Departure time choice for the car-based commute

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1 Introduction

Peak period traffic congestion commonly occurs in urban transport networks when traveller demands are at their greatest. In Sydney, the commuting trip purpose accounts for 39% of all private vehicle kilometres travelled in the AM peak, while during the PM peak commuting accounts for 29% of private vehicle kilometres. Corpuz (2007) further identifies the significance of private vehicle travel for the commute and for many other trip purposes in Sydney.

Peak period demands are therefore heavily influenced by travel from home to work and vice versa, which in turn leads to traffic congestion. Urban traffic congestion and in particular peak period congestion caused by the car impacts negatively upon on the economy, the environment and on society in general. It is estimated that fuel consumption per vehicle under congested traffic conditions is approximately twice that under free flow and that the annual economic cost due to congestion in Australia is $12.8 billion (BTRE, 2007). In addition, congested travel conditions are estimated to contribute 10.5 million tonnes of carbon dioxide to the atmosphere with Sydney responsible for 38 per cent of this pollution and Adelaide responsible for 9 percent (BTRE, 2007).

The nature of the peak period travel behaviour and the influence of peak spreading policies are a growing concern for transportation planners. Current models are often lacking in their ability to adequately represent trip flexibility with respect to departure time choice for the car-based commute. There is a need to improve forecasting models to better represent the temporal element of travel choice. This is emphasised by the findings of the UK Standing Advisory Committee on Trunk Road Assessment who report that peak spreading “is an important behavioural reaction to changes in road capacity, second only to changes in route” (SACTRA, 1994).

This paper outlines research into the development of a departure time change model based on Australian data. It presents the approach and results of an on-line survey and subsequent choice model development as it is applied to a policy-based test scenario.

2 Modelling Approach

The term ‘peak spreading’ refers to a reduction in traffic proportions during the most congested part of the peak period, with corresponding increases during the peak shoulders. There are many techniques that have been applied for the estimation of peak spreading, ranging from simplistic models based on historic traffic data to detailed representations with forecasting abilities. Examples of such techniques are summarised by Cambridge Systematics Inc (1997), Bolland and Ashmore (2002), and DTLR (2005).

For peak spreading strategy evaluation, it is desirable for the modelling approach to have policy forecasting abilities. Choice modelling approaches to the trip timing decision are a suitable methodology for representing the effect of peak spreading. Notable examples of various departure timing choice models include:

- A discrete choice approach to departure time modelling to determine peak period proportions in large scale models by Daly *et al.* (1990)

- An equilibrium incremental logit model of departure time and route choice, where successive equilibrium assignments of peak period matrices with the temporal distribution of demand flows based on an incremental logit choice model by Chin, Van Vliet and van Vuren (1995)

- A discrete choice modelling analysis of the combined travel mode and departure time choice for shopping trips in urban areas by Bhat (1998)

- The development of a simple binomial logit model representing the choice between peak and non-peak travel by Purvis (1999)

- A nested logit model of pre-work trip making and home departure time choice, including parameters related to worker personal attributes, household attributes and mode of travel by Yun and Lee (2000)

- A discrete choice model representing travel time choice between many disaggregate travel time alternatives across the day by Holyoak (2002)

- An error-components logit model to determine the joint choice of time of day and mode for car and train travellers in the Netherlands by de Jong *et al*, (2003).

Saleh and Farrell (2005) discuss an investigation on the impacts of variable congestion charging on departure time choice involving a stated preference survey based in Edinburgh, Scotland. Reported results of this investigation have proven useful in establishing a basis for the survey adopted as part of this research.

2.1 Model Structure

Due to the significance of peak period travel made by the private vehicle commute trip, the model is adapted for travel during both the AM and PM peak periods, from home-to-work and work-to-home trip purposes made only by the car mode. The study reported in this paper will also focus mainly on travel within the Sydney metropolitan region. It is also important to note that it is intended to operate in harmony with existing model structures such as the Sydney Strategic Transportation Model (STM) or the Metropolitan Adelaide Strategic Transportation Evaluation Model (MASTEM) which are founded in traditional four stage modelling theories.

The adopted modelling approach for this study is introduced in previous papers (Holyoak and Chang, 2006; Holyoak, 2007) with two modelling stages identified to simplify the discussion of model operation. The following paragraphs will initially recap on the first stage then continue to discuss the development second modelling stage, which is the core purpose of this paper.

2.2 Model Stage 1: Departure Time Allocation

The first modelling stage is designed to initially accept total AM and PM peak period demands that result from the mode-choice stage of a larger modelling framework (such as STM or MASTEM). Commuter car-based demands are allocated to hourly time allotments representing the critical and shoulder peak hours as displayed in Table 1.

Table 1 – Time period definitions for AM and PM peak periods.

Peak Period	*Time period definition*	*Time period duration*
AM	Pre-peak shoulder	6:00 a.m. – 6:59 a.m.
	Critical peak	7:00 a.m. – 7:59 a.m.
	Critical peak	8:00 a.m. – 8:59 a.m.
	Post-peak shoulder	9:00 a.m. – 9:59 a.m.
PM	Pre-peak shoulder	2:00 p.m. – 2:59 p.m.
	Critical peak	3:00 p.m. – 3:59 p.m.
	Critical peak	4:00 p.m. – 4:59 p.m.
	Critical peak	5:00 p.m. – 5:59 p.m.
	Post-peak shoulder	6:00 p.m. – 6:59 p.m.

A discrete choice modelling approach in the form of a Random Parameters Logit (RPL) is adopted with estimation based on journey and household attributes from the Sydney Household Travel Survey (SHTS) data source. As the choice made is between hour-long alternatives there is a restricted scope to test the policy influence for minor departure-timing changes that would be likely to be made, e.g. 5 or 10 minute changes.

2.3 Model Stage 2: Departure Time Changes

Stage 2 of the model addresses the need for detailed policy scenario testing and allows for more sensitivity relating to the traveller's departure timing decision and willingness to make relatively smaller changes to their departure time. For demand within each of the hour-long *critical* peak periods identified by the previous stage, the modeller may apply peak spreading policy options that require greater modelling sensitivity in terms of departure time changes. A discrete choice approach is developed for this purpose as depicted in the following illustration.

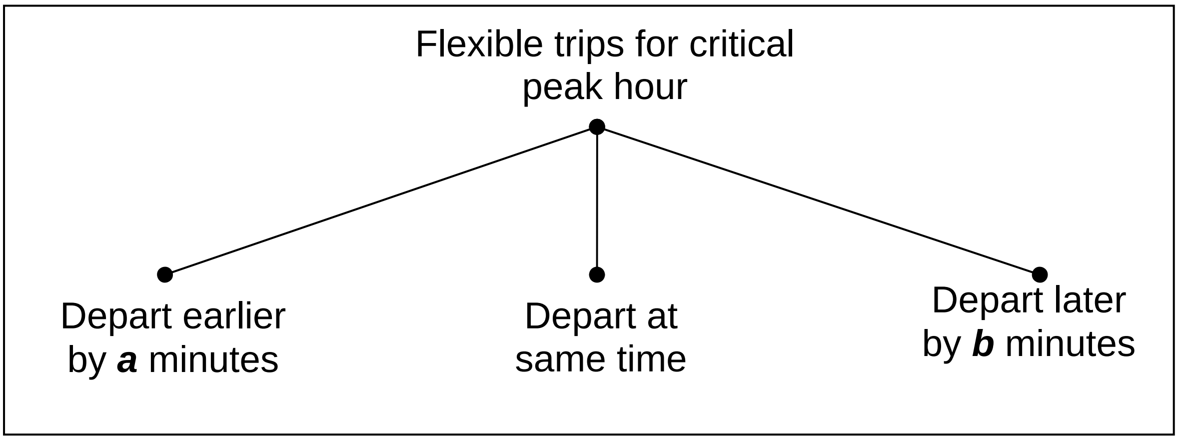


Figure 1 – Departure time change choice for travellers during critical peak hours.

From the demands within each of the critical peak-hour time periods determined from model stage 1 (e.g. 7:00 a.m. to 8:00 a.m.), a proportion of these trips are deemed to be flexible. Each trip within this demand matrix is then subject to the discrete choice of whether to depart earlier, later or at the same time. The modeller may chose how early or late the trip may be (i.e. parameters ***a*** or ***b***). A simple multinomial logit model (Louviere, Hensher and Swait, 2000) is adopted to represent this choice made by the commuter with a range of journey and personal attributes available for inclusion as discussed in following sections of this paper.

As the SHTS is a Revealed Preference (RP) survey, it does not allow for the testing of "*what if…*" type policy scenarios related to the peak spreading problem. Additional Stated Preference (SP) data is required to accurately calibrate the choice model in Figure 1, therefore identifying the need to conduct a traveller survey. Estimation of the Stage 2 model was conducted with the application of the LIMDEP econometric software (Greene, 2002). Various model utility function specifications were tested and assessed based on the significance of the parameter estimate and overall performance of the model.

3 Travel Surveys

To support model development and provide a more detailed insight into the nature of travel during the peak periods (especially relating to the trip timing aspect) a detailed trip-timing survey has been conducted. The survey was structured as a combined RP and SP type survey and therefore contained several sections to collect information about the respondent's travel patterns and personal information. Stated preference scenarios gauged the influence of travel time changes and departure time changes on departure time choice. To customise the survey to individual travel patterns, travel time information reported initially in the RP component was utilised in the latter SP questionnaire component.

The targeted trip types were trips made by the individual respondents to and from work using the car mode on weekdays. Both AM and PM peak period travel was included and responses from the capital cities of Adelaide and Sydney sought. Including both RP and SP components permitted the survey to gain information from respondents concerning the nature of travel during the congested peaks. Data collected from the trip-timing survey supported later model developments.

3.1 Revealed preferences

The questions from the RP survey component asked about usual commuting travel to and from the main workplace. Individual question sets were asked for the home-to-work and work-to-home trip, with these summarised as "to/from" in the following question set:

1. Where is your home address/work address?
2. Where do you usually start/finish your journey to/from work?
3. What mode of transport dominates your trip to/from work?
4. If you use a car, are you usually the driver or passenger on the way to/from work?
5. What time do you normally leave for work/home?
6. What time you normally arrive at work/home?
7. Do you have regular before/after work commitments affecting your departure time?
8. Do you get slowed in heavy traffic during your journey to/from work?
9. If so, how does this make you feel?
10. If you live in Sydney, do you pay a road toll on the way to/from work?
11. If you live in Sydney and pay a road toll on your way to/from work, approximately how much do you pay for the single journey?
12. If you live in Sydney and pay a road toll on your way to/from work, where do you pay?

An additional set of questions about the respondent's personal attributes were asked. These were as follows:

1. Are you male or female?
2. What is your age group?
3. Are your starting and finishing times at work flexible?
4. How many people live at your house?
5. How many of these people are aged 15 and under?
6. How many full-time workers live at your house?
7. How many cars belong to people at your house?
8. What is your gross personal annual income (i.e. before tax or anything taken out)?
9. What is the postcode of your HOME address?
10. What is the postcode of your WORK address?
11. What is your occupation at your main job?

In addition, stated preference question sets were designed and issued as part of the survey. This is discussed in the following section.

3.2 Stated Preferences

The stated preference component of the survey asked the respondent about possible changes to his/her departure time both to and from the workplace. They were asked to choose from Departing Earlier, Depart Same Time or Departing Later. The periods introduced for the possible changes were a 5, 10 or 20 minute departure time change, introduced as earlier or later. A travel time saving was introduced as part of the choice alternative with 10%, 20% and 30% travel time saving possible. An orthogonal design process was applied to determine the structure of the survey and identify critical elements. This approach was preferred over an efficient design approach as locally derived coefficient values that may appropriate as prior parameter estimates were not gained in the review of literature for this model type.

The survey was a labelled type survey with choice alternatives presented to the respondent as 'Depart Earlier', 'Depart Same Time' and 'Depart Later'. The number of levels was not reduced to extreme values and only main effects were identified in the design. The design produced a total of 18 scenarios for the respondents, blocked into 3 sets of 6 with each respondent required to answer a complete block of 6 scenarios. The following table summarises the alternatives, attributes and attribute levels for the survey questionnaire.

Table 2 – Survey alternatives, attributes and attribute levels.

Alternative	*Attribute*	*Levels*	*Level description*
Depart early	Travel time saving	3	10%, 20%, 30%
	Depart time change	3	5, 10 or 20 minute
Depart same time	Travel time saving	3	10%, 20%, 30%
Depart later	Travel time saving	3	10%, 20%, 30%
	Depart time change	3	5, 10 or 20 minute

As a choice alternative, the survey was presented to the respondent in a format that was easily interpreted. An example of the appearance of one stated preference scenario is presented in Figure 2.

	Depart EARLY	*Depart SAME TIME*	*Depart LATER*
Departure for work time:	7:45 AM	7:50 AM	8:00 AM
Arrive at work time:	8:17 AM	8:18 AM	8:28 AM
Travel Time:	32 mins	28 mins	28 mins
CHOICE:	**A** ●	**B** ●	**C** ●

Figure 2 – An example of a stated preference choice scenario.

In Figure 2, the respondent had initially replied in the RP questions that their usual departure time for work was at 7:50 a.m. and arrival time was 8:30 a.m. The SP scenario utilises this information in the creation of the choice scenario alternatives. This can be seen in the *Depart EARLY* option applying a 5 minute departure time change to 7:45 a.m. and a 20% travel time saving, causing the travel time to be 32 minutes instead of 40 minutes.

3.3 Survey Deployment

The targeted respondent group for the survey were persons (male and female) travelling to and from the workplace by the private car mode. Trips of interest were those made to and from work during the AM and PM peaks respectively and respondents were sought from both the Sydney and Adelaide metropolitan regions for the comparative purposes and for possible separate calibrations of the departure time change model to follow.

The deployment of the survey was attempted twice. Initially, a personal interview style was adopted however an internet-based approach later replaced this. Some *pros* and *cons* experienced by each approach are listed in the following table.

Table 3 – Pros and cons of survey deployment approaches.

Deployment	*Pros*	*Cons*
Personal Interview	Good cross-section	Low respondent numbers
	Response consistency	Resource intensive (time, surveyors, $$).
	Survey completeness	
Internet Based	Respondent numbers	Interpretation issues
	Low resources required	Biased response groups
		Response completeness

The initial personal interview survey approach quickly proved to be very slow with difficulty in gaining an adequate number of respondents from the target group and considerable effort required from the surveyors. An internet-based approach presented itself as a better technique as the amount of required resources was greatly reduced. For the internet survey, many private and public organisations were invited to participate with employees from the organisations taking part.

The internet based survey consisted of several interactive components that followed through the RP and SP questions sequentially. The interfaces appeared as:

1. The introduction: containing a brief description of the survey, estimated completion time and UniSA ethics confidentiality statement
2. To work RP questions: as mentioned previously
3. From work RP questions: as mentioned previously
4. Personal attribute RP questions: as mentioned previously
5. To Work SP questions: block of 6 scenarios
6. From work SP questions: block of 6 scenarios
7. Completion and thankyou screen

3.4 Survey Results

In total, 653 responses were obtained from the survey. From these responses, several reported travel outside of the identified target areas, non-peak period travel and non-private vehicle travel, reducing the number of useable responses. From this total, the useable responses are:

- Adelaide HBW Car = 281 (43%)
- Sydney HBW Car = 166 (25%)

Some descriptive results of the survey are presented in the following section. From the reported AM peak departure and arrival times, it is possible to present travel time distributions for both Adelaide and Sydney as in Figure 3.

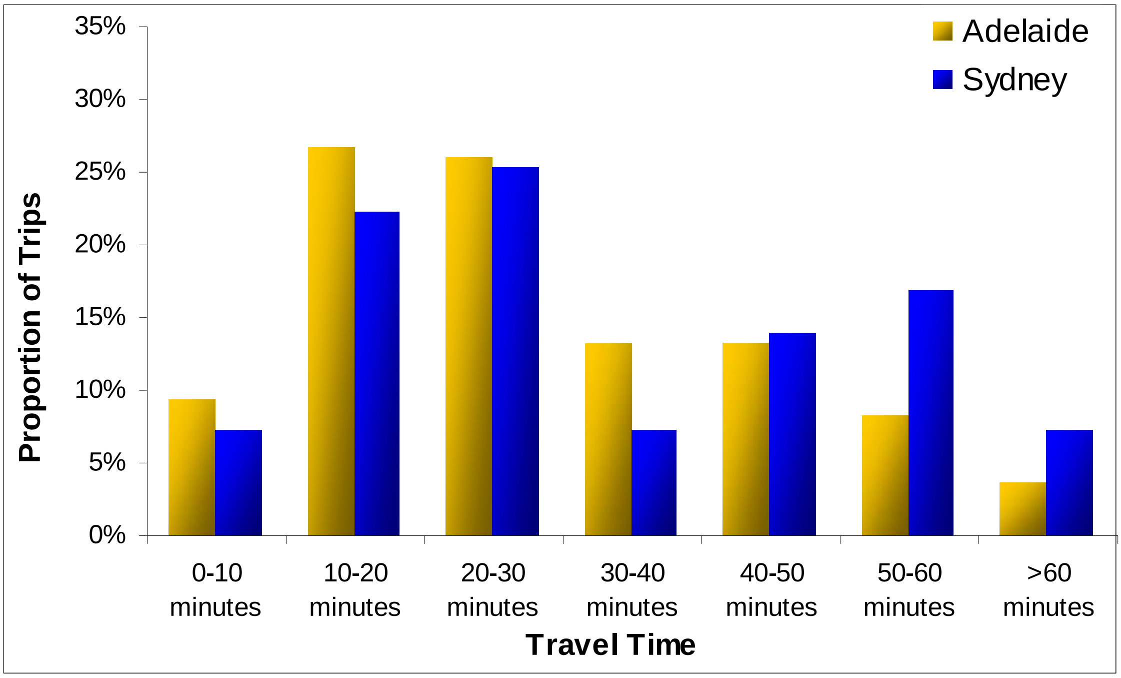


Figure 3 – AM peak car commute travel times for Adelaide and Sydney residents.

In general, a greater proportion of Sydney residents travel for longer time periods. The mean travel time for car-based commute trips in Adelaide is 34.5 minutes compared to Sydney's mean of 38.6 minutes. Sydney also has approximately double the proportion of Adelaide's trips longer than 50 minutes. In both cases, there seems to be an unexpected reduction between in the 30-40 minute time allocation. This may be due to some respondents rounding off their trip departure and arrival times.

Travel time flexibility can be influenced by many external factors. In the case of this survey this has been vastly simplified as the respondents are asked the question of *"Are your starting and finishing times at work flexible?"* The responses gained for both Sydney and Adelaide are summarised in Figure 4.

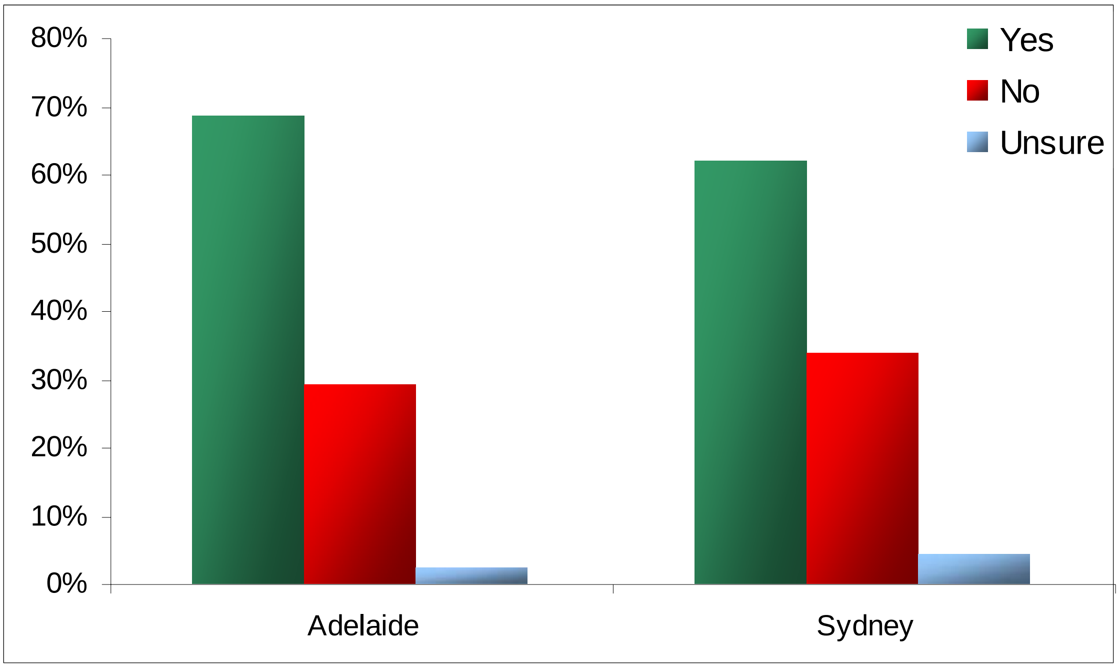
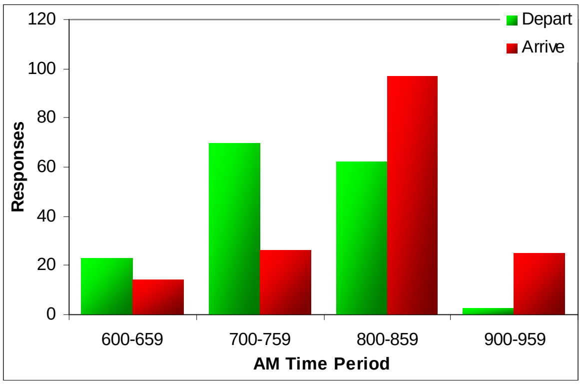


Figure 4 – Starting and finishing time work hour flexibility for Adelaide and Sydney car-based commuters.

The survey reveals that the majority of respondents in both cases report that they do have flexible start and finish times at work, implying that there is some degree of flexibility with travel timing arrangements. These proportions may be influenced by the proportions of 'blue' and 'white' collar workers responding to the survey. The majority of respondents from the survey are white collar workers (90% Adelaide and 83% Sydney) who may have more flexibility with work hours. Only a small proportion of respondents in both cases were unsure of their situation or the question itself.

All respondents were asked to report their usual arrival and departure times for both the AM and PM peak periods. These are grouped together in hourly time bins and when graphed, the following illustrations result for the car-based commute.

From Figure 5, during the AM peak period, the arrival times are more heavily peaked that the departure which has a greater spread across the entire peak period. For the PM peak (Figure 6) however, this situation is reversed as departures are peaked during the 5:00 p.m. to 5:59 p.m. period and arrivals extending to the end of the peak period and beyond. The PM peak also shows that relatively few departures or arrivals occur before the 3:00 p.m. for the car-based commute purpose.



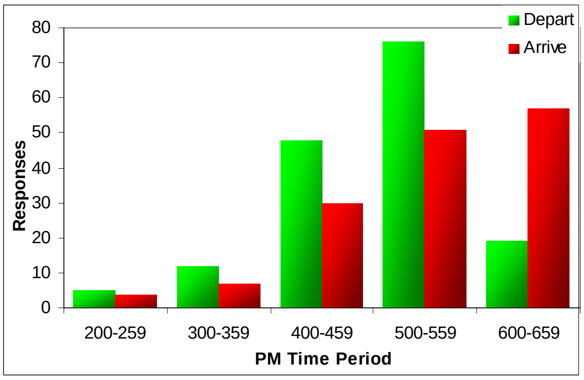


Figure 5 – AM and PM departure and arrival times for Sydney respondents.

Stated preference responses are summarised in Figure 6 as the choices to alter or keep their existing departure time choices for responses to all scenario options are included.

Figure 6 illustrates that respondents have a greater propensity to change their AM departure time when compared to the PM departure time decision. Sydney residents are more likely to depart earlier or later during the AM peak but in both locations the Depart Later option is preferred only slightly more than the Depart Earlier. For both the AM and PM peak period, the most popular option is to Depart Same Time. In both cases approximately 35% of respondents chose to change their departure timing decision. Further data analysis is contained within the model development in future sections where the SP data source is utilised as a calibration database for the departure time change model.

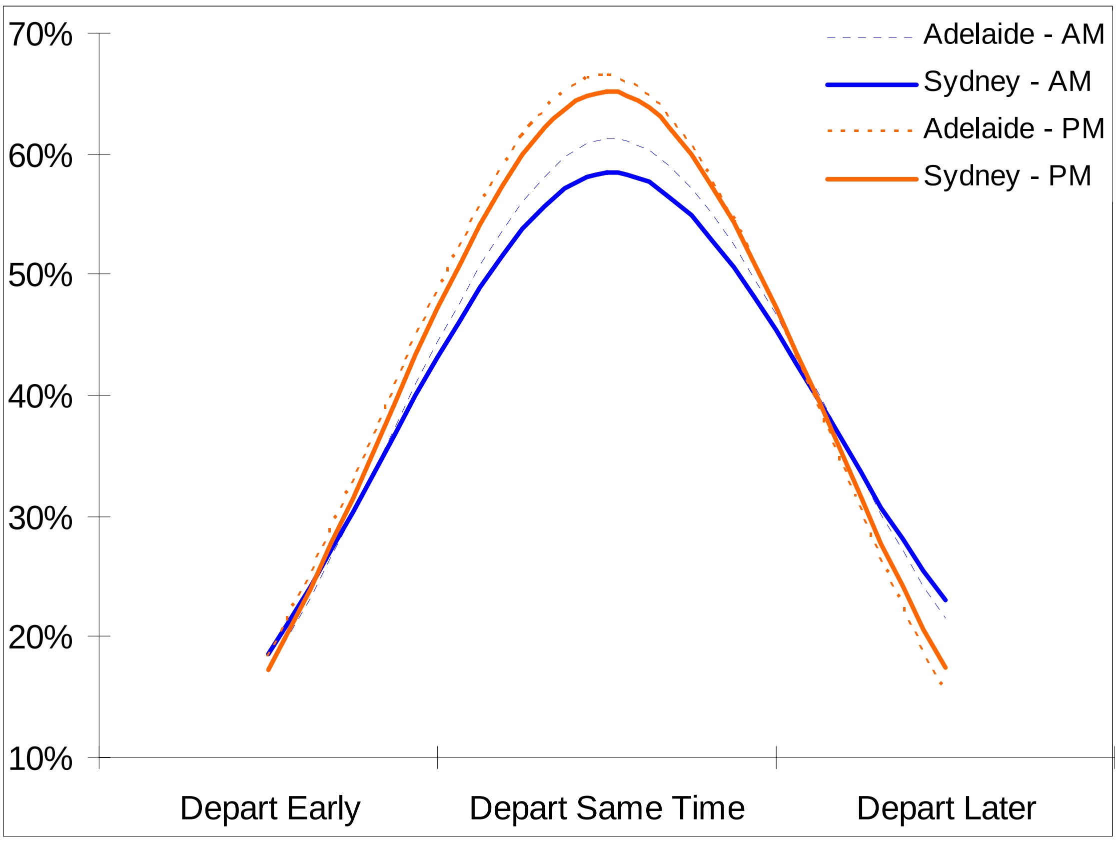


Figure 6 – Departure time change responses for Adelaide and Sydney respondents.

4 Development of Model Stage 2

As previously stated, the aim of this model stage is to present a travel time saving to the commuter and to then estimate the number of trips that will depart earlier or later based on that saving. The modeller is allowed to define the time periods for departing earlier or departing later. Running a variety of scenarios will lead to determinations concerning degrees of peak spreading that are possible. An example of this may be discovering how many trips will depart 5 minutes earlier and how many will depart 10 minutes earlier if a 5% travel time saving is presented to the commuter.

Survey responses used in the calibration datasets are summarised in Table 4 as separate calibrations are desired for each location and time period.

Table 4 – Stated preference scenario inclusions for calibration

	Respondent Location	
Peak Hour Period	*Sydney*	*Adelaide*
7:00 a.m. to 7:59 a.m.	840	1476
8:00 a.m. to 8:59 a.m.	744	1596
3:00 p.m. to 3:59 p.m.	144	120
4:00 p.m. to 4:59 p.m.	576	348
5:00 p.m. to 5:59 p.m.	912	2268

In general, a good number of responses were achieved for both locations with a greater overall number from the Adelaide metropolitan area. In comparison to the other time periods however, the earlier PM period of 3:00pm to 3:59pm does have a relatively smaller calibration dataset. Variables available and appropriate for inclusion in the model include the following:

- Departure time change
- Travel time change
- Journey travel time
- Household children
- Household residents
- Household full time workers
- Household cars
- Personal income.

The form of the multinomial logit model applied to the departure time change model to determine the probability *P* of an individual *q* selecting choice *i* from *j* alternatives is as follows:

$$P_{iq} = \frac{e^{U_{iq}}}{\sum_{j=1}^{J} e^{U_{jq}}} \tag{1}$$

Each choice alternative is represented in the model by a utility function (*U*) which may be summarised as:

$$U = C + a_1 X_1 + a_2 X_2 + ... + a_n X_n \qquad (2)$$

where C represents an alternative specific constant,
a_1 to a_n are the coefficients to be estimated (as summarised in Table 6) and
X_1 to X_n represent the attributes of the individual or the alternative.

The 7:00 a.m. to 7:59 a.m. calibration for Sydney peak period travel is selected for further analysis in the following discussion with similar estimation procedures conducted for all other datasets. Table 5 summarises the results of this process.

Table 5 – Summary of calibration results

Calibration result	*Value*
Number of observations	840
Bad observations skipped	0
Estimation iterations completed	7
Number of parameters	13
Log Likelihood	-376.4
Pseudo R^2	0.345

Table 6 shows that the estimation procedure converged quickly after 7 iterations to estimate 13 parameters. A respectable pseudo R^2 value was also achieved in the estimation assuring a good level of confidence in the result. The selected utility function variables and estimates are displayed in the following table.

Table 6 – Summary of parameter estimation.

Alternative	*Variable*	*Coefficient estimate*	*p-value*
Depart earlier	Constant	7.209	0.000
	Travel time change	-15.850	0.000
	Departure time change	-0.021	0.354
	Travel time	0.019	0.002
	Household children	0.130	0.448
	Household full time workers	-0.024	0.890
Depart same time	Travel time change	-3.860	0.006
Depart Later	Constant	10.141	0.000
	Travel time change	-17.578	0.000
	Departure time change	-0.084	0.000
	Travel time	0.031	0.000
	Household children	0.072	0.631
	Household full time workers	-0.653	0.000

During this process, parameters are trialled with selection based on parameter significance and econometric assessment. The probability value shown, as P[Z>z] (or simply the reported *p-value*) is the value for a two tailed test of the hypothesis that the coefficient equals zero. Therefore the closer this value is to zero, the higher the statistical significance of the parameter. Variables listed in Table 6 are all included in utility functions for each alternative.

Significant coefficients from the estimation appear to result for the alternative specific constants, travel time change and travel time variables. The departure time change is also significant, however this is less so in the Depart Earlier result. A negative sign is achieved for the travel time change and departure time change coefficients indicating that increase in either will cause a greater disutility and hence less attractiveness which would be an expected result. Household attributes were less significant although the *p-value* resulting for the number of full time workers indicates that it is influential on the decision to depart later. In all cases, the constant is highly significant, indicating that this parameter could represent the influence of attributes that have not been represented such as household interactions.

5 Scenario Testing

To demonstrate the ability of the calibrated Sydney 7:00 a.m. to 7:59 a.m. peak hour departure time change model, a test scenario is applied to real life data from the data source. A random set of 5 household cases are selected, each with varying travel to work times during the 7:00 a.m. to 8:00 a.m. time window and household attributes (Table 7).

Table 7 – Attributes of test case households

Household	*Travel to work Time (minutes)*	*Residents*	*Children*	*Full Time Workers*	*Cars*
Case 1	18	2	0	2	2
Case 2	52	4	0	3	2
Case 3	56	2	0	2	1
Case 4	28	6	4	1	2
Case 5	15	6	4	1	2

All household cases are presented with a travel time saving of 5% if they chose to depart earlier with various early departure time changes presented ranging from 1 minute to 30 minutes earlier. The results of the scenario analysis are presented graphically in Figure 7.

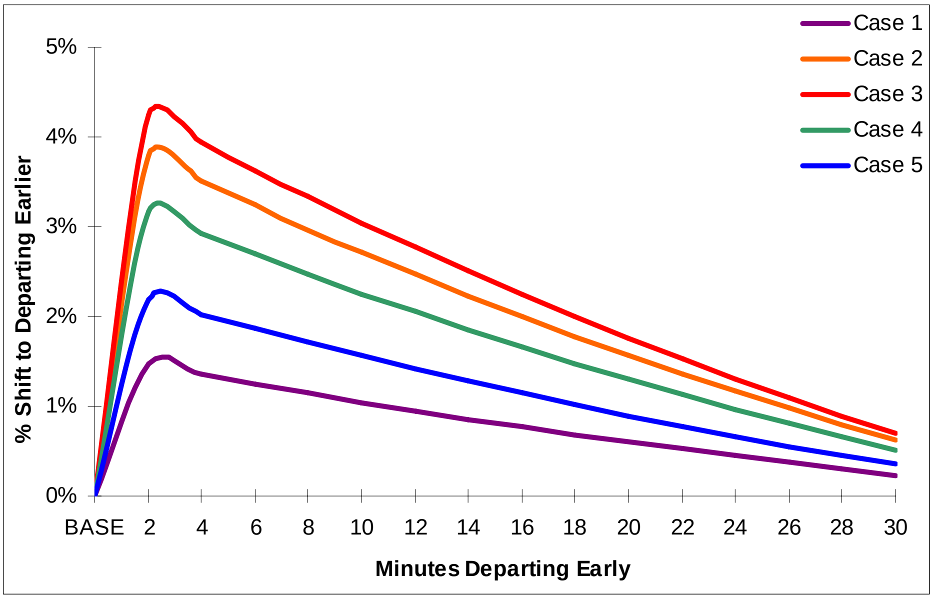


Figure 7 – Percentage of trips shifting to depart early alternatives as a result of a 5% travel time saving.

From Figure 7, all households display a similar trend in their choice behaviour. All cases begin with zero change at the BASE case where no incentive is offered. The departure shift is at its greatest when the traveller only has to depart a few minutes earlier to achieve the 5% saving. As the departing earlier time gets longer, the proportion of travellers choosing to depart early drops off.

The 5% travel time saving is most beneficial to households with a greater overall travel time to work, which results in a more attractive offer. This is noted in household case 3 which has the longest travel time also the largest departure time shift. Cases 1 and 5 have very similar travel times however have quite different household attributes which may contribute to a difference in the departure timing shifts.

Other policy scenarios may develop a more detailed approach, aiming to apply a flat 5 minute saving to all households (i.e. a range of percentage travel time savings appropriate to the overall travel to work time) and this may yield greater variation in the modelling results.

6 Conclusions

This research has presented a model with capabilities in the representation of changes to the traveller's departure time choice. Calibration and validation processes are achieved from internet-based survey results for commuters travelling during the AM and PM peak periods by car. The model has demonstrated abilities for the testing of peak spreading policy scenarios with applications definitely not limited to the discussed scenario. Although the traveller survey and the subsequent model do not include a financial cost component, this may be a direction for future research. Value of travel time saving estimates may be utilised in representing the impact of financial incentives however this would require validation.

Further research may include a refined definition of the "flexible" trip type, calibrations to suit alternative trip purposes and incorporation into wider modelling frameworks to allow for traffic assignment and information feedback mechanisms.

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