Feasibility study of a national trip-end model for New Zealand
September 2010

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NZ Transport Agency research report 413

ISBN 978-0-478-36474-3 (print)
ISBN 978-0-478-36473-6 (electronic)
ISSN 1173-3756 (print)
ISSN 1173-3764 (electronic)

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Bolland, J and R Jones (2010) Feasibility study of a national trip-end model for New Zealand. *NZ Transport Agency research report no.413.* 92pp.

Keywords: distribution, four stage, freight, gravity model, household travel survey, inter-urban, model, mode split, national, New Zealand, passenger, regional, tourism, transport, trip end, trip generation, zone

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Acknowledgements

The authors would like to thank the following for their assistance and support:

Shane Vuletich and Andrea Carboni at Covec
Susanne Becken at Lincoln University
Andrew Murray, John Row and Tim Wright at Beca
John Davies and Jojo Valero at Auckland Regional Council
David Young
Dick Bullock
Tony Brennand
Bill McMaster at Environment Waikato
Julie Ballantyne at Traffic Design Group
James Bevan at Latitude Planning Services
Jennifer McSaveney and Lynley Povey at the Ministry of Transport

Abbreviations and acronyms

AADT	annual average daily traffic
ANZSIC	Australia and New Zealand Standard Industrial Classification
ART	Auckland regional transport
ART ECS	Auckland regional transport (model) external cordon surveys
CTM	Christchurch transportation model
DTS	Domestic Travel Survey
GIS	geographic information system
HBW	home-based work
IVS	International Visitor Survey
NFM	national freight matrix
NTEM	national trip-end model
NTM	national transport model (UK)
NTS	National Travel Survey (UK)
NZHTS	NZ Household Travel Survey
OMIP	Oregon Modelling Improvement Plan
O-D	origin-destination
SH	state highway
TA	territorial authority
TFA	tourism flow area
TFM	tourism flow model
TLD	trip length distribution
TJUMIP	Transportation and Land Use Model Integration Program
TTM	Tauranga transport model
Western BoP	Western Bay of Plenty. This is used to refer to the Tauranga transport model; especially the roadside interviews conducted for it. This is because most of the roadside interview sites were in Western Bay of Plenty district.
WTSM	Wellington transport strategy model

Contents

Executive summary

Most of New Zealand's road network is outside the coverage of urban traffic models and there is generally little consistency between the modelling of adjacent areas. To allow major policy issues to be addressed nationally in a robust and consistent manner would therefore call for trip generation, distribution and mode split to be considered at the national level. In view of this, the purpose of this study was to investigate the feasibility of developing a national trip-end model (NTEM) for New Zealand.

The overall structure of the four-stage model, as used in the urban areas of New Zealand and elsewhere, has changed little since the 1960s. First, data on demographic and economic variables is used to estimate a trip generation model for each zone. In the next stage (distribution) the trip ends are tied together resulting in a trip matrix. The third stage allocates each trip to a mode (car, bus, train etc), and in the fourth the trips are assigned to each modal network, resulting in a flow along each link. This study looked only at the first three stages, omitting assignment, for the whole of New Zealand.

A review was undertaken of models developed overseas which would be of relevance to the NTEM. The review did not look at urban models, only at those which were state or country wide. The four-stage approach, modified as necessary, was found to be commonly used but other approaches, including econometrics for freight, were also in use. There were a number of complicating factors unique to freight, for example the relationship between volume transported and the number of vehicles required.

The use of 'urban' approaches in interurban modelling was found to be common. The main advantages of this would be the availability of proven software and refined, robust theories and algorithms. However there are also a number of disadvantages: the convenience of the software may prevent implementation of better methods; urban models may be overly complex; and data requirements may be excessive although this can be overcome by simplified structures. There seems to be no realistic alternative to the four-stage approach but its limitations must be acknowledged.

In terms of the different stages of modelling, the factors driving trip generation often relate to employment in specific sectors, with different freight models for different commodities. The gravity model seems to be the accepted approach for trip distribution. Mode split is clearly different from the urban passenger situation and alternative approaches such as elasticities have been proposed.

The literature review revealed a range of techniques available which might be used in the development of a NTEM for New Zealand. However the unusual distribution of population and the topography of the country are likely to give rise to issues which have not been encountered elsewhere.

The study examined the data currently available in New Zealand which might be used to develop the NTEM. This data could provide forecasts of variables such as population and GDP that might be used to predict future trip patterns, and also provide information on current trip-making in order to calibrate the model.

During the course of the research the only national model which came to light was the tourism flow model (TFM) which was built for the Ministry of Tourism and produces – amongst other things – projections of future travel by tourists, segmented by domestic and international tourists. TFM does not cover only 'tourists' *per se*; despite the name, it covers all overnight trips (except journeys to work) and day trips over 40km made by New Zealand residents.

A possible source of data is the New Zealand Household Travel Survey (NZHTS), which is run continuously; 4600 households a year are interviewed and travel information is recorded for two days for each person in the household.

In view of the lack of data at the national level, data which has been collected at the local level could play a major role in the development of a national model such as a NTEM. Trips entering or leaving the major centres are likely to be significant contributors to national movements, for example distributing goods from manufacturing centres such as Auckland. In this context, several regional models are currently being developed or have been developed within the last few years and this necessitated collecting movement data on the boundaries of the respective regions.

A comparison of TFM with surveys from two urban models found that in many cases there were significant differences between the data sources, although the order of magnitude of the results for each origin destination pair was similar. Factors which might explain this include different survey methodologies, faulty data or day-to-day variation.

The study found that to produce a NTEM of longer-distance trips with currently available data would be challenging. There are only two sources of data appropriate for national passenger trip making: the NZHTS and the TFM. The former has a very small sample which makes it unsuitable for use with zones of a reasonable size since some zones would have no trips recorded. However the data has other potential applications in relation to trip length distribution and mode choice. The expansion of the NZHTS to collect more data nationally would be a major and costly undertaking. Additionally, while a national model would only cover longer-distance trips, the majority of trips made are short, which means there would be a lot of data that is of limited use for a NTEM, although it may have other applications.

The TFM excludes certain trip purposes along with shorter trips so the data is incomplete. It is also unclear whether the TFM survey methodology of asking people to recall their trips over a period of up to a month might lead to under or misreporting of travel. Other potential difficulties include the fact that the TFM does not fully differentiate between road modes and does not adopt the usual transport modelling (four-stage) framework. A possible approach to enhancing the TFM data might be to start with a TFM for passenger trips and use state highway (SH) flows to do matrix estimation. However it is unclear how to reconcile the two data sources as SH flows would include local trips that are not in the TFM.

Major urban areas such as Auckland, Hamilton, Tauranga and Christchurch each have their own urban models and most of these have been updated in the last few years. However in terms of the totality of trips made in the country these models omit substantial areas, including a large part of the South Island and the central North Island. Even if the models of smaller urban areas such as Taupo are included there are large areas with no coverage. Moreover, an examination of two different urban models indicates a very low level of consistency with national models. Overall, then, urban models alone do not provide enough information at a national level.

In terms of the approach to a NTEM, for trip distribution the standard gravity model would be satisfactory for passenger travel as it can be fitted to the available data. Previous work has concluded that gravity models can be a useful tool for freight trip distribution, but that it may be necessary to construct regional models with dummy variables for alternative transport modes (rail, shipping) and regional generators/attractors (airports, ports and distribution hubs).

Building a mode split model for longer-distance surface passenger trips would be difficult as the NTS suggests that there are very many more long-distance trips by car than by bus or train. It is therefore likely that there would be insufficient data to calibrate a mode split model. A possible means of simplifying freight mode split would be to use the captive/choice approach of urban models, since many commodities are highly unlikely to be moved by rail and so are captive to road.

In the absence of intermediate stops, freight modelling is essentially confined to route and mode choice. However a key consideration is load factors, the key relationship between goods moved and truck movements, which is dependent on a range of factors. Freight models also usually consider annual quantities to address issues such as seasonality.

The study concluded that the NTEM would be a 24-hour model, with a limited number of trip purposes that separate passenger and freight. The zoning system would be relatively coarse and a possible system, based on territorial authorities, has been proposed.

The strength of a modelling approach such as the NTEM is that it makes explicit those factors which influence travel growth. For example, population growth fluctuates and currently the population projections for the Auckland region are higher than those done a few years ago. The other key factor which affects trip numbers is the impedance of travel; while this may change at the detailed level (eg through the construction of Roads of National Significance) the basic New Zealand road network is unlikely to change. This suggests that a simplified approach, based on future changes in population and travel times, could be appropriate in some circumstances and for some parts of the country and would have the advantage of much reduced data requirements.

On the other hand the factors driving trip growth around areas such as Auckland, Hamilton and Tauranga are more complex. In addition, the three regional models in that area provide a wealth of trip data. A first step in building a national model might therefore be to build a model of vehicle travel in the upper North Island. Data is already available to begin building such a model and the programme of surveys required would be much less than that required to build a NTEM for whole country. Such a model would also be particularly useful in the national context in the light of the national economic significance of the area covered.

Abstract

This report presents the findings of a research project to investigate the feasibility of developing a national trip-end model (NTEM) for New Zealand. The rationale for this is to allow policy issues to be addressed nationally in a consistent manner with trip generation, distribution and mode split considered at the national level.

The research examined large area models from overseas and concluded that while there were a number of parallels with the 'four-stage' modelling paradigm used in urban areas, there were also a number of differences.

If a NTEM were to be developed in New Zealand there are a number of forecasts which could be used for the input variables. On the other hand there is very little trip data available nationally which could be used for calibration so the development of a national model would require a substantial data gathering exercise, either through household or roadside surveys. On the other hand the area between Auckland, Tauranga and Hamilton includes three recently developed models which together comprise a rich source of data. It is therefore suggested that this area serve as the starting point for a NTEM, with traffic growth in other areas forecast on the basis of simple variables.

1 Introduction

1.1 Purpose of the study

In New Zealand there is an increasing emphasis on transport planning at the wider, strategic level, for example the preliminary work by Transit NZ (now NZ Transport Agency (NZTA)) on a national model. However, most of the country's road network is outside the coverage of urban traffic models and there is generally little consistency between the modelling of adjacent areas. This could be overcome by considering trip generation, distribution and mode split at the national level. It would also allow major policy issues to be addressed nationally in a robust and consistent manner.

The purpose of this study, funded by the NZTA, was to investigate the feasibility of developing such a national trip-end model (NTEM) for New Zealand. Specifically the research objectives were to:

- examine the feasibility of developing a national trip-end model for NZ, including the availability of appropriate land-use projections
- develop simple trip generation, distribution and mode split models at the national level.

Drawing on the outcomes of this, the next stage was to undertake a case study examining the practicality of developing a New Zealand NTEM from available data.

The research mainly focused on modelling vehicle trip ends of longer-distance trips, although other issues were explored including modelling of person trip ends, mode shares for rail and bus, inter-island travel and air travel. While some of these – such as air travel – lay outside the scope of the study it was useful to look at issues relating to them.

It should be noted that during the life of this study there were some changes: for example the Waikato region implemented a new transport model, although details were unavailable when the review of the regional models was undertaken. It was decided not to review it later as it was unlikely to change the conclusions of this study.

1.2 Structure of this report

The remainder of this chapter provides a brief introduction to the theory of the classical four-stage model, on which it was envisaged the NTEM would be based. Only three of the four stages are described in detail as assignment (loading traffic onto the network) is beyond the scope of a NTEM.

Chapter 2, the literature review, initially looks at experience from overseas, concentrating on high-level, inter-urban models. There are separate sections on Australia, the USA (where there are a number of state-wide models), the UK and elsewhere. Given the nature of the New Zealand economy, it is to be expected that the transport of freight at a national level is a significant contributor to movements. For this reason chapter 2 has a section which specifically considers freight modelling, how it differs from passenger trip modelling and overseas experience. Chapter 2 closes by looking at relevant previous modelling in New Zealand, which is limited.

Chapter 3 draws conclusions from the literature review for the development of a New Zealand NTEM. This covers the three stages (generation, distribution and mode split), freight and more general issues.

Chapter 4 describes the data sources available in New Zealand which could be used in developing a NTEM for the country.

The following four chapters each cover a different aspect of a possible New Zealand national model Chapters 5, 6 and 7 cover the three stages of generation, distribution and mode split. Chapter 8 is called 'Model parameters' and discusses aspects such as the zoning system and the period to be modelled.

Conclusions are presented in chapter 9, with particular emphasis on the implications for a possible national model for New Zealand.

1.3 Theory of the four-stage model

1.3.1 Overview

The overall structure of the four-stage model has changed little since the 1960s, although within that framework there have been considerable advances in modelling techniques, not least as a result of significant increases in available computing power (see, for example, Ortuzar and Willumsen 1990).

At the outset the transport system is simplified into a series of links (representing the various available networks) and zones (where trips begin and end). The broad purpose of each stage is as follows:

1. Trip generation: data on demographic and economic variables is used to estimate a model of the total number of trip productions and attractions for each zone. Trip productions are defined as the home end of a home-based trip or the origin of a non-home-based trip; trip attraction is the other end of the trip in both cases. Both ends of non-home-based trips are defined as attractions.
2. Trip distribution: the trip ends are tied together, resulting in a trip (or origin-destination (O-D)) matrix.
3. Mode split: each trip is allocated to a mode such as car, bus or train.
4. Trip assignment: the trips are assigned to each network, resulting in a flow along each link.

Iteration between stages is common and varies from model to model. For example, if the assignment stage produces a very congested road network it may be appropriate to 'revisit' mode split as the congestion may cause a switch to passenger transport. The order in which mode split and trip distribution are done varies from model to model and in some cases they are simultaneous. The order is determined by the data during the model calibration.

However, once done, the first stage of trip generation is usually fixed and there is no iteration as a result of later stages. That said, there has been some recent use of variable trip matrices which depend on transport supply. This is based on the reasonable assumption that a higher level of service, such as a major new link, will encourage travel and therefore lead to higher trip generation. This is sometimes called 'induced trips'. The term 'induced traffic', includes induced trips but is also used to cover redistribution, mode changes and change of time of travel as the result of a new project.

As discussed in section 1.2, the assignment stage has not been covered in this study. However at the national level the available route choice is more limited than in the urban areas and it is likely, for example, that most traffic between Wellington and Auckland will use SH1, although they may use other roads for part of the journey, such as SH4. Another example is Auckland to Tauranga where there are two routes to choose from. Hence the absence of assignment may not be a significant issue, except in a limited number of cases.

In some recent urban studies a further stage, time of day choice, has been included to reflect the phenomenon of 'peak spreading'. However this is unlikely to be an issue at the national level as the peaks are much less pronounced and time of day modelling is not usually of interest.

1.3.2 Trip generation

The trip generation stage of the four-stage model aims at predicting the total number of trips generated by, and attracted to, each zone of the study area, with trip production and attraction defined in section 1.3.1. It is a forecast of the amount of personal or freight travel. To achieve this, the first step is to develop a model of existing trip making, which can then be used to forecast the future.

In summary, this stage is about 'how many trips?'. For example, the number of trips originating in a zone will depend on factors such as how many people live there; similarly the number arriving in a zone might be related to employment or the extent of retail activity.

Trip-making behaviour clearly depends on a multiplicity of factors and the trip generation process attempts to analyse these. At the highest level, the literature usually distinguishes between home-based and non-home-based trips. The former would include both the journey to work from home and the return evening journey, as well trips for other purposes such as education. Non home-based trips include, for example, those made by people who travel as part of their work, such as salesmen, and are generally around 15–20% of all trips.

The two factors most commonly used to break down how trips are made are:

- purpose
- person type.

The trip purposes commonly used are:

- home based: work, education, shopping, social and 'other'
- non-home based: employer's business, other
- freight.

Different models are developed for each purpose as clearly travel-to-work behaviour will depend on different factors when compared with shopping trips, for example. Note also that for freight the volume of road or rail traffic generated is a function of both the volume of goods and the load factor (eg 12 tonnes/truck).

Personal factors which drive trip generation include income, car ownership and household structure. However, it can be seen that stratification in this way leads to a large possible number of combinations; for example with just six income brackets and household types and three car ownership levels, there are over 100 possible categories.

Trip attraction will usually depend on economic factors. Typically those used relate to employment and proxies for the level of activity such as the floor area given over to retailing or manufacturing.

Freight productions and attractions will depend on factors such as the number of employees, sales and floor area (which may in practice be 'field area' or 'forest area').

As discussed in section 1.3.1, trip generation is the first stage of four, so any errors here will be carried through to the remaining stages. It is therefore important to minimise errors as far as possible.

The usual method of producing a trip generation model is to use the zones in the network as data points and carry out a regression of the dependent variable (usually the number of trips for a particular purpose, although it could be trip rate) against independent, explanatory variables such as population and employment. The use of non-linear forms and dummy variables is not unusual. In this way it is possible to determine the form of a model for the base year such as:

$$\textit{work trips} = F(\textit{population, car ownership}) \quad \text{Equation 1.1}$$

Given forecasts of population and car ownership in a future year, the work trips in that year can also be forecast using the above equation.

Some caution is required in developing this type of model as the explanatory variables may be correlated, for example high income is likely to coincide with high car ownership.

A similar approach can be used (but clearly with different variables) for trip attractions. Once trip generations and attractions have been forecast for all zones, the respective row and column totals in the trip matrix are known. In practice it is rare for total generations and attractions to match exactly; normally generation forecasts are considered more reliable so attractions are factored to match them. However it would be a cause for concern if the difference between the two was much greater than 10% prior to balancing.

Category analysis is an alternative to the above approach. In this, trip behaviour is assumed to vary not between zones but between household categories. For example, a household with one occupant and no cars will make fewer trips than one with four occupants and two cars. For forecasting purposes, the trip behaviour in each category is assumed constant but the breakdown between categories will change, for example due to increasing car ownership or smaller households. Thus, forecasts are needed of the number of households in each category. Category analysis has both advantages and disadvantages relative to the zonal approach.

The forecasting of variables used in a trip generation model is clearly central to future year modelling. A detailed explanatory model of trip generation is of little use if the required forecasts cannot be obtained. It must be assumed, for example, that population forecasts take account of cohort effects, the aging population, more women working and so on, all of which will affect trip making.

The available population projections from Statistics NZ are segmented by five-year age groups and gender. It would therefore be possible to build a trip generation model which takes account of changes in the age structure of the population. The difficult part is to project what changes will occur in people's behaviour, an example of which has been the increased number of women working. There would have been two problems if we had tried to project the impact of this change before it happened: first, how quickly and by how much the change would be, and second, the effects of the change (eg Will they take their children to school by car? Will they make separate shopping trips or do them on their way home from work?)

A possible current/future example is changes in the number of people over the age of 65 still working. An aging population and no fixed retirement age are likely to result in more over 65 year olds working. Working people have different trip-making behaviour from those who are retired, but projecting the magnitude of the change is difficult as we need to know how many of a given age are likely be working for a particular future year.

The approach to trip generation modelling is essentially based on using cross-sectional data but in practice longitudinal effects will also play a part. The limited studies which have been carried out into the temporal stability of trip generation show that car trip rates are closely correlated with changes in real fuel prices, which generally cannot be forecast. Thus, for example, the assumption of constant trip rates during a period of increasing fuel prices will overestimate the amount of travel.

1.3.3 Trip distribution

Having established, through the trip generation stage, the number of trip productions and attractions for each zone, trip distribution determines how the trip ends are related, ie how many trips produced in origin zone Z_0 will be attracted to destination zone Z_i.

The most commonly used form of trip distribution model is the gravity model. In this the number of trips produced in zone i and attracted to zone j is assumed to depend on three factors:

- the population of i or a similar measure of activity
- the population of j or a similar measure of activity
- some measure of the cost of getting from i to j.

The higher the cost, the lower the number of trips; in the early models, trips were assumed to vary with the inverse square of the distance between zones, hence the use of the term 'gravity'. Current best practice uses exponential or power functions or both and is based on the generalised cost[1] of a trip. This term is sometimes called the impedance function or friction factor.

The output from the trip generation model for the future year is the total number of trips generated by, and attracted to, each zone; in other words the row and column totals of the trip matrix. The output of the gravity model is a full trip matrix but clearly this must meet the constraints given by the row and column totals. Models can be either singly constrained (either row or column constraints are met but not both) or doubly constrained (both row and column).

The solution to the gravity model entails the use of balancing factors for each row and column, giving the formulation:

$$T_{ij} = A_i\, O_i\, B_j\, D_j\, f(c_{ij}) \qquad \text{Equation 1.2}$$

Where T_{ij} is the number of trips from i to j, O and D are the origin and destination constraints, A and B are the balancing factors and c_{ij} is the generalised cost from i to j.

The values of A and B can be determined iteratively by a process known as either Furness or Fratar. During model calibration, the parameter(s) in the function f are determined from the observed trip length distribution (TLD); this too is an iterative process.

The gravity model is easily the most commonly used form, although there are alternatives. For example, the 'intervening opportunities' model is based on the relative accessibility of opportunities which satisfy the trip objective. While a mathematical formulation is possible, this approach is not often used for a number of reasons, not least in that it offers no theoretical or practical advantages over the gravity model.

Intrazonal trips (on the diagonal of the trip matrix) are generally not well represented in the gravity model, not least because of the difficulty of measuring their cost function. It is usually preferable to remove these from the gravity model and model them in other ways.

In general the form of the gravity model will vary between trip purposes. For example, work trips will be doubly constrained while most other purposes will be singly constrained, eg shopping trip attractions being estimated on the basis of retail floor area. Additionally, the form of the cost function will vary by purpose, ensuring that discretionary trips (eg leisure) are more cost sensitive than mandatory (eg work) trips.

[1] Generalised cost is the total cost of the trip to the person undertaking it. It not only includes all out-of-pocket expenses, but also the value of the person's time. For example, a bus trip will include not only the bus fare, but also the value of the time taken to walk to/from the bus stop, the time spent waiting and the time spent on the bus. Each time component may be valued differently as, for example, people dislike waiting more than being on the bus. Therefore the cost per minute will be higher for waiting time than in-vehicle time. The generalised cost can either be expressed in minutes or dollars, as the value of time can be used to convert between the two.

1.3.4 Mode split

The development of a mode split model as a function of trip purpose is part of the NTEM study. At the national level it would appear that land transport mode split is strongly correlated with trip purpose (air travel and coastal shipping were both excluded from the study). Leisure trips are able to use car, bus or passenger rail depending on the O-D pair and are influenced by domestic and international tourism. Freight trips have the choice of road or rail, again depending on the particular O-D pair, trip length and commodity type. Business and other trips are almost exclusively made by car for shorter distances and air for longer.

For the reasons just given, there is much less commonality between inter-urban and urban mode choice than is the case with trip generation and distribution. While there is a considerable body of knowledge on mode split in an urban context, this is less true of wider area models.

It is therefore not appropriate here to review in detail the theory of urban mode split as it is generally not easily transferred to the inter-urban situation. Nonetheless, it is worth briefly reviewing the factors which influence the choice process and which must therefore be represented in some way in any form of mode choice modelling.

The factors influencing mode choice can be classified into three groups:

- characteristics of the trip maker: age, income, car availability, household structure
- characteristics of the trip: notably purpose but also time of day
- characteristics of the mode: travel time, cost and qualitative factors such as comfort and reliability.

As far as possible the second and third of these are combined in the generalised cost of the trip, which includes the time costs and out-of-pocket costs such as fares and parking. There are a number of formulations allowing mode split to be forecast using the generalised costs of the competing modes.

While the above relate to passenger travel, there are clear analogies in freight.

1.3.5 Land-use transport models

Usually in four-stage modelling the land-use forecasts are derived by a stand-alone process based on demographic and economic modelling, with some adjustment for development capacities and other local factors. A land-use/transport model does projections of future population and employment at a zonal level integrated with the (often four-stage) transport model. The key difference in this system is that the land-use model takes as one of its inputs travel costs (or disutilities) between all the zones in the transport model. It then uses this in deciding where to allocate (usually just growth) in population and employment. More accessible zones are more attractive for increments of population and employment, with less accessible zones being less attractive to increments (and more attractive to decrements).

A land-use/transport model therefore has feedback effects between land use and transport and can model the impact of transport policies and infrastructure on land-use location. An example might be where a new road is built to an area (eg the ALPURT northern motorway extension to Puhoi, near Auckland). The new road will improve accessibility to the area near Puhoi due to faster journey times and therefore reduce travel costs, attracting new development to the area.

The land-use model usually also has a property market model incorporated allowing competition between different groups for the same floorspace; for example higher socio-economic group households can displace lower socio-economic group households from an area by outbidding them for houses.

There are also demographic and economic models either built in or used as inputs for the land-use model, so the effects of demographic and economic changes on the transport system can be modelled in a more realistic fashion. Hence the employment market and where people choose to work is also part of the land-use model.

Examples of this kind of model are the Oregon models discussed in section 2.1.3. They have been used in quite innovative ways; for example looking at the effects on the economy of truck weight restrictions on aging bridges (Gregor 2005). The model not only allows truck routes to adjust due to the weight restrictions, but also allows for the second-order effect of businesses moving (due to the changes in travel costs) and households moving (a third-order effect due to the businesses moving).

2 Literature review

2.1 Overseas practice

2.1.1 Introduction

In this chapter we present a review of models developed overseas which are relevant to a NTEM. The review does not claim to be exhaustive – for example it does not cover every US state model – but is broad enough to provide many useful pointers for a NTEM. Generally the review does not look at urban models but at those which are state or country wide. Additionally, aspects outside a NTEM such as surveys and data collection have not been reviewed.

2.1.2 Australia

2.1.2.1 BTRE working paper 66 (BTRE 2006)

This paper concerns demand projections for the non-urban corridors in Australia (collectively called 'Auslink'), covering the methodology used and the resulting projections. The freight model used is covered elsewhere in this report (section 2.2.2); the passenger model is called 'OZPASS'. This makes forecasts to 2025 from a base year of 1999; urban travel is not addressed.

OZPASS is essentially incremental; it forecasts growth in the dependent variable based on growth in the independent variables. It uses a gravity model formulation, with forecast growth in travel demand based on the forecast growth in three variables:

- population
- income
- travel costs.

Because of the way the model is formulated, it is necessary to constrain the growth in trip generation in any region to be less than the growth in trip-making potential in that region.

Rather than the conventional logit approach, OZPASS uses a process known as 'logistic substitution' for mode split. This is essentially a series of 'rule of thumb' measures indicating how the competitiveness of each mode varies with distance; for example air is more attractive than other modes for trips between 400 and 800km, and considerably more attractive for longer distances.

The impact of visitors is covered but is considered minor; international visitors make up less than 3% of total inter-regional trips although the proportion is higher on specific corridors.

Overall the predicted growth in inter-urban passenger movements is 2.6% pa to 2025. Growth in car movements is similar to the average but the rate for air trips is 4% and for rail, less than 1%.

Overall, this paper uses some interesting concepts which will be useful when considering possible model forms for New Zealand. For example, the approach to mode split is appropriate at the national level, which is not generally true for urban mode split modelling. The incremental approach is also worth further investigation.

2.1.2.2 Bullock (1977)

A paper provided by Dick Bullock, peer reviewer for this project, discusses patterns of rural travel in Australia and the development of models to summarise and describe these patterns. The original impetus for the work came from the development of the national highway network and the need to predict their effect on travel patterns.

The paper suggests strongly that trip generation and distribution should be treated simultaneously in the non-urban situation since total trip generation is a function of accessibility (put another way, people make fewer trips if there are fewer places to go to). It also neglects mode split to a large extent on the grounds that most trips are by car and the study did not have access to data on other modes.

A fundamental distinction is made between travel to/from the nearest regional centre and other travel; this is because the available data shows that 'trade areas' are major determinants of travel patterns. In terms of the conventional gravity model the implication is if the number of trips generated by/attracted to a centre with population P is proportional to P^k, then the value of k will vary between centres.

Central place theory is used as a means of classifying centres of population, from hamlets up to cities. While the original theory uses six levels, the paper reduces this to four for the Australian model, with level A being cities such as Hobart while D is villages. This allows trip making to be forecast differently according to the levels of the trip ends and the paper develops a series of models on that basis.

Factors underlying the growth of rural travel are also analysed. However the paper concludes that, despite high-quality data, it is not possible to produce definitive conclusions on the underlying determinants of rural traffic growth. On a route-by-route basis it concludes that changes in employment opportunities will be just as significant as changes in population in affecting the level of traffic.

In all, the paper looks at five different types of travel according to the nature of the trip ends. All the models estimated are of the gravity type. The elasticity of trip making with respect to distance is found to increase from -0.5 for local travel through -1.2 for primary trade area travel and -1.6 for secondary trade area travel to -2.5 for long-distance travel. Trip generation is found to be approximately proportional to $P^{0.7}$ for a centre of population P. The paper concludes that rural travel is not homogeneous but governed by the hierarchy of population centres.

2.1.3 USA

2.1.3.1 Rhode Island (Murthy and Salem 1999)

This paper describes the development of a state-wide model for Rhode Island using the package TransCAD. The information given, however, is limited.

The model follows the classical four-stage approach as described in chapter 1 of this report. In terms of trip generation, productions are a function of vehicle registrations and population. Attractions depend on:

- employment (only) for home-based work (HBW)
- retail employment, non-retail employment and population (two different functions with the same independent variables) for home-based non-work and non-home-based trips.

Trip distribution uses a gravity model (the exact form is not clear) and mode split is based on generalised costs.

For future year modelling, growth factors are applied for each zone based on forecast changes in vehicle ownership and employment. A Fratar process is used for balancing.

A number of case studies are given in which the model has been applied. These include roading improvements, lane restrictions and land-use changes. Freight modelling is cited as one possible future development.

2.1.3.2 New Hampshire (Sharma and Lyford 1999)

This paper, from 1998, describes the development of a state-wide model for New Hampshire, to be used for schemes such as new highways and policies such as tolling. It covers vehicles and transit (passenger transport), peak and off-peak and has a base year of 1990.

Unusually, the model is based on tours, not trips, so that a single tour includes both trips from home to work and back home again. At the time of writing it was one of only two such state-wide models in the US. The overall approach is similar to the conventional four-stage approach but time-of-day choice is included and truck trip modelling is separate.

Category analysis (see section 1.3.2) is used for the generation of tours, with categorisation by household size, number of workers, income, vehicle availability and dwelling type. Not surprisingly, the available future year forecasts of population required extra work to provide forecasts in all the relevant categories. The breakdown of tour types is conventional, primarily work, education, shopping and other.

Truck trips are modelled separately, with daily trip ends being estimated on the basis of zonal employment. A gravity model is used for truck trip distribution.

The socio-economic variables used in the model are given in the paper but the functional form of the relationship is not. There are no unexpected variables.

Overall, the tour-based approach is innovative but it is debateable whether the extra effort required in model development is worthwhile. It provides a good illustration of the difficulties of forecasting when category analysis is used for trip generation.

2.1.3.3 Idaho (Idaho Transportation Department Planning Division 2001)

This paper describes the development of a state-wide model for Idaho, with particular emphasis on trip generation rates and friction factors.

Again category analysis is used in the trip production model, with three income brackets, four household sizes and four levels of car ownership. Trip production is divided into HBW, home-based recreation and home-based other; trip attraction uses the same three plus non-home based.

The socio-economic and related variables used in modelling are:

- population
- households
- household breakdown by income, size and car ownership
- employment: split between retail, service and other
- land area.

The last two of these are used in trip attraction modelling for their respective purposes. The number of attractions is significantly below productions but no action has been taken on this other than to factor up the attractions.

Trip distribution uses the gravity model approach, with a friction factor including both power and exponential elements; in other words, if T is the travel time,

$$Friction = a * T^b * exp\ (cT) \qquad \text{Equation 2.1}$$

The parameters a, b and c vary by purpose and are fitted using log-linear regression.

It is not clear from the paper how (or indeed if) freight is modelled.

2.1.3.4 Wisconsin (Proussaloglou et al 2004)

The Wisconsin state-wide model is covered in this paper. It is described as a policy-sensitive model of freight and passenger flows. The paper begins with a brief overview of state-wide models, citing the key differences between them as:

- the way in which external trips are treated
- the level of detail and integration with urban models
- whether they are based on trips or tours
- the extent to which freight is included.

As with many other state-wide models, the trip generation uses category analysis, based on number of workers and number of cars. However a number of categories were found to have few data points (eg two workers, no cars) and these were combined with other, similar categories. The end result is a manageable number (12) of categories.

Trip attraction uses equations obtained by regression and relating to employment in a number of sectors; for example home-based shopping trips depend on retail employment at the attraction end.

The usual gravity model is used for trip distribution. Mode split is considered only in the urban areas.

An interesting feature of the Wisconsin model is that three different approaches are used in regressing trip productions and attractions against the independent variables. These are:

- state wide
- by urban/rural
- using five geographic areas.

For example, if shopping trips is K* retail employment, with approach ii there would be two different values of K, one urban and one rural. In the final model, approach iii is used.

2.1.3.5 Oregon

Introduction

In 1994, the Oregon Department of Transportation embarked upon a comprehensive Oregon Modelling Improvement Program (OMIP) to technically support new federal and state policies and regulations. A significant part of OMIP is the Transportation and Land Use Model Integration Program (TLUMIP) initiated in 1996.

TLUMIP is an integrated transportation, land-use and economic model for use in transportation planning and policy analyses at the regional and state-wide levels. The first generation of the model, called Oregon1, has now been successfully applied to several complex policy issues. Using information gained from these initial applications, Oregon2 significantly refines and expands elements of the program in a state-of-the-art modelling framework. This framework covers Oregon's 36 counties and parts of adjoining states. It operates at various levels of geography, including a 30m grid of study area land use. (Weidner 2005)

TLUMIP has therefore been aimed at developing a suite of models even more ambitious than the one implemented in Auckland. It has the advantage of allowing a wider range of policy questions to be analysed properly. The drawbacks are the cost and data needed. Whether a particular type of model is adequate for a task depends upon the questions we are trying to answer and the quality of the analysis required.

Appendix A looks at the technical work in this project.

2.1.3.6 Guidebook on statewide travel forecasting (FHWA 1999)

This publication presents the state of the art in state-wide travel forecasting and provides advice for those developing models. It is largely concerned with aggregate four- (or possibly three-) stage models and covers passengers and freight separately.

The paper discusses the use of urban approaches in state-wide modelling. The main advantages of this are seen as the availability of proven software, and refined, robust theories and algorithms. However there are also a number of disadvantages: the convenience of the software may prevent implementation of better methods; urban models may be overly complex; and data requirements may be excessive.

Urban algorithms may not be readily transferable to intercity applications; for example assignment methods rely on the notion of capacity to achieve results. Also, the size of inter-urban networks may be excessive for detailed urban modelling and large zone sizes may lead to coarse assignment results. A typical state-wide model will have 1000 to 2000 zones.

The paper suggests a simplified purpose breakdown for intercity travel: work related or business, recreation and other. Corridor studies should also include travel to work. Another consideration is that state-wide models often consider the day as the period to be modelled, rather than specific time(s) of day which is usually the urban approach.

The paper offers advice on the zoning system and degree of aggregation. These are governed by two key considerations:

- the level of aggregation of socio-economic data, both current and forecast
- the proposed use of the model (eg small- or large-scale planning).

In general, the socio-economic variables used in trip generation and attraction will be similar to those in urban models. The paper implies that category analysis is the usual approach. It appears that small towns and urban areas tend to generate more trips per capita than urban areas. In some models (Michigan is an example), some specific developments, such as airports and camp sites, have their own trip attraction functions.

The paper suggests the usual gravity model approach to trip distribution, with trip attractions being factored to match productions for each purpose. Typical friction factors are suggested. In at least two states of the USA, which have state-wide models, there have been problems finding a cost function for the gravity model which fits both long- and short-distance trips. This can be overcome by having two different functions.

Within the gravity model, the number of intrazonal trips is controlled by the intrazonal trip time; hence great care is required when defining the latter. The paper concludes that it may be best to exclude intrazonal trips from the gravity model (by giving them a very high cost) and estimate trip numbers by other means.

Air, rail and bus are suggested as alternative modes to road. There is a discussion of various forms of the logit formulation for mode split modelling but no specific recommendations relating to intercity travel.

The guidebook's recommendations in relation to freight forecasting are discussed in section 2.2.2 below.

2.1.3.7 NCHRP synthesis 358: statewide travel forecasting models (2006)

This document is both recent and comprehensive in terms of the state of the art in the USA.

The past 10 years have seen the use of state-wide models burgeoning to the extent that almost half the states in the USA now have them. This is due in part to increased computing power but also to huge improvements in the available socio-economic databases. The synthesis compares information from all the states which have models and includes five specific case studies. It also gives a comprehensive literature review.

With the exceptions of Ohio and Oregon, state-wide models still follow urban models in structure when modelling passenger travel. However there is a trend away from truck-only freight components to a commodity-based freight approach. Ohio and Oregon are implementing a new paradigm which integrates the forecasting of economic activity and land use (see above).

State-wide models are primarily used for intercity corridor planning and state-wide system planning; however, they are increasingly used for providing input to urban models. The level of detail varies greatly between states and not all models cover both passenger and freight movements. Most passenger components are multi-modal.

In general the networks and zones are coarser than urban models; nonetheless, some models have several thousand zones. Most states run 24-hour traffic assignments, not least because of the time taken to make many intercity trips. Trip purposes usually cover the traditional urban ones and others which are specific to longer distances. Passenger modelling is usually similar to the urban, four-stage approach.

There are two different types of freight forecasting: direct forecasting of vehicle flows and forecasting of commodity flows which are then converted to vehicle flows. Only three states model freight mode split explicitly, the remainder relying instead on historical mode shares as indicators of future shares.

2.1.4 United Kingdom

The TEMPRO program, prepared by the UK Department for Transport, is designed to provide projections of growth over time for use in local and regional transport models. It presents projections of growth in planning data and car ownership and resultant growth in trip-making by different modes of transport (under a constant-cost assumption).

TEMPRO is recommended for use in three circumstances to:

- derive local adjustment factors for applications where there is no transport model
- derive trip growth factors for use in highway-only models
- provide growth factors for trip matrices in strategic multi-modal models.

The TEMPRO software is a presentation tool aimed at making data available in a convenient format. The software which derives these figures is known as the NTEM. This is now a fully integrated part of the UK national transport model (NTM) framework which is currently being developed.

The NTEM provides the demand growth inputs to the NTM, thus forming the starting point for national forecasting work, which is increasingly concerned with policy-sensitive forecasts. Publication of these inputs through the medium of TEMPRO allows local models to be developed on a fully consistent basis.

The NTEM works by relating the number of trip ends in each zone to a range of demographic and land-use factors, such as the number of households with cars in each zone, and the number of people employed in each zone. TEMPRO trip-ends are based on the UK National Travel Survey (NTS) trip rates applied to projections of the household population. They should therefore include all journeys made by people living in households in Britain.

Trip destination purposes are aggregated in TEMPRO into eight purposes and further split into home-based and non-home-based trips. The purposes are:

- shopping
- work
- visiting friends and relatives at home

- recreation and leisure
- personal business
- education
- holiday and day trips
- business trips.

For each trip purpose the total number of trip attractions is controlled to be equal to the number of productions at the level of 'balancing areas'.

The NTEM adopts people as the unit for trip making rather than households. However, the population is segmented into categories based on the characteristics of the households in which they reside as well as characteristics of the individual. The traveller type disaggregation used internally within the model includes:

- age (under 16, 16–64, 65+)
- gender
- employment status (for 16–64 age group)
- household car availability
- household size (number of adults).

However the outputs are not available at this level of detail.

On the basis of there being no strong evidence of any increase in trip rates per person over the past 10 years, a constant trip rate is adopted for each of the disaggregate categories in the NTEM. However projected total trips still increase over time, due to population growth and shifts in the distribution of population between categories (including car ownership bands).

There are six modes in TEMPRO:

- walk
- bicycle
- car driver (including motorbike and van driver)
- car passenger (including taxi passenger)
- bus (including coaches)
- rail (including underground and light rail systems)

For the base year, the NTEM estimates trip productions for each trip purpose, zone and traveller type. These estimates are then segmented into time periods and modes, based on a set of factors derived from the NTS data. The NTEM relates trip attractions to employment and other land-use indicators in each zone. A set of modal weights (derived from the NTS) is then defined for the purpose of dividing the trip ends within a zone by mode.

There are three stages to the NTEM projections, namely:

- planning data
- car ownership
- trip ends.

Each of the three stages works at the level of NTEM zones, a system of around 2500 zones covering Great Britain. These zones nest within local authority areas, splitting these areas into different area types based on settlement size and population density. The average zonal population is around 20,000. Planning data comprises projections of population by age group, households, workforce and jobs.

For each zone in each future year, the car ownership model outputs the number of persons in each of 88 car ownership/person type categories. The trip-end model then applies to each of these a constant NTS-derived trip rate for trips by all modes, for a number of trip purposes.

The NTEM aims to set out a robust 'reference case' growth scenario for input to transport models. It does not assume the success or failure of any current or proposed policy initiative, land-use development, or infrastructure project. Where such policies or projects are likely to have a numerically significant impact on the case for a transport project, it is expected that the project appraisal will take these into account separately.

Part of the role of TEMPRO is to act as a nationally consistent benchmark for the distribution of growth in planning data. Without such a benchmark, it would, for example, be easy to end up in a situation where every area of the country justified transport proposals on the basis of above-average employment growth.

More details can be found in appendix B.

2.1.5 Other countries

There are many reasons why national and European transport models have attracted increased attention during recent decades. The broadening of national transport policy from strategic infrastructure investments to infrastructure management with regard to efficiency, environmental, safety and regional equity objectives has led to a need for advanced analytical tools. The increase in inter-regional and international mobility requires forecasting tools that go beyond the urban or regional level. The competition for national infrastructure investments between regions, and for trans-European investments between nations, has to be resolved by decisions and decision support systems at the appropriate spatial level. Environmental impacts transcend regional and national boundaries and transport policies affecting these environmental impacts involve all spatial levels.

Tavasszy (2005) identified some 27 models at the EU level, mostly multi-modal, of which 12 were passenger, eight were freight and seven covered both. Some of these were transnational, eg covering the alpine crossings. It appears there are national models in (at least) Italy, Denmark, Holland and Spain, although no detailed information could be found.

2.1.6 Summary

While there are a number of state-wide models in the USA, most of the states are not directly comparable with New Zealand, eg in terms of factors such as area, population and degree of urbanisation. Nonetheless the methodologies used in the various states provide a number of lessons for a NTEM. Oregon is the closest state to New Zealand in terms of population and area but it is clear that the modelling approach used there is very complex with substantial data requirements.

The UK's TEMPRO could be seen as a possible paradigm for New Zealand. While it may be too complex at this stage of national modelling in New Zealand, it may be a goal to aim for. As with the USA, there are many differences between the UK and New Zealand.

Ideally, any parallels with Australia would have to be at state level but such models do not seem to exist. Nationally, however, the approach used in OZPASS offers a number of interesting possibilities.

The wide range of models covered by this review shows clearly the trade-off between level of detail on the one hand and cost and complexity on the other; this would need to be taken into account in developing a New Zealand model.

2.2 Freight modelling

2.2.1 Introduction

Until recently the modelling of freight has generally had lower priority than urban passenger travel, probably because urban congestion has been seen as more of an issue. Moreover freight movements are harder to model in many ways; the process is more complex, involving many more parties, with inherent complexities such as the link to inventory control.

The factors affecting freight movements include:

- location, eg the sources of raw materials or produce
- a very wide range of products
- physical features of the goods, such as perishability, which result in the need for a wide range of vehicle types
- operational factors
- geographical factors such as the location of markets (which may be ports)
- dynamic factors such as seasonality
- pricing factors and how transport contributes to total price.

In principle, the four-stage model could be applied to freight movements and this approach has been used elsewhere. For example, freight generations could be estimated from zone properties such as employment. A gravity model might be possible for trip distribution although it could require a complex cost function to fully represent the types of factor listed above. Similarly, any attempt at mode split must take into account, through the cost function, aspects such as reliability.

From the point of view of a national model for New Zealand, one of the key outputs in relation to freight would be truck volumes on the roading network. This requires information on freight volumes (tonnes shifted); use of other modes, especially rail; and load factors, which relate volumes to truck numbers.

2.2.2 Overseas practice

2.2.2.1 Austroads (2007)

This is an internal Austroads report covering the state of the art in city and national modelling of freight transport in Australia as at 2006. It also contains a useful review of freight modelling internationally.

The closest thing Australia has to a national freight model is FreightSim, which is an econometric, commodity-based model covering 16 commodities and six modes. Its purpose is to estimate inter-regional freight volumes on key national corridors and how these change with economic variables. It does not produce vehicle flows as an output, although there is another model (FreightTrucks) which attempts to do this. In view of the methodology used, it has only limited parallels with the trip-end approach which is the basis of this study.

There are a number of interesting findings in the international review, particularly in terms of European practice. In most models, the commercial vehicle matrix is based largely on gravity models; however, this is changing with increasing interest in commercial vehicle movements for environmental and economic reasons, combined with the increasing dominance of road for all freight movements, particularly over longer distances.

The report notes that there are ‘substantial obstacles’ in the way of producing freight transport models which approach the capability of person transport models. These include the wide variety of commodities, many with specialised requirements; the highly controlled nature of freight movement; the specialised nature of logistics, which may not be understood by modellers; and problems with data such as commercial confidentiality.

For forecasting changes in freight activity, the ‘production–consumption’ paradigm is essential, in a similar way to ‘production–attraction’ with person movement. However there is a high incidence of intermediate stops, making it difficult to implement this concept.

In the absence of intermediate stops, modelling is essentially confined to route and mode choice. However a key consideration is load factors, and freight models usually consider annual quantities to address issues such as seasonality. Load factor is the key relationship between goods moved and truck movements but it is dependent on other factors such as the perceived cost of inventory holding.

Differentiation between commodity types is essential but it is likely that substantial approximations will have to be made to reduce the huge number which exists in practice to a tractable number (say a few tens) for modelling.

Imports and exports are an important part of freight movement. This raises a number of issues, in particular in terms of the trip distribution stage of the model. For example, in the New Zealand context, exports from the port of Tauranga may include kiwi fruit and logs, both of which come from highly specific areas in a way that could not be represented by the conventional approach. Nonetheless, the report concludes that in linking trip ends there is little choice but to use a gravity model.

Overall the report states that the absolute minimum is to try to build a base O-D matrix of road movements (eg using matrix estimation) and allow it to be sensitive to road network variations. Over time these matrices would be factored up to account for growth.

2.2.2.2 Guidebook on statewide travel forecasting (FHWA 1999)

The passenger aspects of this guidebook were discussed in section 2.1.3. The freight methods given draw on experience in five states, all of which broadly follow the four-stage process.

In terms of freight forecasting, the report points out that, in addition to a knowledge of the drivers of freight transport, such as economic activity, freight forecasting also requires an understanding of the behaviour of carriers and shippers and the characteristics of the respective modes. Factors affecting freight demand are complex and many of them are beyond the planner’s control.

The key steps in developing a freight model are given as:

- produce the modal networks
- devise a commodity grouping
- relate the commodity groups to industrial sectors or economic indicators
- establish base year commodity flows
- forecast growth by industrial sector
- split commodities by mode

- convert commodity flows to vehicle numbers.

Recommendations are given on how to go about these steps but many are specific to the USA. The details of how the model will deal with each of these depends on factors such as the level of accuracy required and the type of policy the model is designed to reflect.

For each commodity, trip generation can be represented as a function of activity or employment. For example, the Indiana state model uses regression equations giving tons produced per employee in each of 12 sectors.

The usual form of the gravity model is proposed for trip distribution, using production at the origin end of the trip and consumption at the destination. The friction factor is a function of distance; for example Indiana uses the exponential form $\exp(-bD_{ij})$; the value of the parameter b was found to vary considerably between commodities.

Three possible approaches to mode split are suggested:

- diversion models or elasticities
- 'expert opinion'
- mode split models, depending on factors such as cost, time, quality and access.

In terms of forecasting, the report points out that related factors may change over the forecast period. For example, if a forecast depends on employee numbers, it is necessary to allow for future improvements in productivity and the possibility that load weights and shipment sizes may change with time. These can affect the ratio between the quantity of goods and the number of truck movements.

The report gives summaries of state-wide passenger and freight models in existence in the USA at the time of writing, for example the number of zones and the modes and journey purposes covered. There are also a number of references. However this information is now several years out of date.

2.2.2.3 NCHRP synthesis 298: truck trip generation data (2001)

When estimating truck trip patterns it is necessary to know how trip generation is related to land use. The objective of this synthesis is to identify available truck trip generation data and to provide an assessment of the state of the art.

Compared with passenger modelling, current practice in truck trip generation is described as 'fairly primitive'. However, recent developments have gone some way to addressing that.

Truck trip generation data has generally been limited to land uses most commonly associated with truck use, such as warehousing and manufacturing. However other land uses, particularly in the retail sector, will also generate truck trips. Moreover, categories of land use are very broad and trip rates vary considerably within these categories and from place to place.

Commodity-based models do not develop truck trip generation rates; rather they forecast annual commodity tonnage which is then converted into truck movements using a payload factor. These methods tend to underestimate trips in urban areas as they do not account for trip chaining and local pick-up and delivery activity.

Most truck trip modelling attempts to classify by truck type, reflecting the different characteristics of freight carried which result in different generations. However there is no consistency in this approach.

While employment is often used as the explanatory variable for truck trips, the relationship between output and employment varies within broad industry categories, from firm to firm and (importantly from the point of view of forecasting) with time. A related issue is that employment data for detailed industry categories is generally difficult to obtain at the model zone level.

The issue of collection of movement data is also addressed. Direct surveys tend to produce low response rates, not least because of commercial confidentiality. Automatic counts have limited ability to differentiate vehicle types and any form of count presents problems in the choice of a suitable location where only traffic of interest will be picked up.

2.2.3 Freight summary

The use of the four-stage approach, modified as necessary, for freight is common but other approaches, including the use of econometrics, are also in fairly wide use. There are a number of complicating factors unique to freight, for example the relationship between volume transported and the number of vehicles.

The factors driving trip generation often relate to employment in specific sectors, with different models for different commodities. The gravity model seems to be the accepted approach for trip distribution. Mode split is clearly different from the urban passenger situation and other approaches such as elasticities have been proposed.

2.3 New Zealand models

2.3.1 National

2.3.1.1 NZTA

As operator of the state highway network, the NZTA is particularly interested in how state highway (SH) traffic volumes are likely to change in the future. Its predecessor, Transit NZ, commissioned three related studies to forecast SH volumes, namely:

- a trend analysis of SH volumes since 1992
- a review of economic growth trends by region
- a three-stage model (no mode split) using population growth as the driver of trip making.

Clearly the third of these is the closest to what is being planned for a NTEM, so we describe it here in more detail. The work built an emme/2 model (in fact, two models as the North and South islands were not connected), taking the SH network and having a total of 42 zones (27 North Island, 15 South Island). The zones were based on main population centres, as a result of which some areas of the country were not covered. The network was not coded in detail, for example there was no representation of different road types and congestion was not modelled. The base year was 2001 and the model covered a 24-hour period.

The trip generation model used a combination of SH volume counts and population data to give a trip rate per head of population for each zone. The trip rates varied between zones, being either specific to an area or taking the default value. Factors were applied to allow for the geographical areas not covered.

Trip distribution used a gravity model based on distance and with an exponential impedance function. The model parameters were not based on observed data. Some areas were considered together (for example the four zones in Auckland) and in that case no trips were generated between zones. Assignment was effectively all-or-nothing (ie all traffic used the shortest path).

The resulting base year flows were compared with actual and found to be 8–10% low on average, with a fair degree of variation. Traffic forecasts for future years (2006, 2011, 2016.....2031) were produced from population forecasts. The level of confidence in the outputs is said to vary between routes.

A number of possible improvements were identified, which clearly are relevant to the development of a NTEM:

- Zones should be extended to cover the whole country (not just the main population centres).
- The network should include travel time functions, capacities etc as in the 'conventional' assignment approach.
- Trip generation should be extended to include other drivers of trip making, not just population, for example economic activity and tourism.
- The approach to trip distribution should be improved.
- More and better quality data should be collected.

2.3.1.2 National freight matrix (Bolland et al 2005)

A Land Transport NZ research study carried out between 2003 and 2005 aimed to develop a national freight matrix (NFM). The study objective was to:

- develop estimates of the main (non-urban) freight movements within New Zealand, by commodity, tonnage, mode and origin-destination
- relate these movements to the location of processing/export facilities in the case of primary flows
- relate them to population and industrial production in the case of manufactured and consumer goods.

In particular, the focus was on:

- the land transport modes of road and rail, with some investigation of coastal shipping
- longer-distance and higher-tonnage movements
- existing movements, rather than forecasts of future freight movements.

The study involved the collation of freight data from all sources, standardisation to the base year (2002) and to a common format, and its categorisation by commodity and mode. Individual modes were then separated, allowing a complete rail matrix to be constructed directly from the available data, with rail bypassing the subsequent road matrix estimation process. Data deficiencies precluded the creation of a final sea matrix and any split by commodity.

Matrix estimation formed the core part of the development of the freight road matrix due to the limited range of road-based data available. This process began with an initial matrix based on available industry data then used link-based data in the form of road traffic counts to update the initial matrix in an iterative process until convergence was reached. Once completed, the road matrix was combined with the rail matrix to give a total land transport matrix.

The development of a total freight-trip-end model was examined and compared with the total matrix to check its suitability as a simplification of the previously applied matrix estimation process. A trip-end model for freight origins and destinations took freight productions and attractions estimated by the matrix estimation process and tried to relate these to explanatory variables in the same way as is done in trip generation. This is simpler to implement than the full matrix approach, does not require detailed data collection, and gives the ability to crudely estimate future year matrices. However the resulting matrix is not as accurate as the fully estimated matrix.

The main findings were:

- Of the three main modes (road, rail and shipping), road transport conveys most freight within New Zealand, having an approximate 83% share of tonnage and a 67% share of tonne-km. Rail has an approximate 13% of tonnage and 18% of tonne-km, and coastal shipping has a corresponding 4% of tonnage and 15% of tonne-km. Road has the shortest average haul of the three main modes, while coastal shipping has the longest.
- Three regions – Auckland, Waikato and Bay of Plenty – account for the production and attraction of over half of all road and rail freight, reflecting a concentration of population and industry. Canterbury, the largest region by area, is the only other region with a share of more than 10% of freight productions and attractions.

Over two-thirds of all road movements are less than 200km, with the Auckland region dominating and accounting for around a quarter of both the production and attraction of all freight. The greatest road tonnage corridors are, in descending order, Auckland to Auckland, Canterbury to Canterbury, Waikato to Waikato, Bay of Plenty to Bay of Plenty, Waikato to Auckland, and Waikato to Bay of Plenty. These corridors account for nearly half of all road freight tonnage and show the preponderance of short-haul movements by road.

Higher rail tonnages correspond to the locations of major industrial plants, mines and ports. The greatest tonnage corridors for rail are, in descending order, Bay of Plenty to Bay of Plenty, West Coast to Canterbury, and Waikato to Bay of Plenty. These three corridors account for nearly half of all rail tonnage.

The primary industries of agriculture and forestry are the largest originators of freight that can be categorised into a specific commodity group. The transport of logs, milk and livestock accounts for a significant share of total freight movements.

A trip-end model for freight origins and destinations shows some correlation to the modelled matrix, but further improvements in both the data and process would be required to achieve a reasonable level of accuracy.

2.3.1.3 Tourism flow model

The Ministry of Tourism (in conjunction with Lincoln University, Covec and Eagle Technologies) has developed a tourism flow model (TFM) to provide public agencies with information on past, present and future tourism demand. As well as international visitors, this includes domestic tourism involving either overnight stay(s) or day trips longer than 40km. In summary, the TFM is a statistical model with a front-end geographic information system (GIS). (Vuletich 2006)

The basis of the TFM is data on the origin, destination and travel mode of tourism trips, collected through the:

- International Visitor Survey (IVS)
- Domestic Travel Survey (DTS).

The IVS is undertaken as an exit survey at New Zealand's main international airports and has an annual sample size of around 5500. The DTS has an annual sample size of about 15,000 and takes the form of telephone interviews. Historic data is available for the past nine years.

The TFM collapses the survey data into 128 'catchments', each of which is represented by a node connecting the catchment to the transport networks (primarily road and air). The catchments are clearly the equivalent of the zones used in four-stage and other transport modelling.

While the tourism data is segmented, for example by type of visitor, transport mode and time of year, some aggregation is required to give meaningful sample sizes. In addition, use is made of conversion rates to translate trip numbers into passenger movements. Passengers can in turn be converted into vehicle numbers, using an occupancy rate of around four (which reflects the fact that cars are likely to have several occupants and some people will travel by bus).

The TFM network includes state highways, other known tourist routes, link roads (centroid connectors) and ferry routes. The model includes the equivalent of the assignment of trips to the network, which is based on both the travel time and tourist value of a route segment. There is also a similar, but simpler, air network; again mode split is part of the market segmentation.

Tourism flows in New Zealand are split roughly 25% international, 75% domestic. The former is growing quite rapidly, at around 5% pa, but the latter is fairly static. On some roads tourist flows comprise up to 50% of the total but the average is around 10–15%. The largest tourism flow on the SH network is between Auckland and Hamilton, although clearly this also has high flows of other traffic, including freight.

Forecasts of tourist flows up to seven years ahead are available, using an external forecasting programme based on the same segmentation of the market as the base data. The forecasts are not specific to geography in the sense that there are no ‘main attractors’. Changes in travel patterns are driven by changes in market composition over time, not by changes in travel patterns within market segments. This means that the approach used is not the same as in trip generation, where tourism flows would be a function of factors such as the land area given over to tourist attractions. Similarly, trip distribution is based on historic patterns rather than the synthetic gravity model approach.

In summary, it is clear that the TFM contains much that is useful in respect of tourism and leisure, key generators of longer-distance trips. The methodology used is however very different from the conventional four-stage transport model.

The Ministry of Tourism supplied data and forecasts from the TFM which have been used in the ongoing development of the NTEM.

2.3.2 Regional

2.3.2.1 Overview

There are three major regional multi-modal transport models in New Zealand – in Wellington, Auckland and Christchurch. Over the period 2007–08 the latter two were completely rebuilt, both timed to coincide with the 2006 census. The new Wellington transport strategy model (WTSM) was completed in 2003 to a 2001 base and later updated to a 2006 base. In general the models in other cities, such as Tauranga, are pure roading models.

While this study was underway a new multi-modal transport model for the Waikato was built. Its details were unavailable when the review of the regional models was undertaken and it was decided not to review it later as it was unlikely to change the conclusions of this study.

Urban and regional models are of interest to the New Zealand NTEM for two reasons:

- The methodology used for aspects such as trip distribution may have implications for the NTEM.
- The data collected during model development is likely to be of use in the case study.

2.3.2.2 The Wellington transport strategy model (WTSM)

Trip productions in the trip generation modelling take the form of a trip rate for each person, with the rate varying by characteristics of the person and (in some models) their household. For example, in the HBW model there are four trip rates according to full- or part-time and whether or not the person is an employee; for home-based education there are four rates for each of four age ranges.

Zonal attractions are a function of planning variables and zone type. The model was calibrated using regression of observed attractions against planning data, taking account of the following factors:

- choosing the explanatory variables carefully
- considering possible characteristics of outliers
- considering using more than one model where the observed values cover a wide range
- being cautious of correlation between explanatory variables.

The resulting models have the expected explanatory variables, for example employment in the case of HBW. An interesting feature is the use of a 'TLA correction factor', so that otherwise identical zones in, say, Kapiti and Porirua will attract a different number of trips.

This approach requires the use of a family structure model, which uses population-based planning data to forecast the implications for car ownership and family structure. While planning forecasts provide population numbers in seven types and households in five types, the trip production model requires a full cross-classification of the population in each zone by seven person types and 15 household categories. This is estimated in the family structure model. There is also a separate car ownership model.

Distribution and mode split are considered together in the WTSM; in the HBW model they are simultaneous while in the remainder mode choice is done first. However the mode split is of an urban nature and not of immediate interest to the NTEM.

Trip distribution takes the form of a doubly constrained gravity model with an exponential cost function. The impedance between zones i and j takes the form

$$k_1 + k_2 * cost\ (i,j) \qquad \text{Equation 2.2}$$

Where k_1 and k_2 are constants for each sector (group of zones).

Intrazonal costs are given special attention and are set to the lesser of five minutes and the minimum interzonal cost.

For commercial vehicle modelling in the WTSM, a deliberately simple approach was taken to address two key issues:

- identify trucks separately in the model
- address under-reporting in business trips during the household surveys.

Separate light and heavy commercial vehicle models were developed, although in this review we will concentrate on the latter as it is of much greater relevance to NTEM. Light commercial vehicles are combined with other light vehicles and in forecasting are separated in order to apply a higher growth rate than cars.

In essence, a base year, 24-hour heavy commercial vehicle trip matrix was developed and then grown to future years. The base year matrix used a prior matrix and screenline counts as inputs to a process of matrix estimation; the final base matrix was taken as the average of the estimated matrix and its transpose on the grounds that all trips would balance over a 24-hour period.

To produce the forecast trip matrices, employment types with expected similar trip rates were aggregated into five categories. The trip rates from previous studies elsewhere were then used to produce an estimated rate for each category based on number of employees. Employment classifications were deliberately chosen to be simple in order to minimise the impact of any future changes in classification.

It was noted that heavy commercial vehicles had grown faster than either gross domestic product (GDP) or population and to take this into account a process of economic growth, additional to trip-end growth, was included. Total growth in heavy commercial vehicle trips is thus a combination of:

- employment growth trends by zone, which will predict geographic changes
- an additional growth factor based on GDP per capita to avoid double counting.

2.3.2.3 ART3 (Auckland)

The original Auckland regional transport (ART) model was a four-stage transport model for the Auckland urban area and parts of the adjacent rural area produced for the Auckland Regional Council in the early 1990s. Since then it has been subject to limited updating, but in 2005 tenders were called for a new four-stage model to be known as ART3.

The ART3 project is a completely new model and has the following features:

- It is calibrated to 2006 data including the census, household travel surveys, passenger transport surveys, commercial vehicle surveys, traffic and passenger transport counts and other data.
- The modelled area is the whole of the Auckland region (as of 2006) plus Tuakau and Pokeno. This area is split into 512 zones.
- Road and passenger transport networks are more refined in ART3 than in the previous ART model.
- The trip generation model determines the total number of trips on a daily basis and then allocates them to five specific time periods.
- The distribution of trips across the region simultaneously takes into account travel costs by different modes when choosing destinations.
- Trips are allocated to a time period according to the cost of travel in each period after distribution and mode split.
- Assignment is carried out for three periods of two hours; the am peak, interpeak and the pm peak. The interpeak assignment is a two-hour average of the six-hour interpeak.
- Commercial vehicle modelling is much improved and light and heavy vehicles are separate on the network.
- The full demand for passenger transport is derived and then assigned onto the full passenger transport network (rail, ferry, bus) during each of the three assignment periods. Route choice (and thus mode choice) occurs during assignment according to the cost of travel on each route.
- Active mode productions (walk and cycle combined) are partly modelled in that only the daily origins (not destinations) of active trips are calculated. Refinements include increased active trip making in CBD and CBD-fringe areas and adjustments to car and passenger transport trips according to the amount of active trip making.
- Junction modelling has been enhanced: link delays and intersection delays are now modelled at a reasonably comprehensive level.

The original ART model worked with a land-use model known as ASP, thus forming a land-use/transport model. In parallel with the development of the new transport model a new land-use model known as ASP3 has been developed using the DELTA software which in this application allocates future regional projections of persons, households and employment across the 512 ATM2 zones.

There is a requirement for the land-use projections to have a finishing date of 2051 and hence for the land-use/transport models to project out to this date.

2.3.2.4 Christchurch transport model

The new Christchurch transportation model (CTM) was developed for the multi-party client of the NZTA, Environment Canterbury, Christchurch City Council and Waimakariri District Council. The objective of the project was to develop a robust analytical tool to predict demands for, and use of, the transportation system in the greater Christchurch area. The scope of works was to develop a completely new, traditional, four-stage multi-modal model of greater Christchurch representing average weekday person travel. The model enables strategic plans and policies to be evaluated in a consistent manner, promoting long-term multi-modal strategic transportation planning in the context of the NZ Transport Strategy (NZTS) and the Land Transport Management Act 2003 (LTMA).

The observed travel data fundamental to the development of the model included a comprehensive household interview survey, roadside interview surveys and an on-board public transport passenger interview survey.

The CTM adopts a land-use-based category approach for daily person trip generations considering household characteristics and vehicle availability for eight trip purposes. The trip attraction model is linear in form relating daily person travel to land-use variables. The mode split/distribution model is a nested logit formulation and estimates daily person travel by three main modes, namely private vehicle, public transport (bus and ferry) and bicycle. An occupancy model applies observed vehicle occupancies to convert person trips to vehicle trips. Integral to the main person-based model is the Christchurch commercial vehicle model, which is a three-stage vehicle-based model relating medium and heavy commercial vehicle travel to available land-use data. The final stage of the model is the road assignment (peak-period vehicle trips for light and medium/heavy vehicles) and the public transport assignment (peak-period person trips).

The CTM has a base year of 2006, consistent with the national census and benchmark forecast years (2016, 2026 and 2041) relating to land-use forecasts developed through the Greater Christchurch Urban Development Strategy..

3 Conclusions from the literature review

3.1 General

There are a number of innovative approaches to four-stage modelling, including the use of tours, rather than trips, and the integration of transport with land use. However it must be debateable whether the extra effort required in model development is worthwhile. On the other hand, the approach used in OZPASS is essentially incremental, which may be worth further consideration. In simple terms it forecasts growth in the dependent variable based on growth in the independent variables.

The use of urban approaches in inter-urban modelling is clearly common. The main advantages of this are seen as the availability of proven software and refined, robust theories and algorithms. However there are also a number of disadvantages: the convenience of the software may prevent implementation of better methods; urban models may be overly complex; and data requirements may be excessive although this can be overcome by simplified structures. There seems to be no realistic alternative to the four-stage approach but its limitations must be acknowledged.

A simplified purpose breakdown for intercity travel – such as work related or business, recreation and other – may be adequate for most purposes. Corridor studies should also include travel to work. Another consideration is that state-wide models often consider the day as the period to be modelled, rather than specific time(s) of day which is usually the urban approach. This reflects, among other things, the time taken to make many intercity trips.

In general the networks and zones are coarser than urban models; nonetheless some models have several thousand zones.

In general state-wide models serve similar purposes to urban models, allowing transport schemes or policies to be tested and evaluated. In the UK, part of the role of TEMPRO is to act as a nationally consistent benchmark for the distribution of growth in planning data.

The early work by Bullock (1977) identified that trip generation and distribution should be considered simultaneously as they are related behaviourally. It also used different model parameters according to the nature of the trip ends (eg regional centre). Similar approaches have been used elsewhere, as discussed in section 7.2 of this report. The concept of catchments which was used in rural Australia seems intuitively to be promising for New Zealand if a suitable framework can be devised.

It is noted that no example was found of a national or state model developed from an observed base year matrix or matrices which are then factored for forecasting.

While US and UK models appear to have been implemented successfully, it must be borne in mind that the geography of those two countries is very different from that of New Zealand. For example, longer-distance (private) trips may be more common in the UK than here because of that country's extensive inter-urban motorway network. Additionally the UK TEMPRO is based on many years of NTS data, something NZ does not have to the same degree.

3.2 Trip generation

In general, the socio-economic variables used in trip generation and attraction will be similar to those in urban models. Category analysis, in which trip making depends on factors such as age and car ownership, is the usual approach. There is some evidence that small towns and urban areas tend to generate more trips per capita than larger urban areas.

A possible drawback with category analysis, based for example on employment status, number of workers and number of cars, is the large resulting number of possible categories. However a number of categories are usually found to have few data points (eg two workers, no cars) and these can be combined with other similar categories giving a manageable number overall.

In both the Wisconsin and Wellington models the modelling of trip productions and attractions against the independent variables varies between geographic areas.

The forecasting of variables used in a trip generation model is clearly central to future year modelling. A detailed explanatory model of trip generation is of little use if the required forecasts cannot be obtained. It must be assumed, for example, that population forecasts take account of cohort effects, the aging population, more women working and so on, all of which will affect trip making.

Category analysis may require the use of a family structure model, which uses population-based planning data to forecast the implications for car ownership and family structure. For example, in the WTSM, while planning forecasts provide population numbers in seven types and households in five types, the trip production model requires a full cross-classification of the population in each zone by person type and household category. This is estimated in the family structure model. There is also a separate car ownership model.

The approach to trip generation modelling is essentially based on using cross-sectional data but in practice longitudinal effects will also play a part. The limited studies which have been carried out into the temporal stability of trip generation show that one of the factors affecting car trip rates is changes in real fuel prices, which generally cannot be forecast. Thus, for example, the assumption of constant trip rates during a period of increasing fuel prices will over-estimate the amount of travel.

On the other hand, a constant trip rate is adopted for each of the disaggregate categories in the UK NTEM model. This is due to there being no strong evidence of any increase in trip rates per person over the past 10 years. However projected total trips still increase over time, due to population growth and shifts in the distribution of population between categories (including car ownership bands).

The NTEM model works by relating the number of trip ends in each zone to a range of demographic and land-use factors, such as the number of households with cars in each zone, and the number of people employed in each zone. TEMPRO uses NTS trip rates applied to projections of the household population.

The NTEM model adopts people as the unit for trip making rather than households. However, the population is segmented into categories based on the characteristics of the households in which they reside as well as characteristics of the individual. The traveller type disaggregation used internally within the model includes factors such as age, gender, employment status and car availability.

3.3 Trip distribution

The usual (possibly the only) approach to trip distribution is the gravity model, with trip attractions being factored to match productions for each purpose. In a number of cases there were problems finding a cost function for the gravity model which fitted both long and short distance trips; this could be overcome by having two or more different functions or by choosing functions which vary geographically.

Within the gravity model, the number of intrazonal trips is controlled by the intrazonal trip time; hence great care is required when defining the latter. Indeed it may be best to exclude intrazonal trips from the gravity model (by giving them a very high cost) and estimate trip numbers by other means.

3.4 Mode split

There is much less commonality between inter-urban and urban mode choice than is the case with trip generation and distribution. While there is a considerable body of knowledge on mode split in an urban context, this is much less true of wider-area models. In terms of non-freight trips the key choice for long-distance travel is between car and air; for business trips air may be the only realistic choice.

Rather than the conventional logit approach, OZPASS uses a process known as 'logistic substitution' for mode split. This is essentially a series of rule-of-thumb measures indicating how the competitiveness of each mode varies with distance. This has potential for application in New Zealand.

3.5 Freight

There are two different types of freight forecasting; direct forecasting of vehicle flows and forecasting of commodity flows which are then converted to vehicle flows. In the USA, only three states model freight mode split explicitly, the remainder relying instead on historical shares.

Truck trip generation data has generally been limited to land uses most commonly associated with truck use, such as warehousing and manufacturing. However other land uses, particularly in the retail sector, will also generate truck trips. Moreover categories of land use are very broad and trip rates vary considerably within these categories and from place to place.

It is generally true that the number of heavy commercial vehicles has grown faster than either GDP or population and to take this into account a process of economic growth, additional to trip-end growth, can be included. Total growth in heavy commercial vehicle trips would thus be a combination of employment growth trends by zone, which will predict geographic changes; and an additional growth factor based on GDP per capita.

Again the unusual topography of New Zealand, combined with the industrial dominance of Auckland, will have an effect on trip patterns and particularly trip distribution. In this context distance is likely to be less of a deterrent than might otherwise be the case; for example the NFM work showed that there was a considerable volume of freight being moved from Auckland to Christchurch.

3.6 Summing up

The literature review has shown that there is a wide range of techniques available which might be used in the development of a NTEM for New Zealand. However the unusual distribution of population and the topography of the country are likely to give rise to issues which have not been encountered elsewhere. It is also clear that there is a relative dearth of data here compared with some other countries.

4 Case study sources

4.1 Introduction

In this chapter we examine the data currently available in New Zealand which might be used to develop a NTEM for the country. The main purposes for such data would be to provide:

a) information on current trip making in order to calibrate the model

b) forecasts of variables such as population and GDP that might be used in the NTEM to predict future trip patterns.

Possible sources of a) include existing models at the urban, regional and national levels and these are discussed in sections 4.2 to 4.4. Another source of the data in a) is any surveys, such as traffic counts and these are covered in section 4.5.

Section 4.6 covers item b), the forecasts which are available and would be of use as predictors of future behaviour.

Sections 4.7 to 4.9 present the findings of a review which has been undertaken comparing available trip data from two urban models and the TFM to ascertain the level of consistency between the data sources.

4.2 Tourism flow model

4.2.1 Introduction

The TFM was built by Covec for the Ministry of Tourism, with a GIS front end by Eagle Technology. It produces projections of future tourism numbers, segmented by domestic and international tourists. It consists of two parts: the dynamic module and the static module. We are interested in the dynamic module which produces projections of future travel patterns by tourists. The static module produces projections of what visitors do when they reach their destination (eg number of nights, activities undertaken, expenditure) (Vuletich 2006). Information on the TFM can also be found at www.tourismresearch.govt.nz along with information on the two surveys discussed below.

The TFM is of interest to the NTEM project as it has produced O-D matrices for past and future years. These are at the level of tourism flow area (TFA), which are either aggregations of territorial authorities (TAs) (eg the four Auckland cities and Papakura District are one TFA) or aggregate to form a TA (eg Rodney District is made up of three TFAs).

The TFM is based on two surveys: the IVS and the DTS. These are ongoing surveys so the model is based on a number of years of data from both surveys.

4.2.2 Domestic Travel Survey

The DTS measures the travel patterns of New Zealanders within New Zealand and is a telephone survey with 15,000 interviews per year of the usually resident population aged 15 years and older. It was first conducted in 1983 and ran until 1989–90. The DTS was not conducted again until 1999 and has continued to run through to the present.

A range of data is collected, including day trips, overnight trips, nights away, places stayed, main reason of trips, transport used, activities undertaken and expenditure.

Results for the DTS are presented on a rolling 12-month basis (year ended March, year ended June etc), and are available on www.tourismresearch.govt.nz [2]

The survey has the following sections: recording of trips made; main overnight or day trip; main overnight/day loop; expenditure on other items; overseas trips; demographics.[3]

It records all overnight trips and day trips over 40km from home within the last four weeks by usually resident persons aged 15 years and older. It covers all trips by domestic visitors; who are defined as 'persons residing in a country (ie New Zealand), who travel to a place within that country outside their usual environment for a period not exceeding 12 months, and whose main purpose of visit is other than the exercise of an activity remunerated from within the place visited'.[4]

The survey collects a large amount of information about the trips that people have made, some of which is of no interest to us (eg amount ($) spent).

4.2.3 International Visitor Survey

The IVS is carried out near the departure gate of international flights and collects a range of information from visitors to New Zealand about their visit including 'the transport and accommodation types used, and places visited'.[5] It was conducted in 1990/91 and 1992/93 and re-commenced in January 1995. It is now a continuous ongoing survey, providing quarterly information on visitor trends to assist industry planning and development.

It provides us with information on the travel patterns of international visitors to New Zealand. However it must be questioned whether international visitors contribute enough to the total amount of travel in New Zealand to merit inclusion in a national model, with the possible exception of their contribution to travel near places such as Rotorua and Queenstown.

4.2.4 How the TFM works

The TFM takes the data from the above surveys and uses it to construct an O-D matrix of all travel by international visitors, all overnight trips by New Zealand residents and all day trips over 40km by New Zealand residents. This is likely to cover most of the private car travel that would be included in the NTEM, as it only excludes day trips 40km and under by New Zealand residents, travel to work and freight traffic. However a stop of an hour or more causes a split into two trips. For example, a journey by car from Auckland to Wellington, with a stop in Taupo for a meal for an hour is recorded as two trips – one from Auckland to Taupo and another from Taupo to Wellington. This is potentially problematic, particularly for trip distribution, when constructing the NTEM.

The TFM trip matrix obtained for use in the NTEM is expressed as the number of person trips by quarter of the year. It is segmented into the travel modes: road, air and other (eg rail, bicycle and walking). Hence there is no distinction between people travelling in different road modes such as cars, camper vans and coaches. As there is no information on vehicle occupancy it is difficult to relate the person flows to vehicle flows. Covec related them by multiplying vehicle flows at Transit NZ (now NZTA) telemetry sites by 4.5. This was based on an assumed occupancy of two for light vehicles and 25 for heavy vehicles (Vuletich 2006, p22).

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[2] The preceding three paragraphs are almost direct quotes from: www.tourismresearch.govt.nz/Datasets/Domestic+Travel+Survey/default.htm

[3] Quoted from: www.tourismresearch.govt.nz/Datasets/Domestic+Travel+Survey/Questionnaire.htm

[4] Quoted from: www.tourismresearch.govt.nz/Datasets/Domestic+Travel+Survey/Classifications+and+Definitions.htm

[5] Quoted from: http://www.tourismresearch.govt.nz/Datasets/International+Visitor+Survey/Survey+Methodology.htm

The methodology used to produce a TFM is somewhat different from that used to produce a transport model, although there is only a limited description of it in the documentation supplied. There is more information about the data sources and how they were manipulated to produce the model inputs.

The TFM is constructed as an add-on to the GIS package ArcMap with the road flows presented on a map of New Zealand. A future scenario is supplied with the model; these outputs being pre-defined. It is possible to create different scenarios, for example growing the arrivals from one particular market (eg Australia) faster or slower than in the base scenario that comes with the model. Other types of analysis are possible, for example selecting visits by visitor origin (McDonald 2006).

The TFM also contains information on the assignment of road trips onto a road network using the shortest travel time algorithm in the ArcView GIS package. Air trips were assigned using information supplied by Air New Zealand. They acknowledge that the assignment algorithm is relatively crude, although it does take into account factors such as distance, straightness of road etc and 'tourist value' (represented by the attractiveness of popular tourist routes). They also point out that there is only one viable route between many destinations in New Zealand (Vuletich 2006).

Compared with a transport model the TFM is relatively unsophisticated as most transport models have equations built into them that allow the testing of different policies (eg what happens if we introduce a toll road along this route?). Therefore while the outputs of the TFM may be useful in providing trip data for a NTEM, it offers little in terms of a theoretical structure.

It seems likely that a reasonable percentage (probably most) of longer-distance trips can be obtained from the TFM. While freight is excluded, it is covered in other sources such as the NFM research (Bolland et al 2005) and the *National freight demands study* (Paling et al 2008). The other exclusions are trips to work, which for longer distances are likely to be small in number, and trips under 40km. Some of the latter are likely to be found in a NTEM with TA-based boundaries. Journey purpose is discussed further in section 8.3.

4.2.5 Available information

Two tables have been supplied by the developers of the TFM: a trip table and a flow table. The trip table has the following fields: origin (where the person came from), year (both historic and projected), quarter (of the year), season (summer/winter) and trips. The flow table has the following fields: origin (same as trip table), year (same as trip table), season (same as trip table), (travel) mode, from node (origin in transport modelling), to node (destination in transport modelling), proportion (multiply this by the trips in the trip table to get a flow from the from node to the to node for the relevant origin, year, quarter and season). The proportion is called a conversion rate in the model, possibly reflecting its market research background.

Hence the lowest level of aggregation is the flow from origin to destination by quarter of a particular year for tourists from a particular origin (eg Auckland or Australia). However the Auckland tourists could be travelling from Rotorua to Wellington – they merely live in Auckland.

4.2.6 Possible use of the TFM in a NTEM

The TFM provides the number of people travelling between zones. These zones in many cases are the same as, or relate closely to, the ones we might use in the draft model. The main issue with this is that it models person flows, rather than vehicle flows. The TFM proper has mapped information in ArcMap on road flows (the documentation implies these are person flows), with the facility also existing to map the counts at NZTA telemetry sites (McDonald 2006.) A more detailed examination of the TFM has, however, not been possible as it calls for the ArcMap software which was not available to the project team.

An alternative (and possibly a better option) is to calculate tourist vehicle flows directly, especially given that we are not calculating flows on individual roads. To do this we need information on vehicle occupancy in New Zealand which is available from the following sources:

- The NZTA (2010) *Economic evaluation manual*. Information is available in appendix A2.5; but only includes cars, and light, medium and heavy commercial vehicles. Buses are not included.
- An analysis of the 1997/8 NZ Household Travel Survey done by Pinnacle Research. Unfortunately the survey only covers urban travel and is over 10 years old. (Pinnacle Research 2003)
- The papers by Becken and Cavanagh referenced in the TFM methodology documentation (Becken 2002; Becken and Cavanagh 2003).

Using these assumptions we could relate person flows to vehicle flows between origins and destinations and this would help with constructing a trip generation and distribution model. It would be especially helpful in modelling trips (eg international visitors) that do not relate closely to the parameters found conventional trip generation models. These issues are discussed further in chapter 5.

4.3 Other New Zealand national models

During the course of the research no national models, other than the TFM, came to light.

4.4 New Zealand regional models

4.4.1 Introduction

Data which has been collected at the local level is likely to play a major role in the development of a national model such as a NTEM. This is particularly so in view of a comparative dearth of data at the national level (see section 6.2.1). Trips entering or leaving the major centres are likely to be significant contributors to national movements, for example distributing goods from manufacturing centres such as Auckland or taking forestry products to port for export.

As discussed in section 2.3.2, regional models of the three major centres are currently being developed or have been developed within the last few years. This includes collecting movement data on the boundaries of the respective regions, for example SH1 and SH2 out of Wellington. All the other main urban centres, such as Tauranga, have their own traffic models and it is to be expected that data on trips between internal and external zones can be obtained from them. During the case study we examined the availability of this data.

4.4.2 The ART-3 model

ART-3 was described in section 2.3.2. As part of its development, new travel surveys were carried out as the existing model was based on those done in 1991. The recent surveys are a potential source of data for a New Zealand national model and consist of the:

- household travel survey – this involved all members of a sample of households keeping a travel diary for a specified 24-hour period
- external cordon survey – roadside interviews were conducted at 16 sites around the edge of the modelled area. At each site a sample of traffic was surveyed in one direction from 7am to 7pm on one day

- public transport intercept survey – a survey of public transport passengers regarding their origins and destinations, trip purpose, trip timing, car and parking availability
- commercial vehicle survey
- traffic counts
- private vehicle travel time surveys
- public transport travel time surveys, including school bus surveys
- vehicle O-D surveys.

4.4.3 Other urban models

We reviewed the availability of data from other projects that might have a good sample of longer-distance trips. We found the following data sources in addition to those mentioned above:

- roadside interviews for the update of the Western Bay of Plenty transport model (2007): this data was obtained and analysed
- roadside interviews (done in 2008) for the Waikato regional transportation model: we attempted to obtain this data, but were unsuccessful
- surveys carried out for the new Wellington regional transport model (2001): unfortunately this data is no longer available and it may also now be considered out of date
- other North Island data: from the authors' experience there are a number of other urban areas which have traffic models, for example Napier–Hastings and Palmerston North. However it was not possible to ascertain the quality of the external trips for each of these, which would have been useful for the NTEM. Some of the models would include external data; for example the Taupo urban model was used to justify the bypass there. Further work may be justified in this area, although nationally the overall amount of data from any one model is unlikely to be large.
- surveys carried out for the new Christchurch transport model; we attempted to obtain this data, but were unsuccessful.

Given the paucity of data in the South Island and the finite budget we decided to restrict the case study to the North Island only. This also avoided the problem of modelling inter-island trips which are likely to behave differently from conventional road trips given that the time and cost of travelling between the two islands by sea is high in relation to the distance involved.

4.5 New Zealand national data

4.5.1 NZ Household Travel Survey

The NZ Household Travel Survey (NZHTS) started life in the 1989–90 June year when 4400 households were approached (gross sample). In 1997–98 the survey covered approximately 8000 households. From 2003 to June 2008 the gross sample was 2200 households per year and since July 2008 this has increased to an annual gross sample of 4600 households.[6]

[6] See the Ministry of Transport website for further information on the NZHTS *www.transport.govt.nz/research/LatestResults/*

An interviewer visits the household and interviews all the persons in the household. Two days in the week are selected for each household, including weekdays and weekends. Travel information is recorded for each day and each person in the household. This includes:

- trip purpose
- destination
- household demography
- information on the vehicles in households including number, size etc
- mode including car, walking, cycling, train, bus and ferry.

Geographic spread: the sample is spread throughout the country and covers all regions. It is believed that this spread gives a reliable snapshot when aggregated to local government regional levels. The data set includes information on travel across Cook Strait.

Survey data is available from the Ministry of Transport (MoT). There is no charge for the information unless significant staff time is required to retrieve it. Reports summarising the annual data sets and the survey questionnaire are available on the MoT website.

In conclusion, the survey appears a useful data set which may assist in building a national trip-end model. The availability of information over an extended time period provides an opportunity to examine the stability of trip rates over time. The statistical distribution of trip lengths which can be obtained from the NZHTS is likely to be useful in modelling trip distribution. However there may be some issues with definitions in the NZHTS (eg trip and purpose definitions) which may limit its usefulness.

4.5.2 State highway traffic data

The NZTA has a programme of counts which are done annually at intervals around the SH network (NZTA, published annually). These provide annual average daily traffic (AADT) flows, with commercial vehicles at some sites identified separately. This data was used in the matrix estimation stage of the NFM project (see section 5.1.2).

Although no matrix estimation is planned for the NTEM (not least because it requires assignment which is not being covered), the SH data may still be of use. For example, it would be possible to draw a screenline between the Taranaki region and the rest of the country and assume that most of the traffic crossing that screenline has been generated within, or attracted to, the region. Similarly it is likely that much of the traffic on SH1 south of Picton is related to inter-island movements.

Cook Strait presents an unusual problem. As all rail and road movements across the strait are carried by ferry, the possible use of volume data from the ferry operators may be precluded by considerations of commercial confidentiality.

4.5.3 Specific data for freight

Imports and exports are recorded by Statistics NZ and this data could provide at least one trip end for some freight movements. The *National freight demands study* (Paling et al 2008) identified a number of other possible sources. However the value of data on single trip ends is limited without matrix estimation.

Another issue in modelling with single trip ends is the distribution of trips; for example timber exports at Napier will have come from a wide range of origins, although the possible range will be quite specific.

4.5.4 Economic data

Statistics NZ publishes employment data from the following sources: Business Demographic Statistics (commonly called the Business Directory), available every year, it covers all businesses and most of the information is now collected through GST returns; census (workplace question records where people work), available every fifth year; Household Labour Force Survey (this is carried out quarterly, but as it is a sample survey it is only of limited use to us); Quarterly Employment Survey (again a sample so only of limited usefulness to us).

GDP is one of the outputs of the Statistics NZ national accounts and is published quarterly. Economic performance varies between regions and the need for sub-national estimates (which are available) should be investigated.

Transport fuel prices (both nominal and real) are published by the Ministry for Economic Development for both petrol and diesel. They are available back to 1974.

4.5.5 Demographic data

Population is measured at the five-yearly census, with the last one being in March 2006. The census data is available down to meshblock level which is much smaller than the level required for a national model. Population estimates are done between censuses at 30 June each year at TA level. There are currently 74 TAs in New Zealand.

The number of households is also measured at the five-yearly census and again is available down to meshblock level. Quarterly estimates are done by Statistics NZ of the number of households and dwellings in New Zealand. This is not broken down into smaller areas, although combined with the TA-level population estimates we could (subject to some limitations) estimate the number of households at a TA level.

Car ownership: vehicle registration data is available from NZTA registration statistics. Most of the published data for cars is about vehicles newly registered in New Zealand (either new or used imports). It may be necessary to request one of the custom tables for modelling purposes. The standard tables on the NZTA website only segment new registrations by postal district (eg Whangarei, Auckland, Hamilton). It is possible to order custom tables and enquiries would have to be made as to what can be supplied. There is also a motor vehicle (excluding motor bikes) availability question in the census dwelling form. This data is available – subject to Statistics NZ confidentiality rules – down to meshblock level. For measuring vehicle availability to travellers this is possibly better data than the registration statistics as it ties the vehicle to the household where it is kept; whereas vehicles may be registered to a different location from the one where they are available for use.

4.6 New Zealand forecasts

4.6.1 Available forecasts

Population projections are produced by Statistics NZ for the whole of New Zealand. They are available down to area unit level, segmented into five-year age bands and also by gender. Statistics NZ produces three scenarios; low, medium and high. The projections are for every fifth year, starting with a census year. At the time of writing the projections base year is 2006. For the purposes of a national trip model we would want to use more aggregate projections than area unit, of which there are 1860 in New Zealand. TA-level projections would be suitable. Household projections can be derived by applying a household occupancy rate – this is generally assumed to decline over time. Notice however that, as in the WTSM model, the independent variables in the trip generation model may require more detailed forecasts – in the Wellington case this was achieved through the use of a 'family model'.

Employment: Statistics NZ does not do projections of future employment. Treasury does projections at a national level and it is possible that some of the other forecasters listed in the paragraph below also do these. TA-level projections are available from Market Economics Ltd.

GDP: The Treasury produces forecasts for the next five years as part of their half-year economic and fiscal update[7]. The New Zealand Institute of Economic Research produces quarterly predictions which also look ahead by five years. Note that the end date may not be five years from the date of publication; it runs from the last piece of historic GDP data. The following organisations also produce forecasts for GDP growth in the New Zealand economy: ANZ Bank, BERL, BNZ, IMF, Deutsche Bank, Infometrics, First NZ Capital, UBS, OECD, Westpac and Reserve Bank. TA-level projections are likely to be available from Market Economics Ltd.

Fuel prices are likely to be a driver of trip rates. In New Zealand, modelling of future oil prices is done for/by the Ministry of Economic Development. Samuelson and Taylor (2005) propose two scenarios. In the low scenario the oil price peaks at about US$60 a barrel for the years around 2010, with a decline to US$40 a barrel for the remaining years out to 2030. The high scenario has the price at US$80 a barrel in 2008, US$100 a barrel in 2009, US$120 a barrel in 2010. It then remains at US$120 a barrel until 2015, but then declines to US$75 a barrel in 2020. For comparison, the price per barrel was US$76 on 24 June 2010, ie between the two forecasts.

The high scenario is consistent with conventional oil production peaking in 2008, but 'unconventional' (eg oil sands or shale oil) taking an increasing share of production. The authors argue that there are ample opportunities to produce alternative liquid fuels at US$75 a barrel.

The authors acknowledge there is considerable uncertainty over the modelling of any future prices, due to the uncertainties over reserves (little effort is put into measuring reserves accurately until someone wants to exploit them), the pricing power of groups such as OPEC and political instability in the Middle East where many of the conventional reserves are located. It looks likely that oil prices will continue to be volatile.

The question for us is how much effect this will have on travel. The general evidence is that demand for fuel is relatively inelastic (at least in the short term), although as we are modelling longer-distance trips (which have a higher fuel cost per trip) some discretionary trips (eg leisure) may be shortened or cancelled if oil prices are high. There was anecdotal evidence of this when oil prices peaked in 2008.

There is also a second round response in that if oil prices stay high for a number of years people purchase more fuel-efficient vehicles (conversely if oil prices are low as they were for most of the 1990s people purchase less fuel-efficient vehicles). Furthermore, sustained high oil prices can also affect the performance of the world economy which is also likely to trim demand.

As a NTEM is likely to be looking forward a number of decades, we should acknowledge in our modelling the considerable uncertainty in the future price of oil; however, unless the price becomes extremely high it is unlikely to impact much on travel demand. In addition if the price does become extremely high this is likely to trim demand throughout the economy due to second-order effects.

4.6.2 Long-term projections

Transport modellers are often required to look 10 or more years into the future. This is due to the long life of infrastructure and the fact that the built environment only changes slowly. However caution is

[7] These are available at *www.treasury.govt.nz/budget/forecasts*

needed when looking more than a few years into the future as some values we attempt to forecast are extremely volatile due to unexpected changes in the factors which influence them.

The variables we are interested in listed from most to least volatile are:

- fuel prices – as discussed above.
- GDP growth – this is quite volatile and is affected by random factors (eg shocks to the New Zealand economy from overseas) which are difficult to forecast
- employment – this is closely linked to GDP
- population and households – although migration is quite volatile and not properly modelled by Statistics NZ.

The usual way of dealing with these uncertainties is to have a variety of scenarios.

4.7 Comparison between ART and the TFM

Auckland Regional Council supplied us with the data from roadside interviews carried out for the external cordon survey for the ART3 model (ART ECS). The data was coded to the ATM2 zones used by the ART3 model, with external trips being coded to the external link leading into the modelled area. The location of external origins or destinations was not required for the ART3 model but the address was recorded. We then geocoded this address to our zoning system, which is described in section 8.10. For the ART3 internal zones we had an equivalence table between these and TAs which gave an equivalence to our zones.

Two expansion factors were supplied which allowed us to expand up to 24-hour vehicle and person trips. This allowed comparison with the TFM which calculates trips between its zones on a quarter year basis. We divided this number by 91 to get a daily number.

This was done in two parts: trips to the north of Auckland (Northland) and trips to the south (rest of the country:

- For Northland, the trips originated in the modelled area (zones 1 to 512: all of the Auckland region and the area around Tuakau and Pokeno; to zone 513: SH 1 north of Te Hana – the northern entrance to the Auckland region). As the TFM only counts day trips over 40km (one way) there was a risk of short distance trips across the regional boundary between Auckland and Northland being counted. Inspection of the data showed this not to be the case.
- For the rest of the country, the trips originated in the modelled area (zones 1 to 512) to zones 514 and greater (all the externals to the south of the Auckland region). Trips to the part of Franklin District outside the Auckland region were eliminated as many of them are short distance trips across the regional border. Trips to the South Island and trips to Northland that were miscoded as being to the south were also eliminated.

Table 4.1 Comparison between the TFM and ART external cordon trips from Auckland region to Northland

From zone	To zone	TFM daily trips	ART ECS expanded person trips	Ratio of ART ECS trips to TFM
Rodney	Far North	88.82	42.48	0.478273
Rodney	Whangarei	191.91	286.42	1.492435
Rodney	Kaipara	170.05	111.19	0.65383
Auckland	Far North	1909.99	984.88	0.515644

From zone	To zone	TFM daily trips	ART ECS expanded person trips	Ratio of ART ECS trips to TFM
Auckland	Whangarei	2873.66	1657.94	0.576942
Auckland	Kaipara	1018.44	540.90	0.531107
Franklin	Far North	36.48	83.73	2.295413
Franklin	Whangarei	35.95	140.39	3.905027
10	Kaipara	8.28	18.71	2.259319
	Total	**6333.58**	**3866.62**	

The ART ECS expanded person trips were calculated using the appropriate expansion factors. We can conclude from this table that at the individual zone pair level there is a significant variation around the average difference between the two data sources. One possible source of error is the difficulty in getting concordance between trip purposes for the two data sources.

Clearly the journey purpose, HBW, should be excluded, as apart from overnight trips, the TFM includes HBW travel. We can safely assume that any overnight work-related travel would be coded as business travel.

For the Northland comparison we had planned to exclude the ART ECS trip purpose 1 (HBW). However inspection of the trips with this journey purpose revealed journeys to work that were unlikely to be day trips; eg from central Auckland to Whangarei. These would have been included in the TFM as they were overnight trips and have therefore been included in the NTEM.

Therefore all surveyed trips from Auckland to Northland were included, although there was the possibility of double counting trips at the southern survey points 11 and 12. This is because they might have passed through more than one survey station. However as only nine trips were surveyed at points 11 and 12, out of more than 300, this was dismissed as not being an issue.

The above TFM data for travel between Auckland and Northland was checked for the split between domestic and overseas tourists. This was 61% overseas (351,434 trips per quarter) and 39% domestic (224,922 trips per quarter); such a split for actual travel seems unlikely as the TFM includes all travel, except travel to work and day trips under 40km. This number of domestic trips gives an overnight or day trip greater than 40km to Northland every 561 days for the average resident of the Auckland region (population used was 1,387,800).

There also seems to be some pattern to the ratios between the number of ECS and TFM trips for the Auckland and Franklin zones. For Auckland, the ECS gives approximately half the number of trips between the O-D pairs compared with the TFM. Conversely for Franklin, ECS gives between two and a quarter and four times the number of trips between the O-D pairs compared with the TFM. One possible explanation for this discrepancy could be the way the two surveys did their sampling. While the ART ECS took a sample of vehicles from the traffic flow on the roads north out of Auckland, the TFM relied upon a telephone survey of domestic tourists and surveys at the departure gate for international visitors. The domestic survey relied upon people recalling all their longer-distance trips in the past four weeks to a telephone interviewer; this seems a less reliable way of sampling people than the conventional roadside interview or travel diary.

4.8 Comparison between Western BoP and TFM

The Tauranga transport model (TTM) was updated during 2007, with among other things, roadside interviews being undertaken at five locations in the Western Bay of Plenty (BoP). The locations were as follows:

- SH2 Katikati
- SH36 Pyes Pa
- SH2 west of SH2/SH33 intersection, Paengaroa
- SH29 Tauriko
- SH2 Bethlehem.

As we were only interested in long-distance trips in our analysis, the last site at Bethlehem was not used, as long-distance trips passing this site would also pass the Katikati site. This left us with four sites, three of which were surveyed in the inbound direction and one outbound (Katikati). For the purposes of the comparison with the TFM we assumed that the trips were symmetrical in direction and inverted their direction. Although commonly done, this is potentially unreliable with longer-distance trips as their direction and number can vary by day and season. For example, people go away for the weekend, leaving home on Friday night and returning on Sunday night.

The roadside interviews were conducted from 7am to 7pm on a Tuesday, Wednesday or Thursday during May 2007. They are therefore a snapshot of a normal day during a normal month, whereas the TFM is a sample of trips nationally over a much longer period (four weeks for domestic and international tourists).

There are also differences in trip purposes between the two surveys, with the TFM recording all overnight trips and day trips greater than 40km by New Zealand residents over the age of 15 (excluding journeys to work) and all travel by overseas tourists. The TTM surveys recorded origin and destination journey purposes. A matrix was constructed which compared these against the TFM information. TTM trips which had origin and destination purposes included in the TFM were used in the comparison.

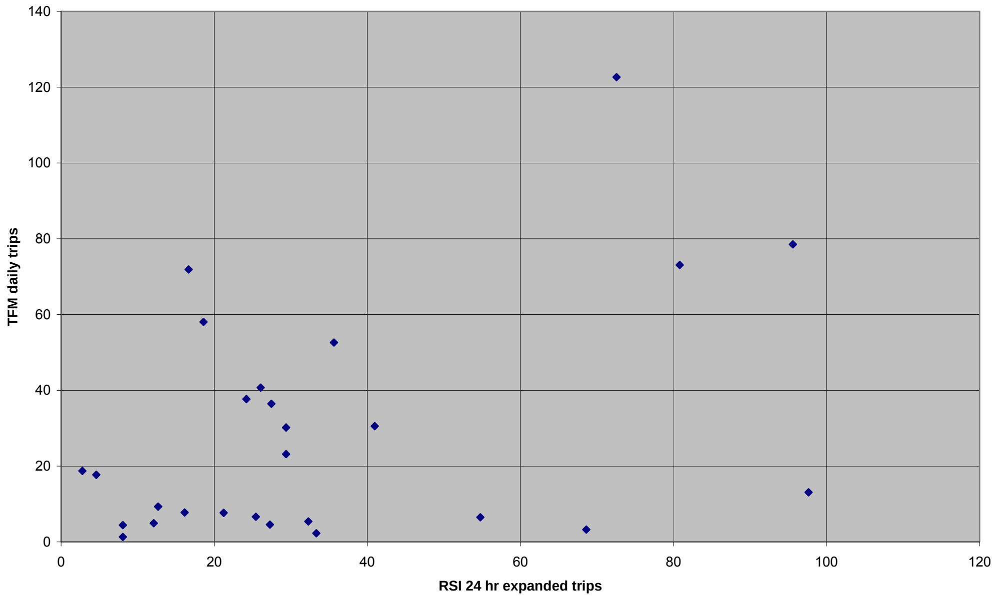
The comparison was conducted on a 24-hour period with the roadside interview data being expanded up to 24 hours from the 12-hour survey period using traffic counts and the TFM quarterly data being divided by 91 to get a daily figure.

In our zoning system Tauranga City and Western BoP District are separate zones. Internal trips within either of these zones or between them were excluded from the comparison. It should be noted that the roadside interview sites are not on the edge of Western BoP District, so may miss some trips which potentially could be included in the TFM.

Some anomalies were found in the roadside interview data; for example, outbound trips were found in the survey data, although all comparisons were conducted in the inbound direction. (Remember that we inverted the data at the Katikati survey site.) In some cases the discrepancy could be explained; in others it appears that there was an error in the survey data. No such checks were possible with the TFM data as we were only supplied with summarised data – effectively an O-D matrix.

The numbers of expanded trips from the Western BOP roadside interview data was compared with the number of daily trips from the TFM. Generally the former had more trips than the latter between the O-D pairs: 27 compared with 16. Figures 4.1 and 4.2 below compare the trip lengths between the two data sources. They are the same graph; with the first one showing O-D pairs where there are fewer than 100 expanded trips from the Western BoP roadside interviews per 24 hours and the second one showing the remaining O-D pairs (ie where there are more than 100 expanded trips). They suggest that the roadside interview data is often greater than the TFM; if there was complete agreement between the two data sources then all points on the graphs would be on the diagonal.

Figure 4.1 Western BoP 24-hour expanded person trips (< 100 trips per 24 hrs) vs TFM daily trips



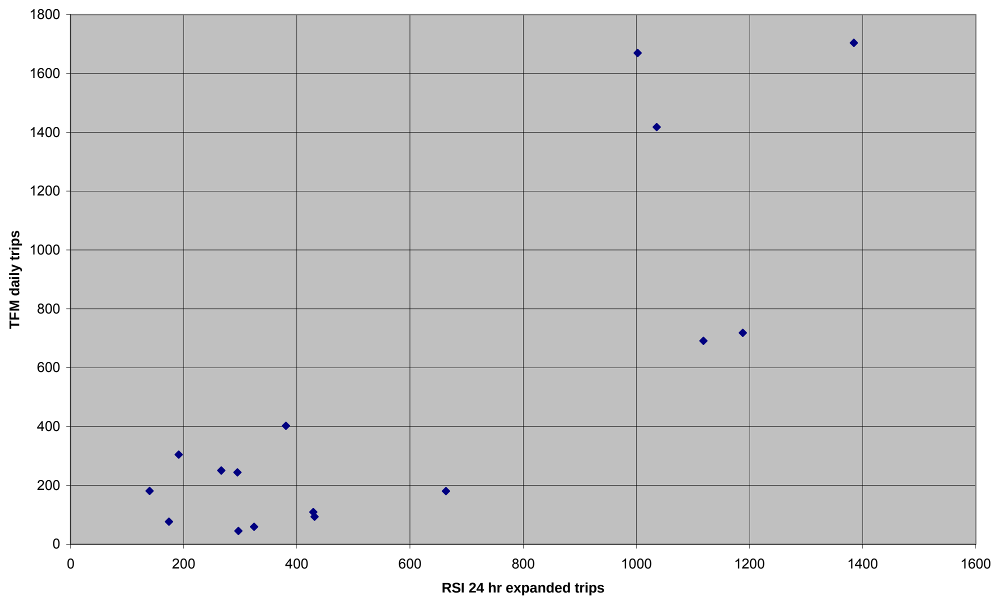


Figure 4.2 Western BoP 24-hour expanded person trips (> 100 trips per 24 hrs) vs TFM daily trips

4.9 Comparison between ART, Western BoP and TFM

A comparison was conducted between the ART ECS, the Western BoP cordon surveys and the TFM for trips from the Auckland region to the Tauranga and Western BoP zones. The results are in table 4.2:

Table 4.2 Comparison between ART ECS, TFM and Western BoP surveys

Origin	Destination	ART ECS expanded daily person trips	TFM daily trips	WBoP surveys expanded daily person trips
Rodney	Tauranga City	106	45	67
Auckland	Tauranga City	1778	2006	1002
Franklin	Tauranga City	131	63	73
Rodney	Western BoP District	Nothing surveyed		25
Auckland	Western BoP District	231	377	381
Franklin	Western BoP District	34	30	25

As with the other comparisons; while the numbers of trips from the three sources are of the same order, the numbers themselves are generally different.

4.10 Conclusions

It can be seen that in many cases there are significant differences between the data sources, although the order of magnitude of the results for each origin destination pair is the same. Factors which might contribute to this include the following:

- Different survey methodologies – the TFM is based on a telephone survey and aircraft departure gate methodology asking participants to recall their travel over a period; the other two are based on roadside interviews that only ask people about the trip they're currently making.
- Faulty data – for example there is a small number of interviews in the Western BoP survey data which are in the wrong direction. (The interviews were conducted in one direction only.)
- In the case of the roadside interview, there is variation between different days, which is in contrast to the TFM where the aim is to establish the trip pattern over three months or a year.

In order to resolve some of these issues a more extensive programme of surveys would be needed as the ECS were only designed for external trips, which are a minority of trips in a regional model. It is also unclear how the TFM was constructed and whether it would provide sufficient data for the uses required of transport models.

A more extensive survey programme would also address daily and seasonal variation in longer-distance trips.

5 Trip generation

5.1 Introduction

The trip generation stage of the classical four-stage model aims at predicting the total number of trips generated by, and attracted to, each zone of the study area. It is a forecast of personal travel or freight movements. To achieve this, the first step is to develop a model of existing trip making which can then be used to forecast the future.

A model for forecasting trip numbers would include a number of explanatory variables: to take a simple example, the number of trips from a zone may be proportional to the zone population. Statistical techniques, in particular linear regression, are used in the development of such models. However, implicit in this approach is the assumption that forecasts are available for any explanatory variable. For example, if trip numbers today depend on today's population, it is necessary to know the future population in order to forecast future trips.

Urban models are typically mostly concerned with person trip making and trip generation and attraction is predominately dependent on the location of households and employment. Travel to work or education is likely to be a dominant trip purpose. In predicting the amount of travel, population is often segmented based on factors such as age and employment status, while employment is often segmented by factors such as the type of industry.

At the national level two factors are likely to be different. In a long-distance model, compared with an urban model, freight is likely to assume a bigger share of movements and the drivers of person movement are different. At the national level, tourists form a higher percentage of travel on some routes and the proportion of journeys to work or education trips (which are the majority in urban areas) will be lower than for shorter distance trips and may indeed be negligible.

The second difference is that zones will be larger in a national model than in an urban model, meaning that national zones are less likely to be homogeneous in terms of variables such as car ownership and other demographic factors. While factors such as average income may be meaningful for a small urban zone with a wide range of values between zones, they may not be for a much larger zone.

Additionally, in the context of a national model we are dealing with vehicle rather than person numbers.

The process known as trip generation covers the number of trips starting and ending in a particular zone. In this report we assume that the techniques relating to both are interchangeable.

The next section of this chapter lists the possible explanatory variables and goes on to discuss each of them. Essentially the choice of variables is a trade-off between what is suitable and what is available.

5.2 Explanatory variables

5.2.1 Introduction

This section covers the explanatory variables that could be used in the trip generation stage of a New Zealand NTEM. As has already been discussed, this type of model is different from the typical urban model in that the drivers of long-distance trip making are different from those driving urban trip making.

The following are possible explanatory variables for trip generation and attraction for a NTEM. With the exception of tourism numbers they have been selected from variables used in overseas models in the literature review or variables used in the NFM research project. Tourism numbers have been included as projections of their numbers and movements are available from the TFM.

The variables discussed are:

- person numbers (by where they live), possibly segmented by age, sex, employment status etc
- household numbers, probably segmented by socio-economic group or (more likely) household composition (eg number of workers). They can also be segmented by area as is done in the NTEM model in the UK
- employment numbers (by work place), probably segmented by industry type
- real GDP – may need to be segmented by the areas in the model
- real income – this is often used in trip generation models of personal travel and also car ownership models
- freight volumes into/out of ports (including airports). Freight will need to be modelled separately and possibly segmented
- tourism numbers – we need to know where tourists are going as they are often not tied to any stationary activity, apart from accommodation
- travel costs – these are difficult to project for reasons discussed below
- car ownership - Booz Allen completed a NZTA research contract for the 'Development and application of New Zealand car ownership and traffic forecasting model' in late 2009. However due to time constraints it was not possible to incorporate the findings.

5.2.2 Household and person numbers

These are being dealt with together as the information is related. Both come from the census and projections of household numbers usually derived from population projections. Projections of both are readily available for the whole country, down to area unit level for population and TA level for households.

Household and person numbers segmented into various groups are widely used in overseas models. To take an extreme example, the UK NTEM has:

- 11 person types based on age, sex and employment status
- eight household types based on the number of adults and cars
- eight household area types including two London areas, metropolitan areas, four urban areas and rural areas (Department for Transport nd).

Population is also used in the OZPASS model.

However the Statistics NZ projections are not segmented in a way that is useful for transport modelling; households are segmented by:

- couple without children
- two parent
- one parent
- other multiperson
- one-person.

While these categories are some help it is likely that a national trip generation model segmentation could cover other factors such as the number of workers per household. The Statistics NZ data confidentiality rules are a potential issue for a national model of longer-distance trips, as they have caused problems in the development of recent regional models. However as the zone sizes are likely to be larger in a national model than in a regional or local model, the problems could be less severe.

5.2.3 Employment

Employment data is generally segmented by industry type with the most convenient one in terms of data availability being the Australia and New Zealand Standard Industrial Classification (ANZSIC) one digit. The most disaggregate category by which data is available is ANZSIC six digit. When the categories are examined it is clear that by aggregating up to one digit some categories with quite different transport characteristics are grouped together (eg newspaper printing and publishing is grouped with pulp, paper and paperboard manufacturing). However for most purposes this does not matter and it only becomes a problem if one of these sub-categories grows much more quickly relative to the other sub-categories with different transport characteristics.

The NFM work (Bolland et al 2005) showed that trip generation (both origin and destination) was dependent upon employment. The NFM segmented employment into ANZSIC one digit categories and examined whether the number of employees in each helped to explain the estimated number of trips either generated or attracted. The results are shown in table 5.3.

One apparent anomaly, given the large number of people employed and the need to shift its products to market, is the absence of manufacturing, which was excluded from the models as not being significant (both origin and destination) and of the wrong sign (origin).

Table 5.3 Significant variables for freight traffic generation/attraction

ANZSIC 1 digit category	Significant for origin/destination?
Agriculture, Forestry & Fishing	Both
Mining	Origin
Construction	Destination
Wholesale trade	Both
Transport & Storage	Both
Accommodation, Cafes & Restaurants	Both
Finance & Insurance	Both
Property & Business Services	Both
Health & Community services	Both
Port	Both
Constant	Both

Source: Bolland et al (2005)

Employment projections at a TA level are available using the economic futures model produced by Market Economics Ltd (G McDonald, pers comm 2007), which also produces flows between regions segmented by industry. These are expressed as industry 1 in region A selling $X of product to industry 2 in region B.

5.2.4 Real GDP

Growth in real GDP has been identified as being closely linked to growth in heavy vehicle km in both New Zealand and internationally (Mackie et al 2006b). They confirmed earlier work and identified a relationship where real GDP raised to the power of 1.4226 multiplied by a scaling factor of 0.0002 gave a good fit to heavy vehicle km. Bolland et al (2005) used a linear factor of 1.96 to relate freight growth to GDP growth.

Mackie et al (2006b) also produced regional projections of heavy vehicle km using projections of regional economic growth and the NFM (Bolland et al 2005). Mackie et al (2006b) suffered from the limitations of the NFM, along with the assumption that regional economic performance (as measured by the National Bank's regional indicators) would be the same between 2005 and 2020 as it was between 1996 and 2005.

While the general approach to producing regional projections is sound it shows the paucity of data available on which to base such projections. It is also questionable how reliable projections of both national and regional GDP are, as GDP growth tends to be much more volatile than population growth.

While GDP is projected at a national level, there are no known official projections of regional GDP in New Zealand with most work relying on the information produced by the National Bank which is based on indicators such as employment and retail sales (National Bank 2007). The economic futures model referred to in the previous section produces TA-level projections, which are likely to be the best available.

5.2.5 Real income

There is no known source of future projections of real income at a regional or TA level. The economic futures model only produces projections of wages and salaries. Historic income data is available from Statistics NZ. Projections of the growth rate of regional GDP are commonly used as a substitute to grow historic data; although caution has to be exercised as GDP can show a different growth path from income, due to changes in the amount of claim that persons outside the area have on what is produced in the area.

5.2.6 Freight volumes into/out of ports

Historic data relating to volumes of freight entering and leaving all New Zealand ports is available from Statistics NZ and was used in the NFM trip-end calculations (Bolland et al 2005). No source of forecasts has been found, however. As noted above, how these volumes translate into the number of vehicles on the road depends on a number of other factors.

5.2.7 Tourism numbers

Tourist numbers are important for two reasons:

- They are a significant driver of traffic numbers on some roads; with possibly the most extreme example being SH94 between Te Anau and Milford Sound, with the northern part through Fiordland National Park existing solely because of tourism. Conventional transport modelling variables are unlikely to model flows correctly on this road.
- Good data is available on their movements from the TFM, which will facilitate the building of a New Zealand NTEM (see chapter 4).

Tourism is not covered in any of the standard urban models. However there are some examples in other countries; for example, the UK NTM has two journey purposes (home-based recreation and non-home based other) (Department for Transport 2000) which would broadly cover trips in this category.

As pointed out in the literature review (chapter 2), 'Tourism flows in New Zealand are split roughly 25% international, 75% domestic. The former is growing quite rapidly, at around 5% pa, but the latter is fairly static. On some roads tourist flows comprise up to 50% of the total but the average is around 10%–15%. The largest tourism flow on the SH network is between Auckland and Hamilton, although clearly this also has high flows of other traffic, including freight'.

As noted above tourism trips are often not tied to any stationary activity, apart from accommodation. This makes them difficult to deal with in a conventional transport modelling framework, although the use of a dummy variable for 'honeypots' such as Queenstown may be a way of getting around this.

One possibility is to ignore international tourists, but include domestic tourists who are the majority. This has the advantage that in many cases at least one end of the trip will be home based. Further information is needed for the following:

1 The percentage of tourism flows for all or most state highways, with a breakdown between domestic and international. This could be calculated using an assumed vehicle occupancy for the TFM trip matrix.

2 Correlation between the location of residences of households/persons and accommodation; and generation/attraction of domestic tourism trips. Residential location information is available from the census, with Statistics NZ also conducting an accommodation survey which could provide useful information on the location of commercial accommodation. It doesn't cover people staying with friends or relatives.

3 How closely the domestic and international visitor flows correlate. If they do correlate closely this will allow us to use a factored version of one as a proxy for the other.

While the issues under 1 have been dealt with in this project, the issues under 2 and 3 are considered to be beyond the scope of this project.

It should also be pointed out that the TFM provides forecasts of tourism flows which may of themselves be of use outside a 'conventional' (ie four-stage) trip generation modelling framework. However it should be borne in mind that the TFM is intended to cover longer (above 40km) trips made for purposes other than tourism, eg business.

5.2.8 Travel costs

Costs affect trip generation as increased travel costs act as a deterrent to longer-distance travel. The two main factors which affect the marginal cost of private car transport for people are the cost of fuel and vehicle fuel efficiency. For the total cost we would also include the cost of vehicles and other costs of owning and operating them, such as maintenance and licensing.

For any given journey it is the marginal cost which determines behaviour, whereas for longer-term trip generation we must look at the total cost. The two factors interact as the marginal cost is driven by the price of fuel and the type of vehicle driven. Higher fuel prices are likely to lead to increased sales of more fuel-efficient vehicles. The total cost is affected by the type of vehicle purchased and how fuel efficient it is.

While the long-term tendency has been for the real costs of vehicles to decline,[8] the real oil price has been quite volatile. Projecting future oil prices is quite difficult with fundamental differences of opinion between different commentators as to when and whether the effects of peak oil will occur. Any modelling should

[8] We tried finding consumer price index data on the Statistics NZ website to back this up, but the requisite data appears not to be available.

also include the effects of any policy changes made to address global warming (eg carbon trading) which are unclear at the moment.

Further, if there is a significant increase in the price of oil that persists for a long period it is likely that vehicle purchasing behaviour will be affected, both as to the type of vehicle purchased (eg high fuel prices will make hybrids and diesel vehicles more attractive) and when older (larger) less fuel-efficient vehicles are scrapped. High oil prices are also likely to make alternative fuels, such as bio-diesel more attractive and the rate of substitution may affect travel behaviour.

We can therefore state that this would require a separate model using information that is probably not currently available (eg how quickly and by how much is people's vehicle purchasing behaviour affected by a sustained oil price increase). In addition projecting the price of oil is very difficult – for a further discussion of this see the literature review. Both issues lie outside the scope of this study.

Freight traffic is driven by the economy, with truck vehicle-km having grown at around 1.5 times that of GDP (Baas and Latto 2005). This has meant a significant increase in energy use by the heavy vehicle fleet in recent years. Fuel costs make up around 10%–15% of the costs of operating a heavy vehicle, although they state with margins being very low in the industry, even small savings in fuel costs could significantly increase profitability. The report identified many ways in which the heavy vehicle industry could save fuel, ranging from purchasing more fuel-efficient vehicles to driver behaviour.

If fuel costs increase significantly for a sustained period (as we have seen in recent years) it is likely there will be both short-term and longer-term adaptation. The short-term effect is that fuel costs are passed through into higher shipping costs. If this is significant enough shippers will make changes in the way they use trucks. This could mean that they change their shipments so trucks are fuller more of the time.

Responses by trucking companies are unclear – while large operators are likely to instigate measures to save fuel, the large number of small operators may do very little unless they face competitive pressures to do so.

Overall, while acknowledging that cost is an important issue, a NTEM will make the common assumption of constant real travel costs, largely because there is no basis on which to make any other assumption. A possible future enhancement would be to derive longitudinal personal trip rates from the NZHTS. This would allow a comparison of trip rates over time, although attributing changes to particular factors would be difficult. Also, the survey does not provide any information in respect of freight.

Finally, freight costs are also driven by load factors and these vary considerably by commodity.

5.2.9 Conclusions

This section has covered the possible variables that could be used in a trip generation model. Projections of many of the variables at a relevant spatial level are either available (for persons, households, employment, real GDP and tourism numbers) or possible (real incomes). The key exceptions are travel costs and freight volumes into/out of ports. For the former we can adopt the assumption that they remain constant due to lack of information on how they might change and the consequential effect on trip rates; and for the latter we only have projections on overall freight growth based on historic relationships. While freight volumes into/out of ports are probably at least partially linked to GDP, other factors are likely to influence them. For example, timber exports are likely to be affected by how much wood is available, international log prices and shipping rates.

It may not be possible to use the trip numbers in the TFM directly in a trip generation model, but other data on where tourists stay may prove useful as a trip generation variable.

6 Trip distribution

6.1 Introduction

Having established, through trip generation, how many trips are generated by and attracted to each zone, trip distribution determines how the trip ends are related, ie how many trips starting in origin zone Z_0 will go to destination zone Z_i.

The most commonly used form of trip distribution model is the gravity model. In this the number of trips between origin zone i and destination zone j is assumed to depend on three factors:

- the population of i
- the population of j
- some measure of the cost of getting from i to j.

The higher the cost, the lower the number of trips; in early models, trips were assumed to vary with the inverse square of the distance between zones, hence the use of the term ‘gravity’.

This chapter covers the following issues:

- the different model forms used in trip distribution (section 6.2)
- a review of the trip distribution components of the UK NTM and the Oregon2 models which were chosen as they represent examples of the state of the art (sections 6.3 and 6.4)
- comments on special New Zealand issues (section 6.5)
- a review of trip-length distributions from the case study data used in chapter 4 (section 6.6).

6.2 Different trip model forms

The standard method of doing trip distribution is a gravity model with the balancing of origin and destination (row and column) totals using Furness or other methods. The literature review notes that intrazonal trips are not well represented in the gravity model; this should not be an important issue in a national model as intrazonals are best dealt with in a local model. The gravity model is discussed in the literature review and will not be covered further here. It should be noted that any trip distribution method we use is going to need some measure of travel cost which will be at least partly distance based. Calculating this may require access to a GIS package with a national road network.

There are a variety of different measures of travel costs (also called impedance, friction factor, or the utility or propensity function) that could be used. Originally gravity models used a distance decay factor of 1/distance; nowadays non-linear functions are usually used with the impedance function incorporating other factors in addition to distance, such as time and out-of-pocket expenses. A variety of forms have been used; for example: $1/\text{impedance}^2$ or a negative exponential. The rate of decline of the interaction (called alternatively, the impedance or friction factor, or the utility or propensity function) has to be empirically measured.

6.3 The Oregon approach

This section is devoted to other trip distribution forms with most of the information being taken from a document prepared for the Oregon Department of Transportation. (Parsons Brinckerhoff 1995). For Oregon metropolitan planning organisations the paper recommends the logit form ‘where resources and time permit’. The discussion of the gravity model includes zone-specific K factors – these are zone-specific factors that allow for special attributes in that zone (eg a physical or geographical barrier).

For the logit model they note that one advantage is the ability to include other explanatory variables; the example given is the presence in a zone of a recreational area; while in the New Zealand context this may translate to special trip generators such as ports.

The paper also discusses the attributes that a measure of travel costs (called ‘a composite impedance’ in the paper) should have. These are:

- sensitivity to all modes of travel
- sensitivity to both travel times and costs
- sensitivity to the income or auto ownership of the traveller.

The values must be combined so that:

- the combined values fall within an acceptable range
- the combined values decrease as the cost or time taken by any mode decreases
- the combined values increase if any mode is unavailable.

Two formulations are discussed which meet the above criteria: harmonic mean and the log sum, with the latter being recommended as the former lacks a theoretical basis.

It is recommended that separate trip distribution models should be developed for each trip purpose. Each of these models should then be calibrated by individual time period, with the HBW model also stratified by income.

The situation with a national model is somewhat different from a regional or local model. Work trips are likely to be a much lower percentage of trips (see section 8.2) and we are dealing with a much larger area so it is difficult to achieve the degree of segmentation that might be achieved in a regional or local model. An example of the issues that arise with a high degree of segmentation (whether it is geographical, trip purpose etc) is shown by the approach that was adopted for the UK NTM (see below), where a three-pass structure was adopted with different disaggregations in each of the three components.

6.4 UK national transport model

The UK NTM is a multi-modal transport model with a number of components which are discussed in appendix B.

The parts of the model that correspond to the trip distribution, mode split and assignment stages of a four-stage model are carried out by three models; called ‘Pass1’, ‘Pass2’ and ‘Pass3’. The three-pass approach was chosen in order to make a computationally feasible model.

The Pass1 model has a high segmentation of people but is geographically sparse. Pass2 has a reduced level of person segmentation and an increased level of spatial detail compared with Pass1. Finally, the Pass3 model is spatially detailed with limited person segmentation. All three models carry out trip distribution at their level of spatial detail, with each model relying on the output of the previous one – Pass2 relying on Pass 1 and Pass3 relying on Pass2.

6.5 Special New Zealand issues

6.5.1 Two islands

This should not pose any problems for the trip generation. Although trip generation may vary by area, this is not an issue specific to two islands. There are two possible approaches: a) a separate model is built for each island, with the interisland traffic being handled by a separate model or as an external zone, or b) a national model is built with special costs for the inter-island crossing being incorporated for the trip distribution model. As our model is only land based we can assume that everyone will cross the Cook Strait by sea. There may be a slight complication in that some travellers arrive in Wellington by one mode (eg rail) and leave Picton by another (eg bus). However the numbers are probably so small that we can safely ignore them.

6.5.2 Limited alternative routes

This factor should make building a model simpler than in some other countries as there are fewer routes to consider during the assignment process, with some notable exceptions such as Auckland to Tauranga. Also, in an uncongested inter-urban network the calculation of costs for use in the mode split and trip distribution process should be simpler. While we are not looking at assignment in this project we still need a measure of travel costs for use in the trip distribution process and possibly mode split.

6.5.3 Topography

New Zealand is a mountainous country with the road distance between many locations being much longer than the straight line distance. Driving along winding roads is usually slower and more tiring than the equivalent distance along a straight road. This can be dealt with by the use of appropriate equations in calculating travel cost or disutility which include not only the road distance and/or travel time between two locations, but also include other factors which act as a disincentive to use a winding road.

New Zealand contains several towns which can be thought of as ‘middle sized’, for example Masterton. The size of a town will affect the number of external trips it generates; for example many residents of Wellington may leave the city only rarely whereas those in Masterton may make regular trips to Wellington for goods or services they cannot get locally. At the next level down, residents in, say, a small settlement in South Waikato may make frequent trips to Te Kuiti for basic needs but may also to travel to Hamilton for more specialised purposes. This suggests that two different distribution models could be appropriate, one for travel within a catchment (eg Masterton to Wellington) and one for travel outside (eg Masterton to Taupo).

6.5.4 Unsealed roads

Most major highways are now sealed so unsealed roads only become an issue if a significant number of minor roads are included in a national model. Similarly the disincentive to use winding roads is not only the reduced travel speeds, but also the effects of dust, noise and the reduced ease of driving on an unsealed road. As a national model will most likely only include major roads which are sealed we can conclude that this is not an issue.

6.6 Trip distribution modelling in New Zealand

As discussed in section 4.2 the trip data obtained from the TFM and the two urban models was geocoded which allowed the length of each trip to be measured. The results of this were then examined to look at the trip length distribution (TLD) and whether this fitted any of the standard model forms.

As discussed in the literature review, the gravity distribution model states that the number of trips between origin i and destination j is

$$K\ Oi\ Dj\ f(cij) \quad \text{Equation 6.1}$$

Where K is a constant, Oi and Dj are the total trip ends for the origin and destination respectively and f(cij) is a generalised function of the travel cost between i and j.

While this equation forecasts a particular entry in the trip matrix, all trips in the matrix will follow the form of the function f(c). Hence if we plot the TLD from the survey data it should allow us to calibrate the function.

The most commonly used form for the TLD is:

$$K\ exp(\alpha c)\ c^{\beta} \quad \text{Equation 6.2}$$

Where c is the cost or deterrence function (in this case we have used distance) and K, α and β are constants. Usually the data is split into distance bands (eg 51 to 75km) to smooth the curve and this has been done here.

Figure 6.1 shows the TLD for the TFM data using 25km bands. It also shows the curve which has been fitted using regression. The best fit is given by the equation

$$Trips = 11.55\ e\text{-}0.0116d\ d1.19 \quad \text{Equation 6.3}$$

Where d is the distance. This was found to have an R^2 value of 0.92.

Figure 6.1 TFM trip- length distribution

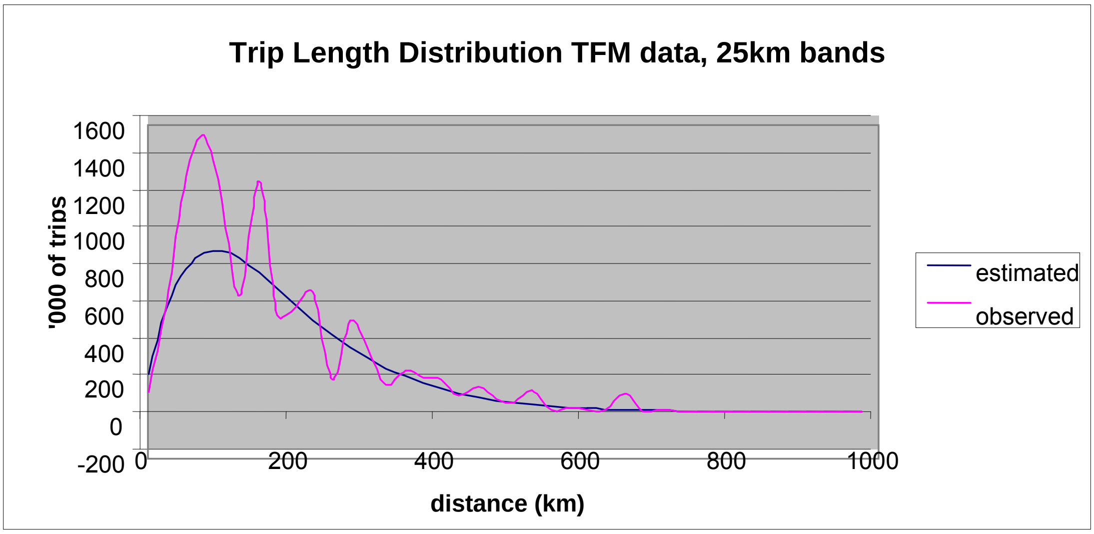


Figure 6.2 shows the same distribution taken from the expanded NZHTS. In this case the fit is good, with an R^2 value of 0.95, but the form of the relationship is different from the TFM:

$$Trips = 2{*}10^{7}\ e^{0.016d}\ d^{-3.3} \quad \text{Equation 6.4}$$

Figure 6.2 NTS trip-length distribution

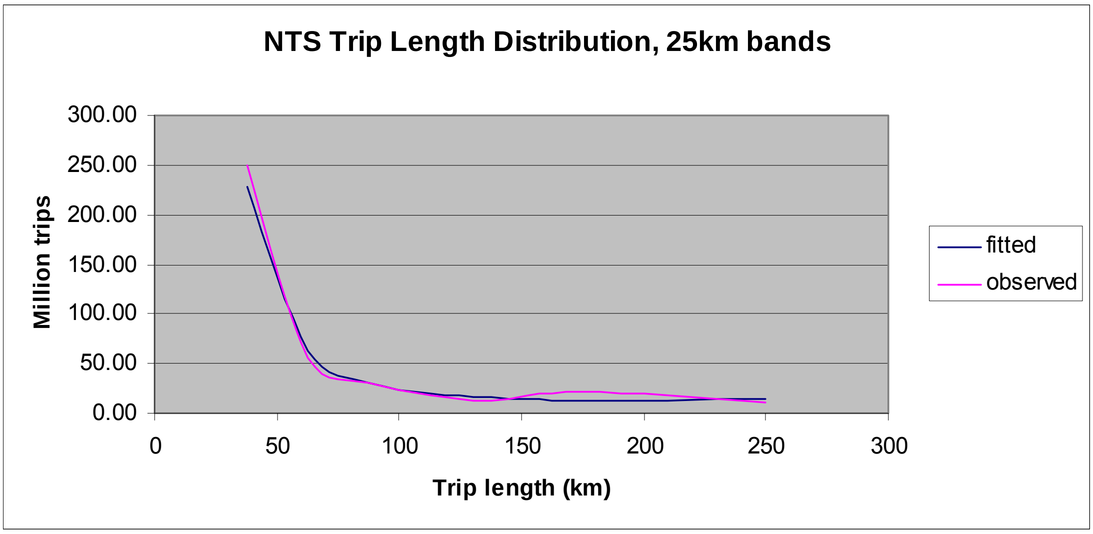
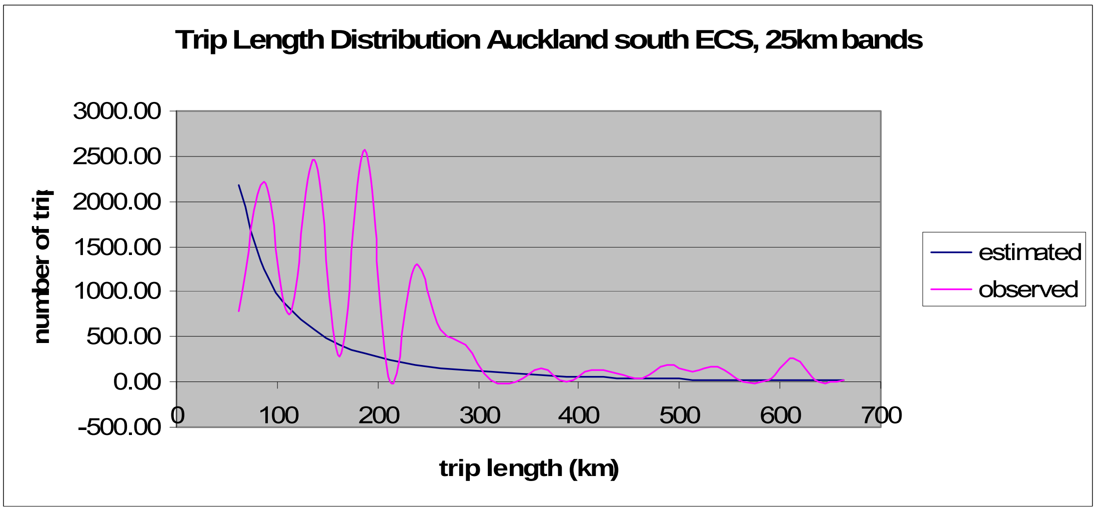


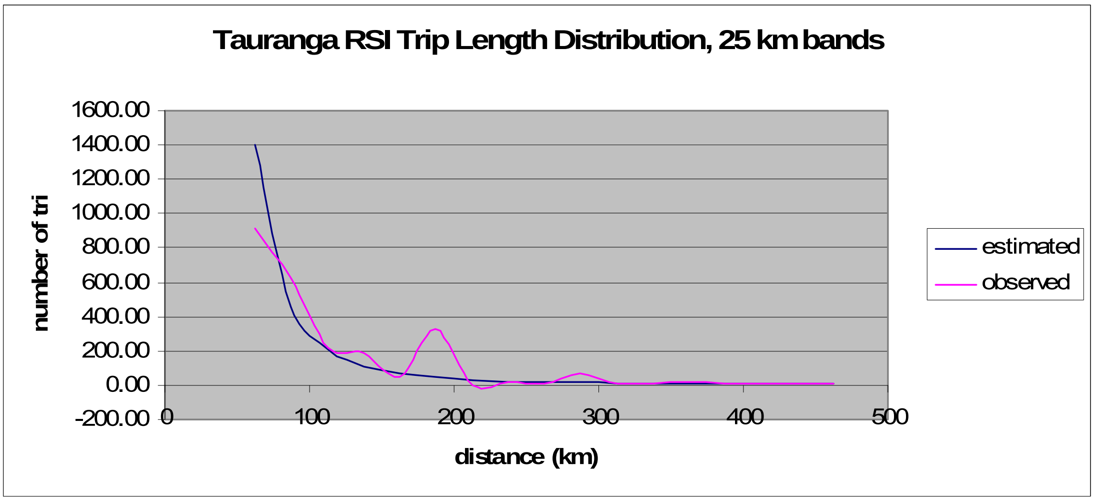
Figure 6.3 shows the same curve fitted to the ECS at Auckland south. In this case the curve is not such a good fit and has an R^2 of 0.37. As would be expected with a much smaller sample than the TFM there is much greater variability in the data.

Figure 6.3 Auckland southern cordon survey trip-length distribution



Finally, figure 6.4 shows the TLD for the BoP survey data. The curve fitted to this data has an R^2 of 0.74, with the fit being better than Auckland but not as good as the TFM.

Figure 6.4 Tauranga RSI trip-length distribution



On the basis of the limited data available it would be possible to develop a trip distribution model at the national level. The TFM data in particular, which covers about 10 million trips each quarter, demonstrates a good fit to the standard model form for the quarterly data we have used here. It can be expected that this fit would improve for a longer period.

The survey data for the two urban models examined does not provide such a good fit to the standard form and constitutes a much smaller sample. It is also likely to be specific to the locality being considered and may not be transferable, for example to smaller centres, as it will also depend on the trip attractions at a given distance. For example, going north from Wellington, the number of trips will become very low beyond Waikanae but may then show peaks for Otaki and Levin.

6.7 Conclusions

This chapter looked at how to calculate trip distribution with different approaches being discussed and various equations being tested on the data that we have available. New Zealand specific issues were also discussed.

Relatively complicated methods were recommended for Oregon MPOs. The UK NTEM approach is also relatively complicated using models with a number of passes, which is not appropriate in New Zealand as we are only modelling longer-distance trips meaning that a simpler model will be adequate.

Some New Zealand specific issues were discussed, but do not appear to pose any particular problems. We fitted the data we have from the TFM, NZHTS, ART ECS and the Tauranga RSI to equations with the best fits being found with the TFM and the household survey, most likely because of their larger sample sizes.

In summary there appear to be no major issues in constructing a trip distribution model for longer-distance travel in New Zealand, assuming that adequate survey data is available. A relatively simple mathematical form is likely to prove adequate and is easy to implement in comparison with the approaches in the UK the NTEM and Oregon.

7 Mode split

7.1 Introduction

7.1.1 Model form

The literature review concluded that there is much less commonality between inter-urban and urban mode choice than is the case with the trip generation and trip distribution model stages. While there is a considerable body of knowledge on mode split in an urban context, this is much less true of wider-area models.

The urban approach to mode split is to calculate the generalised cost of trips by the respective modes and to calibrate a model (usually logit or a derivative) to predict mode split using the difference or ratio of generalised costs by the respective modes. This can be further enhanced by the use of a hierarchy, for example calculating the split between car and passenger transport at the highest level and then further dividing passenger transport trips between (say) bus and rail. Whatever the model form is, there must be a sufficient amount of data on trips by each mode for calibration to be possible. If one mode (most likely to be passenger transport) has a very low share of all trips then the margin of error may be such that any model would be considered unreliable.

The literature review found that most models examined either did not include mode split or dealt with it the same way as an urban model. There was one notable exception to this: rather than the conventional logit approach, OZPASS uses a process known as 'logistic substitution' for mode split. This is essentially a series of rules of thumb indicating how the competitiveness of each mode varies with distance. The review concluded that this has potential for application in New Zealand.

7.1.2 Passengers and freight

In terms of non-freight trips the key choice for longer-distance travel is between car, coach, air and (for a small number of origins and destinations) rail. Journey purpose will have an effect: for business trips air may be the only realistic choice because of time constraints, while for leisure trips car may be seen as being cheaper or offering greater flexibility.

As explained in section 1.1, air travel is outside the scope of this study although it cannot be ignored completely. It is intuitively obvious that car will dominate land-based modes for longer-distance travel in New Zealand, although the extent of this needs to be quantified if possible.

For freight transport in New Zealand it is clear that rail and road compete, for some commodities at least. Numerous studies and published statistics indicate that rail has an appreciable share of the freight market, particularly if traffic is measured in tonne-km rather than tonnes.

It must be concluded that in considering mode split in NTEM, freight and passenger movements should be considered separately and this is done in the remainder of this chapter.

7.2 Passenger travel

7.2.1 Data sources

Data sources in New Zealand are discussed in greater detail in the literature review and case study sections but are covered here in summary as the availability and nature of data will clearly influence how mode split might be modelled.

The two key sources of data on personal trips by road which have national coverage are the TFM and the NZHTS. However, as discussed below, both these have disadvantages in terms of mode split modelling.

In terms of urban models, the ART ECS did not include bus or coach as a mode and had no vehicles with more than nine people in it. The Western BoP survey also did not include bus or coach as a mode, although it did include 13 vehicles with 10 or more people. On this basis, and in view of their limited geographical coverage, we have not considered local models further as possible sources of data for national mode split modelling.

7.2.2 Modelling issues

There is a danger that the number of car trips is so large in comparison with other modes that it is not possible to meaningfully calibrate a statistically robust model. If however this is not the case then the data would help decide the model hierarchy. The main possibilities are:

- car v coach v air
- road v air at the top level with road then being split into car v coach.

If rail is introduced into the mix the number of possible structures increases but it seems unlikely that the number of rail trips would be sufficient to allow this.

For passenger trips we would also expect mode split to be a function of journey purpose, eg air may be more likely to be chosen for business trips than leisure ones. Since trip generation is also a function of journey purpose this is not an issue in terms of the overall NTEM, although it does increase the number of mode split models which would have to be developed.

Distance will also be a factor in mode choice with air becoming more likely as the trip gets longer as a result of the time savings it offers. However, in urban mode split models trip time and length are both part of the generalised cost and the same approach could be used for inter-urban travel. .

7.2.3 Tourism flow model

As discussed in the literature review, the Ministry of Tourism has developed a TFM to provide public and private bodies with information on past, present and future tourism demand. As well as international visitors, this includes domestic tourism involving either overnight stay(s) or day trips longer than 40km.

The basis of the TFM is data on the origin, destination and travel mode of trips, collected through the International Visitor Survey (IVS) and the Domestic Travel Survey (DTS).

The IVS is undertaken as an exit survey at New Zealand’s main international airports and has an annual sample size of around 5500. The DTS has an annual sample size of around 15,000 and takes the form of telephone interviews. Historic data is available for the past nine years.

The data below was extracted from the TFM database. Note that the trip numbers are for the whole country for a quarter (90 days). The fourth quarter of 2006 was chosen to coincide with the ART ECS (September to November 2006) and the second quarter of 2007 was chosen to coincide with the Western BoP survey (May 2007).

Table 7.1 Total trips in TFM during the last quarter of 2006

Year	Mode	Total trips	Percentage
2006	Road	27,206,652	92.2%
2006	Air	1,651,346	5.6%
2006	Other	658,550	2.2%

Table 7.2 Total trips in TFM during the second quarter of 2007

Year	Mode	Total trips	Percentage
2007	Road	24,727,523	91.5%
2007	Air	1,913,855	7.1%
2007	Other	391,948	1.4%

Each mode includes the following:

- road: army bus/truck, backpacker bus, coach tour/tour coach, commercial bus/ferry, company car/van, motorbike/scooter, private campervan, private car/van, rental campervan, rental car/van, scheduled coach service between cities/towns, school bus/private bus, taxi/ limousine/car tour, truck
- air: domestic air, helicopter, private plane
- other: air ambulance/ambulance, cycling, don't know, hitchhiking, horse, other (specify), train, walked, cruise ship, inter-island ferry (Cook Strait only), rental boat, yacht/private boat.

It can be seen that the TFM does not differentiate between the main road modes of coach and car. Moreover, while rail is separate from road it is mixed in with other modes such as cycle.

Both the DTS and the IVS code each travel mode separately, thereby allowing a distinction to be made between car, coach, train and cycle. Therefore the raw survey data would need to be processed again to get O-D information by travel mode.

If it were possible to access the raw data in the TFM then it might be possible to calibrate, say, a car/coach mode split or even one which also includes air. Otherwise the TFM would not be suitable for calibrating the required form of mode split model.

7.2.4 NZ Household Travel Survey

The NZHTS is a survey of household travel which has been undertaken annually since 2002. The survey is run throughout the year and since 2003 the survey has been continuous.

Every year more than 4600 households are interviewed, with an interviewer visiting the household and interviewing all the persons in the household. Two days in the week are selected for each household, including weekdays and weekends. Travel information is recorded for each day and each person in the household.

It follows that the total sample size from all NZHTS surveys grows every year but it covers all trips so the proportion of longer-distance trips may be small.

The Ministry of Transport, which runs the NZHTS, provided some basic data from it for the five-year period to 2008. Expanding this data indicated that during this period around 13 billion trips were undertaken by ‘four-wheeled passenger vehicle’ (mostly car), which is about 2600 million a year.

MoT undertook a separate analysis of car trips over 40km in length in the expanded NZHTS data. This found that there were some 580 million such trips in the five-year period, around 116 million annually. This constitutes around 4.5% of all car trips. This is of relevance to the NTEM as it can be taken as an indication of the likely size of the trip matrix in a national model if local trips are excluded.

The main possible use of the NZHTS in the NTEM context is whether there is sufficient data to permit calibration of a mode split model. MoT has therefore provided us with a breakdown by mode of the number of trip legs sampled in the five-year period to 2008. This is shown in table 7.3 below.

The table shows clearly the dominance of car, with around 80% of the trips sampled being either ‘car driver’ or ‘passenger’. Another 16% are ‘walk’. Of particular interest to the NTEM are the modes associated with longer-distance travel:

- plane
- bus trips over 40km
- rail trips taking longer than one hour.

Table 7.3 NZ Household Travel Survey mode shares

Mode	Trip legs sampled	% of total
Walk	23,201	16.11%
Vehicle driver	75,023	52.08%
Vehicle passenger	39,034	27.10%
Bus < 40km	2716	1.89%
Bicycle	2193	1.52%
Other	542	0.38%
Taxi	525	0.36%
Train < 1 hour	358	0.25%
Plane	133	0.09%
Bus trip > 40km	128	0.09%
Mobility scooter	99	0.07%
Ferry	74	0.05%
Train > 1 hour	21	0.01%
Total	**144,047**	**100.00%**
Total of plane, bus>40km, rail>1 hour and ferry	356	0.25%

Note: Where no time or length is specified, all trips by this mode are included (eg walk)

As the table shows, the total sample for plane and longer bus and rail trips is a quarter of 1% of all trips sampled and for each of them it is less than 0.1%. Put another way, there have been about 900 car trips sampled for every long-distance bus trip; for rail trips the equivalent figure is about 8000 car trips. With such a low absolute number of longer bus trips, the coverage, in terms of factors such as trip length, will be very limited.

There may also be issues over the definition of terms such as ‘trips’ and ‘trip legs’ in the NZHTS when compared with the usual conventions in modelling. In view of this and the very low sample sizes for long distance passenger transport it seems highly improbable that the NZHTS data could provide the basis for calibrating a mode split model.

7.3 Freight

7.3.1 Modes

The *National freight demands study* (NFDS), undertaken for the MoT (Paling et al 2008), gave estimates of mode share for freight traffic in New Zealand. In terms of tonnes carried, road was dominant with 92% of the market, followed by rail at 6% and coastal shipping at 2%. However in terms of tonne-km, which is probably a better measure from the point of view of the NTEM since it reflects the amount of traffic on the road, road had a 70% share with rail and coastal shipping both around 15%. For both measures the share moving by air was less than 0.5%.

Neither air nor shipping is within the brief of the NTEM and this is clearly not an issue for air given its negligible share. However if freight is moved by boat it will not be on either road or rail which potentially complicates the modelling of mode share. While shipping could be included in mode split modelling, this would lead to a more complex model structure. On the other hand to exclude it would mean some types of policy measure could not be modelled as the model would tacitly assume that the shipping mode share does not change. On balance we have decided to simplify mode split in the NTEM as being a choice between road and rail.

The NFDS also looked at the key issues which influence the choice of mode for the consignor of the goods and these findings are clearly relevant to mode choice in NTEM.

To quote from the NFDS (Paling et al 2008):

> *Mode choice is a complex issue involving the trade-off of the range of the attributes of particular modes in terms of price and the components of service quality. It must also be stressed that the choice is ultimately made on the basis of the overall journey from origin to destination which may consist of a number of separate legs with different price and quality attributes.*

Clearly, then, the drivers of mode choice are different for different commodities and for mode choice to be modelled as it would be in an urban model these factors would need to be included in the generalised cost. For goods which have a low inherent value, such as aggregates, minimising the cost of transport is the major consideration. On the other hand, for high-value products such as fast-moving consumer goods, whose inherent value is high and for which the selling price is less affected by transport costs, a high quality of service and reliability and security of delivery are much more important factors.

NFDS identified the following factors as the main drivers of mode choice:

- price
- service time, reliability and flexibility of transport mode
- modal connectivity
- security and potential for damage
- ease of intermodal transfer
- need for specialised handling
- value-added activities within the supply chain.

In similar vein, Mackie et al (2006a) give the following factors that determine freight contestability:

- transport costs and the pricing structure of each mode
- the location and capability of loading and unloading facilities, especially for rail
- size of the freight task (bigger tasks are advantageous for rail)
- length of journey (longer journeys are advantageous for rail)
- availability of backloads
- time and frequency
- reliability and service
- congestion, especially for road
- physical restrictions (eg tunnel clearances, especially for rail).

One consequence of this is that for a number of commodities the rail mode share is effectively zero; Mackie et al (2006a) give the example of time-sensitive general freight from Auckland to Wellington, which leaves Auckland in the evening and needs to be in Wellington for the start of business the next day.

While longer freight trips are more likely to be made by rail, which is something that could be included in the generalised cost, it can be seen that the majority of the mode choice factors given by these studies, and the tendency for rail to be used for certain commodities, cannot readily be represented in the generalised cost.

In modelling terms, if mode split were to be modelled as a function of commodity then it might be possible to include at least some of the above factors. However other, larger problems then emerge, notably that if mode split depends on commodity then other stages of the model, for example trip generation, would also have to be done by commodity.

The NZTA (2010) *Economic evaluation manual* (EEM), volume 1, appendix A13 gives price elasticity estimates for rail freight for four different types of commodity: food, wood, paper products and machinery. They represent the % change in rail volume with respect to % change in rail to road price. However the values have several ‘health warnings’ such as ‘elasticity depends on the level of inter-modal competition’. They also cover a wide range; for example the value for wood is -0.05 to -1.97 (ie from almost inelastic to highly elastic). Overall this information seems to be unhelpful for a NTEM, especially since again it is commodity specific and only covers certain commodities.

In terms of other New Zealand freight studies, the NFM looked at mode share in building the matrices but did not attempt to model it or to examine the drivers. A confidential study by Booz Allen for Transit NZ, concerned with possible increases in the maximum weight of trucks, estimated the likely shift from rail to road if truck sizes were to increase but again this was done on a commodity-by-commodity basis.

Overall, there is a dilemma in incorporating freight mode split into the conventional four-stage approach, because:

- mode split is highly dependent on the commodity being transported
- if a breakdown by commodity is included in mode split, it also needs to be part of the other stages such as trip generation.

It can be seen from the literature review that other models similar to the NTEM do not appear to resolve this: either mode split is modelled ‘stand alone’ by commodity, with the number of trips modelled econometrically, or trip generation is not linked to mode split (eg only road trips are considered). A possible compromise, which has been used, would be to model perhaps six key commodities, such as petroleum, in some detail and to cover the remainder using a generalised modelling approach.

A possible way to resolve this might be to borrow a concept from passenger mode choice modelling. It is usual for travellers to be classified as either:

- 'captive', ie they have no choice but to use passenger transport, or
- 'choice', ie they have a choice between car and passenger transport.

In theory it should be possible to split commodities into those for which there might be a rail share ('choice') and those for which road is the only option ('captive'). This reduces a potentially large number of commodities down to effectively two, reducing the number of trip generation and distribution models to two and defining the number of trips for which mode split needs to be modelled.

7.4 Conclusions

There is much less commonality between inter-urban and urban mode choice than is the case with the trip generation and trip distribution model stages. While there is a considerable body of knowledge on mode split in an urban context, this is much less true of wider area models

For urban transport modelling, logit models are commonly used for mode split but there are difficulties in using them for inter-urban passenger modelling as the share of some modes is extremely small. For example, the NZHTS found that plane trips, bus trips > 40km and rail trips of more than one hour in duration made up less than 0.2% of all travel, which means that to calibrate a mode split model including these modes would probably require surveys that over sample or specifically target these modes.

For freight model mode split there are a number of factors affecting which mode is chosen, with the trade-off between them being different for each commodity. It is suggested that the captive and choice concept from passenger mode split modelling could be used, with some commodities being captive to road and others having a choice between road and rail. This would split the commodities into two groups which would simplify the modelling.

8 Model parameters

8.1 Introduction

This chapter covers a number of parameters relating to transport models which apply to all four stages of the classical framework. It includes issues such as the trip purpose, zoning system and the time period covered.

8.2 Trip purpose

The Auckland and Western BoP survey data was examined to determine the percentage of work and education trips. We surmised that the percentage of these trips was likely to be appreciably lower than in urban trips and that it might be possible to ignore them.

For the ART ECS all trips which had an origin or destination greater than zone 512 were examined. These were the externals to the ART model, although it still picked up some short-distance trips crossing the survey points and trips to and from Northern Rodney. The results were as follows:

Table 8.1 Trips to/from external zones in the ART ECS

Trip purpose	Number	Percentage
Home-based work[9]	446	13.2%
Home-based education, excl primary	70	2.1%
Home-based shopping	144	4.3%
Home-based social	235	7.0%
Home-based other	915	27.1%
Home-based business travel	649	19.2%
Non-home based business travel both ends	501	14.9%
Non-home based business travel one end	102	3.0%
Non-home based travel - employer's business one end	74	2.2%
Non-home based other	237	7.0%
	3373	

Note – This table includes all vehicle types, including trucks.

Journey to/from work and education therefore made up 15.3% of trips.

The Western BoP trips only had origin and destination purposes coded and were not explicitly coded to a trip purpose. For the purposes of this analysis we considered work trips to be trips which were from home to work or back again; education trips were those that started or ended at education. We only considered trips which had an origin or destination outside the study area. The results were as follows:

[9] This is the term used in the ART3 documentation and refers to journeys from home to work or vice versa.

Table 8.2 Trips to/from external zones in Western BoP roadside interviews

Trip	Number of trips	Percentage
Home to work	117	
Work to home	142	
Total work	**159**	**11.6%**
To education	38	
From education	29	
Total education	**67**	**3.0%**

No trips were recorded from education to education. Work and education made up 14.6% of trips – a similar percentage to the ART ECS. There also seemed to be a reasonable number of work trips to Auckland in the Western BoP database which is surprising given the distances involved. In reality these may have been miscoded business trips.

We also calculated the percentage of surveyed vehicles that were trucks. They were 10.35% in Western BoP and 5.4% in the ART ECS.

Data was obtained from the NZHTS with particular reference to trips over 40km. From the expanded sample there are about 2600 million trips every year in New Zealand, of which 116 million (4.5%) are 40km or longer.

Looking specifically at trips to and from work which are longer than 40km, the annual figure is 22.4 million trips, slightly less than 20% of the total of all longer trips. This proportion is higher than the Auckland and BoP figures; but this may be due to the inclusion in the NZHTS of trips in all parts of New Zealand, including rural areas where all trips, for whatever purpose, will tend to be longer.

The number of education trips in the NZHTS data for trips over 40km is about half of 1%. While the proportions from the urban data are slightly higher at around 2–3%, this is likely to be largely due to ‘cross border’ trips. Overall the data indicates that education trips can safely be ignored at the national level without any loss of accuracy.

Overall it would appear that if we ignore work trips at the national level we would be ignoring no more than 20% of long-distance trips. Near urban areas the percentage would be less since the survey data includes some shorter-distance trips and the proportion of work trips in it is less than 15%.

The contribution of work trips to traffic nationally depends on both their number and length. However more detailed information about work trips nationally, for example the trip length distribution, is available as it is collected as part of the national census. O-D information is available, although its usefulness is limited by the Statistics NZ data confidentiality rules, which include rounding to multiples of three. This is a considerable limitation, although it may be possible to obtain trip length information if Statistics NZ is supplied with distances between the areas used (eg area units). Intuitively though we would expect such trips to be relatively short compared with other long-distance trips, perhaps no more than, say, the distance from Auckland to Hamilton.

If longer-distance work trips are shorter than the average for longer-distance trips as a whole, then their contribution to overall vehicle-km might be less than 10%, which means that excluding them would become less significant. Whether to include them also depends upon how easy it is to collect the data – if a method such as roadside interviews is being used then it would be easy to include them, whereas with some other methods it would be more difficult.

In summary the key conclusions on trip purpose are:

- The journey purpose splits used frequently in urban models are unsuitable at the national level.
- Data from roadside interviews and the NZHTS indicates that education and possibly work purposes could be omitted.
- Data availability (and other factors) points to the need for simplicity, eg the use of three or four purposes: business, leisure, freight and possibly 'other'.

8.3 Zoning system

8.3.1 Introduction

The purpose of this section is to discuss how we might put together the sources of data discussed above to build the zoning system for a national model. As with other aspects of the case study we have concentrated on the North Island on the basis that it contains the bulk of the population and economic activity. The method for constructing a zoning system should be consistent with good modelling practice (see, for example, section 3.4 of *Modelling transport* (Ortuzar and Willumsen 1990)). Zones are homogeneous where possible and generally do not include natural boundaries such as major rivers. Zone boundaries coincide with existing boundaries and zone size is consistent with a high-level model.

8.3.2 Possible zone structure

The obvious starting point for a national zoning system is based on TAs, possibly with some aggregations of these. A more detailed approach would result in considerable added complexity, for example in obtaining data at a lower level than a TA. This might be justified for a full NTEM, but we think for a draft model a zoning system based on TAs is the most suitable approach. This section discusses a possible zoning system for the North Island involving aggregation of urban TAs and also some of the smaller rural TAs.

It should be noted that a few centres have the majority of the North Island's population. In 2006 Auckland region had almost 43% (1.37 million) of the North Island's 3.19 million population, with the Wellington region (excluding Wairarapa) having another 13.4% (426,800), Hamilton City 4.2% (134,400) and Tauranga City 3.3% (106,700). All of the other TAs recorded a population of less than 100,000 and in some cases less than 10,000.

The dominance of Auckland is reflected in the traffic flows. According to 2006 AADT figures, the Bombay telemetry site south of Auckland recorded over 35,000 vehicles a day and the flow was still 20,260 at Taupiri (just south of Huntly). In comparison the Pukerua Bay telemetry site near Wellington recorded 22,000 vehicles a day, and Ohau (just south of Levin – a fairer comparison with the Bombay site as this is well clear of the urban part of Wellington) recorded just under 15,000.

In contrast, flows in the urban areas were much higher in many cases with the most extreme being the 168,000 vehicles that crossed the Auckland Harbour Bridge daily. This suggests that we should model the Auckland and Wellington urban areas as a whole, rather than having a TA-based zoning system within them. For example we could combine Auckland City, Manukau City, North Shore City, Waitakere City, Papakura District, Rodney District and the part of Franklin District that lies within the Auckland region. The boundary of the Auckland region runs in an east/west direction roughly along the top of the Bombay Hills; whereas on SH1 the Franklin boundary is just north of Meremere and on SH2 it is just beyond Mangatawhiri.

Most of the ECS sites in the south for the ART model lie just outside the Auckland region, but still well within Franklin District. It should make model development easier if the ECS sites are on or near a zone boundary.

This is also an issue in the north, where the ECS sites are largely near the Hibiscus Coast with one just south of Helensville. This is because the northern boundary of the ART model area is within Rodney District. If zone boundaries coincide with TA boundaries it will be difficult to use the information from the ECS. One possibility might be to make Rodney its own zone and have an urban Auckland zone that ends at the North Shore City boundary. Flows between North Shore/Waitakere and Rodney could be taken from the ART model. However if we use the Auckland region as the boundary in the south then we will have a very odd urban Auckland zone that contains quite a lot of rural land in the south, but very little in the north.

In the case of Wellington we should probably combine Wellington City, Hutt City, Upper Hutt City, Porirua City and Kapiti Coast District, although Kapiti does extend well north of Waikanae.

For both Auckland and Wellington the areas that would be internal within the proposed zones are largely well covered by existing models – another reason not to subdivide and model them.

Otorohanga District and Waitomo District could be combined into one zone as their combined population is less than 20,000.

Stratford District could be combined with either New Plymouth District or South Taranaki District. New Plymouth had 71,100 people in 2006, whereas South Taranaki had 27,200 people and Stratford District only 9100. From a zone size equalisation perspective it makes the most sense to combine South Taranaki and Stratford which is what has been done in figure 8.1. Another possibility would be to combine all three TAs to form one zone for the whole of Taranaki.

The Wairarapa TAs could be combined into one zone. This would combine Masterton District (23,200 people) with Carterton (7300 people) and South Wairarapa (9100 people). Tararua District (18,100 people) and Central Hawke's Bay (13,200 people) could be combined, and Rangatikei District (15,100 people) and Manawatu District (29,000 people) could also be combined.

Napier City (56,800 people) and Hastings District (73,200 people) could be combined if one zone for Hawke's Bay was preferred, especially as leaving them separate would mean that we would have to model flows between the urban centres in Hawke's Bay. However, from a population perspective this would be a relatively large zone.

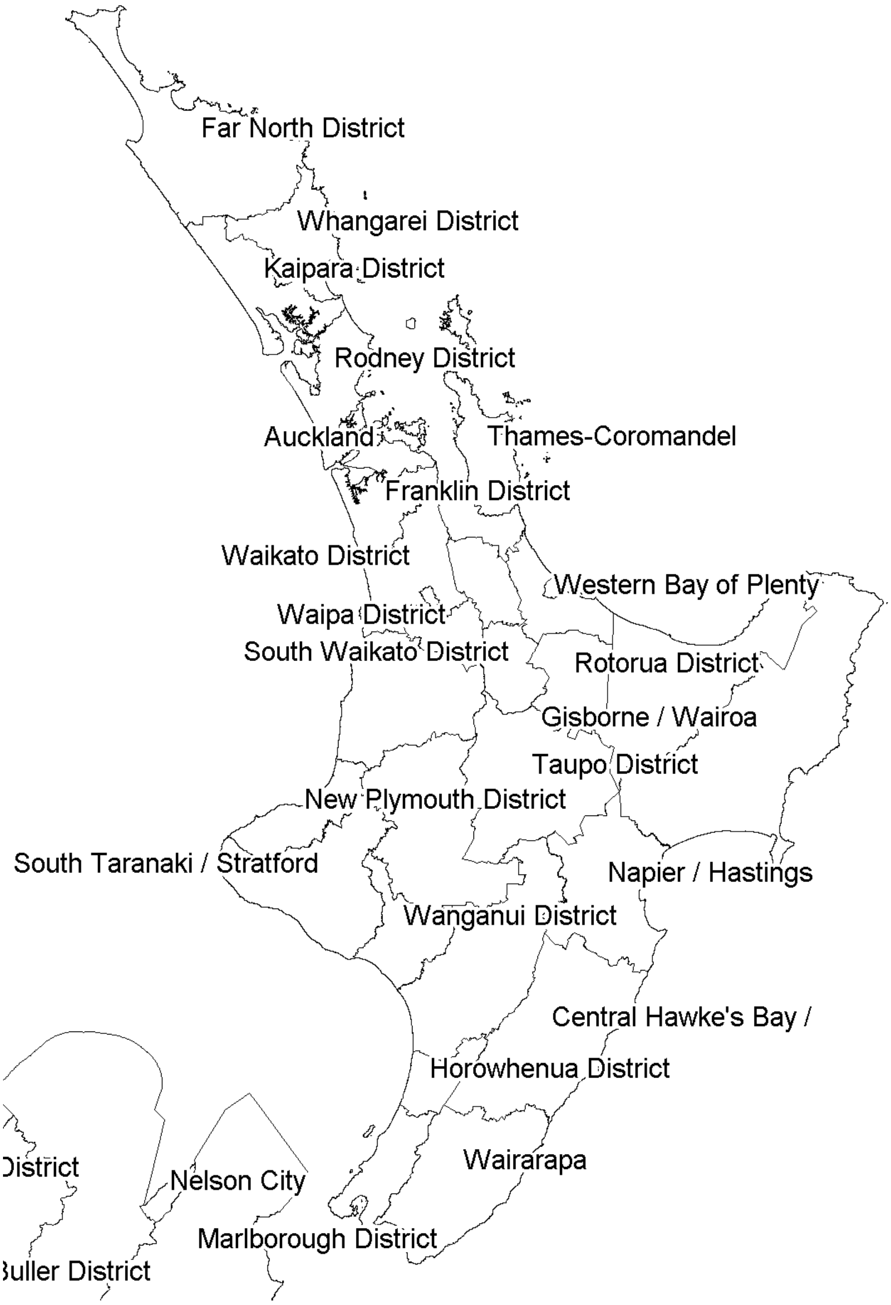
Gisborne District (45,900 people) and Wairoa District (8700 people) could be combined.

Kawerau District (7100 people) which lies as an island within Whakatane District (34,500 people) should be combined, and Opotiki District (9200 people) could be combined with them.

Due to their size Hamilton, Tauranga and Palmerston North have been left as separate zones.

The above changes have been incorporated into figure 8.1, although the urban Auckland zone only includes Auckland City, Manukau, North Shore, Waitakere and Papakura. Rodney and Franklin District have been left as separate zones. The result is a model with around 30 zones. Other possible changes are to combine Thames Coromandel District with Hauraki District and Kaipara District with Whangarei, although the latter has quite a large population on its own.

Figure 8.1 NTEM zoning system



8.4 Modelled period

Discussions so far have centred on producing a daily model. An hourly model could be problematic in determining whether the hour was the departure or arrival hour, but as most trips are completed within the same day, a daily model would probably be the most effective option.

Some daily flows are reasonably large; for example, the average daily number of road trips in the TFM between Auckland and Wellington for the fourth quarter of 2006 was 523 trips.

8.5 Seasonality

The main data sources we had available to assess seasonal variation in trip making were the TFM and the traffic counts from Transit NZ.

Table 8.3 Variation in seasonal trip making for 2006

Origin	Destination	Q1	Q2	Q3	Q4
Auckland	Wellington	669	474 (70.9%)	492 (73.5%)	523 (78.2%)
Auckland	Rotorua	2333	2179 (93.4%)	2322 (99.5%)	2178 (93.4%)

The percentages in brackets are the ratio of that quarter to the first quarter.

The table shows that the seasonal variation in trip making is more pronounced in trips between Auckland and Wellington than in trips between Auckland and Rotorua. Clearly seasonality is an issue and it can be addressed in a number of ways. Possibilities include:

- ignoring seasonality and creating an average annual model (maybe for an average day)
- calculating variation factors by season, quarter or month (these may already exist for project evaluation or other purposes)
- creating separate models for each season or quarter.

In the urban context the first of these is generally used and this would appear to be the preferred approach at the national level. It is also consistent with the use of AADT in traffic counts. Certainly the third adds a large degree of complexity with limited additional benefits. Seasonal factors might be considered a useful add-on once a basic model has been developed.

8.6 Specific freight issues

Most of the above (sections 8.2 to 8.5) also apply to freight (eg seasonality applies to the movement of crops such as kiwi fruit). At the national level a single trip purpose for all freight would probably be sufficient, although as discussed in section 7.3 it might be appropriate to differentiate between freight which is ‘captive’ to road and that which could potentially use other modes (‘choice’).

Load factor is the key relationship between tonnes of freight moved and the number of vehicles on the road. In a national model it would be necessary to at least assume a typical value for all loads (eg 12 tonnes per truck) or perhaps to have typical load factors for a small number (say up to 10) of commodities.

8.7 Intrazonal trips

We think these should be excluded to keep the model simple. Many of these trips are well covered by the urban models (eg Auckland), although there is some interaction between the intrazonal and interzonal trips which would not be covered, eg when an intrazonal trip becomes an interzonal one due to a transport network change.

9 Conclusions

This project had two objectives which were outlined in section 1.1:

- To examine the feasibility of developing a national trip-end model for New Zealand, including the availability of appropriate land-use projections
- To develop simple trip generation, distribution and mode split models at the national level.

After reviewing international best practice we conclude that it is feasible to develop a NTEM for New Zealand. However at this stage it is not really possible to meet the second objective, largely because of the lack of suitable national data and inconsistency between data sources.

In terms of the classical four-stage model the research into a NTEM explicitly excluded the assignment stage.

9.1 Passenger trips

The project found that to produce a NTEM of longer-distance trips with currently available data would be challenging. There are only two sources of data appropriate for national passenger trip modelling: the NZHTS and the TFM. The NZHTS has a very small sample which makes it unsuitable for use with zones of a reasonable size since some zones would have no trips recorded. However the NZHTS data has other uses, such as looking at trip-length distribution and mode choice.

The TFM appears to be the only source of national trip (ie O-D) passenger data. Despite its name the TFM does not cover only ‘tourists’ per se, but also all day trips over 40km made by New Zealand residents. However, it excludes certain trip purposes along with short-distance trips so the data is incomplete. It is also unclear whether the TFM survey methodology of asking people to recall their trips over a period of up to a month might lead to under or misreporting of travel. Other issues include the fact that the TFM does not differentiate between road modes and that it does not adopt the usual transport modelling framework.

A possible approach to enhancing the TFM data might be to start with a TFM for passenger trips and use state highway flows to do matrix estimation, but this would require assignment of trips. It is also unclear how to reconcile the two data sources as SH flows would include local trips. The only exception might be on roads that carry a lot of inter-urban traffic but which have no significant local traffic generators near the count site. The Desert Road (SH1) would be an example of this. Another issue this approach raises is what types of vehicle should be included, for example light commercial vehicles might be in use for either passenger or freight purposes and automatic counters might not distinguish between these.

The project also compared TFM data with data from the roadside interviews conducted for the updated ART model and the TTM. When expanded the three data sources gave quite different trip results, even at the higher level (eg trip distribution equations), which suggests incompatibility between the data sources. Possible reasons for this include the completely different survey methodologies, the actual data collected and the way the data is expanded.

Perhaps the greatest issue raised by the differences in data is that they may call into question the reliability of TFM data as a starting point for any national model.

In order to collect data for a future national model, two types of surveys could be considered; an expanded NZHTS and roadside interviews. The former would resemble the survey used in the UK’s NTEM which models the ends of all trips made in the UK at a high level of disaggregation. In the New Zealand situation an expanded NZHTS could potentially serve a similar purpose but it would capture a lot of data on short distance trips together with the longer ones. While a national model would only cover longer-distance trips, the majority of trips are short, which means there would be a lot of data that is of limited use for the model, although it may have other applications. The expansion of the NZHTS in this way would be a major and costly undertaking.

A national programme of roadside interviews would also be costly as a lot of locations would need to be covered, unless it is assumed that some locations have similar trip generation rates to other nearby locations. Matrix estimation would be difficult, unless all travel is included or assumptions are made about the percentage of flows that are local trips. Regular updates would also be required.

The major urban areas of New Zealand, such as Auckland, Hamilton and Tauranga, each have their own urban models and most of these have been updated in the last few years. However in terms of the totality of trips made in the country existing models omit large areas, including virtually all the South Island. Even if the models of smaller urban areas such as Taupo are included there are large areas with no coverage. Moreover, an examination of two different urban models indicates a very low level of consistency with national models. Overall, then, there seems to be little prospect of using urban models at a national level. Research into the quality of external data in city models such as Palmerston North would be informative.

9.2 Freight

It is clear there are a number of obstacles in the way of producing freight transport models that approach the capability of person transport models. This is true regardless of the scale of the model but must be particularly so at the national level. Factors affecting freight demand are complex and many of them are beyond the planner’s control.

In the absence of intermediate stops, freight modelling is essentially confined to route and mode choice. However a key consideration is load factors, and freight models usually consider annual quantities to address issues such as seasonality. Load factor is the key relationship between goods moved and truck movements but it is dependent on a range of other factors such as the perceived cost of inventory holding.

For example, if a forecast depends on employee numbers, it is necessary to allow for the possibility of productivity improving in the future, and load weights and shipment sizes changing with time. These factors could affect the ratio between the quantity of goods and the number of truck movements.

Because of the considerable differences in how different commodity types are transported, some disaggregation in modelling is essential. However it is likely that substantial approximations will have to be made to reduce the huge number of existing categories to a tractable number (say less than 20) for modelling. Moreover any such disaggregation would have to be carried through the model, eg to trip generation.

While employment is often used as the explanatory variable for truck trips, the relationship between output and employment varies within broad industry categories, from firm to firm and (importantly from the point of view of forecasting) with time.

A base matrix for freight movements already exists as a result of the 2002 NFM research project (Bolland et al 2005). A simple freight trip-end model was constructed as part of this project. It used a linear regression model with employment in various sectors as the independent variables for trip generation and attraction. This project did not, however, cover future projections of freight movements and construction of a future matrix involves finding suitable explanatory variables for which future projections are available.

However the NFM project is now several years out of date, especially in the light of recent economic events worldwide. The *National freight demands study* (Paling et al 2008) used a 'bottom up' approach to deriving a matrix covering all major freight movements in New Zealand. While the resulting matrix will have changed as a result of the recession it would provide a starting point for deriving trip generation functions for that stage of a national model.

9.3 Approach to modelling

A possible zoning system for a national model has been devised as part of this research. It is based loosely on the level of TAs with about 40 zones in the North Island.

The *Guidebook on statewide travel forecasting* (FHWA 1999) endorses having simplified trip purposes and an all-day model for larger area models; it also endorses ignoring intrazonal trips. The guidebook further suggests having two different gravity models for long and short distance trips respectively. In New Zealand, this could be related to the 'catchments' of larger cities such as Wellington. The remaining recommendations are also appropriate for a national New Zealand model.

Category analysis, in which trip making is a function of factors such as household structure and car ownership, is a common approach for modelling trip generation in urban models such as ART. However it is considered too detailed at the national level and a simpler approach, in which trip making is related to variables such as employment, is recommended.

Projections of many of the variables needed for a trip generation model at a relevant spatial level are either available (for persons, households, employment, real GDP and tourism numbers) or possible (real incomes). The key exceptions are travel costs and freight volumes into/out of ports. For the former we can adopt the assumption that they remain constant due to lack of information on how they might change and the consequential effect on trip rates; and for the latter we only have projections on overall freight growth based on historic relationships. While freight volumes in and out of ports are probably at least partially linked to GDP, other factors are likely to influence them. For example, timber exports are likely to be affected by how much wood is available, log prices and shipping rates. At the least, the use of dummy variables in trip generation, eg to represent ports and other major attractors and generators, is likely to be necessary.

For trip distribution the standard gravity model will be satisfactory for passenger travel as it can be fitted to the available data. A research report for Land Transport NZ by Jewell at al (2007) concluded that gravity models could be a useful tool for freight trip distribution, but that it might be necessary to construct regional models with dummy variables for alternative transportation modes (rail, shipping) and regional generators/attractors (airports, ports, distribution hubs).

Building a mode split model for longer-distance surface trips would be difficult as the NZHTS suggests there are many more long-distance car trips than bus or train trips. It is therefore likely that there would be insufficient data to calibrate a mode split model. A formal mode split model was not part of the NFM research project, with the rail and road matrices being constructed separately.

A possible means of simplifying freight mode split would be to use the captive/choice approach of urban models, since many commodities are highly unlikely to be moved by rail and so are captive to road.

In Australia the OZPASS model of passenger movements forecasts incremental growth in the dependent variable (eg trip generation) based on growth in the independent variables such as population. If suitable data was available, this incremental (or pivot point) approach would be appropriate for New Zealand.

OZPASS uses logistic substitution for mode split in which the use of modes changes with trip length. Again, a similar approach could be used in New Zealand if the data was available (eg from an expanded NZHTS).

Finally, there are a number of issues specific to New Zealand which would have to be taken into account in a NTEM. These include the manufacturing dominance of Auckland and the commercial – and hence potentially confidential - nature of data relating to volumes crossing Cook Strait.

One of the peer reviewers raised the issue of whether simpler techniques would be suitable for the uses a NTEM would be put to. For example, the EEM (NZTA 2010) provides arithmetic growth rates, either based on historic growth rates at the site or standard growth rates for forecasting in each region. The limitation of this approach is that it does not take into account how things might be different in the future from the past. On the other hand forecasts of population growth would be available and could be assumed to be the same as trip growth.

The strength of a modelling approach is that it makes explicit those factors which influence travel growth. For example, population growth fluctuates and currently the population projections for the Auckland region are higher than those done a few years ago as is a result of higher growth rates in the recent past. The other key factor which affects trip numbers is the impedance of travel; while this may change at the detailed level (eg through the construction of the Roads of National Significance) the basic New Zealand road network is unlikely to change. This suggests that a simplified approach, based on future changes in population and travel times, could be appropriate in some circumstances and would have the advantage of much reduced data requirements.

This raises the possibility of a limited model of long-distance travel being more appropriate in some parts of the country than others. Many parts of New Zealand are relatively unpopulated and the rate of change in population and employment is relatively modest, although it does fluctuate. Therefore changes in vehicle flows are relatively predictable, although there may be localised special issues, such as logging trucks when pine plantations are being harvested.

On the other hand the factors driving trip growth around areas such as Auckland, Hamilton and Tauranga are more complex. In addition, the three regional models in that area provide a wealth of trip data. A first step in building a national model might therefore be to build a model of vehicle travel in the upper North Island. Data is already available to help build such a model and the programme of surveys required would be much more limited than that required to build a NTEM for the whole country. Such a model would also be very useful in the national context, given the national economic significance of the area covered.

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Appendix A: Review of Oregon TLUMIP programme

Introduction

In 1994, Oregon Department of Transportation embarked upon a comprehensive Oregon Modelling Improvement Program (OMIP) to technically support these new federal and state policies and regulations. A significant part of OMIP is the Transportation and Land Use Model Integration Program (TLUMIP) initiated in 1996.

TLUMIP is an integrated transportation, land-use and economic model for use in transportation planning and policy analyses at the regional and state wide levels. The first generation of the model, called Oregon1, has now been successfully applied to several complex policy issues. Using information gained from these initial applications, Oregon2 is significantly refining and expanding elements of the programme in a state-of-the-art modelling framework. This framework covers Oregon's 36 counties and parts of adjoining states. It operates at various levels of geography, including a 30m grid of study area land use.[10]

TLUMIP has therefore been aimed at developing a suite of models even more ambitious than what we are implementing in Auckland. This has the advantage that a wider range of policy questions can be analysed properly. The drawbacks are the cost and data needed. Whether a particular type of model is adequate for a task depends upon the questions that we are trying to answer and the quality of the analysis required.

The rest of this review looks at what has been done technically in this project.

Differences from a conventional transport model

The advantage of the integrated land-use/transport/economic models is that the modelling framework integrates more factors that influence each other than a conventional transport model.

A conventional four-stage transport model takes demographic and employment projections and uses these to generate trips which are then distributed, assigned to a mode and finally to a route.

The integrated models have feedback between different parts of the model system. For example, the location of households and employment (land use) is affected by the cost of access to other households and employment and the cost of locating in a particular zone. Ideally demographic projections would be affected by economic projections, as the economy has a significant effect on migration in and out of New Zealand.

Development staging

The Oregon TLUMIP project has had three phases (so far): Oregon1: which had the simplest model structure (although relatively advanced by most standards), fewest zones, transport network links, and segmentation of industries, households etc; Oregon2TM (transitional model): which has been implemented in the past couple of years and Oregon2 which is a forthcoming phase.

[10] From: http://tmip.fhwa.dot.gov/clearinghouse/docs/case%5Fstudies/omip/

The Oregon 1 model covered the entire state, with Oregon2TM also including counties near the state border in adjoining states. This makes it different from New Zealand which consists of two geographically isolated islands.

The Oregon 2TM has a lot of detail (Weidner 2005):

- zones (2950 vs 125 in Oregon1)
- transport network (40,000 links vs 2000 in Oregon1)
- industries (25 + 14 white-collar vs 12 in Oregon1)
- goods (42 vs 12 in Oregon1), services, labour occupations
- floorspace types (19 vs 2 in Oregon1)
- HHs by HHsize and income group (18 vs 3 in Oregon1)
- truck weight configurations (5 vs 3 in Oregon1)
- 1-year time increments (5 years in Oregon1).

This makes it more expensive and difficult to implement compared with a simpler model, especially in terms of the data that is required.

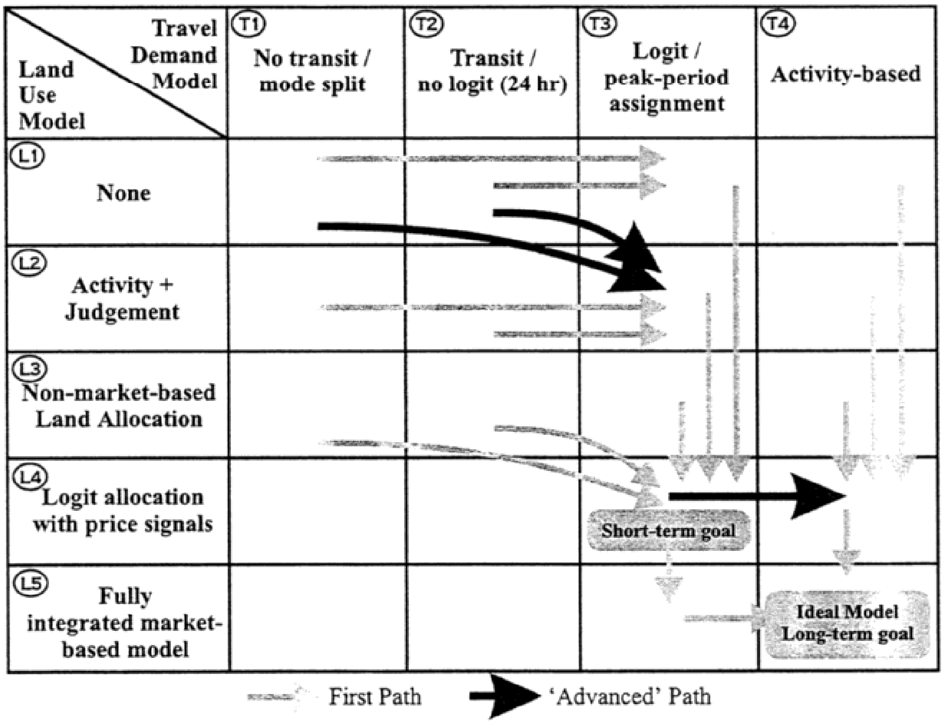
Where does it fit on the continuum of modelling?

The following diagram relates to strategies for improving land-use and transport models in US metropolitan planning agencies. While it is specifically directed at urban models, it is relevant in this case as it is a good diagram to show the thinking in the Oregon TLUMIP project. With Oregon2 they are aiming to reach the box in the bottom right had corner, whereas TRANUS which was the land use model used in Oregon1 is still on L5, but only occupies T1 or T2.

The Oregon2TM does activity-based daily microsimulation modelling for six million people and tour based freight movements with distribution centres. There is also peak/off peak microsimulation assignment. The land-use model is also (at least partly) a microsimulation model. This places it in the bottom right-hand box, although the TLUMIP project has further ambitious plans with Oregon2.

Figure A1 A taxonomy of transport – land- use models

Figure ES.3
A Taxonomy of Transportation - Land-Use Modeling Capabilities

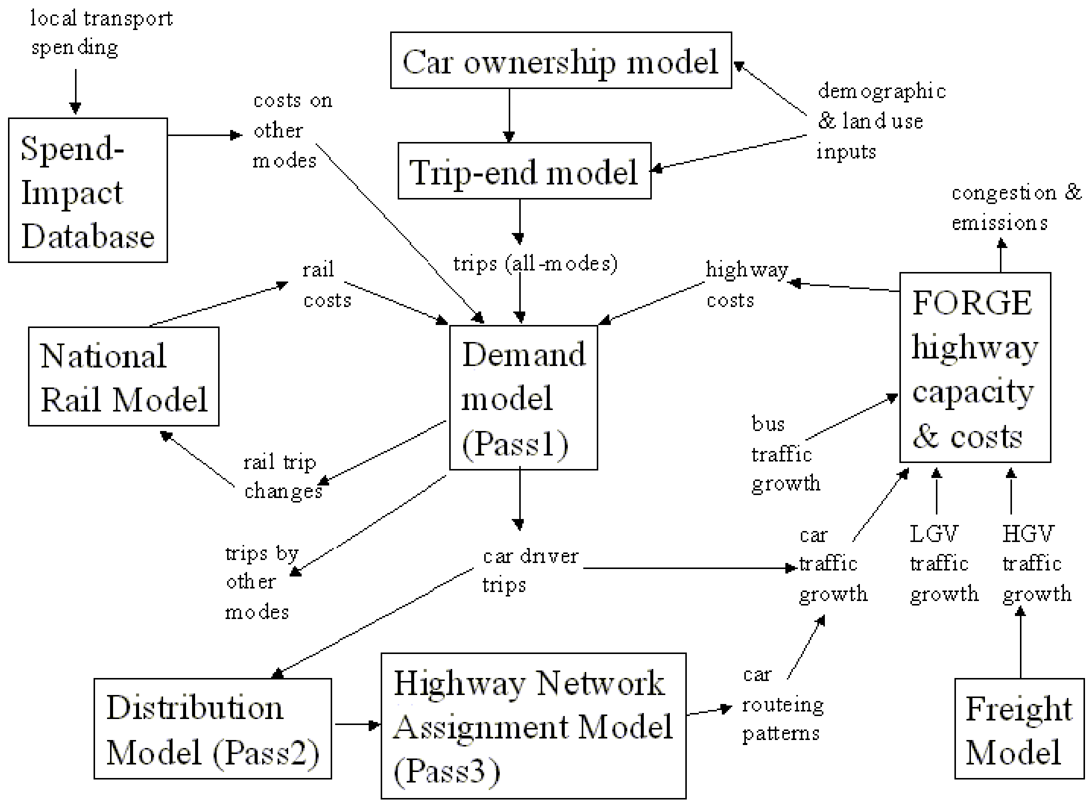


Appendix B: UK national travel model

Introduction

The following diagram shows the structure of the UK national travel model (NTM).

Figure B1 The structure of the UK national travel model



Source: National transport model – working paper 1

In the centre of the system is the demand model (sometimes referred to as Pass1). This is where mode choice is modelled. The inputs are total numbers of trips (which are taken to be invariant to cost) and the costs by each mode. The outputs are numbers of trips by each mode, highly segmented by trip length, trip purpose, and person type.

At the top of the diagram, the car ownership and trip end models estimate the number of trips in each future year, as a function of demographic and land use inputs, and various economic forecasting assumptions.

At the bottom of the diagram, there are two possible paths through the system. The Pass2 and Pass3 models take a long time to run, and are currently run only once for each future year. A synthetic matrix of car driver trips is estimated and assigned to a UK highway network, and data from this run is stored as a set of routeing patterns (referred to as 'mileage profiles'). These relate car trips between different origins and destinations to car traffic on different types of road within different parts of the country. For policy tests, these fixed routeing patterns are used to convert trips into traffic without rerunning the Pass2 and

Pass3 models. In the bottom-right hand corner of the diagram, a freight model forecasts HGV traffic growth.

FORGE is the model which gives estimates of highway congestion and pollution, and models the traffic response to charges and changes in speed on particular road types.

On the opposite side of the diagram, the national rail model assigns the rail passenger trips from the demand model to a detailed geographic network of rail services. The resulting journey time, crowding, and rail fare outputs are sent to the demand model, and the assignment results are used for detailed analysis of policy impacts on rail.

There is an interface to local policies which is made up of two parts; the expenditure policy database which is a database of local transport plan (LTP) expenditures categorised into different policy types and the spend impact database (SID) which translates this expenditure into changes in the generalised cost of travel for each area type/mode combination, for input into the Pass1 mode split/distribution model.

The LTP expenditures are projected forward to cover the full 10-year period, so as to estimate what total 10-year plan expenditure is likely to be in terms of spending on each type of policy within each area type.

Estimating the impact of spending for input into SID is more difficult and is either based on experience of policy impact from local modelling work or case studies or where there is little quantified evidence of the impact of a particular policy, the modelled effect is based largely on judgement.

National trip-end model

The trip-end model produces estimates of person travel by all modes (including walk and cycle) for each ward in Great Britain. The model also produces modal trip ends for each journey purpose. Trip distribution and assignment which is the role of national passenger transport modelling framework; a three pass model developed by ME&P/WSP for the UK Department of Transport.

Overview of Pass1 model

Trip distribution in this model is carried out by the Pass1 demand model which incorporates the trip distribution and mode split of a conventional four-stage model. There are three choice mechanisms that operate within the Pass1 model for each input trip production:

- choice of distance band (13 bands)
- choice of attraction zone
- choice of mode of travel (6 modes).

The distance band choice model takes the trip productions by purpose and traveller type and then splits them into the distance bands with the proportion in each band being calculated using a logit segmentation function based on the relative disutilities of travel from each production zone for the different distance bands

The distribution model takes the demand (trip productions) by purpose, traveller type and distance band and then distributes the trips amongst the attraction zones according to the level of disutility of locating in each zone. Zonal trip attractions by purpose from the trip end model are used as constraints to the distribution model.

The mode choice model is a hierarchical logit model for each of the trip purpose, traveller type and distance band combinations output from the distribution model.

In the model there are 17 zone types ranging from Central London to small urban and rural. There is a high degree of segmentation of trip demand segments with there being 105; made up four person types, five household types, eight trip purposes and three socio-economic groups.

Overview of Pass2 model[11]

The Pass2 model is the intermediate step between the highly segmented but geographically sparse Pass1 model and the spatially detailed Pass3 model with limited segmentation. The Pass2 model therefore contains a reduced level of segmentation compared with the Pass1 model described above, and an increased level of spatial detail.

The Pass2 model takes as input the zonal trip productions and attractions for trips by purpose from the revised multi-modal NTEM model. A further input is the set of trip productions by purpose, mode and distance band for the whole country from the Pass1 model. The distribution module splits the zonal trip productions into distance bands and modes to match the control totals from the Pass1 model. As for the Pass1 model, the distribution model operates in the MEPLAN LUSA software and uses the term factors to represent the different categories of trips. There are 208 categories of trips characterised by different purpose (eight types), mode (car driver and other) and distance band (13 bands). Travel characteristics used in the distribution model for both the car driver and other modes of travel are derived from the Pass3 highway assignment model described below.

The stages in a run of the Pass2 model are the same for each of the trip purposes, namely:

1. Input trip productions are split into 26 segments (13 distance bands and 2 modes) based on input highway travel costs and zonal weights (by purpose and mode)
2. Trips productions by purpose, mode and distance band and allocated to attraction zones based on travel costs and modal trip attraction weights
3. Constraints on numbers of trips by purpose, mode and distance band from Pass1 applied, modifying location costs
4. Steps i) to iii) are repeated until the results from Pass2 match those imposed by the results from the Pass1 demand model.

Distance band and mode choice model

The distance band and mode choice model is embedded within the Pass2 trip distribution module. The trip productions by purpose and traveller type input from NTEM are split into the distance bands and modes using the same logit segmentation type function as in the Pass1 distribution model. In this case the travel disutilities by distance band are derived from the Pass3 model assignment while the relative attractiveness of the modes is imposed by the Pass1 model results.

Distribution model

The functional form of the Pass2 distribution model is a single level, multinomial logit model of discrete choice as for Pass1. The model takes the demand (trip productions) by purpose, distance band and mode and then distributes the trips amongst attraction zones according to the level of disutility of locating in each zone. Zonal trip attractions by purpose from NTEM are used as constraints to the distribution model.

[11] The text on the Pass2 and Pass3 models is an edited quote from *demandmodel.pdf* which was downloaded from the NTM section of the UK Department of Transport website.

Zone definition

The Pass2 zone definition is based on a geographical breakdown of the country into the 67 counties combined with segmentation into the area types that form part of the Pass1 model zone definitions. If a county contains wards of three different area types this will create three Pass2 zones. There are 167 Pass2 zones with zone IDs ranging from 11 to 679.

Overview of Pass3 models

The purpose of the Pass3 model is to produce an unbiased assignment of traffic to different road types within different area types and sub-regions of the UK. Because a spatially detailed zoning system was required to enable this objective to be met, there is only very limited demand segmentation in this model. Even with this level of aggregation it was necessary to model the country using a set of regionally focused models each containing distribution and assignment stages to allow the path-building and assignment process to be carried out using conventional software on PCs. Thus the Pass3 model is actually a set of identically structured models with a different regional focus.

Each Pass3 model carries out a GB distribution process to apply more spatial detail to the Pass2 model results and then assigns the spatially detailed car matrix to a detailed representation of the Great Britain road network. The model takes as input the spatially detailed trip origins and destinations from the revised multi-modal trip end model. A further input is the set of trip origins and destinations by mode and distance band from the Pass2 model. The distribution module splits the zonal trip origins into distance bands and modes to match the control totals from the Pass2 model.

The travel cost inputs to the Pass3 distribution models are currently derived from the highway assignment model, but are applied to both car and non-car modes of travel. This is not ideal, and is compensated by the application of mode specific attraction weights and modal constraints by distance band from Pass2. Trip ends to and from zones not close to the focus region and input by mode directly from the Pass2 results. The primarily output is the traffic by road type and hence car travel costs and times are of primary importance.

The resulting spatially detailed car matrices are input to an assignment model to determine routes through the road network. Once the complete set of Pass3 models has been run, summary statistics are derived showing the estimates of traffic by road type, area type and sub-region.

The focus of the Pass3 model is the assignment of the car trips to the spatially detailed road network. To achieve this, spatially detailed car trip matrices have to be built using a distribution model. Because the Pass3 model is operating close to ward level, a model of the whole country at the most disaggregate level would mean working with 10,000 zones. This is not computationally feasible even with limited segmentation. To make the process manageable the country was divided into 13 regional components. The 13 models are based on the 11 Government Office regions, with the largest regions: Eastern and South East further subdivided.

Conclusion

The UK NTM models all travel in the UK which is an ambitious undertaking that results in the computational complexity of the three pass model. New Zealand has a smaller population which means that modelling all travel would not be as complex as in the UK; however, this approach is not recommended for the following reasons:

- it is high risk as we have no experience with national models and this is the most ambitious type of national model we could build
- It is unnecessary as the major urban areas already have satisfactory urban models.

The main purpose of the UK NTM is to indicate to policy-makers the likely impacts of national policies, and the cumulative national impact of policies that can only be applied locally. This type of analysis is quite complicated in the UK with a larger population, more population centres and a more complicated transport system. In New Zealand analysis is less complex as the population is concentrated into fewer centres and the transport system is simpler.