



PATREC

Planning and Transport Research Centre (PATREC)

FINAL REPORT

TRANSPORT MODELLING REVIEW: INDEPENDENT REVIEW

Submitted to	Transport Modelling Review Working Group (DoP, DoT and MRWA)
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EXECUTIVE SUMMARY

Purpose

This Transport Modelling Review Report examines the transport modelling practices in Perth, Western Australia and benchmarks them against best practice in Australia and overseas. It offers a framework for the evaluation of modelling approaches, a comparison of the two current transport models STEM and ROM24 and other practical approaches around the world, analyses three possible options for model development in WA, and suggests a pathway for a new best practice approach.

Background

This Report was prepared in accordance with the Project Proposal and the Project Plan prepared by the Transport Modelling Review Team in response to the Scope of Work prepared by the project Steering and Working Groups, comprising members from Main Roads WA (MRWA), the Department of Transport, the Department of Planning, the Public Transport Authority and Treasury. The Scope of Work was prepared on the basis of an intensive engagement process with all transport-modelling stakeholders to identify needs and gaps. The Planning and Transport Research Centre (PATREC) was appointed to undertake the research, commencing on 18 November 2013.

Approach

This Report includes information from the previous four interim and progress reports and has the following structure: Section 2 is a brief review of the perceived modelling needs and gaps. The report first addresses land use, as the basis for the transport system and the potential for interactive land use-transport modelling (Section 3). Best practice in transport modelling is presented in Section 4. The Report continues with the description of three feasible options (Sections 5-7), data requirements and validation (Sections 8-9). The comparison of the options and the steps required for the development of the recommended strategy are included in Sections 10-11. The use of resources and well as potential implementation issues close the report (Sections 12-13). The Report also includes a number of Annexures, where detailed supporting information is provided.

Key needs and gaps, identified from the reports detailing the results of an intensive engagement process with transport modelling stakeholders, provided to the PATREC Transport Modelling Review Team, are presented in Section 2 and can be summarised as:

- Land use - transport feedback;
- Disaggregation and segmentation – scale, zonal, socio-economic and modal attributes;
- Behavioural foundation and responses to policies and demand management measures; and
- Incorporating dynamics (treatment of time).

The analysis of the best practice ('best production models'), discussed in Section 4 of this Report, highlighted a number of commonalities, which were summarised as assessment criteria and further used in this Review to assess the current modelling options in Perth and recommend a development strategy.

They are:

- Land use and transport models directly interacting;
- Tour-based trip modelling;
- Simultaneous mode and destination choice giving logsum benefits;
- Time of day modelling taking account of peak spreading;
- Static traffic assignment as a base case;
- Mesoscopic traffic assignment;
- Hybrid mesoscopic and microscopic modelling; and
- Increased focus on detailed modelling of traffic streams.

Findings

Three feasible options for development were identified:

1. To continue the current development of both STEM and ROM24 models, attempting to improve their integration, rather than pure parallel development, duplicating many tasks;
2. To develop a model that takes the best features of the current two models plus additional best practice developments;
3. To develop a new best practice model, with strong feedbacks from the transport model to the land-use model and from the dynamic traffic assignment to the previous stages of the strategic model, also integrating the freight component.

Pursuing each of these options poses certain challenges, either in addressing the local needs or in terms of resources allocation, as discussed in Sections 5-7.

Recommendations

This Transport Modelling Review recommends option 3 as the solution for addressing the modelling needs in WA and describes the features of this new best model (called PLATINUM – **Perth LAnd and Transport INtegrated Urban Model**) in Section 10. PLATINUM is in fact a system of models, closely coupled and exchanging information among them, comprising:

- Pt_STM: the Perth Strategic Transport Model, a five-step tour-based multi-modal transport model, supported by a land use model and outputting to a regional impacts model. This is the component of PLATINUM for use in long range planning, scenario analysis and system wide transport policy analysis;
- Pt_RTM: the Perth Road Transport Model, a hybrid meso-micro assignment model of the metropolitan road network including all road-based travel by time of day, and delivering results to a local area impacts model. This model provides enhanced capability for modelling assistance in road project planning and evaluation, traffic management and control, congestion management, local area traffic impacts, event planning and incident management planning;
- Pt_XTM: the Perth External Travel Model (fed by the WA Statewide Transport Model);
- Pt_FTM: the Perth Freight Transport Model, made up of an improved FMM and a separate model for light goods vehicles (LGV).

The links between the models emphasise the level of integration. Pt_STM would provide road passenger/vehicle O-D matrices, by time of day and for planning horizon years as required by MRWA, to Pt_RTM. Pt_RTM would consider this data as well as freight vehicle and external vehicle trip matrices from Pt_FTM and Pt_XTM. In 'return', Pt_RTM can provide

Pt_STM with information on network travel times, delays and queuing for use in the strategic modelling as required.

Development of such a suite of models requires: a) *specification or re-specification of several current model components and alignment of data* (consolidate the current 1,500 zones STEM and ROM24 networks, document, unpack/revise MLUFS); b) *enhancements to the current models* (higher granularity in capturing travel behaviour through additional household types, travel purposes, by time of day, using tours instead of trips, and updating parameters of the mode choice model (including travel time variability, crowding and perhaps estimating new models of destination choice); and c) *creation of new component models* (including departure time, using a hybrid meso-micro dynamic traffic assignment model of all road-based travel by time of day, considering quasi-dynamic traffic assignment as a better starting point for mesosimulation, a new model assessing wider benefits of projects, feedback to land-use, and authentic integration of all components).

The way forward

With these specifications, PLATINUM is expected to be highly responsive to policy changes, provided that the data associated with the model is secured. The timing of the next Perth and Regions Travel Survey (PARTS) and of the Commercial Vehicles Survey (CVS) will have a bearing on model development and the extent to which the PLATINUM model enhancements and new components will be ready for integration. Related to this, calibration and validation of all model components, essential for model credibility (making sure it will produce appropriate responses), may be impacted by data availability.

Although substantial additional resources are required to meet the new model requirements (a number of 16 FTE is suggested based on the set of implementation activities and extra support during the transition phase), this approach will maximise the use of available modelling resources, provide a greater span in modelling capability and the opportunity to extend that capability to meet future modelling challenges in WA.

GLOSSARY OF TERMS [Traffic Assignment]^{1,2}

- **Dynamic traffic assignment:** Traffic assignment models that are time-dependent and account for the continuous modifications of travel conditions over the duration of a journey. They are generally applied at a fine level of detail of a network. **Wardrop equilibrium for dynamic traffic assignment:** Under equilibrium conditions, in networks where congestion varies over time, traffic arranges itself, so that at each instant the costs incurred by drivers on those routes that are used are equal and no greater than those on any unused route.
- **Quasi-dynamic traffic assignment:** A static traffic assignment model treated as a special case of a dynamic model. The quasi-dynamic assignment is consistent with traffic flow theory (often captured in a fundamental diagram), explicitly considering capacity constraints and allowing for physical queues and spillback.
- **Static traffic assignment:** Assignment models used at strategic level and making use of several limiting assumptions, primarily one 24-hour O-D matrix or peak-off peak O-D matrices. Static assignment assumes that the travel costs between every O-D pair remain the same throughout the modelled time period regardless of the level of ongoing congestion in the network.
- **Macrosimulation:** Assignment models at strategic level, part of the traditional four-step models and applied to large-scale areas. Typically, they are applied to 24-hour O-D matrices, or several time periods of a day, they use simplified representations of network links and nodes and make use of relatively simple volume-delay functions.
- **Mesosimulation:** Traffic models that operate at a less disaggregated level of detail than the microscopic models. They are based on traffic flow theory and apply analytical procedures that do not require random sampling from statistical distributions of input variables. They are particularly useful for area-wide traffic management and congestion management issues.
- **Microsimulation:** Simulation models that provide a very detailed view of the traffic by tracking movements of individual vehicles through the network and updating frequently (seconds) the position, speed and trajectory of each vehicle. They operate on the basis of traffic flow theory (e.g. car following theory, gap acceptance and lane changing behaviour), accounting for the behaviour and characteristics of the traffic participants (driver, pedestrian, cyclist). They require a detailed description of the network (design of links and nodes/intersections).
- **Nanosimulation:** The most refined level of traffic modelling, seeking to replicate the behaviour of individuals using different modes of travel. It is particularly concerned with modelling waiting times, interaction between individuals, etc. The model requires network description similar to micro-simulation, however enriched with data on pedestrian spaces and corridors. They can also be used in the design of transport terminals (such as railway stations) and access to buildings and other facilities.

¹ The list includes a sample of terms used in the traffic assignment literature without unique connotations. For definitional clarity, we specify their use in this Report. Other terms, used in land use and transport modeling, but with well-established definitions, are not mentioned, given the level of expertise of the members of the Steering Group and Working Group.

² Ortúzar, J de D and Willumsen, LG (2011). *Modelling Transport*, 4th Edition, John Wiley and Sons, Chichester.

- **Hybrid modelling:** Combination of mesoscopic and microscopic models in a single modelling framework. It allows the modeller to perform microscopic simulations within focus areas inside the full network mesoscopic simulation of the network.

1 INTRODUCTION – CHANGING TECHNOLOGY AND MODELLING

1.1 Background and Purpose

This Independent Transport Modelling Review, conducted by the Planning and Transport Research Centre (PATREC), was undertaken as part of a broader transport modelling review process underway in the WA state government to “*move towards the development of a new strategic transport model for the Perth and Peel region and one modelling team*” (Scope of Work: 2). As part of the wider review process, and feeding into this Independent Review, government transport modelling needs, capabilities and gaps were identified through a rigorous transport modelling stakeholder engagement process.

The aim of this Review then, was to propose:

- a preferred transport modelling approach for metropolitan Perth on the basis of
 - the needs, capacity and gaps identified with respect to current modelling approaches; and
 - benchmarked against the evidence emanating from a rigorous best practice review of international and national modelling trends; and
- an implementation strategy for the way forward.

The specific objectives of the study were to:

- ✓ Determine the appropriate place and application of macroscopic, mesoscopic and microscopic models;
- ✓ Recommend the appropriate way to incorporate land freight movements into the integrated transport model;
- ✓ Identify the required land use inputs and how to compile them, and also the issues and risks associated with the land use forecasts; and
- ✓ Identify transport modelling data requirements.

This Report is presenting the results of an examination of current transport modelling practices in Perth, Western Australia and a benchmarking against best practices in Australia and overseas. It offers a framework for the evaluation of modelling approaches, a comparison of the two current transport models STEM and ROM24 to other practical approaches around the world, analyses three possible options for model development in WA and suggests a pathway for a new best practice approach.

1.2 Methodological Approach

The overall methodological approach to the review is summarised in Figure 1. As the first step in developing the preferred modelling approach, a review of the *Needs Assessment*, *Capability Assessment* and *Gap Analysis* was conducted to obtain a firmer understanding of the requirements of the model, the view of current performance in terms of meeting requirements and the definition of the evaluation criteria in the evaluation framework.

From the needs assessment and learning from exemplars presented in the literature, a set of evaluation criteria was developed to assess the available best practice modelling approaches

in relation to needs and requirements. The performance of available best practice modelling approaches was then assessed in relation to needs and requirements as specified in the evaluation framework.

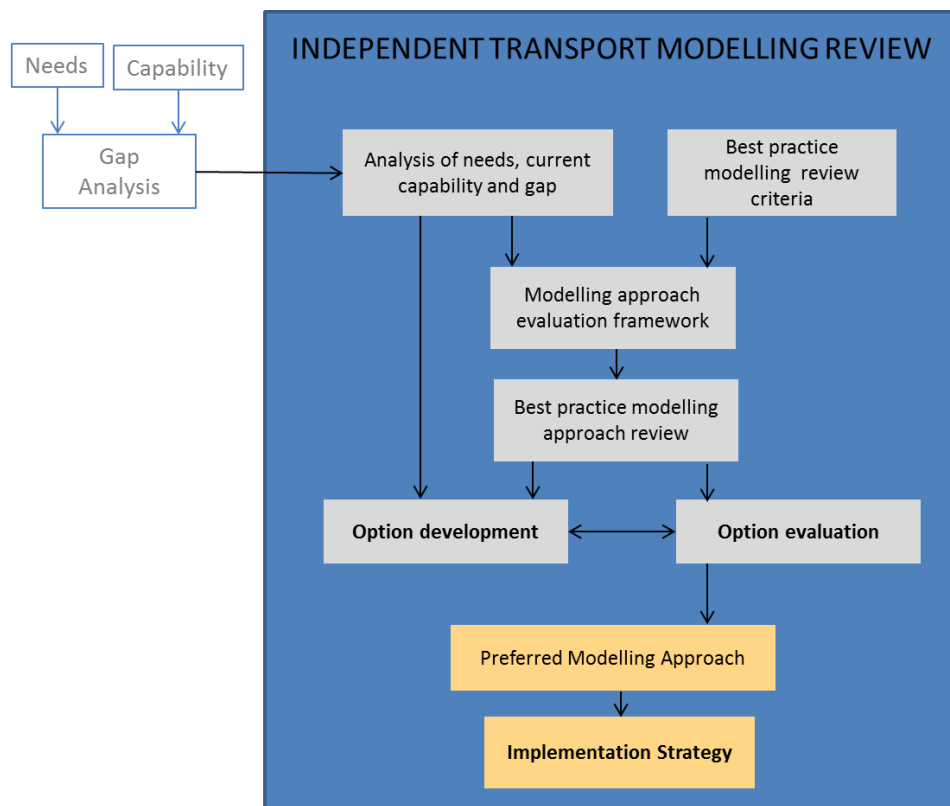


Figure 1: Methodological approach to the modelling review

The Scope of Work for the project indicates three possible options for meeting strategic level modelling needs:

- Do nothing: maintain the status quo, i.e. develop both STEM and ROM and improve the integration between them;
- Develop a new strategic model by taking the best features of STEM and ROM and considering other world’s best practice developments; or
- Develop a new best practice approach.

In this report, these options form the basis of a development sequence that can be managed over a reasonable time span. These stages have been considered:

- Parallel, but upgraded models, meeting separate needs;
- Two closely associated models:
 - A policy and public transport oriented model generating the O-D matrices and the static assignment of traffic;
 - A dynamic model of the entire region using the latest assignment modelling methods;

- Total integration of the models, with strong feedback from the dynamic traffic assignment (DTA) to the mode choice modelling phase.

The first of these could be seen as 'business as usual' and is reviewed and assessed in Section 5. It has become apparent from the review of Australian and world's best practice that there are significant developments in recent years that should be incorporated in the recommended modelling approach. This applies particularly to the proposed final stage of total integration of the models with strongly enhanced collaboration between modelling teams (Section 7), perhaps taking advantage of the new 'cloud based' computing environment, or even integration of the modelling groups into a single group.

Each of the three staged options are evaluated on the basis of the best practice assessment criteria and a preferred option proposed, followed by an initial implementation strategy.

1.3 Structure of the Report

After a brief review of the perceived modelling needs and gaps, the report deals first with land use modelling, as the basis for the transport system, and the potential for interactive land use-transport modelling. The review continues with the current advances (best practice) in transport model development, description of three feasible options, their comparison and the steps required for the development of the recommended strategy. The use of resources and well as potential implementation issues close the report.

2 NEEDS AND GAPS IN RELATION TO CAPABILITY

This Review follows or is concurrent with substantial changes or enhancements of the current two models used in Perth by the MRWA and Department of Planning, ROM³ and STEM models. The capability of both models has been considerably improved but the full effects are yet to be established because the changes are recent or still being made.

2.1 Capability of the Modelling Teams

This Scope of Works document seeks an assessment of modelling capability in the three modelling streams – macroscopic, mesoscopic and microscopic. The STEM team applies the four stages of macroscopic transport modelling – trip generation, trip distribution, mode choice and assignment (Ortúzar and Willumsen, 2011) – but has previously passed on the mode choice proportions to the ROM team, who are skilled in static macroscopic traffic assignment. Both teams also have expertise in microsimulation and ROM24 team has been applying it to model small area traffic situations. This has become a vital element in planning such things as traffic signals, parking facilities, shopping access and any other facility involving vehicle movements in a restricted area. In the field of mesoscopic modelling – dynamic traffic assignment (DTA) – neither team has much experience. Dynamic traffic assignment (especially as expanded mesosimulation) is relatively new but is now being actively developed worldwide and in Australia. Capacity to handle this type of modelling has now become a key requirement and needs to be developed in the Perth teams.

MRWA' Transport Modelling Section (TMS), which is responsible for ROM24, PEAK2012, three regional models and the Statewide model, has four permanent full-time staff, with access to up to four contract staff as the need arises. The annual dedicated TMS budget is \$1.045M. The Department of Planning's Scenario Modelling Section, which is responsible for STEM, has four permanent full-time staff and a specialist consultant part-time. Separate funding was provided for the STEM conversion to Cube (\$0.2M) and there is separate funding in the current year (\$0.3M).

The great majority of client responses indicated that both the ROM and STEM staff provided responses quickly or at least on time. Occasionally, a waiting time of as much as two weeks for STEM output was mentioned, but accompanied by an acknowledgement that this was reasonable for the size of task.

The active enhancement of ROM24 and STEM by the modelling teams reflects both their experience in meeting client needs and also their understanding of what the models can achieve and how they can best serve the needs of government agencies, local governments and the private sector. To some extent the enhanced model capability widens the gaps in professional understanding and thus exacerbates the problem of clients underestimating

³ The current MRWA model is ROM24, superseding the previous ROM model. This report refers to ROM24 features, except Section 2 where the workshop and stakeholder comments were based on model ROM. The main differences between the models refer to the improvements in traffic assignment (sequential series of 24 one-hour assignments under the restraint of hourly capacities) and a mode choice capability.

what models can do. This is not a serious problem with ROM/ROM24 clients, who are unlikely to misjudge model capability because they are predominantly MRWA officers and local government engineers, as well as consultants. However the STEM team has commented that a number of clients tend to limit their requirements to what they think the model is able to produce and this has provided little information on what the client would really like to be able to do.

2.2 Gaps in Relation to Perceived Needs

The needs expressed in responses from agencies, as well as internal and external clients have been listed in Tables 1 and 2. Table 1 deals with needs considered important by agencies and clients, while Table 2 deals with more detailed model enhancements. These topics are discussed in subsequent sections of this Review, but the initially assessed capability to deal with each issue and the suggested remedy are shown in the tables. It is important to note that the development of ROM24 commenced in 2013 and the needs identified during the stakeholder workshops are based on ROM.

Table 1: Perceived major needs and initially suggested remedies

CLIENT NEED (and source)	CAPABILITY AT THE TIME OF WORKSHOPS	REMEDY SUGGESTED INITIALLY
More zones – well defined (all agencies and clients)	ROM24: 1,160 zones STEM: 472 zones	Both ROM24 and STEM to move to common zoning (≈1,500 zones).
A microsimulation platform for dynamic modelling of vehicles (all agencies and clients)	A microsimulation service is provided by MRWA modelling staff	Major initiative required – centre of expertise has been suggested
A mesosimulation platform (all agencies and clients)	Saturn in Perth City; MRWA has tested the Cube Avenue package	Major initiative –within centre of expertise?
Interactive land use and transport modelling (all agencies and clients)	No feedback of accessibility to LU	Incorporate feedback to land use
More extended land use forecasts – to 2041 & 2051 and scenario evaluation capability (all agencies and clients)	Forecasts based on MLUFS are to 2031	Requires more MLUFS resources and some ‘unpacking’ of MLUFS
Mode choice model more responsive to fares and wait times (DoP, DoT, MRWA, Private)	STEM the main provider of mode split estimates; ROM24 also has mode split capability	Upgrade of STEM mode choice to be completed in December 2014
Peak spreading and departure time choice (DoP, DoT, MRWA, Private)	-	Module planned for STEM; ROM24 has potential for a departure time choice model
Improved project evaluation and cost-benefit analysis (DoP, MRWA)	ROM24 module (BCRATIO) in present form superseded	ROM24 module (BCRATIO) being updated; New cost-benefit module for STEM scheduled for Dec 2014
Speed flow curves and link capacities for managed freeways and intelligent vehicles (MRWA, Private)	MRWA’s Continuum Flow Model (CFM) has been developed to model freeway traffic flow	Extension of CFM capability
Managed freeways: integration of model with online modelling tools – STREAMS and SCATS (MRWA)	-	CFM, a recently developed mesoscopic model, could be linked to the data streams from the online tools – with substantial work
Improved freight modelling, including commodity tonnages (DoT, MRWA)	STEM models light and heavy commercial vehicle (LGV and HCV) trips by four time periods. ROM24 also models HCV and LGV and MRWA is the custodian of FMM that is being updated.	Developing commodity assignment would require substantial resources

Note: The workshop and stakeholder comments relate to ROM, currently in use at the time of preparing the scope of work for this review.

Table 2: Suggested modelling enhancements

NEED (and source)	PRESENT CAPABILITY	INITIALLY SUGGESTED CHANGE
Improved models of walking and cycling (DoT, Private Sector)	Both walk and cycle are 'Green Modes' in STEM, with choice parameters; ROM24 has walking and cycling in the mode choice model (May 2014)	Walk and cycle as access modes being modelled in ARC Linkage project LP110201150.
Improved models of train station access (DoT, Private Sector)	STEM has a park & ride (PnR) distribution module; also kiss & ride (KnR)	ROM24 parking model to be extended to PnR; STEM PnR module to get improved parameters from ARC Linkage project.
Improved modelling of peak traffic (Private Sector)	MRWA's PEAK2012 model (linked to ROM24) assigns peak hour traffic to the metropolitan network	NO serious gap
Modelling peak traffic to ports, airports and freight terminals (Private Sector)	Such traffic is included as part of the general loading in ROM24 and STEM	Specific treatment would draw on PEAK2012 and the improvement of freight modelling (Table 1).
Treatment of reliability and risk in transport modelling (DoT, Private Sector)	-	Risk and uncertainty response parameters being estimated from survey returns in LP110201150.
Modelling public transport crowding (Private Sector)	-	Crowding response parameters being estimated from survey returns in LP110201150.
Activity based modelling, ABM (MRWA, Local Govt.)	-	Planned for ROM24 in 2016, even if ABM is yet to become the standard in general production models (Section 4.4)
Develop pilot land use model (DoP)	-	Cube Land software to be tested with STEM
Implement strategic transport projects consistent with land use policies (DoP)	Applications of STEM	Refinement of STEM mode choice and PnR will tend to favour public transport, cycling and walking rather than car use.
A transport demand elasticity database for Perth (Private Sector)	-	Current studies and model refinements will contribute to meeting this need.
Development of co-ordinated ramp metering algorithms (MRWA)	-	Possibly import overseas software; will enhance the effectiveness of the Continuum Flow Model (CFM).
Parking demand model to assess parking policies (DoT)	STEM parking equilibrates with capacity limitations, ROM24 by raising costs as approach parking capacity	NO serious gap
Vehicle use for business purposes (DoT)	STEM models home based white collar trips	Current disaggregation of STEM non-home-based trips into Work and Other could be refined to Business Car and other
Take account of air passengers	-	Include in traffic flows in ROM24 and STEM.

3 LAND USE: THE BASIS OF THE TRANSPORT SYSTEM

3.1 Importance of Land Use Inputs

Transport modellers rely on land use forecasts as input data. Transport models are very sensitive to land use inputs and small changes in land use assumptions can have a significant impact on model output. It emerged clearly from the needs assessment that, amongst others, land use inputs:

- are often not delivered in a timely fashion and can have an adverse impact on model development progress;
- in terms of capability, land use forecasting and modelling suffer from the same lack of dedicated resources and reliance on one or two key individuals as transport modelling;
- are inconsistent across different sources:
 - there are often big differences between land use forecasts produced by the DoP and local government;
 - sometimes there are significant differences between ABS population projections and DoP population projections;
 - sometimes there are significant differences between internal population projections produced by DoP (MLUFS vs. WA Tomorrow).
- are trend-reinforcing - MLUFS is a “trend” forecast and there are often questions raised regarding whether or not the MLUFS land use forecasts should reflect the WA Government’s “Directions 2031” policy or not.

While these issues are largely independent of modelling approach and thus lie outside the scope of this review, whichever approach to land use modelling is followed, the response time, capability and data issues need to form part of the solution.

3.2 Best Practice Trends in Land Use modelling

Land use modelling and modelling the interactions over time between the land use system and the transport system are key concerns in the development and use of modern transport models. In the case of Perth, there is a particular need to consider the future of the MLUFS urban model and its relationship with STEM. The literature review revealed a number of critical best practices necessary for land use modelling in meeting the requirements expressed in the stakeholder needs analysis: behaviour and location choice; the degree and nature of “linkage” between the land use and transport models/model components; the degree of disaggregation and the ability to simulate longer term futures.

3.2.1 Behaviour

In relation to land use inputs to the transport model and the ability to evaluate the effects of both transport and land use policy initiatives through feedback from transport to land use models/components, it is crucial that the land use model can model behavioural responses through the incorporation of location choices of households and business. Land use models

with a strong grounding in land market economic theory thus currently dominate international best practice. Econometric models can be either *input-output* or *microeconomics*-based.

- In regional economic theory-based approaches, zone activities arise from spatial input-output model that predicts trade-flows, which drive the demand for space. In most cases, goods movements are explicitly modelled, models are integrated in terms of land use and transport with O-D matrices produced within the land use side of the model and models tend to operate at a more aggregate level.
- Microeconomic-based approaches are based on random utility theory and use a bid-choice framework to model land and floor space markets. Demand is modelled (in the examples considered) in the form of a willingness-to-pay framework.

Rule-based models, which dominate the land use modelling side of integrated land use – transport planning in Australia, which MLUFS could be considered to be, do not explicitly model location choice responses, but rather deterministically assume behaviour according to a set of rules relating to past trends, constraints, plans and suitability. This type of modelling approach cannot evaluate behavioural response to land use policy scenarios including comprehensive land use plans, growth management regulations such as urban growth boundaries, density policies, mixed-use development, redevelopment, environmental restrictions on development, development pricing policies, as well as a range of transport infrastructure and pricing policies through the connection with the travel demand model.

Spatial interaction approaches use gravity theory to allocate households on the basis of distance to workplace and the intensity of work opportunities at those locations. There is no representation of land markets with explicit prices.

3.2.2 Feedback to land use

Whilst the process of land use models providing activity-based population and employment inputs to transport models is well established in practice, the feedback to land use is lauded but less well done, if at all. Best practice approaches have well established feedback mechanism to influence land use choices through accessibility/composite utility values either in a fully integrated or connected manner. However, recent best practice trends have tended to favour the land use models “connected” to transport models. Fully-integrated models are understood to be those where the O-D matrix is generated on the land use side of the model, using spatial economic flows generated from composite utilities in the mode choice model. Connected models are where the O-D matrix is generated in the transport model and feedback to the land use model is via composite utility values from logit models in the transport destination choice model. The benefit of connected models is that any [new] land use model can theoretically be “bolted” onto an existing transport model, whether the transport model is a traditional four-step (Ortúzar and Willumsen, 2011) or even agent-based model (e.g. UrbanSim has been connected in practice to both traditional four-step and agent-based models). While the fully integrated approach is theoretically “elegant” and

ensures internal consistency, the connected approach is more flexible, accounting explicitly for the fact that accessibility is only one of a number of factors which influences residential and firm location (Hunt *et al.*, 2005⁴: 343).

With the technical means to ensure feedback to land use well established in most modelling approaches, the problem is largely institutional with misaligned institutional processes, objectives and timeframes mitigating against feedback in practice. Modelling response time is important so that iterative feedback between land use and transport is handled efficiently, without delaying either land use or transport planning processes, which the modelling is informing. While there is an element of human efficiency involved in response time, if the model has to be manually manipulated each time an iteration occurs, feedback will be further constrained. So technically, it is important that required feedback mechanisms are hard-coded and automated within the modelling system to expedite feedback. This was highlighted as a critical aspect of the relationships between the land use and transport models in Perth.

3.2.3 Disaggregation

As computing power, data availability and data synthesis methods have improved, best practice trends are clearly toward more disaggregated land use models in terms of both zone size, level of disaggregation of socio-economic classes of household and firm/employment activity and number of “agents”. The main benefits of more disaggregated approaches are minimisation of model bias, maximisation of model statistical efficiency, improved policy sensitivity and improved model transferability (Miller, 2003)⁵. Results can be aggregated to a larger geographic scale, policies can be more specifically evaluated in relation to responses of different socio-economic groups e.g. equity issues, and the closer the model to modelling individual agents, the more likely the results to reflect patterns of emergence. The well-recognised trade-off that has to be made with increased levels of disaggregation is that of greater data requirements. In recognition of this, advances in data synthesis methods are often reported in the literature alongside trends in microsimulation. Synthesis is the process of generating data for disaggregated, individual units or agents (e.g. households) from available aggregate data (e.g. census data), usually using some form of Monte Carlo simulation (Miller, 2003).

Rule-based, spatial interaction and input-output approaches tend to be modelled at the more aggregate level, whereas microeconomic approaches tend to be more disaggregated with smaller and more zones and more socio-economic classes of activity. The most highly disaggregated operational model currently is UrbanSim, which uses traffic zones on the travel demand side, but uses land parcels for land supply and demand. It models 111 household types and can be run using a large weighted sample of households. This level of

⁴ Hunt, JD, Kriger, DS and Miller, EJ (2005). Current operational urban land-use-transport modelling frameworks: a review, *Transport Reviews*, 25(3), 329-376.

⁵ Miller, EJ (2003). Microsimulation, in K.G. Goulias (Ed.) *Transportation Systems Planning Methods and Applications*, 12-1 – 12-22 (Boca Raton, FL: CRC Press).

disaggregation enables impacts on specific sub-groups to be evaluated (equity, distribution of costs and benefits). MUSSA⁶ is another example of a disaggregated model with 264 zones and 65 household types in Santiago, Chile, which can be run using a large weighted sample of households in essentially a “static microsimulation” format.

3.2.4 Longer Term Forecasting

Best practice in terms of enhanced ability of land use models to model land use patterns into the longer term future, has been firmly established by the development of models within a microsimulation framework. The “micro” part of the work relates mainly to disaggregation as discussed above while “simulation” refers to modelling a system as a dynamic and/or complex system, whose behaviour must be explicitly modelled over time (through process of “updating”) and where complexity is incorporated through modelling:

- decisions of individual and different actors interacting in complex ways;
- processes that are path dependent (future system state depends on current system state and explicitly on how system evolves from the current state over time);
- as an open system (on which exogenous forces operate over time influencing internal behaviour); and
- with significant probabilistic elements (uncertainties) (Miller, 2003).

By more explicitly incorporating system dynamics and complexity, microsimulation is beneficial in that it:

- can generate detailed forecast inputs for each actor simulated through attribute synthesis required by disaggregated models;
- allows very detailed analysis of model results;
- is computationally more efficient than conventional methods for dealing with large-scale forecasting problems;
- can predict outcomes that are not hard-wired into the model, i.e. emergent behaviour; and
- despite its complexity in technical detail and implementation, it may be easier to explain or sell to decision-makers as its fundamentally conceptual design is simple to convey as it is formulated at the level of individual actors (Miller, 2003).

All the model approaches considered solve for static equilibrium in the forecast year, by adjusting demand and supply elements until demand and supply balance, with model end state being path independent, not requiring solution for intermediate years (although intermediate year results can be generated in most cases). The exception is UrbanSim, with

⁶ Martínez, FJ (1992). The bid-choice land use model: an integrated economic framework, *Environment and Planning A*, 24, 871-885; Martínez, FJ, Aguila, F, and Hurtubia, R (2009). The constrained multinomial logit model: a semi-compensatory choice model, *Transportation Research B*, 43, 365–377; Martínez, FJ and Donoso, P (2010). The MUSSA II Land Use Auction Equilibrium Model. In Pagliara, F, Preston, J, and Simmonds, D (Eds.) *Residential Location Choice: Models and Applications*. Advances in Spatial Science, Springer, Berlin.

its model end state being path dependent, requiring a solution for each intermediate year. It can be considered a dynamic disequilibrium model of building stock demand and supply with annual time increments. Expected revenue is based on price lagged by one year, new construction choices are only assumed to be available in the subsequent year, demand is based on lagged prices and current supply and prices are adjusted based on balance of demand and supply in each submarket in each year. Despite this difference in the consideration of time between the static equilibrium traditional four-step transport models, this has not posed a problem in connecting UrbanSim with these types of transport models.

3.3 Land Use Options Evaluation

A range of broad land use modelling approach options, broadly in line with the diagram presented in Interim Report 1⁷ and Annexure 2 (after Iacono *et al.*, 2008: 325)⁸, are evaluated against the necessary capabilities discussed in the previous sections (Table 3).

With spatial interaction modelling approaches discounted on the basis that these are in decline in practice having largely been replaced by econometric-type models, the options are essentially:

- Business-as-usual (MLUFS), with a possible opportunistic connection to “What-if” which offers improved useability and visualisation through being on-line, having user interface, GIS integration and scenario building and evaluation capabilities. The main disadvantage other than its aggregated nature, is that no explicit location choices are modelled with only rule-based behaviour included. Whichever choice is made, the input data, collected as part of MLUFS, will be useful. It is the allocation part of MLUFS, which would differ.
- Spatial econometrics: input-output approach - although still widely used in the UK and with the ability to included freight, the main disadvantages are that it is a fully integrated approach which means the land use component cannot simply be attached onto an existing transport model and it is fairly aggregated.
- Spatial econometrics: microeconomics-advantages include, strong behavioural modelling capabilities, disaggregated level and ability to connect to transport modes:
 - Static microsimulation, static equilibrium, path independent approach (e.g. MUSSA) – additional advantage is practical in that it is implemented as the Land module in Cube (Ortúzar and Willumsen, 2011: 497), with Cube already in use in Perth as the basis for the STEM and ROM24 models.
 - Dynamic microsimulation, dynamic disequilibrium, path dependent approach (e.g. UrbanSim) – best available for longer term time period simulation, open source availability, now well-supported, strengths in long term simulation and

⁷ Although most relevant parts of the progress and interim reports are included in the current document, as Annexures, the reports submitted between November 2013 and February 2014, in draft form, include additional useful information for the reader.

⁸ Iacono, M, Levinson, D and El-Geneidy, A (2008). Models of Transportation and Land Use Change: A Guide to the Territory, *Journal of Planning Literature*, 22(4), 323-340.

modelling of urban system as dynamic, complex system with emergent properties with data synthesis and updating capabilities. Has been successfully connected to both four-step and agent-based transport models in practice.

Table 3: Summary of land use modelling approach options

Options	Allocation	Feedback to LU	Time	Aggregation	Practical
Business-as-usual (MLUFS)	Rule-based – no location choices	None	Static equilibrium Path independent	Smaller zones aggregated to transport zones	Processes in place but limited resources and slow response time
Rule-based (“What-if”)	Rule-based – no location choices	Accessibility in suitability index	Static equilibrium Path independent	Aggregate	AURIN application for Perth, similar to current, user interface/GIS
Spatial Interaction (ITLUP/ METROPILUS - GIS)	Gravity-based, no land market with explicit prices	“Integrated” and/or “connected”	Static equilibrium Path independent	Very aggregate (zones, socio-economic classes)	Few examples of these models remain
Spatial Econometrics: input-output (MEPLAN)	Trade-flows drive the demand for space	“Integrated”	Static equilibrium Path independent	Aggregated	Widely used in UK and supported; includes commercial vehicles
Spatial Econometrics: Microeconomics (MUSSA)	Random utility theory based – bid-choice framework for land markets	“Connected”	Static equilibrium Path independent	Highly disaggregated (zones, classes)	Incorporated in Cube Land; partly static microsimulation
Spatial Econometric: Microeconomics within microsimulation framework (UrbanSim)	Random utility theory based – bid-choice framework for land markets; hedonic price functions, Monte Carlo simulation, emergence	“Connected” to 4 step and agent-based	Dynamic disequilibrium Path dependent	Most disaggregated (zones, supply side-land parcels, classes)	Open Source; significant increase in practice and consulting support

3.4 Preferred option and pathway

The spatial econometrics: microeconomics approach is the reviewers preferred option for the land use modelling component of integrated land use-transport modelling, on the basis

of the ability to model behavioural responses, level of disaggregation and ability to connect to [any] type of transport model. Within the broader spatial econometric: microeconomics approach, the further choice is between a static equilibrium approach and a dynamic disequilibrium approach within a microsimulation framework. The main practical advantage of the static equilibrium approach is that this type of approach is available as part of the Cube platform (as Cube Land), which is one of the current strategic transport modelling software packages being currently being used in Perth, but as this is a proprietary software, there is an acquisition cost and ongoing licence fees. The main practical advantage of a dynamic disequilibrium approach within a microsimulation framework is that there is an operational model freely available in open source, supported through an international collaboration, Open Source Platform for Urban Simulation (OPUS)⁹. Theoretically, the microsimulation framework approach enables the simulation of urban dynamics and complexity over the longer term and has the ability to synthesise and update sample data, reducing the need for detailed primary data. While equilibrium is a powerful and convenient concept for modelling complex systems (since it provides the criteria needed to solve for a future year system state), it is a strong assumption in relation to the reality of the way urban systems evolve. Disequilibrium approaches seem intuitively more reflective of the likelihood that urban systems are in reality in a constant state of inertial adaptation, with actors' decisions being based on both past system states and performance and anticipated future conditions, i.e. a dynamically evolving system. Hunt *et al.* (2005: 340)¹⁰ caution that *“relatively little experience exists...and more experimentation with models of this sort would appear to be warranted”*.

Further investigation is needed to explore more detailed options within the broader spatial econometrics: microeconomics approach before a recommendation on static equilibrium vs dynamic equilibrium within a microsimulation framework can be made. Furthermore, this land use modelling review has been largely incidental to the primary transport modelling review and has concentrated more on the relationship with transport models, which are extremely sensitive to land use inputs. In practice, the value of land use modelling goes far beyond just providing input to transport models. Before any final decision is made on an approach into the future, the various approaches should be re-evaluated in the light of all potential uses.

It is estimated from previous experience that an initial version of a spatial econometrics: microeconomics model could be operational within a two-year period, largely dependent on data availability. UrbanSim is available online as open source software, but any model establishment requires consulting support and funds for data acquisition and preparation.

⁹ Waddell, P, Ševčíková, H, Socha, D, Miller, E and Nagel, K (2005). OPUS: An Open Platform for Urban Simulation, Paper presented at the 9th International Conference on Computers in Urban Planning and Urban Management (CUPUM), London, 29 June-1 July 2005.

¹⁰ Hunt, JD, Kriger, DS and Miller, EJ (2005). Current operational urban land-use-transport modelling frameworks: a review, *Transport Reviews*, 25(3), 329-376.

In the short term, there may be value in considering the translation of MLUFS into an on-line, GIS-based “What-if” model similar to the one being implemented by the DoP’s Corporate GIS section as part of the Australian Urban Research Infrastructure Network (AURIN). It does not model behavioural response, but has the capability of including some sort of feedback to land use through the incorporation of accessibility as part of the land suitability module. Regardless of the solution adopted, the land use modellers need to assess and reconcile the differences between the forecasts produced by many government departments and organisations that are using land use inputs.

The literature review (Annexure A.2) highlighted that a common recent trend across most modelling approaches is to [re]develop models within a GIS environment for data handling capabilities, enhanced visualisation and user-interfacing and spatial aggregation and disaggregation capabilities, it is further recommended that any further development of the land use modelling side of the integrated land use-transport modelling system be done within a GIS environment.

4 Best Practice in Transport Modelling

Best practice criteria in transport modelling is reviewed in Section 4.1, the international and national developments in transport modelling practice in Sections 4.2 and 4.3, and then the Options for meeting the strategic level modelling needs of Perth are assessed in relation to Australian and international best practice in Section 4.4. The latter section draws together not only the options but also the related topics that have been discussed in this review.

4.1 Best Practice Review and Criteria

The review criteria adopted in the *Transport Modelling Review* are largely qualitative in nature and did not consider specific features of individual models. Rather, they were selected to provide a broad perspective on an overview of modelling needs and performance, in terms of noted 'gaps' in modelling capability previously identified by WA modelling stakeholders and drawn together in the first progress report in this study.

In terms of a review of 'best practice', there is a need to distinguish between *Production* and *R&D* models – these may exist side by side, with the production model in use and the R&D model 'off line' and under test. The production model is that available for use by or on behalf of users outside the model development-management group. The R&D models are those being developed and tested within the group, and may well represent potential advancements (perhaps in theory, scope or application) on the Production model(s), but not in a suitable state for production purposes (e.g. they may not be fully verified, calibrated or validated). It should also be noted that R&D models include both new models for real world application and theoretical 'proof of concept' models (which exist mainly in the academic world). The latter may be theoretically advanced, but not feasible for practical implementation for real world applications. Indeed, many of the academic models populating the research literature, in the opinion of this Review team, include simplistic representations of transport networks and their properties, which make them of limited use for purposes of transport planning practice in the real world. Worthwhile conceptual and theoretical developments in modelling will in time find their way into model productive use, once they have been firmly established and efficient methods for their implementation devised.

Hence, a starting point in consideration of what constitutes 'best practice' modelling is a need to clarify the terms 'Production' and 'R&D' models. A *production* model is one that is currently being employed in applications on real world plans and projects, in other words the current formulation/version of a transport model being employed by a transport agency. This model should be cast at the level of the regional transport network for the study region in question (e.g. the metropolitan area) and be supported by comprehensive and statistically valid databases representing land uses, transport networks, population, employment and economic and social activity in the region. This will be almost certainly a large model, comprising hundreds if not thousands of zones and thousands if not tens of thousands of network links. The model will have been calibrated (i.e. undergone parameter estimation) to

fit a base year and validated to test its performance when applied with other input data (e.g. calibration and validation may have been done with different screenline data sets, or other means). The production model would be regarded as defensible in the public arena in terms of its ability to reproduce observed travel activity and to provide useful indicative forecasts of future travel activity. In modern times these models are generally implemented in one or other (or a combination) of the advanced software modelling packages now available from the major international software developers and with support from those developers and model package user groups. The production model is an 'online' model immediately available for applications.

R&D models on the other hand represent new developments in transport models and may be seen in two separate ways:

- The first way is new model theory and development, usually emanating from research institutions and academia. These models are clearly visible in the research literature. They generally present new advances in model theory and modelling methods, but are often limited in scope of application and not suitable for application to large scale (i.e. real world) networks. They may not be implemented (or indeed presently suitable for implementation) in the major software packages, a further limitation on their more general use. Such models are prototypes and represent 'proof of concept' ideas. However, once an academic model receives some traction in terms of its utility and potential application, it can be adopted and adapted to fit into the modelling packages. This is a continual process that has helped to fuel the major advances in transport modelling software over the last 20 years or so.
- The second class of R&D models are new model developments being undertaken within the transport agencies themselves. Such models are generally, but not always, incremental advances on the production model, perhaps to introduce a new feature (e.g. say congestion charging) and are thus formulated within the same shell as the production model. However, they are not available for application by the model user/client group until they have been fully tested, calibrated and validated – when the R&D model may then become the new version of the production model. This R&D model may thus be seen as an 'off line' version of the production model.

Worthwhile conceptual and theoretical developments in modelling will in time find their way into model productive use, once they have been firmly established and efficient methods for their real world application devised¹¹. This is an ongoing process and points to the continual international efforts to extend and improve transport modelling.

¹¹ Examples of these developments over the last 30 years include algorithms for static equilibrium traffic assignment, applications of discrete choice models, and most recent the development of efficient algorithms for dynamic traffic assignment. Advances in computer and information technology, database management and user interfaces also help facilitate the developments.

The effective application of a *production* model depends on the level of operational support available for it, which includes the availability of skilled human resources (the modellers), the specifications of model application requirements, and support on modelling issues and problems. There is generally a need for ongoing liaison with the software providers (e.g. to resolve newly arising issues or to seek enhancements of a model for specific purposes) and this process is enhanced by the existence of active, mutually supportive model user groups. These twin areas of support are common and expected features of the new generation of transport modelling packages. Transport modelling is no longer a ‘cottage industry’ with each modeller operating his or her own and distinct model. Rather, while all models are bespoke in the sense that they relate to a specific (and unique) region, they are created within a software platform that is in use by many other modellers and agencies around the world. The parallel is with the use of a word processor package in writing a report. The report is unique, but the package used to create it is in general use – so with modern transport modelling software. Further, the current modelling environment is supported by several multinational software providers, dedicated to the development and use of transport planning software packages, each providing ongoing user support and advice.

Three broad areas of interest may be considered in defining a set of review criteria for purposes of the review. These areas are:

- theoretical and technical relevance;
- user support and activity; and
- ability to meet WA needs and fill gaps.

Theoretical/technical relevance

In terms of theoretical and technical relevance consideration need to be given to the following factors:

- current state of the art nationally and internationally – and how do WA models sit in that space;
- model development, estimation and validation and the methods employed for them;
- capture of traveller behaviour and its representation in the model;
- fitness of the model for purpose and scope in the required region and scope of application;
- availability or obtainability of suitable data;
- understanding of the principles on which the model is based and the degree of transparency communicable to users and stakeholders;
- ability to use existing travel/traffic databases for current situation/short term modelling.

User support and activity

This area for assessment concerns the extent to which there is an established body of knowledge and expertise regarding the model and its application to the study region. It includes the degree of technical and administrative support available to modellers and

model users and the extent of active interest and communication regarding the model. Issues for consideration include:

- software developer and agents
 - availability and presence in Australia and in WA
- (expert) active user groups
 - established usage
- understanding of model capabilities and potential applications in the (local) user/stakeholder group.

Meeting needs and filling gaps

The identified modelling needs and gaps for WA identified in the task 1 Progress Report (Section 2.2) formed the basis for the review, in terms of the extent to which particular alternative model formulations and implementations can meet the needs and fill the gaps.

Summary of review criteria

The criteria indicated above were used to provide a fulcrum for the review of best practice in transport modelling and relevance to practice in WA. The criteria are broad and qualitative in nature, being suggested as the means for appraising alternative model systems and their data and knowledge requirements, rather than focusing on specific model features and outputs. Issues considered in the evaluation included:

- the use of a system of models, rather than search for an ‘all-in-one’ model;
- clear definition of the domains identified for particular models in that system, and any potential overlaps between models;
- linkages between the models, especially in terms of
 - primary data, i.e. networks, travel demand, zoning etc.;
 - realisation that the level of detail of data items may vary between models at different levels, but with a degree of compatibility as necessary to ensure efficient (if not automated) data sharing;
- collective body of knowledge on models assembled and maintained, such as the existence of ‘centres of excellence’, modelling liaison groups, information sharing schema, etc.
- visualisation and transparency of the models and the linkages between them;
- case study applications and reviews.

The best practice review included consideration of the academic and professional literature in the field, including online sources such as the US Federal Highways administration (FHWA) *Travel Model Improvement Program* (TMIP), www.fhwa.dot.gov/planning/tmip/, and the UK Department for Transport ‘Transport analysis guidance (WebTAG)’, www.gov.uk/transport-analysis-guidance-webtag, and the websites of transport software providers, including

Caliper (www.caliper.com), Citilabs (www.citilabs.com), Inro (www.inrosoftware.com), Omnitrans (www.omnitrans-international.com), PTV (www.ptv-vision.com) and Transport Simulation Systems (www.aimsun.com). Other information sources include the Transport Modelling primer (Ortúzar and Willumsen, 2011), modelling guidelines published by NSW Roads and Maritime Services (RMS, 2013¹²), recent reviews of Australian practice (SKM, 2009¹³ and GHD, 2013¹⁴), and information on model developments provided by the NSW Bureau of Transport Statistics (BTS), www.bts.nsw.gov.au, amongst others.

4.2 International Developments in Transport Modelling Practice

The scan of international developments in strategic transport modelling practice suggested a number of recent advances in the field, namely:

- replacement of the trip-based modelling approach by a tour-based schema, while remaining in the overall ‘four-step’ modelling system;
- introduction of time of day modelling capability, certainly for production of ‘n-hour’ O-D matrices to cover the hours of the day, but not necessarily incorporating peak spreading;
- extensive segmentation of demand by household type, travel purpose and other input variables, to give discrete choice modelling formulations for destination, mode and departure time choice;
- dynamic traffic assignment (DTA), including number of alternative formulations including dynamic equilibrium, non-equilibrium and quasi-dynamic assignment, which enable modelling of delays, queuing and congestion dynamics;
- mesoscopic traffic assignment models¹⁵ for large networks, covering entire metropolitan areas, and including ‘hybrid’ modelling capability so that small parts of the entire network can be modelled microscopically in the meso model, on a ‘case by case’ or ‘project specific’ basis.

The review also found strong interest in the development of better freight models as an integral part of strategic transport models, but freight model development continues to be hampered by the lack of suitable and reliable freight-specific data. Conceptual modelling approaches for successful freight models now exist, but with the exception of a very few

¹² RMS (2013). *Traffic modelling guidelines ver 1.0*. Roads and Maritime Services NSW, Sydney.

¹³ Sinclair Knight Merz, SKM (2009). *Critical Review of Transport Modelling Tools (Implementation Options)*, Report to Department of Infrastructure, Transport, Regional Development and Local Government, ATC Urban Congestion Working Group and National Transport Modelling Working Group, www.skmconsulting.com.

¹⁴ GHD (2013). *Stage 2 final report: initiatives to improve toll road patronage forecasting*. October 2013. Report to Bureau of Infrastructure, Transport and Regional Economics, Canberra.

¹⁵ Mesoscopic modelling capability has been facilitated through the advances in dynamic traffic assignment modelling (DTA). DTA are also required for activity-based models.

cities (e.g. Calgary, see Hunt and Stefan, 2007¹⁶), comprehensive freight models have not been implemented for production-type modelling.

Land use-transport integration features as a strong component of international interests in contemporary transport planning and so land use models are of wide interest, especially in North America – see for example TRB (2010¹⁷: 2):

‘Land use models are implemented for two reasons. On the one hand, they allow the testing of land use policies, such as urban growth boundary or transit-oriented development. On the other hand, they can be integrated with travel models to simulate the interaction between them. This interaction includes the effects that a new highway may trigger in land use patterns as well as new land use development that may worsen congestion.’

Around the world there are noted continental differences in some of the directions taken in new model implementation. For instance, European implementations have largely concerned the adoption of tour-based schema for travel as a replacement for the historical trip-based approach, whereas North American interest has been in activity-based models (ABM). That said, the tour-based schema is an inherent part of the activity-based modelling framework. The difference is thus less significant – tour-based models retain the conventional ‘four/five step’ approach with feedback iteration (e.g., see Wood *et al.*, 2008¹⁸ and Milthorpe and Daly, 2010¹⁹) while ABM focus on the generational of synthetic populations (households) which are then furnished with activity-travel schedules. TMIP (2012) indicated the state of development and implementation of ABM in the USA – see Figure 2 for a geographical summary. Rasouli and Timmermans (2014²⁰) provided an overview summary of developments in ABM and the issues faced in the development of production level ABM. The main issues with ABM implementation concern data availability and the general tailored nature of the models, with no widely established transferable framework for model implementation at present. Each ABM is unique – while the concept is clearly established the model implementation tools are not, as yet. ABM implementations have also tended to be developed for specific purposes and policy analysis – a good example being models developed for transport planning for large scale special events, such as the

¹⁶ Hunt, JD and Stefan, KJ (2007). Tour-based microsimulation of urban commercial movements. *Transportation Research B* 41, 981-1013.

¹⁷ TRB (2011). Dynamic traffic assignment: a primer. *Transportation Research Circular no E-C153* June 2011, US Transportation Research Board, Washington DC.

¹⁸ Wood, R, Ashley, D, Young, D and Bates, J (2008). Innovations in modelling time-of-day choice: the Auckland Regional Transport Model (ART3, 2008). *Papers of the 31st Australasian Transport Research Forum*, September, Gold Coast, Queensland Transport, www.atrf.info/papers/2008/index.aspx.

¹⁹ Milthorpe, F and Daly, A (2010). Comparison of trip and tour analysis of Sydney Household Travel Survey data. *Papers of the 33rd Australasian Transport Research Forum*, Sep-Oct, Canberra, www.atrf.info/papers/2010/index.aspx.

²⁰ Rasouli, S and Timmermans, H (2014). Activity-based models of travel demand: promises, progress and prospects, *International Journal of Urban Sciences* 18(1), 31-60, <http://dx.doi.org/10.1080/12265934.2013.835118>.

2010 Vancouver Winter Olympic Games (PTV, 2010²¹). The Seattle model (Bradley and Bowman, 2006²²) is one example of a more general purpose ABM.

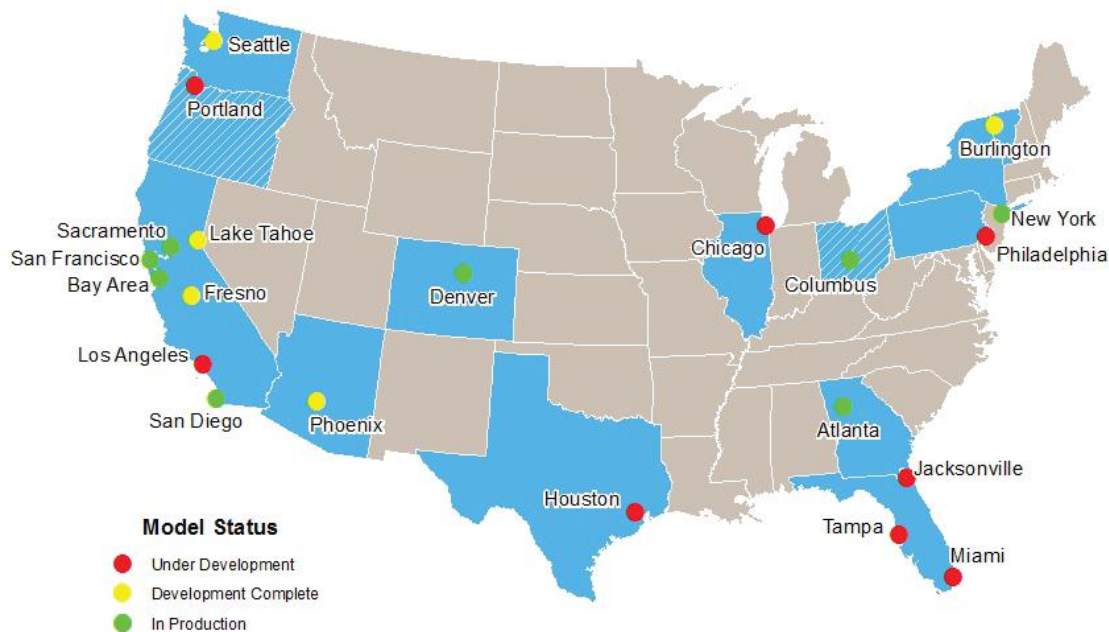


Figure 2: Activity-based transport models in the USA [source: TMIP (2012)²³]

The requirements and rationale for tour-based modelling, whether in conventional model structures or in ABM, is discussed in Sener *et al.* (2009)²⁴.

The use of discrete choice models for the distribution-mode-trip timing choices that provide the core of travel decision making is also now well advanced, with major implementations of (especially) nested logit models found in many cities, and countries, especially in Europe (The Netherlands having led the way in this regard, see Sener *et al.* (2009) and Jovicic and Hansen (2003))²⁵.

Congestion management is another key issue internationally. Mesoscopic assignment models are being widely applied in this area. These models can provide useful information on queuing and delays, and the development and dissipation of congestion across a

²¹ PTV (2010). *Vancouver 2010 Winter Olympic Games transportation modelling*. PTV User Group Meeting, October 2010. PTV America, Portland OR.

²² Bradley, M and Bowman, JL (2006). Design features of activity- based microsimulation models for US Metropolitan Planning Organizations: a summary. *Transportation Research Board Conference Proceedings 42 'Innovations in Travel Demand Modeling', Vol. 2*, May, US Transportation Research Board, Washington DC, 11-14.

²³ TMIP (2012). *Activity-based modeling resources at a glance*. FHWA-HEP-13-020, Travel Model Improvement Program, Federal Highways Administration, Washington DC.

²⁴ Sener, IN, Ferdous, N, Bhat, CR and Reeder, P (2009). *Tour-based model development for TxDOT: evaluation and transition steps*. Report FHWA/TX-10/0-6210-2 to FHWA and Texas Department of Transportation, October 2009, Texas Transportation Institute, Texas A&M University, College Station TX.

²⁵ Jovicic, G and Hansen, CO (2003). A passenger travel demand model for Copenhagen. *Transportation Research A* 37(4), 333–349.

network. The main feature of the mesoscopic models is their ability to model queues 'horizontally', i.e. the queue occupies a physical length of road (along the links) rather than the 'vertical' queuing (queue stacking at the downstream end of the link) which occurs in the static assignment modelling of the strategic models. Thus, the mesoscopic models can indicate the spread of queuing in the network, the incidence of blockages of upstream intersections and, in the extreme, the development of 'gridlock'. The mesoscopic models require time of day O-D information, which is usually taken from the outputs of a strategic level model.

4.3 Australasian Transport Models in Practice

All of the major cities of Australia and New Zealand operate strategic transport models. A review was undertaken of these models in the capital cities, building from the comparative overviews provided by SKM (2009) and GHD (2013), and seeking updated information from the respective modelling groups. The review asked for updates on the characteristics of the models since the SKM review and posed the following seven questions:

1. Is there any interest in the addition, or development of, a land use-transport interaction modelling component to your strategic transport model?
2. Is there any interest in, or development of, a departure time choice component in the model?
3. Is there any interest in, or development of, a tour-based model as a replacement for the existing trip-based model?
4. Is there any interest in the development of an activity-based model as a replacement for the existing model?
5. Is there interest in, or development of, mesoscopic traffic modelling capability either in the strategic model or as an addition to the model? If so, what is the extent of the modelled mesoscopic network?
6. Is there interest in the use of the strategic model (and any additions) in congestion management?
7. Are there any other plans for extensions to or modification of the strategic model?

The following three tables provide a summary of the review outcomes. Table 4 provides a summary overview of the current characteristics of the models, while Annexure A.3 lists the contact people in each city. The actual responses received for the seven questions are shown in Annexure A.5.

The similarities between the models and recent developments from the different cities are striking. The four-step, trip-based modelling methodology predominates, although Sydney has moved to a tour-based model. Sydney has also undertaken substantial reworking of its STM, now using extensive segmentation in its treatment of generation, distribution and mode choice. The use of quasi-dynamic assignment is also noted for the 'emerald city'. Milthorpe and Daly (2010) discussed the advantages and features of the tour-based Sydney Strategic Transport Model (STM).

Extensive development and application of mesoscopic traffic assignment models is also noted, with Adelaide and Melbourne developing models of their respective metropolitan areas, while Sydney has a mesoscopic model of the inner city. Brisbane has seen the use of mesoscopic modelling on a project-by-project basis, with no attempt as yet to develop a consolidated mesoscopic model. In Perth, MRWA is undertaking a mesoscopic modelling trial focusing on Canning Highway and its interchange with the Kwinana Freeway, as part of its congestion management strategy. The development of ROM24 (Jacoby and Soet, 2013²⁶) as a strategic level model with detailed assignment modelling capability for hour by hour application should be compared to the developments in mesoscopic modelling being undertaken elsewhere.

Departure time choice remains an area of interest for most of the models²⁷ ('the next thing to do'), although none of the production models currently employs that choice. The development of a departure time choice option in the Auckland transport model (Wood *et al.*, 2008) is of note, representing the one major city in Australasia where such development has occurred. The Auckland model is also a tour-based model.

²⁶ Jacoby, G and Soet, W (2013). *ROM24: a new transport modelling paradigm*. Transport Modelling Section, Main Roads WA, Perth.

²⁷ Additional information can be found in Ortuzar and Willumsen (2011), Chapter 11.

Table 4: Summary of the Australasian Major City Models

Model component	Adelaide	Brisbane	Canberra	Melbourne	Perth		Sydney	Auckland	Wellington	Christchurch
	MASTEM	BSTM	CSTM	VITM	STEM	ROM/ ROM24	STM	ASP/ART	WTSM	CTM
Software package	Cube Voyager	EMME	EMME	Cube Voyager	EMME (MAX – DoT) & Cube Voyager (DoP)	Cube Voyager	EMME	Delta/EMME	EMME	Cube Voyager
Region covered	Adelaide Statistical Division	Brisbane Statistical Division	Entire ACT	State of Victoria	Perth Greater Metropolitan Area	Perth Greater Metropolitan Area	Sydney Greater Metropolitan Area	Auckland Region	Greater Wellington Region	Greater Christchurch
Model structure:										
4-step model	●	●	●	●	●	●	●	●	●	●
Iterative feedback of travel costs	●	●	●	●	●	●	●	●	●	●
No of zones	304	1,509‡	835	~7,000 (2,893 in metro Melbourne)‡	484 (under revision, ~1,500 proposed)‡	1,239 (possible increase to ~1,500)‡	2,715	557	225	498 (approx. 45 currently unallocated)
No of time periods	3	4	1	4	4	24	4	5	3	4
No of trip purposes	8	8	6	9	7	11 (8 directional, 3 non-directional)	7	6	6	8
Segmentation of generation, distribution and mode choice	●	●	●	● (combined distribution/mode choice)	●	●	● (extensive segmentation is a major feature)	●	●	●
Commercial vehicle trips included	● (using Adelaide FMM)	●	×	● (HCV from FMM, LGV as proportion of light vehicles)	●	●	● (separate models for HCV (Sydney FMM) and LGV)	●	● (HCV from survey, LGV as proportion of light vehicles)	● (integrated 3 stage model for combined MCV/HCV)
Trip making unit	Trip (will consider tour in next version)	Trip	Trip	Trip	Trip	Trip	Tour	'Simple' tour (full tours in next version)	Trip	Trip
Land use modelling	×	×	×	×	×	×	×	●	×	×
Peak spreading	×	×	×	×	×	×	×	×	●	×
Networks:										
Public transport network	●	●	●	●	●	●	●	●	●	●
Capacity constrained public transport	×	×	● (optional)	●	● (MAX DoT), × (DoP)	×	×	○ (in separate public transport demand model)	×	×
Junction modelling	●	×	×	×	○	○	×	●	○	●
Cycling	○	-	●	-	-	-	-	● (walk/cycle)	×	●

Key: ● model has this feature ○ model has this feature in part × model does not have this feature - not known ‡ Under revision, considering ABS SA1 level

4.3.1.1 Australian best practice in mode and destination choice

Sydney STM is well abreast of current international best practice in its modelling of mode and destination choice simultaneously²⁸. Doing this achieves a substantial gain in efficiency. This step in the STM distributes the tours from each travel zone to their most likely destinations and assigns the most likely mix of travel modes by each population segment between each zone pair. The STM Population Synthetiser generates 128 weighted population segments for the mode-destination choice model. Modelling both mode and destination as choices also means that a true logsum measure of utility is achieved.

4.3.1.2 Australian best practice in freight modelling

Freight modelling continues to lag while continuing to be recognised as an important and necessary feature. Melbourne – the originator of the FMM model family – appears content with its FMM model, but other cities are less so although Sydney continues to make strong use of its FMM model (in the absence of much else) (see also BTS, 2010a²⁹). The main feature of freight modelling in Sydney is the inclusion of a specific model for light goods or commercial vehicles (LGV), which uses generation rates for LGV trips (by residences and businesses) in the development of LGV O-D matrices (BTS, 2010b³⁰). Given the known substantial growth in this sector of road travel demand, focus on LGV movements is important for all future modelling considerations.

The extension of the Melbourne model to cover the whole of Victoria is interesting, and enables the inclusion of the previous models for regional centres in the wider model. MRWA has indicated that it will be including models of regional centres (e.g., Geraldton, Bunbury and Busselton, Albany) in the WA Statewide Model. One important justification for this inclusion is that it provides the means for the ongoing maintenance of the individual models, which might otherwise be seen as ‘project specific’ tools, which become unsupported after the conclusion of the project(s).

On the basis of this information the Sydney STM emerges as the Australian model perhaps best aligned with current international best practice, because of its tour-based approach with extensive traveller segmentation in its travel choices. Its interest in quasi-dynamic assignment and use of separate freight vehicle models for HGV and LGV is also of note. The development for Adelaide and Melbourne of metropolitan-wide mesoscopic traffic models linked to the corresponding strategic models is a second development of substance, and in line with international best practice. Yet, data collection appears to be a major hurdle in attaining credible freight models for the Australian capital cities. More so in Perth, where FMM is relying on limited data from WA. As further discussed in Sections 10-12, data

²⁸ Fox, J, Daly, A and Patrui, B (2013). *Additional Estimation of the Sydney Strategic Travel Model*, Technical Report, RAND Europe, Cambridge, available from: jfox@rand.org.

²⁹ BTS (2010a). *TDC heavy vehicle forecasts* (February 2010 Release). Report TR2010/02. NSW Bureau of Transport Statistics, Sydney, www.bts.nsw.gov.au.

³⁰ BTS (2010b). *TDC light commercial vehicle forecasts* (February 2010 Release). Report TR2010/03. NSW Bureau of Transport Statistics, Sydney, www.bts.nsw.gov.au.

collection should become a priority for transport modellers, in order to calibrate their models.

4.4 Overview of Best Practice

On the basis of the literature and practice review undertaken in this study, a summary of current international best practice in strategic transport modelling is provided in Table 5. The table indicates the cities that may be described as examples of specific modelling features, and indicates those cities regarded as having obtained a high level of achievement of particular modelling features. The table contents are illustrative rather than exhaustive.

This table indicates that no one city or one model combines all of the features collectively forming current best practice. It does, however, indicate that different cities and regions have included best practice features in their production models. A tour-based strategic model:

- including departure time choice, and possibly extending into peak spreading;
- with extensive segmentation for modelling of destination, mode and trip timing choices;
- with the opportunity to provide feedback to land use;
- supported by a freight modelling capability which provides separate vehicle O-D matrices for HGV and LGV;
- possibly (but not necessarily) using quasi-dynamic macro assignment, and;
- most certainly working in conjunction with a mesoscopic traffic network model for the entire study region;
- as part of an integrated modelling suite,

would represent the combined set of best practice for a general purpose production model of metropolitan travel demand at the present time³¹.

4.4.1 Best practice assessment criteria

The principal best practice criteria used in this Review to assess the three modelling options are:

- Land use and transport models directly interacting;
- Tour-based trip modelling;
- Simultaneous mode and destination choice giving logsum benefits;
- Time of day modelling taking account of peak spreading;
- Static traffic assignment as a base case;
- Mesoscopic traffic assignment;
- Hybrid mesoscopic and microscopic modelling;

³¹ It can be expected that the Activity Based Models (ABM) will continue to evolve and be developed and refined sufficiently in the next 10-15 years to become the 'next generation' strategic travel demand models for general-purpose production usage. At present, however, this modelling methodology is not sufficiently developed for that purpose. The main applications of ABM to date tend to be for special purpose analyses, such as in transport planning for special events (e.g., the 2010 Vancouver Winter Olympic Games, see PTV, 2010) and for small area applications of high intensity usage (e.g. the Sentosa leisure complex in Singapore). Some bespoke ABM are in operation, e.g. in Seattle (Bradley and Bowman, 2006).

- Increased focus on detailed modelling of traffic streams.

Table 5: Apparent achievement of best practice in production transport models

Needs	Modelling Feature	Data need intensity	Ease of use	Level of achievement		Approach suggested	
				Low achievement	High Achievement		
Detailed spatial resolution	Appropriate number of zones	High	Easy	STEM	ROM ESTRAUS (750)	SYD, London, Dallas ³²	Alignment of number of zones (≈1,500)
More accurate behavioural responses – household types	Household types	High	Moderate	STEM	ESTRAUS ³³	SYD ³⁴	Sufficient number of household types to capture travel patterns
More accurate behavioural responses - purposes	Destination purposes	High	Difficult	ESTRAUS (4) STEM (7) SYD (7) ADL (8) BRIS (8)	MELB (9) ROM24 (11)		Additional trip purposes
A stronger behavioural foundation	Tour based	High	Moderate	Auckland, SYD, New York, Los Angeles,	Columbus, Copenhagen		Move towards tour-based modelling
Vehicle use for business purposes	Additional trip purpose	Moderate	Easy		SYD		
Treatment of the four steps as dimensions of choice	Logit trip distribution	High	Moderate		Calgary	SYD	
More accurate behavioural responses - peak spreading	Departure time modelling	High	Difficult (especially for joint	Portland, West Midlands, Santiago	Auckland, London		Include departure time as part of the choices made by

³² Ortúzar and Willumsen (2011): 130.


³³ De Cea, J., Fernandez, J.E., Dekock, V., and Soto, A. (2005). Solving network equilibrium problems on multimodal urban transportation networks with multiple user classes, *Transport Reviews*, 25, 293-317.

³⁴ The Sydney segmentation accounts for household types (car ownership, licence holding, age groups, workforce), but also combinations of traveller attributes for different choices situations. Sydney HTS is the most comprehensive database of its kind in Australia (followed closely by Melbourne VISTA) and uses the continuous survey data.

Needs	Modelling Feature	Data need intensity	Ease of use	Level of achievement		Approach suggested
				Low achievement	High Achievement	
			time, mode, destination)			households
More accurate behavioural responses - pricing, parking options, etc.	Mode choices	High	Difficult	ROM24 (6)	STEM (7) SYD (9), ESTRAUS (11)	Re-estimate parameter estimates
Capability to evaluate benefits of various measures	Logsum benefits	High	Moderate	San Francisco, Netherlands	SYD, MELB, West Midlands	Change approach to jointly model destination, mode, departure time
Responsiveness to changes in transport services	Feedback to land-use	High	Difficult	STEM, Dortmund, New York, Auckland	Leeds San Francisco, Santiago	Integration of transport model with land-use model
Freight modelling, including commodity tonnages	Freight modelling	Moderate	Moderate	MELB, SYD, Washington³⁵, Oregon³⁶	Calgary	
Modelling peak traffic to ports, airports, freight terminals	Part of freight modelling	High	Difficult			
Public transport crowding	Inclusion in mode choice utility functions	High	Difficult		SYD ESTRAUS	Include in utility functions
Reliability and risk	Inclusion in mode choice utility	High	Difficult		SYD	Include in utility functions

³⁵ TRB (2008a). Forecasting Statewide Freight Toolkit: Cross-Cascades Corridor Analysis Project. *NCHRP Report no 606*, Transportation Research Board, Washington DC, 110-118.

³⁶ TRB (2008n). Forecasting Statewide Freight Toolkit: Oregon Statewide Passenger and Freight Forecasting Model. *NCHRP Report no 606*, Transportation Research Board, Washington DC, 119-129.

Needs	Modelling Feature	Data need intensity	Ease of use	Level of achievement		Approach suggested
				Low achievement	High Achievement	
	functions					
More accurate behavioural responses – activity based	Activity based modelling	High	Difficult	Qatar, Sentosa, Sacramento, Seattle		
Representation of queuing	Dynamic traffic assignment (mesosimulation)			SYD, BRIS, MELB, London, ADL, Madrid, Berlin, Barcelona		
Link-based models do not accurately represent queues in the network	Quasi-dynamic macro-assignment			SYD Netherlands		Node based
Co-ordinated ramp metering algorithms	Mesosimulation			Minneapolis		

No one existing model identified by the review team meets all of these specifications, but the Sydney STM comes close and the metropolitan-wide mesoscopic models in Adelaide and Melbourne complete the picture. A mesoscopic model including hybrid simulation approaches (meso and micro level) – as exemplified in Marsico *et al.* (2013)³⁷ – offers the highest level of flexibility in this modelling domain.

³⁷ Marsico, M, Weeks, A, Opie, K and Aycin, M (2013). Double vision, *ITS International* 19 (Nov/Dec), 19-21.

5 MODELLING OPTION 1: PARALLEL DEVELOPMENT

To assess the first option of “developing both STEM and ROM and improving the integration between them” it is necessary to consider their main characteristics and differences.

5.1 Main Roads WA: ROM24 and Associated Models

5.1.1 General specifications

Conversion of MRWA’s transport models to the Cube Voyager platform provided the opportunity to develop ROM24 as an enhancement to MRWA’s strategic Regional Operations Model (ROM). The revised traffic zone system will comprise a total of 1,239 zones – 1,218 internal, 12 external and 9 special generator zones. In Stage Two, commencing in 2014-15, a notional total of 1,500 zones has been indicated – allowing for additional zones as development intensifies.

ROM24 road model networks are true shape networks and the network model nodes are aligned to Node Elements in MRWA’ Integrated Road Information System. This allows for easier updating of road inventory attributes such as the number of lanes, speed limits and observed traffic counts. New attributes can be defined easily on the model networks, such as horizontal and vertical geometry and pavement condition.

In ROM24 assignment, all day (or time period) link capacities are replaced by hourly capacities. The sequential assignment means that residual congestion on saturated links can dwell into the subsequent assignment hour, through updated speed-flow functions. Thus ROM24 can mimic traffic flow breakdown and recovery and the new assignment methodology integrates MRWA’ peak hour and all day models. Figure 3 illustrates the capacity to ‘remember’ congestion in previous assignment hours and thus deal with collapsed flow and recovery.

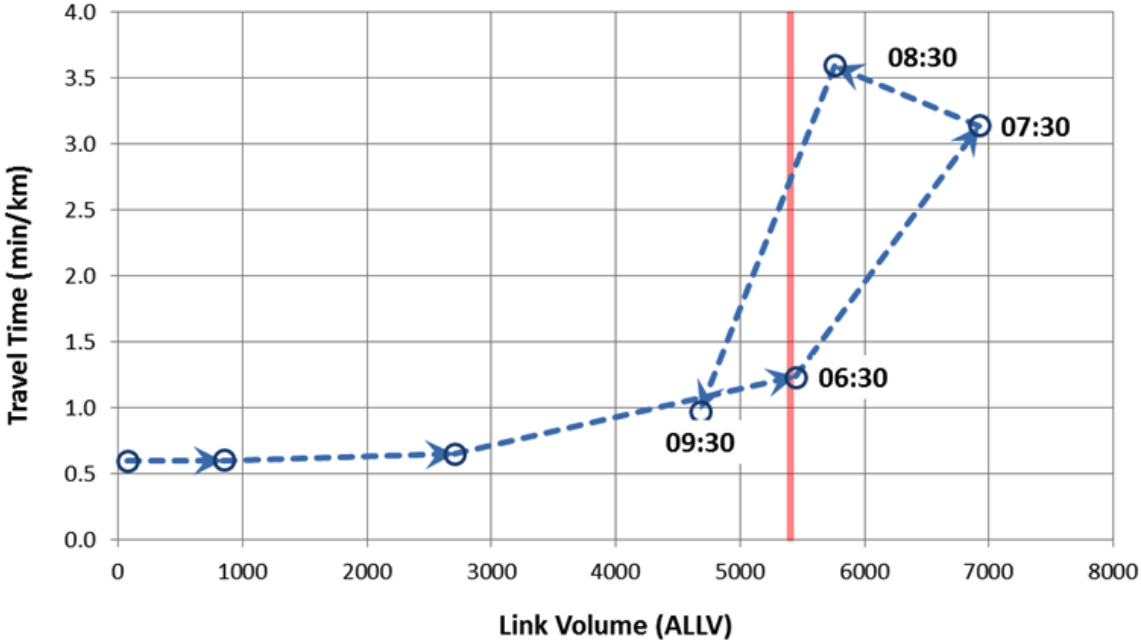


Figure 3: ROM24 modelled travel time by time of day on Kwinana Freeway Northbound

The Transport Modelling Section of MRWA is also developing a mesoscopic model in the Canning Highway area using the software package Cube Avenue. This software will tie in with TMS's models ROM/ROM24 and PEAK2012 to assess projects with greater detail than a strategic model and with far less cost than an equivalent micro-model.

5.1.2 Projects and service

Numerous projects are carried out by the Transport Modelling Section. Thirty-three recent transport modelling projects are listed in MRWA (2013)³⁸. These projects are varied and include regional centres, grade separation, CBD diversion, airport access, highway extension and upgrading and modelling tasks in association with local governments. Particular attention is given to the following:

Bridge projects: Fremantle, Canning, Shelley, River crossing (options) study;

Regional centres: Stirling, Cockburn;

Traffic flow: Continuum (Freeway) Flow Model; Peak.

Development of the Continuum Flow model (currently focused on modelling freeway traffic) gives particularly good capacity to deal with traffic streams at a detailed level. This includes dealing with the estimation of time lost in traffic jams, modelling ramp-metering strategies, automatic incident detection, modelling variable speed limits, and modelling all-lane running.

5.2 Department of Planning: STEM and Associated Models

5.2.1 General specifications

There are currently two versions of STEM in production. The first version has been converted from the EMME platform to the Cube Voyager platform (STEM DoP) and is maintained by the WA Department of Planning. A second version of STEM (MAX DoT) was developed during the MAX LRT project by the WA Department of Transport and continues to run on the EMME platform. The expansion of the STEM zones from 472 to approximately 1,500 has been proceeding – allowing for special and dummy zones to provide particularly for park-and-ride. STEM uses a less detailed road network than ROM24. However, bus routes are fully specified even where they include local roads. STEM is designed to provide output to meet policy and public transport needs.

Irrespective of the platform (Cube or EMME), the STEM modelling suite follows the four-step structure, but the model is being extended to peak spreading and public transport crowding. Major parameters in the mode choice model are being re-estimated by stated choice methods.

5.2.2 Projects and service

Recent and current projects include activity centre structure plans, modelling for railway extensions (Yanchep, Midland, Southwest, Thornlie-Cockburn), south and northeast

³⁸ Main Roads WA (2013). *Transport Modelling at Main Roads WA*, November.

structure plans, modelling for 2031, light rail transit, accessibility indices. The framework for accessibility calculations could be easily adapted in the future to logsum derivation, in a model incorporating mode and destination choice. Provision of services to meet the needs of land-use planners is an important function. The WA Department of Planning is currently considering a proposal to develop a pilot land use model using Cube Land.

5.3 Assessment of Option 1: Parallel Development

As befits their role, MRWA have a strong focus on modelling road traffic and operations. The work on the Continuum Flow model is an excellent and highly creditable example. The focus on MRWA responsibilities appears less strong in the statement *“ROM24 also heralds the arrival of a modal choice capability, which will enable Main Roads to independently assess land-use transport interactions and end Main Roads’ reliance on DoP for the provision of mode split factors”* (Main Roads WA, 2013). MRWA have understandably advised that this step with ROM24 was taken as a direct response to a perceived lack of service from STEM.

The desire for independence is further reflected in the following response with respect to differentiated network development and improvement paths:

“The ROM and STEM model networks are ‘similar’ in that they are representations of the same road network, but there are marked differences. Further, the differences between ROM24 and STEM networks are even more significant. These differences include:

- *ROM24 road model networks are true shape networks;*
- *More detailed zone connector coding in ROM24 – as a consequence of 1,132 zones;*
- *More detailed coding of public transport networks in ROM24 whereby each individual bus stop is coded in the ROM24 networks, allowing the connection from the zone centroids to all PT stops;*
- *STEM and ROM24 have different speed-flow functions and intersection coding;*
- *The alignment of the ROM24 road network model nodes to Node Elements in Main Roads’ Integrated Road Information System (IRIS)...”*

The STEM modelling team also has specific functions and meets particular needs. There is a strong relationship with the land-use modellers in the Department of Planning and that connects to modelling for regional structure plans. However the modelling work is heavily oriented to public transport, broad policy work and long-term projections.

Thus a case can be made to allow the two modelling teams to continue to stand alone, providing specialised services to the current clients. Statements in MRWA documents indicate that the two models have been moving apart in some respects, even as they come together in others. This may be irrelevant if both are providing good service – and the responses on which Tables 1 and 2 are based indicates satisfaction with both models by most members of two groups of clients.

Nevertheless duplication of core functions is not resource efficient and special services to particular clients could better be provided by a combined modelling system, using shared and common core functionality. If the two modelling teams separately draw on inputs from

the land-use modellers that too will put an unnecessary strain on Department of Planning resources. The driver for the apparent current duplication of effort appears to be lack of confidence and trust in the ability of other teams to provide inputs in a dependable, accurate and timely manner, which poses a significant risk to downstream modellers. This is an issue unrelated to a particular modelling approach, but rather to institutional arrangements, providing further motivation for a combined modelling system.

Although both ROM24 and STEM use sound modelling methods, on present directions, neither could be claimed to be best practice by world or Australian standards.

5.3.1 Applying the best practice assessment criteria to Option 1

To complete the assessment, the principal best practice criteria indicated in Section 4.5.1 are considered as follows:

Land use and transport models directly interacting There would continue to be provision of land use data from MLUFS to the transport models. This would be far short of direct interaction between land use and transport models.

Tour-based trip modelling Would probably be adopted gradually.

Simultaneous mode and destination choice giving loqsum benefits Not feasible currently but might be achieved when STEM moves to choice based destination selection.

Time of day modelling taking account of peak spreading Both transport models have this objective.

Static traffic assignment as a base case Both models already do this.

Mesosopic traffic assignment The development work by the ROM24 team would continue.

Hybrid mesoscopic and microscopic modelling Could be expected to develop gradually.

Increased focus on detailed modelling of traffic streams This work by the ROM24 team would continue, but could not be expected to accelerate substantially.

6 MODELLING OPTION 2: CLOSELY ASSOCIATED MODELS

ROM24 now operates on the Cube Voyager platform, while versions of STEM operate on both Cube Voyager and EMME. Similarity of the software platforms allows not only for easier collaboration, but also for storage of models and databases in a cloud-computing environment, so that all authorised users of the model can access the same/latest versions of the models.

6.1 Bringing the Two Models Closer

Given the common platform and the capability for model sharing, a possible development is to make STEM and ROM24 function as a combined strategic level, long-term forecasting model. This would also allow the development of a connected suite of models for more detailed (and perhaps shorter-term) planning studies and analyses.

The combined models would still follow the conventional four steps, with much greater attention to departure time, which this Review has called Step 5. Availability of O-D matrices by time of day is a critical factor in the application of the latest assignment models and opens the door to better assessment of traffic and congestion management plans. Trip generation would still be done effectively by STEM (or its successor), along with greatly improved trip distribution.

The modelling steps are briefly reviewed in the following sections and some immediate improvements are recommended.

6.1.1 Household Classes, Vehicle Availability and Trip Production

STEM is already well specified in comparison to other models, with twelve household types and a car ownership model. Trip production is calculated for each household type for each of seven trip purposes: work (blue collar and white collar), education (school and tertiary), shopping, other home based and non-home based trips (including personal business, escort children, recreational, pick-up/drop-off, transfer - without differentiation). Similar trip production is undertaken in ROM24 with 11 trip purposes (eight directional – work, education school, education tertiary, shopping and return - and three non-directional – home-based other, accompany others, non-home based).

Three measures of employment accessibility are used in the vehicle availability module:

- Jobs accessible to a zone within a given walk time – a measure of the employment density close to a zone and an indication of the potential for walking to work;
- Jobs accessible to a zone within a given travel time by public transport – a measure of public transport service with respect to the job market;
- The proportion of metropolitan jobs accessible to a zone within a given highway distance – a measure of employment density around a zone beyond walking distance.

The model also generates other measures of accessibility, which are used as indicators for land use planning. These uses are discussed briefly in section 7.2.4.

6.1.2 Trip Distribution

The trip attraction models for each of seven (STEM) or 11 (ROM24) trip purposes are estimated by regression from zone and survey trip records. The work trips attracted to a particular zone are directly related to the number of job locations by industry in that zone, estimated from Census data. MLUFS also projects job location by industry into the future at five yearly intervals. For other trip purposes, added attractors are the number of dwellings and educational enrolments.

An important item in the STEM work program is to develop tour based modelling. It is essential to recognise that a car trip from home means a return trip by car, but the concept of tours can be extended to other linkages, as used in Auckland (Wood *et al.*, 2008 and Annexure A.6 in this document) or Sydney³⁹. The primary benefit of tour based modelling is that the distribution applied in the time choice of the return trip should be consistent with that of the outward trip, which is achieved by considering the travel as a single 'tour' rather than as a collection of individual trips⁴⁰. Miller *et al.* (2003)⁴¹ give a theoretical assessment and application. Both models apply gravity/entropy-based approaches, which require substantial revealed preference data for calibration (Ortúzar and Willumsen, 2011). In addition, STEM uses a second distribution model, called parking destination choice model. The parking destination is based on a logit model for trips with destination in the CBD, and park-and-ride and kiss-and-ride trips. Although not yet included in STEM, conversion from gravity distribution to destination choice is planned to start in 2015.

A major need reported in the Needs and Gaps report was to model peak spreading and departure time choice (DoP, DoT, MRWA, Private). Both ROM24 and STEM have the potential for a departure time choice model.

6.1.3 Mode Choice

Ensuring that the shares of travellers going by the various modes are projected with reasonable reliability requires not only a good fit to current data but also responsiveness to changed or hypothetical conditions that may be considered by government. The mode choice algorithm in ROM24 has choice between car driver, car passenger, public transport, park and ride, cycling and walking. The mode choices used for 'white collar' trips in STEM are shown in Table 6.

A major need reported in the Needs and Gaps report was to make the mode choice model more responsive to fares and wait times (DoP, DoT, MRWA, Private). Table 6 shows that determination of the mode choice is heavily influenced by the model constants (in *italics*), leaving the service parameters (in **bold**) to make relatively smaller contributions.

³⁹ Roads and Maritime Services NSW, 2013, *Traffic Modelling Guidelines*, ISBN 978-1-922194-21-3, NSW Government.

⁴⁰ SKM (2009). *Critical Review of Transport Modelling Tools (Implementation Options)*, www.skmconsulting.com.

⁴¹ Miller, EJ, Roorda, MJ, and Carrasco, JA (2003). A Tour-Based Model of Travel Mode Choice, *10th International Conference on Travel Behaviour Research (IATBR) Moving through Nets*, Lucerne, August, 10-15.

A problem is shown by the gaps in the travel service parameters in Table 6 – note ‘a’ indicates the needed coefficients; approximate parameter estimates have now been inserted. Such gaps have meant, for example, that there will be no modelled response to a cost change in any mode except car driving. There was a response to waiting time by kiss-and-ride travellers but none by the other two groups of public transport users, so that the latter were modelled as not responding to train and bus frequencies.

Table 6: White Collar Work Trips Mode Choice Parameters in STEM

VARIABLE	MODE	Car Driver	Car Passenger	Park & Ride PT	Kiss & Ride PT	Walk to PT	Cycle	Walk
Inclusive parameter (Nested Logit)		0.180	0.458	0.180	0.458	1.000	1.000	1.000
<i>Mode specific constant</i>			-5.718	-10.378	-5.339	-2.988	-2.670	-0.445
<i>CBD dummy variable</i>		-7.648	-0.901			1.574		
Total cost (\$)		-0.001		a	a	a		
Highway time (min)		-0.112	-0.079					
Total travel time (min)				-0.075	a	a		
Cycling Time (min)							-0.025	
Walking distance (km)								-0.317
PT access and egress time (min)				-0.110	-0.103	-0.017		
PT wait time (min)				a	-0.127	a		
PT in-vehicle time (min)				a	a	-0.014		
Cycles per household							0.444	
School age children per household							-0.417	-0.249
Vehicles per household		6.258	0.568				0.328	
Licence holders per household		-3.163						
Adults per household						0.246		
Workers per household			0.557				-0.432	

a. Needed parameters (see text)

Source: Derived from Asymptote Consulting (2011) *STEM: Technical Report on Calibration and Validation of Spectre 3.3*, Table 7.8.

Conversely, those who walked to the station were the only ones who would be modelled as responding to a change in public transport in-vehicle time. The total travel time coefficient for park-and-ride has implicitly reflected the response to in-vehicle and wait time but there was not a total travel time coefficient for the other two public transport user modes. The use of a CBD dummy variable appropriately reflects the ‘bias’ away from the CBD by car drivers and towards it by public transport users; however, there is no coefficient for this dummy for two of the PT user classes. There are similar deficiencies in the blue-collar work, shopping and education models.

Despite the repairs to the functions, a further problem is that when the choice response parameters in Table 6 are expressed as elasticities⁴², there is a lower level of responsiveness than is indicated by the ATC Guideline⁴³ elasticities (Table 7). The STEM choice elasticity (responsiveness) to changed in-vehicle time is about a third of what is shown in the current ATC Guidelines and the elasticities with respect to frequency of service and to costs are smaller proportions of the ATC elasticities⁴⁴. The choice elasticities with respect to fares would have to be converted to demand elasticities if the full travel response to a change in fare or pricing policy is required⁴⁵.

Table 7: Australian Transport Council Guidelines: Short-Run Elasticities

	PEAK	OFF-PEAK
Fares (costs)	-0.25	-0.50
Frequency of Service	+0.25	+0.50
In-Vehicle Time	-0.30	-0.50

Source: ATC (2006) *National Guidelines for Transport System Management*, Volume 4.

The new choice parameter estimates should be made by the advanced stated choice (SP) methods that have been developed in the Australian Research Council Linkage project LP110201150, in consultation with Professors Hensher at Sydney University and Rose at Institute for Choice, UNISA. The method is much more efficient than attempting to estimate from large scale surveys, mainly because of the precise and comprehensible specification of choices and their attributes but also because the surveys are smaller.

The resulting estimates should fill the unacceptable gaps in Table 6 and the similar tables for blue collar work, shopping and education trips. If gaps still remain then it has been suggested that industry standard values could be used as a fallback⁴⁶. The modified functions would need to be recalibrated but would respond to potential policy changes.

To achieve a fully responsive choice model it will also be necessary to model additional factors. Travellers are increasingly sensitive to crowding on public transport, to highly variable road travel times and to parking availability. Thus a satisfactory mode choice module should contain parameters reflecting responses to these factors, as well as the time and cost parameter estimates already included.

⁴² Some concern has been expressed about the transferability of elasticities from larger cities to Perth. An elasticity is a dimensionless measure of responsiveness to e.g travel time or cost and is reasonably transferable because it reflects similarity of people’s behaviour. An elasticity would not be transferable if based on extreme values – very high costs or extremely slow service for example. The ATC elasticities are essentially averages, not based on extremes.

⁴³ The ATC National Guidelines for Transport System Management in Australia (NGTSM) are currently being updated and one of the members of the Working Group (Dr Wes Soet) is part of the Steering Group for the NGTSM Update. Revised parameter values and elasticities will be available by June 2015.

⁴⁴ MWH (2013) *STEM – Independent Model Review*, prepared for the MAX Project, PO Box 3602, South Brisbane, QLD 4101.

⁴⁵ Smith, B and Taplin, J (2014). Derivation of demand elasticities from travel choice elasticities, *Journal of Transport Economics and Policy*, available online at www.ingentaconnect.com/content/lse/jtep/pre-prints/content-2795_Smith.

⁴⁶ Douglas, N (2013). *A way forward for forecasting patronage and economic effects of the Perth MAX LRT*, Draft Working Paper to WA DoT, DouglasEconomics@ihug.co.nz.

To sum up, the mode choice (split) module must have soundly based choice response parameters to deal with actual and emerging conditions and any potential policy changes. Accordingly, the preferred modelling approach requires a reliable specific coefficient in each choice function for:

- Prices, costs and charges;
- Waiting time (not for car driver or passenger);
- Access and egress time (not for car driver or passenger);
- In-vehicle time;
- Crowding (not for car driver or passenger);
- Variability of travel time;
- Probability of finding a park-and-ride parking place.

Revealed preference data from the planned mobility survey PARTS, combined with stated choice data would assist the models' calibration.

6.1.4 Traffic Assignment

The widespread international advent of mesoscopic traffic models has significantly changed the situation regarding traffic assignment modelling (Ortúzar and Willumsen, 2011). This new class of models, which are based on traffic flow theory, driver behaviour and better representation of road capacity (through more detailed description of road geometry, intersection design and traffic control parameters), now provide methods for more realistic modelling of queues and delays in road networks. The software implementations of these models also permit their use on large scale networks, comprising thousands of intersection nodes, and perhaps representing entire metropolitan road networks.

The assignment modelling strategies in these new models are termed dynamic traffic assignment (DTA). There have been many research models for DTA developed, and now many implementations in the commercial software packages. Two recent American publications serve to define the current state of practice in DTA. These are practice reports from the US Transportation Research Board (TRB) and the US Federal Highways administration (FHWA)⁴⁷. They explain and summarise the theories behind DTA and the input data requirements, describe a number of case study applications, and discuss calibration and validation requirements and the areas of application of DTA models.

A major benefit of DTA is the ability of this modelling method to account for spatial and temporal effects of congestion on traveller behaviour and choices (Ortúzar and Willumsen, 2011). The method is also versatile, in that it can be used for 'long run' planning studies (at least up to medium term, say ten year, planning horizons, in which regular behaviour ('equilibrium' conditions) may be assumed, and for studies of short term behaviour, such as driver responses to incidents and accidents, construction zones and temporary road closures. Operational strategies and management plans, including ITS implementations,

⁴⁷ FHWA (2012). *Traffic analysis toolbox volume xiv: guidebook on the utilization of dynamic traffic assignment in modelling*. Report FHWA-HOP-13-015. Federal Highway Administration, US Department of Transportation, Washington DC.

ramp metering, corridor management and travel demand management can also be studied using DTA.

The versatility extends to the level of detail included in or required for a study. Macroscopic, mesoscopic and microscopic simulation models can use DTA methods. Hybrid modelling, in which results from one model are fed into – or integrated with – another in an iterative process are feasible and are now finding applications in practice. Hybrid modelling is further discussed later in this report (Section 7.1).

The basis of (static) user equilibrium assignment is Wardrop's first principle of traffic assignment, which may be expressed in the following general terms: *'in a network with multiple possible routes between an O-D pair, all used routes will have equal and lowest travel times (generalised cost). No traveller may decrease their travel time (generalised cost) by unilaterally changing to a different route'*. Assignment models such as those currently in STEM and ROM use this principle, for which there are well-established algorithms that ensure convergence to a unique solution. A commonly agreed definition of dynamic (i.e. time-dependent) user equilibrium has been provided by FHWA (2012): *'in a network with many O-D zones and in a specific time period, for each O-D pair and departure time period, all used routes will have equal and lowest experienced travel times (generalised cost) and no traveller may decrease their experienced travel time (generalised cost) by through unilateral action'*.

Whereas in static assignment the path travel time (generalised cost) is simply the sum of link travel times (generalised costs) along the path, dynamic assignment includes time-varying travel times (generalised costs) on links and at nodes, where the variations occur due to the build up and dissipation of congestion. Travellers are thus assumed to consider the times (costs) they would encounter whilst traversing the chosen path. The experience travel time (generalised cost) thus has to account for the instant of time at which a traveller arrives at each node (or enters a new link) along the path. This provides a more realistic representation of traveller behaviour in the face of traffic congestion.

A dynamic equilibrium assignment model will yield a solution consistent with the definition provided above. This provides a useful schema for planning models. A mesoscopic trial is underway within ROM24 using Cube Avenue and Analysis Drive for dynamic matrix estimation.

Non-equilibrium assignment models are also available. These models include route choice mechanisms in which drivers react to information, including the evidence of their own eyes, about unexpected traffic or environmental/weather conditions and use this information in conjunction with their prior experiences (day to day learning and adaptation). This approach

is of value in evaluating the potential impacts of incidents, evacuations, or even the provision of pre-trip or on-route real time information (Mahmassani *et al.*, 2001⁴⁸, 2013⁴⁹).

TRB (2011) provides a comprehensive account of the concepts and methods employed in DTA. FHWA (2012) provides a classified list of recent applications to DTA to real world networks. These include:

- Bottleneck removal studies;
- Active Transport and Demand Management (ATDM) strategies;
- Integrated Corridor Management (ICM) strategies;
- Intelligent Transport Systems (ITS) strategies;
- Incident management and response scenarios;
- Transport planning for special events;
- Work zone impacts and construction diversion;
- Managed lanes and toll road projects.

Thus DTA provides a powerful modelling methodology, primarily (if not exclusively) for applications to sub-area or corridor networks. TRB (2011) discusses the realms of application of DTA. Primarily these lie in studies that require representation of the effects (in capacity, queuing and delays) of traffic control systems (especially traffic signals and freeway operations), although they may lack the detail for realistic modelling of advanced traffic control systems (e.g. adaptive control systems such as SCATS). They require a degree of detail in their network descriptions, including road geometry, numbers of lanes by turn type at intersections, short lane lengths, perhaps lane widths, parking restrictions and signal settings. This level of detail is familiar in the context of microscopic simulation models. It is not likely to be available for long term planning applications where these design details will not be clear (and indeed where technological innovation in future years may significantly alter traffic system performance). Thus DTA implementations are likely to be of substantial value and importance in short term studies and evaluation, but may be less useful for long term planning studies. DTA models are not a universal panacea for transport modelling, but should and will play an increasingly important role in future modelling, especially for operational strategies and plans (Ortúzar and Willumsen, 2011). The alignment of the ROM24 road network to Node Elements in MRWA's Integrated Road Information System (IRIS) allows for easier updating of road inventory attributes or definition of new attributes of interest and facilitates the development of a metro-wide mesoscopic/hybrid model for Perth.

⁴⁸ Mahmassani, HS (2001). Dynamic Network Traffic Assignment and Simulation Methodology for Advanced System Management Applications, *Networks and Spatial Economics*, 1, 267-292.

⁴⁹ Mahmassani, HS, Saberi, M, and Zockaie, A (2013). Urban network gridlock: Theory, characteristics, and dynamics, *Transportation Research C*, 36, 480-497.

Much of the discussion on assignment modelling focuses on private vehicle movements through a network. Consideration of transit assignment (i.e. the use of public transport services and routes in a multimodal travel environment) is also of importance and is becoming more so as planners place greater emphasis on public transport use and access, and on travel by the active modes of walking and cycling. New issues arise for transit assignment models, especially in crowded transit systems where passengers may have difficulty in accessing the vehicles of their first choice. Alternative model formulations for assignment to transit networks and services are in use, and a useful summary of the research models in this field is provided by Schmoecker *et al.* (2008)⁵⁰. The EMME version of STEM (MAX DoT) includes a congested public transport assignment module.

6.2 Freight

Modelling of freight movements is an important, if not vital component of travel demand modelling, but is still the least developed part of travel demand analysis. The basic information required in urban and regional transport planning for freight includes O-D matrices by mode (road and rail) and vehicle type - heavy goods vehicles (HGV), and light goods vehicles (LGV), also known as 'light commercial vehicles'.

Two reasons exist for the lagged development of component freight models. The first is the serious lack of reliable and representative data on freight vehicle movements. Many cities, including Perth, are operating with the results of Commercial Vehicle Surveys (CVS) conducted many years ago. The review team understands that a new CVS for Perth is planned for 2016/17. This is timely.

The second issue is the approach to modelling. Previous modelling attempts have tried to use the same basic procedures as for passenger transport, with model frameworks analogous to the 'four-step' model. Recent research indicates that the analogy between freight and passenger modelling is misplaced, because of the significant differences in choice and decision processes between the two areas. Given the economic importance of freight transport (at regional, metropolitan, national and international levels), and the considerable design requirements placed on transport systems by freight movements, transport agencies should be making strong considerations for freight in the provision and management of transport systems, networks and infrastructure.

⁵⁰ Schmoecker, J-D, Bell, MGH and Kurauchi, F (2008). A quasi-dynamic capacity constrained frequency-based transit assignment model. *Transportation Research B* 42: 925–945.

6.2.1 International developments in freight modelling

Drawing on Chow *et al.* (2010)⁵¹, the review of the international literature and reported developments in freight modelling by Taylor (2011)⁵² identified seven broad approaches to freight modelling. These are:

1. *Link-level factoring models*. These are simple models that use historical trend analysis or economic growth forecasts to estimate growth factors that can then be applied to base year link volumes. These models lack any behavioural basis and cannot be used to consider changes to a transport network.
2. *Factored truck trip table models*. These are simple models similar to link-level factoring. The difference is that growth factors are applied to a base year trip table. This type of model can be used to analyse changes to a network, but it is limited to the land use activity pattern in the base year, and again has little behavioural basis.
3. *Commodity-based freight models*. These models use databases and forecasts of commodity flows. They can include mode choice considerations, and convert commodity tonnages to freight vehicle trips as part of the modelling process. Countries such as Australia, the USA and other developed economies generally have good commodity flow databases at national, state and regional levels, so that there is good overall data on commodity flows. The difficulty with this approach is a lack of detail on commodity flows at the traffic analysis zone (TAZ) level, which is the normal maximum level of aggregation used in metropolitan travel demand modelling. Further, there is typically a lack of information on local pick-up and delivery trips (as these are generally not captured in the commodity flow data sets) and on service trips (which are excluded).
4. *'Three-step' truck models*. These models use the traditional 'four-step' modelling approach from passenger transport, excluding the modal choice step (because they are generally only used to estimate truck origin-destination movements and assigned truck volumes on network links. This they involve the steps of trip generation, trip distribution and trip assignment. These models do not generally distinguish between types of trucks (e.g. rigid and articulated). They have limited capability for handling trip chaining (tours).
5. *Hybrid models*, which combine features of the commodity-based models and the '3-step' models. Typically, in the hybrid model, inter-regional or long-haul (import-export) freight flows are modelled using a commodity-flow approach, whilst local truck trips are modelled using a '3-step' approach.

⁵¹ Chow, JYJ, Yang, CH, and Regan, AC (2010) State-of-the-art in freight forecast modeling: lessons learnt and the road ahead, *Transportation* 37, 1011-1030.

⁵² Taylor, MAP (2011). *Review of the Perth Freight Movement Model (FMM): a report to Main Roads Western Australia*. Barbara Hardy Institute, University of South Australia, Adelaide.

6. *Supply chain/Logistics chain models*. These models seek to simulate logistics choices through a supply chain for a given industry. Truck trips result from those parts of the supply chain operations that require movement of a commodity between spatially separated facilities. These models are most widely used for intermodal systems and are not necessarily suitable to urban areas.
7. *Tour-based models*, which are activity-based models that focus on the tour (trip chain) characteristics of freight vehicle operations. This generally means a concentration on truck trips, and on the sequence of trips between pick-up and drop-off points made during the daily work operation of the vehicle.

6.2.2 Perth Freight Movement Model

The existing Perth Freight Movement Model (FMM) may be classified as a *hybrid model*, in which the primary component is a commodity-based model and with elements of the ‘3-step’ model. In fact, the Perth FMM has elements of the modal choice step as well, in that it divides heavy goods vehicles into two types – rigid trucks and articulated trucks – and treats these as separate ‘modes’. Recent extensions of the model involved the inclusion of a choice between road and rail. While the FMM model family (there are similar models for Adelaide, Brisbane, Melbourne and Sydney) has not lived up to its initial promise, probably due to limitations in existing data sources on the actual behaviour (e.g. trip (or tour) length frequencies by urban freight vehicles) it is available as a pragmatic method for the estimation of road and rail O-D freight vehicle matrices. A national review of FMM performance was conducted in 2011. This review developed an R&D agenda, based on collaboration between transport planning agencies across the nation, to improve the performance of the FMMs. This research agenda was picked up and reported by GHD in its recent report on toll road forecasting.

What is clear is that freight modelling is of significant economic and operational interest in transport planning and that major efforts are required to develop and test good models of freight movements for inclusion in metropolitan transport models. This includes the need for the acquisition of new and improved data on freight vehicle movements, as discussed in Interim Report 1 and Section 8 of this Review.

Currently MRWA has engaged AECOM to script the FMM model into ROM24 (Cube Voyager).

6.3 Impact Models – Post-Modelling Analysis

Interim Report 1 gave consideration to the use of transport model outputs in further analysis of both transport system performance and land use plans under different planning scenarios. Social, economic, energy and environmental impacts of transport can be assessed using model outputs, as indicated in Figure 4.

The development of suitable impact analysis modules to cover cost-benefit analysis for project evaluation, energy consumption, greenhouse gas emissions and air quality pollutant emissions should form part the transport modelling suite. In addition, there is important analysis of accessibility (to services and facilities by residents and consumers and for services

and facilities, by businesses and firms), which can be done using the already available outputs from the transport model⁵³ (e.g., similar to SNAMUTS⁵⁴ or enhanced). Work in this area is already being undertaken by the STEM group. This form of socio-economic analysis should also be complemented by further studies of social impacts, such as the regional household vulnerability studies exemplified by the Griffith University VAMPIRE ('Vulnerability Assessment for Mortgage, Petrol and Inflation Risks and Expenditure') index⁵⁵. The ability to use a combined land use and transport modelling system to undertake socio-economic analysis for alternative transport and land use development scenarios should be a prized feature of the modelling suite.

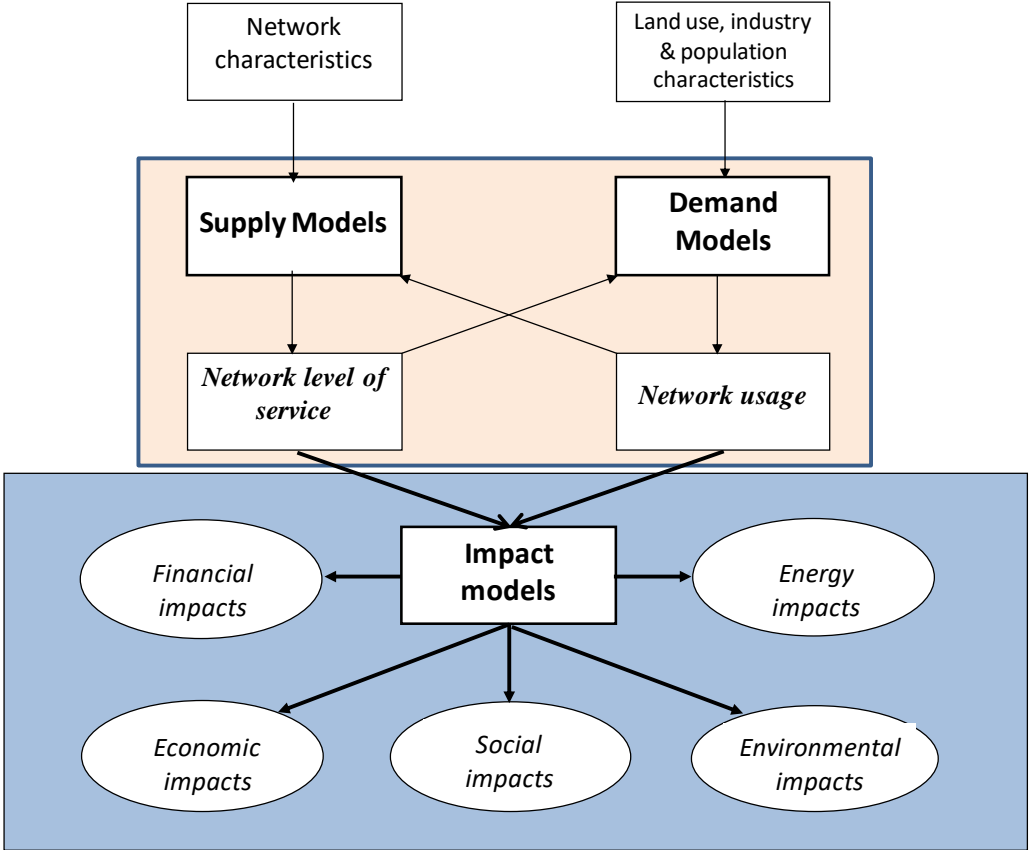


Figure 4: The demand-supply transport modelling system including impact analysis for regional studies (economic, social, environmental and energy impacts)

6.4 Assessment of Option 2: Closely Associated Models

The main advantage of this option is that the ROM24 team could cover the whole range of road traffic modelling needs with emphasis on mesosimulation and on traffic streams at a detailed level using the Continuum Flow model to deal with traffic jams, ramp metering,

⁵³ Accessibility analysis as now an accepted part of transport modelling and some of the commercial software packages include a module for the analysis, based on established accessibility indices (e.g. those indices developed by the UK DfT).
⁵⁴ Curtis, C and Scheurer, J (2010). Planning for Sustainable Accessibility: Developing tools to aid discussion and decision-making. *Progress in Planning* 74, 53-106.
⁵⁵ Dodson, J and Sipe, N (2006). *Shocking the suburbs: urban location, housing debt and oil vulnerability in the Australian city*. Research Paper 8, Urban Research Program, Griffith University, Brisbane.

incident detection, variable speed limits, and all-lane running. There are evident advantages in using limited resources to go much further in detailed traffic modelling – time-dependent where appropriate. Expanded freight modelling would also be the responsibility of the ROM24 team. The main departure from Option 1 would be to rely on STEM for advanced choice modelling.

This is a feasible and reasonable extension of Option 1, giving greater productivity and bringing the two modelling teams back into collaboration.

6.4.1 Applying the best practice assessment criteria to Option 2

To complete the assessment, the principal best practice criteria indicated in Section 4.5.1 are considered as follows:

Land use and transport models directly interacting There would continue to be provision of land use data from MLUFS to the transport models, but little if any direct interaction between land use and transport models.

Tour-based trip modelling Might be adopted somewhat more quickly than in Option 1.

Simultaneous mode and destination choice giving logsum benefits The STEM team could be expected to achieve choice based destination selection and therefore logsum benefits somewhat more quickly than in Option 1.

Time of day modelling taking account of peak spreading Both transport modelling teams could be expected to pursue this objective.

Static traffic assignment as a base case Both models already do this.

Mesosopic traffic assignment The development work by the ROM24 team could be expected to accelerate.

Hybrid mesoscopic and microscopic modelling Pursuit of this objective could also be expected to speed up.

Increased focus on detailed modelling of traffic streams This work by the ROM24 team could become the focus of modelling, given their expertise.

7 MODELLING OPTION 3: INTEGRATED MODELS

Model development is an evolving, dynamic process and needs to be considered as such. All models need ongoing updating, both in terms of parameters and calibration as new data become available and as modelling methods, in the form of improved algorithms and approaches, emerge. The ongoing developments with the current STEM and ROM24 models clearly illustrate this process. In some respects STEM and ROM24 have tended to come together, but the effects of the changes in the zoning system is unclear and the specification of the road networks is different. Other differences are in the first three steps of the 'four-step' system, where there are different specifications of the alternative transport modes. ROM24's prime function is to model road network performance and so provide information for road project planning and traffic management. The new assignment method using 24 separate one-hour periods, with modified penalty functions to represent situations of exceeded capacity, means that its assignment step is the main focus, and this step needs to be fed by origin-destination (O-D) matrices of travel demand. This assignment function is crucial to MRWA. A single strategic model supplying the required O-D matrices to a detailed, dynamic road-based assignment model would meet this requirement.

The limited resources available for transport modelling in Perth are also of some concern. Two separate modelling groups, while collaborating and cooperating but yet still undertaking some duplication of tasks, may not be the optimum way to use the precious resource.

A powerful development, providing both a best practice transport modelling system for Perth and maximising the use of the modelling resources, would be the development of an integrated transport modelling suite, including an updated multimodal strategic model for long-term planning and an advanced metropolitan-wide assignment model for short-medium term operational use. This assignment model would be fed directly by O-D matrices from the strategic model. A structure for this integrated model is discussed in Section 10.3. The fully integrated model would achieve much stronger feedback from the dynamic traffic assignment to the mode choice modelling phase than is feasible when the models are separate. The close association between traffic assignment and the generation, distribution and mode choice modelling stages would be the key to success. Mode choice is particularly important because the performance of the road network, as well as the public transport system, is highly sensitive to the allocated travel flows.

7.1 A New Approach to Traffic Modelling

The crucial development, having an important bearing on option 3 'Develop a new best practice approach', has been to recognise that the traditional reliance on speed-flow functions may lead to misrepresentation of what really happens in an urban network where queues form at intersections and also at road constrictions. This has been well understood and has led to the use of microsimulation and mesosimulation, but the large network models have continued to use speed-flow relationships as a computationally tractable

approximation. It has now been established that three modelling enhancements are feasible and readily applied:

- Mesosimulation – dynamic assignment – can be broadened to cover a whole urban network;
- Quasi-dynamic traffic assignment, which can replace the speed-flow function with queue development in an otherwise large scale static model;
- Hybrid modelling, which can provide flexibility through the integration of microscopic modelling of small parts of a network within the mesoscopic modelling framework for a large area network.

While the first of these developments has been predictable, the second is more radical in that it achieves the global result in a moderate number of iterations and has been shown to converge on the optimum result (Tampère *et al.*, 2011⁵⁶). Convergence is also guaranteed for the traditional assignment methods but in those cases the ‘optimum’ is based on the seriously flawed method of representing delays. Table 9 shows results obtained for four cities by Bliemer *et al.* (2013)⁵⁷ when they used a strictly capacity constrained static network model to move all traffic instantaneously through the network (consistent with static assumptions) subject to turn capacities, which are outcomes of the node model specified in Tampère *et al.* (2011).

The standard static macro model used to assign traffic is well known to reach reasonable approximations to actual traffic flows. However static models are not strictly capacity constrained and fail to represent queuing behaviour or gridlock with spillback. These desirable properties are found in dynamic simulations but such models may not reach unique solutions. A compromise exhibiting the desirable properties of both is the quasi-dynamic model, combining low computational complexity with realistic flow propagation. A key contribution has been made by Tampère *et al.* (2011) who presented a class of macroscopic node models capable of producing realistic and consistent results. Taking account of unsignalised and signalised intersections, these models apply an oriented capacity proportional distribution of the available supply over the incoming links of a node.

Quasi-dynamic traffic assignment models use the physical description of network infrastructure as the basis for their network performance (supply model) assessment. The node based models can also allow for the interactions between intersecting traffic streams to be incorporated in the supply model, which is important for networks with at-grade intersections and for freeway merging points – but requires good knowledge of intersection geometry and traffic control settings. Conventional macroscopic models using travel time

⁵⁶ Tampère, CMJ, Corthout, R, Cattrysse, D and Immers, LH (2011). A generic class of first order node models for dynamic macroscopic simulation of traffic flows, *Transportation Research B* 45(1): 289–309.

⁵⁷ Bliemer, M, Raadsen, M, de Romph, E, Smits, ES (2013). Requirements for Traffic Assignment Models for Strategic Transport Planning: A Critical Assessment, Paper presented at the 36th Australasian Transport Research Forum, October 2-4, Brisbane, Australia.

functions are not able to do this, as the functions generally define link travel time in terms of the traffic volume on the link itself (perhaps allowing for different vehicle types in that traffic). For short- to medium-term studies where data on and knowledge of network configuration can be assumed, the quasi-dynamic assignment models have an advantage over conventional models. However this advantage diminishes in long term strategic studies in which detailed geometry and settings would not be available. The dynamic models also require more detailed demand data input in the form of time specific travel demands.

TRB (2011) and FHWA (2012) discuss the appropriate circumstances for the application of static and dynamic assignment models. A comparison of static, quasi-dynamic and dynamic models with respect to desired properties is shown in Table 8.

The comparison in Table 8 suggests that static models are robust, reliable, and easy to use but may lack realism. On the other hand, dynamic models are seen to be realistic and consistent but less easy to use, less reliable and less robust. In between, the quasi-dynamic models are designed to be more realistic than static models, as well as being robust, consistent, reliable, and easy to use.

Table 8: Comparison of Static, Quasi-Dynamic and Dynamic Models on Desired Properties

	Static Macro	Quasi-Dynamic Macro	Dynamic Macro	Dynamic Meso	Dynamic Micro
Multiple vehicle types	+	+	+	++	++
Multiple user classes	+	+	+	++	++
Strictly capacity constrained	--	++	++	++	++
Queue spillback	--	+	++	++	++
Realistic link model	--	+	++	++	++
Realistic node model	--	+	+	++	++
Stable outcomes	++	++	+	+	-
Convergence to equilibrium	++	+	+	+	-
Existence and uniqueness	++	++	-	-	--
Low model complexity	++	+	-	-	--
Short run time	++	+	-	-	--
Little input required	++	++	-	-	--
Ease of calibration	+	++	-	-	--
Consistent with dynamic micro model	--	+	++	++	

Source: Adapted from Bliemer *et al.*, 2013.

The practical applicability of the quasi-dynamic assignment model, using an event-based procedure, is indicated by Table 9 and Figure 5.

Table 9: Applications of Test Quasi-Dynamic Models to Four Cities

	Zones	Links	Nodes	Routes	OD pairs	Vehicles	CPU seconds per iteration
Amsterdam	418	9,408	4,281	266,505	275,722	271,772	3
Rotterdam	1,744	17,187	6,422	1,394,853	737,415	260,324	18
Gold Coast	1,067	9,565	2,987	1,221,524	592,856	243,838	19
Sydney	3,264	75,379	30,573	2,394,496	1,045,156	1,569,698	89

Source: Bliemer *et al.*, 2013.

The time taken for a route choice iteration (last column of Table 9) shows that a city as large as Sydney does not pose an unacceptably high computational load. Key outputs shown for Gold Coast in Figure 5 are the (horizontal) queues. These (and the 'vertical' queues) are also available for the other cities.

In the test applications on which the results (Table 9 and Figure 5) are based, shockwaves through the network are simulated for the whole simulation time period. This is fast and efficient primarily because an event-based procedure responds to changes in the flow rates. Since this is a static traffic assignment, the input is a stationary flow and the flow rates only change when forward or backward shockwaves hit the other end of the link. Secondly, the dynamic model only has to compute in the local area around the bottlenecks, not the entire network.

For long-term strategic planning studies where details of future detailed network geometry and traffic controls are unlikely to be available, the use of static assignment remains a valid approach.

Professor Bliemer, the first author of the paper quoted, is an expert consultant to this Review.

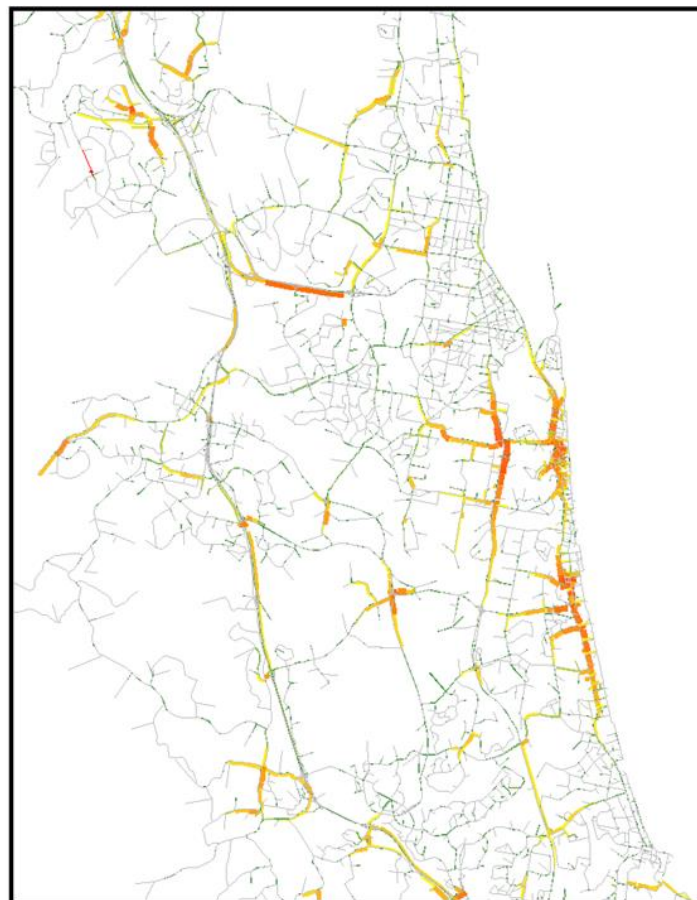


Figure 5: Queues Generated by the Gold Coast Quasi-Dynamic Traffic Assignment Model Developed by Bliemer *et al.* (2013)

Major developments in mesoscopic modelling are now taking place in Adelaide, Brisbane and Sydney. In the case of Adelaide, a mesoscopic assignment model for the full metropolitan area has been developed, while the Sydney and Brisbane developments focus on their CBDs and environs. A further important aspect of these developments is the application of hybrid modelling approaches, within the same software modelling packages. Hybrid modelling generally means the capability to undertake microsimulation modelling of some network components (e.g. a small set of neighbouring intersections) within a mesoscopic model of a larger area containing that set, but some packages also allow for macroscopic modelling (i.e. of O-D matrices for a large area application) within the same model.

7.1.1 Hybrid simulation

Hybrid traffic simulation provides the capability to embed microscopic simulations of ‘focus areas’ (e.g. an intersection or intersection cluster) in the mesoscopic simulation of a larger network. This overcomes the issue of sub-area O-D matrix extraction, which has provided significant problems in studies when microscopic models have been used in stand-alone mode, or when manual extraction of new O-D matrices for focus areas has been attempted. Marsico *et al.* (2013) provided an account of the potential severity of this issue and showed a case study example from New York on how hybrid simulation can resolve the issue. A useful benefit of hybrid meso-micro simulation modelling is that it can provide increased computational speed and calibration requirement for the mesoscopic simulated area, while providing the required increased level of detail in focus areas. Marsico *et al.* (2013) indicated specific examples of the improved model outputs that resulted from the approach, including more realistic movements of different freight vehicle types in critical parts of a network, such as port access.

Some hybrid models also include a macro-level simulator to provide a third level of modelling capability in the same model shell. The macro- simulator is used to provide O-D matrices by mode and time of day.

Adelaide has recently implemented a meso-microscopic model of the metropolitan area and a similar model for the Sydney CBD and inner suburbs is being developed for Transport for NSW (Aimsun, 2014⁵⁸). VicRoads has developed a mesoscopic model for metropolitan Melbourne and is currently developing links between the model and the Melbourne SCATS system to supply actual traffic signal settings for use in the model. Mesoscopic modelling of parts of the Brisbane metropolitan road network has been undertaken by Brisbane City Council and Queensland Transport and Main Roads for specific projects, but as yet there has been no attempt to consolidate these models.

⁵⁸ Aimsun (2014). The Sydney CBD Commuter-Aimsun model. www.aimsun.com.

7.2 Model Outputs to Meet Planning Needs

The integrated model would generate the usual travel outputs, but there would be improved and added outputs including actual traffic outcomes, particularly queue lengths. The following list, which is not exhaustive, draws attention to the policy relevant outputs and accessibility measures:

- Passenger demands, by time period during the day;
- Trips by mode – the basic mode choices giving shares of trips between modes;
- Travel times and link speeds;
- Trip forecasts
 - Metropolitan region flows in future years;
 - Flows resulting from particular land use developments;
 - Flows resulting from particular highway or railway extensions;
- Road traffic flows by link or at screen lines;
- Road vehicle queue lengths – illustrated in Figure 5;
- Public transport patronage: system wide and at particular locations;
- Impacts of specific policies;
 - Traffic management;
 - Price changes;
 - Parking;
 - Reduced crowding through the provision of more rail cars or buses;
 - Reduced variability in freeway travel times – through, e.g., ramp metering;
- Cost-benefit ratios;
- Measures of accessibility.

7.2.1 Effects of changes in traffic management

Given that transport planning is increasingly concerned with management of existing systems, infrastructure and facilities, there is a need to examine the potential uses of traffic management techniques in optimising the use of existing facilities. For this reason the transport models need to be sensitive to changes in traffic management schemes, especially road space allocation and the wider introduction of separate on-road facilities for different road users, such as cyclists and public transport. Clearway restrictions on arterial roads, which will vary by time of day, are another traffic management measure that needs to be included in models, and can be handled by time-of-day modelling.

7.2.2 Effects of price changes

Prices and charges can be used to make the transport system economically efficient and equitable. They have been used for this purpose in the Perth public transport system, but have yet to be used on the road system as a policy instrument. Nevertheless a transport model should be capable of determining the full effects of a pricing policy proposal.

In an economic sense, any price or charge rations the use of something and on the other side a price provides a return for a service or for provision of a scarce resource (May *et al.*, 1997⁵⁹; Armelius, 2005⁶⁰; de Palma and Lindsey, 2011⁶¹) such as parking space. A price is normally generated by the market, but in the transport system it is often due to a determination by a government authority or occasionally a private monopoly.

A best practice production model is expected to have the ability to provide answers to changes in transport systems as a response to applying various financial tools, as described next. Recently, in Perth, congestion charging has become an emerging issue, that is likely to receive further attention. No matter the imminence of any price changes, the capability of a strategic transport model to provide indications on the effect of financial instruments has obvious implications on the type of data that needs to be collected.

7.2.2.1 Road pricing and tolls

One form of road pricing is the fuel tax, which recovers the cost of road damage by heavy vehicles and is indirectly a general charge on light vehicles for access to the road system – as is vehicle registration. Other charges (tolls) are set to recover the construction cost of bridges or limited access roads.

Congestion charges are an efficient way of rationing the scarce road resource and probably preventing serious breakdowns when traffic exceeds capacity. As already indicated, a best practice model must be able to analyse the potential impacts of transport policies that may include alternative regimes for pricing and charging for use of transport facilities and services, including congestion charging, road user pricing, mobility charging etc.

7.2.2.2 Fare changes and differentials

Public transport fares are set to achieve community policy goals while recovering some proportion of costs. The goal of achieving a balance between cars and public transport means that peak train and bus fares are kept well below costs. On the other hand, the off-peak discounts represent rational pricing in relation to resource costs. In view of its policy goals, the Government has been wary of any substantial fare increases.

7.2.2.3 Operating cost changes due to rising fuel prices

The major operating cost changes are due to fluctuations in petrol and diesel prices. The effect of rising fuel prices were masked for some time by the high Australian dollar but there has been a persistent increase in world prices and these are expected to continue. Thus transport models need to incorporate reliable cost response parameters in order to deal

⁵⁹ May, AD Milne, DS, Smith, MJ, Ghali, MO, and Wisten, MB (1997). A comparison of four alternative road pricing systems, In Hensher, DA, King, J, and Oum, T (eds.) *Proceedings of the 7th World Conference on Transport Research*, 3, Pergamon, Sydney, 335-346.

⁶⁰ Armelius, H (2005). An Integrated Approach to Urban Road Pricing, *Journal of Transport Economics and Policy*, 39(1), 75-92.

⁶¹ De Palma, A and Lindsey, R (2011). Traffic congestion pricing methodologies and technologies, *Transportation Research C*, 19(6), 1377-1399.

with projected increases in vehicle operating costs. Electric vehicles will ameliorate this effect.

7.2.2.4 Mobility charging

This is a generalised concept to deal with the idea of using price to change or restrict travel in general. Road pricing and fares can be viewed as part of ‘mobility charging’ (Schönfelder *et al.*, 2007⁶²; Deloitte *et al.*, 2014⁶³) but it may be possible to devise more generalised charges to achieve broad environmental goals.

7.2.3 Cost-benefit ratios

The cost-benefit ratio is a capital efficiency ratio measuring the payoff to government investment capital:

$$\text{Cost – Benefit ratio} = \frac{\text{Benefits} - (\text{Maintenance costs} + \text{Disbenefits})}{\text{Initial Investment of Scarce Capital}} \quad (1)$$

This is a significant measure required by the Government to allocate its scarce investment resources. All elements in the ratio are discounted to the base year at an approved discount rate. The individual ratios will enable the Transport Portfolio Investment Sub Committee to prioritise transport projects within the framework of the combined portfolio Strategic Asset Plan, as recommended by Treasury. Ranking projects in terms of capital efficiency requires a cost-benefit tool based on the single set of demands generated by the transport model. The resulting ratio will assess and rank all transport projects on a consistent basis.

There is now a professional consensus that the user benefits should be measured on the basis of the logsum accessibility measure, which computes changes in consumer surplus⁶⁴. The measure covers accessibility benefits from transport changes using the logsums already produced by the discrete choice travel-demand models. These are calculated in the choice modelling procedure noted in Section 6.1.3. However the logsum method of benefit calculation also requires destination choice modelling. The composite disutility (logsum) is being used in the STEM destination gravity model but it is recognised that this is not conceptually as good as the logit model for destination choice. Nevertheless the combined application of the logsum method of benefit calculation for mode choice and destination attraction is being tested in a cost-benefit module. Meanwhile the ‘rule-of-half’ can still be used to calculate benefits⁶⁵.

⁶² Schönfelder, S, Rich, J, Nielsen, OA, Würtz, CJ, and Axhausen, KW (2007). Road Pricing and its Consequences for Individual Travel Patterns, *Mobilities*, 2(1), 75-98.

⁶³ Deloitte, Infrastructure Partnerships Australia, Australian Automobile Association, NRMA, RACQ and RACV (2014). *Road Pricing and Transport Infrastructure Funding: Reform Pathways for Australia*, available at: <http://www.SwiftPage4.com/Speclicks.aspx?X=2W18CXIAIDOBTKW02VKWV>.

⁶⁴ For a formal treatment of the logsum measure of benefit, see: Geurs, K, Zondag, B, de Jong, G, and de Bok, M (2010). Accessibility appraisal of land-use/transport policy strategies: More than just adding up travel-time savings, *Transportation Research D*, 15: 382–393.

⁶⁵ Taplin, J, Qiu, M, Salim, V and Han, R (2005). *Cost-Benefit Analysis and Evolutionary Computing: Optimal Scheduling of Interactive Road Projects*, Edward Elgar, Chapter 3, 39-47.

It must be recognised that the cost-benefit ratio generated by the model is a ranking device that takes account of transport user benefits but not the disbenefits, which may be suffered by some users and non-users as a result of transport project construction. The environmental impacts may also be substantial. To incorporate these in an absolute, rather than a relative, ratio would require individual analysis in each local situation.

Fundamentally a cost-benefit evaluation compares a base case ('do nothing' – or very little) with the project case and, in the past, occasional mis-specification of the base case has invalidated the result. As a hypothetical and unlikely example, a project might be a large acquisition of new rail cars for delivery in 2021. The incorrect base case would be to take the projected 2021 patrons and load them into the existing rail car stock to produce large disbenefits from passenger delays and crowding. With this mis-specification, the acquisition would appear to generate large benefits by eliminating the imaginary disbenefits. In fact the effects of inadequate capacity would be much less because the transport system is a network and if passengers are dissatisfied with a service they move to alternatives. There would still be project benefits but these could only be calculated by doing a full run of the model – assigning travellers to modes and routes – for the 'without project' case and another full run for the 'with project' case. This hypothetical example is presented because correct evaluation involves a modelling procedure to be followed in all cases so that projects are properly ranked.

7.2.3.1 Wider economic benefits

The importance of benefits in themselves is recognised by MRWA in calculating Wider Economic Benefits. Some transport measures produce substantial benefits even though there is little outlay of scarce investment capital. Important cases are measures to improve the management of traffic and modifications to reduce road crashes, thus reducing injuries and loss of lives. The fact that they do give large cost-benefit ratios is a true indication of worth but the net present value (NPV) of all costs and benefits is also a useful measure, which should be generated by the transport model. Such a project has an operational cost and the NPV is a good indicator of its place in the operating budget.

7.2.4 Accessibility measures

Accessibility calculations are already an integral part of the trip generation process in the STEM model (Section 6.1.1) but in addition the transport model generates the current and projected travel times used to measure job accessibility. Thus a transport model is also an accessibility planning tool, indicating where to put houses and jobs to improve accessibility and minimise adverse impacts. There is a substantial literature on accessibility, particularly with respect to social equity⁶⁶.

⁶⁶ Recent articles include: Karou, S and Hull, A (2014). Accessibility modelling: predicting the impact of planned transport infrastructure on accessibility patterns in Edinburgh, UK, *Journal of Transport Geography*, 35: 1-11; Delbosc, A and Currie, G (2011). Using Lorenz curves to assess transport equity, *Journal of Transport Geography* 19: 1252-1259.

From the transport point of view, accessibility measures can also show how to utilise the transport system more fully. For example, to get more people on outbound trains (away from the city centre) in the AM peak the jobs accessibility measure can show where to locate new jobs to the north and south of the city⁶⁷.

7.3 Assessment of Option 3: Integrated Models

The primary objective of integration would be to reach and even surpass the transport modelling standard already reached in major cities of the advanced countries. This would mean extensive coverage with mesosimulation (dynamic traffic assignment) interacting not only with the macro and micro models, but also directly with improved mode choice modelling and trip distribution. The interaction through feedback mechanisms would be a major gain from integration. However it would clearly take time to achieve a high level of model integration.

At the operational level, the benefits of integration are the converse of the disbenefits of completely separate models; the waste of resources through duplication of functions would be eliminated. Also the unnecessary strain on the WA Department of Planning land-use modellers in providing separate sets of inputs to two transport models would be eliminated.

These changes should not in any way impede the work on traffic streams with the Continuum Flow model and possibly others on detailed questions such as estimation of time lost in traffic jams, modelling ramp metering strategies, automatic incident detection, modelling variable speed limits, and modelling all-lane running. Similarly, specific modelling such as park-and-ride, kiss-and-ride, bus-and-ride and accessibility, now done by STEM, would be strongly supported.

Major gains would also result from improved workflow and resource utilisation. Estimating the extent of such gains would involve a management and governance assessment, which is outside the range of this Review.

7.3.1 Applying the best practice assessment criteria to Option 3

Achievement of the best practice criteria outlined in Section 4.5.1 would be a major objective. The gains would primarily result from removal of duplication and efficient deployment of resources but would also be due to better focus on specialised tasks. The following assessments refer to the proposed integrated modelling suite, PLATINUM, presented in Section 10.3, and two of its components Pt_STM and Pt_RTM.

Land use and transport models directly interacting The use of appropriate software such as MUSSA-based Cube Land or UrbanSim, with the incorporation of MLUFS, would enable efficient exchange of land use and transport data on an iterative basis to achieve the needed direct interaction between land use and transport models.

⁶⁷ See also Primerano, F and Taylor, MAP (2005). An accessibility framework for evaluating transport policies. In Levinson, DM and Krizek, KJ (eds.) *Access to Destinations*. (Elsevier: Oxford), 325-346.

Tour-based trip modelling The Pt_STM module of PLATINUM would not only be modelled on a tour basis, with business trip extensions as in Sydney STM, but would also be enhanced to include deviations – dropping children at school for example. That would be a considerable step towards world best practice with full representation of all tour segments throughout the day.

Simultaneous mode and destination choice giving logsum benefits An important objective for the Pt_STM module would be to develop simultaneous mode and destination choice modelling, as in Sydney STM, in order to achieve efficient trip modelling. This would also make the important step of generating valid logsums, constituting the trip benefits to be incorporated in the cost-benefit analysis.

Time of day modelling taking account of peak spreading At the basic trip level, this would be the task of the Pt_STM module of PLATINUM and would involve a major extension of the trip choice and response behaviour of travellers. However the most significant impacts on traveller responses would be generated by the Pt_RTM module of PLATINUM in modelling the traffic delays by time of day throughout the road network. These would feed back to Pt_STM.

Static traffic assignment as a base case The static assignment of all road, rail, bus and other trips would be done by the Pt_STM module and provided as a base case for the Pt_RTM module to initiate the mesoscopic and hybrid meso-micro assignment models of the metro road network. This feature of model integration is a key part of modelling best practice.

Mesoscopic traffic assignment This will be the core of the PLATINUM modelling suite with respect to road traffic modelling. When fully developed, it will bring Perth up to world best practice in dynamic traffic assignment (DTA).

Hybrid mesoscopic and microscopic modelling The hybridisation is best practice in providing the capability to embed microscopic simulations of focus areas in the mesoscopic simulation of a larger network. This overcomes the difficulty of sub-area O-D matrix extraction, which is a problem with stand-alone microscopic models.

Increased focus on detailed modelling of traffic streams This will facilitate best practice in road modelling by allocating more resources to the Continuum Flow model and to such activities as estimating time lost in traffic jams, ramp-metering strategies, incident detection, variable speed limits, and modelling all-lane running.

8 Data Requirements and Issues

As transport models heavily rely on good quality data, model selection should be jointly considered with data availability. The community of researchers and practitioners has increasingly recognised the importance of advanced knowledge of the surveys and data collection designs that are situated upstream of the models (Ortúzar and Willumsen, 2011⁶⁸). A fairly sophisticated model could not reach its intended objectives if it is limited by input data readiness. Measurement units, the uncertainty and timing of the data, all impact the analysis/modelling. Hence, harmonisation and ‘triangulation’ of various data sources would benefit modelling by reducing costs and potentially addressing biases. This section highlights the need for aligning the input data with the transport model (here PLATINUM) and discusses the challenges arising in this process. They can be broadly divided by type of data used (cross-sectional versus longitudinal), the ability to test causal relations, and spatial resolution.

8.1 Data issues

Transport models need both travel behaviour and transport data, but also data on their determinants (attitudes, motivations, preferences) and on the context.

Most travel surveys (including PARTS) are based on a single day for each household, despite substantial evidence that travel behaviour differs by day of the week. Longitudinal surveys would address this problem (panels offer the ability to rigorously determine the dynamics of changes in travel behaviour), however they are very expensive and difficult to maintain. In addition, the relative stability in making travel choices over time (Raimond, 2009⁶⁹) may dwarf their advantages even more. Hence, continuous/ongoing surveys (not requiring the same sample) appear to be a promising solution to address simultaneously the problem of having up-to-date data and longitudinal trends and is expected to meet the future modelling needs in Perth. The Sydney Continuous Household Travel Survey (HTS) and Victoria Integrated Survey of Travel and Activity (VATS/VISTA) are good domestic examples in this sense (Ampt *et al.*, 2009⁷⁰; Battelino and Peachman, 2003⁷¹). Overseas, many countries in the two American continents and Europe have been using continuous surveys. In Europe, UK, Sweden, Denmark, The Netherlands, and Czech Republic have considered continuous surveys in the last few decades, though “these surveys have not yet made it into the

⁶⁸ Ortúzar, J de D and Willumsen, LG (2011). *Modelling Transport*, 4th Edition, John Wiley and Sons, Chichester.

⁶⁹ Raimond, T (2009). Moving Towards Continuous Collection of Large-Scale Mobility Surveys, in Bonnel, P, Lee-Gosselin, M, Madre, J-L, and Zmud, J (Eds.) *Transport Survey Methods: Keeping up with a Changing World*, Emerald, UK, 541-548.

⁷⁰ Ampt, L, Ortúzar, J de D, and Richardson, AJ (2009). Large-Scale Ongoing Mobility Surveys: The State of Practice, in Bonnel, P, Lee-Gosselin, M, Madre, J-L, and Zmud, J (Eds.) *Transport Survey Methods: Keeping up with a Changing World*, Emerald, UK, 505-539.

⁷¹ Battelino, H and Peachman, J (2003). The joys and tribulations of a continuous survey, in Stopher, P and Jones, P (Eds.) *Transport Survey Quality and Innovation*, Oxford: Pergamon, UK, 49-68.

mainstream” (Stopher, 2009⁷²: 26). The main competitor is the use of rolling averages in modelling, but the possibility of understanding trends and change is a major gain. Continuous surveys offer “*compelling advantages in terms of improved data quality, and costs and administrative efficiency, with few if any trade-offs*” (Raimond, 2009: 546).

There is a lack of indicators of change (dynamics) and usually validation is at an aggregate scale, based on reported travel behaviour. In order to identify real changes, confounding elements need to be accounted for (changes in fuel prices, seasonal differences, etc.) in the models. The recommended way is to use well designed surveys with ‘treatment’ and ‘control groups’, if possible, to compare reported with observed data and to integrate multiple data sources.

Lower response rates and inability to assess the response bias (hard to reach people: recent movers, out of home during survey time, disengaged from broader community because of language barriers, refusals for various reasons), means that statistical weighting procedures have to be carefully applied to reduce the distortion in the results. This is particularly relevant for the choice models (trip making, mode, destination, time-of-day, route) (Ortúzar and Willumsen, 2011). Likewise, the shift to tour-based modelling and perhaps activity-based modelling requires additional data on trip chaining, activity participation, travel party involved, which also affects the response rate. A continuous travel survey is anticipated to cope better with this aspect, as the sample size for each time period is markedly reduced compared to a ‘one-off big survey’. Similarly, the use of new technologies (including GPS devices and stated preference survey methods) enable the collection of better quality data and perhaps smaller sample sizes.

Dynamic data is essential for planning because of the peak travel. Furthermore, detailed and accurate information on public transport is required for planning and management (modal split and time of day are particularly important). SmartRider data offers new possibilities to complement the household and passenger surveys, with the benefit of being already geocoded and time-stamped and identifying sequences of trips and multimodal journeys.

Quality of public transport is already captured in the PTA Customer Satisfaction Survey and a number of intercept surveys have recently elicited the importance of individual transport service features along with their evaluation (e.g., LP110201150 regarding PnR). Indirectly, stated preference (SP) surveys provide indications on the factors that contribute most to the mode, route, departure time, or destination.

In terms of spatial resolution, when transport modellers refer to measurement, the level of aggregation and the geographical unit are crucial. Most of the information for land use is based on areas, but there are also nodes and links/lines. Whereas aggregation of small areas

⁷² Stopher, PR (2009). The Travel Survey Toolkit, in Bonnel, P, Lee-Gosselin, M, Madre, J-L, and Zmud, J (Eds.) *Transport Survey Methods: Keeping up with a Changing World*, Emerald, UK, 15-46.

to a larger area seems easier (except underestimating internal trips/flows), a change to a smaller area is a complex task and requires numerous assumptions.

The spatial aggregation leads to scale and zoning effects. In their review, Páez and Scott (2004⁷³) showed that applying the same analytical technique produces different results according to the level of spatial resolution. Also, for a given level of spatial resolution there are various possible outcomes from an analytical technique due to changes in spatial partitioning. Thus, a way of reducing the modifiable area unit problem (MAUP) is to apply the smallest area possible. The two modelling teams in Perth are already moving to a more refined zoning system (1,500 areas), which will significantly improve the accuracy of the results if it is coupled with the input data system. However, this is not a trivial matter and current MLUFS users have acknowledged the need for simulation-type approaches to offer the required land-use data.

Whereas capturing and analysing data on the built environment benefits from wide-scale detailed geo-referenced datasets on land use and transport, we cannot say the same about travellers, carriers or shippers. Self-reporting instruments combined with direct/passive measurement/monitoring and geo-location tracking may be the best way to obtain accurate and complete measures. Thus, integrating surveys with secondary data sources is an avenue that needs to be explored.

8.2 Freight Data

The interactions between freight and transport services have increased in complexity, yet the sources of freight data “*struggle to meet new requirements. There are a number of challenges in freight surveys, not the least of which is definitional – exactly what is freight?*” (Bonnell *et al.*, 2009⁷⁴: 8). Recognition of the need to understand whether the modelling interest is in measuring what is moved, where and how is moved, or a combination of them assists in new approaches for collecting data on freight (Roorda *et al.*, 2009⁷⁵). Compared to passenger travel surveys, freight surveys are still in their early years of development and numerous gaps were identified: data about light goods vehicles, about the vehicle trips in urban areas, about the supply chain as a whole, about loading/pick-up and unloading/delivery operations, etc. In addition, sampling for freight is more complicated, the commercial movement involves a number of decision makers in separate organisations, and

⁷³ Páez, A and Scott, D (2004). Spatial statistics for urban analysis: A review of techniques with examples. *GeoJournal* 61, 53–67.

⁷⁴ Bonnel, P, Lee-Gosselin, M, Madre, J-L, and Zmud, J (2009). Keeping up with a Changing World: Challenges in the Design of Transport Survey Methods, in Bonnel, P, Lee-Gosselin, M, Madre, J-L, and Zmud, J (Eds.) *Transport Survey Methods: Keeping up with a Changing World*, Emerald, UK, 3-14.

⁷⁵ Roorda, MJ, Meyburg, A, and Browne, M (2009). Surveys on Urban Freight Transport: Synthesis of a Workshop, in Bonnel, P, Lee-Gosselin, M, Madre, J-L, and Zmud, J (Eds.) *Transport Survey Methods: Keeping up with a Changing World*, Emerald, UK, 289-295.

often mode shifts. Patier and Routhier⁷⁶ (2009) made an inventory of freight data sources (primarily in Europe) and concluded that collection efforts were more prominent at national, rather than city level, and that multiple reasons and methodologies used in data collection make it difficult to compare and merge datasets. Some datasets represent surveys (establishment, driver, transport companies), others traffic counts, GPS/cell phone tracking, automated number plate recognition or radio frequency identification. Even with technology advances, so far there are no solutions to readily integrate various data sources and extrapolate the observations to entire city areas. Bayart *et al.* (2009)⁷⁷ discussed two methods of fusion: micro (construction of a complete synthetic file including all necessary data even if not observed directly) and macro approach (initial files, including variables of interest and common/gateway variables, are used to estimate the joint distribution functions). Both of them are more difficult in transport than other fields, because of the resolution level and of the need to treat simultaneously the spatial, temporal, and semantic dimensions. Their observation was not meant to diminish the interest in integrating various sources, but rather to alert the research community of the need for a more systematic endeavour to harmonise data sources and have a longer-term view when planning data collection.

8.3 Data Fusing/Linkage

Even for cross-sectional data, modellers are facing increasing difficulties with travel surveys, including diminishing response rates, sampling frame limitations, privacy concerns. Despite changes in the recruitment and data collection procedures (face-to-face interviews combined with intercept, telephone, mailed-back surveys and online), maintaining high response rates is still problematic. Given the increasing challenges to obtain the required (quantity and quality of) data from a reduced number of sources, many modellers have started to adopt a new approach, data fusing. This means expansion of travel and transport or freight surveys and alignment/linkage with other secondary data streams.

GPS/GSM helps to produce more accurate data for longer time periods, but at a much higher cost (including both data acquisition and processing). Stopher (2013) highlights the benefits of using position aware devices (PAD) and the feasibility of combining the space-time information with activity-travel data, at least for the validation of travel surveys (e.g., VISTA). International experience has shown that large samples have been successfully collected in

⁷⁶ Patier, D and Routhier, J-L (2009). How to Improve the Capture of Urban Goods Movement Data? in Bonnel, P, Lee-Gosselin, M, Madre, J-L, and Zmud, J (Eds.) *Transport Survey Methods: Keeping up with a Changing World*, Emerald, UK, 251-287.

⁷⁷ Bayart, C, Bonnel, P, and Morency, C (2009). Survey Mode Integration and Data Fusion: Methods and Challenges, in Bonnel, P, Lee-Gosselin, M, Madre, J-L, and Zmud, J (Eds.) *Transport Survey Methods: Keeping up with a Changing World*, Emerald, UK, 587-611.

Canada and Europe (Bricka, 2009⁷⁸). However, passive GPS is likely to be more successful than active GPS, which requires respondents to provide additional information.

Computer-assisted and Web-based surveys have increasingly being used for their convenience, easy/interactive and attractive manner of completion, and cost, however their design requires substantially more work. Yet, these surveys suffer from what is called “techno-literacy challenge”, with age and income effects (Murakami *et al.*, 2009⁷⁹), which makes them unfit as a unique source of data, but ideal in combination with others.

Attitudinal surveys are expected to increase along with stated choice surveys, given the importance of preference and attitudes in determining travel behaviour and transport decisions and continuing and expanding the existing PTA Customer Survey is a beneficial exercise.

More recently, online panels have increasingly been used by researchers to understand the behaviour of travellers (Sheldon *et al.*, 2013⁸⁰; Mulley *et al.*, 2014⁸¹). In Australia, PureProfile (<http://www.pureprofile.com/au>) provides a convenient and cheap source of data to complement the existing travel surveys.

To summarise, the inventory of data sources, along with their benefits and limitations leads towards data fusion in WA and a ‘plea’ for a Transport Data Linkage WA, similar to the initiative in health and medical research in our state (<http://www.datalinkage-wa.org/>). This system could connect transport and land-use geo-referenced data, Census journey-to-work (JTW), the existing PARTS, TravelSmart, and any other surveys (regardless of their deployment - online, face-to-face, mail, etc.), the SmartRider database, and any additional digital technologies that could aid data collection and processing and incorporate more visualisation (traffic counts, GPS/phone data, etc.). Existing datasets can be merged and the new ones that will be collected and/or made available could be added to the core system. This implies that suitable processes need to be put in place and resources allocated to develop an efficient repository of data for future modelling in WA.

⁷⁸ Bricka, S (2009). What Is Different about Non-Response in GPS-Aided Surveys?, in Bonnel, P, Lee-Gosselin, M, Madre, J-L, and Zmud, J (Eds.) *Transport Survey Methods: Keeping up with a Changing World*, Emerald, UK, 403-427.

⁷⁹ Murakami, E, O’Connor, S and Gould, J (2009). Electronic Instrument Design and User Interfaces: Synthesis of a Workshop in Bonnel, P, Lee-Gosselin, M, Madre, J-L, and Zmud, J (Eds.) *Transport Survey Methods: Keeping up with a Changing World*, Emerald, UK, 464-472.

⁸⁰ Sheldon, R, Dix, M, Flynn, T, Metcalfe, P (2013). Workshop report: good data is key to the development of good models: so how is innovation in data collection keeping apace, in Hess, S and Daly, A (Eds.) *Choice Modelling: The State of the Art and the State of Practice*, Edwards Elgar, Massachusetts, US, 125-143.

⁸¹ Mulley, C, Hensher, DA, Rose, J (2014). Do preferences for BRT and LRT vary across geographical jurisdictions? A comparative assessment of six Australian capital cities, *Case Studies on Transport Policy*, doi: 10.1016/j.cstp.2013.11.001.

9 Validation

A validated transport model is essential to provide confidence in the use and credibility of the model (Petty, 2010⁸²), although validation does not mean that the model will be free of errors in forecasting, for the input data for future years will also be estimates (perhaps from other models, such as demographic models of populations), and thus subject to their own errors. Full validation must also be seen as a two part process; first comes model calibration, in which model parameters are adjusted to provide a best level of fit with some observed data, then follows validation in which outputs from the calibrated model are compared to an independent set of observed data (i.e. holdout sample, data not used in the calibration)⁸³.

Validation of model outputs is typically undertaken by comparing modelled traffic volumes with observed values, and perhaps supplemented by comparisons of travel times (and queue lengths) given the availability of suitable data. Validation is undertaken for a set base year.

There are well established criteria for comparisons of volumes, generally based on 'goodness of fit' measures, such as Root Mean Square Error (RMSE) and the GEH statistic, backed up by graphical displays ('scatter plots') and correlation analysis, with various agencies setting performance criteria in terms of proportions of links with modelled volumes complying with each of the criteria. Good examples are those provided by the UK Department for Transport⁸⁴ and by NSW RMS in its traffic modelling guidelines⁸⁵. Table 10 reproduces the assignment modelling criteria provided in those guidelines. However it is recognised that a model may be fit for purpose, even if it does not meet these criteria, if the purpose does not require this level of accuracy.

⁸² Petty, MD (2010). Verification, validation and accreditation. In Sokolowski, JA and Banks, CM (eds.) *Modeling and simulation fundamentals: Theoretical underpinnings and practical domains*, John Wiley & Sons, Hoboken, NJ, 325-372.

⁸³ See Taylor, MAP (1979). Evaluating the performance of a simulation model. *Transportation Research A*, 13(3), 159-173, for a full explanation of model calibration and validation principles.

⁸⁴ UK Dft (2014). www.gov.uk/transport-analysis-guidance-webtag, and 'TAG UNIT M3.1 Highway Assignment Modelling'.

⁸⁵ RMS (2013). *Traffic modelling guidelines ver 1.0*. Roads and Maritime Services NSW, Sydney.

Table 10: Assignment modelling target calibration/validation criteria [taken from RMS (2013), Table 10.3: 84]

Network element	Criteria
Link or turning movement	<p>Results to be tabulated in appendices and summarised in main report</p> <p>Tolerance limits for network-wide area:</p> <ul style="list-style-type: none"> 95% of individual link volumes to have $GEH \leq 5.0$ 85% of individual turning volumes to have $GEH \leq 5.0$ (if applicable) All individual link and turn (if applicable) volumes to have $GEH \leq 10.0$ <p>Plots of observed v modelled (hourly) flows required for all observations</p> <ul style="list-style-type: none"> Plots to include lines showing $GEH = 5$ tolerance limits R^2 value to be included with plots and $R^2 > 0.9$ Slope equation to be included with plots (intercept to be set to zero) <p>$RMSE \leq 30$ for all counts</p>
Screenline or cordon	<p>Tolerance limits for network-wide area:</p> <ul style="list-style-type: none"> Each directional screenline or cordon total to have $GEH < 4.0$

10 Proposal Based on Best Practice Assessment

The proposal for an integrated transport modelling suite for Perth is based on the individual assessments of the three options in Sections 5-7. These initial assessments are briefly recalled before the presentation of the proposal.

10.1 Initial assessments

Option 1: Parallel Models

It was noted in Section 5.3 that a case can be made to allow the two modelling teams to continue to stand alone, providing specialised services to the current clients. However, MRWA documents indicate that ROM24 has been moving away from STEM and it was concluded that duplication of functions wastes resources, that special services to particular clients could be provided by a combined modelling system, and that although they use sound methods neither model could be claimed to be best practice by world or Australian standards.

Option 2: Closely Associated Models

The main advantage of this option is that the ROM24 team could cover the whole range of road traffic, using limited resources to extend the work on detailed traffic modelling as well as freight. The main departure from Option 1 would be to rely on STEM for advanced choice modelling. It is a feasible extension of Option 1, giving greater productivity and bringing the two modelling teams back into collaboration.

Option 3: Integrated Models

The objective would be to reach and even surpass the transport modelling standard already reached in major cities of the advanced countries. Waste of resources through duplication of functions would be eliminated, but the change need not impede specialised and advanced work being done by the ROM24 and STEM teams. Substantial gains could be expected from improved work flow and resource utilisation.

10.2 Summary assessment of alternative options by best practice criteria

Table 11 gives a brief summary of the assessments made in sections 5.3.1, 6.4.1 and 7.3.1.

Table 11: Options in relation to best practice criteria

Criteria	Option 1	Option 2	Option 3
Land use and transport models directly interacting	Little change	Little change	Appropriate software to exchange land use and transport data
Tour-based trip modelling	Gradual adoption	Slightly faster adoption	Extended tours with deviations
Simultaneous mode-destination choice;	Depends on STEM achieving	May achieve destination choice	Full development of mode-destination choice

logsum benefits	destination choice	more quickly	and logsums
Time of day modelling and peak spreading	Both models have this objective	Both models have this objective	Impact of traffic delays fed back to mode choice and departure timing
Static traffic assignment	Current procedure	Current procedure	Upgraded to provide the base for mesosimulation
Mesosopic traffic assignment	Being developed by ROM24 team	Accelerate current work	To become the core traffic assignment model
Hybrid mesoscopic and microscopic models	Gradual development	Accelerated development	Embed microsimulation in mesoscopic network simulation
Increased focus on detailed modelling of traffic streams	Current work	Accelerate current work	Allocate more resources to traffic flow and lane modelling

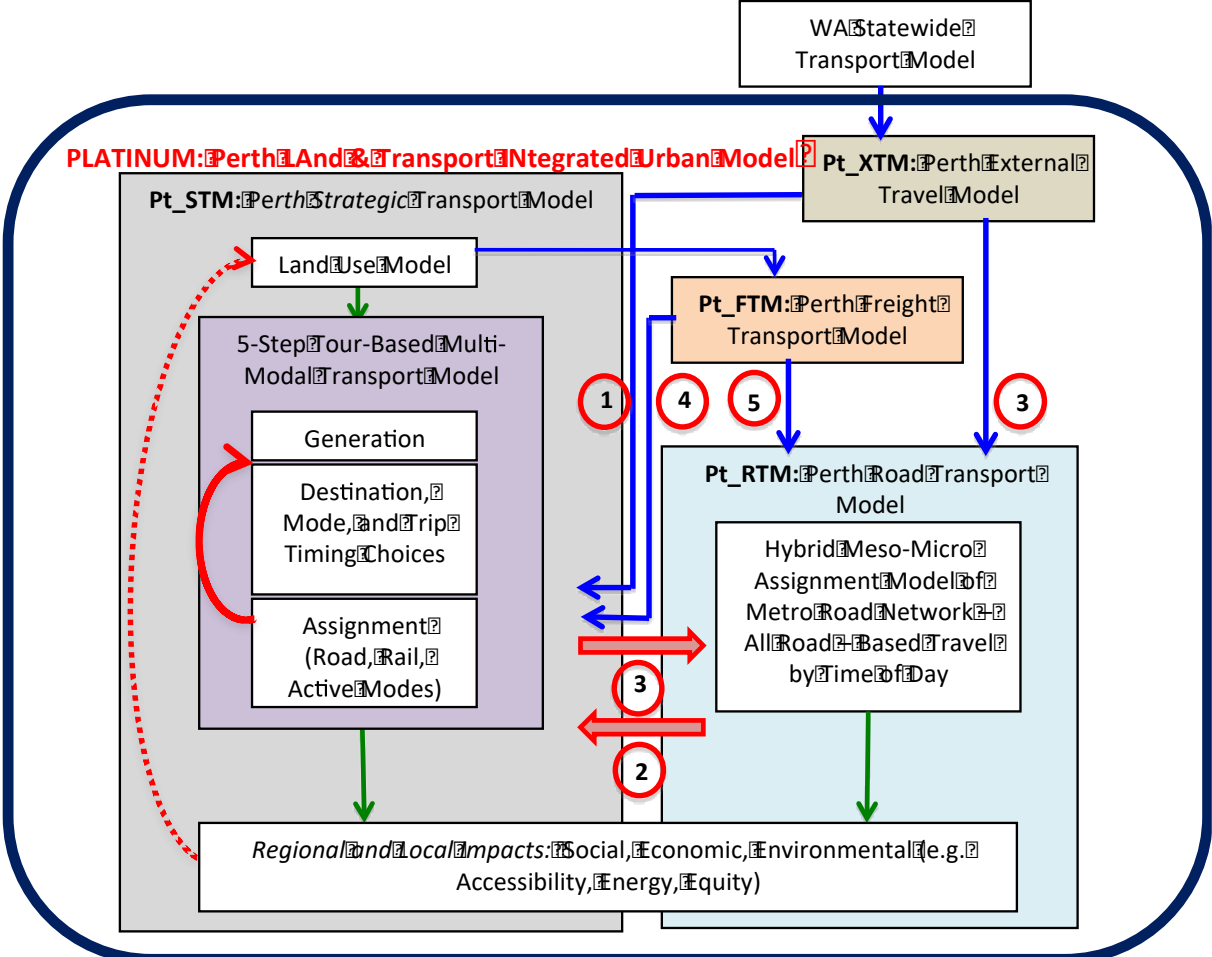
Option 2 and even Option 1 would approach some of the best practice goals, whereas Option 3 would achieve most goals quickly and the remainder somewhat more gradually. Australian best practice would be achieved in the short term and current world best practice would be reached in the medium term. The conclusion of the Review is that Option 3, Integrated Models, is the best course for Western Australia to take. On this basis, the proposed modelling suite is presented in Section 10.3.

10.3 A Proposed Integrated Transport Model for Perth

The proposed integrated transport modelling suite for Perth is presented schematically in Figure 6. This suite is termed PLATINUM, the ‘Perth LAnd and Transport INtegrated Urban Model’, as suggested by Dr Peter Lawrence, consultant to the WA Department of Planning. PLATINUM consists of a number of linked components, namely:

- Pt_STM - the Perth Strategic Transport Model, a 5-step tour-based multi-modal transport model, supported by a land use model and outputting to a regional impacts model. This is the component of PLATINUM for use in long range planning, scenario analysis and system wide transport policy analysis;
- Pt_RTM: the Perth Road Transport Model, a hybrid meso-micro assignment model of the metropolitan road network including all road-based travel by time of day, and outputting to a local area (project-level) impacts model. This model provides enhanced capability for modelling assistance in road project planning and evaluation, traffic management and control, congestion management, local area traffic impacts, event planning and incident management planning;
- Pt_XTM: the Perth External Travel Model (fed by the WA Statewide Transport Model);
- Pt_FTM: the Perth Freight Transport Model, which is made up of an improved FMM and a separate model for light goods vehicles (LGV).

Pt_STM provides road passenger/vehicle O-D matrices, by time of day and for planning horizon years as required by MRWA, to Pt_RTM. Pt_RTM can provide Pt_STM with delayed information on network travel times, delays and queuing for use in the strategic modelling as required. Pt_RTM also takes freight vehicle and external vehicle trip matrices from the other model components, Pt_FTM and Pt_XTM.



Note: 1 indicates – Road passenger/vehicle O-D matrices; 2 – Travel times, delays, and queuing details; 3 – Time-dependent O-D matrices; 4 & 5 - Heavy (Truck) and LGV O-D matrices

Figure 6: Structure of the proposed Perth Land and Transport Integrated Urban Model (PLATINUM), showing linkages between model components and feedback loops in the strategic model (Pt_STM)

11 Implementation Strategy

In considering whether the current models should be developed or whether a totally new model is required, this Review concludes that both should be done in an implementation sequence leading to an integrated model. We have assessed how well the current models meet the needs of transport planning and travel projection in Perth and found that the results fall short of what could be achieved. More importantly, the existing models do not equip the transport planning agencies to meet the needs of a rapidly growing city and deal with changing transport technology and changing expectations of transport users.

The recommended strategy, based on the reasoning outlined in the preceding sections, is that an integrated transport modelling suite should be developed for Perth. However it should be a staged transformation process with the final result being a new model. An integral part of the development will link transport and land use, not only through enhanced land use forecasts but also through a modelling interaction between transport and land use projections.

11.1 The Elements to be Implemented

The components of the strategy are embodied in Figure 6, the suggested resources in Table 11 and the set of implementation activities are shown in Annexure A.8. The elements fall into three groups: specification, re-specification and clarification; enhancements; new component models.

11.1.1 Specification, re-specification and clarification

Create 1,500 new zones for PLATINUM The Department of Planning has undertaken to provide the residential and employment data for the 1,500 zones. These will generally correspond to the SA1 zones of the Australian Bureau of Statistics but some aspects of the land use will be more specific than is given by ABS. With GIS support, there is no difficulty in splitting an SA1 where necessary.

Consolidate the STEM and ROM24 networks for Pt STM and Pt RTM The ROM24 road network has previously been more precisely specified than the STEM road network. Both STEM and ROM24 public transport networks are fully specified.

Document and 'unpack' MLUFS This step is essential to enable re-coding of MLUFS to make it compatible with the chosen software platform, which will be used by Pt_STM.

Create the integrated transport model PLATINUM This suite is specified to comprise the linked components: Pt_STM, Pt_RTM, Pt_XTM, Pt_FTM.

11.1.2 Model enhancements

Additional household types, more travel purposes The existing models will benefit from a more refined understanding of household travel patterns, using additional travel purposes by time of day.

Estimate and re-estimate mode choice parameters The existing parameters for cost, travel time, in-vehicle time, waiting time, access and egress time and walking distance will be re-estimated and the missing parameters for these variables in the three public transport modes (note 'a' in Table 6, Section 6.1.3) will be estimated. This work will be done with stated choice sampling and modelling⁸⁶ and is already in progress.

New crowding and trip time variability parameters These variables have not previously been estimated. Crowding affects the choice of public transport; trip time variability mainly affects road users and the possibility of changing to another mode. Estimation has begun with stated choice sampling and modelling. In addition, elements of comfort and reliability could be included in the modelling when additional stated choice data will be collected (Raveau *et al.*, 2012⁸⁷).

Revision of park-and-ride modelling The existing park-and-ride module will be re-specified for Pt_STM and the coefficients re-estimated. This work is already in progress.

11.1.3 New component models

Consistent cost-benefit model This model will process transport modelling outputs to provide cost-benefit (capital efficiency) ratios enabling consistent ranking of all transport projects, as discussed in Section 7.2.3. Benefits to transport users will be fully covered but not the impacts on non-users. The economic impact outputs from both Pt_STM and Pt_RTM in Figure 6 include cost-benefit evaluation that is to be carried out by the same model for all modes and transport investments.

Departure time module This is currently scheduled for commencement in 2015 and completion at the end of 2016. The module is required for both Pt_STM and Pt_RTM; we recommend that it be commenced in 2014. The reader is recommended Arellana *et al.* (2013⁸⁸) as a starting point.

Perth strategic transport model Pt_STM This 5-step tour-based multi-modal transport model will take inputs from the land use model and output to a regional impacts model, which feeds back to the land use model. This is the component of PLATINUM for use in long range planning, scenario analysis and system wide transport policy analysis. Pt_STM will provide road passenger/vehicle O-D matrices, by time of day and for planning horizon years, as required by MRWA, to Pt_RTM.

⁸⁶ While most 'production' models rely on simpler specifications of choice models (e.g., multinomial logit), without segmentation by income, for policy appraisal differential values are important. However, they could be achieved with more sophisticated choice models (e.g., random parameters model).

⁸⁷ Raveau, S., Yáñez, M.F. and Ortúzar, J. de D. (2012) Practical and empirical identifiability of hybrid discrete choice models. *Transportation Research B* 46(6), 1374-1383.

⁸⁸ Arellana, J., Ortúzar, J. de D. and Rizzi, L.I. (2013) Survey data to model time-of-day choice: methodology and findings. In J. Zmud, M.E.H. Lee-Gosselin, M.A. Munizaga and J.A. Carrasco (eds.), *Transport Survey Methods: Best Practice for Decision Making*. Emerald, Bingley, 479-505.

Perth road transport model Pt RTM This is a hybrid meso-micro dynamic traffic assignment model of all road-based travel on the metropolitan network by time of day, taking freight vehicle and external vehicle trip matrices from the other model components. It will output to a project-level impacts model and provide enhanced capability for modelling assistance in road project planning and evaluation, traffic management and control, congestion management, local area traffic impacts, event planning and incident management planning. Pt_RTm will provide Pt_STM with delayed information on network travel times, delays and queuing for use in the strategic modelling.

Freight transport model Pt FTM This model will comprise an improved Perth Freight Movement Model and a separate model for light commercial/goods vehicles, noting that MRWA has already committed to script the FMM into ROM24.

External travel model Pt XTM This model will take its inputs from the WA Statewide Transport Model.

The mesoscopic traffic assignment and further development of hybrid simulation, as well as freight models would greatly benefit from the level of expertise developed in the ROM24 team, whereas advanced choice modelling, including tour-based, time-dependent and destination choice model seems to better match the STEM team capabilities.

11.2 Linkages and Feedbacks

Successful implementation of the strategy will depend to a considerable extent on the linkages and feedbacks illustrated in Figure 6. Four of these are concerned with land use and transport interaction. Part of the implementation program requires documentation and unpacking of MLUFS to enable re-coding for compatibility with the Cube platform, which may be used by Pt_STM as an interim step given the current use of the software package by STEM. The feedback from regional transport impacts to the Land Use Model will include the accessibility measures indicating where to put houses and jobs (Sections 6.1.1 and 7.2.4). Between the component transport models, feedback (perhaps iterative) on network travel times, delays and queuing from Pt_RTm to Pt_STM will have substantial impacts on the enhanced mode choice model.

The point to be recognised is that a key part of the implementation strategy will be the careful specification and activation of these and other links between component models within the PLATINUM modelling suite.

11.3 Resources Required

The following estimates have been made with a view to meeting Perth's real needs. They are certainly not extravagant.

11.3.1 Personnel

There has been an average of eight permanent staff responsible for ROM24 and STEM, with five contract staff who have been used fairly heavily. The PLATINUM suite of linked component models (Pt_STM, Pt_RTM, Pt_XTM and Pt_FTM) is estimated to require the following staff (Table 12). The use of contract staff on a semi-permanent basis is a matter for management judgement; these estimates are in full-time equivalents.

Table 12: Personnel Requirements

Task/activity	FTE
Model maintenance and continuous support	4
Database management (including upkeep of PARTS, Census JTW, TravelSmart and reporting to data requests)	1
Microsimulation	2
Mesosimulation	1
Client service and specific projects - MRWA	1
Client service and specific projects – DoT, DoP, PTA, other state government departments	1
Client service and specific projects – local governments, private sector	1
Operate and support freight and external models, Pt_FTM & Pt_XTM	1
Operate and support cost-benefit model and environmental impacts	1
Land use and feedback from the transport model (apply accessibility outputs to land use)	1
Major model developments and enhancements (not the transition)	2
Total Staff (FTE)	16

Note: The requirements are for operational tasks only and FTEs do not include the management team.

Clearly staff members would not be continuously dedicated to particular tasks, as this list might be taken to imply. On the other hand, some could be expected to specialise. The majority of staff members would constitute a pool to deal with emerging requirements. Staff will also benefit from the opportunity to learn more and share knowledge about the entirety of the integrated model system.

11.3.2 Resources during transition

The transition phase will involve both enhancements and model conversion. A number of the transition activities summarised in Annexure A.8 are enhancements, which would be undertaken by the professional modelling staff. The main tasks requiring consultants will be to develop the new modelling suite PLATINUM and the two key models, Pt_STM and Pt_RTM. As the staff load of other tasks will be substantial, it may also be necessary to contract out the development of the cost-benefit module as well as the improved freight

model Pt_FTM and the external model Pt_XTM. Annexure A.8 indicates how the tasks will be spread.

11.3.3 Moving from the Current Models to the Preferred Approach

When the implementation elements are expressed in terms of time they become steps in moving from the current models to the preferred approach. However determination of the transition steps and the required sequence of activities need a full project analysis and critical path study. Such a study will depend upon detailed knowledge of the resources available within each department or agency, as well as the governance involved.

A major issue is the impact of the timing of the next Perth and Regions Travel Survey (PARTS) to be held in 2016 and the extent to which a new, or upgraded, model can be developed prior to the completion of the survey and the associated survey data processing. The new commercial vehicle survey CVS also has to be taken into account when judging the timeline to achieve the new Pt_FTM. The contribution of the Review to this timing question must be limited to the purely speculative chart shown in Annexure A.8. In general terms it draws attention to the required activities and to the point, already noted, that while the modelling teams continue their normal work the model improvement projects will strain resources.

12 Potential Implementation Problems

The following two sections deal with the potential problems of not implementing the new approach and also problems that may arise in the course of implementation.

12.1 Likely impacts of not Developing a Coordinated Modelling Approach

The most likely impact of not developing a coordinated modelling approach for the three streams of modelling – macroscopic, mesoscopic and microsimulation – is that the cases of inadequate service to model clients will become more severe. As the technology of transport and the expectations of transport users are both changing, the model outputs would not adequately represent the physical performance of the system nor meet the needs of users, if not integrated. The recommended approach includes substantial improvements to the choice model, which will greatly reduce the risk of errors.

Of the three streams mentioned in the Scope of Works, microsimulation is the least dependent on a coordinated approach. If it is used independently on a specific small area with reliable input data then the outputs can be expected to meet the particular need.

Failure to coordinate macroscopic and mesoscopic would lead to serious problems. The static macroscopic traffic assignment for the morning peak, for example, is optimal within its own specification but in fact can seriously misrepresent the real life outcomes. Even with improved intersection specification, the reliance on speed-flow functions leads to poor and incomplete representation of what happens at nodes and on links. Dynamic traffic assignment (DTA, especially enlarged mesosimulation) does reveal the queues forming at intersections and gives realistic estimates of transit times. However effective DTA simulation needs to commence from the initial static solution provided by a macroscopic model.

In fact, DTA – large area mesosimulation – is not yet used in Perth, so that not developing a coordinated modelling approach would probably mean no DTA. That would leave macroscopic traffic assignment to continue delivering not only poor representations of traffic outcomes but also no information on queue development and incorrect transit times.

12.2 Potential Issues and Risks Associated with Moving to the New Approach

The major risk associated with moving to the new approach would be delays and glitches in implementing the software development. However such a delay would not prevent the continued operation of existing models, and their coordination at least as well as at present. Nevertheless an implementation delay would throw strains on the modelling teams; in effect they would be struggling to do two jobs, running the existing models and trying to implement the new.

Whether there is a software problem or not there are also the normal risks of implementing a new system. There is the risk of poor management of the process and the possibility that interpersonal difficulties may arise. Computer modellers are highly trained and skilled

professionals who enjoy their work but a change in the working environment may lead to conflict or dissatisfaction. These are risks that require careful and sympathetic change management. Finally, the risk of data sources not being available in time may delay considerably the integration of PLATINUM.

13 Conclusions and Recommendations

This Transport Modelling Review report has set out a preferred approach to the development of transport and traffic modelling in Perth over coming years. This is a specific response to the requirement in the Scope of Works document to ‘develop an implementation strategy for a practical way forward’ within the three options specified. All new modelling developments will need to take account of the next PARTS travel survey, to be undertaken in 2016, and the CVS, as the data from these survey and associated studies (such as stated preference surveys) will be invaluable in populating the new model developments. There will also be significant demand on financial and human resources in this process.

The Review team recommends that transport modelling for Perth be reorganised into an integrated transport modelling suite, comprising the two main elements of a multi-modal strategic ‘5-step’ model connected to a hybrid meso-micro dynamic assignment model, with both main elements supported by modules for freight transport and external trips. The strategic model would be used for long term planning, scenario analysis and transport policy appraisal. The hybrid assignment model would be used for short-medium term studies, with an emphasis on congestion management, traffic management and road project evaluation. This modelling suite will maximise the use of available modelling resources, provide a greater span in modelling capability and the opportunities to extend that capability to meet future challenges, along with greater versatility, in modelling terms, of time horizons and level of detail. The information produced from the model is a key asset because of the role played in support of decision-making: priority setting, design of options for future scenarios or changes in land use and transport, impact of projects, identification of operation issues, etc., hence, the Review team recommends considering investing in data acquisition and fusion, both for passengers and freight. Creation of a continuous panel of data would provide measures of change, in addition to updated timely data reflecting changes in travel behaviour, preferences, or organisation structures. In addition, progress could be made in aligning SmartRider, PARTS, Census data with traffic and public transport monitoring and supplementing these with some automatically collected data using mobile phones, GPS, etc.

The review team also recommends that the new modelling suite be highly responsive to policy changes. The necessary focus of practitioners on calibrating and validating their models against real data should not lead them to overlook any aspect of the capacity to test government policy proposals. This is well understood when the policy is to physically alter the road or public transport system, but there are also other types of policy change. Any potential charge affecting the transport system needs to be modelled before implementation is considered; a model which appears to be reliable when validated against observed flows may well respond poorly to a hypothetical cost change. A weakness of this type can be traced back to the mode choice model, which must be capable of responding

fairly accurately to a policy to raise or reduce a charge (either mobility charging or parking). Similarly there must be well-calibrated parameters to ensure that the effect of a policy change to reduce waiting or transit time, or increase comfort and reliability, will produce an appropriate response by the model.

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15 Annexures

ANNEXURE A.1: International advances in land use modelling

Modelling approaches

There have been a number of classifications of models presented in the literature for a range of purposes, but mainly to facilitate review of models. As with all classification systems there are always exceptions and overlaps, but it is helpful to simplify the plethora of models out there into broad categories. For the purpose of this review, four broad modelling approaches are referred to, based primarily on the classification of Iacono *et al.* (2008). There is an element of historical evolution of approaches over time as Iacono *et al.* (2008) suggest in Figure A.1, but all approaches are applied in various forms today in practice and all still enjoy continued academic innovation to various degrees.

Rule-based allocation approaches are not even considered ‘models’ in most model classifications, with Pettit *et al.* (2008)⁸⁹ referring instead to the more all-encompassing term of planning support systems. Often GIS rule-based allocation approaches distribute an independent dwelling projection for an urban region to small geographical zones, by mimicking the land development process. Allocation is based on an estimate of each zone’s probability of development in each projection interval, which is often assumed to be influenced by factors such as amount of available land, zonings, distance from employment nodes, transportation availability, access to schools, etc. MLUFS could be included in this approach. Such rule-based applications may have a useful role in making models more accessible, but there is a risk that users could interpret the models as being more behavioural than their rules actually are (Waddell and Ulfarsson, 2004; Waddell, 2011⁹⁰). Typical international examples are the CUF model (Landis, 1994⁹¹) and What-if? (Klosterman, 1999⁹²).

Spatial interaction approaches, also referred to as Lowry-tradition and gravity-based approaches and *econometric models* are considered “top-down” – interactions are specified as a set of aggregate relationships based on the behaviour of a representative individual, usually the mean calculated from a representative sample of the population. The vast majority of current operational models used in planning practice follow these approaches. Examples of spatial interaction models are ITLUP, updated to METROPILUS (Putman, 1983, 2001⁹³), PLUM (Goldner, 1971⁹⁴) and IRPUD (Wegener, 1982⁹⁵). Examples of spatial econometric approaches are TRANUS (de la Barra, 1989⁹⁶), MEPLAN (Echenique *et al.*, 1969, 1990⁹⁷), MUSSA (Martínez, 1992), and DELTA (Simmonds, 1999⁹⁸).

⁸⁹ Pettit, C, Keyser, J, Bishop, I and Klosterman, R (2008). Applying the What If? Planning Support System for Better Understanding Urban Fringe Growth. In *Landscape Analysis and Visualisation: Spatial Models for Natural Resource Management and Planning*, in Pettit, C., Cartwright, W., Bishop, I., Lowell, K., Pullar, D. and Duncan, D. (eds.) 435-454. New York: Springer.

⁹⁰ Waddell, P (2011). Integrated Land Use and Transportation Planning and Modelling: Addressing the Challenges in Research and Practice. *Transport Reviews*, 31(2): 209–229.

⁹¹ Landis, JD (1994). The California Urban Futures Model: a new generation of metropolitan simulation models. *Environment and Planning*, 21B, 399–422.

⁹² Klosterman, RE (1999). The What if? collaborative planning support system, *Environment and Planning B: Planning and Design*, 26, 393-408.

⁹³ Putman, SH (1983). *Integrated urban models: Policy analysis of transportation and land use*. London: Pion.

Putman, SH (2001). The METROPILUS planning support system: Urban models and GIS. In Brail, R.K. and Klosterman, R.E. (eds.) *Planning support systems: Integrating geographic information systems, models and visualization tools*, Redlands, CA: ESRI Press, 99-128.

⁹⁴ Goldner, W (1971). The Lowry Model Heritage, *Journal of the American Institute of Planners*, 37(2), 100-110.

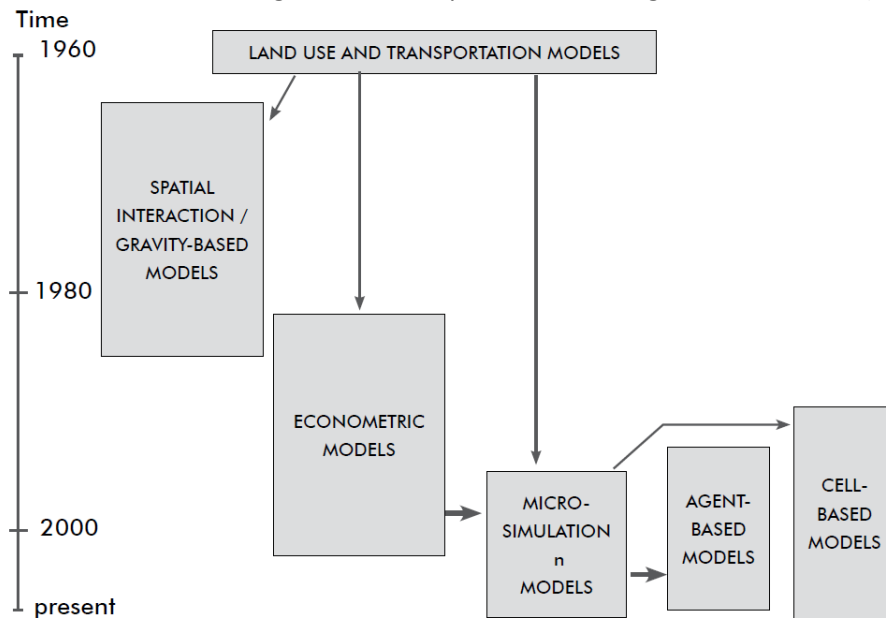
⁹⁵ Wegener, M (1982). Modeling urban decline: A multi-level economic- demographic model of the Dortmund region. *International Regional Science Review*, 7(1), 21-41.

⁹⁶ de la Barra, T (1989). *Integrated Land Use and Transport Modelling*. Cambridge University Press: Cambridge.

⁹⁷ Echenique, MH, Crowther, D and Lindsay, W (1969). A spatial model for urban stock and activity, *Regional Studies*, 3, 281–312.

The category of *microsimulation models* includes approaches that attempt to disaggregate population and simulate changes from the “bottom-up”. This category includes activity-based travel and multi-agent models and a special type of multi-agent model, cell-based models. Examples of agent-based models are UrbanSim (Waddell *et al.*, 2003⁹⁹), ILUMASS (Moeckel *et al.*, 2003¹⁰⁰) and ILUTE (Salvani and Miller, 2005¹⁰¹). SLEUTH (Clarke, 2008¹⁰²) and CUF (Landis and Zhang, 1998a,b¹⁰³) are examples of models using cellular automata.

Microsimulation¹⁰⁴ models can be used as experimental laboratories for studying the effect of interactions between agents at “multiple scales and organisation levels” (Castle *et al.*, 2006¹⁰⁵).



Source: Iacono *et al.* (2008:325)

Figure A.1: Evolution of land use and transportation models (after Iacono *et al.*, 2008: 325)

Echenique, MH, Flowerdew, ADJ, Hunt, JD, Mayo, TR, Simmonds DC and Skidmore, IJ (1990) The MEPLAN Models of Bilbao, Leeds and Dortmund, *Transport Reviews*, 10, 309–322.

⁹⁸ Simmonds, D (1999). The design of the DELTA land-use modelling package. *Environment & Planning B*, 26, 665–684.

⁹⁹ Waddell, P, Borning, A, Noth, M, Freier, N, Becke, N and Ulfarsson, G (2003). Urbansim: A Simulation System for Land Use and Transportation. *Networks and Spatial Economics*, 2(1), 43–67.

¹⁰⁰ Moeckel, R, Spiekermann, K, Schürmann, C and Wegener, M (2003). Microsimulation of land use, *International Journal of Urban Sciences*, 7(1), 14–31.

¹⁰¹ Salvani, P and Miller, EJ (2005). ILUTE: An operational prototype of a comprehensive microsimulation model of urban systems. *Networks and Spatial Economics*, 5(2), 217–34.

¹⁰² Clarke, KC (2008). Mapping and Modelling Land Use Change: an Application of the SLEUTH Model, *Lecture Notes in Geoinformation and Cartography*, 353–366.

¹⁰³ Landis, J and Zhang, M (1998a). The second generation of the California urban futures model. Part 1: Model logic and theory, *Environment and Planning B*, 25(5), 657–666.

Landis, J and Zhang, M (1998b). The second generation of the California urban futures model. Part 2: Specification and calibration results of the land-use change submodel, *Environment and Planning B*, 25(6), 795–824.

¹⁰⁴ TRESIS (Hensher, ITLS) uses set of behavioural choice models, equilibration conditions and a profile of the base transport system, base automobile market and location market, to generate synthetic households (http://sydney.edu.au/business/data/assets/pdf_file/0014/30830/ITS-RR-01_01.pdf).

¹⁰⁵ Castle, CJE and Crooks, AT (2006). *Principles and Concepts of Agent-Based Modelling for Developing Geospatial Simulations*, Centre for Advanced Spatial Analysis, University College London.

Trends

Rule-based land use allocation approaches dominate practice and research in Australia with recent developments to establish an online version of *What if?* in the AURIN portal, further cementing this trend.

According to Waddell (2011), during the 1970s and 80s when modelling activity was in general decline after Lee's critique, only two integrated modelling frameworks were found in practice: the spatial interaction model system of Putman (1983), ITLUP (including DRAM and EMPAL) and the spatial econometrics (input-output) model systems of TRANUS (de la Barra, 1995) and MEPLAN (Echenique *et al.*, 1990).

Spatial interaction and econometric models continue to be the most well established models in practice, with strong proprietary underpinnings and well supported by consulting practices. ITLUP is the most widely used spatial allocation framework in the USA with over a dozen active applications (Putman, 1997¹⁰⁶), with over 40 calibrations having been performed across the USA and elsewhere (Hunt *et al.*, 2005). MEPLAN has been applied to over 25 regions of the world (Hunt *et al.*, 2005). A recent version of ITLUP, METROPILUS and MEPLAN, have enjoyed recent advances in relation to integration with GIS, amongst others. There are more recent efforts to model environmental impacts as part of MEPLAN (Echenique *et al.*, 2012¹⁰⁷).

There have been significant advances in population and employment prediction and forecasting approaches beyond top-down allocation of population and employment projections on the basis of structure planning, e.g. agent-based simulation where the pattern and quantum of population and employment "emerges" in response to individual agent decision-making – from the "bottom-up". The most significant trend, however, is that agent-based modelling systems have increasingly migrated out of academia and into operational environments. In 2005, Hunt *et al.* counted three operational applications of UrbanSim in the USA. In 2009, Lee concluded on the basis of a survey, that UrbanSim is now used far more by metropolitan planning organisations in the USA than any other land use model.

In relation to advances in feedback from transport to land use, in practice, agent-based land use systems have been loosely coupled with traditional 4-step transport models with annual iterative feedbacks (Nicolai *et al.*, 2011¹⁰⁸). This approach relies on interactions with external transport models to update traffic conditions resulting from the current land use with standard feedback from the transport model to land use models in the form of aggregate, zone-zone impedance matrices, including generalised costs of travel between any given pair of zones on aggregate zone level. Agent-based land use models then use the matrix as input for location choice decisions of residents, firms and developers (Nicolai and Nagel, 2012¹⁰⁹).

In the academic realm, and not yet operational, research is underway with establishing fully integrated agent-based land use to agent-based transport modelling. This research is undertaken in recognition that the benefits of disaggregated agent-based land use models are not realised if transport inputs are aggregated into O-D matrices. In the EU SustainCity project, work is

¹⁰⁶ Putman, SH (1997). *LINKAGES Newsletter of Integrated Transportation and Land Use Analyses* (Townsend, DE: S.H. Putman Associates).

¹⁰⁷ Echenique, MH, Hargreaves, AJ, Mitchell, G and Namdeo, A (2012). Growing Cities Sustainably, *Journal of the American Planning Association*, 78(2), 121-137.

¹⁰⁸ Nicolai, TW, Wang, L, Nagel, K and Waddell, P (2011). *Coupling an Urban Simulation Model with a Travel Model - A First Sensitivity Test*. Working Paper 6.3, TU Berlin, Available at <http://www.sustaincity.org/>.

¹⁰⁹ Nicolai, TW and Nagel, K (2012). *Coupling Transport and Land-Use: Investigating accessibility indicators for feedback from a travel to a land use model*, Available at www.sustaincity.org.

underway to couple agent-based land use models with agent-based transport models (MATSIM) using synthetic land use. Modelling (UrbanSim) population directly at the agent level, simulates their joint travel behaviour and updates traffic conditions in the land use model using utility-based accessibility measures (like the so-called econometric logsum term can be used for this purpose at the example of work place accessibility) (Nicolai *et al.*, 2011; Nicolai and Nagel, 2012).

Waddell *et al.* (2005) suggests that rapid advances in transport modelling and planning **research** since the mid-1990s has been along four axes of innovation within a unifying theme of **land use and transport choices at individual level:**

- Integrated land use and transport modelling research projects have developed new platforms including ALBATROSS (Arentze and Timmermans, 2000¹¹⁰), ILUTE (Miller and Salvini, 2003) and UrbanSim (Waddell, 2002¹¹¹; Waddell *et al.*, 2003¹¹²);
- Activity-based travel modelling including CEMDAP (Bhat *et al.*, 2003¹¹³) and FAMOS (Pendyala *et al.*, 2004¹¹⁴);
- Dynamic traffic assignment models using meso- and microscopic approaches such as MATSIM (MATSIM, 2005¹¹⁵) and METROPOLIS (de Palma *et al.*, 1997¹¹⁶); and
- Increasingly sophisticated discrete choice models and tools with which to estimate them (Train, 2003¹¹⁷; Bierlaire *et al.*, 2004¹¹⁸).

Waddell *et al.* (2005) proceeded to describe an international collaborative initiative underway to improve efficiencies in development and use. The initiative is creating an Open Platform for Urban Simulation (OPUS), that simulates land use, activity-based travel demand and dynamic traffic assignment and that can be extended by users and adapted to alternative applications. It is recognised that with the rapid pace of development, few standards and architectures have emerged, which created difficulties and inefficiencies in coupling, even loosely, models with different:

- software languages;
- data formats;
- restrictions on internal data structures; and
- algorithms of coupled components.

Iacono *et al.* (2008) report that despite advances in computer processing power and data storage which have sorted some issues, modelling continues to be resource intensive due to:

- concomitant expansion of scope of models – microsimulation;

¹¹⁰ Arentze, TA, and Timmermans, HJP (2000). Conceptual Framework. In Arentze, T.A. & Timmermans, H.J.P. (eds.), *ALBATROSS: A Learning Based Transportation Oriented Simulation System*, Eindhoven: European Institute of Retailing and Services Studies, 71-80.

¹¹¹ Waddell, P (2002). UrbanSim: modeling urban development for land use, transportation and environmental planning, *Journal of the American Planning Association*, 68(3), 297–314.

¹¹² Waddell, P, Borning, A, Noth, M, Freier, N, Becke, M and Ulfarsson, G (2003). Microsimulation of Urban Development and Location Choices: Design and Implementation of UrbanSim, *Networks and Spatial Economics*, 3 (1).

¹¹³ Bhat, C, Srinivasan, S and Guo, JY (2003). *Activity-Based Travel Demand Modeling for Metropolitan Areas in Texas: A Micro-Simulation Framework for Forecasting*, Center for Transportation Research, University of Texas, FHWA/TX-03/4080-4, 2003.

¹¹⁴ Pendyala, R, Kitamura, R and Kikuchi, A (2004). FAMOS: The Florida Activity Mobility Simulator, Presented at the Conference on *Progress in Activity-Based Analysis*, Vaeshartelt Castle, Maastricht, The Netherlands, May 28-31, 2004.

¹¹⁵ MATSIM (2005) www.matsim.org.

¹¹⁶ de Palma, A, Marchal, F and Nesterov, Y (1997). METROPOLIS: A Modular System for Dynamic Traffic Simulation, *Transportation Research Record* 1607, 178-184.

¹¹⁷ Train, K (2003). *Discrete Choice Methods with Simulation*. Cambridge University Press, Cambridge, UK.

¹¹⁸ Bierlaire, M, Bolduc, D and Godbout, M-H (2004). *An introduction to BIOGEME* (Version 1.0), URL: www.roso.epfl.ch/mbi/biogeme/doc/tutorial.pdf.

- still high levels of complexity with many interacting sub-models; and
- calibration remaining a daunting task.

They do however acknowledged the partial resolution of the following aspects:

- microsimulation models are no longer static and can simulate changes over time;
- nearly all models now can model land markets with explicit prices and are able to simulate the behaviour of agents in the land development process;
- level of aggregation is being reduced, especially in comprehensive microsimulation models;
- size of zones are much smaller, but could still be improved; and
- the theoretical basis has improved, especially in ongoing efforts to reconceptualise the relationship between individual activity patterns and travel choices for travel demand forecasting (Iacono *et al.*, 2008).

Despite the many classifications of modelling systems, most prominent urban models today are invariably “hybrid models” using “mixed-method” approaches, with Waddell (2011) for example referring to the UrbanSim modelling platform. UrbanSim uses discrete choice modelling to predict location choices of households and real estate development choices of developers. Many of its computations involve GIS-based spatial analysis, integrated into the software. By using a cell-based representation of land, and a probability of change in development type from one year to the next that is influenced by the state of neighbouring cells, the real estate development model component parallels models using cellular automata. UrbanSim reflects specific agents (developers) interacting with other agents (households, jobs, and governments) within a simulation environment, which reflects aspects of multi-agent simulation, though in UrbanSim the granularity of interactions is at the model component level, rather than at an individual agent level (Waddell and Ulfarsson, 2004).

Another reason for hybrid models is that despite all the justification for approaching urban simulation from the local level, a case can also be made for observing constraints such as planning restrictions applied to urban systems from the “top-down”. If these are included, the resulting hybrid model would simulate the aggregate dynamics of urban systems in the conventional sense using techniques such as spatial interaction, input-output tables and discrete choice, while leaving micro-scale dynamics to cellular and agent-based models in an integrated and seamless fashion. In this sense, urban systems with processes operating from the bottom up as well as from the top down could be modelled from micro to macro level (Torrens *et al.*, 2000¹¹⁹).

Drivers

Land use modelling approaches have evolved not only as a result of technical and mathematical advances, but also as urban realities and theoretical conceptualisations of cities, the form of planning and policy objectives have changed. It can be generalised that prior to Lee’s watershed “Requiem for large-scale models” (1973¹²⁰), models developed were predominantly linear, deterministic, static and aggregate, based on analogies from Newtonian physics and Keynesian economics as manifest in spatial interaction, econometrics and optimisation techniques, broadly following the Lowry modelling tradition. At this time, model development took place in an era where cities were based on industrial economies and conceptualised as simple systems with a finite number of weakly interacting individual elements (Sui, 1997). Cities were seen as stable structures with dominant functions occurring in the central business district. In the time of the industrialised city, urban planning was institutionalised to deal with the problems of industrial and population growth, using a

¹¹⁹ Torrens, P (2000). *How land-use-transportation models work*, Centre for Advanced Spatial Analysis, University College London.

¹²⁰ Lee, D (1973). Requiem for Large Scale Models. *Journal of the American Institute of Planners* 39 (3).

top-down, location control zoning approach. Models developed in this period reflected this planning approach.

Models post-Lee (1973), after a hiatus in model development in the 1970's and 80's, were developed on the basis of the evolving conceptions of cities based on knowledge, as organic, complex-adaptive socio-ecological systems, with large numbers of individual, intelligent, self-organising, adaptive agents, continually modifying their behaviour in response to new information. Interactions between agents are pre-eminent and generate unexpected outcomes. Models are accordingly based on non-linear dynamics, chaos theory, fractals, cellular automata, neural computing etc. and are highly disaggregated.

“Only recently, as part of the growth of complexity theory, which in turn is the modern expression of general systems theory, has our attention turned to how cities grow and evolve, to urban dynamics, and to how the patterns that we observe with respect to urban form and structure, emerge from a myriad of decisions from the bottom-up” (Batty, 2005¹²¹). “Science is gradually getting used to fact that complex systems are built from the ground.... central planning there is not: there are only the actions of individual elements whose coordination results from the remorseless processes of competition and adaptation” (Batty, 2005).

¹²¹ Batty, M. (2005) *Cities and Complexity: Understanding Cities with Cellular Automata, Agent-Based Models and Fractals*, Cambridge, MA: MIT Press.

ANNEXURE A.2: LU Modelling Developments in Australia

Metropolitan Land Use Forecasting System (MLUFS)

With its origins dating back to 1989, MLUFS is the small area monitoring and forecasting system developed by the WA Department of Planning for the Perth and Peel region, which generates data on existing and future dwellings, population, labour force and employment by class and location. Further details of the component modules are provided in Taplin (2009).

Since the Taplin (2009) review, a number of enhancements have been implemented in relation to MLUFS but largely to do with improvements to the quality and accuracy of input data, including reconciling various contributing sources, and zoning refinements, rather than to mathematical algorithms and approaches.

Scenario planning software tool review

A review of land use scenario planning and modelling software was conducted by Curtin University (Hughes and Heckbert, 2012¹²²) to assist the WA Department of Planning in selecting the most appropriate tool to support:

- scenario planning at different scales to generate a range of possibilities associated with different planning options; and
- visualisation of planning options and infrastructure at different scales for enhanced stakeholder participation.

A range of 19 modelling software tools were evaluated in relation to design, data requirements, policy questions addressed, user friendliness and cost. It was concluded that with the exception of UrbanSim and ALCES (A Land-use Cumulative Effects Simulator), most tools reviewed considered first order effects only and did not include the more complex feedback loops required for effective strategic scenario planning. It was further recognised that most tools evaluated only focus on a part of the system (i.e. water, vegetation, transport) and require collaboration and support from the tool developer for effective use (Hughes and Heckbert, 2012).

Implementation of Online What if? for Perth as part of AURIN

The Online ‘What if?’ GIS-based growth allocation model, an open source version of the desktop What-if rule-based land use allocation model, developed by Klosterman (1999), is being made available through the Australian Urban Research Infrastructure Network (AURIN). It is described as a policy-oriented planning support tool to explore what could happen if policy choices are formulated and if assumptions concerning the future are correct (Pettit *et al.*, 2013). It is acknowledged that the system does not incorporate the real life aspects of spatial interactions, land market mechanisms, or behaviours of household, business or developer agents (Pettit *et al.*, 2013). It is in this respect a “top-down” approach, as the land use pattern is imposed by planners from above through structure plans, rather than emerging through the complex interaction of a range of actors making choices according to market conditions and planning conditions and controls. The major limitation of *What if?*, identified through a review of scenario planning software tools for the WA Department of Planning (Hughes and Heckbert, 2012: 33), is that although it appears to be a sophisticated land use change model, “the model user defines all the land use scenarios and conversion rules [and with] few endogenous processes occurring, the model appears to simply grow out the pattern that is defined by the user”.

The approach is described by Pettit *et al.* (2013)¹²³ as “bottom-up”, but this is rather in relation to the spatial base unit of the model which are “vector overlay-generated homogenous land units” to which

¹²² Hughes, M and Heckbert, S (2012). *Scenario Planning Software Tool Review*. A report for the WA Department of Planning by Curtin University.

land use demands are allocated on the basis of alternative policy choices and which are then aggregated to larger “small area land use population and employment projections” (Pettit *et al.*, 2013: 352). Future land use patterns are derived by balancing land demand with supply on the basis of land suitability. They explicitly make the trade-off between an approach which is “easy-to-use and understand”, rule-based policy-oriented model versus a perceived more difficult to use and understand agent-based, market-oriented, interaction-centre approach.

The desktop *What-if?* tool was previously applied in Hervey Bay (Pettit, 2005¹²⁴) and the online version is currently being implemented as part of AURIN in Perth and Townsville (Pettit *et al.*, 2013).

Land use modelling in other Australian cities

In SKM’s (2009) review of transport models in Australian states and territories for the purpose of determining their ability to model road user charging application, it was found that no land use modelling was occurring. This deduction was obviously made with a certain definition of land use modelling in mind, but it seems that in practice in Australian cities, land use inputs to transport models are mostly provided through some form of population and employment trend forecasting, as is the case in of MLUFS in Perth, with limits to growth in small areas being set by planning intentions and/or land suitability conditions i.e. rule-based allocation.

A number of applications of land use models in part of Australian cities have been reported in the academic literature. With the exception of the UrbanSim application, all the reported land use models are some form of rule-based allocation model:

- case study implementation of UrbanSim in Logan City as part of an urban sustainability assessment framework (Brits, 2013¹²⁵; Brits *et al.*, 2013¹²⁶);
- other *What-if?* applications in Mitchell Shire, Victoria (Pettit *et al.*, 2008);
- LSUM, a large scale urban model, applied in South East Queensland to simulate potential future patterns of population and dwelling construction and the location of economic activity and jobs in industry sectors at a spatially disaggregated level of scale up to 2026, using a rule-based, GIS-based methodology to integrate a measure of geographic attractiveness of localities in the process of allocating growth (Chhetri *et al.*, 2007¹²⁷; Stimson *et al.*, 2012¹²⁸).
- QSAM, the Queensland Small Area Model, constructed by Demographics Australia in the mid-1990s for use by the Queensland Government (Demographics Australia 1996, 2000). The model produces annual projections of total population and dwellings for up to 500 small areas within an urban Local Government Area (LGA) over a projection horizon of up to 20 years. Projections of population and dwellings for an LGA are distributed to small areas within the LGA on the basis of past shares of growth and land availability (Wilson, 2011¹²⁹).

¹²³ Pettit, C., Stimson, R., Tomko, M. and Sinnott, R. (2013) Building an e-infrastructure to support urban and built environment research in Australia: a Lens-centric view, *Proceedings of the Surveying & Spatial Sciences Conference, April Canberra, Australia, available at http://sssi.org.au/userfiles/docs/SSSI%20General/documents_13741225281237907562.pdf*.

¹²⁴ Pettit, CJ (2005). Use of a collaborative GIS-based planning support system to assist in formulating a sustainable-development scenario for Hervey Bay, Australia. *Environment and Planning B*, 32(4), 523–546.

¹²⁵ Brits, A (2013). Embedding Urban Growth Modelling in Planning Practice. Paper presented at the *State of Australian Cities Conference*, Sydney, 26-29 November.

¹²⁶ Brits, A, Burke, M and Tiebei, L (2013). Improved modelling for urban sustainability assessment and strategic planning: local government planner and modeller perspectives on the key challenges, *Australian Planner*, 51(1), 76-86.

¹²⁷ Chhetri, P, Corcoran, J, Stimson, R, Bell, M, Cooper, J and Pullar, D (2007). Subjectively Weighted Development Scenarios for Urban Allocation: A Case Study of South East Queensland. *Transactions in GIS*, 11(4), 597-619.

¹²⁸ Stimson, R, Bell, M, Corcoran, J, and Pullar, D (2012). Using a large scale urban model to test planning scenarios in the Brisbane-South East Queensland region, *Regional Science Policy and Practice*, 4, 372–392.

¹²⁹ Wilson, T (2011). *A Review of Sub-Regional Population Projection Methods*, available at <http://gpem.uq.edu.au/gcpr-docs/SubRegionalProjectionMethodsReview.pdf>.

- PUP, Projections for Urban Planning, is a model designed to forecast land use change and dwelling growth small areas on the urban fringe of Adelaide (Bell *et al.*, 2000¹³⁰). Essentially, “PUP is a land-use model which allocates an exogenous regional forecast of housing construction to constituent zones based, primarily, on their shares of available residential land” (Op.Cit.: 577).

¹³⁰ Bell, M, Dean, C, and Blake, M (2000). Forecasting the pattern of urban growth with PUP: a web-based model interfaced with GIS and 3D animation, *Computers, Environment and Urban Systems*, 24, 559-581.

ANNEXURE A.3: Contacts for the Capital City Models

City	Model	Contact
Adelaide	MASTEM Metropolitan Adelaide Strategic Transport Evaluation Model Adelaide hybrid meso-micro model,	Lindsay Oxlad, Manager, Road Transport Policy and Investment Infrastructure Division Department of Planning, Transport and Infrastructure Tel: (08) 8204 8805 Email: lindsay.oxlad@sa.gov.au John Yates, Transport Systems Analysis Manager Department of Planning, Transport and Infrastructure Email: john.yates@sa.gov.au
Auckland	ASP/ART Auckland Strategic Planning (land use) and Auckland Regional Transport models Auckland Public Transport Model	Jojo Valero, Team Leader Transport Modelling Transport Strategy Unit, Auckland Council Tel: +64 9 980 5136 Email: jojo.valero@aucklandcouncil.govt.nz John Davies, Transport Modelling and Monitoring Leader DDI (+64) 9 447 4432 Email: john.davies@aucklandtransport.govt.nz
Brisbane	BTSM Brisbane Strategic Transport Model	Ben Pool, Principal Transport Modeller Policy, Planning and Investment Division Department of Transport and Main Roads Tel: (07) 3066 1495 Email: benjamin.h.pool@tmr.qld.gov.au
Canberra	CSTM Canberra Strategic Transport Model	Justinieta Balberona, Principal Transport Modeller Strategic Planning Environment and Sustainable Development Directorate Tel: (02) 6207 5539 Email: justinieta.balberona@act.gov.au
Christchurch	CTM Christchurch Transport Model	Julie Ballantyne, Senior Associate / Christchurch Branch Manager Traffic Design Group Limited / Gabites Porter Consultants Tel: +64 3 348 3215 Email: Julie.ballantyne@tdg.co.nz
Melbourne	VITM Victorian Integrated Transport Model	Neville Wood, Manager – Transport Modelling Strategy and Information Division Department of Transport, Planning and Local Infrastructure Tel: (03) 8392 6503 Email: neville.wood@dtpli.vic.gov.au
Perth	STEM Strategic Transport Evaluation Model ROM24 Regional Operations Model	Renlong Han, Transport Modelling Manager Strategy, Policy and Projects Department of Planning Tel: (08) 6551 9124 Email: renlong.han@planning.wa.gov.au Wesley Soet, Transport Modelling Manager Main Roads Western Australia Tel: (08) 9323 4173 Email: wesley.soet@mainroads.wa.gov.au
Sydney	STM Sydney Strategic Transport Model	Frank Milthorpe, Transport Model Development Manager Bureau of Transport Statistics Transport for NSW Tel: (02) 8202 2566 Email: frank.milthorpe@transport.nsw.gov.au
Wellington	WTSM Wellington Transport Strategy Model	Nick Sargent, Team Leader Data & Analysis Strategic Planning Greater Wellington Regional Council Tel: +64 4830 4268 Email: nick.sargent@gw.govt.nz

ANNEXURE A.4: Responses to the Review Questions

Question	Responses
<p>Is there any interest in the addition, or development of, a land use-transport interaction modelling component to your strategic transport model?</p>	<p>Adelaide: Not at this stage in the development of land use modelling (given it is very much a manual approach and less an algorithmic approach). We are aware of the existence of land use/transport interaction models but have not seen much evidence of widespread use outside academia. As a general principle though we certainly would be interested in a transport/ land use interaction model but note that the timing of land use decisions by individuals and governments are significantly different to transport decisions and I am not sure if one can iterate to a balance – analysing the impact of land use decisions on transport behaviour seems more likely to be the way we will go. The wider economic benefits debate would seem to be a useful addition to modelling capability – as we have found with MASTEM.</p> <p>Auckland: Already in place as the ATM2 model run by AC: ASP3 is the land use model based on Delta software (David Simmonds UK).</p> <p>Brisbane: Not in the short-medium term.</p> <p>Christchurch: Not to my knowledge. Land use separately calculated by Councils; different land use models being tentatively investigated by local Council but unlikely to be interactive with transport model. Full rebuild of CTM should be considered for 2023 Census and at that time, model form will be reassessed.</p> <p>Melbourne: The Victorian Transport Integration Act encourages consideration of LUTI, so we are interested. But there is no current or planned modelling activity. If there were, we would use Cube Land with a simplified model of Melbourne.</p> <p>Sydney: BTS has undertaken a pilot project with the aim to create a model, which incorporates land use transport interaction. At this stage it is not ready for general implementation and it is currently unclear as to the timeframe, or in fact whether or not it will actually be suitable for general use.</p> <p>Wellington: No. There are plans for a ‘loose coupling’ of the transport model with an integrated land-use model (i.e. including economics, demographics) that is currently being developed but this just at a conceptual stage.</p>
<p>Is there any interest in, or development of, a departure time choice component in the model?</p>	<p>Adelaide: Yes, as part of a complete reappraisal of the MASTEM suite following the completion of the Adelaide Regions Travel Survey.</p> <p>Auckland: Time of day choice model is a feature in ART – included in ART3 (possible future modifications?).</p> <p>Brisbane: Yes. Currently under development.</p> <p>Christchurch: Four peak periods currently modelled (AM, interpeak, PM, and overnight). Consideration would be appropriate during full model rebuild (2023 Census).</p> <p>Melbourne: No. VITM uses 4 time periods (2 h am and pm peaks, interpeak and offpeak). We have considered peak</p>

	<p>spreading, and could consider departure time choice in the next 2 years. [We are introducing new features into the model gradually, in keeping with available resources.]</p> <p>Sydney: BTS has identified this as an area where we would like to extend our modelling capability. The practical issues are: (1) existing data to demonstrate the phenomena as there is surprising little evidence for it even though we believe it to be the case, (2) getting good data to develop behavioural models for implementation, and then (3) when implementing it, how many time periods should be modelled. It appears that the normal approach is to use Stated Preference data rather than Revealed Preference data to develop behavioural models, (4) for strategic purposes five time periods can be used, whereas for detailed traffic modelling the requirements are for matrices on a half-hourly basis.</p> <p>Wellington: WTSM includes a peak spreading sub-component. There is no plan to develop time choice.</p>
<p>Is there any interest in, or development of, a tour-based model as a replacement for the existing trip-based model?</p>	<p>Adelaide: Yes, as part of a complete reappraisal of the MASTEM suite following the completion of the Adelaide Regions Travel Survey. The need was highlighted in the BITRE study on toll road forecasting and on travel demand management analysis.</p> <p>Auckland: Current ART model is based on 'simple tours' i.e. forward-return tours. Full tour-based model will be considered in future model update.</p> <p>Brisbane: Not in the short-medium term.</p> <p>Christchurch: Not to my knowledge. Household interview survey data collected by activity and hence appropriate for development of tour-based model. Consideration would be appropriate during full model rebuild (2023 Census).</p> <p>Melbourne: We are aware of tour-based modelling but we have no demands to see it implemented. The model will be recalibrated in 2015 and will review the model structure as part of that activity. Not sure it would offer any improvement to the existing model.</p> <p>Sydney: The STM is already a tour-based model. Tour-based models allow greater inclusion of behavioural aspects to travel. With the additional aspect of a high level of segmentation, this provides a significant step towards what activity models can deliver, but through a standard modelling platform. A key modelling decision is whether to include intermediate stops (detours) or just the main destination.</p> <p>Wellington: Not with the current version of the model. Next update will be following the 2018 census and this will probably involve a significant overhaul of the model so this type of significant changes might be considered then.</p>
<p>Is there any interest in the development of an activity-based model as a replacement for the existing model?</p>	<p>Adelaide: Very much so (our 1986 and 1999 household travel surveys were designed to facilitate this) and the future MASTEM suite will be an activity based model following a the completion of the Adelaide Regions Travel Survey given the development of such models is maturing from just academic "proof of concept" to useful practical models (all be it data hungry and processing intensive) (See Citilabs website for examples).</p> <p>Auckland: Yes, we are closely monitoring progress in the US and will be considered in future model update – a long term</p>

	<p>development.</p> <p>Brisbane: Not in the short-medium term.</p> <p>Christchurch: Not to my knowledge. Consideration would be appropriate during full model rebuild (2023 Census).</p> <p>Melbourne: Same response as for Q3. We are aware of ABM but not considering it.</p> <p>Sydney: BTS certainly has an interest in activity-based models. We note that currently activity based models are mostly restricted to the USA, which limits to pool of firms with experience with these models. The STM with its very extensive segmentation already incorporates a number of the features and advantages of activity based models. One area of concern, however, is that there is currently no single standard platform for delivering such models. We are not aware of examples elsewhere but it is quite possible there are examples, for instance in the US.</p> <p>Wellington: Same as above.</p>
<p>Is there interest in, or development of, mesoscopic traffic modelling capability either in the strategic model or as an addition to the model? If so, what is the extent of the modelled mesoscopic network?</p>	<p>Adelaide: Yes Aimsun meso model covers the whole metropolitan transport network and forms the basis of more detailed corridor and area studies using the meso model. The meso model inputs are linked to MASTEM outputs to ensure consistency between the two model suites.</p> <p>Auckland: Yes, AT is currently reviewing applicability of a region-wide meso model. This is likely to be a separate model with travel demands linked to strategic model.</p> <p>Brisbane: Project-focused mesoscopic models have been developed in SATURN and AIMSUN for sub-areas using the strategic model for demand forecasts. These are not generally maintained after the conclusion of the project.</p> <p>Christchurch: Strategic SATURN model developed with junction modelling within Christchurch City only (i.e. no junction modelling of Waimakariri and Selwyn parts of model, which are coded in buffer). Limited to trips starting and ending within one hour modelled period. Microsimulation models built as required</p> <p>Melbourne: VicRoads has developed a VISUM mesoscopic model of the Melbourne metropolitan network, and are tapping this in to SCATS to obtain detailed traffic signal settings, link and intersection capacities – this is still work in progress (‘nearly there’). The model will be used for event planning, construction zones, level crossing removal programs etc. Initially it is likely to be used as an operational model for short term studies. VITM supplies the OD matrices for the meso model. VicRoads are proposing use of this model by authorities like Public Transport Victoria for detailed corridor work (e.g. tram priority treatments on a specific corridor), and by councils for local area traffic studies. DTPLI is also considering use of Cube Avenue for its own purposes.</p> <p>Sydney: Transport for NSW has developed an AIMSUN meso model with micro functionality for the CBD light rail project. It is being used and improved by our roads agency RMS for CBD bus changes. Similar models are either being developed or are about to be developed for a number of other areas of Sydney, including the Northern Beaches, the Parramatta Road Corridor, The North West sector, and the Bay’s precinct. BTS is currently attempting to integrate a feedback process between the mesoscopic model and the strategic model.</p>

	Wellington: Same as above. WTSM does include some junction delay calculation but Saturn models are used for more detailed highway modelling / project modelling. Improving highway assignment in the next occurrence of the model will probably be one of the main priorities, although we don't know in what form at the moment.
Is there interest in the use of the strategic model (and any additions) in congestion management?	<p>Adelaide: Yes it has already been used to broadly test impacts of road pricing initiatives and any new MASTEM suite will be developed to address this issue with more rigour.</p> <p>Auckland: Answer probably yes, but question a bit vague. Any development is likely to be a separate model with links to the strategic model (see response regarding mesoscopic models).</p> <p>Brisbane: Unsure of response. Macro models aren't great at congestion management but improvements in the model will increase the ability to address congestion management.</p> <p>Christchurch: Strategic models not ideally suited for congested network modelling. SATURN and microsimulation models generally applied.</p> <p>Melbourne: The VicRoads meso model is used for this, not the DTPLI strategic model. VITM is used for broader policy questions, road pricing, priority of on-road public transport, toll road modelling (which is the latest addition).</p> <p>Sydney: Not at this stage – notwithstanding the general purpose of strategic models – which includes the need to plan for future growth (and hence, by implication, congestion). UNSW's rCITI team (Professor Travis Waller) are working on something similar to this and TfNSW is collaborating.</p> <p>Wellington: Not sure what is meant by congestion management here. The model has been used for strategic impact of tolling and car parking charges, but clearly not the right tool for more traffic engineering based initiatives.</p>
Are there any other plans for extensions to or modification of the strategic model?	<p>Adelaide: Not at this time. Our focus is on developing a hierarchy of multimodal models that are interlinked and consistent with each other to meet the needs of DPTI for strategic (transport/ land use) planning, concept planning, project planning and project delivery as well as economic and social impact analysis.</p> <p>Auckland: Yes, we are currently developing a Trip Frequency module based on the WebTag UK guidelines. Note that a public transport model is linked to the strategic model. The PT model has features such as a crowding function.</p> <p>Brisbane: An independent review of the strategic model was undertaken. As a result a new model is under development to incorporate many of the improvements and additional functionality recommended in the review ... (a copy of this report was supplied to MRWA Transport Modelling Review project team).</p> <p>Canberra: the ACT, through a Consultant, has just completed the recalibration of the strategic transport model based on the 2011 ABS Census journey to work and other demographics data. Among the improvements done are the inclusion of cycle network and cycling mode choice as well as inclusion of park and ride facilities and mode choice in the model.</p> <p>Christchurch: Not to my knowledge.</p> <p>Melbourne: Toll road model, park-and-ride capacity constraints, parking constraints, airport travel demand. For freight,</p>

	<p>the existing Melbourne FMM is seen as satisfactory, its capability is fine – we are quite comfortable with the existing model. It is used for freight planning, gateway/access for ports, etc. A copy of the report summarising the recent developments of VITM was supplied to MRWA Transport Modelling Review project team.</p> <p>Sydney: The next short term improvement to the STM is likely to be in the area of peak spreading. A related area for improvement is pivoting off observed data. The strategic model is used to forecast the growth (change) in demand. This growth is applied to an observed base year matrix. This is particularly important for us when presenting results in the 'do nothing'/do minimum scenario.</p> <p>Wellington: the 2013 update is currently in progress and the only major change will be an improved freight sub-model, based on observed movements (GPS data from fleet management companies). Again, no plan for any other significant modification in the short-medium term. We are starting to think about possible forms for the next iteration of the model after the 2018 census, but all the components mentioned in this questionnaire are unlikely to be considered beforehand.</p>
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ANNEXURE A.5: ‘5-step’ modelling: incorporating trip timing in the ‘4-step’ model

Inclusion of trip timing in the modelling framework can be done by considering the core choices of mode and destination (MD), once the decision to travel at all has been made. Departure time fits into this set, which becomes mode, destination, departure time (MDT). Figure A.2 provides a starting point for consideration of trip timing as a component of the general travel demand modelling system. In this figure, the trip timing question is located after trip distribution but before modal choice. Feedback loops include an additional link between trip assignment and trip timing. This framework will generate travel matrices by mode and time of day (for different trip purposes, vehicles types, etc.).

Note that Figure A.2 indicates the provision of land use information and vehicle availability information as inputs to the model. It also indicates that the application of the model is for a 24-hour period.

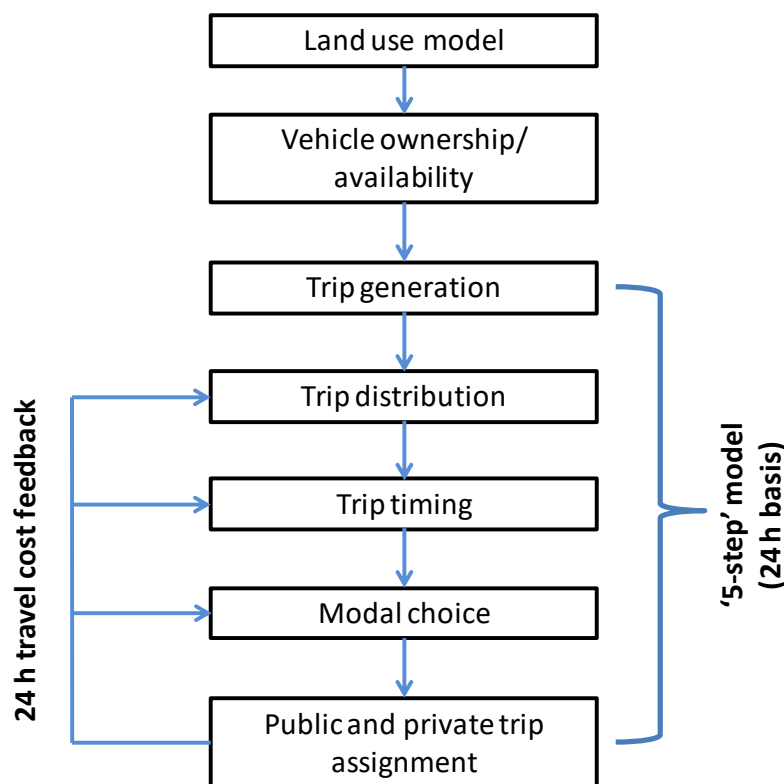


Figure A.2: Incorporating trip timing in the travel demand modelling framework – the ‘5-step’ model

A good example of the implementation of a trip timing component in a real world travel demand model is for Auckland, New Zealand as reported by Wood *et al.* (2008). In this case the new model was designed as an adaptation of an existing model for the Auckland region, which was required not to alter (or indeed complicate) the model estimation process. At the same time, the model brought in some important innovations. In particular, it recognised that trip timing decisions require consideration of trip tours by travellers, not individual (and hence unconnected) trip movements between origins and destinations. Decisions made by travellers earlier in a day influence decisions made later on. The Auckland approach was to utilise the concept of *tour groups*, representing combinations of outbound and returning time periods. A trip timing choice model was then developed to estimate changes in the proportions of tours in these groups as a result of alternative transport policies (such as congestion charging, which would influence traveller choices of departure

times) or changes in congestion levels in a network over time of day (Figure A.3). The structure of the Auckland model is shown in Figure A.3. In this implementation, trip timing choice occurs after modal choice and destination choice, as described by Wood *et al.* (2008).

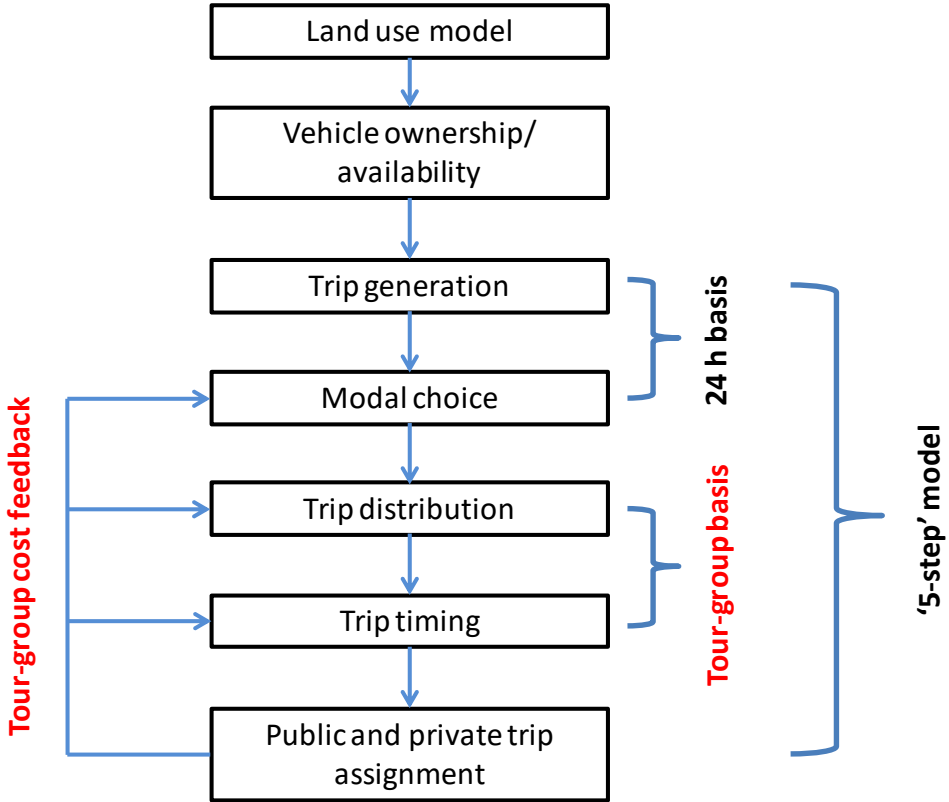


Figure A.3: Structure of the Auckland 5-step travel demand model

The specification of the tour groups is of interest. In the Auckland case, four *tour groups* (designated A, B, C and D) were identified for all home-based travel, on the basis of the time periods incorporated in the original model (am peak, inter peak, school peak, pm peak and off peak) spanning the 24 hours of a day. Household travel survey (HTS) data were analysed to uncover patterns of tour making, in terms of the departure and return periods of travel in the region. Tour group A involved a tour with the outbound trip in the am peak with a return in the pm peak, group B was all other travel with initial departure in the am peak, group C was for travel departure in the pm peak with return in other periods except the am peak, and group D was all other period combinations. Table A.6 shows this structure of tour groups.

Table A.6: Home-based tour groups in the Auckland regional travel model [source: Wood *et al.*, (2008)]

Outbound time period	time	Return time period				
		AM peak	Inter peak	School peak	PM peak	Off peak
AM peak		B	B	B	A	B
Inter peak		D	D	D	C	D
School peak		D	D	D	C	D
PM peak		D	D	D	C	D
Off peak		D	D	D	C	D

Strictly, Table A.6 should be read in the upper half (the diagonal and above) only, to keep the sequence of times (a tour starting in one time period cannot be completed in an earlier time period if travel within the given day of the week is being considered) over the hours of a single day.

Table A.7 indicates the percentage splits of tour groups by travel mode and trip purpose. The numbers in this table should be read across each row. Thus, in the table, 53% of all work tours by public transport occur in tour group A (am peak out, pm peak return), while 23% of these tours are in group B, etc.

Table A.7: Auckland home-based tour group (base) splits by mode and purpose [source: Wood *et al.*, (2008)]

Mode	Purpose	Tour group			
		A	B	C	D
Car	Work	39%	21%	15%	25%
	Education	14%	59%	5%	22%
	Shopping	5%	13%	16%	66%
	Other	7%	21%	16%	56%
Public transport	Work	53%	23%	14%	10%
	Education	19%	65%	6%	11%
	Shopping	5%	19%	11%	65%
	Other	18%	31%	14%	37%

The Auckland model estimates trip timing choice using a multinomial logit (MNL) model with the alternatives being the five available time periods throughout the day. It is of interest that MNL is also used in this model for both modal choice and destination choice.

ANNEXURE A.6: Developments in Traffic Assignment Modelling

The discussion on the 4/5-step travel demand modelling system indicated the dual roles of trip assignment models in that system, as:

- determining the demand-supply equilibrium balance in terms of actual travel costs in a network for all modes, and
- providing link loads (passenger and vehicle flows, by vehicle type) on the network, perhaps by time of day.

In addition, the outputs of the assignment model (link volumes) provide the data for use in model validation, which is generally seen as matching modelled volumes with observed volumes over a subset of network links in a given base year.

Assignment modelling may be done at different levels of detail and there are different model formulations that may be applied at each level. In strategic modelling, for which the '5-step' model is appropriate, most modern assignment models use a 'user equilibrium' model formulation based on Wardrop's first principle for traffic assignment (Ortúzar and Willumsen, 2011).

This principle is a broad level simulation of traveller behaviour based on the idea that individual travellers seek to minimise their own travel costs given that all other travellers are doing the same. The result is an equilibrium state which may be an 'imperfect' solution (i.e. not the best result that could be obtained were travellers to cooperate – but this latter 'ideal' (Pareto optimum) solution is unstable because some individuals may be worse off under it), and thus 'break ranks'.

The original time-based equilibrium assignment is now replaced by travel-cost-based alternatives using generalised travel costs (weighted combinations of travel time, distance, money expenses and other factors), which allow for the inclusion of other factors besides mean travel time, such as money costs (fares, tolls, road user charges, parking charges, etc.), driver preferences for certain road types (e.g. freeways) or public modes (e.g. suburban rail) and reliability of travel time. It is also possible to introduce traveller perceptions of travel costs, thus allowing for imperfect knowledge of network conditions, through stochastic user equilibrium models.

Equilibrium assignment models in general use for strategic applications tend to be static models ('static user equilibrium') in that they do not account for variations in travel conditions over time of day. However, new developments in 'dynamic traffic assignment' have seen the introduction of time-dependent assignment models that account for changing travel conditions over the duration of a journey. These models are generally applied at a finer level of detail than the strategic models, in terms of the data description of the networks to which they are applied. This gives rise to the concept of a hierarchy of models, which may be simply described as 'macro/meso/micro'.

The initial use of dynamic assignment models for route choice came in the new generation microsimulation models introduced in the late 1990s and improved ever since. Microsimulation models track the passage of individual vehicles through a network, updating the position, speed and trajectory of each vehicle over very small time intervals (perhaps a second or less). These models operate on the basis of traffic flow theory and driver behaviour for vehicle (or pedestrian) movements, in terms of 'car following' theory, 'gap acceptance' theory and 'lane changing' behaviour, with observed parameters for these behavioural components built into the models. Microsimulation also considers vehicle types, dimensions and kinematic performance. Thus they provide a detailed view of traffic movements, much akin to the potential observations of actual traffic (given the necessary data collection capacity). Microsimulation models should be seen as tools for use in traffic engineering and traffic management, with particular use for traffic performance assessment of engineering design for road sections and intersections.

Of note is the observation that, being probabilistic in nature – the mechanics of the microscopic model being based on large numbers of small random events – the microscopic model would never give the same outputs in repeated runs with the same inputs. This mirrors real world behaviour of day-to-day travel, and can be used to indicate the potential levels of variability in the model outputs (e.g. link volumes) over a specified time period. It does, however, mean that multiple runs of the model need to be made before a reasonable picture of network performance can be gauged. This is quite different to the strategic level user equilibrium model, which is an analytical model and which at convergence will provide a given set of outputs for a given set of inputs (Ortúzar and Willumsen, 2011).

The most recent developments have been in the intermediate class of ‘mesoscopic’ traffic models, which operate at a less disaggregated level of detail than the microscopic models – one issue with microsimulation is the required computational time, especially in larger networks. The mesoscopic models are also based on considerations of vehicle progression based on traffic flow theory and thus use network descriptions similar to those for the microscopic models, but are based on analytic procedures that do not necessarily require random sampling from statistical distributions of input variables. The advantages of mesoscopic models are that they can be applied dynamically and provide better representations of traffic congestion and queuing in a network – strategic models generally employ ‘vertical’ queues (i.e. a queue appears at a point in the network) whereas the mesoscopic models use ‘horizontal queues’ (where the queuing takes place along a section of road). The mesoscopic model is thus more realistic in representing traffic behaviour and can be employed in traffic management and congestion management studies.

All assignment models require O-D trip matrices as their basic input. The assignment model takes the trips described in the O-D matrix and determines suitable routes through the network. A major issue in the use of any assignment model is thus the validity of the O-D matrices used with it. This has been a particular issue with the use of microscopic and mesoscopic models.

Assignment model hierarchy

A useful way to picture the range of available assignment models is through a hierarchy of the models, based on the level of detail required in model inputs, the spatial coverage of the study area network/region, and the time duration (hours of the day) covered by the model.

Under this perspective models have been identified as ‘macroscopic’, ‘mesoscopic’, ‘microscopic’ and (even) ‘nanoscopic’.

Macroscopic models

The *macro models* are the strategic level assignment models of the type described above and which form an integral part of the 4/5-step modelling framework. They are applied at the level of a large region (e.g. a metropolitan area) to a strategic level network (representing the basic skeleton of public transport routes, freeways and arterial roads, perhaps with some collector roads), which spans the region. Generally they use have simplistic representations of the network links and nodes, at this level, such as number of lanes (but not lane widths) midblock, perhaps including bus-only or HOV lanes) and coarse descriptions of intersection control types (signalised, freeway merge/diverge, roundabout, priority road, etc.). Turn bans may be included through detailed coding of individual intersection nodes, but this would not be done for all nodes. Volume-delay functions, which reflect the link travel time corresponding to a given link volume are reasonably simple and need to comply with mathematic requirements (such as monotonic increase in delay with increasing volume) embedded in the assignment algorithms. The volume-delay functions seldom include the impacts of opposing or intersecting traffic streams, although they may allow for the effects of different vehicle

types in the link traffic volume. Ortúzar and Willumsen¹³¹ (2002: 323-327) provide a useful account of most of the common forms of volume-delay functions and their generalisation into volume-travel cost functions.

Some macro- models, especially those for multimodal planning studies, may adopt a corridor approach to network representation, in which the links included in a model network may represent a band of parallel roads/routes rather than necessarily each individual road or route. Link volumes from such a model need to be treated with care, as the split of traffic between the individual roads in the band is not modelled explicitly.

Macro- models are generally applied over a 24-hour period, even if this period is split into different time periods (such as am peak, inter-peak and pm peak). The shorter time periods allow for more realistic study of the use of available link capacity matching periods of travel demand activity. Further, the models are used in long-term planning and scenario investigation studies in keeping with planning horizons for urban and transport planning, typical in the range 15-30 years. This also means that a macro- (strategic) model should to allow for significant technological innovation in transport systems and vehicles, and lifestyle and traveller behaviour and attitudinal changes, over time. The main use of the macro models is then in scenario planning studies, although the model has to be rooted firmly to the present day in terms of its validation for existing conditions.

Some strategic models, such as Adelaide's MASTEM model (also the MRWA ROM24 and the STEM models) have attempted to include junction modelling. One issue in doing so is the appropriate designation of traffic signal performance variables (e.g. green time/cycle time ratios) for future year networks.

The macroscopic model is the main source of full trip O-D matrices because it is that model, through its trip distribution, modal choice and trip timing components that produces the general matrices for a study region over a long planning horizon. The meso- and micro- models tend to be employed in sub-regional studies and so require O-D matrices representing travel in and across the sub-region. Modern software packages for travel demand modelling will include facilities for sub-region matrix extraction from the macro- model. However, care is needed in a sub-region study in which travel conditions in the sub-region network may be affected by policies, plans or measures under study (e.g. say the introduction of a one-way street system, or implementation of bus-only lanes). Such measures may actually affect the demand to use the sub-region network, and so the analyst needs to return to the macro- model to estimate new O-D demand matrices.

Mesosopic models

Meso models are applied to networks with more realistic representations of the physical network, such as lane widths, parking provisions, separate turn lanes, access points along the roadway, bus stop locations etc. As indicated previously, this level of detail is more in tune with a traffic engineering representation of the route. Turn bans are included directly, as are intersection control types and relevant control parameters and settings, such as traffic signal timings and phasing arrangements, lengths of turn lanes, and stop or give way controls. More local streets can also be included in the sub-region network, which may not longer be limited to the main road system – and as such permits study of potential 'rat running' and traffic diversions. Vehicles are represented by type, which may include specifications of vehicle dimensions and performance capabilities.

A typical mesoscopic model routes packets of vehicles through the network, in which travel times on links and delays at junctions vary over time in response to traffic loads, using principles of dynamic traffic assignment and will thus seek to optimise some measure of travel (as is the case in the macro

¹³¹ Ortuzar, J de D and Willumsen, L.G (2002) *Modelling Transport* (3rd ed), John Wiley and Sons, Chichester.

models). The 'packet' becomes the basic unit of traffic flow, which is later translated into vehicular volumes for output. Queuing can extend upstream from bottlenecks, so that blocking of upstream intersections can be studied, as can blockage of turning or through lanes at a junction, as a result of queues formed for particular turning movements. Bus (or other on-road public transport) progression along a route can be studied in the meso- model. Typical modelling periods for meso-models would be for some hours of the day (e.g. separate analysis of am and pm peaks). The planning horizon for which meso- models would be employed is likely to be the short to medium term, perhaps five years or up to (say) ten years (given the need to provide detailed network descriptions (e.g. estimated traffic signal timings). Mesoscopic models may be applied at both sub-regional and full region levels.

Meso- models are currently seen as providing a useful balance between effort and model results.

Microscopic models

The *micro* traffic simulation models work with similar levels of network detail to the meso- models, except that:

- the basic unit of flow (and analysis) is the individual vehicle, so that individual vehicle movements can be tagged and traced, and
- the models operate in a simulation environment involving random processes (sampling driver and vehicle characteristics, for instance) and so do not generally conform to an optimisation objective. Rather they seek to reproduce observed or expected traveller behaviour as resulting from sequences of events.

The basic modelling components in a microscopic model refer to traffic flow and capacity, driver behaviour and vehicle dimensions and performance. In consequence, the main use of the microsimulation models is for short-term intensive study of traffic or passenger operations, generally at a localised level (such as an individual intersection and its environs). The modelled time period is likely to be one to three hours (with a need to incorporate additional 'warm up' and 'cool down' periods around the modelled interval). A particular application for microsimulation is in examining short-term events such as road closures for special events such as street parades, roadwork zones, and building construction sites, where short term removal of some road space, or partial road closures, may be required.

Nanoscopic models

Some model developers and analysts are now concerned with what are termed *nanoscopic* models, which seek to model travel behaviour by people at a finer level of detail than the micro models, which are seen as relating to the level of the individual vehicle. The *nano* model is concerned with the occupants of the vehicle (whether car, bicycle, bus or taxi, etc) and so focuses on the actual use of different modes and vehicles by individuals (singly or in groups) making trips. Thus there is attention to waiting at bus stops and terminals, hailing taxis or waiting at a taxi rank, using a vehicle to drop-off individuals along a route, etc. The nanoscopic models are also suitable for detailed studies of interactions between pedestrians and other road users (e.g. at pedestrian crossings or a major transport terminals), and may be used for simulations of pedestrian movements in plazas, malls and building (including use of stairways, lifts and escalators). The nano- model requires network/space descriptions compatible with those for the microsimulation model, with the addition of data on pedestrian spaces and corridors.

Relationships between the models

In all of the above cases the basic source of O-D trip data is the O-D matrices generated by a strategic level transport model applied to a large study region. Sub-regional analysis then requires the extraction of O-D movements through or internal to the sub-region network. Pedantically, these matrices should be termed 'matrices of movements' for they include segments of trips, rather than

the full trip movements. A major issue is that O-D flows in a sub-region may vary depending on network state and conditions in the sub-region, hence iterative use of a model covering the full region (which is generally a macro- model but can include meso- models) to generate revised sub-region O-D matrices is required.

A pictorial represent of the macro/meso/micro-nano level models is given in Figure A.4, taken from Marsico *et al.* (2013).

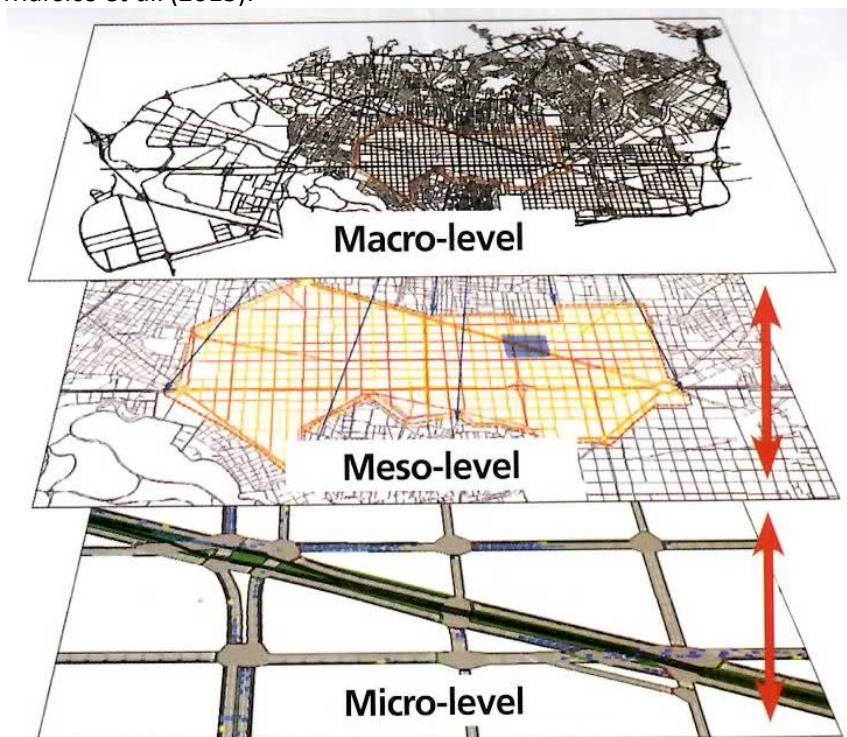


Figure A.4: Spatial relationships between assignment modelling levels [source: Marsico *et al.*, (2013)]

This picture indicates the increasing level of detail yet diminishing spatial scope of application in moving from the strategic (macro) to the local (micro) levels.

Important new developments may be found in integration of assignment models at each of these levels off detail, to provide a more streamlined and accurate assembly of the required sub-region O-D demands and for more versatile assessment and interpretation of assignment model outputs. This development is termed 'hybrid' modelling.

Hybrid assignment models

The hybrid assignment model is a combination of mesoscopic and microscopic models in a single modelling framework. This allows the modeller to perform microscopic simulations within focus areas inside the full network during mesoscopic simulation of that network. The network can be the full region, or a part thereof. The hybrid approach removes the need for separate extraction of sub-area O-D matrices, as any traffic diversion occurring in a focus area is automatically handled by the mesoscopic modelling in the surrounding network. At the same time, the focus area microsimulations allow for detailed study of the traffic performance of individual parts of the network and by specific vehicle/road user classes at those locations. The study by Marsico *et al.* (2013) provides the example of hybrid simulation applied to an expressway corridor in New York, but there are at least two recent Australian examples: (1) the Sydney CBD and (2) metropolitan Adelaide. The Adelaide case study is reported in some detail here because of its relevance and illustration of the opportunities and issues involved in mesoscopic and hybrid modelling.

Mesoscopic modelling in metropolitan Adelaide

The South Australian Department of Planning, Transport and Infrastructure (DPTI) has recently completed the development of a mesoscopic (hybrid) model for metropolitan Adelaide¹³². This exercise provides a useful view of the applications and utility of the hybrid approach, issues involved in establishing a compatible and mutually supporting system of travel demand models, and methods to overcome the issues.

Previously DPTI used a combination of a macro level model (MASTEM¹³³, the Metropolitan Adelaide Strategic Transport Evaluation Model) and micro level modelling for intersection and local area studies. In addition, there were previous mesoscopic models of parts of the Adelaide region (e.g. the Adelaide CBD) although these had fallen into disuse. This meant that there was a growing ad hoc collection of models relating to different parts of the metropolitan area. Further, there were noted inconsistencies between the different levels of models, which were causing some problems, for example:

- traffic projections used by the meso- and micro- models often differed from those produced by the macro- model;
- traffic patterns estimated by the micro- models often differed from those produced – albeit at a coarser grain – than those from the macro- model, which had impacts on the economic analysis results used in project evaluations;
- the traffic management and traffic control strategies taken from the micro- models differed from those assumed in the macro- model, but were not being fed back into the macro model so that region-wide impacts on travel behaviour could be examined (and O-D matrices modified accordingly).

At a broader level this mismatch was also leading to unintended consequences, including:

- strategic misrepresentation through the use of inconsistent assumptions regarding travel demand, mode choice and destination choice;
- optimism bias through the use of historical trends modified by aspiration to develop assumptions about future levels of traffic demand at the micro level;
- undermining of the business case and particularly the economic analysis results that underpinned that;
- reduced credibility of the full modelling process (macro, meso and micro) so that project proponents (or others) could seek to ‘correct’ model outputs if the outputs differed from preconceived (but erroneous) expectations.

DPTI consequently adopted an integrated approach linking macro-, meso- and microscopic models. In this approach the MASTEM model is used as the foundation for providing future year travel demand projections to be used by all subsequent models. A mesoscopic model covering the whole metropolitan area and using MASTEM controls and demand projections was then developed, to form the basis for all sub-regional meso- and micro models. All microscopic model applications are now linked to MASTEM controls and travel demand projections and to each other, to ensure consistency.

Figure A.5 provides an example of the previous ad hoc nature of micro- model applications in the Adelaide region. Each shaded area in the map represents a separate ‘bespoke’ micro model study. This map clearly shows the development of a ‘jumble’ of independent models, some with overlaps.

¹³² The discussion on the Adelaide mesoscopic model is a summary of the information provided by Messrs Lindsay Oxlad (Manager, Road Transport Policy and Investment) and John Yates (Transport Systems Analysis Manager) of DPTI, and presented by them at the AITPM SA Branch Technical meeting in Adelaide on 18 November 2013. Thanks are due to them for provision of this information, which is presented with the permission of DPTI, although the department bears no responsibility for the comments made by the project team.

¹³³ MASTEM is a multimodal travel demand model for medium to long range (30 year) strategic investment planning.

This implies degrees of duplicated effort and potential inconsistencies in model projections due to differing assumptions made for the different projects.

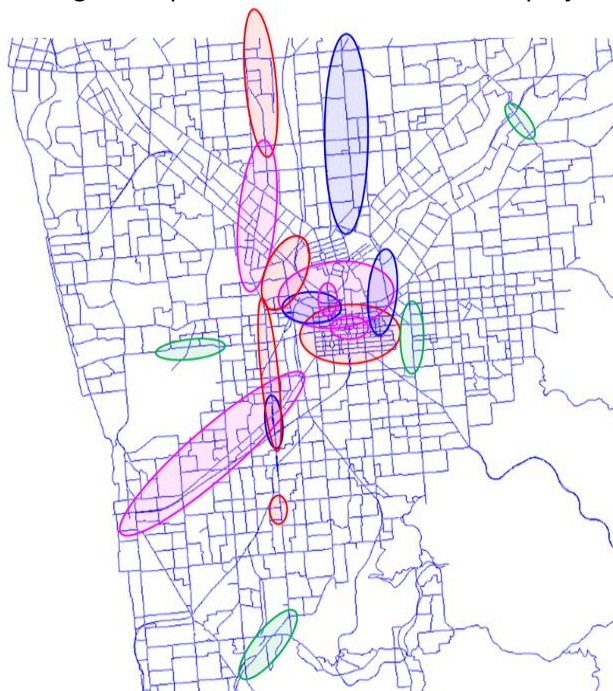


Figure A.5: Previous ad hoc arrangement of micro models in metropolitan Adelaide [source: Yates (2013)¹³⁴]

DPTI then sought to integrate its transport models into a single system of models. The process adopted for this was:

1. Use MASTEM to develop a macro- model formulation compatible with the available mesoscopic model (which had macro- modelling capabilities);
2. Refine, calibrate and validate a meso- model based on this formulation;
3. Apply this model to restricted areas in the metropolitan region, starting with the CBD and looking at the base year 2011. The meso- model covered the modelling periods am peak (07:00-09:00), inter-peak (12:00-14:00) and pm peak (16:00-18:00);
4. Use the resultant meso- model as a hybrid simulator allowing micro level simulations of specific focus areas.

The full scope mesoscopic model for the metropolitan area includes:

- network geometry;
- road section data (lanes, speeds, shapes, volume-delay functions);
- intersection data including signal timing and phasing, approach lanes and type, and turn bans/penalties;
- public transport data – routes, frequencies and stops;
- O-D matrices by time period by vehicle type.

The initial implementation of the resulting meso- model framework is shown in Figure A.6.

¹³⁴ Yates, J. (2013). Adelaide meso model. Presentation to AITPM SA Branch Technical meeting, Adelaide 18 November.

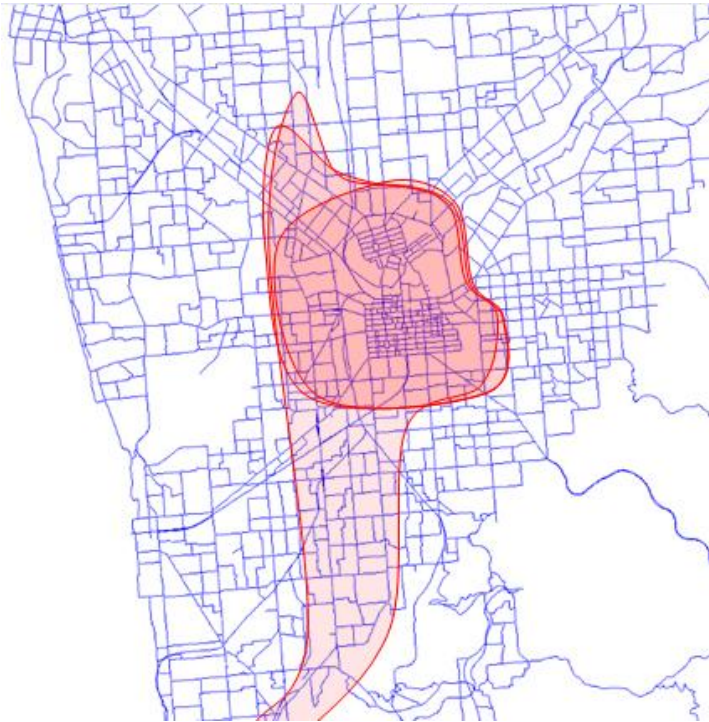


Figure A.6: Initial implementation of the Adelaide meso- model [source: Yates (2013)]

Subsequently, the Adelaide mesoscopic model has been extended to cover the full metropolitan area. Present work involves the development of a common model database, which will include and service the macro- and meso- models of metropolitan Adelaide as well as the state regional transport model (SARTAM).

This case study presents a pertinent account of the potential use of mesoscopic/hybrid modelling for metropolitan transport planning.

ANNEXURE A.7: Suggested possible set of transition activities

Activities	Duration (months)		Prior activities	Comments
	Optimistic	Pessimistic		
Completion of PATREC Review (TMR)				Completed May 2014
Create new transport analysis zones	10	15		
Consolidate networks for Pt_STM and Pt_RTM	6	8		
Create structure for the new integrated transport model PLATINUM	9	15	TMR, consolidate networks	
Document and 'unpack' MLUFS	9	15	TMR, consolidate networks	
Re-estimate existing mode choice parameters	12	18	TMR, new data collection	
Crowding and trip time variability parameters	9	14	TMR	
Revision of park-and-ride modelling	9	15		
Develop consistent cost-benefit module	8	12	TMR	
Develop departure time module	10	14	TMR	
Implement new strategic model Pt_STM	12	18	TMR, consolidate networks	
Develop new road transport model Pt_RTM	12	18	TMR, consolidate networks	
Implement new freight transport model Pt_FTM	10	14	TMR, consolidate networks	
Implement new external travel model Pt_XTM	8	12	TMR, consolidate networks	
Prepare and implement PARTS survey	18	24	TMR	Scheduled for 2016
Prepare and implement the CVS survey	12	16	TMR	
Complete new integrated transport model PLATINUM	12	20	Development of Pt_STM, Pt_RTM, Pt_FTM, Pt_XTM	
Calibrate and validate the completed model	12	20	Development of Pt_STM, Pt_RTM, Pt_FTM, Pt_XTM	

Suggested possible sequence of activities

Type of activity	Activities	2014				2015				2016				2017			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
	Completion of PATREC Review (TMR)																
Specification, re-specification, and clarification	Create 1,500 new transport analysis zones																
	Consolidate networks for Pt_STM and Pt_RTM																
	Create new integrated transport model PLATINUM																
	Document and 'unpack' MLUFS																
Model enhancements	Re-estimate existing mode choice parameters																
	Crowding and trip time variability parameters																
	Revision of park-and-ride modelling																
New components/ Models	Develop consistent cost-benefit module																
	Develop departure time module																
	Implement new strategic model Pt_STM																
	Develop new road transport model Pt_RTM																
	Implement new freight transport model Pt_FTM																
	Implement new external travel model Pt_XTM																
Data collection	Prepare and implement PARTS survey																
	Prepare and implement CVS survey																
Integration components, validation	Complete new integrated transport model PLATINUM																
	Calibrate and validate the completed model																

Note: In **Blue** - specification, re-specification, and clarification activities; In **Green** – model enhancements; in **Red** – New components. Light shades correspond to the pessimistic estimates of duration, whereas the dark shades to the optimistic estimates.