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Paper title: **Travel demand modelling in Australia – reviews of practice and promise in Perth and Adelaide**

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Abstract (200 words):
This paper describes two recent reviews of travel demand modelling undertaken by the Transport Systems Centre (TSC). These reviews were instigated by two state transport departments, who sought advice about the state of practice in modelling in their respective states (WA and SA) and who also sought to define future directions for the development, enhancement and use of models for metropolitan transport planning. The reviews also required base information about modelling practice and developments in other states and beyond, so that a reasonably complete picture of travel demand modelling in Australia emerged, as did indications of developments in modelling in New Zealand and North America. The paper focuses on the salient issues found in the two reviews, and especially on their common features – which included the chronic shortage of skilled modellers and expert model users, and the poor understanding of the capabilities and limitations of contemporary travel demand models amongst transport planners and the wider community. The reviews provide positive advice and guidance on how to improve the understanding and use of models in transport planning practice.

Introduction

Between 2002 and 2004 the Transport Systems Centre (TSC) was invited to conduct reviews of current travel demand modelling practice and the needs for new model development and implementation, firstly for Adelaide (for SA Department of Transport and Urban Planning, DTUP) and then for Perth (for WA Department for Planning and Infrastructure, DPI).

This paper provides a summary discussion of the two reviews, centring on the states of practice in modelling in their respective states (WA and SA) and how these compared with practices elsewhere. It then suggests some directions for the future development, enhancement and use of models for metropolitan transport planning. The reviews also required base information about modelling practice and developments in other states and beyond, so that a reasonably complete picture of travel demand modelling in Australia emerged, as did indications of developments in modelling in New Zealand and North America. The full story may be found in Taylor and Scrafton (2003abcde). This paper focuses on some of the salient issues found in the two reviews, and especially on their common features – which included the chronic shortage of skilled modellers and expert model users, and the poor understanding of the capabilities and limitations of contemporary travel demand models amongst transport planners and the wider community.

The Adelaide review was in two parts. First was an initial strategic review of the current status of travel demand analysis and transport planning modelling undertaken by DTUP, to establish the extent to which the current models and modelling capability meet user business needs and to identify the means by which they can be enhanced. DTUP's expressed aims were to:

- enhance its capability for integrated multi-modal travel demand analysis and transport planning
- increase ease of use and transparency of modelling
- better model freight transport and commodity movements
- improve its ability to account for present and emerging issues in policy development, and
- generally ensure that its travel demand analysis and transport planning modelling capability meets current international best practice.

The second stage of the Adelaide review involved:

- the development of a detailed functional specification for a suite of integrated multimodal travel demand models for metropolitan Adelaide that fulfils the requirements identified in the review, particularly the needs of the various stakeholder groups in DTUP, and
- the development of curriculum for a program of basic and advanced training aimed at ensuring that the portfolio agencies maintain and continuously improve their internal travel demand modelling and analytical capabilities and expertise.

The Perth review was initiated so that DPI could examine the capabilities and needs for transport modelling for the Perth metropolitan area. There are three models currently in use in Perth, the Main Roads Western Australia's (MRWA) Regional Operations Model (ROM), the DPI's Strategic Evaluation Model (STEM) and the Perth City Council's SATURN model. The main catalyst for the review was criticism of the MRWA model by some organisations and individuals who disagreed with some of the road planning decisions made on the basis of, or supported by, traffic flow data from the model.

The key tasks of the Perth review were:

- establish the transport modelling requirements for metropolitan Perth

- identify the purposes and use for which the existing models have been used, and any limitations on their use
- determine whether the models satisfactorily meet these purposes and uses, and those of their key stakeholders and users
- provide a comparative assessment of the three models with respect to strengths, uses and limitations
- assess whether any or all of the criticisms directed at the MRWA model are justified and if so, what changes can be made to rectify the deficiencies in the model
- identify any other areas where the models could be improved, and
- establish a strategy to best satisfy Perth's future transport modelling needs.

The Perth review was conducted in three stages. The first stage was a review of the ROM model operated by MRWA. This model covers the main road network in the Perth metropolitan area and is used by MRWA for program and project planning associated with that network. The second stage involved a comparative assessment of ROM with the DPI and City of Perth models. DPI's STEM model is a strategic level model of the multimodal metropolitan transport system, originally developed for the recent 'Future Perth' long range planning study, and now widely used in the department for transport and land use policy assessment, and for scenario investigations. The City of Perth's SATURN model is a dense network model of the road traffic system in the Perth CBD and environs. The third stage of the Perth review provided recommendations on the future direction of transport modelling for Perth.

For the purposes of the review, DPI defined 'transport modelling' to be

> 'the use of computer software packages incorporating analytical techniques to estimate travel patterns and travel demand for a range of scenarios based on existing and projected demographic, land use and travel data'.

Given that transport modelling is an activity or process that involves the use of 'transport models', or alternatively 'travel demand models', the study review team therefore believed that it is also important to define 'transport models'. The definition adopted for a transport model (or travel demand model) was

> 'a computer-based decision support tool established for a specified region, including a computer software package for travel demand analysis and transport network analysis, databases describing the region's transport systems infrastructure and networks, population distribution an demographics, land use distribution and intensity, and observed travel behaviour, which is used to estimate the spatial and temporal distributions of travel activity in the region under designated scenarios for the provision of transport infrastructure and the operational and control systems used in the management of that infrastructure'.

In addition, in September 2003 Austroads held a national workshop on practices in travel demand modelling and freight modelling. This workshop, attended by more than 40 delegates from around the country, explored a number of the issues raised in the Perth and Adelaide reviews and provided information on practices in the other states. The proceedings of this workshop were subsequently published on CD by Austroads (2003).

A common methodology was adopted for both reviews. This included:

- extensive, in-depth interviews with a wide range of stakeholders, including model developers, management teams responsible for modelling, established users of the models, potential users, other transport and urban planners, consultants, academics and researchers
- information searches and readings using library and on-line resources

- comparative assessment of different models
- synthesis of interview outcomes and other findings to generate conclusions and recommendations

Supporting concepts for model appreciation

Two underlying concepts – the 'hierarchy of models' and the 'model development process' – were found to be invaluable in both reviews, in:

- explaining the purpose of models
- comparing models
- explaining the approaches and methods used in model formulation, validation, testing and application
- gaining an appreciation of the role of models in transport planning.

These concepts are presented in this paper to inform the reader, and then applied in each of the reviews.

Hierarchy of models

A useful concept for identifying specific modelling needs and for illustrating differences in scope and similarities in application between models is that of the hierarchy of models. This concept was particularly useful in the WA review, where it provided a clear understanding of the differences between the three travel demand models (STEM, ROM and CPM) available in Perth. For the SA review, the hierarchy proved an ideal vehicle for identifying and connecting the modelling needs of different stakeholders in DTUP, and thus in defining the required functional specifications for the proposed suite of models for Adelaide. The hierarchical perspective reconciles model applications for analysis over a range of levels of detail, from sketch planning to detailed local area studies. It provides an overall framework which defines different levels of detail for travel demand modelling and indicates the specific forms of models to be applied at those levels, as discussed in Taylor (1991, 1999) amongst others. The hierarchy combines:

(a) relevant modelling theories and concepts, to identify the ideas and relationships that area directly applicable to a given problem
(b) appropriate levels and detail of input data
(c) appropriate choice of computing methods and capacity, and
(d) relevant model outputs that describe the performance of the system under study at an accuracy commensurate with the validity of the theories used and the input data.

A model hierarchy: The following seven-level hierarchy has been found useful for traffic analysis and modelling (Taylor, 1991, 1999). Starting at the most detailed (micro-) level, the hierarchy is:

(1) *microscopic simulation* of individual units in a traffic stream, for example, for the assessment of vehicle performance at a junction or along a link, or the movements of pedestrian traffic at a railway station or an airport terminal
(2) *macroscopic flow* models in which the flow units are assumed to behave in some collective fashion on some element of a transport system, for example, aggregate models of flows on a link or at an intersection
(3) *simulation* models of flows in network for the optimisation of network performance for fixed route choice. In this condition of fixed level and distribution of travel demands, the simulation model can suggest the likely effects on delays and queuing that will occur as

different system variables (e.g. traffic signal timings or bus service frequencies) are altered. The model thus indicates the changes in system performance – on the assumption that the intensity and distribution of travel demand are unchanged

(4) *dense network* 'high resolution' models, including both trip assignment models and models for creating synthetic origin-destination matrices. This level of the hierarchy introduces a direct demand response to changes in system performance, e.g. deviations in route, destination, mode and trip timing choices as the characteristics of the transport system are modified. As well as indicating the likely changes on system performance (as in (3) above), the dense network model will also suggest how travellers will react to the altered system, through changes in the pattern and intensity of travel demands

(5) *strategic network* 'medium resolution' models, typically involving the 'four step' process of trip generation, trip distribution, modal choice and trip assignment. In modern applications a 'fifth step' – trip timing – can be added to this model type, to indicate the temporal pattern of travel demand over the hours of the day. This level is that of the typical travel demand network analysis package

(6) *strategic network* 'low resolution' models for analysis of the impacts of transport infrastructure projects and to provide data for project planning, and for study of the local and regional impacts of new land use facilities, or the redevelopment of existing facilities. These models use similar approaches to those of the 'level (5)' models but are designed to produce coarser level outputs (e.g. for Perth, at 'level (6) STEM provides corridor and screenline flows, whereas the 'level (5) ROM model produces link volumes)

(7) *sketch planning* models of land use-transport interactions. At this level the spatial connections between spatial elements may only occur as notional representations. These models have application in broadbrush planning decision making – e.g. the decision to proceed or not with a particular policy initiative, with at initiative then to be tested using analysis at the more detailed levels (i.e. (6), (5), (4), (3), (2), (1)) as appropriate

Spatial and temporal dimensions of the hierarchy: The hierarchy provides a means of classifying and comparing transport models. Its levels may be distinguished on the bases of spatial aggregation and time duration, with both area and duration tending to increase as one moves from level (1) to level (7). Areas increase from the isolated junction or road section (individual site), to areas of several hectares (district centre), to several square kilometres (dense network), and to an entire metropolitan region. Study period durations for the microscopic simulations are generally of the order of a few minutes, increasing to a peak 'hour' for the local area models and a 24-hour period (or indeed much longer) for the sketch planning models.

Figure 1 provides a pictorial representation of the spatial dimension represented by the hierarchy. In this figure, we can see the spatial relationships between models at levels 1-6 inclusive, and some implications for the higher level (7) too.

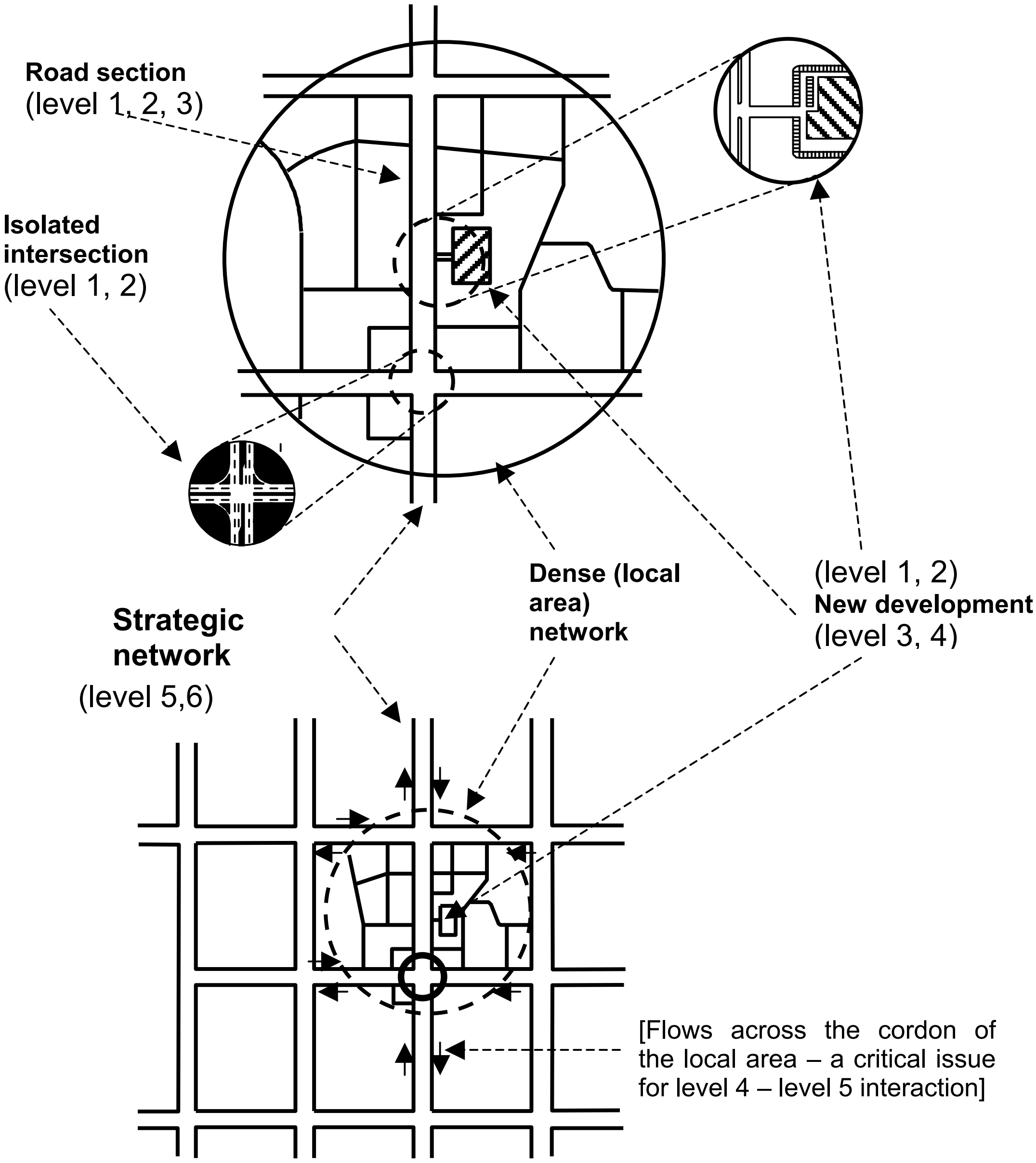

Figure 1 Spatial representations of level (1)-(6) models in the modelling hierarchy

Information flows in the hierarchy: The linkages between models from each level in the hierarchy are of great importance. These provide the means for the information transfers that are the essential features that turn a collection of models into an integrated modelling suite. For example, the outputs from models at one level become the inputs to the next level, and this process allows for the overall study of a given area or situation and the concentration on some particular aspects of it. Information flows occur in both directions, and in general terms these flows may be seen in terms of travel demand or system performance: (a) from the higher levels down, outputs from one level may be used as inputs (or constraints) to the next level. This progression may be seen as the transfer of demand information (i.e. who will attempt to use some part of the transport system over a given time period, and how will they use it), and (b) reverse direction flows, where model outputs from a lower (more detailed) level may be used as measures of performance, that is as system response ('supply') information.

The hierarchical approach to modelling offers a practical, integrated methodology for examining transport systems models. It provides a framework for judging the appropriate position and use of a particular model, and its relationships with other models. The framework allows the development of a comprehensive strategy for the use of models in transport analysis and provides one plank for the definition of acceptable model performance.

Data needs in the hierarchy and integrated databases permitting data flows between models at different levels in the hierarchy are discussed in Thompson-Clement, Woolley and Taylor (1996). The use of Geographic Information Systems (GIS) approach to database integration for a region (e.g. a metropolitan area) is an important consideration in the process of developing and implementing an integrated modelling suite. This may involve the use of standard GIS packages linked to the travel demand modelling packages, the use of travel demand modelling packages that have GIS functionality, or the use of GIS specifically developed for transport planning applications ('GIS-T'). All of these are viable alternatives. Further discussion on the integration of GIS and travel demand analysis models is given in Affum and Taylor (1999) and Thill (2000).

Having decided on the desired characteristics of a model, perhaps using the paradigm of the hierarchy of models to establish the appropriate level of detail for the model application to a given study area, the next step is the implementation and testing of the model to produce a calibrated and validated model for use in the study area. A general model development process can be defined, as described below.

Model development process

Travel demand models provide useful tools that assist transport planners in examining the effects of changes in the supply of transport infrastructure and in the ways that people will use the available transport systems (i.e. to allow transport planners to 'anticipate and manage' future travel demand rather than 'predict and provide' infrastructure as may have occurred in the past). Of common concern is the issue as to which is the best or appropriate model to use in a given circumstance. Some insights into the selection of models can be obtained through consideration of the tasks involved in the formulation, development, validation, evaluation and application of models. This overall process may be described as the model development process.

Models are merely tools that assist the user to transform some available data (the 'model inputs') into estimates of required information (e.g. the 'model outputs') needed in a planning and decision making process. Thus models should not be seen as being the planning or decision making process themselves, rather they are aids to be used by analysts and planners to optimise systems performance, evaluate likely impacts of policies or plans, or assist in decision making. A general model development process is shown in Figure 2. This defines a number of component steps and the linkages between them, that are involved in modelling. As with any process, the individual steps may not be entirely independent, nor clearly differentiated from their predecessors and successors. Nevertheless, there is some merit in discussing the process as though it is a series of discrete steps.

Figure 2 shows the model development process as a 13 step process in a closed system. The latter stages of the process often provide feedback that can be used in the early stages of subsequent rounds of model development. The feedback loops that connect the intermediate and final steps of the process to the initial steps indicate that the development of a given model is an ongoing process, in which experience with the applications of the model, the availability of new data and the need to consider new situations will serve to require ongoing maintenance, upgrading, improvement and extension of the model.

The 13 steps in the model development process of Figure 2 are summarised in Table 1. A full description of the process of Figure 2 is given in Young, Taylor and Gipps (1989).

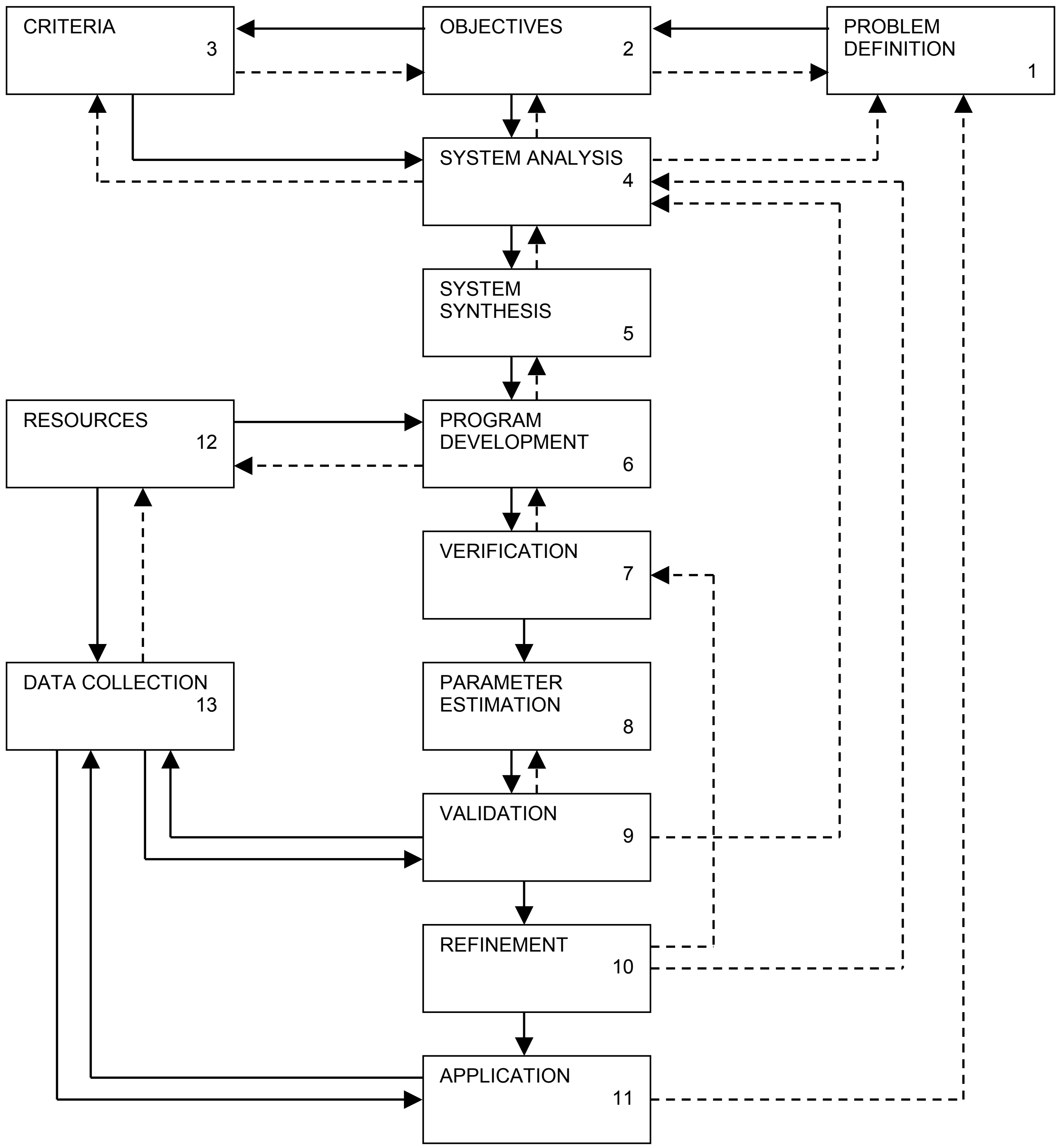

Figure 2 The model development process (source: Young, Taylor and Gipps, 1989)

Table 1 Summary of the model development process of Figure 2

Step no*	Descriptor	Summary description
		Steps 1, 2 and 3 provide the backdrop for model usage …
1	Problem definition	Realisation of the need for availability and use of the model, including the information to be generated by it
2	Objectives	Definition of the level of detail needed in the model and its outputs. This includes an assessment of the likely needs and model users and how the model can help satisfy those needs
3	Criteria	Definition of the criteria to be used in assessing the efficiency and/or effectiveness of the model outputs when applied to a range of different types of problems
		Steps 4, 5 and 6 constitute the model building phase …
4	Systems analysis	This step is required to identify the essential components and interactions between components in the system (network, region and land uses) to be modelled
5	Systems synthesis	Synthesis includes the detailed specification of the model, the model components and the model parameters, along with the definition of the input database(s) (e.g. network definition and zoning system)
6	Program development	The assembly of the optimal version of the specified model
		Steps 7, 8, 9 and 10 constitute the model evaluation phase …
7	Verification	Establishment of the correctness of the logical structure of the model
8	Parameter estimation	Calibration of the model to best reproduce known or observed (travel) behaviour in the study region, including the estimation of parameter values for the implementation of the model to the study area
9	Validation	Testing of the model's ability to replicate the system under study in one or more observable states (e.g. its ability to reproduce present day conditions). Properly, this should involve the application of the model to known situations using data independent of those used in the parameter estimation step
10	Refinement	The process of attempting to reduce the complexity of the model without reducing its analytical power
		Step 11 provides the general operational phase of the model …
11	Application	The process of applying the validated model as a decision support tool to inform the planning process for policy analysis, and examination of future development scenarios, plans and issues
		Steps 12 and 13 represent the monitoring and control phase …
12	Resources	Assessment of the financial, technological, human and information resources available for the initial and ongoing development and use of the model
13	Data collection	The collection, assembly and application of the necessary data to operate the model, including ongoing appraisal and monitoring of the performance of the implemented model

* Note that the process is a closed system so that whilst it is presented as a sequence of steps, some of the steps (especially problem definition, resource management and data collection) are in operation continuously.

The reviews

Whilst a number of common results emerged, which are described later in this paper, there is value in first examining the principal outcomes for each review.

Adelaide

As discussed in the first stage report for the Adelaide review (Taylor and Scrafton, 2003a), the key result of the discussions across the agencies of DTUP was that a modern, integrated, multimodal model for metropolitan Adelaide was an essential resource for strategic and tactical transport planning in DTUP. This model is needed both for its technical capabilities and as a demonstration of the department's strong commitment to a multimodal urban transport system. The model should serve the needs of the department as a whole. Thus the constituent agencies of DTUP need to be aware of the relevance of their specific databases for use in the model, to prepare their data in formats suitable for inclusion in the model, and to keep the databases up to date. Those responsible for the model itself need to espouse its role and capabilities to the agencies, and facilitate a wide understanding throughout the department of the usefulness of the model to specific agencies. This includes the capability to model the effects of policies or projects that seek to induce mode shifts, to established alternative modes such as public transport or to other alternative modes, such as cycling, that have considerable potential to attract more usage. The ability for future models to represent changes in people's travel behaviour (e.g. trip timing decisions) also needs to be recognised. Other issues such as peak spreading, trip chaining, trip timing, induced traffic and elastic travel demands (changes in the total amounts of travel measured either in terms of numbers of trips or distances travelled) are also of concern.

In general, the main need for travel demand modelling in DTUP is for system and project planning, which includes the need for information pitched at a detailed level (e.g. routes and road segments, intersection turning movements, individual public transport services and routes, or access to public transport interchanges by foot, bicycle or car). 'Strategic' analysis (i.e. policy appraisal) is certainly no less important but is probably a less frequent need. Thus there is a real need for modelling aimed at levels that require more detail than may normally be provided by a metropolitan-wide model, but in addition these detailed models may require inputs from the metropolitan model. This requires suitable modelling tools for the specific levels of application and the means to link models at different levels of detail so that relevant data can be moved between them[1]. In the case of public transport studies, the models must be able to perform some kind of scheduling analysis, to provide outputs on service performance variables such as bus-hours or seat-hours, bus-km, and peak buses in service. This is essential data for estimating the costs of proposals for public transport service operations.

In terms of policy analysis, there is also a need for simplified 'sketch planning' models that do not require the description of a physical transport network for their application. Sketch planning models have an increasingly important role in transport policy (and related urban, retail and employment policy) appraisal. DTUP has investigated a number of sketch planning models in recent years, including GENIE and TRESIS, and now has a copy of TRESIS.

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[1] The 'hierarchy of models' described previously in this paper is one way to achieve these outcomes

The AIMSUN traffic microsimulation model has also been adopted by DTUP for the more detailed analysis of road improvement proposals, particularly complex intersections for which there is a high level of public interest and debate.

Whilst there was some interest in the development of an integrated model of transport and land use within the travel demand modelling suite, this was not seen as being of high priority. Suitable model platforms exist for this, but overseas studies (e.g. Simmonds and Echenique, 1999) indicate that considerable resources are required for full implementation of land use-transport interaction (LUTE) models. Available resources may be better committed to the refinement and extension of existing travel demand modelling capability, especially in terms of enhanced capability to model public transport projects. Choice of a suitable modelling framework that allowed for the future incorporation of a land use-transport interaction model would assist in the long term.

A significant issue, found in both reviews but observed acutely in Adelaide, was that many planners have a lack of knowledge and understanding about the nature and use of transport models. In some quarters this has led to reluctance to use model results or, in the extreme, a rejection of those results. What the models can do, how they do it, what outputs they can provide and how those outputs can be applied is poorly understood. A discussion of this important issue follows in the 'common issues' part of this paper, given its general implications for Adelaide, Perth and beyond.

The TSC prepared the functional specifications of the new model suite and the development of a draft curriculum for DTUP, as reported to the department in July 2003 (Taylor and Scrafton, 2003b). The functional specifications determined by this study are given in Table 2. The specifications include the adoption of the hierarchy of models and aim to provide an integrated suite of models capable of use at a variety of levels of detail to suit a wide range of applications.

Table 2 Functional specifications for the new DTUP metropolitan Adelaide travel demand modelling suite (source: Taylor and Scrafton, 2003b)

1.	Comprise a suitable, soundly based, well established and supported commercial travel demand modelling software suite the developers are committed to continuously developing and improving the suite to enhance its capabilities and functionality by incorporating new modelling developments as they occur, thereby maintaining the value of DTUP's investment over time.
2.	Be 'user friendly' with a clear structure and transparent methodology and parameters (overall and for its component parts) and not require the informed (suitably trained and experienced) user to possess advanced computer programming knowledge or skills to operate its component parts or the suite as a whole.
3.	As far a possible use a common database of socio-economic, demographic, employment, transport system and operational and other related data which are capable of being used by the various elements of the model suite without the need for the development of duplicate data sets or manual re-entry of data.
4.	Be capable of operating on a stand-alone (i.e. not networked) basis on the standard high performance personal computer platforms operating within DTUP and be capable of being interfaced seamlessly with associated Geographic Information Systems operated within DTUP to, inter alia, enable the display of model inputs and outputs.
5.	Be multimodal, enabling the integrated analysis of walking, cycling, train, bus and tram passenger transport travel and private and commercial (i.e. car, light and heavy) vehicle travel individually and collectively.
6.	Fulfil the particular analytical and planning needs associated with public passenger transport (train, tram and bus travel) in terms of the level of detail required and the multimodal characteristics of passenger transport travel (e.g. park-and-ride, walk, interchanging, cycling, etc).
7.	Enable travel demand analysis to be undertaken at the detailed (local area/ link/ intersection) level, the strategic (metropolitan-wide, area and corridor) level and at the sketch planning level on a consistent basis (i.e. so that results obtained at one level are consistent with those obtained at a different level).
8.	Enable a range of freight transport and logistics scenarios to be analysed at the detailed and strategic level.
9.	Be calibrated and validated using the data from the 1999 Metropolitan Adelaide Household Travel Survey and other supplementary and complementary data as required to produce a demonstrably valid model of the metropolitan multimodal transport system.
10.	Enable information required for economic and investment analysis to be produced either as part of the model suite or linked to special purpose external models.
11.	Enable integrated, multimodal medium and long-range projections of travel demand (for each mode separately, for groups of modes or all modes combined) to be produced for different transport-land use and other scenarios to form the basis for detailed, strategic and sketch level analyses and infrastructure, service and investment planning of the metropolitan transport system.
12.	Enable trip timing and the temporal distribution of travel demand to be analysed.
13.	Enable household activity based analysis to be undertaken for a range of different policy scenarios (e.g. changing school and shopping hours, etc).
14.	Enable travel demand management measures, road pricing, congestion pricing, parking (supply and charging), tolls, fares, subsidies, trip timing, trip chaining and other identified transport policy measures and issues to be analysed effectively and used to formulate policy advice to Government.
15.	Provide the required travel and transport system performance data to allow road safety and environmental impact analysis to be undertaken for different policy scenarios.

Perth

The Perth review is reported in a sequence of three reports (Taylor and Scrafton, 2003cde), corresponding to the three stages in that review. There is a long history of transport modelling experience in WA and a consequent recognition of modelling as a core business, especially in MRWA. DPI's transport policy and planning section has had a strong interest in modelling the metropolitan multimodal transport system for many years, which began in the days of the former Department of Transport. There are major differences in the emphasis of the models and model applications in the two organisations. MRWA's modelling interests concentrate on vehicle flows on the main road network. DPI's interests are broader because of the need to view the multimodal transport system, with special emphasis on public transport modes and on transport policy initiatives in the area of travel demand management. Further, the interaction between the transport system and the land use system is of major concern across DPI. STEM's major outputs are the spatial distribution of travel across the metropolitan area, the split of that travel between the different transport modes available, and vehicular flows at the corridor level. This may be contrasted to the basic outputs from ROM, which are concerned with link flows of vehicular traffic on the metropolitan road system.

DPI requires a multimodal travel demand model such as STEM to undertake its core business (e.g in transport policy evaluation and in land use-transport planning scenario investigation), but the model and its use and applications cannot yet be said to be institutionalised in the department. For example, the model has been supported on a project by project basis. It needs clear acceptance as ongoing part of the capability and work of the department. Firm and transparent funding arrangements need to be established to ensure the ongoing availability and development of STEM. For example, at present the human resources to operate, maintain and develop the model are limited, comprising a principal consultant, with consulting assistance from time to time. The future of the model in DPI is thus of some concern, as is the question of succession planning for maintenance of modelling expertise in the department. The proper use of the STEM model is for strategic planning, scenario investigation and policy analysis which are ongoing tasks, whereas the development and applications of the model to date have tended to be for specific projects. Different sections within DPI would be expected to have different perspectives on the model and its use. For example, the transport policy section is interested in quantitative and analytical studies, whereas other sections of the department (e.g. urban planning) may not. This may mean that separate treatments are necessary.

One issue of growing concern in DPI about the future development of the Perth metropolitan area is that, because the network and land use in the inner parts of the metropolis (say up to 15 km from CBD) are firmly settled, there is little opportunity there for new infrastructure development. The existing capacity of the road reserves has already been used. In this region the new question is how to manage existing infrastructure and systems, including traffic management, road space allocation, travel demand management etc (e.g. the push to retrofit bus lanes to arterial roads – which while straightforward in some places, has implications for capacity reductions in others). A multimodal model such as STEM is an important tool for analysis of these issues as well as for urban development and transport infrastructure development scenarios. To do so the models must explicitly recognise that maximum road capacity has been provided in the inner area.

The STEM developers see the need for parallel applications and development of the model – noting that model development is never complete. This can be accomplished by having a production version of the model for general day-to-day use, and a development version in which model enhancements are being tested. The modular architecture of the model is useful in this, as new modules can be tested whilst keeping the rest of the model intact.

The STEM developers believe that users want to use the model to investigate opportunities that may be present in the existing transport system, for instance to highlight parts of the network or metropolitan area that are not being served as well as desired. They also want to be able to test ideas (transport and land use) that are not part of the existing system, and to gain understanding of how well the current system operates. It is important to provide good information about the model, its availability and its potential applications. Thus the developer group has run a series of STEM seminars. These have covered (1) modelling in general, (2) STEM specifically and (3) trip distribution and trip assignment in STEM. The seminars have proven to be very popular, with attendances averaging more than 30 people per seminar. This has been a positive initiative to help address the general problem of a lack of understanding of transport models and the application, as also noted in the Adelaide review.

Encouragingly, urban planners in DPI proved to be positive about the potential for STEM to assist them. There was strong interest in ‘forward planning’ to investigate the likely impacts of alternative land use scenarios, for which STEM provided a powerful tool for testing strategic options for the future. These planners saw their modelling requirements as including fast data input for alternative scenarios, fast turnaround of model results – which meant 1-2 months – and broad results (‘roughly right’) rather that precise numbers. For scenario testing, the concept of the ‘80/20’ rule – 80 per cent right is enough, as chasing the remaining 20 per cent will double the effort required – was quite sufficient. STEM had already proved useful for evaluations of different land use scenarios. Scenario testing requires that STEM should be calibrated to reflect strategic land use context, i.e. how can the model be used to suggest the development pathway to achieve a favoured future land use distribution and transport system. The urban planning perspective requires that the model be updated in terms of land use planning developments as well as transport systems developments. For instance, the department’s population and land use forecasting model MLUFS (Metropolitan Land Use Forecasting System, see WADP (1996)) should be considered along with the transport models. Transport-land use interaction has been studied using STEM, but with land use always an exogenous input, according to different scenarios. Future attention has been suggested for a fully interactive transport and land use version of STEM.

The MRWA’s ROM model was designed to provide that agency with an essential planning and evaluation tool for its internal purposes, such as road planning, project evaluation, program planning and priority assessment. The model is solely concerned with the estimation of traffic flows on road links in the Perth metropolitan road network and the changes to those flows from new road infrastructure projects. ROM allows MRWA to undertake detailed traffic modelling tasks for the Perth metropolitan road network. The agency requires detailed traffic forecasts for basic operational uses such as analysis of through traffic in sub-regions of the network, traffic impacts of new road projects and traffic movements at intersections, as essential inputs in intersection and interchange design. ROM uses the same road network to that employed by STEM, but there is a major difference in the zoning systems of these two metropolitan models. STEM zones are aggregations of ROM zones, reflecting the more strategic, ‘low-resolution’ nature of STEM when compared to ROM. ROM is concerned solely with modelling vehicular flows on the network. It uses the DPI’s preferred land use development scenario for Perth as its land use inputs for traffic forecasts, which currently is the ‘business as usual’ scenario employed in STEM. Further, ROM estimates the numbers of vehicle trips on the network using the modal choice proportions produced by STEM. Currently there is no model of Perth’s public transport system cast at the same level of detail as ROM. One recommendation of the Perth review was that the needs for such a model should be further investigated (Taylro and Scrafton, 2003e).

Thus STEM and ROM are complementary, and differ in the level of detail and areas of application. In terms of the 'hierarchy of models' concept – as described previously in this paper – the two Perth metropolitan models may be classified as follows:

1. STEM is a 'level 6' model, for land use and transport policy assessment. It is built using an established strategic network travel demand analysis package (EMME/2) and a multimodal transport network and land use (zoning system) database for the metropolitan area that is suitable for broadbrush studies of differences in travel patterns on that network for different land use scenarios and transport policy options. The outputs of the model are flows of vehicles and travellers at the cordon or screenline level, and measures of the performance of the metropolitan transport system in terms of economic efficiency, social impact and broad environmental impact
2. ROM is a 'level 5' strategic network model, for assessing the impacts of road infrastructure projects and wide area traffic management measures in the metropolitan area. It is built using an established strategic network travel demand analysis package (CUBE/TRIPS) and a main road transport network and land use (zoning system) database. ROM is suitable for studies of the road traffic impacts of road infrastructure projects and for providing traffic volume data for use in the planning design of elements of the road traffic system, such as interchanges and intersections. It may also be used to study regional traffic impacts of land use development projects in the metropolitan area. The model outputs flows of vehicles at the network link level, and measures of metropolitan road network performance in terms of economic efficiency. Its outputs may also be used for studies of social and environmental impact

Table 3 summarises the applications areas for the two models.

Table 3 Application areas for Perth's ROM and STEM models

Application area	ROM	STEM
Network analysis	Link level, road network, 1158 traffic activity zones*	Corridor level, road and public transport networks, 484 traffic activity zones*
Economic assessment	Road projects	Scenario and policy studies
Environmental and social assessment	External to model	External to model
Policy analysis	No	Yes
Public transport analysis	No	Yes

* STEM zones are all aggregations of ROM zones

A national view

As suggested earlier, the 2003 Austroads national workshop on transport modelling provided a useful overview by which to assess the specific review from Adelaide and Perth. This workshop was convened to consider a number of key issues for transport modelling practice in Australia, that were raised in two recent reports commissioned by Austroads (Austroads 2000, ARRB 2003). More than 40 delegates from around the nation participated in the workshop, including officers of DTUP and MRWA. The key issues addressed in the workshop were:

- developments in modelling, including the need for advances in model capabilities to support policy and decision making, e.g. for pricing and tolls, and multimodal investment decisions
- data processes, including the generation, collection, compilation and analysis of travel demand and transport system performance datasets
- expertise in transport agencies and in the modelling industry
- ownership of models and data

A large number of presentations were made at the workshop, by model developers, researchers, model users, and transport planning. The proceedings of the workshop are available on CD (Austroads, 2003). The workshop concluded that there is a definite and established need for the development and maintenance of modern, fully configured transport models for Australian metropolitan areas, supported by current data on personal travel behaviour and freight transport. Modelling capability was seen as an essential input for both policy and planning. Whilst specific policy settings are largely a jurisdictional matter, there are shared issues such as congestion and environmental impact across the jurisdictions. Pursuing policy areas such as pricing requires modelling and analysis. Austroads could consider offering guidance on common approaches to model development and data collection that could make better utilisation of limited resources.

Common findings

Of particular interest for a broader audience is the commonality of findings and outcomes from the two reviews. These common findings included:

- a general lack of understanding of the applications, capabilities and limitations of travel demand models, which was accompanied by a lack of knowledge and understanding of modelling concepts and theories for many planners
- a general and chronic shortage of skilled and experienced modellers exists, in both the public and private sectors. Travel demand modelling seems to have been restricted to a handful of specialists and to be suffering a crisis of ‘lack of succession planning’ as those specialists age
- despite these difficulties, there is a significant use of models in planning and policy evaluation studies in both cities, and new uses for the models (e.g. in planning and evaluation of new project types, such as. ‘public private partnership’ ventures and toll roads). A reasonable minority of planners regularly seek model inputs into their work
- recent advances in specialist commercial software packages for travel demand modelling have made the models more accessible to a wider range of users and will increasingly diminish the perspective of modelling as a specialist task – given the development of a better understanding of modelling amongst transport planners. One ongoing confusion that remains to be overcome is that the commercial packages are not of themselves the model for a specific region. Rather they provide the shells in which a specific model can be developed – in the same way that a spreadsheet package provides the platform for analysis of a data set, but the analysis can only be performed after the user has defined the computation tasks and provided the necessary instructions
- microsimulation models (in which the model builds up overall systems performance by focusing on the behaviour of individual units (travellers or vehicles) in the system) are growing in importance and scope of application, so that they may replace conventional model forms in the medium to long term (e.g. the TRANSIMS project currently funded by the US Department of Transportation, see US DoT, 2003)

- there is a growing need to develop impact assessment tools (e.g. for social, economic, environmental and energy impacts) that use the outputs from the travel demand models as their inputs (e.g. the EU's recent PROPOLIS urban area environmental assessment research program, see Spiekermann and Wegener, 2003)
- whilst passenger modelling methods are well developed, the same cannot be said of freight modelling – which is an area of growing importance and concern.
- a broad understanding of modelling methods, applications and limitations can be gleaned by using the concepts of the 'hierarchy of models' and the 'model development process'.

These issues of a lack of understanding of models and the concepts of the hierarchy of models and of the modelling process are summarised below.

Understanding models

The two reviews indicated that there is a significant lack of understanding amongst many planners of the nature, role and purpose of travel demand models. There is some belief that models of themselves provide planning solutions ('predict and provide') that then dictate the planning process, which runs counter to the more informed view of models as no more than decision support tools. Models should be seen as enabling planners and policy makers to better 'anticipate and manage' travel demand in the future (particularly in a constrained funding environment).

Many planners appear to see modelling as complex and difficult to understand, if not 'opaque'. Better 'transparency' of the modelling process and of the workings of specific models is essential. Transparency means, in the first place, better understanding of the underlying concepts and principles of the travel demand modelling methodology – not the adoption of more simplistic approaches to modelling. There is a highly developed modelling methodology which has great power to assist in analysis and decision making, and indeed in the presentation of policies and plans to government, industry and community. This methodology needs to be better understood by a wider group of transport planners. The means to accentuate transparency are also important. One view is that the adoption of a single integrated modelling system supported by a single reliable supplier with good secondary support in training and expertise may be a crucial element in this. Whilst such a model system is likely to contain a number of separate modules for different applications and levels of application, the fact that these reside within the one package will facilitate their use and acceptance. This would also make it easier to maintain the model in a fully operational state. The first priority should be to meet the needs of users in the most visibly straightforward way possible.

Another priority, almost as important as meeting user needs in the most straightforward way, is to raise the general level of awareness of the capabilities and limitations of travel demand models and to raise the level of understanding of the concepts, theories and processes that underpin the models. It is important to realise that expertise in travel demand modelling is a scarce international resource, and that even a basic level of awareness of modelling capability can only be achieved through expressly designed programs. For example, the knowledge and expertise is seldom taught to any depth in undergraduate level courses – when it is taught, it tends to be in specialist postgraduate programs in transport planning.

A current solution to this problem for organisations such as DTUP and DPI is to seek special in-house training programs, to provide exposure to travel demand modelling, and to seek out specific programs delivered by universities or model user groups. Historically, the pattern in DTUP and DPI (and similar bodies elsewhere) has been for there to be a small expert modelling group within the department, which could supplement its expertise from time to time by engaging consultant travel demand modellers. There have been a number of longstanding relationships of this kind. However, the reviews found that while some consultants do possess high levels of expertise, they themselves have limited and aging personnel resources with that expertise, on a par with the situation certainly found in DTUP and (perhaps to a slightly lesser extent) in DPI. There is a definite need to broaden the base of demand modelling expertise, especially in terms of 'young blood'. This is one area where university groups such as TSC can provide assistance.

Awareness and training programs

Both the Perth and Adelaide reviews identified the need for awareness and training programs to lift the general level of understanding of model application, capability and limitation. DTUP and DPI are keen to ensure that their transport and urban planners can develop, maintain and continuously improve their internal travel demand modelling and analytical capabilities and expertise. To meet DTUP's needs, TSC proposed a two phase training and development program in which:

- the first phase provides a professional development and awareness program to provide participants with a basic understanding of the concepts, principles and practice of travel demand modelling, including the capabilities and limitations of the models, the data requirements of the models, the range and types of outputs produced by the model, and the roles of models in the transport planning process
- the second phase provides a higher level program which includes a more thorough examination of the concepts and theories in travel demand modelling and an introduction to recent and emerging developments in the field, as well 'hands on' training with the software platform on which the travel demand model is based. This course will include topics on the model development process, including model validation and calibration.

Professional development and awareness program: The recommended professional development and awareness program employs a half day seminar designed to introduce the topic of travel demand modelling and the applications of the models. The topics for inclusion in the seminar program are listed in Table 4. This program is designed for a wide audience of transport professionals and is intended to provide a general familiarity with model capabilities. Whilst the program could be used in any jurisdiction, there is good sense in using local (i.e. for DTUP, Adelaide) case study applications to illustrate the topics, principles and notions shown in Table 4.

Table 4 Basic structure of the professional development and awareness seminar

Topic		
What is a travel demand model?	Identify model as a simplified representation of travel by individuals and vehicles on a road or public transport network	Model components include: • study area • zoning system • land use database • O-D trip tables • transport network • set of mathematical relationships
What are travel demand models used for?	Forecast travel patterns and transport outcomes for different transport and land use scenarios applied to the study area	Modelled impacts include: • effects of land use developments or population growth on the transport network • new public transport networks or services • new road facilities or upgrades • pricing policy including VOC, tolls and charges, parking and fares etc
Why are travel demand models important?	Models indicate possible travel patterns based on a given network and projected land use. They enable the testing of different policy options against set criteria.	
Travel demand models in perspective	How do models fit into the overall transport planning process? How reliable are model forecasts?	• Models are merely tools for the evaluation of transport systems and networks • They need to be supplemented with other analyses and information • They can provide forecasts only for those factors and alternatives that are explicitly included in the model definition • Reliability of model outputs depends on the validity of the data inputs • Also, on the representation of the transport network in the model • And, the acceptability of the zoning system to represent population, land use and travel patterns •
How is travel modelled?	Alternative modelling approaches Hierarchy of models	• Empirical methods • '4-step' model • Travel activity • Microsimulation
Data resources to populate the models	Household travel survey data Road and public transport networks Land use and population Traffic information systems Supplementary data sources	
What models are available for Adelaide?	Identify the models used in the department, local universities and other organisations	Include examples of model outputs

Advanced travel demand modelling training program: A higher level program is suggested for those transport professionals who are or intend to be users of the metropolitan travel demand model. A prerequisite for this program is attendance at the professional development and training program or experience comparable with that. The advanced training program is more intense and should run over at least two days, delivered in workshop mode. At the conclusion of the program its participants should have developed a good understanding of travel demand modelling theories and applications, and have had some 'hands on' experience with the travel demand modelling software. They should also be familiar with the general process for development of travel demand models. Graduates would not be expected to be expert users of the travel demand model – such expertise requires experience with the use of the model for the study of real world problems – but they will have the full background needed to develop that expertise and will gain practical experience with the model as an integral part of the course. Table 5 provides an outline of the proposed advanced training program.

Future directions for model development

The reviews identified a number of directions for future model developments, including:

- *freight transport modelling capability* supported by high quality new data on urban freight and commercial vehicle movements in the metropolitan area is an essential requirement for future transport planning in Australian cities. The basic data requirements are for freight flows in and around the metropolitan area and origin-destination information for commercial vehicle movements. The work of the NSW Transport and Population Data Centre for freight in Sydney provides the best available example for such data collection (see Raimond, Peachman and Akers, 1999)
- *traffic microsimulation modelling*, the analysis of transport systems performance by modelling the movements of individual flow units (vehicles or pedestrians), is a powerful new tool for planning, design and analysis that is now finding extensive applications around the world and opens new possibilities for traffic investigations, planning studies and community consultation. These tools are then of immediate relevance to road traffic agencies. They are also of interest to transport planning agencies, for local area studies of specific land use development projects involving major traffic generators
- *environmental impact* (e.g. air and noise pollution) *assessment tools* and procedures using traffic data generated by transport models (or equivalent data taken from real world observations) provide important capabilities in policy studies, project planning and traffic management investigations. These tools and procedures may be applied as 'post processors' of model outputs, to estimate air and noise pollution impacts and to provide indicators of sustainability performance. Coupled with new geovisualisation tools (for the display and analysis of socio-economic, land use and transport data in a spatial mapping context, say using 3-D GIS) they can convey powerful messages about environmental performance
- *modelling and analysis of metropolitan public transport networks* at a level of detail suitable for route and service planning and design. The databases for the existing travel demand models generally contain most of the required information for a detailed public transport model. The opportunity to develop such models has been demonstrated (e.g. in Melbourne) and should be considered in other cities. Such models might best be located in the public transport authorities, as these agencies would make most use of them in route and service design and operations monitoring. One issue for such models is the need to enrich the data sets on public transport usage, especially for cities such as Perth and Adelaide. The available HIS data are inadequate in this respect.

Table 5 Basic structure of the advanced training workshop

	Topic	
Day 1	Review roles of travel demand models	Include: • hierarchy of models • travel statistics and data for the metropolitan area
	The model development process (MDP)	As outlined in an earlier section of this paper. See also Young, Taylor and Gipps (1989)
	Introduction to the available metropolitan travel demand model(s)	Theoretical background to each stage of the model: • household categorisation and market segmentation • vehicle ownership and availability • trip generation • trip distribution • modal choice • trip assignment • model outputs
	Model structure Model validation and calibration	• modular form • development and replacement of individual modules as necessary • check credibility of outputs from each module • sensitivity tests • availability of model outputs • Processes, criteria and parameters for calibration and validation • Performance appraisal • Monitoring and model updating
Day 2	Household segmentation Vehicle ownership and availability Trip generation	• Household types, demographic forecasts • Vehicle ownership trends • Trip productions and trip attractions • Trip purpose • Time of day considerations
	Trip distribution Modal choice	• Trip length frequency distributions • Distribution models • Origin-destination tables • Discrete choice models (including importance of traveller attributes) • Comparisons between modes • Utility functions • Access, waiting and in-vehicle components of a trip
	Trip assignment Model outputs Post-modelling analysis	• Private vehicle trip assignment modelling • Transit trip assignment • Commercial vehicles • Tabular and graphical output forms • Economic analysis • Environmental impacts
	'Hands on' practice	• Direct experience with modelling software in supervised environment

- *modelling of the impacts of TDM initiatives*. Models such as ROM and STEM can offer important insights into the likely impacts of specific policies and initiatives, given recognition of the explicit domain in which each model can operate effectively. Further model developments are needed to provide the useful capabilities in this regard. For instance, STEM has recently been modified and extended to enable it to model the changes in modal split and destination choice resulting from physical restraints on car parking in a specified subregion (e.g. the CBD or a regional activity centre) in the metropolitan area. This has implications for the assessment of both parking controls and the use of 'park and ride' facilities at suburban railway stations. Time of day modelling capability is important for studies of the build up and dissipation of congestion in a network. Peak spreading is an important phenomenon recognised in international transport planning practice that includes both the overflow effects of capacity restrictions due to congestion and temporal shifts in travel demand as a behavioural response to congestion. Policies aimed at achieving peak spreading may result in more efficient usage (and hence provision) of transport infrastructure and services. On the other hand the incipient development of peak spreading may reflect growing capacity problems. Either way, there is a growing need to be able to model the phenomenon. Time of day modelling is a necessary first step in this process, but it is not of itself enough unless behavioural models of trip timing choices can be developed and implemented
- *international practice in transport modelling*, especially in the USA, is leaning towards the adoption of activity-based models of travel choices. These models may better capture individual travel behaviour because they tie travel choices (and constraints) to the activities that individuals and households undertake over the course of a day. This strongly impacts on mode and destination choice, and perhaps on the need for and willingness to travel. At this stage the activity-based models are not firmly established in practice, and it may not be appropriate to seek such models unless specific circumstances require this. The useful response for the present is to deliberately monitor and keep abreast of the developments that are taking place. An information dissemination service such as that provided by TMIP (US DoT, 2003) is an invaluable resource in this regard

This paper has not discussed survey requirements and methods in any detail – this is a subject for much further study – but the availability of comprehensive, contemporary and reliable data on travel behaviour for both passenger and freight transport and on the performance of transport infrastructure and systems is vital.

Conclusions

Travel demand modelling is entering a new era, largely due to recent advances in computing technology and the development of new commercial modelling packages that can operate with largescale transport networks on commonly available computers. When coupled with modern GIS software for database maintenance and presentation of model results, modern transport models offer a powerful new medium for disseminating the results of scenario planning studies and policy evaluation. What is missing, as found in the recent reviews of modelling practices in Adelaide and Perth, is a reasonable level of understanding amongst general transport planning practitioners of the roles and capabilities of travel demand models. Professional development to assist in the attainment of a reasonable level of understanding is therefore an important area for ongoing work. With such understanding, a more widespread application of modelling tools to assist in transport and urban planning will be possible. The models already have an established place in planning practice, but this needs to be reinforced and supported if better value is to be gained from the models and their supporting databases. Some gaps in the current modelling tools can be identified – e.g. in freight modelling, TDM applications and fine grained public transport systems analysis – but the means to fill these gaps can already be recognised and further model development undertaken.

Modelling has had a chequered history, but the needs for good modelling tools are becoming more obvious and the resources to develop these tools more accessible. The future is therefore likely to be one of considerable promise. To fully realise this promise will, however, require considerable expansion of our efforts in the education and training of transport planners.

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