Dynamic Modelling

A case study

(Model Specification)

By

M. G. Smith

Director
Gabites Porter (NZ) Ltd

Dynamic Modelling – a Case Study
(Model specification)

By MG Smith
BE(Civil), C.Eng, MICE, MIPENZ

Abstract.

When a four step model is used in a conventional form, the public transport assignment, and the road assignment are undertaken as an average of the period being modelled – typically, for example, a morning peak two hours. Generalised costs are then skimmed off these for the mode choice phase, with the result that the mode split is also an average over the period.

The City Centre study in Wollongong required a more detailed approach as the mode share alters over the day as congestion changes. Accordingly, the model has been set up as a 24hour model, but split into a number of time slices, incorporating a dynamic road assignment, a dynamic public transport assignment, and a dynamic parking model.

In this way, mode choice is able to be changed every few minutes in the peak periods, and the supply of parking at the destination is also incorporated into that phase.

This paper describes the specification for the model, the theory behind it, and the way in which the three components are integrated. This is the first in a series of papers that will document the progress of the study, the problems involved with the process, and the performance of the model.

1. Introduction

The urban are of Wollongong and Shellharbour are the largest urban centre in the Illawarra with a 2001 census population of around 247,000.

In 1992 Wollongong City Council and the New South Wales Roads and Traffic Authority embarked on a modelling exercise for the Illawarra Region, and for the urban areas of Wollongong and Shellharbour. The initial models, calibrated, and validated against 1991 census data comprised a 24hour model of the whole Illawarra region, and a morning peak and evening peak period model for the urban area.

These models were three step vehicle driver models and used the best available technology of the time, which was

- *Trip generation.*
  Household category model for trip generation and regression models for trip attractions and commercial vehicles
  .
- *Trip Distribution*
  Gravity model distribution by person

- *Assignment*
  Time sliced capacity restrained assignment using link speed flow relationships, and intersection delays calculated at the approach level

In 1996, the city undertook a central area study, and at that time, a parking model was added which replicated the search patterns of motorists looking for spaces to park.

The latest round of updates occurred in 1998, when the models were revalidated using 1996 census data, and they have bee used in several roading project analyses over the years.

In 2002 the City began a *Wollongong City Centre Access and Movement Strategy* study which required models that were significantly more detailed and which included public transport. One of the aims of the study was to show how the strategy would contribute to a reduced demand for road and parking infrastructure in favour of increased public transport usage and non-motorised modes of travel.

This was in response to the NSW Government's goal of achieving zero growth in total vehicle kilometres travelled by 2021, and the strategy adopted for the City Centre had to clearly demonstrate the contribution to that objective.

This paper begins by briefly describing the conventional way of preparing a four step model, and then set out the changes that were needed in order to better meet the analytical requirements of the study. It is the first in a series of papers that will document the study, and concentrates on the model specification.

The model form which emerged from extensive technical discussion involved a partnership between the City, Department of Transport, the RTA and Gabites Porter. It required a completely different approach to the model, and significant changes to the software, as will become apparent later.

2. A Conventional Four Step Model.

There are a number of ways in which a conventional four step model can be applied, but a reasonably common approach comprises the following

- *Trip generation.*
  Household category model for person trip generation and regression models for trip attractions, commercial vehicles and external trips.
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- *Trip Distribution*
  Gravity model distribution by purpose
- *Mode Split*
  A nested logit model
- *Public Transport Assignment*
  Public transport trips are assigned to shortest cost paths using the public transport route structure. Generally not capacity restrained.
- *Road Assignment*
  Time sliced capacity restrained assignment using link speed flow relationships, and intersection delays calculated at the approach level.

Usually, the model is set up for a morning, interpeak and evening peak, with each period effectively as a separate model. The implicit assumptions contained in this process are:

- All trips which leave their origin in the period will reach their destination during the period. The trip generation rates are usually calculated on the basis of including those trips that began in the period (or ended) in the period. It is seldom comprised of trips that began <u>and</u> ended in the period.
- That the destination choice and mode choice (the distribution and mode split stages) can be made on the basis of average travel costs over the period.

- That the route travel times for buses can be taken from the average times over the period.

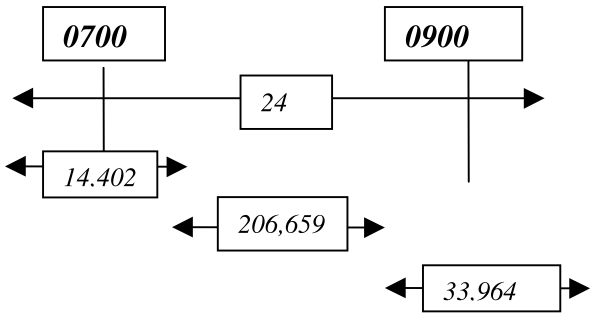
- That the counted volumes on a link represent demand rather than supply.

In reality, none of these assumptions hold. In an uncongested system, they become less of an issue, but in a congested system, the inaccuracies can be significant.

Trip timing

Clearly, if we look at a morning peak period of 0700 to 0900 hours, there are some trips that leave home at 0659 that are on the roads, and will reach their destination, and others that leave home at 0859 that will not finish the journey before 0900. The conventional model assumption is that those numbers are the same.

A quick analysis from the 1991 Auckland home interview survey will demonstrate the point. These are car driver trips over the whole of Auckland.



If the definition of trips starting and ending in the period is taken, then there would be 206,659 trips in the model.

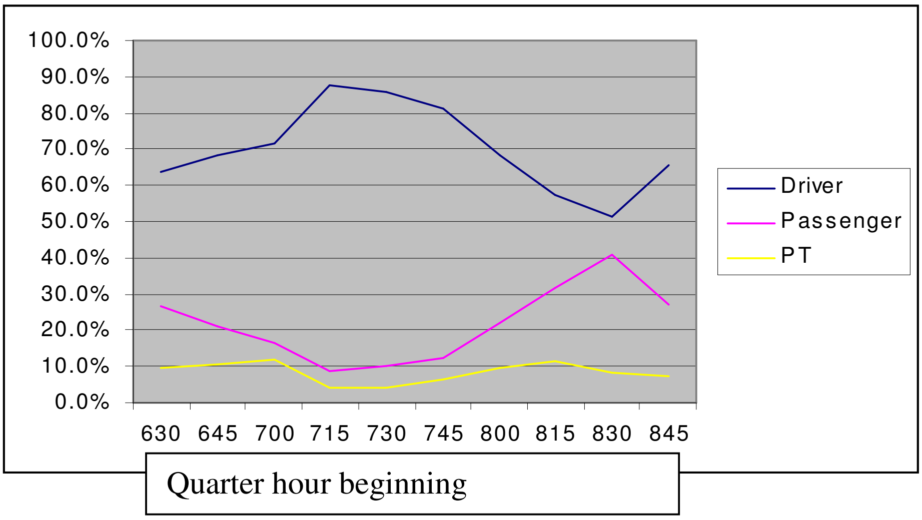
If the definition were to be trips beginning in the period, then there would be 240,623, while if it were trips ending in the period, the number would be 221,061.

At any point on the network, there will be some from each of these components, and a different proportion at every point.

Destination and mode choice

At different times of the day, the levels of congestion change, and the choice of destination and mode will also change depending on the congestion level. Again. looking at the Auckland HIS, there is some evidence of this. In the morning peak period, trips which reach their destination between 7:15 to 7:30 are almost 90% as car driver. In stark contrast, trips which finish between 8:30 and 8:45 are only 51% as car driver. Public transport trips vary less, generally sitting around 10% in each quarter hour. The variation over the period is shown on the diagram below.

Change in mode split during the morning peak period – Auckland 1991



Clearly, as congestion builds up there is a major shift from car driver to car passenger, but that shift could also be to public transport if the level of service was sufficiently good. One of the behavioural responses in Auckland to congestion is that those people who wish to drive to work, time their journeys so that they miss the peak congestion times – that is they leave from home at 7:15 and arrive at work before 8:00 am.

There is no reason to believe that, given a good public transport system, the shift would be to public transport as well.

However, the key conclusion is that mode split changes with time of day, and even within the peak periods generally used in conventional models.

Bus travel times.

The conventional models use car travel times from a loaded network as a means of assessing the trip time by public transport. However, these are either an weighted average of the travel times during the period if a time sliced assignment is used, or the final (peak) travel times if an incremental or equilibrium assignment is used. Given that buses run during congested and uncongested times, that assumption cannot be correct.

Validation.

Following assignment there are two validation checks that are normally carried out to confirm that the model is fairly replicating the existing situation. These are checking that assigned volumes match counts, and the second is that modelled journey times match those that have been measured.

Traffic counts measure the number of vehicles that pass over a given point in a period of time. In a congested situation, and particularly when a queue builds, the number of vehicles passing is a function of the capacity of a piece of road – that is the number of vehicles that can physically pass through. Additional demand simply makes the queue longer. In these circumstances the count is a measure of supply.

A traditional assignment requires every vehicle to reach its destination even though delays can be very high. The assigned flow on a link is therefore a measure of demand. Clearly, the two measure are incompatible. One example of this is the Auckland harbour bridge where the two hour count southbound in the morning peak is around 16,000 vehicles, but there are some 2000 vehicles still queued at 9:00am. The conventional model value of demand is consistently higher than the count at around 17,500 vehicles.

The journey time validation is possibly the only measure that is correctly replicated by a conventional model. A number of moving car runs would normally be made in a period, and a mean and standard deviation calculated. The modelled journey time, as an average over the period, is compared against the measured mean.

3. A Dynamic Model.

The Wollongong study required resolution of these issues, and in addition needed the mode split phase to be sensitive to the supply of parking, in particular the supply of commuter parking in the central core.

Accordingly, a specification for a dynamic model was produced and is described in the following sections of this paper.

The brief was to develop a model which captured

- The change in mode choice over the day
- The change in mode choice because of parking restraints

- The change in mode choice because of demand restraints
- The actual network times experienced by travellers
- The effects of peak spreading

The concept behind the model was to better represent the decisions made by travellers, and to remove as many of the assumptions inherent in a conventional model as possible.

Trip generation

Trip rates for the full 24hours of and average weekday were derived from the Transport Data Centre's home interview survey. The centre also provided the profile of trips over the day in 5 minute intervals by mode and purpose. From this, a number of periods were defined, and each period was further divided into a number of slices.

Initially, the periods were defined as in table 1

Wollongong Centre City Study – Period and slice definition		**Table 1**
Time	***Period***	***Slice***
0000 hrs to 0600 hrs	Six periods of one hour	One slice per period
0600 hrs to 1100 hrs	Twenty periods of 15 mins	5 minute slices
1100 hrs to 1600 hrs	Fourteen periods of 30 mins	2 slices per period
1600 hrs to 1900 hrs	Twelve periods of 15 mins	5 minute slices
1900 hrs to 2400 hrs	Five periods of one hour	One slice per period.

This gives a total of 57 periods, and 135 slices.

Distribution and Mode Split

A conventional distribution and mode split stage is performed for each period based on the costs at the end of the previous period. The costs are fed to these stages as follows.

- Public transport costs come from the public transport assignment. The travel times are calculated according to the speeds and delays on the network at the time that the link is being traversed. For example, a trip which leaves home at 0700hrs and reaches a destination at 0800hrs will use the 0700hr speeds and delays on the first link, and the 0800 hrs speeds and delays for the last link. This requirement means that the model has to be iterated so that time in 'future' periods are known from the previous iteration.

- Car driver and car passenger times come from the vehicle assignment. The network speeds and delays are calculated over the whole journey, even if the journey spans several periods.

- Parking costs added to car driver network costs come from the parking model which calculates costs according to the amount of parking available in each zone, and its cost.

Vehicle Assignment.

The key process is the vehicle assignment. This is a dynamic assignment which works as follows.

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For time slice one (for example 0700-0705hrs)

- Take the platoon or 'slug' of trips that start from origins in this time slice.
- Build least cost paths from all origins to destinations.
- Assign trips so that they travel 5 minutes along the path.
- Calculate new link speeds, intersection delays, and intersection queues.

This provides a snapshot at 0705, and has vehicles on links, and waiting in queues at intersections. Some very short trips may have reached destinations and will not show on the network.

For time slice two (0705-0710)

- Build new shortest paths between origins and destinations for trips setting out in this time slice.
- Take the next increment of trips from the time distribution and allow these to travel for 5 minutes along the zone to zone paths
- Take trips which were held on links, and at intersections and assign these to travel a further 5 minutes along their original shortest paths.
- Calculate new link speeds, intersection delays, and intersection queues.

The process is then repeated until the specified period is ended – say at 9am.

The software keeps track of each slug of vehicles as the assignment progresses, and at the end of each period, outputs the time and distance matrices for the period as input to the distribution and mode split for the next period, and a table of link to destination trips which becomes part of the input to the next period assignment – that is trips that have not reached their destination in the period.

A further output is the number and type of car parks that are taken up and released during the period. Each 'slug' of vehicles has that information attached to it from the parking model as described later in this paper.

The concept behind the assignment is that a driver will make a route choice at the beginning of the journey, based on perfect knowledge of the traffic conditions. That choice is assumed not to change as the journey progresses. In reality, drivers do change route depending on the conditions that they encounter, but the increase in program run times to rebuild paths from each link to destination (as opposed to origin to destination) was not worth this refinement.

There are advantages of this procedure over the traditional assignment. Summing each of the slices is a much better representation of traffic counts of vehicles passing a point than the conventional assignment. It also allows comparison of model temporal distributions to be compared against surveyed distributions at link and screen line levels.

Secondly, it does not make the assumption that every trip gets to the destination in the time period, which enables peak spreading to be evaluated. (The assignment keeps track of vehicles that have not reached their destination in the time period.)

Thirdly, it can capture the wave nature effect of traffic flowing through the network conflicting with other traffic where the conflict is in physical space, but offset in time. The conventional assignment over-estimates delay in these cases.

Fourthly, it enables the 'blocking back' effect to be captured, and the upstream delays caused by a queue to be established.

One interesting side effect is that incident modelling could be undertaken – ie a link could be removed for a period of time (one or more slices), and the resultant queues and diversions identified.

Public Transport Assignment.

The public transport assignment also works dynamically. Passengers are assumed to leave home according to a user specified demand profile, and walk, or drive to access the public transport system. The least cost path from origin to destination is chosen using the link speeds and delays from the loaded network that results from the road assignment. The departure time of each service, and the time it takes to move along the route determines which period loaded network is used for the bus travel times. An allowance is made for the time that a bus is stopped to pick up and set down passengers.

From these times, and the fare structure for the particular operators, the least cost path is determined using one or a combination of services. The cost is a function of

Walk or car access time at the origin
Wait time
Ride time
Fare
Transfer times if more than one service is used
A transfer penalty cost
Walk or car access time at the destination.

If passengers cannot access a bus within the time slice in which they leave the origin they are held over to the next slice, and the wait time adjusted accordingly.

Because the public transport assignment can be timetable based, one of the outputs is an estimate of the number of vehicles needed to operate the specified services. Other outputs include the number of vehicles and passengers passing a point during any given time period, and the zone to zone cost matrices for input to the distribution and mode split stages.

The Parking Model

The parking model takes the demand for parking from the car driver matrices which result from the mode split stage, and the duration of stay required for each purpose, and the supply of parking by type – for example, long stay commuter parking, public free parking, or public paid parking. Initially parking is sought in the destination zone of the trip, but if there is none available, the surrounding zones are checked to find the cheapest park available, including an allowance for the walk trip from the parking zone to the destination.

The trip matrix is then modified so that the car driver trip goes to the parking zone, rather than the destination zone, and if the trip is not a commuter trip, additional circulation trips are generated to replicate the search pattern of drivers.

In the conventional model system, where all trips are assumed to be completed in the time period, this process works well, and the costs of parking in each zone are fed back into the mode split stage.

The dynamic assignment, with time slicing presents a problem. The trip destination modification based on available parks has to occur before the assignment so that vehicles are attracted to the correct zone. However the number of vehicles to reach the destination, and therefore the number of spaces utilised are not known until after the slice has been assigned.

In effect, this means that the decision on where to park, and the cost has to be made on the basis of spaces available at the beginning of each period, even though the trip might not be complete (and the park actually occupied) until a number of periods later. Trips which have a permanent park allocated will not be affected, but most other trips will be to some extent.

One way of handling this is to iterate the model so that a trip can look forward to assess the spaces available during the period that the trip is complete, rather than the period in which it begins. That option will be tested during the model building and validation process.

4. Conclusion

The dynamic model form outlined above will enable many of the problems associated with the conventional model form to be addressed. The software to implement the model is complete, and has been tested using Timaru as an example. However there is little base data available in Timaru, and once the Wollongong project begins, the applications will be able to be established and rigorously tested in a much more demanding environment.

Further development is proposed to display results as a simulation, in a similar fashion to the micro-simulation packages that are currently available.