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Final Report

Zenith Model Establishment and Validation Report

Prepared for the East-West Link Needs Assessment Study Project Team

By
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Travel Demand Forecasting & Transport Infrastructure Planning

07-021
East-West Link Needs Assessment Study

Final Report
Zenith Model Establishment and Validation Report

Project Name	Project No.	Report Name	Version	Date	Author
East-West Link Needs Assessment Study	07-021	Zenith Model Validation Report	1.0	Feb 08	TV/MV
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1.0 Introduction

1.1 Background

This report has been prepared for the East-West Link Needs Assessment Study Project Team by Veitch Lister Consulting (VLC).

VLC's role in the East-West Link Needs Assessment Study is to provide medium and long term travel forecasts using the company's proprietary travel forecasting model (Zenith).

Zenith is required to predict the travel and transport network performance outcomes of alternative land use/transportation system scenarios to be further analysed and considered by other members of the Project Team. The scenarios to be considered and analysed during the course of the study, using travel forecasts produced by the Zenith model, include:

- Freeway standard road infrastructure connecting the Eastern Freeway to the Northern Section of Citylink
- Various freeway standard road options connecting from the Northern Section of Citylink to the Port, the Westgate Freeway, and the Western Ring Road.
- Upgrades to existing arterial road network
- New rail infrastructure under the central city, so as to provide greater capacity in the rail network
- Bus, rail and tram options to Doncaster
- The effect of differing future growth scenarios, including high growth, low growth and consolidated growth scenarios
- The effect of increased future fuel prices

1.2 Scope of and Content of Report

The primary aim of this report is to describe the features of the version of the Zenith model used on the East-West Link Needs Assessment Study, to document the model validation procedures that have been adopted as part of the establishment of the model, and to present the model validation results.

The specific capabilities (or strengths) of the model have been highlighted, as well as areas where the model's predictive capabilities are limited.
The balance of this report is structured as follows:

- **Section 2:** Description of the Zenith Travel Forecasting Model
- **Section 3:** Validation of the Model
- **Section 4:** Travel Modelling Limitations

2.0 Description of the Zenith Travel Forecasting Model

2.1 Introduction

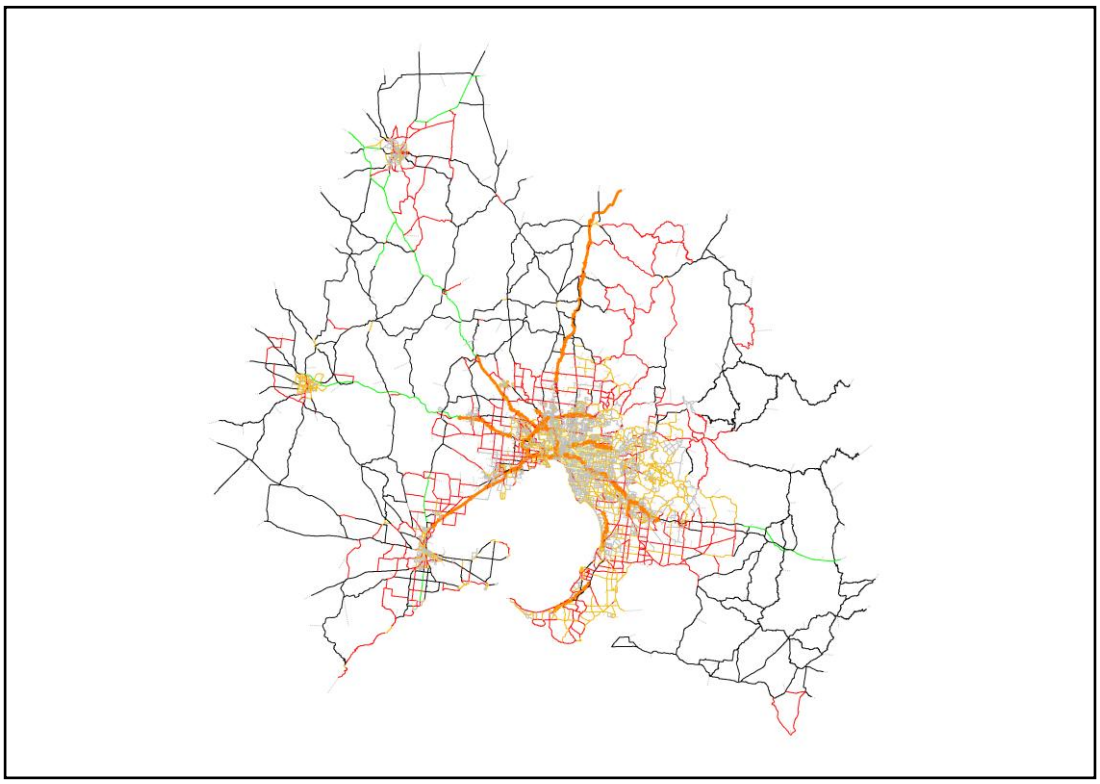
This Section of the report describes the current extent of the Zenith model, its structure and capabilities, and the nature of the outputs it can produce.

In simple terms, the Zenith model can be described as a strategic travel forecasting model with multi-modal and time-period predictive capabilities.

2.2 Current Extent of the Model

The Zenith Travel Forecasting Model simulates the travel demands and patterns of the entire travel market in Metropolitan Melbourne, Geelong, Ballarat and Bendigo, as well as in the surrounding rural areas. This includes travel made by non-motorised modes (walking and cycling), public transport and private car, as well as commercial vehicle travel. The footprint of the model is shown in Figure 1.

Figure 1: The Footprint of the Zenith Model



The transport network within the modelled area is specified in some detail. All freeway, arterial, sub-arterial and collector roads are included in the simulation network, as well as every train line, train station, tram route, bus route and tram/bus stop. The public transport network includes both V-Line and suburban train services.

The large area covered by the model results in a transport network comprising of some 60,000 links (i.e. sections of road or railway line, dedicated tram lines, etc.), for which link attributes (such as free-flow speed and capacity) have to be specified.

Travel demands and patterns are generated at a fairly fine-grained travel zone level. In other words, the model predicts travel demands from each of 2,519 discrete areas of the region (called travel zones) to every other discrete area. Travel made for a range of purposes is separately forecast - i.e. work, education, shopping, recreation, etc. - and travel demand varies by time of day.

The two main "drivers" of the model's travel predictions are the land use structure of the region (i.e. the distribution and intensity of various land uses such as resident population and employment) and the configuration and characteristics of the transport system (i.e. travel speed, capacity, frequency of public transport services, etc.). However, the model's predictions are also influenced to some degree by transport pricing - such as parking charges, petrol price, tolls and public transport fares.

2.3 Outline of the Zenith Model's Structure

The Zenith model has the following basic components:

- Road and rail infrastructure networks (including system capacities and operating speeds).
- Dedicated tram and bus right-of-ways.
- Transit service networks (routes), service frequency and fare details.
- Details of the various land uses in discrete areas of the city - called travel zones.
- Dedicated pedestrian routes/facilities.
- Details of parking charges, tolls and vehicle operating costs (including petrol price).
- Model calibration parameters derived from household travel surveys that require survey participants to submit travel diaries.
- Algorithms to interrogate the model's forecasts and produce a wide range of graphical outputs and transport system performance indicators.

The running of the Zenith model involves four key steps (or program modules) that are executed sequentially, and quantify the following for a specific land use/transport scenario that has been submitted to the model.

1. How many trips will people resident in each travel zone make each weekday - and for what journey purposes? - ***Trip Generation***

2. To which travel zones will they travel to satisfy their travel needs, and at what time of day? - ***Trip Distribution***

3. What mode(s) of travel will they choose? - ***Mode Choice***

4. Which route(s) will be chosen? - ***Trip Assignment***

The above is termed the “classical four-step modelling approach”.

Steps 1 through 3 of the four step procedure involve the production of zone to zone trip matrices, while Step 4 (trip assignment) involves “loading” the travel demands reflected in the trip matrices onto the transport system. For example, car and commercial vehicle trip matrices are assigned (or loaded) onto the road network, and public transport passenger trip matrices are “loaded” onto the public transport system.

How travel demand matrices are derived in Steps 1 through 3 of the 4-step procedure is now described.

2.4 Derivation of Travel Matrices (Trip Tables)

The Zenith travel forecasting model simulates people’s travel behaviour based on travel reported in comprehensive household travel surveys.

The model incorporates the following components in generating travel matrices:-

- a household trip production model (a model of how often households of various types decide to make trips for different purposes - the travel desires);
- a zonal trip attraction model (which produces a measure of how attractive a destination will be in satisfying these travel desires - which will vary by journey purpose - schools attracting education trips, retail/commercial centres attracting shopping, personal business and recreation trips, etc.);
- a trip distribution model (which uses the outputs of the trip production and attraction models to produce estimates of zone to zone travel for each journey purpose);
- a mode choice model (which estimates whether people will choose to travel by car, transit or non-motorised modes such as walking and cycling);
- a vehicle occupancy model (which converts person trips made by car into vehicle trips); and
- a time period model (which allocates trips to parts of the day prior to loading them (assigning them) onto the transport network.

Each of the above modules is briefly described in the following sub-sections.

2.4.1 The Household Trip Production Model

The *household trip production model* estimates the frequency that households of different types make trips for various purposes. The model is run for each household in the modelled area, and then reports the number of trips produced by journey purpose for each travel zone.

Because they display very different characteristics, home-based and non-home-based trips are modelled separately. A non-home-based trip has neither end of the journey at the home, whereas home-based travel has one end of the journey at the home.

Home Based Travel

The *home-based trip production model* estimates travel demands in each travel zone based on the following household attributes (or profiles).

- residents in a household;
- number of blue and white collar workers;
- number of dependants aged 0-17, 18-64, 65 and over; and
- the level of household car ownership.

For the Zenith base year model these household attributes are derived from the 2001 ABS Census, and updated to reflect the current ABS estimates of residential population (ERP). 2006 ABS Census data was not available for use in this project.

When the model is run in "forecast mode" for a future year, these household attributes, and the number of households in each travel zone, are adjusted to reflect anticipated future conditions.

The *home-based trip production model* produces separate trip production estimates for the following categories of travel.

- home-based work - blue collar;
- home-based work - white collar;
- home-based education - pre-school and primary;
- home-based education – secondary;
- home-based education – tertiary;
- home-based shopping and personal business;
- home-based social and recreation; and
- home-based other.

In order to increase the accuracy of the subsequent *trip distribution* and *mode choice models*, the above trip purposes are further disaggregated by the level of household car ownership (0, 1, 2, 3+) using a *travel market segmentation model*.

The final output of the *home-based trip production model* is the number of journeys that each travel zone will make each weekday by journey purpose.

Non-Home-Based Travel

Because of the far more complex travel decision-making relationships that exist for non-home-based travel, a more comprehensive array of zonal variables (17 in total) is used to produce measures of zonal trip production. These are:

- zonal population;
- number of households;
- pre and primary school enrolments;
- secondary school enrolments;
- equivalent full time tertiary enrolments; and
- employment in 12 industry categories (retail, manufacturing, public administration, personal services, community services, etc.).

The model separately forecasts trips for the following trip purpose:

- work-based-work
- work-based-shopping ;
- work-based-other;
- shopping-based-shopping;
- shopping-based-other; and
- other non-home-based travel.

2.4.2 The Zonal Trip Attraction Model

Once trips have been "produced" there is a need for a model that assesses how attractive each zone is as a potential destination. This is the *trip attraction model*, which produces separate measures of zonal attractiveness for each journey purpose

The trip attraction model is calibrated using multiple regression, which relates trips reported in household travel surveys to the 17 zonal variables described previously for estimating non-home-based trip productions.

2.4.3 Trip Distribution Model (produces person trip matrices)

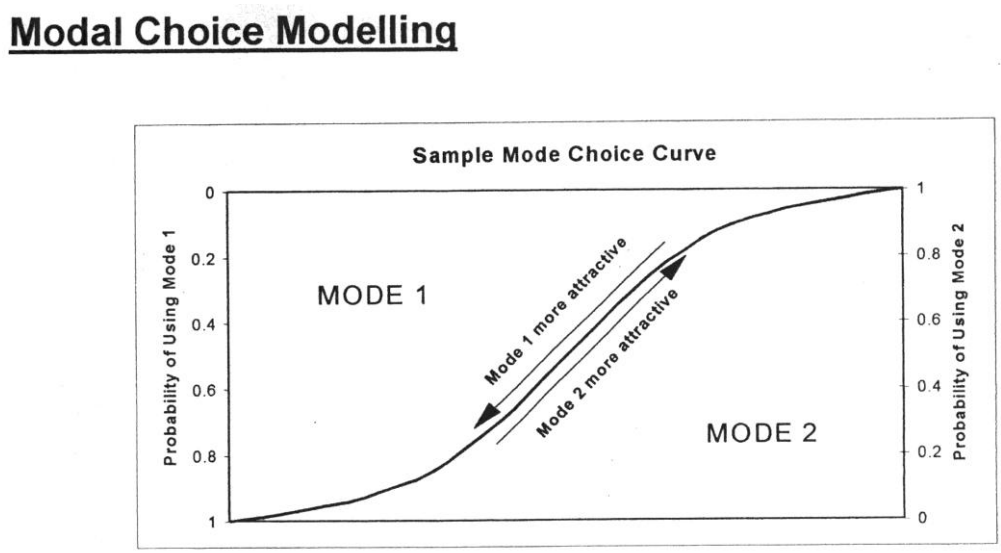
The next step in the process is to distribute the trips produced in each travel zone across the available destinations. This is performed by the *trip distribution model* which uses a process that emulates Newton's theory of gravity - i.e. as a possible destination becomes more costly to reach, then it is less likely to be chosen as a destination. Similarly, if a shopping centre is expanded (i.e. its mass is increased) then it becomes more attractive as a destination, and will therefore attract more shopping trips.

The trip distribution model is run separately for each travel market segment (i.e.. journey purpose) and outputs zone to zone person trip matrices for each home-based and non-home-based journey purpose.

2.4.4 Modal Choice Model

Once the likely travel demands and patterns have been established by the *trip distribution model*, a *modal choice model* is run that further splits person trip matrices into zone to zone person trips by travel mode. This task is performed using a series of *binary mode choice logit curves* that predict which modes of travel will be chosen for trips made between each pair of travel zones in the modelled area. An example of a *mode choice logit curve* is presented in Figure 2.

Figure 2: Sample Binary Mode Choice Logit Curve



Sample Mode Choice Logit Curve

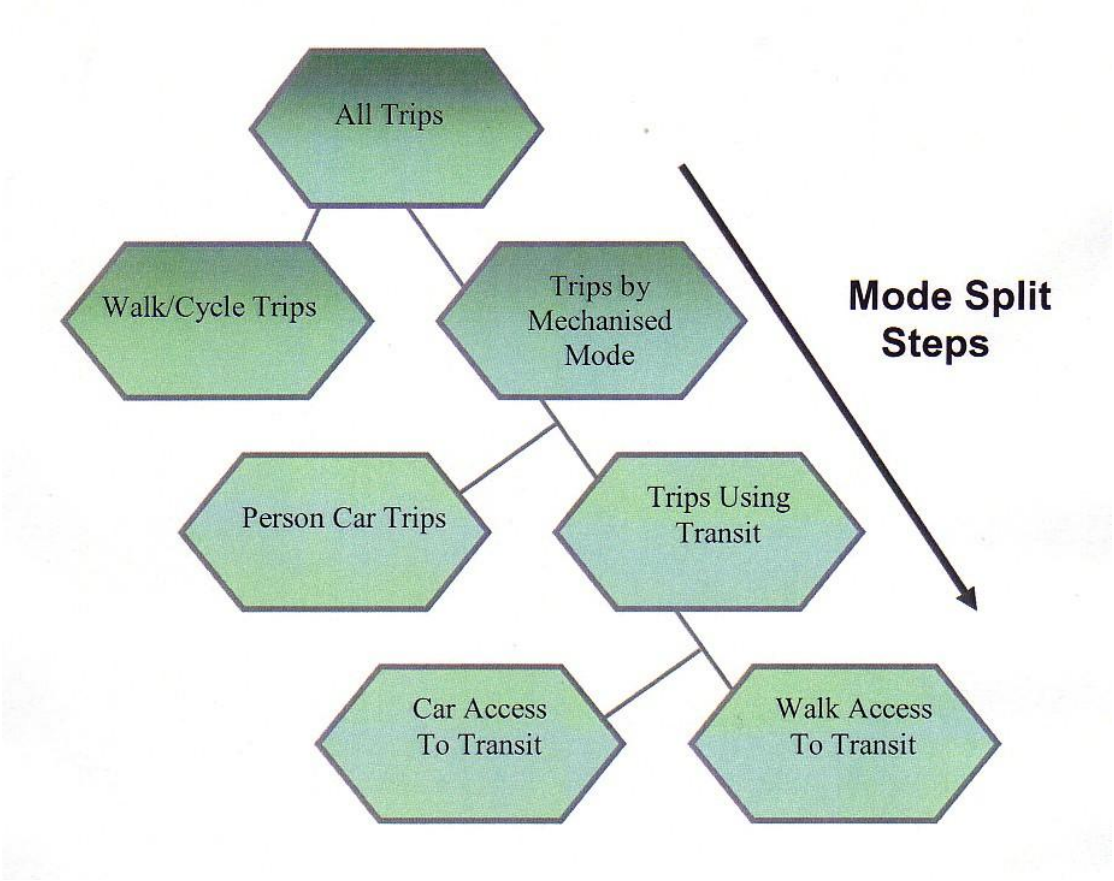
The x-axis in the above diagram is the *perceived generalised cost of travel* difference between Mode 1 and Mode 2. When the difference is zero then half of the travel market will choose Mode 1, and half Mode 2. When one mode is more attractive than another - i.e. its *perceived generalised travel cost* is less than the other - then majority of travellers will choose that mode.

Perceived generalised cost comprises of:-

- in car travel time;
- in transit vehicle travel time;
- transit access time (walking or car);
- transit waiting time (which is a function of service frequencies);
- transit transfer times;
- transit fares;
- car operating costs;
- parking charges;
- tolls; and
- modal perceptions (or preferences).

The *mode choice model* is run for each travel market segment (i.e. trip purpose and car ownership level). The model is applied as an *hierarchical binary tree*, as shown in Figure 3.

Figure 3: The Hierarchical Binary Mode Choice Tree



The first step in the modal choice sequence is to predict motorised and non-motorised (i.e. walk and cycling) modes of travel. Motorised modes are then divided between car and public transport travel. Travel by public transport is then further subdivided into trips that access the system by walking, and those who choose to use a car (i.e. park-and-ride and kiss-and-ride).

Whether transit travellers choose to use a bus, train or tram is determined later during the transit person trip assignment process.

2.4.5 Car Occupancy Model

For travel by public transport a person trip is a trip. In other words the primary aim of the modelling is to predict the flow of public transport passengers through the public transport system at various times of the day. By car, however, several people may travel in the same vehicle, and our primary focus changes to predicting the flow of vehicles through the road network.

It is therefore necessary to convert person trips made by car to vehicle trips using a *car occupancy model*. Car occupancy varies by journey purpose, level of household car availability and whether a journey is being made to the Melbourne Central Business District (CBD) or not. Households with lower car ownership tend to ride-share more often than high car owning households, and there is more scope and incentive (due to high parking charges) for car pooling if travelling to the Central Business District.

2.4.6 Time Period Model

Another key step in deriving trip matrices is to allocate trips made for the various journey purposes to different time of the day (time periods). Some journey purposes are heavily concentrated into short intervals of the day. For instance, journeys to work and school dominate travel demands in the morning peak period, whereas shopping and recreational travel occur to a greater extent in the off-peak).

Allocating travel across the day is performed by the *time period model*. The model is applied following *trip distribution* - immediately before the running of the *modal choice model*.

The time periods considered by the model are:

- 7:00am to 9:00am (AM peak);
- 4:00pm to 6:00pm (PM peak); and
- balance of the day (off-peak)

2.4.7 Other Model Components

The model structure also includes a sub-model for the prediction of light and heavy commercial vehicle travel patterns.

2.5 Features of the Zenith Model

Perhaps the most important features of the Zenith model are its comprehensive simulation of public transport system options and the sensitivity of its forecasts to various pricing mechanisms (fares, fuel costs, tolls and parking charges, etc.).

The following sub-sections describe some of the more important elements of the model, while the model's limitations are described in Section 4 of the report..

2.5.1 Multiple Access Modes to Transit

Unlike most European and Asian cities, in Australian cities it is not sufficient to only consider walking as the sole mode of access to the public transport system. For example, at most outer suburban train stations people travelling to the system by car (park-and-ride and kiss-and-ride) constitute the majority of rail passengers.

For this reason Zenith applications in Australia separately model people walking/cycling to access the transit system, from those choosing to access by car.

2.5.2 Detailed Simulation of the Public Transport System

The model includes an extremely detailed description of Melbourne's public transport system. All bus, tram and train routes are separately specified and all stations and stops are considered as candidate locations for boarding and alighting the system. The model also distinguishes between all stops, limited stop and express services.

As well as accurately simulating where and how people can access the transit system, the integrated model also allows travellers to travel on a bus or a tram to a station and then catch a train. Several interchanges in sequence can be modelled, and the model will also allow people to walk from a stop where they have alighted a service to another stop where they can continue their journey on another service. This capability is critical in assessing the interactions that occur between the various public transport modes (e.g. people exiting Flinders Street Station to catch a St. Kilda Road tram or a Swanston Street tram to the Melbourne University).

2.5.3 Highly Disaggregated Travel Market Segmentation

VLC has found during previous model development exercises that the accuracy of a model's public transport forecasts can be significantly increased by including private vehicle availability within the travel market segmentation. Households with limited private motor vehicle access are likely to display different trip destination choice and mode choice decision-making behaviour from those with a high level of access to private motor vehicles.

In other words, people with no access, or limited access, to a car are more likely to choose a destination that is more accessible by public transport.

The integrated model recognises this and breaks each home-based journey purpose into 4 household car ownership levels (0, 1, 2, and 3+) to give a total of 32 home based travel market segments and six non-home based segments.

2.5.4 Sophisticated Modal Choice and Trip Distribution Models

The choice of travel mode and the choice of trip destination are closely linked in the decision-making process. The model takes this into account so that changes in public transport service characteristics, for example, will be reflected in both mode choice and trip distribution choices.

2.5.5 Realistic Simulation of Transit Passenger Journey Options

The public transport component of the model incorporates a number of processes which make the simulation of journey options particularly powerful. In essence, these processes:

- provide multiple options for zone access to and from the public transport system;
- accurately reflect the range of choices available to a person once they have "entered" the public transport system; for example, whether to alight a public transport at a particular stop and, if so, whether to wait for different service, or walk to a different stop to continue their journey.

2.5.6 Sensitivity to Transport Pricing

Trip distribution, mode choice, and trip assignment can all be influenced by the following pricing mechanisms:

- vehicle operating costs (fuel);

- car parking charges;
- tolls;
- area pricing; and
- public transport fares.

2.5.7 Ability to Test a Wide Range of Transit Options

The model is capable of testing a wide range of transit modes and associated infrastructure and operating strategies.

In its current form the model (and the associated networks) simulates the following modes in detail:

- trains;
- scheduled, fixed route bus services
- tram services

Services can be disaggregated as required (eg. by operating company, by service type etc). In this context the model is capable of simulating the effects of:

- new infrastructure and associated services;
- route restructuring;
- service frequency changes;
- fare levels;
- integration of services;
- express services; and
- transit lanes and high occupancy vehicle (HOV) lanes.

2.5.8 Sensitivity to Road Congestion Effects

Public transport services that operate on roads (for example, buses and trams) are affected by congestion as they travel across the network - particularly during peak periods.

The Zenith model “feeds back” private vehicle assignment results into the public transport travel cost estimation routines, so that the effects of congestion on bus or tram travel speeds can be fully considered by the model.

3.0 Model Validation

3.1 Introduction

Model validation is a procedure that is used to test whether a model is "fit-for-purpose". It involves comparing the model's base year estimates of travel against a comprehensive database of "observed" travel at locations across the modelled network. Clearly if a model cannot adequately replicate existing travel demands then it is unlikely to produce robust forecasts for alternative medium and long term land use and transport scenarios.

For model validation purposes VicRoads has provided VLC with a comprehensive database of recent weekday traffic counts across Melbourne. VLC has also received peak and daily public transport passenger boardings from DoI.

The Zenith base year model is officially a 2006 model. It estimates travel demands across the modelled area for 2006. The transport network input to the model reflects the road and public transport systems as they were in 2006, however the demographic and land-use data input to the model reflect the 2005 situation. The use of 2005 data in this case will cause the model to underestimate 2006 travel demands by approximately 1-2 percent on average. This is not considered to be a problem in validating against 2006 traffic counts.

All the traffic counts and "observed" public transport passenger data are of 2005 and 2006 vintage.

3.2 Model Validation Against Traffic Counts

In 2006 VicRoads undertook a major program of traffic counting across Melbourne to coincide with the 2006 ABS Population Census.

The VicRoads 2006 traffic counts were undertaken at 21 screenlines across Melbourne. The screenline locations are shown in Figure 4. Traffic travelling on all roads crossing each screenline was counted in the survey.

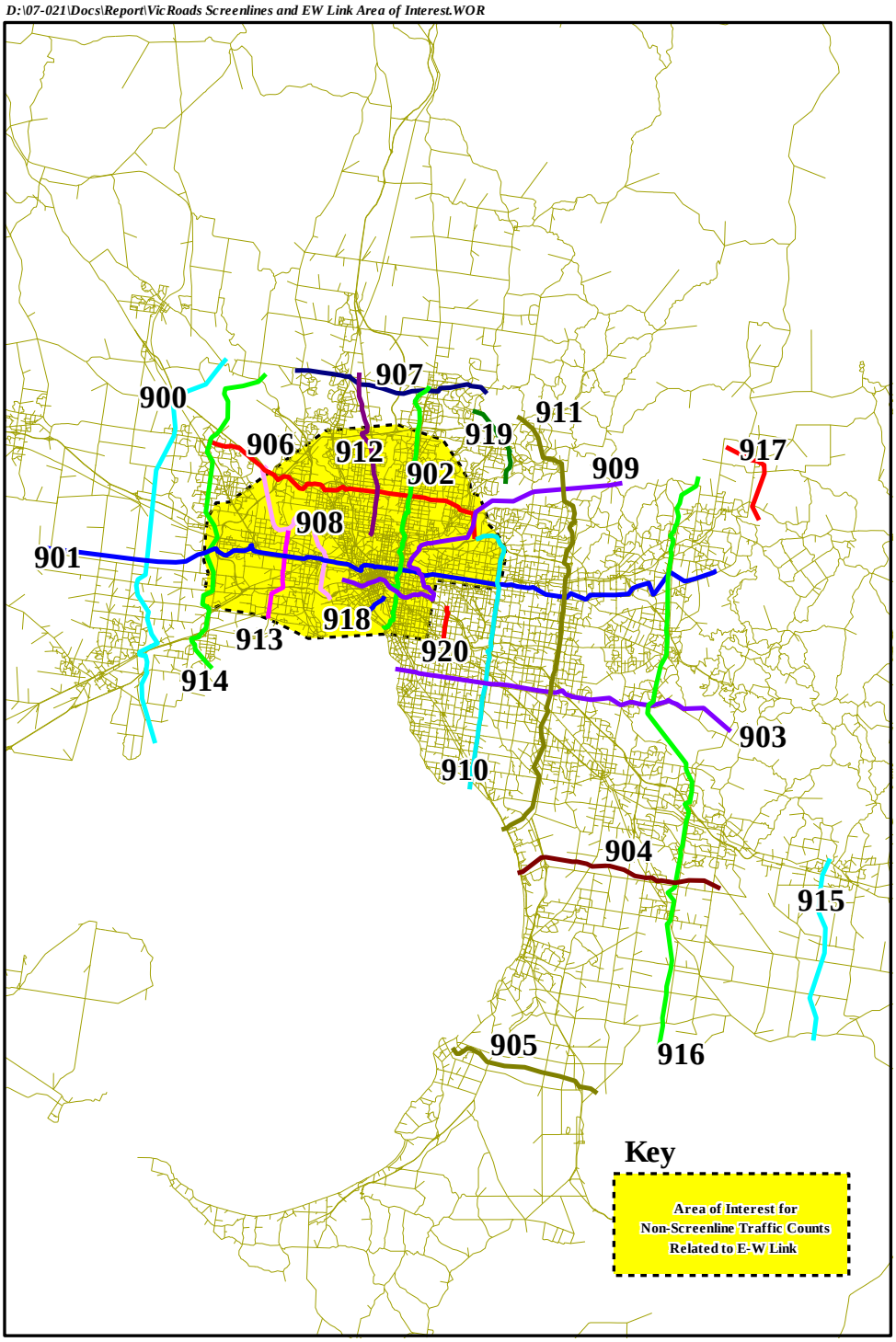
Screenlines are imaginary lines on a map and, if located intelligently, provide a useful way of comparing overall travel patterns and demands predicted by a transport model with observed traffic demands.

VicRoads has also provided VLC with a comprehensive set of SCRAM traffic counts across Melbourne. These are counts derived from vehicle detection devises, usually associated with the operation of traffic signals, and are not confined to the locations covered by the screenlines.

Care has to be taken when comparing SCRAM derived traffic counts and modelled traffic volumes. Some signalised intersections have free-left-turn lanes - i.e. dedicated left-turn lanes where vehicles can perform their desired

manoeuvre outside of the operation of the signals. These lanes do not have vehicle detection devices. As a consequence the derived SCRAM count for an approach to such an intersection will be lower than the modelled traffic volume.

Figure 4: VicRoads Screenline Locations in Melbourne



The Zenith 2006 base year model's traffic forecasts have been validated against the 21 VicRoads screenline counts, and a subset of the SCRAM counts covering the primary study area for the East-West Link Needs Assessment Study.

3.2.1 Validation Against VicRoads 2006 Screenline Traffic Counts

Tables 1 through 4 show a series of comparisons between predicted and observed weekday traffic flows across each of the VicRoads screenlines.

- Table 1 presents average weekday, all vehicle data
- Table 2 presents AM Peak (1 hour), all vehicle data
- Table 3 presents PM Peak (1 hour), all vehicle data
- Table 4 presents average weekday, commercial vehicle data

Figures 5 through 8 present each of the respective datasets as a scatter plot. In each case, the correlation coefficient (r^2) and the equation of the line of best-fit are displayed.

The main points to emerge from the data presented in these tables and figures are as follows:

(a) Over 10 million vehicles cross the VicRoads screenlines each weekday.

(b) The Zenith model's forecast of total screenline crossings is 3 percent lower than the VicRoads counts (refer Table 1).

(c) In terms of replication of weekday traffic flows crossing individual screenlines, there is generally close correspondence between the modelled and the observed. For 11 of the 21 screenlines the modelled traffic volumes are within 5 percent of the count total, and the discrepancy is only greater than 10 percent for 5 of the screenlines. The worst performing screenlines are generally remote from the primary study area, and have little bearing on the investigation.

(d) The screenlines with the largest percentage discrepancy between modelled volumes and the counts tend to those carrying lower traffic volumes. The worst performing screenline is 905 (27 percent discrepancy), most probably due to the Zenith model under-estimating recreational day trippers and visitors to the Mornington Penninsula. This will also be contributing to under-estimation of travel at screenline 904.

(e) The r^2 correlation coefficient between modelled weekday traffic flows and counts at the individual screenlines is extremely good (refer Figure 5). An r^2 of 0.995 has been achieved. For model validation at the screenline level an r^2 of 0.95 or above is considered an excellent result, and an r^2 of greater than 0.90 is acceptable.

(f) The modelled traffic volumes crossing the screenlines in the AM and PM peaks are higher than the VicRoads counts - by 4 percent and 5 percent respectively (refer Tables 2 and 3). This is most probably due to the *time period model*, that allocates trips across the day, not

reflecting peak spreading effects that have occurred since the year 2000 - when the model was last calibrated using the VATS household travel surveys. This modelling limitation is further elaborated upon in Section 4 of this report.

(g) In the AM peak the modelled and observed traffic volumes are within 5 percent for 14 of the 21 screenlines, which is a good result. The model's PM peak forecasts are less robust but still highly credible.

(h) The r^2 correlation coefficients for the AM peak and PM peaks at the screenlines are 0.993 and 0.992 respectively, which are both well within acceptable ranges (refer Figures 6 and 7).

(i) Table 4 compares modelled and observed weekday commercial vehicle flows at the screenlines. In global terms the model's 2006 commercial vehicle forecasts are 14 percent higher than the counts.

(j) Commercial vehicle modelling is a difficult art. Processes associated with the distribution of raw materials, goods manufacture, product storage and distribution to point of sale are extremely complex, vary by industry type, and even vary from one company to the next operating within the same industry. Given these complexities the correspondence between modelled commercial vehicle volumes and counts at screenlines, as depicted Figure 8, is quite encouraging. An r^2 correlation coefficient of 0.919 has been achieved, which is within acceptable limits for commercial vehicle modelling.

The VicRoads Model Validation Guidelines (2006) set upper and lower bound targets for correspondence between modelled screenline traffic volumes and counts that vary depending on the amount of traffic crossing each screenline. These bounds are shown in Figure 9, together with the Zenith model's performance for each screenline. All but one screenline (905) meet, or come extremely close to meeting the target.

3.2.2 Validation Against Counts in the Study Area

The performance of the Zenith model has been further analysed against a set of 1,200 traffic counts within the "primary area of interest" for this study. These counts have been extracted from the VicRoads SCATS database for the defined area of interest previously shown on the screenline diagram (Figure 4).

Figures 10 and 11 present comparisons of modelled predictions with each of these observed traffic flows. Figure 10 presents average weekday flows, while Figure 11 presents AM peak (1 hour) flows.

In terms of weekday traffic there is an r^2 correlation coefficient of 0.937 between modelled and observed flows. The equivalent coefficient in the AM peak is 0.912. For individual count locations, as opposed to sets of counts crossing screenlines, the VicRoads Model Validation Guidelines (2006) sets an r^2 target of 0.9 and above. This has been achieved for all modelled time periods.

The VicRoads Guidelines also require that modelled volumes achieve a Route Mean Square Error (%RMSE) of less than 30 against the traffic count database being used for model validation. The %RMSE for the Zenith model is 25.3, which satisfied the Guidelines.

It is worth pointing out that the area being investigated by the study is the most difficult region to model, due to greater competition across the modes (private car versus multiple public transport modes) and the added complexity of intense periods of traffic congestion during the day.

Table 1: Modelled v Observed Traffic at Screenlines (average weekday)

	Sum of Individual Records				No. of
SL_id	Model	Count	Diff	% Diff	Counts
900	291,581	279,885	11,696	4%	22
901	1,199,239	1,182,455	16,784	1%	110
902	941,649	1,008,417	-66,768	-7%	68
903	708,504	717,445	-8,941	-1%	50
904	226,227	260,572	-34,345	-13%	18
905	73,890	101,532	-27,642	-27%	12
906	808,747	817,532	-8,785	-1%	50
907	199,815	224,292	-24,477	-11%	16
908	566,785	553,029	13,756	2%	20
909	1,160,810	1,142,728	18,082	2%	44
910	685,668	741,069	-55,401	-7%	50
911	892,115	930,425	-38,310	-4%	58
912	346,167	361,698	-15,531	-4%	31
913	303,291	344,824	-41,533	-12%	23
914	442,976	443,599	-623	0%	33
915	72,059	70,326	1,733	2%	8
916	510,193	545,062	-34,869	-6%	54
917	31,668	27,422	4,246	15%	8
918	226,774	234,782	-8,008	-3%	10
919	160,706	178,486	-17,780	-10%	10
920	279,184	300,133	-20,949	-7%	12
TOTAL	10,128,048	10,465,713	-337,665	-3%	707

Table 2: Modelled v Observed Traffic at Screenlines (AM peak one hour)

	Sum of Individual Records				No. of
SL_id	Model	Count	Diff	% Diff	Counts
900	25,931	23,558	2,373	10%	22
901	105,657	92,610	13,047	14%	110
902	80,493	80,655	-162	0%	68
903	62,777	61,189	1,588	3%	50
904	21,690	22,160	-470	-2%	18
905	7,299	8,276	-977	-12%	12
906	68,714	65,225	3,489	5%	50
907	17,186	18,052	-866	-5%	16
908	48,227	45,870	2,357	5%	20
909	98,899	93,868	5,031	5%	44
910	61,584	62,231	-647	-1%	50
911	80,688	80,693	-5	0%	58
912	30,054	27,158	2,896	11%	31
913	26,523	27,089	-566	-2%	23
914	38,568	36,087	2,481	7%	33
915	5,611	5,375	236	4%	8
916	44,977	42,266	2,711	6%	54
917	2,660	2,182	478	22%	8
918	19,953	20,010	-57	0%	10
919	14,563	14,625	-62	0%	10
920	23,545	24,036	-491	-2%	12
TOTAL	885,599	853,215	32,384	4%	707

Table 3: Modelled v Observed Traffic at Screenlines (PM peak one hour)

	Sum of Individual Records				No. of
SL_id	Model	Count	Diff	% Diff	Counts
900	26,259	24,960	1,299	5%	22
901	106,907	96,146	10,761	11%	110
902	81,649	78,788	2,861	4%	68
903	63,264	59,435	3,829	6%	50
904	21,674	23,559	-1,885	-8%	18
905	7,266	8,940	-1,674	-19%	12
906	71,363	65,395	5,968	9%	50
907	17,767	18,215	-448	-2%	16
908	49,165	46,336	2,829	6%	20
909	100,131	88,797	11,334	13%	44
910	61,718	61,370	348	1%	50
911	81,717	79,094	2,623	3%	58
912	30,687	28,546	2,141	8%	31
913	26,835	28,457	-1,622	-6%	23
914	39,921	39,132	789	2%	33
915	5,789	5,959	-170	-3%	8
916	46,074	47,610	-1,536	-3%	54
917	2,779	2,492	287	12%	8
918	20,048	18,347	1,701	9%	10
919	14,757	15,749	-992	-6%	10
920	23,801	23,017	784	3%	12
TOTAL	899,571	860,344	39,227	5%	707

Table 4: Modelled v Observed Commercial Vehicles (average weekday)

	Sum of Individual Records				No. of
SL_id	Model	Count	Diff	% Diff	Counts
900	20,127	17,050	3,077	18%	20
901	46,515	48,279	-1,764	-4%	58
902	58,179	46,909	11,270	24%	34
903	27,896	20,807	7,089	34%	32
904	12,961	14,654	-1,693	-12%	14
905	4,592	7,690	-3,098	-40%	12
906	38,811	29,788	9,023	30%	32
907	17,721	19,811	-2,090	-11%	12
908	57,782	50,154	7,628	15%	16
909	95,868	65,372	30,496	47%	34
910	46,829	39,730	7,099	18%	29
911	48,628	47,261	1,367	3%	34
912	25,947	27,392	-1,445	-5%	21
913	9,898	14,716	-4,818	-33%	17
914	36,201	31,998	4,203	13%	26
915	10,625	10,047	578	6%	8
916	11,056	17,021	-5,965	-35%	34
917	2,267	2,921	-654	-22%	8
918	21,467	9,878	11,589	117%	10
919	6,650	8,773	-2,123	-24%	10
920	3,839	1,056	2,783	264%	2
TOTAL	603,859	531,307	72,552	14%	463

Figure 5: Modelled v Observed Traffic at Screenlines (average weekday)

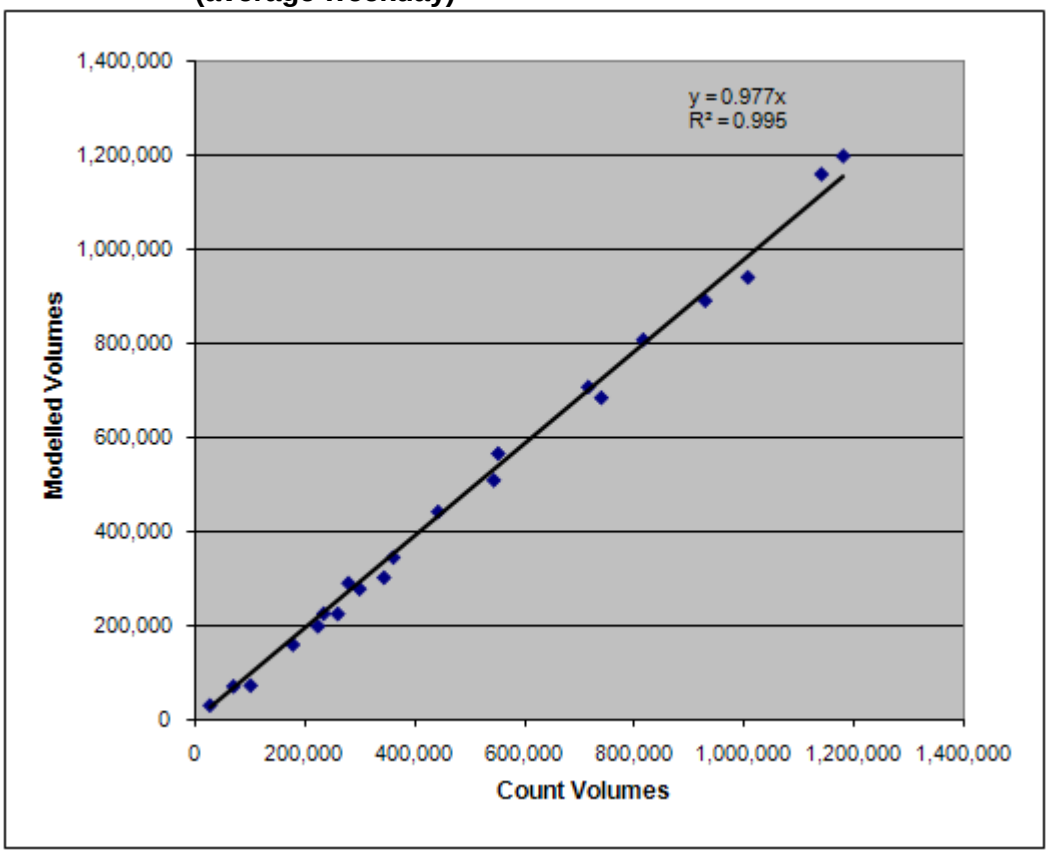


Figure 6: Modelled v Observed Traffic at Screenlines (AM Peak 1 hour)

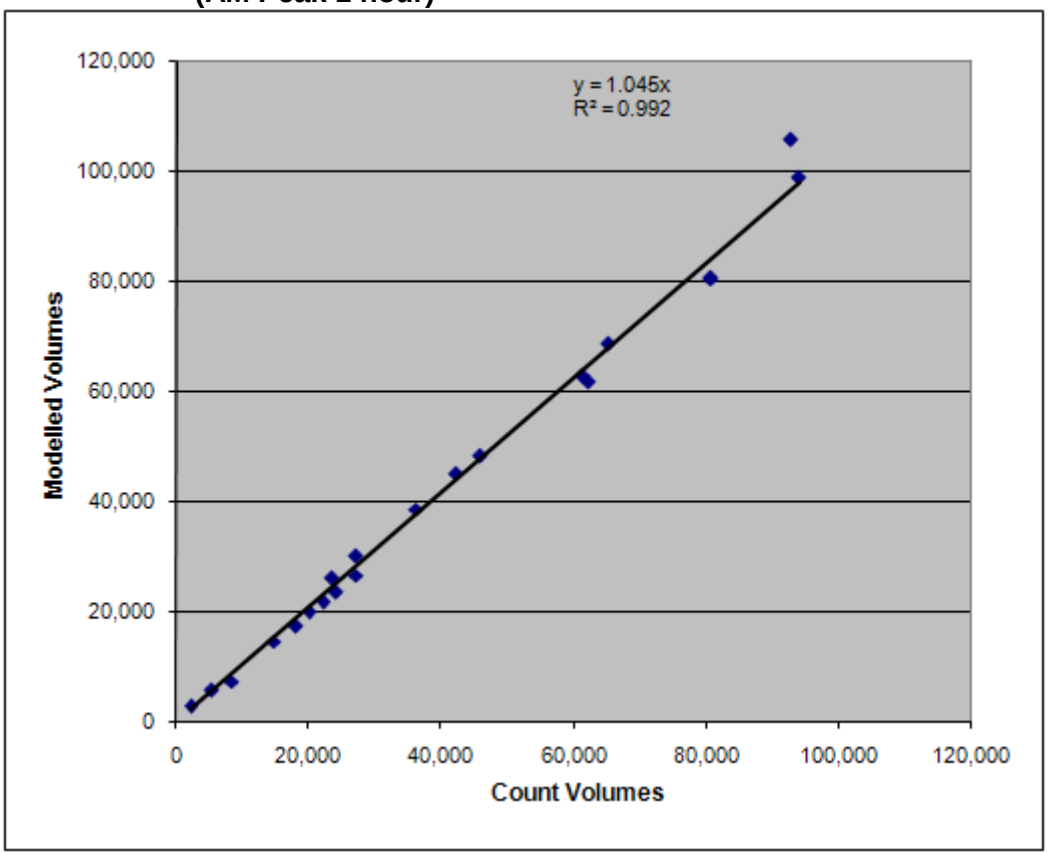


Figure 7: Modelled v Observed Traffic at Screenlines (PM Peak 1 hour)

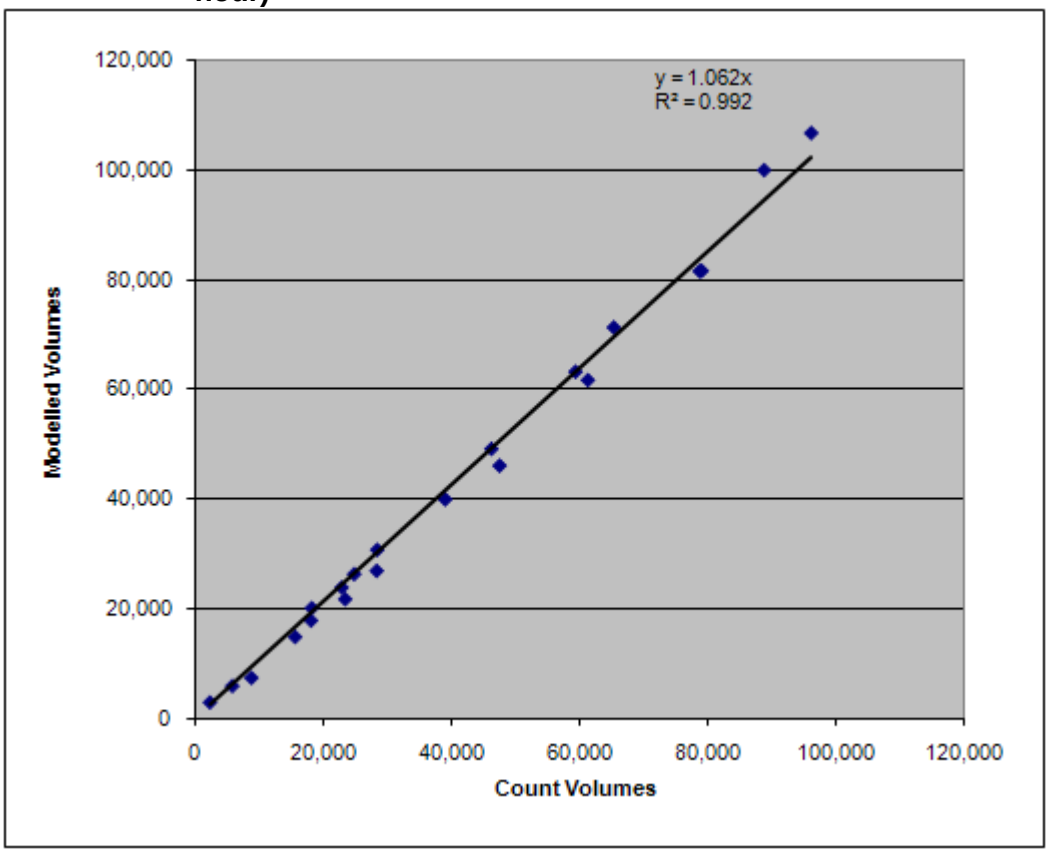


Figure 8: Modelled v Observed Commercial Vehicles (all vehicles)

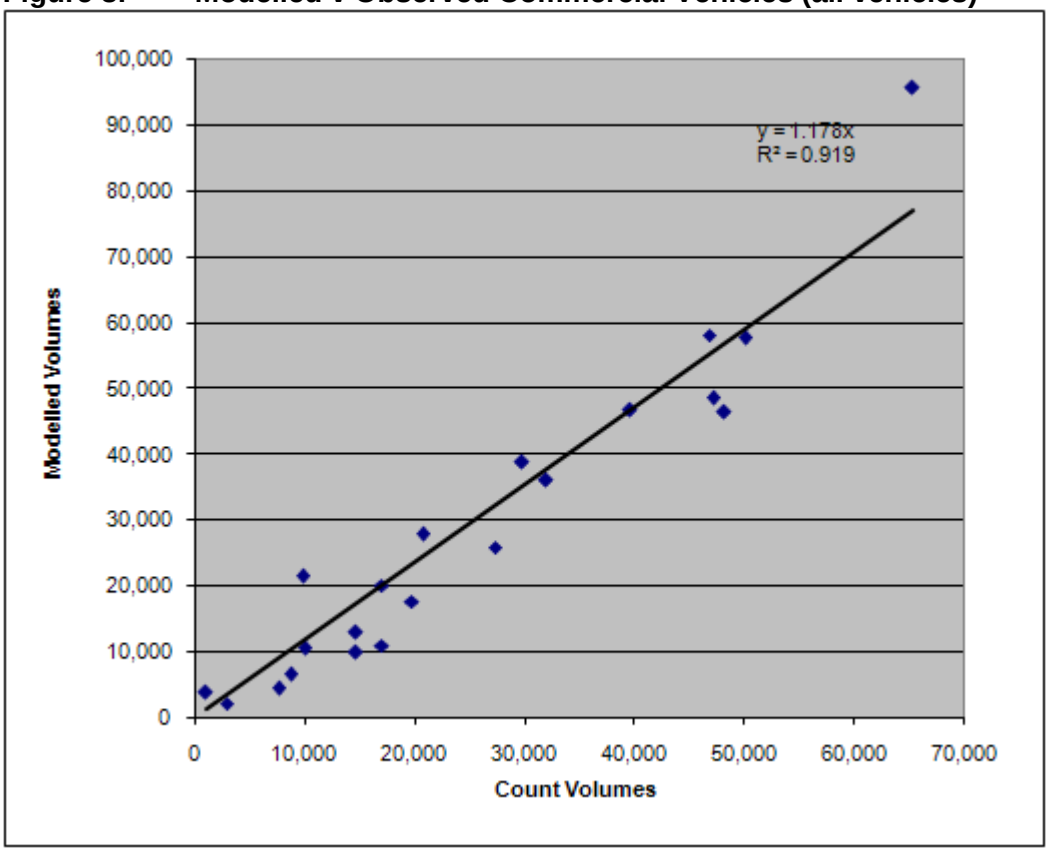


Figure 9: Zenith Model Performance Against VicRoads Screenline Guidelines

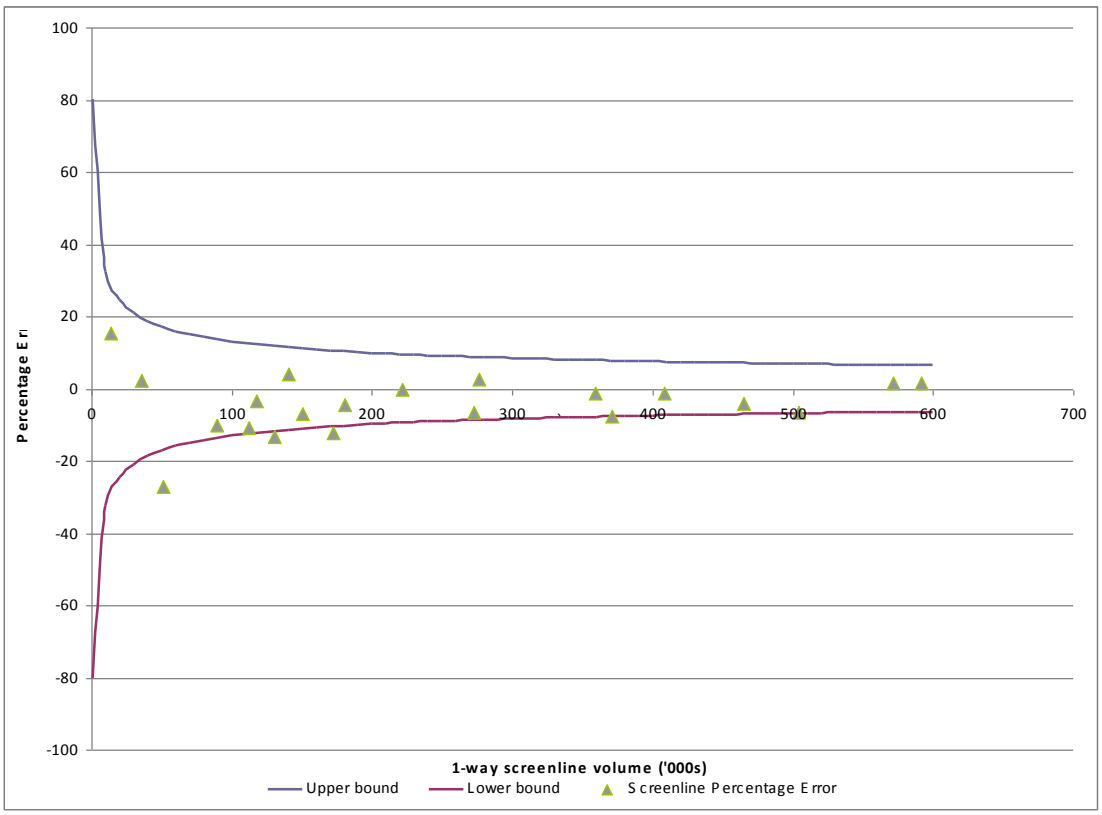


Figure 10: Modelled v Observed Traffic at Individual Study Area Counts (average weekday)

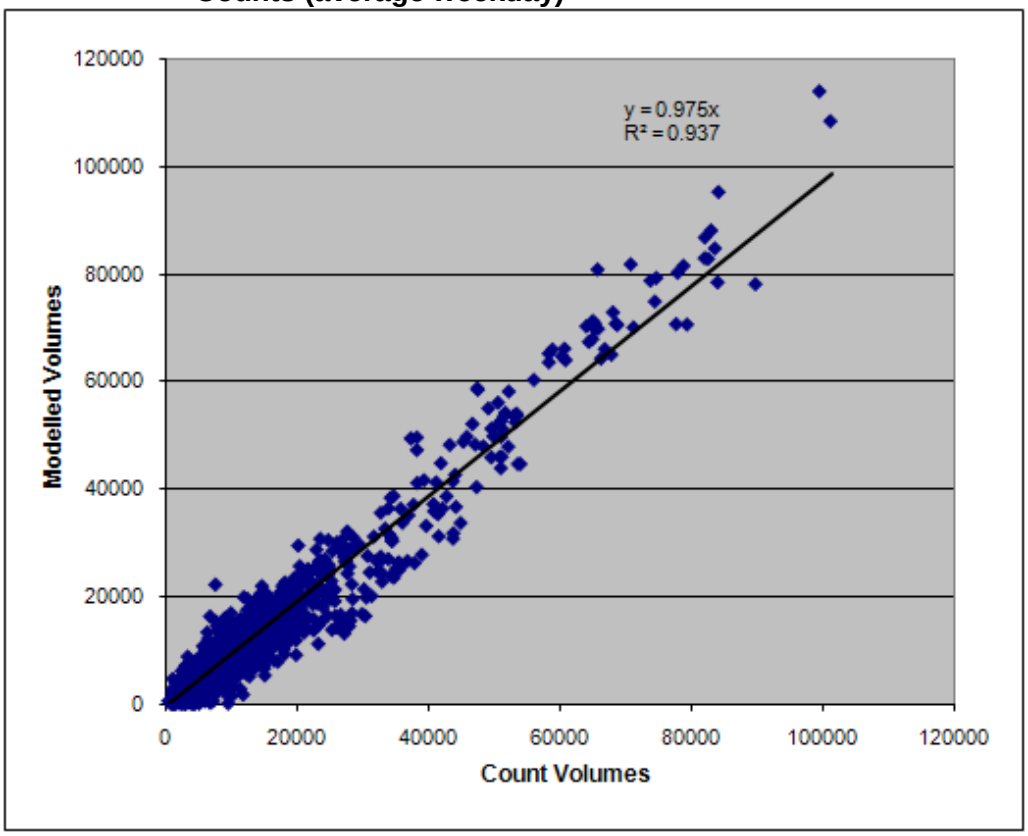
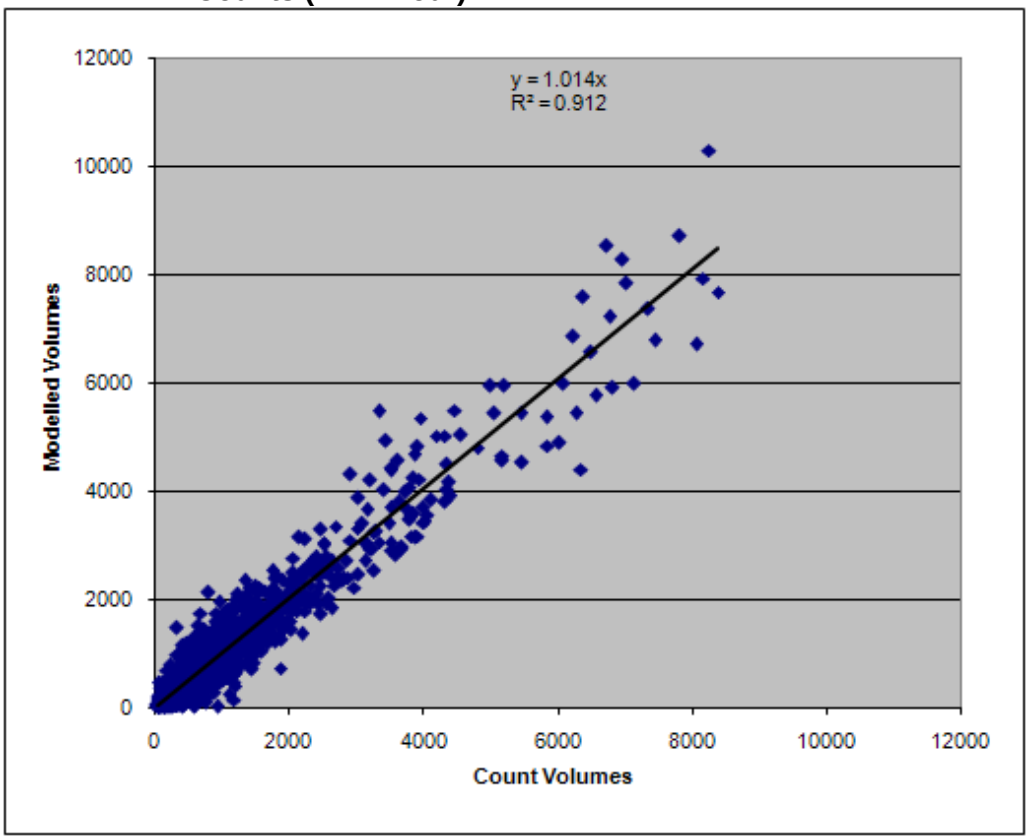


Figure 11: Modelled v Observed Traffic at Individual Study Area Counts (AM 1 hour)



3.3 Model Validation Against Observed PT Patronage

The Zenith model's base year estimates of public transport patronage in Melbourne have been compared with an extensive database of public transport patronage data for rail, tram and bus modes. The patronage data used in this comparison was provided by DoI. It was originally sourced from MetLink passenger boarding counts undertaken at each suburban train station and individual tram services in 2006, and ticket validation data for buses for the 2005/2006 financial year.

The available patronage data suggests that in 2006 there were approximately 1.33 million boardings of the public transport system each weekday. The corresponding Zenith model prediction is 1.26 million, a difference of 5 percent. Given that the land use input to the Zenith model relates to 2005, the train and tram surveys were conducted in 2006, and petrol prices increased in the intervening period, this level of discrepancy is plausible.

3.3.1 Model Validation Against Rail Patronage Data

The available rail data suggests that in 2006 an average of approximately 589,000 people boarded the rail system each weekday. The corresponding Zenith model prediction is 552,000, a difference of 6 percent.

Tables 5 and 6 show a comparison of rail patronage data and modelled predictions for each of the five major rail groups. Table 5 presents data for the average weekday, while Table 6 presents data for the AM peak.

Table 5: Weekday Train Passenger Boardings by Rail Line Grouping

	Daily			
Group	**Observed**	**Modelled**	**Difference**	**Diff %**
Clifton Hill	54,053	51,998	-2,055	-4%
Burnley	117,547	107,913	-9,634	-8%
Caulfield	139,281	130,764	-8,517	-6%
Northern	89,664	83,261	-6,403	-7%
Inner	188,833	178,068	-10,765	-6%
TOTAL	**589,378**	**552,004**	**-37,374**	**-6%**

Table 6: AM Peak Train Passenger Boardings by Rail Line Grouping

	AM Peak			
Group	**Observed**	**Modelled**	**Difference**	**Diff %**
Clifton Hill	20,935	19,703	-1,232	-6%
Burnley	41,812	35,593	-6,219	-15%
Caulfield	48,038	41,386	-6,652	-14%
Northern	33,774	34,528	754	2%
Inner	7,566	11,493	3,927	52%
TOTAL	**152,125**	**142,703**	**-9,422**	**-6%**

The modelled weekday and AM peak passenger boardings are both 6 percent lower than the 2006 counts, which is a good outcome for reasons alluded to earlier (petrol price increases, etc.).

In terms of daily train boardings the modelled patronage for each rail group and the counts are closely aligned. In the peaks the model is most probably under-predicting passenger boardings by about 10 percent.

Tables 7 and 8 show a comparison of weekday and AM peak rail patronage counts and modelled predictions broken down into 25 rail station groups. Generally speaking there is close correspondence between the modelled and counted patronage. There is even close correspondence between modelled boardings and the counts at the individual station level, as evidenced by the scatter-plot presented in Figure 12.

The r^2 correlation coefficient for the data presented in Figure 12 is 0.95, which is a good outcome.

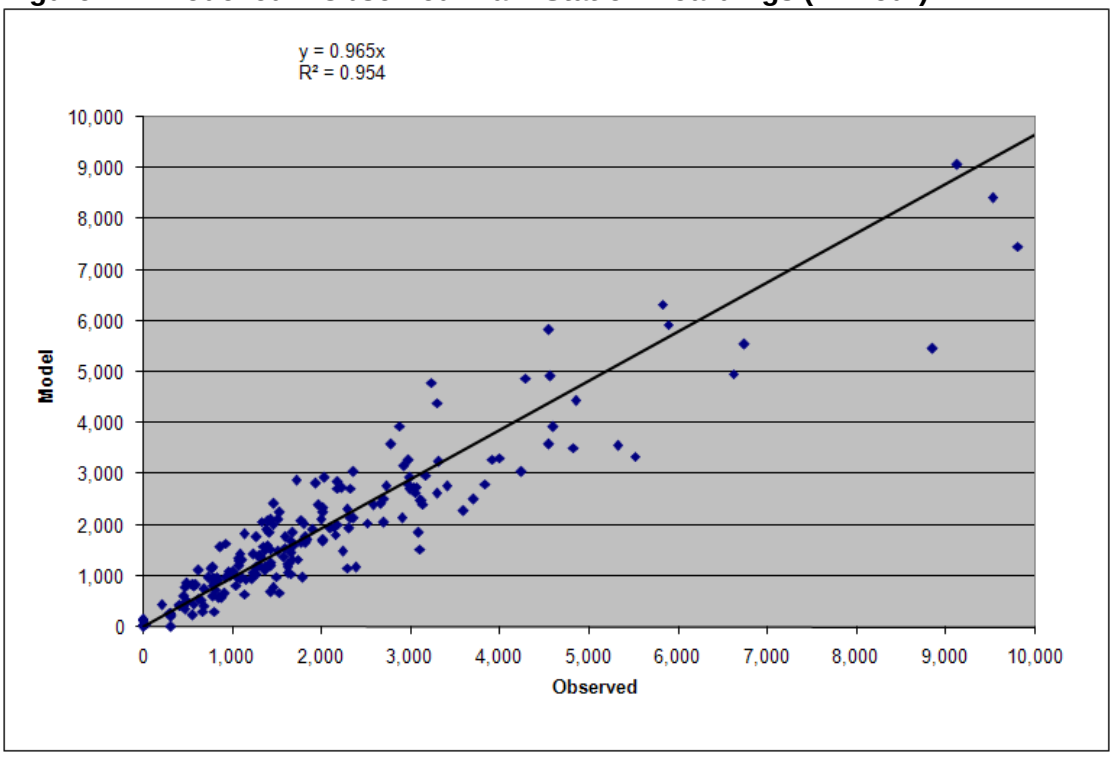
Table 7: Weekday Train Passenger Boardings by Station Group

Group	Line	Observed	Modelled	Difference	Diff %
Clifton Hill	Clifton Hill - Jolimont	8,302	6,170	-2,132	-26%
Clifton Hill	Hurstbridge - Westgarth	26,947	26,393	-554	-2%
Clifton Hill	Epping - Rushall	18,804	19,435	631	3%
Burnley	Ringwood - Camberwell East	39,049	37,713	-1,336	-3%
Burnley	Lilydale - Ringwood East	9,438	8,779	-659	-7%
Burnley	Belgrave - Heathmont	11,781	9,646	-2,135	-18%
Burnley	Camberwell - Hawthorn	20,748	17,076	-3,672	-18%
Burnley	Alamein - Riversdale	5,511	4,684	-827	-15%
Burnley	Glen Waverley - Heyington	25,509	25,262	-247	-1%
Burnley	Burnley - East Richmond	5,511	4,753	-758	-14%
Caulfield	Dandenong - Carnegie	36,064	36,755	691	2%
Caulfield	Cranbourne - Merinda Park	2,227	2,149	-78	-4%
Caulfield	Pakenham - Hallam	8,225	7,751	-474	-6%
Caulfield	Frankston - Glenhuntly	40,643	37,448	-3,195	-8%
Caulfield	Caulfield - Hawksburn	17,863	14,188	-3,675	-21%
Caulfield	South Yarra	9,129	9,078	-51	-1%
Caulfield	Sandringham - Prahran	25,130	23,395	-1,735	-7%
Northern	Watergardens - Middle Footscray	19,145	16,573	-2,572	-13%
Northern	Newport - Seddon	8,383	7,936	-447	-5%
Northern	Williamstown - North Williamstown	3,623	2,516	-1,107	-31%
Northern	Werribee - Seaholme	12,888	11,617	-1,271	-10%
Northern	Footscray - South Kensington	10,604	8,128	-2,476	-23%
Northern	Broadmeadows - Kensington	23,947	24,733	786	3%
Northern	Upfield - Macaulay	11,074	11,758	684	6%
Inner	Inner	188,833	178,068	-10,765	-6%
TOTAL		589,378	552,004	-37,374	-6%

Table 8: AM Peak Train Passenger Boardings by Station Group

Group	Line	Observed	Modelled	Difference	Diff %
Clifton Hill	Clifton Hill - Jolimont	1,989	1,494	-495	-25%
Clifton Hill	Hurstbridge - Westgarth	11,962	10,528	-1,434	-12%
Clifton Hill	Epping - Rushall	6,984	7,681	697	10%
Burnley	Ringwood - Camberwell East	14,675	11,921	-2,754	-19%
Burnley	Lilydale - Ringwood East	3,945	4,610	665	17%
Burnley	Belgrave - Heathmont	4,543	5,007	464	10%
Burnley	Camberwell - Hawthorn	4,492	4,119	-373	-8%
Burnley	Alamein - Riversdale	2,818	1,670	-1,148	-41%
Burnley	Glen Waverley - Heyington	9,997	7,088	-2,909	-29%
Burnley	Burnley - East Richmond	1,342	1,178	-164	-12%
Caulfield	Dandenong - Carnegie	12,498	10,852	-1,646	-13%
Caulfield	Cranbourne - Merinda Park	930	1,126	196	21%
Caulfield	Pakenham - Hallam	3,811	4,576	765	20%
Caulfield	Frankston - Glenhuntly	15,260	11,895	-3,365	-22%
Caulfield	Caulfield - Hawksburn	4,747	4,778	31	1%
Caulfield	South Yarra	1,797	1,452	-345	-19%
Caulfield	Sandringham - Prahran	8,995	6,707	-2,288	-25%
Northern	Watergardens - Middle Footscray	7,674	8,091	417	5%
Northern	Newport - Seddon	3,730	2,569	-1,161	-31%
Northern	Williamstown - North Williamstown	1,217	1,482	265	22%
Northern	Werribee - Seaholme	5,541	6,425	884	16%
Northern	Footscray - South Kensington	2,329	1,587	-742	-32%
Northern	Broadmeadows - Kensington	9,395	10,869	1,474	16%
Northern	Upfield - Macaulay	3,888	3,505	-383	-10%
Inner	Inner	7,566	11,493	3,927	52%
TOTAL		**152,125**	**142,703**	**-9,422**	**-6%**

Figure 12: Modelled v Observed Train Station Boardings (24 hour)



3.3.2 Model Validation Against Tram Patronage Data

Available patronage data suggests that in 2006, an average of approximately 465,000 people boarded the tram system each weekday. The corresponding Zenith model prediction is 460,000 people, a difference of 1 percent.

Table 9 shows daily observed and modelled tram boardings for each tram route. Figure 13 presents this data in a scatter plot, which has a correlation coefficient (r^2) is 0.83.

A lower r^2 for trams relative to that obtained for trains is an anticipated outcome. Trams cater for trips that are on average substantially shorter than train trips. The model's predictive capabilities for trams are therefore compromised somewhat by the granularity of the travel zone system. In other words, the accurate prediction of shorter distance tram travel market requires the adoption of a more refined travel zone system (i.e. smaller zones).

Notwithstanding the above comments, the model's tram forecasts by route are highly correlated with the passenger counts, and certainly accurate enough for tram system planning purposes.

Figure 13: Modelled v Observed Tram Boardings by Route (24 hour)

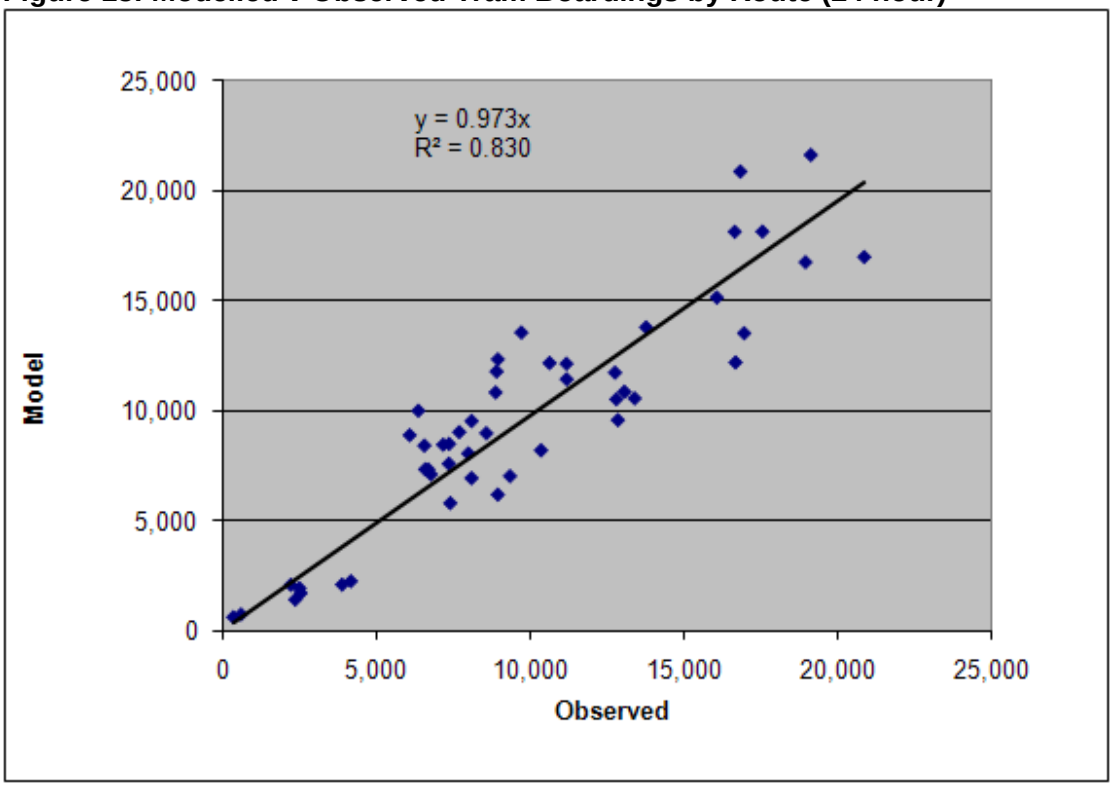


Table 9: Weekday Tram Boardings by Route

RouteCode		Total Daily Observed Boardings	Model Boardings	Actual Diff	% Diff
1S	EAST COB - STH MELB	11,213	12,124	911	8%
3NW	EAST MALVERN - UNI	9,378	7,021	-2,357	-25%
5NW	MALVERN - UNIVERSITY	6,810	7,100	290	4%
6NW	GLEN IRIS - UNIVERSI	8,025	8,043	18	0%
8NW	MORELAND - UNIVERSITY	12,886	9,560	-3,326	-26%
16NW	ST KILDA BEACH-UNI	13,097	10,850	-2,247	-17%
19S	NTH COBURG - CITY	16,098	15,128	-970	-6%
24W	NTH BALWYN-LATROBE	389	618	229	59%
30E	LATROBE-BRUNSWICK ST	2,580	1,708	-872	-34%
48W	NTH BALWYN-CITY	8,916	10,819	1,903	21%
55S	WEST COBURG - DOMAIN	7,393	7,581	188	3%
57E	WEST MARIBYNONG-CIT	7,439	5,791	-1,648	-22%
59S	AIRPORT WEST - CITY	10,664	12,158	1,494	14%
64N	EAST BRIGHTON-UNI	7,208	8,447	1,239	17%
67NW	CARNEGIE - UNI	8,132	9,522	1,390	17%
70W	WATTLE PARK - CITY	6,123	8,879	2,756	45%
72W	CAMBERWELL - UNI	10,387	8,190	-2,197	-21%
75W	EAST BURWOOD - CITY	8,984	12,319	3,335	37%
78N	PRAHRAN-NTH RICHMOND	4,209	2,248	-1,961	-47%
82N	FOOTSCRAY-MOONEE PO	2,538	1,932	-606	-24%
86S	BUNDOORA- CITY	17,581	18,124	543	3%
96S	E BRUNSWICK-ST KILDA	16,682	18,112	1,430	9%
109W	BOX HILL-PT MEL	18,982	16,733	-2,249	-12%
112N	ST K-WEST PRESTON	16,988	13,509	-3,479	-20%
1N	STH MELB - EAST COB	11,219	11,419	200	2%
3SE	UNI - EAST MALVERN	6,621	7,328	707	11%
5SE	UNIVERSITY - MALVERN	8,127	6,929	-1,198	-15%
6SE	UNIVERSI - GLEN IRIS	7,400	8,482	1,082	15%
8SE	MORELAND - TOORAK	13,427	10,553	-2,874	-21%
16SE	UNI-ST KILDA-KEW	12,833	10,509	-2,324	-18%
19N	CITY - NTH COBURG	16,708	12,179	-4,529	-27%
24E	LATROBE-NTH BALWYN	637	740	103	16%
30W	BRUNSWICK ST-LATROBE	2,401	1,412	-989	-41%
48E	DOCKLANDS-NTH BALWYN	8,942	11,771	2,829	32%
55N	DOMAIN - WEST COBURG	6,723	7,332	609	9%
57W	CITY-WEST MARIBYNONG	8,983	6,178	-2,805	-31%
59N	CITY - AIRPORT WEST	12,792	11,715	-1,077	-8%
64S	UNI-EAST BRIGHTON	6,597	8,406	1,809	27%
67SE	UNI - CARNEGIE	7,731	9,019	1,288	17%
70E	CITY - WATTLE PARK	6,400	9,990	3,590	56%
72E	UNI - CAMBERWELL	8,611	8,965	354	4%
75E	CITY - EAST BURWOOD	9,749	13,539	3,790	39%
78S	NTH RICHMOND-PRAHRAN	3,923	2,091	-1,832	-47%
82S	MOONEE PO-FOOTSCRAY	2,258	2,081	-177	-8%
86N	CITY - BUN DOORA	19,156	21,600	2,444	13%
96N	ST KILDA-E BRUNSWICK	16,863	20,849	3,986	24%
109E	PT MEL-BOX HILL	20,893	16,969	-3,924	-19%
112S	WEST PRESTON-ST K	13,800	13,774	-26	0%
	TOTAL	**465,496**	**460,346**	**-5,150**	**-1%**

3.3.3 Model Validation Against Bus Patronage Data

Ticket validations suggest that in 2005/2006 an average of approximately 279,000 people boarded buses each weekday. The corresponding Zenith model prediction for 2006 is 252,000, a difference of 10 percent.

While this is quite a credible outcome, it needs to be treated with caution. The bus patronage data used in the validation have not been derived from field surveys (i.e. passenger counts), but are based on raw ticket validation data factored up by 15 percent to take account of passengers boarding buses who neither buy a ticket, nor validate a pre-purchased ticket.

Surveys undertaken by the DoI and MetLink show that the degree to which reported ticket validations accurately reflect actual passenger boardings varies enormously from one bus route to another, and can vary by time of day. Consequently there is likely to be far greater discrepancies between modelled and reported bus patronage by route than there is for trains and trams, where the patronage used for validation is based on passenger boarding counts. This view is confirmed by the lower r^2 correlation coefficient of 0.58 obtained between modelled and reported bus passenger boardings by individual route.

Buses (like trams) generally cater for the shorter end of the travel market, and will therefore be susceptible to greater modelling error due to the travel zone granularity issue.

4.0 Modelling Limitation

4.1 Introduction

Section 2.0 of this report described the Zenith travel forecasting model, while Section 2.5 highlighted some of the more important features and capabilities of the model.

This section of the report describes the more important limitations of the model. Understanding these limitations, and their likely consequences, are prerequisites for appropriate interpretation of the model's outputs. At the end of the day all models, no matter how detailed and sophisticated they are, are only approximations of the real world. Compromises have to be made in some areas of a model's performance due to computing power constraints and data storage limitations, as well as difficulties in designing suitable algorithms that will execute within acceptable time limits. Some aspects of travel decision choice are extremely difficult to model robustly.

Not withstanding the above, the travel demand forecasts and transport network performance assessments produced by the Zenith model are valuable aids for the future planning and design of the transport system.

4.2 Limitations of the Zenith Model

4.2.1 Land Use Inputs When Undertaking Long Term Forecasts

For the Zenith model to be run to test a future planning scenario requires that the urban fabric be defined and input to the model for the entire modelled area. The future distribution of population (including socio-economic profiles) and employment (by type) has to be specified for all of the 2,519 travel zones, as well as the locations of schools, higher education institutions and shopping centres. The location and scale of other special travel generators such as ports, hospitals and airports also have to be input to the model, and well as the entire transport network that is envisaged for the scenario being tested.

In other words, the model produces travel demand forecasts for a land use structure and associated transport system that is "fixed", and specified exogenously (i.e. external) to the model. The Zenith model, in its present form, does not predict how the distribution of land use and its density might change in response to substantial changes in accessibility that might be afforded by a new major transport infrastructure initiative.

This can lead to under-prediction of travel demands in areas of the city where accessibility is substantially improved in the future. This will most likely be the result of those specifying future land use inputs to the model not correctly interpreting changes in market forces and urban development pressures that can result from changed accessibility. Simply projecting historical urban growth trends into the long term future is not sufficient when analysing the impacts of major road and public transport projects.

It has to be acknowledged that there will almost certainly be some degree of "incompatibility" between the specified land use and the transport system (and therefore modelling error) when making long term forecasts. This is due to our limited and imprecise understanding of how land use changes in response to changing accessibility. The accuracy of the final outcome depends upon the skills of land use planners and urban economists as much as it does the travel modeller.

Recognising these limitations the East-West Link Needs Assessment Study has tested a range of land use scenarios for Melbourne. These have included high and low growth scenarios, suburban intensification that may occur as a result of improved accessibility in the study area, as well as a "carbon constrained" scenario that assumes significant urban consolidation in response to a changed petrol supply/price environment.

The Project Team engaged SGS consulting to define the alternative land use scenarios that were tested during the course of the study.

4.2.2 Use of Fixed Travel Demands in each Time Period Modelled

The Zenith model produces separate travel demand forecasts for the AM peak, PM peak and off-peak. The modelled quantum of daily travel (i.e. number of journeys) is fixed for a given land use, and travel for the various journey purposes is then apportioned to the three modelled time periods using factors derived from household travel surveys.

Travel patterns (as opposed to travel quantum) and choice of travel mode vary depending on the spatial distribution land use, and the configuration and performance of the transport system.

Consequently, within the Zenith model, traffic congestion effects are allowed to influence both choice of destination and mode of travel - but not the time period of day when trips occur, which is fixed.

The model therefore does not predict peak spreading mechanisms, where over time some peak period travellers decide to reschedule their journeys into the shoulders of the peak where travel conditions are less onerous. As our major cities continue to grow, the quantum of travel increases and our ability to cost-effectively expand transport network capacity diminishes, periods of peak congestion will extend. The peak spreading phenomenon applies equally to both the road network and the public transport system.

By not addressing this issue the model will tend to over-state peak travel demands, and under-predict off-peak travel demands, when forecasts are being produced for conditions 10 or 20 years into the future.

4.2.3 Inability to Accurately Model Intense Traffic Congestion

Zenith is a link-based travel forecasting model. Travel speeds on road links (i.e. sections of road between intersections) are estimated as a function of the traffic they are predicted to carry and their capacity. As the traffic demand on a link increases its travel speed is reduced using a *speed-flow* curve.

Zenith does not directly simulate traffic delays at intersections. It does not therefore separately compute the different levels of traffic delay that vehicles turning left, turning right and travelling straight ahead at an intersection will experience. Vehicles queueing on approaches to intersections are also not modelled. Consequently the model does not explicitly handle situations where vehicle queues on the approach to one intersection extend such that they prevent the efficient operation of an adjacent intersection. When these events occur over a protracted period the road system can experience "breakdown" - or "gridlock" - over an extensive area of the network, and traffic delays can increase dramatically.

The model will, when system "breakdown" occurs, over-estimate traffic speeds and under-estimate traffic delays.

The system breakdown issue is not only confined to intersections on urban arterial roads, but is also a problem on the freeway network, where a "pinch point" in the system becomes over-loaded in the peaks and can cause traffic to bank up for many kilometres. An example of such an occurrence is the West Gate Freeway, where queues develop from the West Gate Bridge to the Western Ring Road (and beyond) each morning peak period. Again, delays caused by this queue-back effect are not explicitly handled by the model, which can lead to under-estimation of delays when the system is at saturation.

4.2.4 Infinite Passenger Carrying Capacity of the PT System

The current Zenith model does not restrain the number of passengers that can board the public transport system when passenger demand exceeds the capacity of the network. Essentially the public transport system is assumed to have infinite capacity.

This can result in over-prediction of passengers boarding the public transport system in the peaks, and under-prediction of off-peak demand as some passengers may choose to reschedule their journey. Those people who might choose to travel by car as a result of over-crowding on the public transport system are also not explicitly covered by the Zenith model formulation.

The East-West Link Needs Assessment Study did however perform a model run where peak period public transport use was suppressed to levels that could be accommodated by the public transport system, This involved transferring some person trips from the peak period public transport matrices to the off-peak public transport and car matrices prior to performing trip assignment. These matrix adjustments were performed outside of the main model formulation.

4.2.5 Lack of Available Parking is not Explicitly Modelled

The Zenith model includes a parking charge variable that is added to the *perceived generalised cost* of car travel to selected travel zones. The charge that is applied to individual zones is designed to not only reflect actual parking charges, but also any disincentive there may be for car travel resulting from a shortage of parking supply in a zone.

The latter charge (i.e. the lack of parking supply component) is fairly arbitrary, and is set to reflect the car parking demand/supply situation at the point in time when the model was last validated. The model does not yet have a capability to predict how the balance between parking demand and supply might change in the future, and adjust the parking charge accordingly.

In the case of the Melbourne CBD, where the amount of parking that can be provided in new developments is strictly controlled by the Melbourne City Council Planning Scheme, the parking demand/supply balance may change over time, making travel by car to the CBD more or less attractive. The current Zenith model assumes that this balance does not change in the future.

4.2.6 Paradigm Shifts in Travel Behaviour (TravelSmart Initiatives)

The Zenith model has been calibrated using household travel survey data. The model's behavioural relationships therefore reflect peoples' attitudes and preferences at the time the surveys were conducted.

Some key model parameters, such as how people value their time and make trade-offs when deciding whether, where and how to travel, may change over time. In the model these travel behaviour characteristics and preferences are assumed to remain constant over time. The model makes no attempt to predict "paradigm shifts" in travel behaviour that might occur in the future. In fact the model assumes that such changes will not occur.

It is not only plausible, but likely, that travel behaviour will change in the future in response to such issues as *concern for the environment*. There is also some evidence that travel behaviour can be influenced by government