Veitch Lister Consulting Pty Ltd

Zenith Model Framework Papers - Version 3.0.1

Paper A – Model Design and Architecture

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PREPARED FOR
Public Transport Victoria

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Paper A – Model Design and Architecture

Draft Report

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Executive Summary

The Zenith Models are a family of four step transport models, developed by Veitch Lister Consulting (VLC) and implemented in the OmniTRANS software package for a range of Australian cities and regions. This document is one in a series of working papers that collectively describe the model structure and framework of the Zenith Model; in particular, this document describes the overall Model Design and Architecture and ties together the entire series in an overview format.

The aim of the Model Design and Architecture is to develop an appreciation for what is included in the Zenith Model. With an understanding on how the architecture of the model sits together the set of recalibration and validation papers becomes more understandable and their intricacies in how they fit together to create a demand forecasting model.

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1 Introduction

This Technical Note is one of a series of papers that collectively describe the Zenith Transport Model. Zenith is a four step transport model, implemented in the OmniTRANS software package for a range of Australian cities and regions.

This Technical Note details the overall design and architecture of the Zenith model, including the representation of key drivers of demand within the model (e.g. population, demographics, land uses, transportation networks, etc.), the segmentation of travel into behaviourally homogenous groups, and the modelling processes used to reflect travel choices.

This note is logically read before any of the other technical notes.

1.1 Design Objectives

Zenith is a predictive model of travel within urban environments. The use of the word 'predictive' is key; the primary design objective of Zenith is to predict how people would respond (in terms of altering travel choices), if the urban environment were to change in some way.

The model is designed to be sensitive to the key factors which influence travel behaviour - its inputs - which include:

- **Population and demographics** – workforce participation, age profiles, car ownership levels, etc.,
- **The distribution of land uses** – including office blocks, factories, shops, schools, hospitals, airports, etc.,
- **The level of accessibility** – provided by the transportation network – including travel by car, public transport, walking, cycling, etc.
- **The price of travel** – including tolls, parking charges, fuel costs, public transport fares.

The output of the model – predicted travel demands in response to the model's inputs – can be summarised as follows:

- Predicted traffic volumes on each road link, by time of day and vehicle class,
- Predicted passenger loads on each public transport route / stop, by time of day,
- Predicted pedestrian and cycling demands on each link, by time of day,
- Estimates of travel demands between origin / destination pairs, by each travel market segment, mode and time of day,
- Estimates of travel costs between origin / destination pairs, by each mode and time of day.

By comparing the outputs between two modelled scenarios, the impact of changes to the travel environment can be evaluated and understood, for example:

- The impact of population growth, in terms of growth in demands, increased congestion, public transport crowding, etc.
- The impact of upgrading an existing road
- The impact of opening a new road
- The impact of tolls
- The impact of changes in fuel prices
- The impact of increasing transit service frequencies

- The impact of adding or removing transit services
- The impact of building a new railway line, or extending an existing one
- The impact of change in public transport fares, etc.

Delivering reliable and accurate estimates of these impacts is a key design objective of the model.

The model can also be used to estimate demand levels for new infrastructure and services, which can be used to perform financial and economic evaluations (e.g. toll roads, public transport services), as well as underpinning project design (e.g. decisions regarding road widths, transit vehicle sizing, transit station design).

1.2 Model Architecture

Zenith's high level architecture can be conceptualised in terms of three core elements:

- **The representation of the urban travel environment**, and the key drivers of travel behaviour within that environment – i.e. population, demographics, land uses, transportation networks, pricing, etc.
- **The segmentation of travel into behaviourally homogeneous groups** – resident / visitor / freight travel for a range of activities,
- **The modelling process** used to simulate travel choices within each segment.

1.3 Structure of this Document

The remainder of this document is structured as follows:

- **Section 2:** describes the overall approach to model development, including model estimation, calibration and validation.
- **Sections 3 to 5:** correspond to the key elements of the model's architecture, as outlined in the previous section. Section 3 details the model's inputs, Section 4 details the segmentation of travel, and Section 5 describes the modelling process.
- **Section 6:** summarises the model's limitations, many of which are mentioned throughout the document.

2 Approach to Model Development

2.1 Model Estimation

The Zenith models include numerous ‘parameters’ which are used to model the behaviour of trip makers within each of the model’s demand segments. These parameters include trip generation rates, segmentation parameters, period allocation factors, deterrence function parameters, modal constants, time weights, etc.

The vast majority of these parameters are statistically estimated using available data sources. The most useful data source for statistical estimation is household travel surveys, which include the recorded daily travel itineraries of thousands of surveyed households. The following household travel surveys have played a part in estimating Zenith’s parameters:

- SEQTS 1992
- SEQTS 2003
- SEQTS 2006
- VATS 1994-1997
- VISTA07
- VISTA09
- Sydney HTS 1999-2007

In developing Zenith models for numerous regions, the aim has been to develop transferrable models and parameters, which can be applied consistently across as many markets as possible.

This approach has proved generally successful, with “region specific” parameters only used in cases where it is justified by local evidence. In practice, the need for region specific parameters has been fairly limited, which provides supporting evidence for the idea of an Australia-wide model of travel behaviour.

2.2 Model Calibration

Calibration is the step of adjusting the model’s estimated parameters to improve the level of correlation between the model’s outputs, and observed measures of travel demand such as traffic counts, pedestrian counts, OD surveys, public transport patronage data, etc.

This step can help to correct for errors in the model’s parameters, either due to biases in the data used to estimate parameters, or errors due to sampling (e.g. resulting from small sample), or errors in model specification. In practice, household travel surveys do exhibit strong biases (e.g. under-sampling of off-peak travel), which amplify the importance of model calibration.

Generally speaking, minimal effort is required to calibrate Zenith models. We believe this to be a result of:

- The use of large sample household travel surveys, and the pooling of household travel surveys from multiple regions,
- Extensive efforts to understand and correct for biases in household travel surveys,
- Accurate input data – high quality, up-to-date data is reasonably accessible in Australia (e.g. ABS Census, road network data, transit network data, etc.),
- Robust model specifications.

When macro-level calibration is required, our general approach is to:

- Attempt, wherever possible, to understand and correct for any systematic sources of error. This often involves the creation of new travel market segments which are not well captured by household travel surveys (e.g. travel related to the construction of new homes)
- Globally increase or decrease trip rates (unless evidence exists to support differential factors by trip purpose), to globally boost or decrease travel
- Globally increase or decrease the distance weight by mode, which has the effect of marginally increasing or decreasing average trip lengths,
- Globally increase or decrease the amount of travel occurring in each period,
- Globally increase or decrease the access and transfer penalties for public transport sub-modes. This can help to achieve correctly balanced demands between sub-modes.

In terms of micro-level (local area) calibration, our approach is generally to:

- Check for errors resulting from the coding of travel zones, including incorrectly distributed land uses, centroid connector placements, etc.
- Check network coding – link attributes, transit stop placements, etc.

Zenith's model parameters are very rarely modified to achieve local area calibration.

Techniques such as matrix estimation are not used in the calibration of Zenith, for the following reasons:

- In our experience, the process of manually exploring differences between counts and the model's predictions is valuable, and leads to new insights regarding the model's limitations, and drives further innovation in the model's development. It can also help to uncover errors in counted data!
- In our experience, errors are often the result of incorrect coding of the model's inputs. Implementing matrix estimation would not correct this error, but would instead compensate one error by creating another,
- In our experience, Zenith models achieve an acceptable level of accuracy without the use of matrix estimation.

2.3 Model Validation

Model validation is the independent assessment of model accuracy and validity, using data which was not used to develop, estimate or calibrate the model.

When performing statistical estimation (e.g. using household travel surveys), internal cross validation is used to assess the model's predictive accuracy. This is particularly important when selecting between models, or evaluating the inclusion of extra parameters, or in choosing between alternative model specifications.

A second method of validation is to compare outputs of the base year model with observed measures of travel demand, including traffic counts, pedestrian counts, and public transport patronage data.

The drawback of this approach is that generally the entire count database has already been used during the model calibration step. As such, one would expect the model's outputs to correspond well to counts, at least in aggregate.

A third method for validating the model is to use the model to predict demands for infrastructure under construction, and to then compare the model's prediction with the post-opening demands. This form of validation hasn't been pursued extensively in the past, due to the difficulty of separating model accuracy from the accuracy of model inputs (i.e. a perfectly accurate model will still produce forecasting errors due to errors in the demographic / land use forecasts used as input to the model). Despite these difficulties, this is an area that should be actively pursued in the future.

Overall, completely independent model validation is difficult to achieve, and in practice we find that the best (current) approach is to avoid techniques such as matrix estimation, avoid over-manipulation of the model's inputs, and present comparisons of the model's outputs with counts in an open and objective manner.

3 Representation of the Urban Travel Environment

3.1 Population, Demographics and Land Use

Demographic and land use data are the most important inputs to the Zenith model. In particular, these data determine the scale and type of activities occurring at each location, which directly affect the number of trips produced and attracted by each travel zone.

Demographic and land use variables are defined per travel zone, and typically include:

Resident Population & Demographics

- Population
- Households
- Average household size (Population / Households)
- Average number of **white collar workers** per household
- Average number of **blue collar workers** per household
- Average number of **dependants aged 0-17** per household
- Average number of **dependants aged 18-64** per household
- Average number of **dependants aged 65+** per household
- Average number of **motor vehicles owned (excluding motorcycles)** per household

Visitors

- Number of **Australian visitors** staying overnight
- Number of **Overseas visitors** staying overnight

Land Use

Employment by Industry

- Total number of **agriculture** jobs
- Total number of **mining** jobs
- Total number of **manufacturing** jobs
- Total number of **electricity, gas & water** jobs
- Total number of **construction** jobs
- Total number of **wholesale** jobs
- Total number of **retail** jobs
- Total number of **recreation & personal services** jobs
- Total number of **transport & storage** jobs
- Total number of **communications** jobs
- Total number of **financial & business** jobs
- Total number of **public administration** jobs
- Total number of **community service** jobs

Employment by Occupation

- Total number of **white collar** jobs
- Total number of **blue collar** jobs

Education Enrolments

- Primary school enrolments
- Secondary school enrolments
- Tertiary education enrolments (equivalent full time)

Special Generators

- Port – freight trip ends
- Airport – passengers by journey type
- Recreation – trip ends generated by casinos, theme parks, beaches, etc.

3.2 Transportation Networks

This section describes the way in which transportation networks are represented in the Zenith models.

3.2.1 Road Networks

The Zenith model includes a link based representation of the road network. The key attributes defined for each link are:

- Length
- Link type – defines the set of modes permitted to use the link, and a family of speed-flow curves for modelling the relationship between demand and average travel speed,
- Free-flow speed – defines the expected average travel speed under un-congested conditions. Can vary by vehicle class (e.g. car, heavy truck, etc.), and modelled period.
- Capacity – the estimated hourly link capacity. Strictly speaking, the capacity is defined as the hourly traffic volume at which the travel speed is half of the free-flow speed. Capacities can vary by modelled period.

Zenith does not currently include junction delays. Instead, the effect of junction constraints is included implicitly in link free-flow speeds and capacities.

Turn bans and tolls are also definable, and can be varied by vehicle class and modelled period.

3.2.2 Transit Networks

The Zenith model includes a frequency based representation of public transport services.

The key attributes of public transport routes and stops are as follows:

Public transport routes

- **Mode –** rail, bus, tram, etc.
- **Frequency –** hourly operating frequency. Can vary by model period
- **Number of seats** – the number of seats per vehicle, averaged over all of the runs of the service. Can vary by modelled period
- **Crush capacity –** an estimate of crush capacity per vehicle, averaged over all of the runs of the service. Can vary by modelled period
- **Fare system** – each route can be assigned to a user defined fare system
- **Stopping pattern** – the list of stops where passengers of the route can board & alight. A stop can be marked as “board only”, or “alight only”

Public Transport Stops

- **Stop group** – typically rail / tram / bus / ferry. This attribute is used in the Transit Assignment sub-model to group stops into nests
- **Fare zone –** for zonal fare systems, each stop is allocated to a fare zone

3.2.3 Pedestrian and Cycling Networks

The Zenith model includes walking and cycling links where appropriate.

3.3 Pricing

The Zenith model includes the following monetary costs of travel:

- Tolls
- Fuel
- Parking charges
- Public transport fares

Tolls and public transport fares are included in the traffic and transit assignment models respectively, and feedback to affect choices of destination and mode.

Fuel costs and parking charges are assumed not to affect route choice (they are excluded from the traffic assignment model), but they are included when determining choices of destination and mode.

4 Segmentation of Travel and Activities

This section describes the segmentation of travel demands used in Zenith.

Segmentation is the process of dividing the total travel market into smaller groups that behave in a more-or-less homogeneous way. Each segment is assigned a unique set of model parameters which reflect the idiosyncratic behaviour of that segment.

In Zenith, travel is segmented along three dimensions:

1. **Travel market** (residents, visitors, freight, special generators)
2. **Travel Activity** (work, shopping, education, etc.)
3. **Household Car Ownership Level** (0,1,2,3+)

Section 4.1 briefly discusses the meaning and importance of each dimension, while Sections 4.2 to 4.5 explore the segmentation of travel for each component of the total travel market (e.g. residents, visitors, freight, special generators.)

4.1 Segmentation Dimensions

4.1.1 Travel Market

The total urban travel market comprises several distinct components:

- Resident travel
- Visitor travel
- Freight travel
- Travel related to Special Generators (e.g. airport, port, externals)

Each travel market is unique in terms of its source (residential dwellings, hotels, firms, etc.), its participation in various activities (work, education, shopping, transfer of goods, etc.), and its particular temporal and modal behaviours.

Sections 4.2 to 4.5 are dedicated to each of the 4 travel markets.

4.1.2 Travel Activity

For models to be effective in strategic transport planning, it is essential that they can forecast the level of participation in a range of activities as the basis for estimating travel demands and reflecting travel behaviour.

Travel choices may differ depending on the activity for which the travel is undertaken. The nature of the activity may influence the frequency, timing and duration of participation, the location, as well as the mode of travel and in some cases, the route chosen.

Travelling for shopping or recreation is likely to lead to a different decision context than for commuting to work, for example. Models which do not reflect these differences will produce less accurate forecasts of travel behaviour when significant changes occur to the land use and transport system. The Zenith models identify a set of activities that distinguish the most significant influences on travel behaviour and preferences. This requires that separate travel demand models are specified and applied for each activity identified, including those for trip generation, choice of period, destination and mode.

An indication of the range of activities for which travel is undertaken can be obtained from interviews with travellers, who are asked to describe their recent travel choices and purposes. The Household Travel Surveys (HTS) now conducted in all states are the most comprehensive and reliable source of this information available for this purpose.

The set of main activities chosen to differentiate travel demands in the current Zenith model are:

- Work
- Education
    - Primary (childcare and school)
    - Secondary
    - Tertiary
- Shopping and personal business
- Recreation and social
- Other (including serving the travel needs of another person)

4.1.3 Household Car Ownership

Car availability is a major influence over several key aspects of travel behaviour, especially trip frequency, choice of destination and choice of mode.

It has been found during model development in all Australian cities that segmenting travel by car ownership level, prior to destination and mode choice, significantly increases the accuracy of the resulting models - by acknowledging that households with limited private motor vehicle access are also likely to display atypical destination and mode choice decision-making behaviour.

4.2 Resident Travel

4.2.1 Resident Activities

The Zenith model includes the following resident activities:

Table 4.1: Resident Activities

Activity Code	Activity Description
Home	At home, or someone else's home
White Collar Work	Working away from home – white collar
Blue Collar Work	Working away from home – blue collar
Shopping	Shopping & personal business
Recreation	Social & recreation
Education – Primary	Education – primary
Education – Secondary	Education – secondary
Education – Tertiary	Education – tertiary
Other	Serving the needs of a passenger / accompanying someone

4.2.2 Resident Trip Purposes

Every trip links two activities – e.g. travelling from home to work, or from work to home, or from recreation to shopping, etc. Each combination of activities is assigned a specific *trip purpose*. Trip purposes are a key mechanism by which travel is segmented.

4.2.2.1 Home Based Travel

Trips where at least one end is the activity 'home' are referred to as Home Based trips. The non-home end determines the *purpose* of the trip, with the activities joined by the word 'Based':

- Home Based Work - white collar
- Home Based Work - blue collar
- Home Based Shopping
- Home Based Recreation
- Home Based Education – Primary
- Home Based Education – Secondary
- Home Based Education – Tertiary
- Home Based Other

Home Based Travel is segmented by each of the above trip purposes.

Note that the word 'Based' does not mean: 'To'. In other words, Home *Based* Shopping does not mean Home *To* Shopping. Instead, the word 'Based' is bi-directional, with *home to shopping* and *shopping to home* trips both referred to as *home based shopping*.

Strictly speaking, the convention for defining trip purposes is:

Production Activity **Based** *Attraction Activity*

Production and attraction and activities are defined hierarchically, using the ordering of activities in Table 4.1, above. Given a journey linking two activities, the activity which appears highest in the list is the production activity.

Directionality of travel (ie. the distinction between 'home to shopping' and 'shopping to home') is not specified by the trip purpose. Instead, trips are assigned a separate attribute - *direction* – which can take two possible values:

- Production to attraction
- Attraction to production

Every trip has both a trip purpose and a direction.

Segmentation by Car Ownership Level

In addition to trip purpose, home based trips are segmented by the number of cars (strictly, motor vehicles excluding motorcycles) owned by the household making the trip.

The levels of car ownership are assumed to be: 0,1,2,3+.

The dual segmentation of home based trips by 8 trip purposes and 4 car ownership levels leads to a total of 32 home based travel market segments.

4.2.2.2 Non-Home Based Travel

Non-home based trips are those where neither end is the activity 'home'. With 6 non-home activities, there are potentially 21 unique non-home based trip purposes (6 + 5 + 4 + 3 + 2 + 1). This is deemed too many to reliably estimate, and so some activities are grouped prior to the construction of non-home based trip purposes.

Table 4.2: Grouped Activities for Non-Home Based Travel

Activity Code	Grouped Activity Code (for non-home based travel)
White Collar Work	Work
Blue Collar Work	Work
Shopping	Shopping
Recreation	Shopping
Education – Primary	Other
Education – Secondary	Other
Education – Tertiary	Other
Other	Other

The use of 3 grouped activities leads to the following 6 non-home based trip purposes:

- Work Based Work

- Work Based Shopping
- Work Based Other
- Shopping Based Shopping
- Shopping Based Other
- Other Non-Home Based

Non-home based travel is not segmented by car ownership level.

4.3 Visitor Travel

Visitors are persons staying overnight in the modelled area at a place that is not their main place of residence.

This can include:

- Residents of the modelled area staying overnight at a hotel or a friend's place,
- Visitors who live in Australia, but outside of the modelled area, who are staying overnight in the modelled area,
- Visitors from overseas, staying overnight in the modelled area.

4.3.1 Visitor Activities

Visitors are assumed to participate in the following four activities:

Table 4.3: Visitor Activity Codes

Activity Code	Grouped Activity Code (for non-home based travel)
Visitor Home	At the visitor's place of accommodation
Shopping	Shopping & personal business
Recreation	Social & recreation
Other	Education, serve passenger, accompany someone

4.3.2 Visitor Trip Purposes

For trips where one end is the visitor's place of accommodation, we have the following trip purposes:

- Visitor Home Based Shopping
- Visitor Home Based Recreation
- Visitor Home Based Other

All other trips are assigned the trip purpose:

- Visitor Non-Home Based

4.4 Freight

The Zenith models include three freight segments: light trucks, heavy trucks, and trucks related to the Port (trucks related to the port are a special generator as will be described in the following section). A general overview of the Zenith Freight model is found in Section 5.1.2, with further detail available in Freight specific technical notes.

4.5 Travel Related to Special Generators

In addition to the activities and travel outlined above, there are a range of activities that generate significant levels of travel demand, unrelated to the level of employment or other land use variables from which demands could be estimated. Travel behaviour associated with these activities is generally not consistent with that of residents participating in the normal range of activities within the region, and needs to be accounted for on a case-by-case basis. The special generators typically included in Zenith models are:

- Airports
- Ports
- Special recreation
- Externals

4.5.1 Airports

Airport travel is segmented according to the activity to which the airport is linked. The three segments are:

- Airport Based Home – travel between residential homes and the airport
- Airport Based Visitor – travel made between visitor accommodation and the airport
- Airport Based Work – travel made between the airport and work places

These segments include travel made by resident air passengers, visiting air passengers, and meeters & weepers.

4.5.2 Special Recreation

The Zenith models identify a range of recreational activities that generate significant levels of travel demand which cannot be related directly to the scale of employment.

These recreational activities include venues hosting major events, casinos, theme parks, beaches, national parks, etc.

Special recreation travel is divided into three segments:

- Special Recreation Based Home – travel made between residential homes and special recreation.
- Special Recreation Based Visitor Accom – travel made between visitor accommodation and special recreation.
- Special Recreation Based Special Recreation – travel made from one special recreation generator to another (e.g. beach hopping).

4.5.3 Ports

Ports are a special generator of freight vehicles. Because freight generation at ports differs so markedly from regular land uses, the number of trips to and from the port is defined exogenously, as a user defined input.

All port related travel is part of the segment: 'Port CV'

4.5.4 Externals

Trips which originate (or are destined for) regions outside the modelled area are referred to as external trips. Given that all other trips (resident trips, visitor trips, etc.) are assumed to occur within the modelled area, the model will naturally under-estimate travel crossing its boundary points. This can lead to major distortions and errors in areas near to the model boundary.

While distortions near the model boundary are unavoidable, the effect of errors further away from the boundary (due to long distance external travel such as heavy freight) can be mitigated through the inclusion of special external generators at major links entering and leaving the modelled area.

Zenith models typically include two external segments:

- External Car
- External Truck

5 Modelling of Travel Choices

This section describes the travel modelling process in some detail, but without the inclusion of mathematical formulae. More detail, including the mathematical formulation, is available in the suite of technical notes which accompany this overview.

5.1 Structural Overview

5.1.1 The Standard Zenith Model Process

The "Standard Zenith Model Process" is presented in Figure 5.1 below, and consists of 9 sub-models (the blue boxes), with the output of each sub-model becoming the input to the next.

The Standard Model Process is applied to all multi-modal travel market segments – this naturally excludes freight and externals, which are described in the following sub-section.

Conceptually, the model expresses travel as a series of choices. Expressed as a series of personal choices, we have:

- How many trips for each activity (e.g. work, shopping, education, etc.) will I make today? *(Trip Generation Sub-Model)*
- To where will I make each trip? *(Destination Choice Sub-Model)*
- At what time will I make each trip? *(Period Allocation Sub-Model)*
- By what mode will I make each trip (e.g. car, public transport, walk, etc.)? *(Mode Choice Sub-Model)*
- What route will I take for each trip? *(Traffic and Transit Assignment Sub-Models)*

The household segmentation and travel market segmentation models support the above process by segmenting households and trips into groups that respond to the above choices in a relatively homogeneous way.

In all models except Victoria and ACT, Zenith is trip-based (each trip is modelled independently). This limits the extent to which the model can explicitly consider joint decision making between household members, and the linkages between trips made by an individual (ie. trip tours). The Victorian and ACT models explicitly considers return journeys, but does not include more complex tours.

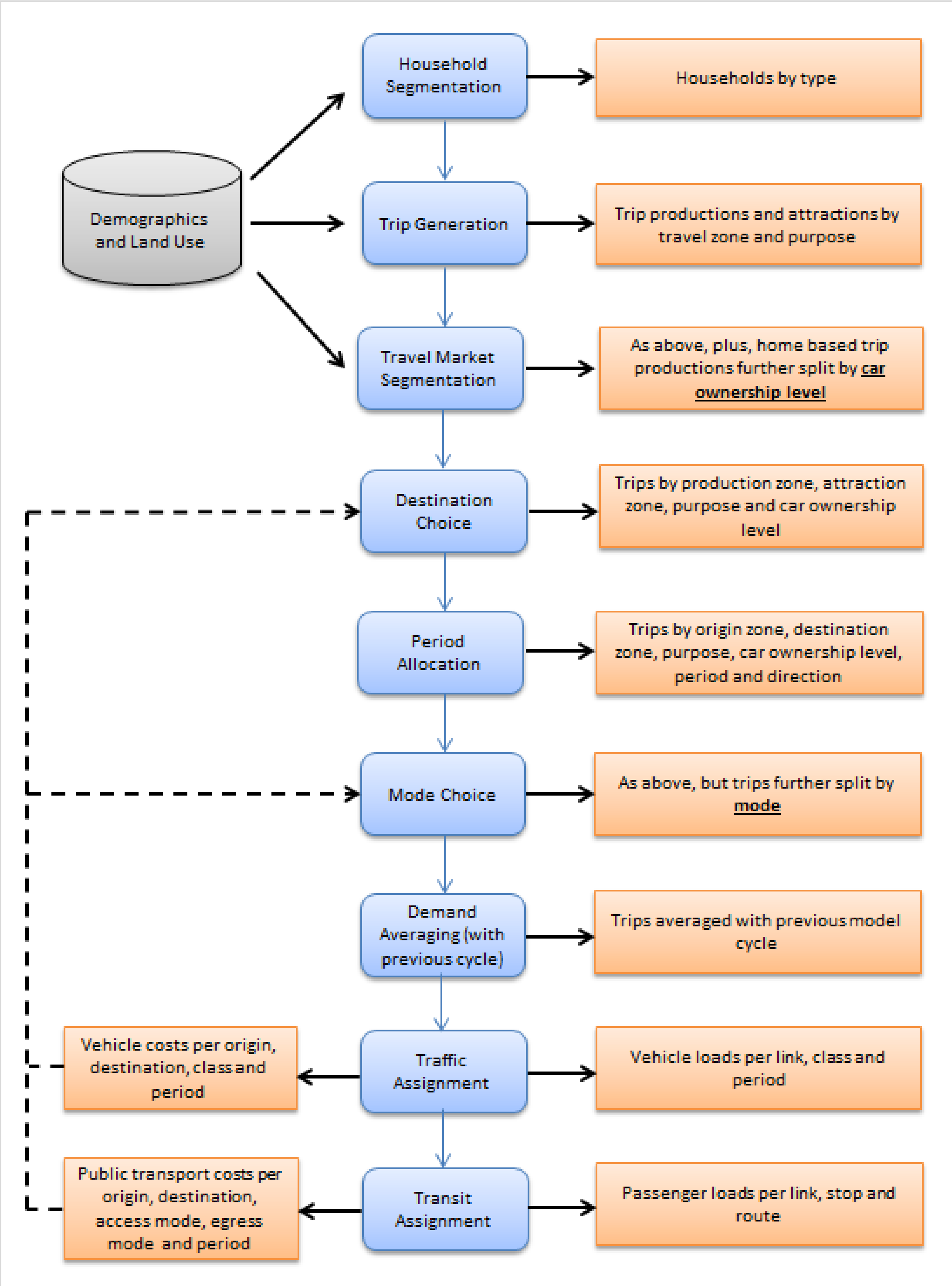
The ordering of destination, period and mode choices is fixed for all travel market segments, with destination choice occurring first, followed by period allocation and mode choice.

Period allocation is not currently a modelled "choice"; rather, fixed proportions of demand are assigned to each combination of period and direction (the directions are: production => attraction and attraction => production). Separate proportions are defined for each travel market segment.

The overall model structure is cyclical, with travel costs from the traffic and transit assignment models feeding back to the destination and mode choice models. Estimates of travel costs fluctuate between cycles of the model, due to fluctuations in the modelled levels of traffic congestion and public transport overcrowding. As such, the model is run iteratively until a satisfactory level of convergence is achieved, ensuring consistency between choices of destination, mode and route.

Each of the key sub-models is described in further detail in Sections 5.2 through 5.2.9. More detail (including mathematical formulations) is available in the suite of technical notes which accompany this overview.

Figure 5.1: Standard Zenith Model Process

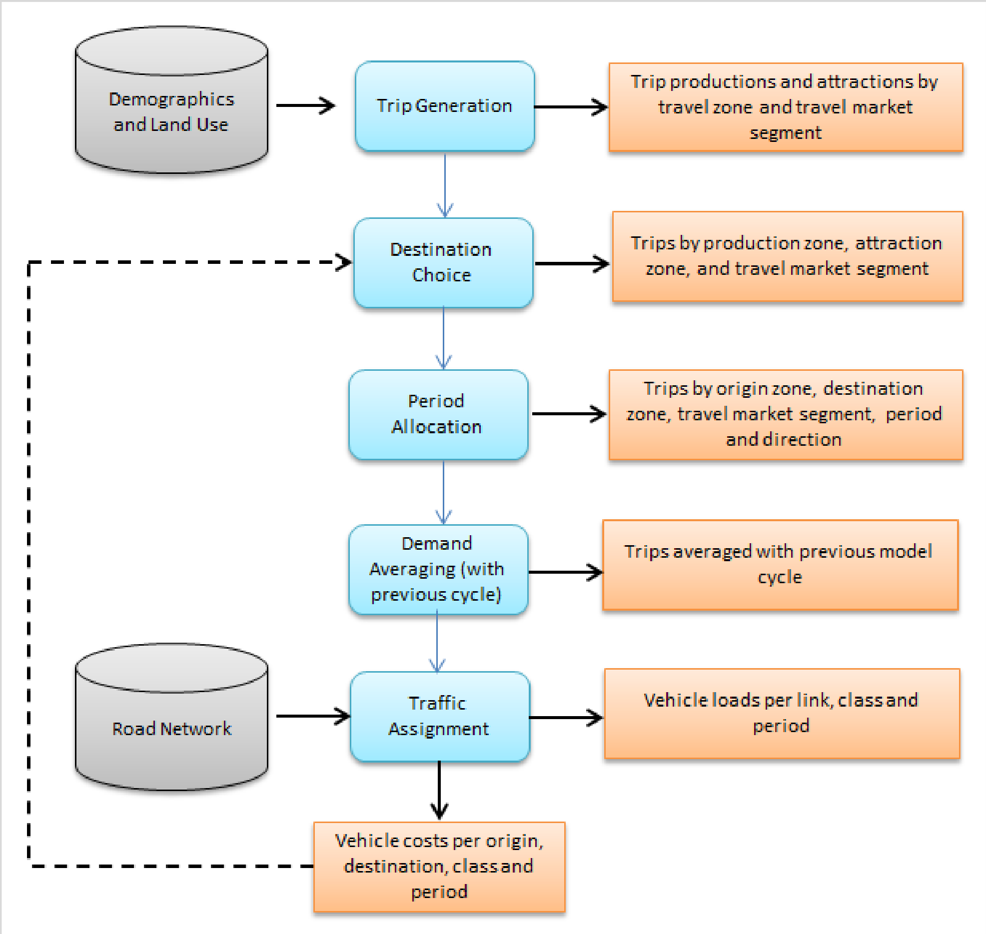


NB: The Zenith model consists of 9 steps, with the output of each step used as input to the next. The Transportation Network (input to Traffic and Transit Assignment) has been left off this diagram due to a lack of space.

5.1.2 The Freight and External Model Process

The modelling process for fixed mode segments (freight and externals) is presented in Figure 5.2, below. The modelling process is somewhat simplified, with key steps such as mode choice and transit assignment removed.

Figure 5.2: The Freight and External Zenith Model Process



NB: Compared with the Standard Zenith Model Process, the modelling of freight and externals excludes the Household Segmentation, Travel Market Segmentation, Mode Choice and Transit Assignment sub-models. Otherwise, the same modelling process is employed.

5.2 Component Sub-Models

This sub-section describes the component sub-models which make up the overall Zenith model process. A high level overview of the key features and limitations of each component is provided. More detail, including mathematical formulations, is reserved for the technical notes which accompany this overview.

5.2.1 Household Segmentation

The aim of the Household Segmentation model is to segment households according to their level of an attribute (eg. level of car ownership), given an average (zonal) value for that attribute.

Segmentation models have been developed for each of the attributes listed in Table 5.1.

Table 5.1: Segmented Household Attributes

Household attribute	Description	Levels
Persons	Number of persons resident in household	1, 2, 3, 4, 5, 6+
Workers (White Collar)	Number of workers employed in 'white collar' occupations	0, 1, 2, 3+
Workers (Blue Collar)	Number of workers employed in 'blue collar' occupations	0, 1, 2, 3+
Dependents (0-17)	Number of non-workers aged up to 17 years	0, 1, 2, 3, 4+
Dependents (18-64)	Number of non-workers aged 18 to 64 years	0, 1, 2, 3+
Dependents (65+)	Number of non-workers aged 65+ years	0, 1, 2+
Cars	Number of private vehicles	0, 1, 2, 3+

The models are derived from ABS Census data at CCD/SA1 level and applied in forecasting mode at zonal level.

Note that the households are segmented along each attribute independently, such that the joint distribution of households across multiple attributes is not calculated.

The household segmentation model is best illustrated through an example. Given a travel zone with 100 households, and an average car ownership level of 1.3, the Victorian Household Segmentation model outputs the following segmentation of households by discrete car ownership level (0,1,2,3+):

- Count of HH with 0 cars: 15.5
- Count of HH with 1 car: 48.5
- Count of HH with 2 cars: 28.3
- Count of HH with 3+ cars: 7.7

The same process is applied independently for the other 6 attributes.

The motivation for segmentation is two-fold:

- The use of segmented households results in a more accurate trip generation model,
- It would be impractical for the modeller to define segmented households as a model input. Therefore, we need a model that reliably converts averages (e.g. average household size), into distributions.

5.2.2 Trip Generation

The Trip Generation model takes zonal demographic and land use variables as input (including the segmented households described above), and outputs estimates of trip productions and attractions for each trip purpose.

The production and attraction functions are all linear in the model's parameters. Nonetheless, non-linear effects are accounted for (in home based trip productions) by dummy coding the discrete levels of the household attributes listed in Section 5.2.1.

An advantage of the linear model structure is that the model can be applied equivalently to disaggregate (ie. individual household) and aggregate (ie. travel zone) level input data.

It is also worth noting that the model outputs the *expected* number of trips produced or attracted by each household or travel zone. This is in contrast to some models which output a trip frequency distribution per household.

5.2.3 Travel Market Segmentation

The aim of the Travel Market Segmentation model is to further segment home based trip productions by the level of household car ownership.

The model calculates the split between car ownership levels separately for each travel zone and each purpose, taking into account the average level of car ownership of the households residing in the travel zone.

The model is applied to home based trip purposes only, as the model does not have direct access to information about the car ownership of households making non-home based trips.

5.2.4 Destination Choice

The Destination Choice model probabilistically assigns a destination to each trip production, by calculating choice probabilities for each alternative destination. The model takes into account the relative level of attraction of each destination (as output from the Trip Generation model), together with the *expected generalised cost* of travel to each destination (from the fixed origin of each trip production).

The expected generalised cost is specific to the travel market segment (purpose & car ownership level), and is a daily composite including all modes of travel. It is calculated as a function of the generalised cost by all modes of travel at all times of the day.

The destination choice model is production constrained.

5.2.5 Period Allocation

The Period Allocation model probabilistically assigns a period and direction to each trip.

The Zenith models typically include 3 periods, though the Victorian model includes 4. The period definitions are provided below.

Three Period Definition

- AM Peak – 7-9am
- PM Peak – 4-6pm
- Off Peak – the rest of the day

Four Period Definition (Victoria only)

- AM Peak – 7-9am

- PM Peak – 4-6pm
- Inter-peak – 9am-4pm
- Off peak – the rest of the day

Zenith models also include two directions:

- production to attraction, and
- attraction to production

Combining periods with directions, and there are there are 6 distinct period / direction combinations (8 in Victoria).

The input to the Period Allocation model is the output from the Destination Choice model: trips by OD, in P->A form (production to attraction).

The output is trips by OD, by period, and by direction.

The Zenith model uses fixed proportions for each period / direction, by trip purpose. As such, the model is not yet capable of modelling peak spreading.

5.2.6 Mode Choice

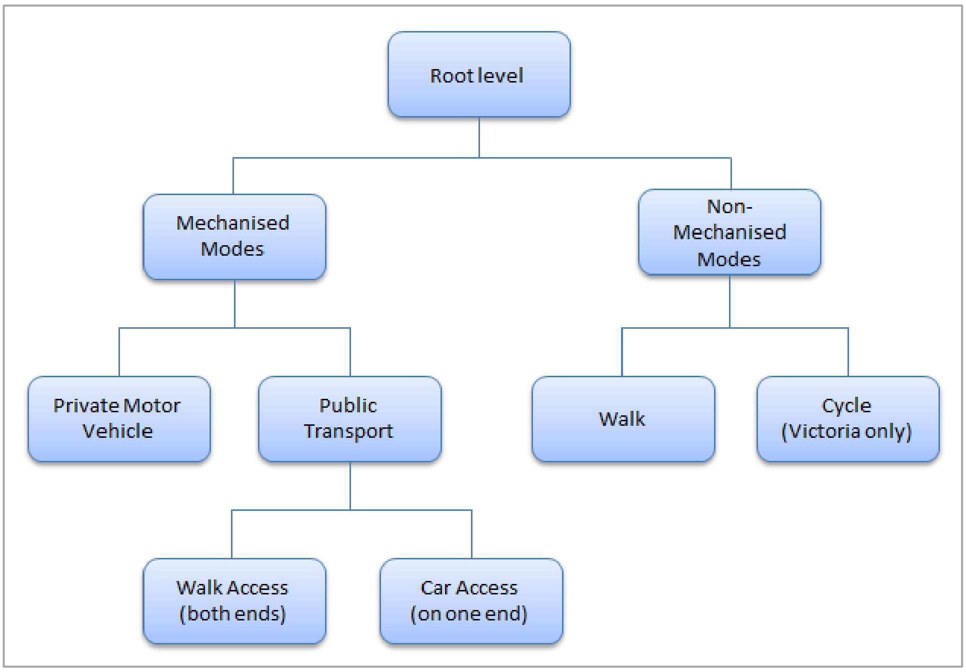
The Mode Choice model follows the period allocation model, and probabilistically assigns a mode to each trip.

Because each trip already has a defined period / direction, the modal choice probabilities depend specifically on the generalised cost of each mode during the defined period. This is important given that the level of service provided by the various modes varies during the day. Public transport is typically most attractive during peak times, when services run with high frequency; conversely, travel by car is generally least attractive during the peaks due to increased travel times resulting from traffic congestion.

The mode choice model also calculates the choice between public transport access and egress modes – for example, walk and car. For car access or egress trips, the car leg is assumed to occur at the production end of the journey.

The Zenith mode choice model employs a variety of nesting; one such example is:

Figure 5.3: Mode Choice Nesting Structure



5.2.7 Demand Averaging

Model convergence is achieved faster through the use of *averaging* between model cycles. Various averaging techniques exist, most of which apply the method of successive averages to one of the model's outputs – typically loads / costs or demands. In Zenith, the demands output from mode choice are averaged with those from the previous cycle, prior to being assigned.

5.2.8 Traffic Assignment

The Traffic Assignment model is responsible for assigning routes to all car and freight trips.

In the absence of tolls, drivers are assumed to minimise travel time. However, when the minimum travel time route is a tolled route, the model calculates a probability of using the tolled route, depending on the level of toll, the purpose of the trip, and the travel time saving compared with the fastest non-tolled route.

If there are several tolled alternatives which each provide a travel time saving compared with the fastest non-tolled route, then the model calculates a choice probability for each tolled alternative. A nested logit model is employed, with all of the tolled alternatives grouped into a single nest.

The model takes account of congestion by reducing link speeds as demand increases. The model does not include junction delays, but does include banned turns.

The traffic assignment model is iterative, with a feedback loop to reflect changes in modelled travel times (related to changes in traffic congestion). Zenith employs a volume averaging technique to combine loads from the various iterations. The asymptotic solution of the volume averaging technique is consistent with the principles of Wardrop's equilibrium.

5.2.9 Transit Assignment

The Transit Assignment model is the final step in the model, and is responsible for assigning routes to all public transport trips.

The algorithm is multi-path, probabilistically assigning demands to a mixture of boarding stops, routes, and transfer and egress options.

The model takes into account walking time, driving time, modal access / egress penalties, transfer penalties, waiting time, in-vehicle time by mode, fares and crowding.

The travel times of vehicles running on-road (busses, trams, cars), are dependent on the congested traffic speeds output from the Traffic Assignment model.

The transit assignment model is multi-class, with each class corresponding to the use of a specific access / egress mode combination. Zenith models typically include three classes:

- Walk access / walk egress
- Car access / walk egress
- Walk access / car egress

The transit assignment model optionally includes the effect of service over-crowding, which impact upon route and stop choices, as well as choices of destination and mode. When crowding is “switched on”, the transit assignment model becomes iterative, which can greatly increase run time. As such, crowding is typically only switched on as needed.

6 Model Limitations & Conclusions

Despite the comprehensive nature of the model specification, there are numerous limitations which should be considered when interpreting the model's outputs, and when deciding if Zenith is an appropriate tool for a specific application.

In considering these limitations, note that all models are by definition simplifications of real world processes, and that the bulk of these limitations are shared by most strategic transport models.

The model's limitations key limitations are as follows:

- Limitations resulting from biased or inaccurate input data
  - Biases in household travel surveys can lead to biased models,
  - The model is reliant on forecasts of demographics and land use as an input. Errors in these forecasts (which are inevitable), will lead to errors in the model's forecasts,
  - The model is reliant on forecast prices, including the price of fuel, parking, public transport fares and tolls. Errors in these forecasts (which are inevitable) lead to errors in the model's forecasts,
- Limitations resulting from a simplified representation of the real-world,
  - The traffic assignment model is link based (doesn't model junctions)
  - The traffic assignment model treats each link independently, and does not include the effect of queues which propagate from one link to another,
  - The transit assignment model is frequency based (doesn't consider the exact timetable)
  - Households and firms are spatially grouped into travel zones
  - Household and firm attributes are limited to those which can be reliably sourced and maintained for the base year, and which can be reliably forecast
  - The model necessarily has a boundary, yet the real world does not,
- Limitations resulting from simplified models of travel choices
  - Trips are allocated to periods using fixed proportions, such that the model cannot currently be used to predict peak-spreading,
  - Joint decision making among household members is not explicitly modelled, except in Trip Generation,
  - Each trip is modelled independently. Therefore, the model ignores linked decisions relating to multiple trips (e.g. trip tours),
  - The discrete choice models employed in Zenith are typically nested logit. Nested logit models include fixed point parameters, and thus ignore the heterogeneity which might exist in the value of each parameter within the population,
  - The traffic assignment model assumes perfect information regarding the estimation of travel times,
- Limitations resulting from the projection of current travel behaviour and processes
  - Generally speaking, it is assumed that the underlying mathematics of travel behaviour (model structures, parameters) will continue to reflect travel behaviour in the future. This ignores potential changes in travel behaviour which might result from, for example, increased tele-commuting.
  - The model does not make any assumptions about major technological changes which might impact upon the way in which travel is undertaken in the future