and retired persons was added. The adjustment was done by Iterative Proportional Fitting[3], which is a standard method for this type of problem.

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

The model was used to produce the constrained forecasts from 2001 to 2006. A new demographic projection was created for 2001-2006 such that total households, population, children, working age adults, retirees, and employment by sector in the fully modelled area would match the 2006 census totals scaled to the 2006 midyear estimates. These 2006 outputs were then redefined as the starting database for the model. Housing floorspace was constrained using Census data on occupied and vacant private dwellings.

3.2 Transport model calibration and validation

The sub-models of ART3 were calibrated using 2006 Census and survey data. The surveys undertaken specifically for the model development included a household travel survey (collecting household, person and a weekday's trip data), passenger transport intercept surveys, traffic counts, travel time surveys and a commercial vehicle survey.

Road and passenger transport networks and assignment procedures were developed within the Emme transport modeling software, and generalised costs for each mode, purpose and time period were created These costs were used in conjunction with observed data from the surveys to calibrate each of the sub-models.

The sub-models were implemented and linked within Emme, and the model was validated against the surveyed traffic counts, travel times and passenger ticket information.

4. SCENARIO ASSUMPTIONS AND FUTURE PLANNING INPUTS

4.1 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 1. 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

[3] Iterative Proportional Fitting (IPF) is a mathematical scaling procedure which can be used to make sure that a two-dimensional table of data is adjusted so that its row and column totals match with constraining row and column totals obtained from alternative sources. IPF acts as a weighting system whereby the original table values are gradually adjusted through repeated calculations to fit the row and column constraints.

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).

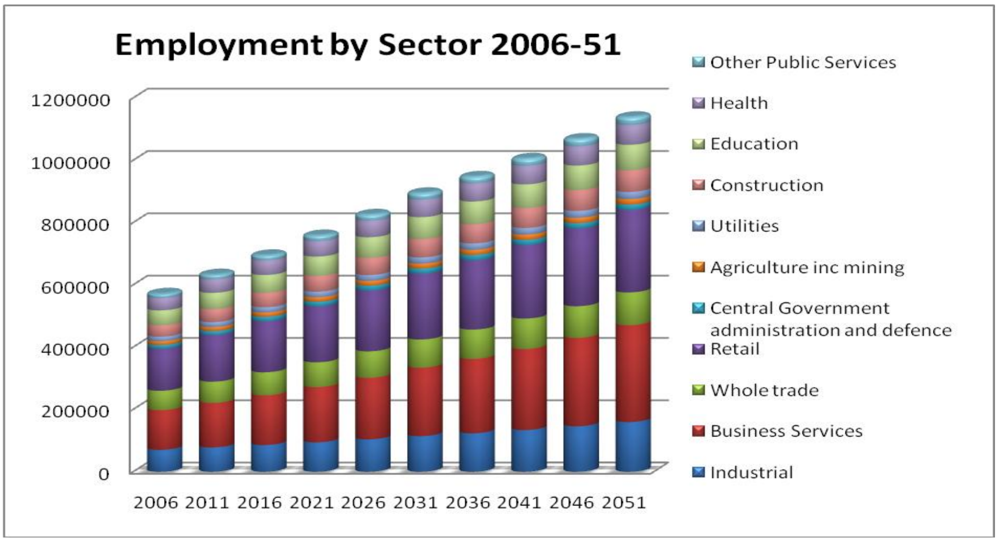

Figure 1 Employment by employment sector

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 at five-year intervals are shown in Figure 2. 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.

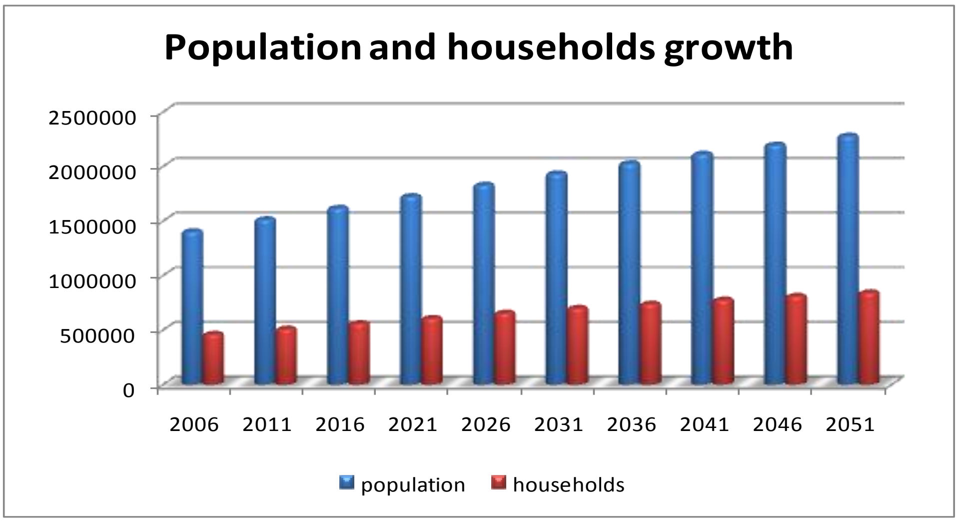

Figure 2 Population and Household Growth

4.2 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. 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.

Permissible development was defined and estimated for residential, retail, office, industrial and warehouse floorspace types. Residential development is split into two categories: "typical density" development and "higher density" development. 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.

4.3 Transport policy and network inputs

A number of other input variables are required for ART3. For this forecasting the values of time, operating costs, parking costs, PT fares have been kept at 2006 values, on the assumption that all prices remain constant in real terms. The GDP growth forecast used in the car ownership and HCV models (1.8% p.a.) is based on historical trends. The 2006 traffic entering and exiting the region on external links, is factored at a rate of 3% p.a. based on historic count data. The growth in flight-related trips to/from the airport is directly related to the forecast growth in flight passengers sourced from Auckland International Airport Ltd. This is 4.5% p.a. for international flights and 3.5% p.a. for domestic flights.

Future transport networks were developed for each modelled year for both roading and passenger transport.

5. FORECASTING RESULTS

5.1 Introduction

The ATM2 modelling system is one in which nearly everything affects everything else - to a greater or lesser extent, and either immediately or gradually - except for the top-level (model-wide) inputs representing the economic and demographic scenario, and the bottom-level (zonal or network) inputs representing planning policy controls and the changes in transport provision. Note that the planning policy and transport inputs are treated as exogenous because the major purpose of the model it to test the impacts of user-chosen changes in these inputs – the modelling team recognize that in reality policies are influenced over time by the change occurring within the region, but in the present context it would not be helpful to try to forecast policy inputs.

The complexity of the linkages and interactions is a virtue of the model but something of a complication in trying to interpret and explain its results. Rather than attempting to follow the workings of the model from year to year, the usual approach is to identify what are the most important effects in the model run or runs to be considered, and to show the key variables involved in those effects first, then to explore the other less critical outputs.

The forecasts that this paper reports on were initial ones carried out only for the purposes of testing the reasonableness of the models' responses and identifying any issues with the models and/or their operation.

5.2 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.

A general point to note about the development processes is that practically all of the permissible development is built. For some floorspace types the development process lags behind the increases in the permissible quantity for the first 15 years, but then catches up to a point where each year's input of permissible development is fully used for construction. There are enormous variations in the rates of development, 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.

The first map of Figure 3 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 3. 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.

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 4 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.

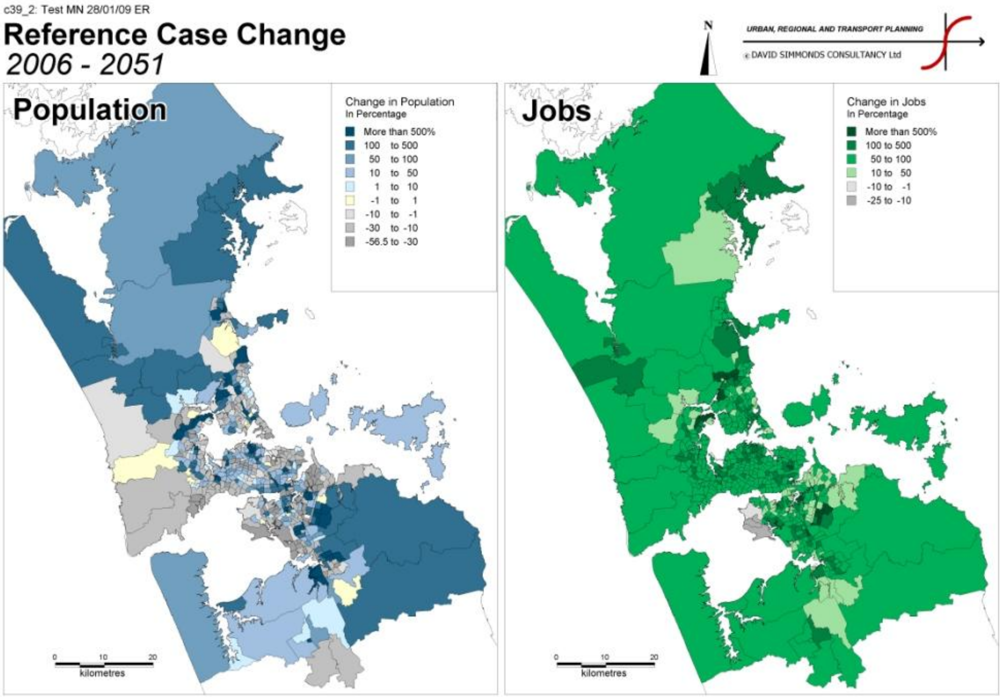

Figure 3 Population and Employment Changes 2006-2051

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 4. 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.

5.3 ART3 forecasting results

Total person trips increase by 68% between 2006 and 2051, compared with an assumed population increase of 58%. Commuting trips have the greatest increase (~100%) and education trips the lowest (27%). The growth in car trips follows similar trends to person trips, increasing at a uniform, but slightly decreasing rate. Trips by PT show more variation in growth than car trips and for all purposes but HBE increase is lower: by 3.5 to 6 times between 2006 and 2051 (c.f. car ~ 50%). The growth in commuting travel during the IP and OP periods is slightly higher than that during the peaks, including the school peak. Passenger-kilometres traveled increase at least fourfold.

6. 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.

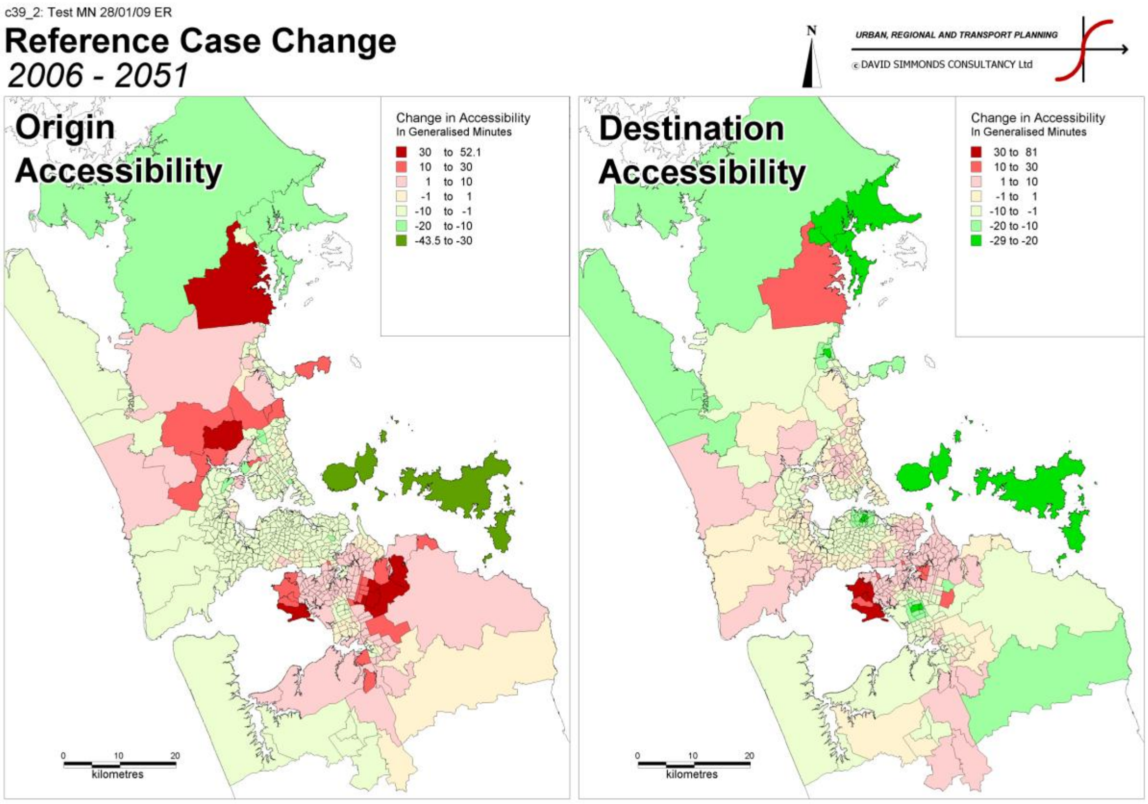

Figure 4 Origin and Destination Accessibility Changes 2006-2051

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