21st Australasian Transport Research Forum
Adelaide, September 1997

Development of a Patronage Demand Model for the Proposed Parramatta - Chatswood Rail Link

Neil Prosser
PPK Environment and Infrastructure

Neil Douglas
Pacific Consulting

Matthew Jones
PPK Environment and Infrastructure

Abstract:

In 1996, Rust PPK Pty Ltd (now PPK Environment and Infrastructure Pty Ltd) were appointed by project managers CMPS&F, on behalf of the Rail Access Corporation of NSW to develop a Patronage Demand Model for the proposed Parramatta - Chatswood rail link in Sydney. This paper describes the structure and development of the mode choice and assignment components of the model and reports on the calibration and validation of the model against base year patronage. An incremental logit mode choice model was implemented that allowed the prediction of changes in mode shares resulting from changes in generalised cost. Base year (1996) mode trip tables were derived from 1991 ABS data. A stated preference survey was used to develop generalised cost parameters and conducted in the study area covering 1,600 people. The mode choice model was incorporated into the EMME/2 modelling package and included three levels of decision making covering car versus transit, bus versus rail and car versus bus access to rail. Some conclusions are drawn regarding the applicability of the model.

Contact Author:

Neil Prosser
PPK Environment and Infrastructure Pty Ltd
PO Box 248
Concord West NSW 2138

telephone: (02) 9743 0333 fax: (02) 9736 1568
email: rustsyd@ozemail.com.au

Introduction

The provision of a heavy-rail corridor between Parramatta and Chatswood has been identified as an important future link in Sydney's public transport infrastructure in strategic documents such as the Integrated Transport Strategy (1995) and the State Rail Strategic Plan (1994) The objectives of the project[1] include providing a high level of public transport service between the residential and employment / education / commerce centres listed in Table 1 and shown in Figure 1.

Table 1: Key Residential and Employment Areas served by the Proposed Parramatta - Chatswood Rail Link

Residential Areas	Employment Areas
Blue Mountains / Penrith / St Marys / Blacktown	Parramatta
Hornsby / Gosford / Wyong	Chatswood
North West corridor	North Sydney
Chatswood / East Warringah Peninsula	North Ryde
	Rydalmere

Additionally, it is expected that such a link would improve overall rail network capacity by supplementing the existing Main Western and North Shore lines.

The planning phase for the link was coordinated by CMPS&F as project managers on behalf of the recently coporatised Rail Access Corporation, and Rust PPK Pty Ltd (now PPK Environment and Infrastructure Pty Ltd) was appointed to develop a Patronage Demand Model for the rail link. The model was to be based on the traditional four-step process (trip generation, trip distribution, mode choice and trip assignment) and was to incorporate variations in the following:

- link mode: heavy rail, light rail or busway
- route alignments and station locations
- connections with the North Shore and Main North Lines
- operating timetables and train running times
- bus feeder services and changes to existing bus services in the corridor
- land-use changes in the metropolitan area

[1] The authors of this paper would like to acknowledge the contribution made by the Technical Steering Committee for the Parramatta to Chatswood Patronage Study in overviewing the development of the methodology. The Committee comprised Helen Battellino and Frank Milthorpe of the NSW Department of Transport; Robert Parrish from the State Rail Authority of NSW; Keith Long and John Gill. EMME/2 modelling expertise was provided by Paul Van Den Bos with the assistance of Hanz Spiess.

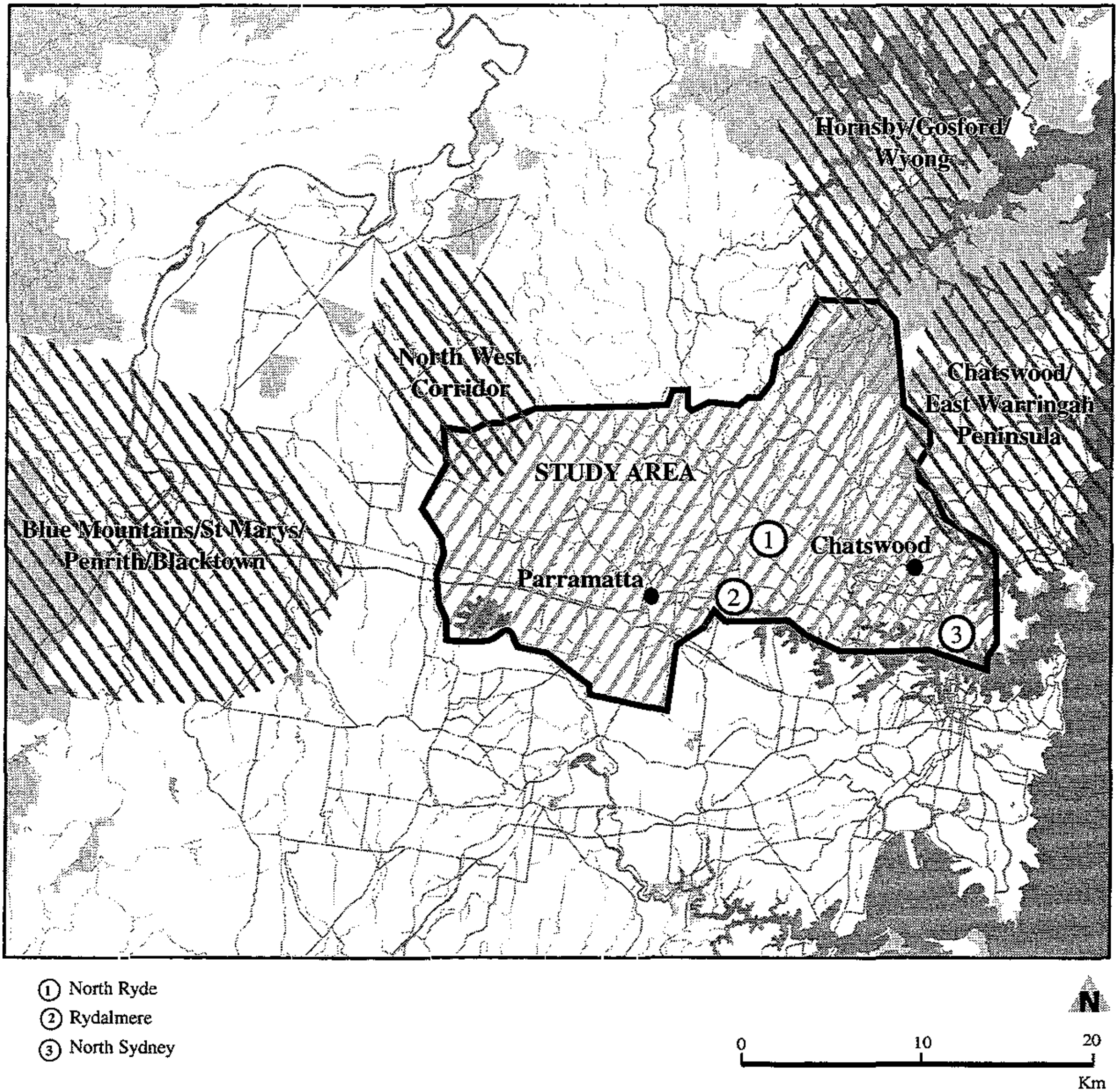

Figure 1 Study Area

The model was required to produce as output weekday AM Peak patronage forecasts for the proposed link as well changes in patronage on the existing CityRail network for different forecast years (2006 and 2021). Additionally, for the purposes of economic evaluation, changes in bus patronage and road volumes in the corridor were required.

The trip generation and distribution steps of the Patronage Demand Model were performed by the Department of Transport's Transport Data Centre using their transport model for the Sydney region. Land-use forecasts for the Sydney region were provided by Long Technical and consisted of both medium and high growth scenarios.

Rust PPK was appointed to develop the mode choice and assignment aspects of the model and to incorporate trip tables provided by the Transport Data Centre. Requirements for the mode choice model, in addition to those described above for the Patronage Demand Model, included separate modelling of bus versus rail travel and car versus bus access to rail. The project brief stated that the mode choice model was to be calibrated on the basis of the results of a large-scale, Stated Preference (SP) survey to be conducted in the study corridor.

This paper describes the methodology used in the mode choice and assignment components of the Patronage Demand Model and the manner in which the mode choice model was calibrated using SP data.

Incremental Mode Choice Models and Stated Preference Surveys

The incremental formulation of the binary logit model (equation 1) was used as the basis of the mode choice model and has the following form:

$$P_{ij}^{au} = \frac{1}{1 + \dfrac{\overline{P}_{ij}^{pt}}{\overline{P}_{ij}^{au}} \cdot \exp\left(\alpha \cdot \left[\left(C_{ij}^{au} - \overline{C}_{ij}^{au}\right) - \left(C_{ij}^{pt} - \overline{C}_{ij}^{pt}\right)\right]\right)} \qquad \text{(Equation 1)}$$

where,

$\overline{P}_{ij}^{au}, \overline{P}_{ij}^{pt}$ = proportion of travel between zones *i* and *j* by car (*au*) and transit (*pt*) in the base year;

P_{ij}^{au}, P_{ij}^{pt} = proportion of travel between zones *i* and *j* by car (*au*) and transit (*pt*) in the forecast year;

$\overline{C}_{ij}^{au}, \overline{C}_{ij}^{pt}$ = cost of travel between zones *i* and *j* by car (*au*) and transit (*pt*) in the base year;

C_{ij}^{au}, C_{ij}^{pt} = cost of travel between zones *i* and *j* by car (*au*) and transit (*pt*) in the forecast year;

α = calibration sensitivity parameter.

The advantage of using a mode choice formulation of the above type is that forecasts in mode share are made as incremental changes in base year mode share. The change in mode share value is dependent only on the relative change in the cost of the competing modes rather than the absolute value of the forecast travel cost. The degree to which the mode share values vary with changes in the travel costs is determined by the value of the sensitivity parameter, α.

A condition for the use of an incremental logit model is that good data on base mode share values be available, and an important part of the building of the mode choice model was development of base year trip tables for the different travel modes.

An equally important component of the mode choice formulation is the calculation of generalised travel costs. As will be seen later, the cost of travel by each mode (car, bus, rail) was assumed to be a weighted sum of different travel components such as in-vehicle time, fare, toll etc. SP surveys were used to estimate the relative weighting of travel time and the time values of monetary costs. All cost components were expressed in terms of equivalent minutes of rail in-vehicle time with values of time used to convert monetary costs such as transit fare and car tolls. Modal penalties - the residual items which explain the preference for or against a particular mode, were also translated into rail in-vehicle time. Further on we describe the generalised time equations and components in more detail.

In contrast to the SP survey, a Revealed Preference (RP) survey was conducted for the purpose of calibrating the sensitivity parameter, α. This hybrid approach, where SP and RP surveys are used in combination, draws on previous work. In particular, it follows the technique for validation of SP parameters described by Kocur (1981). The hybrid approach has been used previously in forecasting demand for different public transport technologies in Phoenix, USA, by Cuthbertson et al (1988).

The aim of the hybrid approach is to achieve the advantages of SP surveys without the potential disadvantages. SP surveys can provide mode choice parameters in a cost-effective way but there can be biases, in particular, respondent's stated preferences need not accord with revealed preferences. A recent review by Crampin (1996) of the Sheffield LRT system after commencement of operation suggests a need for caution in using SP techniques. Crampin found that the SP-based patronage forecasts for the LRT system were nearly three time higher than patronage levels actually realised. Crampin concluded that - "SP is heavily reliant on hypothetical questions about what individuals would do if faced with specific situations, and it assumes that people will actually display the behaviour that they say they will".

Mode Choice Model

Model Structure

The overall structure of the mode choice model used in the study is shown in Figure 2. Mode choice behaviour for people with and without a car available is modelled separately. Input to the mode choice model is an estimate of forecast year, total AM Peak, All Purposes trips for each zone pair (*i,j*)

At the highest level of the mode choice model, a fixed proportion of trips is considered to be captive transit users with no car available. Of the remaining car available trips a split is made between car and transit. A fixed car occupancy value is applied to the car trips to establish vehicle demand, i.e. no prediction is made of changes in car occupancy. At the second level of the model, both car available and car not available transit trips are split into bus and rail trips The rail trips are then further split into car, bus and walk access to rail.

Thus, the overall mode choice model can be seen as consisting of the following binary split sub-models:

Submodel 1: Car v. Transit, Car Available
Submodel 2: Bus v. Rail, No Car Available
Submodel 3: Bus v. Rail, Car Available
Submodel 4: Car/Rail v. Bus/Rail, No Car Available

Note that the third level of the model, where access mode to rail is considered, consists of only a split between car and bus access for trips where a car is available. This submodel is only applied to trips starting at zones remote from the rail network For those zones adjacent to the rail network walking is assumed to be the only mode of access to rail trips. For trips made with no car available from zones remote from the rail network bus is assumed to be the only available access mode.

Each submodel described above is formulated as an incremental logit, binary choice based on generalised time functions The submodels are applied on a zone pair basis - that is, for a trip between each pair of the 121 zones in the model, generalised time values are calculated for each mode and changes in mode share predicted using the incremental logit formula.

Generalised Time Equations

For car, bus only, car/rail, bus/rail and walk/rail modes generalised time values were generated for the two competing modes using the following generic equation:

$$GT = a_W W + a_{PTV} PTV + a_{ST} ST + a_{DT} DT + a_{SI} SI + a_{PTF} PTF + a_{CF} (CT + CF + CP) + a_{ASC} \quad \text{(Equation 2)}$$

where the following symbols are used to denote the different components:

W	=	walk access time
PTV	=	transit in-vehicle time
ST	=	number of same-mode transfers
DT	=	number of different-mode transfers
SI	=	service interval
PTF	=	transit fare
CV	=	car in-vehicle time
CT	=	car toll
CF	=	petrol cost
CP	=	car parking charge

Each component is multiplied by a generalised time weight denoted by a_x where x is the symbol for that component. A mode-specific constant, a_{ASC}, is also applied.

Note that the different components of a transit trip are weighted equally for bus and rail trips. For example, a minute of bus and rail in-vehicle time are considered to be of equal disutility. Any differences in perception between the different transit modes beyond differences in the above time components are embodied in the mode-specific constant for each mode. Transfers between the same mode, eg. bus-to-bus transfers are considered to be valued differently to transfers between different modes, eg. bus-to-rail. Car costs are formulated as the sum of tolls, petrol costs and parking charges with each cost valued equally.

Using the GT equations in the above form requires two tasks: the forecasting of changes in the values of the GT components, and developing weights for each component in each of the four mode choice submodels.

Equation 2 above is used for calculating car, bus only, car-rail and bus-rail GT values. A means of combining these costs is required to estimate rail and transit GT values. The following formula, shown for the case of transit cost, is used:

Submodel 1: Transit = combination of Bus and Rail GT values

$$\text{Transit GT} = -1/\alpha_3 \, \text{Log}\,[\exp(-\alpha_3 \,.\, BusGT) + \exp(-\alpha_3 \,.\, RailGT)] \qquad \text{(Equation 3)}$$

where *BusGT* and *RailGT* are the GT values for bus and rail from Submodel 3, and α_3 is the sensitivity parameter from the same submodel.

Base Year Trip Tables

Base year trip tables were developed by combining Australian Bureau of Statistics (ABS) 1991 Census Journey-to-Work (JTW) data and 1991 Household Interview Survey (HIS) data produced by the Department of Transport. The ABS data provides rich information on 24 hr JTW travel patterns in the Sydney region while the HIS data, when suitably aggregated, provides data on non-JTW trips and trip levels by time of day.

The result of the development process was a set of six trip tables at the 121 x 121 zone level for car driver, car passenger, bus only, walk/rail, bus/rail and car/rail modes.

Stated Preference Surveys

Survey Methods

The SP surveys were undertaken face to face by trained interviewers. Respondents were chosen for interview if they were determined to have made trips within the defined study corridor during the AM peak.

Overall, 1,684 interviews were conducted with quotas specified by transport mode, sex, age and occupation. Advanced survey techniques featuring pictogram presentations and controlled statistical design and analysis were used. Respondents were asked to choose between two transport alternatives with each alternative presented as a bundle of attributes including travel time, fare, walking time etc. The basis of the SP technique is that the respondent will choose between two alternative bundles based on underlying values placed on the different attributes. By carefully designing the attribute levels, weights applied to each attribute can be estimated.

Two types of questionnaires were used - the first set (PT v. PT) involved choosing between alternative transit modes (bus, rail and LRT), while the second set involved choosing between car and transit (car v. PT). Respondents that indicated they had no car available were only given the PT v. PT questionnaire.

Seven attributes were used in the SP questionnaires - mode, transfer, walk time, service interval, in-vehicle time, fare and parking cost. Each attribute had at least three different levels. For example, PT in-vehicle time was either 15, 20, 30 or 40 minutes in the Car v. PT design. The full survey design required 25 different experiments, but to avoid problems with interview fatigue no respondent was asked more than eight SP choices, chosen at random.

After a pilot survey, where design levels were refined, the main survey was conducted over a period of four weeks during April and May, 1996. Surveys of rail users were conducted on the Northern and Main Western lines adjacent to the Parramatta - Chatswood corridor. Interviews were conducted both on trains and at major stations in the area. Bus surveys were carried out at bus stops in the corridor, while car surveys were undertaken at major business and shopping centres.

Parameter Estimation

The parameters were estimated using maximum likelihood regression based on the standard logit model. Estimations were made at a disaggregated level for each mode as well as at an aggregated level for all observations. Tables 2 and 3 show the estimated parameters from the PT v. PT and Car v. PT surveys respectively. Each table presents the parameter estimate, the relative valuation and the 95% confidence interval for the valuation.

Table 2
Specification of GI Equation

Equation	Origin Zone Type	walk time W	PT ivt PTV	same tr ST	diff tr DT	SI SI	PT fare PTF	car ivt CV	toll CT	petrol CF	park CP
SUBMODEL 1											
(Car v. PT)											
Car		0	0	0	0	0	0	Ccv	Ct	Ccv * P	Cp
PT		Combined Bus and Rail Time									
SUBMODEL 2											
(Bus v. Rail no car)											
BUS		Bw	Bptv	Bst	0	Bsi	Bf	0	0	0	0
RAIL	**Bus Access**	BRw	BRptv	BRst	BRdt	BRsi	BRbf + BRrf	0	0	0	0
RAIL	**Walk Access**	BRw	BRptv	BRst	BRdt	BRsi	BRbf + BRrf	0	0	0	0
SUBMODEL 3											
(Bus v. Rail car avail)											
BUS		Bw	Bptv	Bst	0	Bsi	Bf	0	0	0	0
RAIL	**Car/Bus Access**	Combined Car/Rail and Bus/Rail Times									
RAIL	**Walk Access**	BRw	BRptv	BRst	BRdt	BRsi	BRbf + BRrf	0	0	0	0
SUBMODEL 4											
(Car v. Bus access)											
Car / Rail		BRw	Cptv	BRst	BRdt	BRsi	BRrf	CRcv	0	CRcv * P	0
Bus / Rail		BRw	BRptv	BRst	BRdt	BRsi	BRbf + BRrf	0	0	0	0

NOTES:

P = conversion factor for petrol costs

= 1/60 * 40 * 0.7 / 11.0 * 1/1.2 = 0.035 $/min (= $2.12/hr)

which assumes average speed of 40 km/h, petrol cost of 70c/l,

average consumption rate of 11 litres/km and average occupany of 1.2

Table 3
Specification of GI Equations: Car vs Public Transport

Estimated Parameters	Excluding Macquarie University ALL N.C.	Car	Bus	Rail
Car Constant	0.2166	0.5708	0.3983	-0.2505
|t|	nc	2.6	3 9	1 1
Bus Constant	-	0.2016	-	-0.1095
|t|	nc	1 3	-	0.8
R&R Constant	-0.1497	-0.1613	-0.1977	-0 1608
|t|	nc	1.2	3.4	1.3
R&B Constant	-0.2928	-0 07586	-0 3441	-0.4033
|t|	nc	-0.5	5.3	2.9
PT Access	-0 03663	-0.04372	-0.03705	-0.03363
|t|	nc	4.9	9.5	4
PT Freq	-0.01722	-0.01144	-0.01814	-0.02215
|t|	nc	1.6	5.1	3
PT IVT	-0.02629	-0.01932	-0.02727	-0.02764
|t|	nc	3.5	10.4	5.1
PT Fare	-0.3374	-0.3479	-0.3547	-0.3467
|t|	nc	5.3	11 8	5.7
Car IVT	-0.03741	-0.03308	-0.03604	-0.03563
|t|	nc	7.3	17	8.4
Car Park	-0.5909	-0.5493	-0.5928	-0.6388
|t|	nc	15.8	37.8	20.6

Relative Valuations	Excluding Macquarie University ALL N.C.	Car	Bus	Rail
Car Constant	-8.24	-29 54	-14.61	9.06
Bus Constant	-	-10.43	-	3 96
R&R Interchange 5 mins	5 69	8 35	7.25	5 82
R&B Interchange 5mins	11 14	3 93	12.62	14 59
PT Access	1 39	2.26	1 36	1 22
PT Freq	0.66	0.59	0.67	0.80
Car IVT	1 42	1 71	1 32	1 29
Fare / PT IVT $/hr	4.68	3 33	4.61	4.78
Park / Car IVT $/hr	3 80	3.61	3 65	3.35
Park / PT IVT $/hr	2.67	2.11	2.76	2.60

95% Confidence Range +/-	Excluding Macquarie ALL N.C.	Car	Bus	Rail
Car Constant	-	27 74	7.84	16.52
Bus Constant	-	16 78	-	9 82
R&R Interchange 5 mins	-	14 42	4.40	9 05
R&B Interchange 5mins	-		5.24	11 34
PT Access	-	1 56	0.38	0.76
PT Freq	-	0.80	0.28	0.61
Car IVT	-	1 36	0.35	0 70
PT IVT / Fare *60	-	2.24	1 16	2 47
Park / Car IVT * 60	-	1.31	0.61	1.17

Table 4
Specification of GI Equations: Public Transport vs Public Transport

Parameter Estimates	Excluding Macquarie ALL	Car	Bus	Rail
Bus - Rail	-0.5666	-0.5314	-0.3935	-0.7165
|t|	7.6	3.1	2.5	5.5
LRT - Rail	-0.2928	-0.442	-0.1494	-0.3117
|t|	3.9	2.5	0.9	2.4
R&B v Bus	-0.5001	-0.7088	-0.6653	-0.3238
|t|	7.3	4.4	4.4	2.7
R&R - LRT	-0.47111	-0.9386	-0.3393	-0.3361
|t|	5.3	4.7	1.9	2.4
IVT	-0.06159	-0.06931	-0.05978	-0.05902
|t|	21.7	11	10.7	13.4
Freq	-0.03996	-0.04246	-0.03962	-0.03949
|t|	18.2	9.3	9.7	12.2
Access	-0.08441	-0.09521	-0.08692	-0.07769
|t|	27.7	14.5	15.4	17.6
Fare	-0.4059	-0.438	-0.4852	-0.3444
|t|	12.7	6.3	7.4	6.8
Constant	-	-0.1084	-0.03839	0.06194
|t|	-	0.8	0.3	0.6

Relative Valuations in PT IVT minutes	Excluding Macquarie ALL	Car	Bus	Rail
Bus - Rail	9.20	7.67	6.58	12.14
LRT - Rail	4 75	6.38	2.50	5 28
R&B v Bus	8.12	10.23	11 13	5 49
R&R - LRT	7.65	13.54	5.68	5.69
IVT	1.00	1 00	1.00	1.00
Freq	0.65	0.61	0.66	0.67
Access	1.37	1 37	1 45	1 32
Value of PT IVT $/hr	9.10	9.49	7.39	10.28
Q'aire Constant	-	1.56	0.64	-1.05

95% Confidence Interval	Excluding Macquarie ALL	Car	Bus	Rail
Bus - Rail	2.51	5.04	5.30	4.68
LRT - Rail	2.43	5 13	5.46	4.38
R&B v Bus	2.30	4 91	5 36	4.06
R&R - LRT	2 91	6.14	5 95	4.72
IVT	0.13	0.25	0.26	0.24
Freq	0.09	0.17	0.18	0.15
Access	0.16	0.31	0.32	0.24
Fare	1.63	3.40	2 38	3 32
Constant		3.84	4.20	3.43

The relative valuations, defined as the ratio of the parameter estimate over the parameter estimate for PT in-vehicle time, provide the weights for use in the GT equations described earlier. Also presented in tables 2 and 3 are the equivalent monetary values of in-vehicle time. The 95% confidence range provides an estimate of the accuracy of each parameter.

The data suggested that, other things being equal, car travel was preferred to transit by about 8 minutes per trip for all respondents (Table 2 - Car Constant). The preference varied considerably by current mode of travel, with rail users actually preferring transit by 9 minutes and car users preferring their own mode by 30 minutes.

There was little consistency in the indicated preferences for transit mode amongst respondents to the Car v. PT survey. Within the PT v PT design, however, heavy rail was preferred to LRT by about five minutes (Table 3 - LRT v. Rail) which, in turn, was preferred to bus by about four minutes (Table 3 - Bus v Rail).

A same mode (rail to rail) interchange was valued at 6 minutes of in-vehicle time within the Car v. PT survey (Table 3 - Rail-Rail Interchange) whilst a different mode (bus-rail) interchange was valued at 11 minutes (Table 4 - Bus-Rail Interchange). Thus, a transfer between different modes was considered to impose a 5 minute penalty above a transfer between services within the same mode.

A minute of walk time was considered to be equivalent to 1.4 minutes of in-vehicle time by Car v PT respondents - amongst the different modes, car users valued walk time highest at 2.3 minutes with rail users lowest at 1.2 minutes. A similar average weight for walk time was obtained from the PT v. PT survey.

A minute of service interval was valued at an average of 0.7 minutes in the Car v. PT survey but the confidence intervals were quite wide. In the PT v. PT design the weight was 0.65 with tighter confidence intervals. If waiting time is approximated at half the service interval, then these values translate to a value of waiting time of 1.3 to 1.4 minutes of in-vehicle time. This value is less than the commonly accepted value of 2 for waiting time which may reflect the fact that for high service intervals people will not arrive at the bus stop or rail station at random.

The value of PT in-vehicle time as PT fare was $4.70 in the Car v. PT with a range from $3.30 for car users to $4.80 for rail users. The values obtained from the PT v. PT survey were considerably higher - the average value was $9.10 - indicating that fare is more important in choosing between transit modes than when choosing between car and transit

The results for the value of car driving time in terms of car parking costs were low at only $2.70 which is probably a reflection on the unpopularity of parking charges rather than the value of time itself.

Road and Transit Networks

Road Networks

EMME/2 road networks were supplied by the Department of Transport for the base year, 1996 and forecast years 2006 and 2021. The forecast year road networks included modelling of road projects scheduled for completion by each year. The road networks are strategic in nature with only arterial and major collector roads modelled Some further refinement of the road networks was required to allow accurate replication of travel times by car through the inner study area

Transit Networks

EMME/2 transit networks were developed by the DOT's Transport Data Centre for the Patronage Demand Model. The networks model all scheduled bus, rail and ferry services in the Greater Sydney region.

The EMME/2 rail network consists of a series of rail lines made up of links and stations that form the CityRail network. For each line, a generic set of rail services is defined that captures the major differences in actual rail services, such as local versus express services. A rail service is defined by way of a station stopping pattern, running times between stations and service frequency (assumed constant throughout AM Peak period)

Bus services are specified according to their routes through the EMME/2 road network and service frequency. Due to the strategic nature of the associated road networks, the exact bus routes and bus stops are not modelled.

Within the Patronage Demand Model, a combined bus, rail and ferry transit network was used. For a given origin-destination zone pair, EMME/2 develops a set of near-optimum routes through the transit network which can use any combination of the three different transit modes. An earlier section of this paper discusses the manner in which travel times by the different transit modes were estimated using the combined transit network.

Access to bus, rail and ferry services is modelled by a set of walk links connecting zone centroids to bus stops and rail stations and also connecting bus stops to rail stations to allow bus to rail transfers.

Forecasting Changes in GT Component Values

The car and transit networks are the primary source of information regarding likely changes in the values of the GT components for car, bus and rail travel. Modifications to the transit networks were made to incorporate a particular option of the Parramatta - Chatswood rail link. This included new rail links, and new bus feeder and rail services Rail services on the existing network were modified to reflect likely operational changes arising from the new link.

Under a particular forecast scenario, component values for the GT equations are derived by performing a series of assignments on the car and transit networks as summarised below:

Table 5 Networks Used for Assignment Runs

Assignment	Code	Network	Trip Table
Car	C	Road Network	FY Vehicle Trip Table
Bus Only	B	Combined Transit Network (Bus x 1, Rail x 10, Ferry x 10)	Unit Trip Table
Bus / Rail	BR	Combined Transit Network (Bus x 3, Rail x 1, Ferry x 10)	Unit Trip Table
Car / Rail	CR	Convolution of Car and Rail Travel Times	

Note that for each zone pair, travel time information was required for bus only, bus/rail and car/rail trips separately For bus only trips, rather than removing the rail network altogether, rail and ferry travel times were multiplied by a factor of 10 to force use of bus services as much as practical. For bus/rail trips, bus travel times were multiplied by a factor of 3 to encourage, but not excessively penalise, use of buses to access rail stations. The value of this factor was derived through a trial and error process - too small a value results in excessive use of trunk buses; too high a value results in bus access always to the nearest station regardless of available services to the final destination. As a result of the above assignments and other associated procedures, the following travel time values, or skims, are obtained:

Table 6 Travel Cost Skims

Mode	Network Variable	Description
Car	Ccv	car in-vehicle time
Car	Ct	car toll
Car	Cp	car parking costs
Bus Only	Bptv	bus in-vehicle time
Bus Only	Bst	number of bus transfers
Bus Only	Bsi	maximum service interval
Bus Only	Bw	walk access and egress time
Bus Only	Bf	bus fare
Bus / Rail	BRptv	bus and rail in-vehicle time
Bus / Rail	BRst	number of rail transfers
Bus / Rail	BRsi	maximum rail service interval
Bus / Rail	BRw	walk access and egress time
Bus / Rail	BRbf	bus fare
Bus / Rail	BRrf	rail fare
Car / Rail	Crcv	car access time
Car / Rail	Cptv	bus and rail in-vehicle time

All of the above variables were calculated automatically by EMME/2 with the exception of car toll (Ct) and car parking costs (Cp), which were specified manually, and transit fares which were calculated on the basis of trip distance.

The use of these variables in the GT equations for each submodel is shown in Table 2 Note that, as outlined earlier, composite costs are calculated using equation 3 for rail and PT modes. Access to rail from zones remote from a rail station is assumed to be by bus or car, where car is available, and by bus only where no car is available.

Calibration of Mode Choice Submodels

The incremental mode choice formulation used in this study (Equation 1) includes a single sensitivity parameter that determines the change in mode share arising from a given change in relative generalised time for two competing modes. The calibration phase of the mode choice model development involved estimating values of the sensitivity parameter for each for the four submodels.

Calibration of the submodels was done using information on base mode shares obtained from the 1991 ABS data. Generalised time values for each zone pair in the model were calculated for the base year using the results of assignments on the base year road and transit networks (See section 3.2). The calibration equation is as follows:

$$\text{Log}\,[P_1\ /\ 1\text{-}P_1] = \alpha\,(C_2\text{-}C_1) + \beta \qquad \text{(Equation 4)}$$

Where :

P_1 is the trip mode share of mode 1
C_1 is the GT of mode 1 and
C_2 is the GT of mode 2

Note that the intercept constant, β, is not required in the incremental formulation as only the relative differences between generalised time are used

Of the total 14,641 zone pairs in the model, a subset was used for calibration of each submodel based on whether it was determined that a genuine choice existed as revealed by the base mode share results.

Table 7 below summarises the results of the calibration of the four submodels.

Table 7 Calibration Results

	Submodel 1 Car v. PT	Submodel 2 Bus v Rail (No car)	Submodel 3 Bus v Rail (Car Avail)	Submodel 4 Car/Rail v. Bus/Rail
Size of Data Set	2781	416	416	43
α	0.023	0.090	0.085	0.034
|t|	31.2	18.9	17.7	3.2
β	-0.521	-0.775	-0.148	-0.807
|t|	-20.1	-5.9	-1.1	-10.6
Adjusted R2	0.26	0.46	0.43	0.18

The larger the value of the parameter, α, the more sensitive is the submodel to changes in generalised time. Table 7 shows that the mode choice model is least sensitive at the highest Car v. PT level and most sensitive at the bus versus rail level. This is to be expected - for a given change in travel cost, people are more likely to switch between transit modes then between car and transit

Application of Mode Choice Model

The procedure for running the overall Patronage Demand Model for a scenario of a specified forecast year and operating plan is as follows:

Step 1: Modify transit networks to incorporate specified Parramatta - Chatswood option
Step 2: Factor up total and car base year trip tables to the required forecast year.
Step 3: Assign the forecast year trip table to the forecast year road network to produce car travel times
Step 4: Perform transit assignments as described in section 7 to produce transit GT component values
Step 5: Calculate forecast GT values for each submodel
Step 6: Calculate forecast year mode share values using incremental logit equation
Step 7: Apply mode share values to total forecast year trips to produce the trip tables for car, bus only, walk/rail, bus/rail, and car/rail.
Step 8: Assign the trip tables from Step 7 to the following networks:

Total bus and rail patronage is then produced by summing the link and service volumes over each transit assignment

Conclusions

The mode choice model described in this paper allowed the analysis of a wide range of different options for the proposed Parramatta - Chatswood Rail Link. The zone system adopted for the model allowed assessment of benefits at a number of levels including long distance trips made through the corridor as well as trips starting and/or ending in the corridor.

The structure of the mode choice model, with three levels of choice, allowed the "competition" between existing trunk bus services and new rail services as well as the effect of restructuring bus feeder services on rail patronage to be examined.

The use of an incremental approach meant that differences in mode choice behaviour across the Sydney region due to variations in income and car ownership were captured in base mode share values, thus removing the need to include these variables explicitly in the model. This meant, however, that the effect on patronage of changes in these socio-economic factors could not be modelled directly. Rather, the benefits of the rail link were assessed in terms of changes in a range of travel cost variables that included both time components of trips and monetary costs.

The use of an SP survey targeted at potential users of the new link allowed calibration of the mode choice model parameters based on the socio-economic characteristics of this target group.

References

Kocur, G Adler, T Hyman, W and Aunet, B (1981) *Guide to Forecasting Travel Demand with Direct Utility Assessment* United States Department of Transport Urban Mass Transportation Administration

Cuthbertson, T Douglas, N and Smyth, A (1988) *Hybrid Approach to Forecast Demand for New Transport Technologies in Phoenix* PTRC paper

Crampin, J (1996) *Supertram Passenger Shortfall puts spotlight on Accuracy of Forecasting Techniques* Local Transport 25th April

State Rail of NSW (1994) *State Rail Strategic Plan 1994-2016* New South Wales Government

Integrated Transport Strategy (1995) *Integrated Transport Strategy for the Greater Metropolitan Area* New South Wales Department of Transport