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Demand Forecasting for Toll Roads: An Approach to More Accurately Forecasting Traffic Volumes

Tim Veitch[1], Aaron Alaimo[2], Lauren Walker[3]

[1]Veitch Lister Consulting, Brisbane.

[2] Veitch Lister Consulting, Melbourne.

[3] Veitch Lister Consulting, Melbourne.

Email for correspondence: tim.veitch@veitchlister.com.au

Abstract

Over the past decade, tolling has become a popular way to fund the construction and maintenance of greenfield road infrastructure projects. In recent years a number of high profile Australian toll roads have come under financial distress, with traffic volumes falling well short of official demand forecasts.

As a result of these failures, the reputation of demand forecasters and their tools have come under heavy criticism, leading us to question whether travel demand forecasting tools are capable of accurately predicting toll roads, or whether further developments in demand forecasting methodologies or data collection are required.

In this paper, previously unpublished forecasts made by the Zenith Toll Choice model for a number of recent toll roads are documented. These forecasts have proved to be encouragingly accurate, suggesting that the science of demand forecasting is in better shape than would be indicated by a survey of official demand forecasts.

The paper also describes in detail the innovative methods used by the Zenith Toll Choice model, including the automatic generation of tolled alternatives, explicit modelling of the choice between tolled alternatives, detailed travel market segmentation, and explicit treatment of toll caps and other pricing mechanisms.

1. Introduction

A number of Australian and international studies have reviewed the traffic forecasting performance of toll roads, concentrating on the forecasts provided by the successful bidder for each project. Bain (2009) identifies a lack of accuracy in toll road traffic and revenue forecasts to be a major issue in the financial viability of any proposed toll road. A BITRE (2011) study states that “Traffic forecasts for Australian toll roads have proven to be highly inaccurate in recent years.” The media are also becoming cynical about the accuracy of toll road traffic forecasts, with Australian newspapers regularly coming up with headlines like “Toll-road forecasters’ flights of fancy”[1] and “Toll roads and tunnels woes are down to the count”[2].

Not all toll road traffic forecasts undertaken in recent years, however, have proven unreliable. As early as 2003, the Southern and Eastern Integrated Transport Authority (SEITA), the authority responsible for the planning and procurement of the EastLink toll road in Melbourne, conducted a large toll road usage survey to assist in the development of the Zenith Toll Choice model parameters. The resulting parameters underpinned the forecasts for EastLink, which later proved to be very accurate.

[1] The Age (2013), “Toll-road forecasters’ flights of fancy”, The Age, 21 February 2013
[2] Courier Mail (2012), “Toll roads and tunnels woes are down to the count”, Courier Mail 19 November 2012

This paper describes the methodology adopted in the development of the Zenith Toll Choice model, and its application to the EastLink toll road, with a view to demonstrate how accurate demand forecasting for toll roads can be accomplished. It also presents traffic forecasts made for toll roads in other Australian cities using the Zenith Toll Choice model, and compares them with observed traffic volumes after their opening.

2. Data and Methods

2.1 Data Sources

The development of the toll diversion model utilised a number of data sources to estimate, calibrate and validate the Zenith Toll Choice model.

These data sources included:

- CityLink Usage Surveys – in late 2003, a mixed revealed and stated preference survey was conducted on behalf of the SEITA. The surveys were used to develop the Zenith Toll Choice model parameters which underpinned the forecasts for EastLink. The model parameters have evolved since that time based on more recent information, but the structure remains the same
- Traffic counts – VicRoads provided access to traffic counts for the validation of the Zenith Toll Choice model, including various locations on both CityLink and EastLink

2.2 Data Collection

The estimation of the route choice model was performed using the 2003 CityLink Usage Survey dataset. The primary aim of this work was to develop a model capable of estimating the likely usage of toll roads given varying levels of travel time saving and toll.

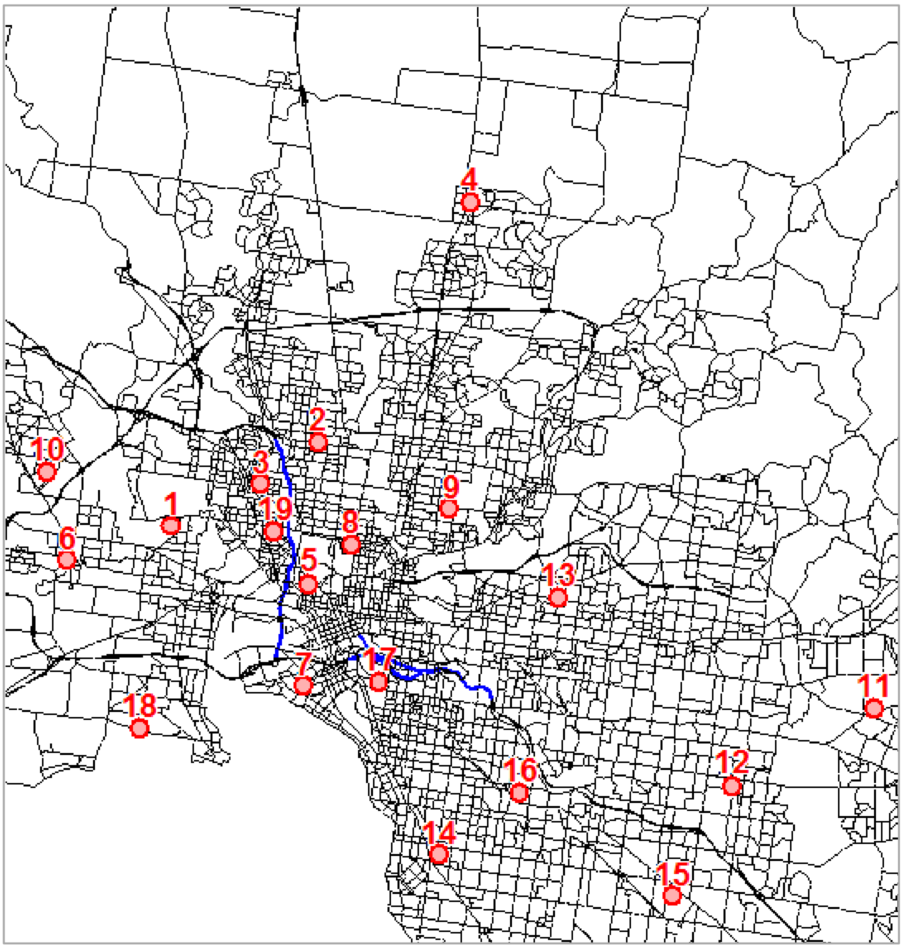
The CityLink Usage Survey was conducted on behalf of SEITA. While the EastLink toll road was not fully operational until 2008, the surveys were collected to support traffic forecasting for EastLink.

The survey collected data relating to both revealed and stated preferences. This led to the development of three separate models: one based on revealed preference, one based on stated preference, and one based on the combined dataset. The revealed preference only dataset proved to be most reliable and formed the basis of the adopted model.

The survey used a cluster sampling technique, with 1,030 individuals surveyed in 19 clusters. The survey clusters are shown in Figure 1, with the CityLink toll road shown in blue. The survey locations were deliberately chosen to maximise the diversity of survey data collected so that results would reflect the possible range of travel time savings achieved, toll levels paid and trip lengths made using the toll road.

The survey was an “individual” survey rather than a “household” survey. While multiple members of the same household could be interviewed, this was not compulsory. All participants were required to have a valid driver’s licence and access to a car.

Figure 1 - CityLink Usage Survey Cluster Locations



The survey consisted of three parts, which are shown in Table 1.

Table 1 - CityLink Usage Survey Structure

Green Form – Demographic information	Blue Form – Recent actual "cross town" trip details	Red Form – Hypothetical "cross town" trip details for pre-defined destinations
-Occupational status -Access to a company car -Place of work	-Origin/destination -Trip purpose -Departure time -Route taken (including toll road entry/exit if toll road was used) -Vehicle type -Personal payment of toll? -Trip duration -Estimation time saving (if toll road was used) -E-Tag account holding	-Whether the respondent would consider driving or taking a taxi to the defined destination -Estimated journey time -Likely route taken (including toll road entry / exit locations if the respondent would use a toll road -Whether the respondent would be required to personally pay the toll -Estimated time saving (if the respondent said they would use a toll road)

The survey was deliberate in requesting details of “cross town” journeys, to maximise the likelihood that CityLink would be considered as an alternative. For interviews conducted in southern and eastern Melbourne, this meant asking about journeys made to the inner city, as well as the northern and western suburbs, and vice versa for residents of northern and western suburbs. This led to two slightly different versions of the survey form. The survey for Melbourne’s southern and eastern suburbs is referred to in this paper as “south”, while the survey for the northern and western suburbs is referred to as “north”.

The survey also included a mix of revealed and stated preference data. The revealed preference data, collected in the Blue Form, asked about the route taken as part of actual journeys. The stated preference data, collected in the Red Form, asked about the interviewee’s likely route for cross town journeys to a series of well-known locations. Statistics relating to the survey sample are presented in Table 2.

Table 2 - CityLink Usage Survey Summary Statistics

	Blue Form (actual journeys, revealed preference)	Red Form (hypothetical journeys, stated preference)
Count of “all trip records”	2,672	2,306
Count of “usable trip records”	1,527	1,428
Trip records where CityLink was used	488	438

The distinction is drawn between “all trip records” and “usable trip records”. “Usable” in this context refers to trip records where the respondent was faced with a legitimate choice between tolled and untolled routes. For this to be the case, the toll road (CityLink) had to provide a time saving compared with the untolled route. In the remaining “unusable” trip records, the untolled route was fastest (and of course cheapest). These records were not used in the estimation of model parameters.

3. Analysis

3.1 Travel Market Segmentation

As part of the analysis, the data was segmented in numerous ways. Of these, the following three-way segmentation was found to be most useful in predicting the likelihood of the usage of a tolled route:

- Airport Travel by car
- Company Car (for non-airport travel)
- Non-Company Car (for non-airport travel)

Figure 2 - Breakdown of the Survey Dataset by Segment

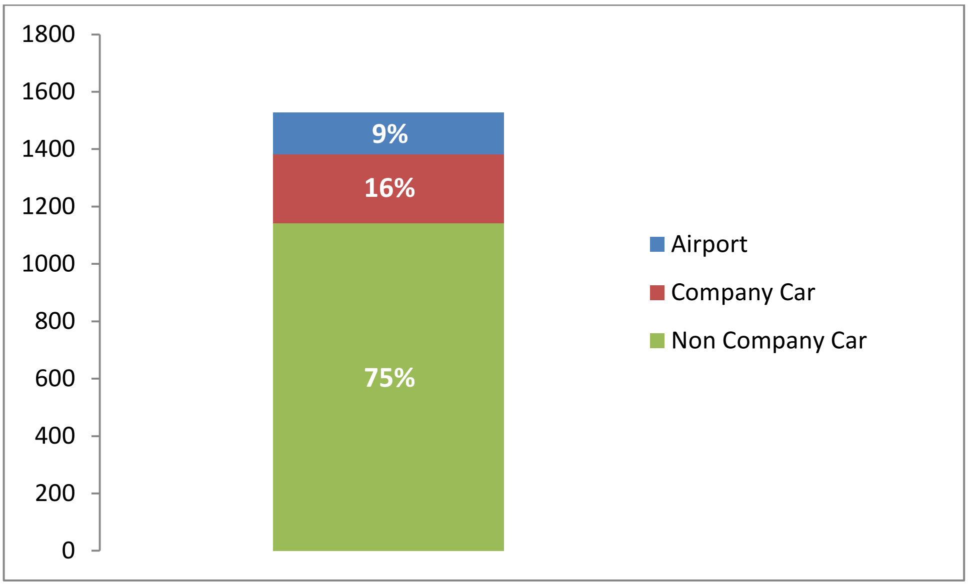


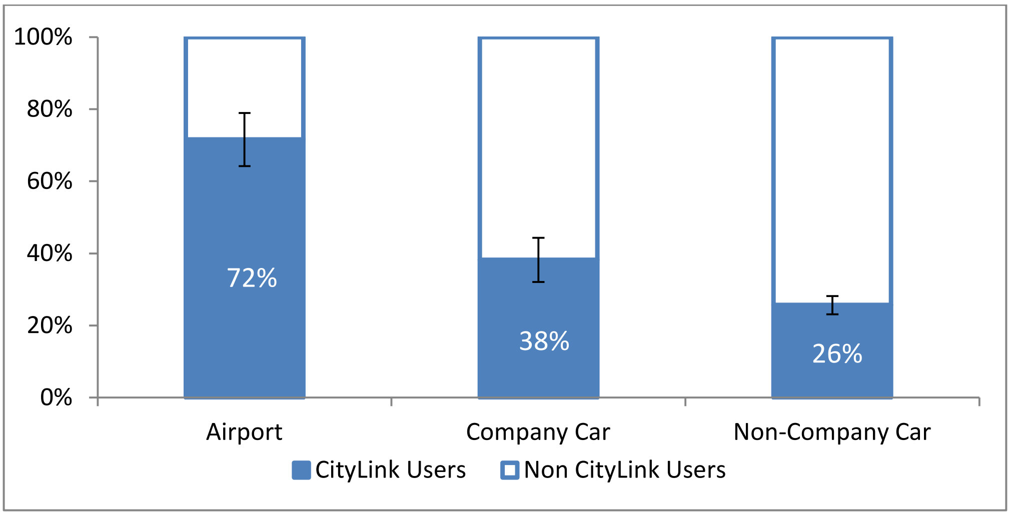
Figure 2 shows that of the 1,527 usable trip records in the revealed preference dataset, 9 per cent were made to / from the airport, 16 per cent were made in a company car, and the remaining 75 per cent were made in a non-company car.

These proportions do not necessarily reflect the breakdown of trips in the real world. The survey was deliberately constrained to collect cross town travel only, resulting in a disproportionately large number of airport trips in the sample. This does not, however, bias the estimated model parameters, given that each segment was estimated separately.

The importance of this segmentation is illustrated in Figure 3 below, which shows the relative proportions of tolled and untolled users for each segment. Of the 144 surveyed airport trips, 72 per cent reported using a toll road. For trips made in company cars and non-company cars, the proportion of toll road users dropped to 38 per cent and 26 per cent respectively. Recognising that these proportions are based on a sample survey, 95 per cent confidence intervals have been calculated, from which it can be statistically asserted (with >95 per cent confidence) that the proportion of airport trips which make use of CityLink is higher than for other trips. It can also be asserted that the proportion of company car trips which make use of CityLink is higher than for non-company car trips.

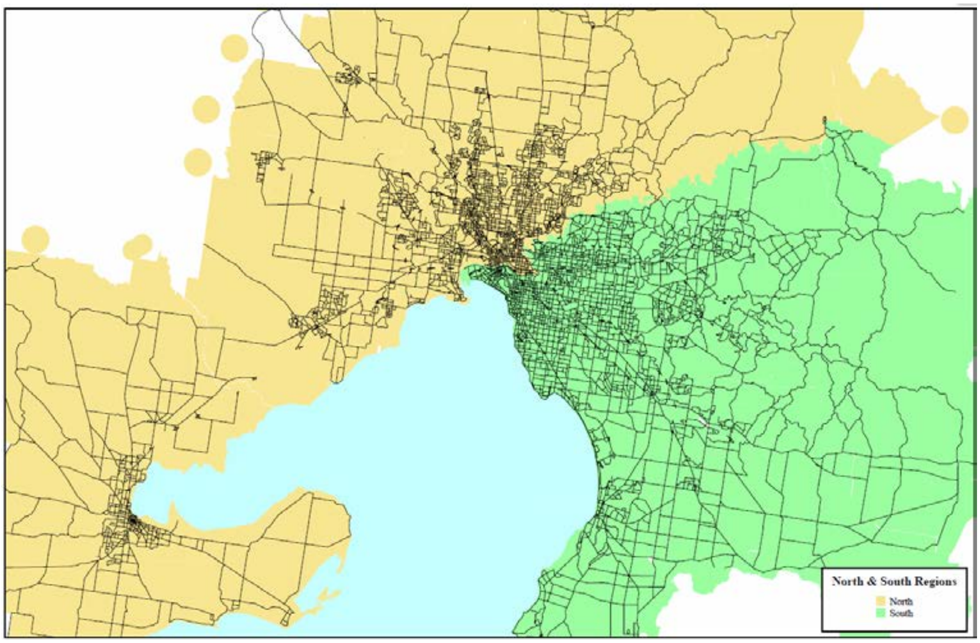
These findings are intuitive; it is understandable that airport trips would favour toll roads given the higher value of time associated with these trips, and the importance of arriving on-time. It is also logical that trips made in a company car would be more likely to use a toll road, given that the toll costs incurred by company cars are often paid for by the company rather than by the individual.

Figure 3 – Breakdown of CityLink and Non-CityLink Users for each Segment



During the model development phase, differences in behaviour between participants in the south and north surveys were observed. These differences could not be explained in terms of the variables included in the survey, and the three-way segmentation was further segmented into two spatial segments, which are shown in Figure 4 below.

Figure 4 - Spatial Segments - North / South



Potential explanations for this difference in behaviour include:

- Higher incomes, on average, in the southern and eastern suburbs
- Attitudes toward paying for toll roads – the development of CityLink involved a mix of new infrastructure, and the upgrading and tolling of some existing infrastructure. For those in the northern and western suburbs, a large amount of existing infrastructure

became tolled (the Tullamarine Freeway, for example) and it is speculated that this may have resulted in some level of “protest” at being charged for a previously free road

While effective in explaining the usage of CityLink, the use of spatial segmentation is not particularly elegant, and in the future, it would be preferable if spatial segmentation could be replaced by the inclusion of other explanatory variables such as income.

As a result of this spatial segmentation, the toll choice model was developed for five segments:

- Airport travel by car
- Non-Company Car North
- Non-Company Car South
- Company Car North
- Company Car South

The implementation of this segmentation is relatively straight forward:

- All trips are spatially segmented (north / south) based on their “production” end. In the case of home based trips, the home location determines the spatial segment.
- The airport market only includes passengers and “meeters and greeters” – it does not include those travelling to the airport for other activities (such as those who are employed at the airport),
- Car driver trips are disaggregated into company car and non-company car using simple proportions by trip purpose, which were derived using data from the South East Queensland Travel Survey (SEQTS) 2003/04. The company car proportions are listed in Table 3.

Table 3 - Proportion of Trips made by Company Car per Trip Purpose

Trip Purpose	Proportion Company Car	Source
Home Based Work	15.7%	Household Travel Surveys
Home Based Education – Secondary	0.0%	Household Travel Surveys
Home Based Education - Tertiary	3.4%	Household Travel Surveys
Home Based Shopping	6.8%	Household Travel Surveys
Home Based Recreation	8.6%	Household Travel Surveys
Home Based Other	7.8%	Household Travel Surveys
Work Based Work	43.7%	Household Travel Surveys
Work Based Shopping	19.6%	Household Travel Surveys
Work Based Other	15.1%	Household Travel Surveys
Shopping Based Shopping	5.1%	Household Travel Surveys
Shopping Based Other	6.5%	Household Travel Surveys
Other Non-Home Based	7.4%	Household Travel Surveys
Visitor Home Based Shopping	6.8%	VLC Estimate
Visitor Home Based Recreation	8.6%	VLC Estimate
Visitor Home Based Other	7.8%	VLC Estimate
Visitor Non-Home Based	7.4%	VLC Estimate
Special Recreation Based Home	8.6%	VLC Estimate
Special Recreation Based Visitor Accommodation	7.4%	VLC Estimate
External Trips	10.0%	VLC Estimate

Work based work (business) trips have the highest proportion of company cars (43.7 per cent), with education trips having the lowest (0.0 per cent for secondary school, and 3.4 per cent for tertiary). 15.7 per cent of home based work trips use a company car, compared with 6.8 per cent for home based shopping and 8.6 per cent for home based recreation.

3.2. Initial Parameter Estimation and Goodness of Fit

The Zenith Toll Choice model includes two utility functions: one which applies to the "upper level" binary choice between tolled and untolled routes, and another which applies to the "lower level" choice between alternative tolled routes.

The utility functions are:

Upper Level – Toll vs. No Toll: $V_r = \beta^U_{time} \times time_r + \beta^U_{toll} \times toll_r$
Lower Level – Tolled route vs. Tolled route: $V_r = \beta^L_{time} \times time_r + \beta^L_{toll} \times toll_r$

Where:
V_r is the estimated mean utility of route r
$time_r$ is the travel time for route r (in minutes)
$toll_r$ is the toll payable (in cents) for route r (in the case of an untolled route, this is zero)
β^U_{time}, β^U_{toll}, β^L_{time}, β^L_{toll} are model parameters

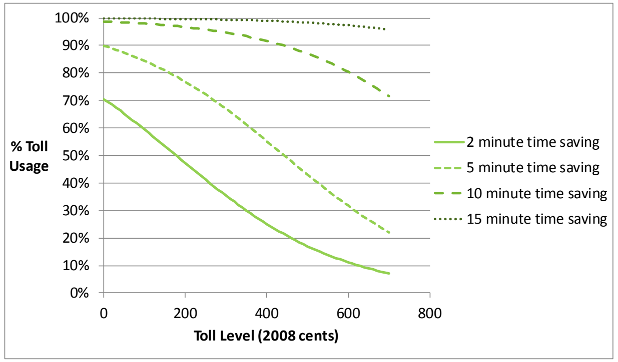
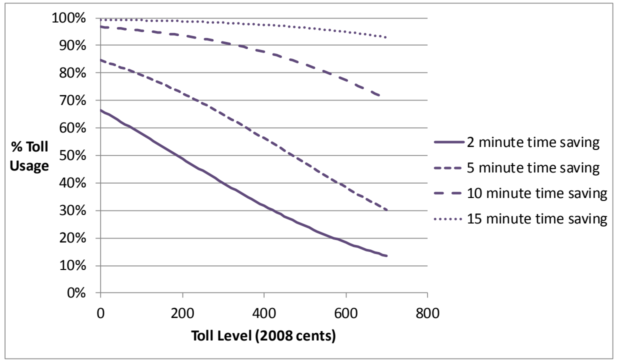
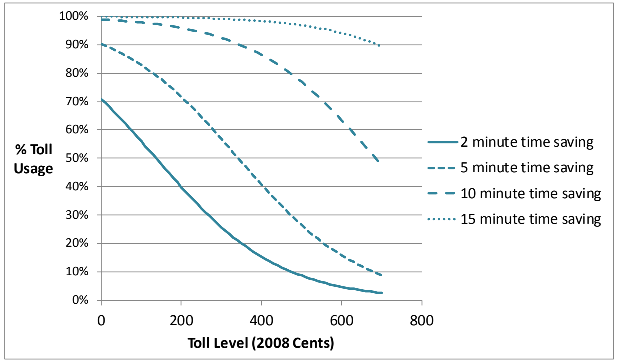
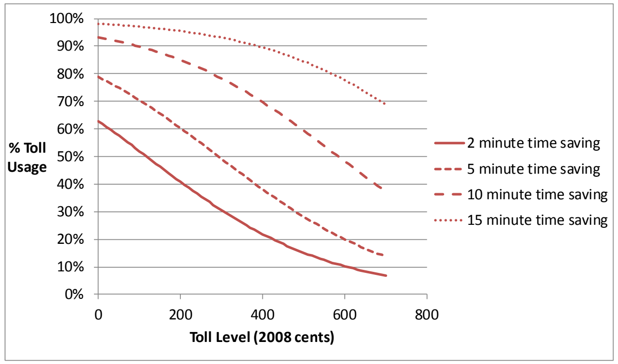
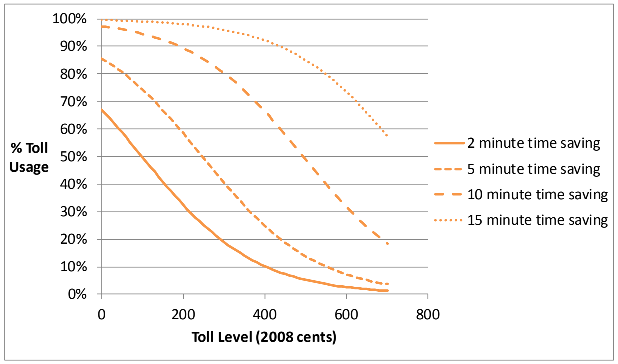
Both functions are linear in travel time and toll, and neither includes an alternative specific constant. The only difference between the functions is the value taken by the model parameters (the βs).

3.2.1. Parameter Estimation

During the initial parameter estimation process, the main area of focus was deliberately directed toward the estimation of the upper level parameters, with the lower level parameters set equal to the upper level parameters (this was the only technically feasible option, given limitations in the toll choice model software at the time).

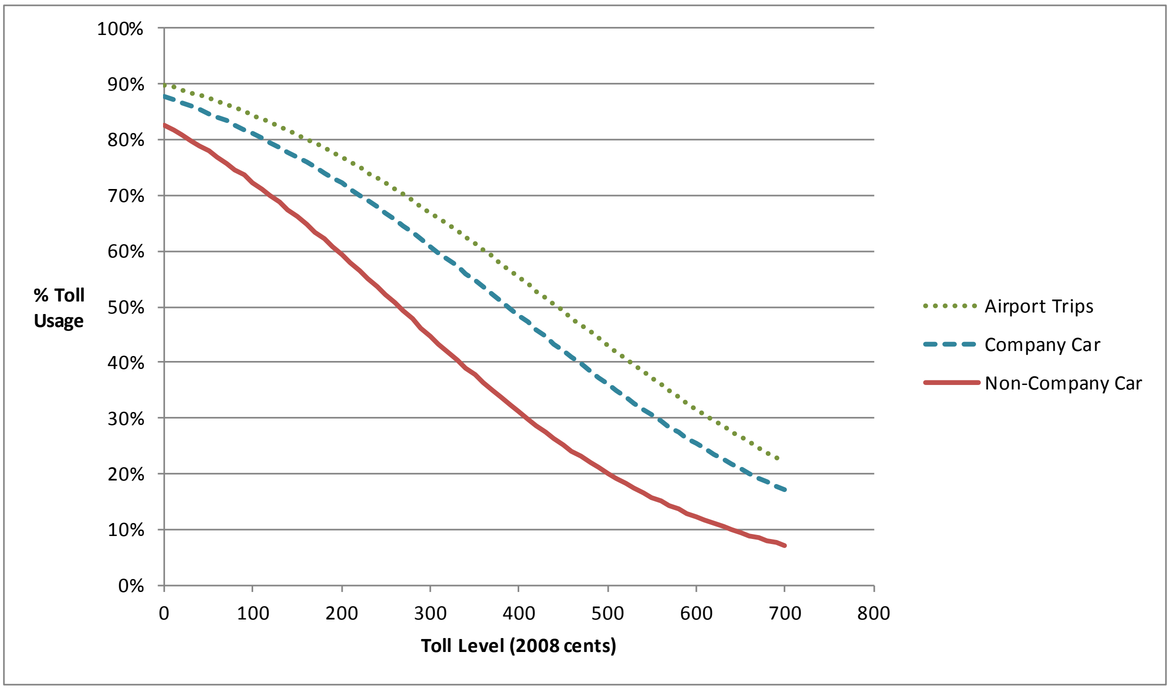
Toll usage curves, depicting the probability of toll road usage at varying levels of travel time saving and toll are presented in Table 4. As expected, toll usage increases with increasing travel time saving, and decreases at higher toll levels.

Table 4 - Toll Usage Curves by Segment

<table>
<tr><th></th><th>North</th><th>South</th></tr>
<tr><td>Airport by car</td><td colspan="2">
</td></tr>
<tr><td>Company Car</td><td>
</td><td>
</td></tr>
<tr><td>Non-Company Car</td><td>
</td><td>
</td></tr>
</table>

The relative likelihood of toll usage between market segments is more clearly illustrated in Figure 5 below, which shows toll usage at varying toll levels (and a fixed time saving of five minutes). For any given time saving and toll, airport trips by car are most likely to pay tolls, followed by company cars and then non-company cars.

Figure 5 - Toll Usage by Airport, Company Car and Non-Company Car for a 5 minute time saving



3.2.2. Goodness of Fit

The resulting models were applied to the surveyed respondents to assess "goodness of fit". Note that the entire dataset was used for both training and testing (i.e. no form of cross validation was used) and may lead to an optimistic assessment of predictive accuracy.

Observed and modelled toll usage was compared for a range of travel time savings. Figure 6 to Figure 10 present the analysis for each market segment. Results shown in blue indicate that the observed toll usage exceeds the modelled toll usage, and orange indicates that modelled toll usage exceeds observed. The data has been grouped into ranges of travel time saving, with ranges deliberately varied between segments to ensure an adequate survey sample in each band.

It can be seen that travel time savings and toll usage generally increase together. This is despite the positive correlations which may exist in the data between time savings and the toll level. Given the uncertainty associated with the observed sample estimates (indicated by the 95 per cent confidence intervals), the model and observed data appear to be satisfactorily correlated. The one apparently systematic area of difference is for high time savings (in excess of 10 minutes), where the model appears to over-estimate toll usage.

Figure 6 - Non-company Car South - Observed and Modelled Toll Usage by Travel Time Saving

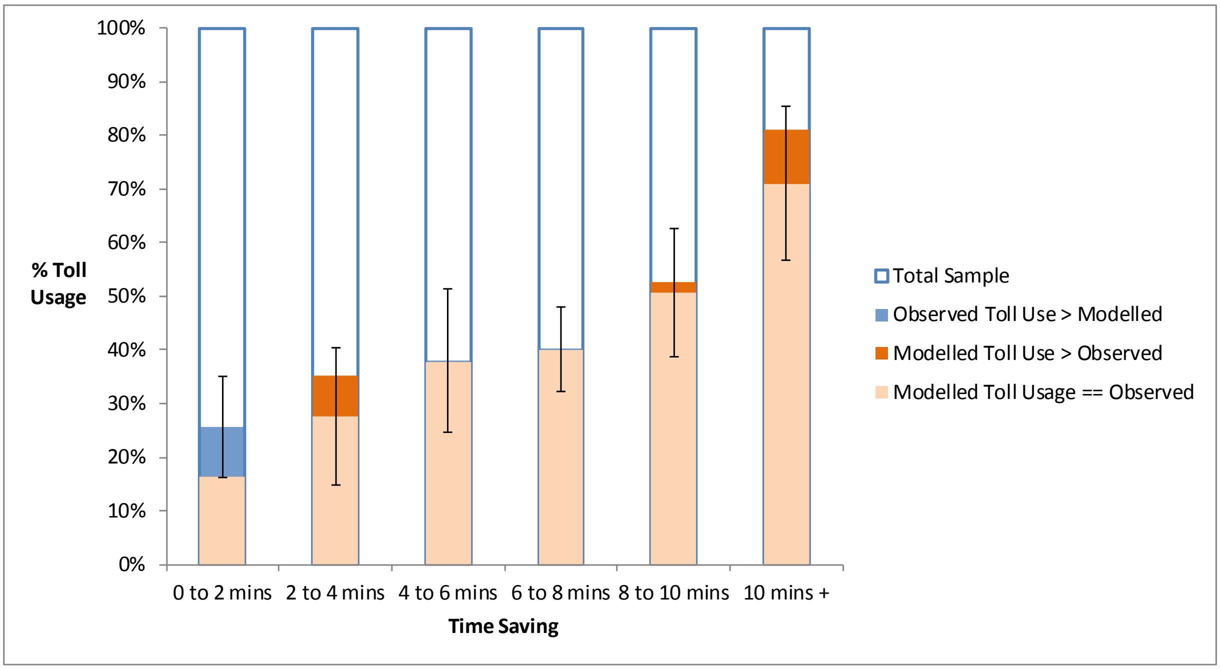


Figure 7 - Non-company Car North - Observed and Modelled Toll Usage by Travel Time Saving

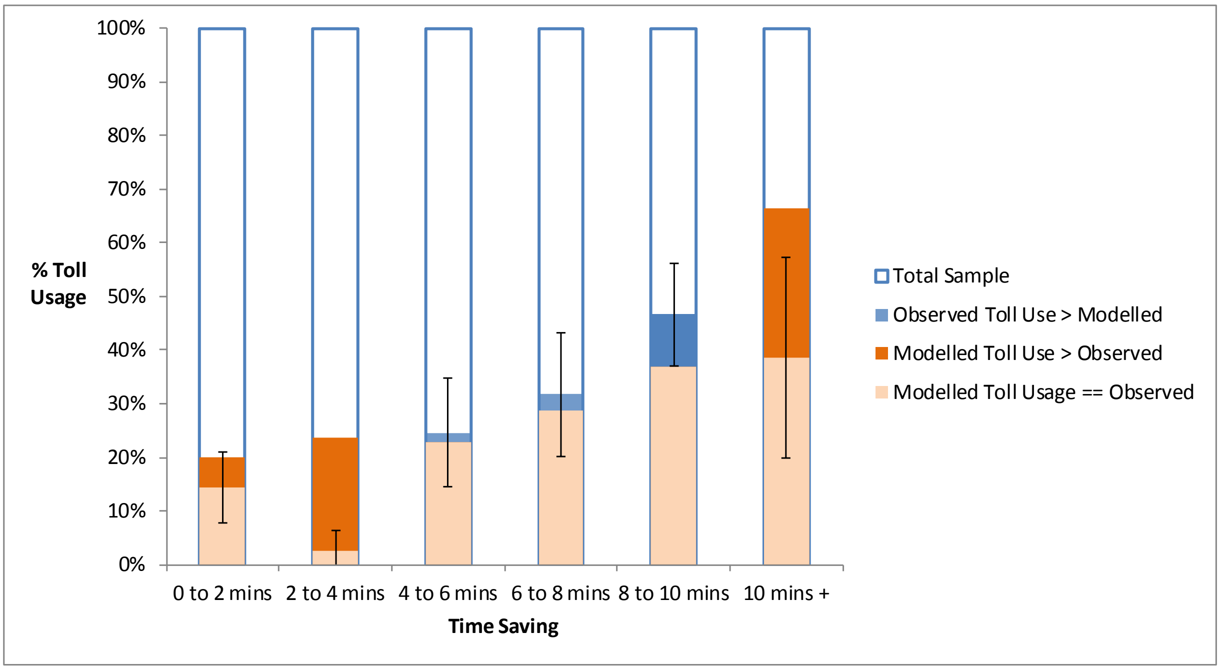


Figure 8 - Company Car South - Observed and Modelled Toll Usage by Travel Time Saving

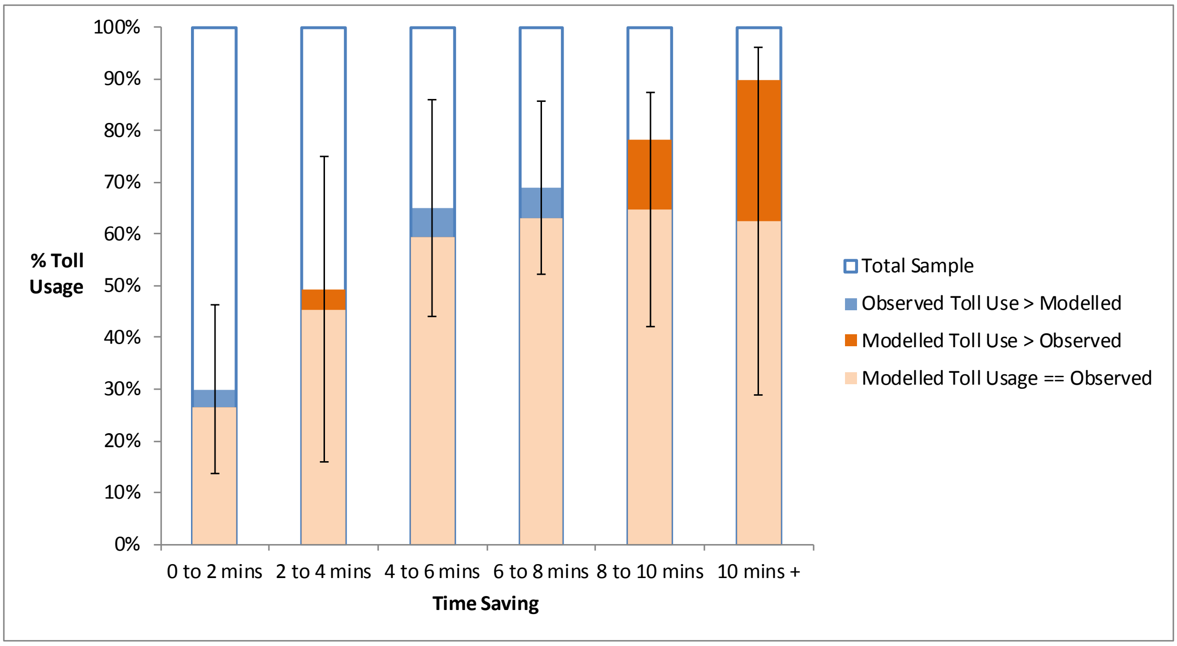


Figure 9 - Company Car North - Observed and Modelled Toll Usage by Travel Time Saving

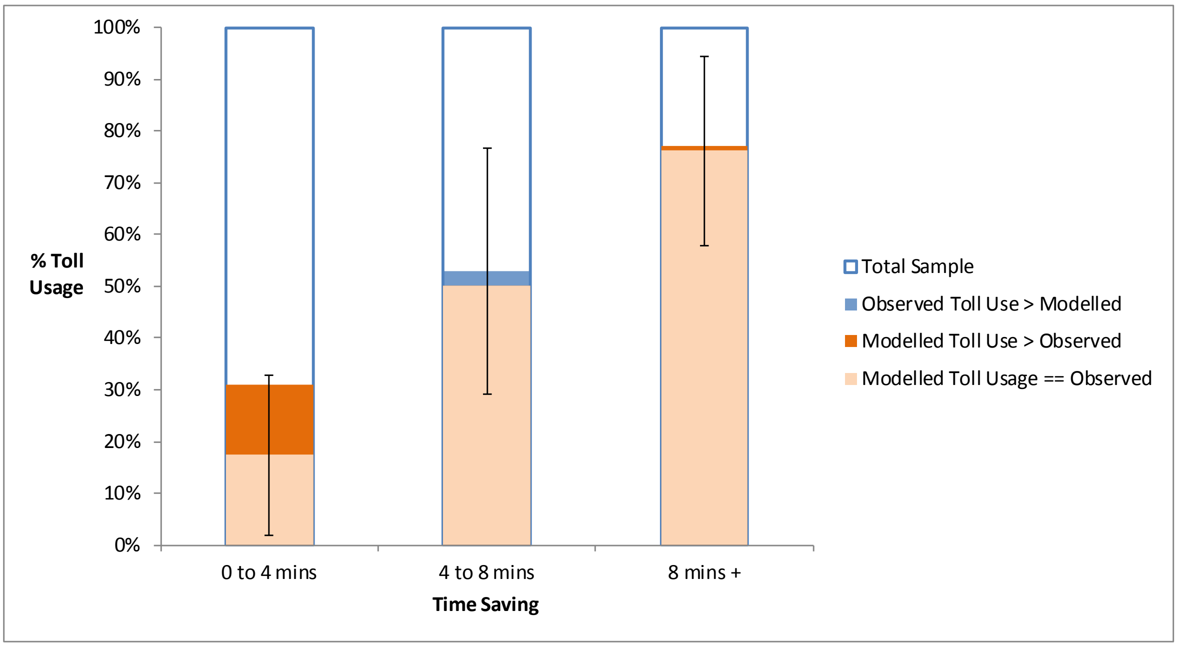
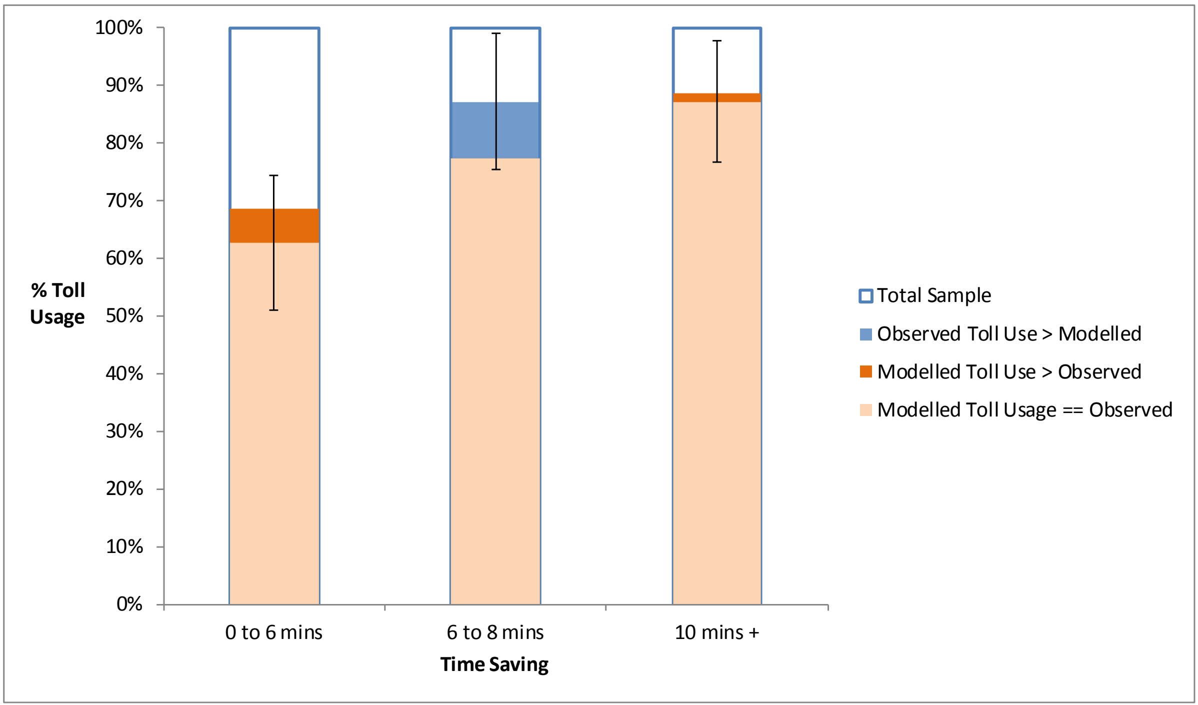


Figure 10 – Airport by Car - Observed and Modelled Toll Usage by Travel Time Saving



3.3. Lower Level Parameters

The "lower level" parameters are responsible for the allocation of demand to the set of tolled alternatives (the "upper level" parameters control the split of tolled and untolled users). Originally, when the model was first developed, there was no differentiation between lower and upper level parameters – the same parameters were used at both levels. Over time it became apparent that the model was under-estimating the allocation of demand to more expensive tolled links, which would attract higher value of time users.

This led us to decrease the toll parameter at the lower level (β^L_{toll}). After some experimentation across models in three markets (Melbourne, Brisbane and Sydney), the value of β^L_{toll} was set to half of β^U_{toll}.

This adjustment also has some intuitive justification. The original upper level parameters were estimated based on the full sample of tolled and non-tolled users in the CityLink Usage Survey. However, the lower level parameters are applied to tolled users only. Tolled users are not representative of the full population – they are, by definition, those people who are prepared to pay tolls! - and it is intuitive that they would be less sensitive to tolls than the rest of the population.

3.4. Commercial Vehicles

The 2003 CityLink Usage Survey did not collect any data relating to commercial vehicles. As such, the model parameters for light commercial vehicles and heavy commercial vehicles have been estimated based on empirical evidence (such as traffic counts), as well as supporting evidence derived from an Ernst and Young report for VicRoads examining the elasticities of heavy commercial vehicles to toll levels (dated October 2009).

3.5. Recent Parameter Calibration

The validation of the toll model was recently updated to reflect the latest available count information. In so doing, it became evident that the model was systematically under-estimating toll usage using the original model parameters, and that they were in need of updating.

The final outcome was a 40 per cent reduction in the toll parameters (β_{toll}^{U} **and** β_{toll}^{L}**).** This could be a result of:

- Increases in toll road acceptance or Value of Travel Time Saving (VTTS) of toll roads over time. This may relate to increases in real earnings, greater proliferation of e-Tags, or a general acceptance of tolls
- Induced destination switching – growth in traffic may also be a result of changes in travel patterns gradually induced by the toll roads. For example, projects such as CityLink and EastLink will affect major life-changing decisions such as the choice of home or work location. These decisions play out over an extended period of time. At the margin, those who alter their home / work location or other travel patterns as a result of toll roads will more naturally be toll road users, while a person who refuses to pay tolls is unlikely to change their travel patterns as a result of a new toll road
- Model misspecification – it is possible that one or more of the model's limitations are being compensated for by biased parameter estimates. As the effect of these limitations evolves over time, the model's parameters would require modification

The need for such a significant change in model parameters does lead us to question the temporal stability of the model's toll choice parameters, and the forecasting capability of the model in relation to toll roads. However, it is worth also noting that Melbourne was still relatively new to toll roads when the original CityLink Toll Usage surveys were conducted. The first sections of CityLink opened in 1999 and it was fully operational by the end of 2000. It is to be expected that Melburnians would gradually become accustomed to tolls, increasing their likelihood of toll usage. The question is, has toll road travel behaviour in Melbourne reached a stable state, or is it still in the midst of transition?

3.6. Convergence

Zenith Toll Choice model convergence was measured by a number of statistics, including the relative changes of link costs between consecutive iterations (RGAP) as the Zenith static traffic assignment uses it as its main indicator for traffic and public transport assignment convergence. The RGAP values of the last iteration for each time period are listed in Table 5.

Table 5 - Zenith Toll Choice model Convergence Details

Model Time Period	RGAP Target	Zenith Toll Choice model RGAP (Final Iteration)	Target Achieved
AM Peak (7am to 9am)	<0.01	0.00947	Yes
Interpeak (9am to 4pm)	<0.01	0.00174	Yes
PM Peak (4pm to 6pm)	<0.01	0.00814	Yes
Evening off-peak (6pm to 7am)	<0.01	0.00321	Yes

All RGAP values were less than 0.01 and therefore met VicRoads (2012) traffic assignment targets on RGAP.

4. Applications

4.1 Validation to Traffic Counts on Melbourne Toll roads

The model parameters have been revised to reflect updated traffic counts. A comparison of modelled and observed traffic flows at 23 one-way toll gantry locations (17 on CityLink and six on EastLink) in the form of scatter plots for each period presented in Figure 11 to Figure 13.

Overall, it appears that the model slightly under-estimates toll road demands in the AM peak period (y=0.97). It is also evident that there is greater variability between modelled and observed estimates during the peaks (reflected in lower correlation measured by the R^2 statistic; 0.99 across the day, but 0.95 in the AM peak 2 hours and 0.97 in the PM peak 2 hours). Taken together, this suggests that the model may be slightly less reliable in estimating travel time savings during peak conditions. This would not be surprising – static traffic assignment models have well-known limitations in relation to the estimation of delays under heavy congestion (particularly delays resulting from intersections and queuing, etc.).

Figure 11 - Comparison of Daily Observed and Modelled Volumes for Tolled Locations in 2011

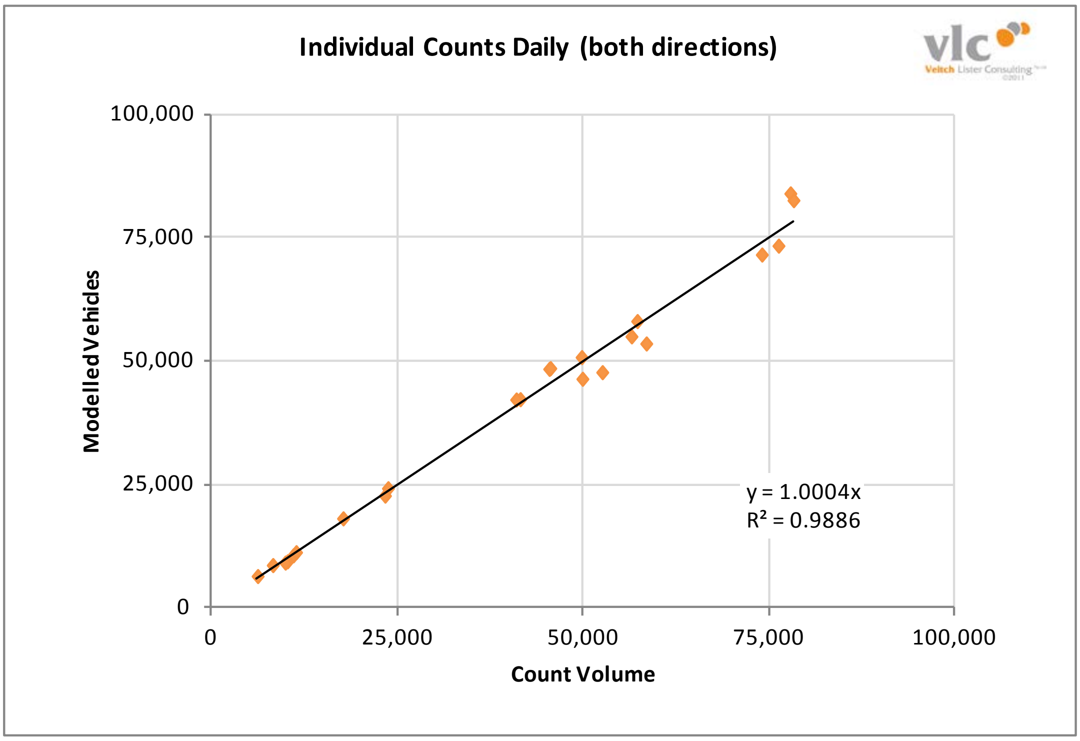


Figure 12 - Comparison of AM Peak (7-9am) Observed and Modelled Volumes for Tolled Locations in 2011

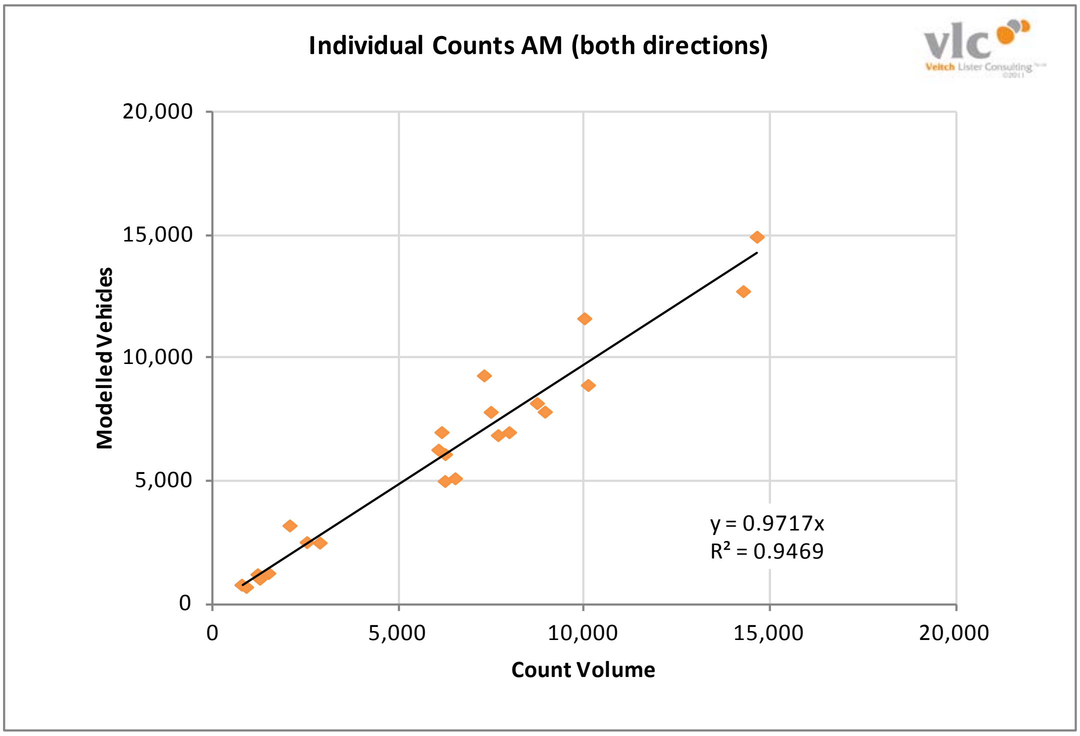
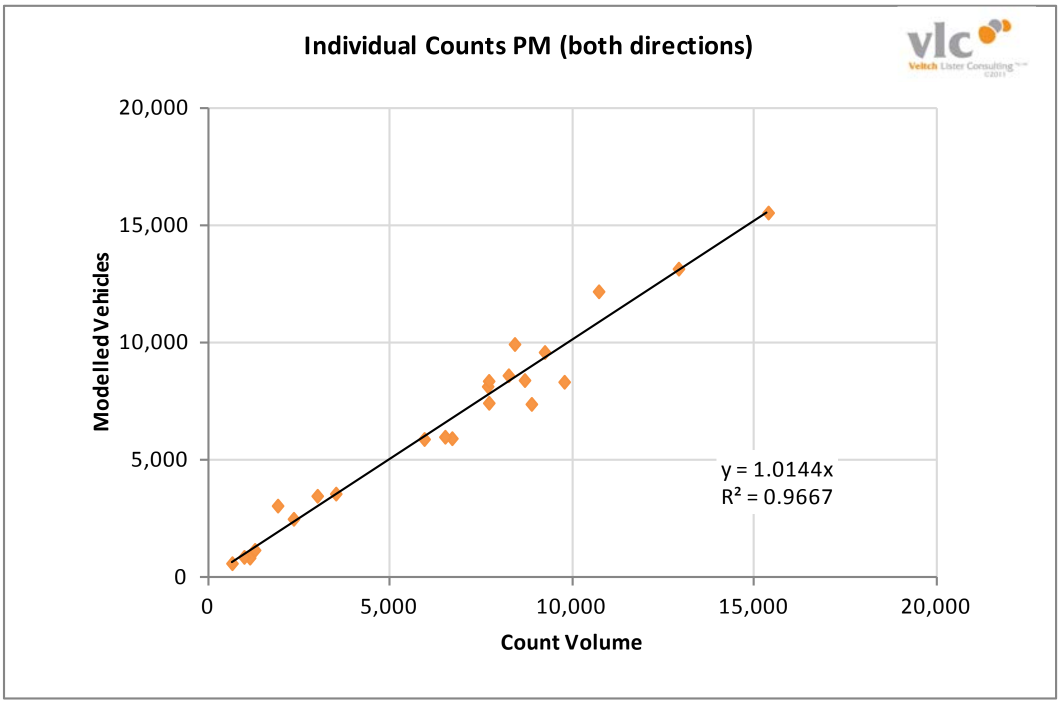


Figure 13 - Comparison of PM Peak (4-6pm) Observed and Modelled Volumes for Tolled Locations in 2011



4.2 Forecasting EastLink

In the early 2000s the State Government of Victoria decided to explore the possibility of the EastLink project (then called the Scoresby Freeway) being delivered by a Public-Private Partnership (PPP) mechanism with tolling.

The Zenith Toll Choice model, using parameters generated from the CityLink Usage Survey, produced traffic and revenue forecasts for different configurations of the project and for different tolling strategies and toll levels during the project's planning stages.

Zenith Toll Choice model forecasts suggested that a viable PPP project could be put to the market. This occurred and the EastLink toll road, after opening in 2008, is now operating successfully.

In the year of opening, the traffic and toll revenue forecasts for EastLink were six per cent higher than actual demand. By 2011, traffic forecasts produced by the Zenith Toll Choice model (sum of all traffic volumes at each toll gantry) were only one per cent high.

4.3 Application to Other Australian Toll Roads

The Zenith Toll Choice model has been applied to a number of other Australian toll roads prior to their construction, including the Lane Cove Tunnel Toll Road in Sydney and the Clem7 Tunnel (NSBT) and Airport Link toll roads in Brisbane. Each of these has proven financially unviable, ending in receivership.

Forecasts for the Airport Link toll road in Brisbane are presented in Table 6. The BrisConnections forecasts reflect volumes published in the BrisConnections' (2008) Product Disclosure Statement (PDS). These are compared to the forecasts made using the Zenith Toll Choice model and actual observed traffic volumes upon opening of the road. In order to make a direct comparison, the Zenith Toll Choice model forecasts were made using the same ramp-up profile seen within the PDS, as well as with a more realistic ramp-up profile derived from the ramp-up profile seen on the M2 Freeway in Sydney. Volumes were also adjusted from 'average weekday' to 'average day' using a factor of 0.898, which was derived from the published Airport Link November 2012 volumes of 59,352 vehicles on an average weekday and 53,313 on an average day.

Table 6 - Airport Link toll road forecasts

Months after opening	BrisConnections	VLC		Actual
	Average Day with ramp-up	Average Day with BrisConnections ramp-up	Average Day with M2 ramp-up	Average Daily Volumes
3	163,629	91,600	75,460	76,935
4	168,845	66,500	54,244	53,313
9	182,244	70,300	60,356	n/a
15	195,378	64,700	57,583	n/a
16	195,378	53,900	48,510	n/a

Using BrisConnections' ramp-up profile, the Zenith Toll Choice model forecast was approximately 25 per cent high four months after the project opened. When the M2 Freeway ramp-up profile was used, VLC's forecast was only 1.7 per cent high after the same period.

This highlights the importance of ramp up assumptions in accurately estimating early year toll road demands.

The Zenith Toll Choice model has also been applied to a number of other Australian toll roads. Comparisons between winning bid forecasts (in the GHD (2011) report for the Australian Government Department of Infrastructure and Transport and Rivercity Motorway (2006)), Zenith Toll Choice model forecasts and actual volumes are presented in Table 7.

Table 7 - Comparisons between winning bid and Zenith Toll Choice model forecasts

Toll Road	City	Actual Volume	Winning Bid Forecast	Zenith Toll Choice Forecast
Cross City Tunnel (2005)	Sydney	32,500	90,000 (+275%)	30,000 (-10%)
Lane Cove Tunnel (2007)	Sydney	57,000	115,000 (+200%)	62,000 (+9%)
Clem 7 (2010)	Brisbane	26,000	109,000 (+420%)	34,000 (+30%)

5. Conclusions and Future Research

This paper has described the development and application of the Zenith Toll Choice model, which has been used to generate toll road forecasts for toll road projects across Australia. It uses a sophisticated toll diversion assignment process that was calibrated using revealed preference surveys that explored how route choice was being influenced by toll roads.

The Zenith Toll Choice model was successfully applied to a toll road in Melbourne, accurately reflecting observed traffic flows and revenue estimates on both CityLink and EastLink. In addition to EastLink, it also has a history of accurately forecasting traffic flows and revenue estimates on proposed toll roads before they are constructed. These include the Airport Link in Brisbane, Cross-City Tunnel and Lane Cove Tunnel Toll Road in Sydney, and the Clem7 Tunnel in Brisbane. Based upon its record, the Zenith Toll Choice model is currently being used by a variety of clients and research projects on a number of other proposed toll roads including East West Link in Melbourne, Legacy Way in Brisbane and WestConnex in Sydney.

While the Zenith Toll Choice model has a track record of accurately forecasting toll road traffic volumes, there are certain features of the existing model that could be improved, which form the basis of future recommended research. The use of spatial segmentation in splitting the Company Car and Non-Company Car segments into north and south could be improved by explaining these spatial variations in terms of social-demographic variables such as average income. This may be possible using household travel surveys from across Australia.

A recent review of toll model parameters indicates that toll usage attitudes have changed, resulting in a recent update to the toll model parameters. This is likely to be related to Melburnians becoming more accustomed to tolls since the CityLink Usage Survey, increasing their likelihood of using tolled roads. CityLink has now been open for 13 years, and another major toll road, EastLink, was opened five years ago. It might therefore be worthwhile conducting a new survey that encompasses users of both toll roads, which may shed some light on changing attitudes towards toll usage. This would help to increase confidence in the ability of the model to accurately forecast future toll road volumes. In addition, all of the results from the surveyed respondents in the CityLink Usage Surveys were utilised in the creation of the toll model parameters, and therefore no independent form of cross validation was used. Conducting a new survey would also address this limitation.

In addition, the current toll model slightly under-estimates toll road demands in the peaks. Peak period modelling of tolled demands should represent a further area of focus for future research.

And finally, the model could be improved through a number of technical enhancements, including the use of value of time distributions (through mixed logit), explicit treatment of the overlap between different tolled alternatives, and improved modelling of road travel times.

Nonetheless, the Zenith Toll Choice model has a history of accurately forecasting traffic volumes on Australian toll roads. Implementation of the recommended future research priorities would serve to further enhance this accuracy.

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