Chapter 26
Pragmatic Incremental or Courageous Leapfrog [Re]Development of a Land-use and Transport Modelling System for Perth, Australia

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Abstract Responding to land-use and transport modelling requirements, identified through a rigorous stakeholder engagement process, current land-use and transport modelling practices in Perth, Western Australia were examined and benchmarked against world-wide best practice. Three alternative model systems were proposed and evaluated. The preferred option, PLATINUM (Perth LAnd and Transport INtegrated Urban Model), is the more radical option, avoiding duplication and other resource inefficiencies, yet not discarding specialised and advanced work already undertaken. The unique contextual design challenges relate to the current modelling situation in Perth. It is concluded that designing model systems should explicitly acknowledge the current system in use and solutions should specify the pathway from the existing situation to the new model system. In addition, the two-edged sword of experience should be recognised as both a positive influence in terms of innovation awareness but carefully handled in relation to potential negative influences of path-dependent, 'incrementality' at the expense of embracing more radical innovations.

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1 Introduction

New generation strategic urban land-use and transport models, increasingly linked with GIS and visualisation tools, can be considered as Planning Support Systems (PSS), developed to "*enlighten*" (Geertman 2006, p. 864) certain tasks involved in the process of integrated land-use and transport planning. Predominantly supporting the tasks of projecting, simulating and evaluating alternative scenarios, land-use and transport models can be classified as "*analysing PSS*" (Vonk 2006, p. 79), specialist tools that are technically complex and difficult to implement, but with the potential to improve strategy-making phases of planning (Te Brommelstroet 2013). Costs and risks of successfully implementing analytical PSS are high and usually tend to outweigh the less tangible benefits of improved scenario modelling and analysis (Vonk 2006).

More traditional land-use and transport models formed the core of the so-called large-scale system models developed and used in the 1960s and 1970s for metropolitan planning. Largely discredited by Lee (1973) on the basis of, amongst other reasons, being too complex and data-hungry, planning support instruments reverted to simple tools supporting routine planning tasks, with more sophisticated analysis, simulation and modelling tools largely neglected in the subsequent two decades (Geertman 2006). According to Waddell (2011), during the 1970s and 1980s, only two integrated modelling systems prevailed in practice: Putman's (1983) spatial interaction model system (ITLUP) and the spatial econometrics model systems of TRANUS (de la Barra 1995) and MEPLAN (Echenique et al. 1990). In 1995, the prognosis was that many of the challenges originally identified by Lee (1973) and subsequently updated by him in 1994 (Lee 1994), still applied (Waddell 2011). Since then, at least in the US, in response to legislation enforcing the coordinated approach to land-use, transportation and air quality planning, there has been a resurgence in urban modelling. Consistent with the intent of contemporary PSS in general, this urban modelling revival has been accompanied by a shift to responsiveness to accommodating a more diverse range and increasingly complex set of policy questions relating to multi-modal and demand-side approaches, incorporating behaviour change and becoming more open and accessible to a wider range of participants involved in the planning process (Waddell and Ulfarsson 2004). This has resulted in model development within the GIS environment, agent-based approaches and increased visualisation (de Ortúzar et al. 2011; Hunt et al. 2005; Iacono et al. 2008 and Miller 2003).

Despite the renewed interest in urban modelling, there are still considerable challenges in transferring the advances made from academic research environments into policy and practice, including aspects of transparency, flexibility and ease of use, behavioural and empirical validity, uncertainty, computational performance and data availability and quality (Waddell 2011). These modelling-specific challenges are echoed in relation to PSS more generally with a significant body of literature devoted to understanding barriers to uptake (Batty 2003; Geertman 2006; Geertman and Vonk 2006, Te Broemelstroet 2013; Vonk 2006; Vonk et al. 2005, 2006, 2007a, b; Waddell 2011). There is agreement that the overriding reason for disappointing levels of diffusion of PSS into practice, despite rapid advances in computer hardware and software, increasing availability of data and information and the growth and diffusion of the Internet, can largely be attributed to the mismatch between supply and demand (Geertman 2006; Harris and Batty 1993; Vonk 2006; Vonk and Geertman 2008).

To narrow the gap between demand and supply, thus increasing uptake, Vonk and Geertman (2008) deem it essential that lessons are learnt and captured by studying the design and implementation of PSS in practice. On this basis, a number of conceptual frameworks, incorporating both supply-side and demand-side criteria, have been proposed to be used in the design and implementation of new PSS to increase the probability of uptake. These frameworks identify sets of development context, internal instrument quality and diffusion factors as being critical in the design and implementation of a successful PSS (Biermann 2011; Geertman 2006; Geertman and Stillwell 2004; Vonk and Geertman 2008). Waddell and Ulfarsson (2004) similarly consider context, policy objectives, policy options to be tested and model requirements in the process they propose and use in the design of a model system for the Puget Sound region in the State of Washington in the US.

The purpose of this chapter is to describe the application of current theoretical insights into critical success factors for PSS to the design of an analytical PSS (Vonk 2006), an integrated land-use and transport model system for the Perth metropolitan area (Perth) in Western Australia (WA). Lessons learnt from other jurisdictions, as well as new lessons generated through application in the specific Perth development, planning and policy context, will in turn be captured to further inform the successful design of subsequent PSS. This will contribute to breaking the "*vicious cycle*", identified by Vonk and Geertman (2008, p. 153), of lack of uptake leading to lack of applications to be studied resulting in few lessons learnt, yielding more, poor quality PSS, in turn resulting in lower levels of uptake.

In order to harness recent advances in addressing the unique contextual and growing challenges of transport modelling and improve modelling operational efficiency in Perth, a transport modelling review process was initiated in response to an agreement between the Director General of Transport and the Chairman of the Western Australian Planning Commission of the Government of Western Australia, to move towards the development of a new strategic transport model and a single modelling team. As part of this broader review process, an independent review of transport modelling was undertaken with a view to providing design options for a new and responsive model system. This chapter describes the process, outcomes and unique design challenges of this review and design initiative with a particular focus on path dependency and the critical choices in moving from current modelling practices to a new model system.

After summarising the methodological approach, the results of the model design process are described for the case of Perth. A discussion of the lessons learnt for the future design of analytical PSS follows concluding with recommendations for future model design processes and conceptual frameworks to enhance the uptake of PSS.

2 Methodological Approach

Waddell and Ulfarsson (2004) incorporate a set of essential criteria identified in the literature for successful PSS as part of the process they propose and use in the design of a model system for the Puget Sound region in the State of Washington in the US. The first four steps in the process are to assess: (1) the development context (institutional, political and technical); (2) the planning and policy objectives; (3) the policy options to be tested; and (4) the model requirements. The outcome of these steps informs the subsequent process steps of (5) making preliminary design choices and (6) selection of modelling approach.

Broadly following the approach by Waddell and Ulfarsson (2004), but with adaptations to suit the particular local situation, the approach to the model system design for Perth is summarised in the following steps (Fig. 1):

1. Assess the development context.
2. Assess the current modelling situation.
3. Assess stakeholder-identified needs, capabilities and gaps identified through a stakeholder engagement process followed in order to obtain an understanding of requirements for the model, current capability to meet requirements and to inform the evaluation framework.
4. Review current international best practice advances in land-use and transport model development from the literature.

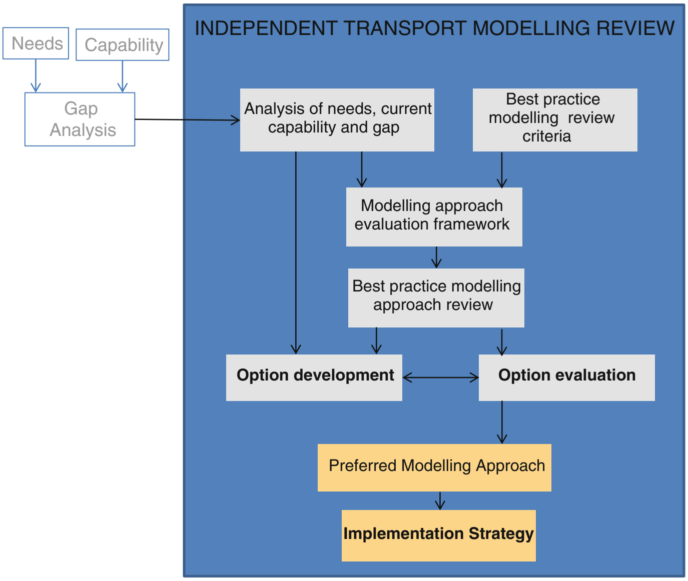

Fig. 1 Methodological approach to the design of a model system for Perth

5. Develop options on the basis of best practice approaches feasible to meet identified needs.
6. Evaluate the options.
7. Select the preferred modelling system approach.
8. Propose an implementation strategy.

3 Results

3.1 Assessment of Development Context

With a 32 % population growth from 1.52 million (2004) to 1.97 million (2013) and an average annual GDP growth of 5.7 % (from 2002/3 to 2012/3) in the Perth metropolitan area, demand for transport and other infrastructure is high, with commensurate urgent demands for infrastructure planning and policy development to meet the growth, supported by modelling. The state government is responsible for planning and transport across Perth and Peel (essentially the metropolitan region of Perth). In WA, as is the case in Australia generally, there is a high degree of centralisation in planning with state governments being the authorities for city planning as well as for remote and regional areas of the state. Local governments exist institutionally and legally, only as an arm of state government with certain designated local planning functions, but ultimately with decision-making power held at the state level. Stakeholder engagement in planning processes is largely limited to formal consultation.

There is a strong tradition of transport modelling in Perth and a high degree of confidence placed in modelling results even to the extent that concern has been expressed by modellers that modelling output is used and interpreted by planners without due recognition of modelling assumptions and limitations. An artefact of a previous dispensation when planning and transport were both part of a single mega-department, subsequently split into a number of different departments, transport modelling is undertaken by two separate, experienced and capacitated modelling teams in two departments: Planning and Main Roads. While there is co-operation between the two teams, there is increasing competition and duplication of effort. Transport modelling in Perth is used primarily for operational purposes and as input to cost-benefit evaluation of discrete land-use and transport projects, precinct and local (structure) plans. There is little evidence of land-use and transport models being used for longer term, scenarios-based, integrated strategic planning. Land-use modelling is limited to highly inflexible and bespoke population and employment forecasting with, trend- and capacity-based allocation to small areas.

Directions 2031 is the current high level spatial framework and strategic plan that establishes a vision for future growth of the metropolitan Perth and Peel region to guide the planning and delivery of housing, infrastructure and services necessary to accommodate a range of growth scenarios (Government of Western Australia 2010). The strategic vision is that "*By 2031, Perth and Peel people will have created a world class liveable city; green, vibrant, more compact and accessible with a unique sense of place*" (p. 2). The Directions 2031 strategic framework is based on the five key themes for a liveable, prosperous, accessible, sustainable and responsible city. The objective for the "*accessible*" theme is that "*all people should be able to easily meet their education, employment, recreation, service and consumer needs within a reasonable distance of their home*" (p. 23) with strategies to achieve that objective identified as being to:

- *Connect communities with jobs and services*. This strategy places emphasis on activity centres and transit-oriented development to achieve better integration of land-use and transport services.
- *Improve the efficiency and effectiveness of public transport*. The focus here is on linking key activity centres and nodes, and significantly improving integration, efficiency and patronage, featuring rail and other rapid transit and high frequency bus services. Achieving minimum residential densities, significantly higher than present densities, around key transport nodes is a key part of this strategy.
- *Encourage a shift to more sustainable transport modes*. The promotion of walking and cycling through the application of transit-oriented development and liveable neighbourhoods design principles, TravelSmart programs and cycling network improvements.
- *Maximise the efficiency of road infrastructure*. Transport demand cannot be satisfied only by building more roads and thus improved efficiency of the road network, congestion management including real time road user information, incident management and ramp metering and intelligent transport systems are part of the strategy.
- *Manage and reduce congestion*. In addition to road use efficiency, an effective public transport network with superior service in terms of travel time and reliability, together with adequate levels of passenger security and comfort and a transport system, land-use pattern and urban design that are conducive to walking and cycling, are part of the strategy.
- *Protect freight networks and the movement economy*. Protecting major transport corridors and freight operations from incompatible urban encroachment, particularly those leading to major ports, is a key element.
- *Consider parking in the overall transport picture*. Parking supply, demand and rights of parking allocation must be carefully managed to support broader accessibility objectives.
- *Plan and develop urban corridors to accommodate medium-rise higher density housing development*. Planning for existing and potential activity centres into the future with an increased focus on transport integration and transit-oriented development, agglomeration of economic activities and mixed-use development including higher density housing.

The following list, which is not exhaustive, draws attention to the policy-relevant modelling outputs and measures relevant to the types of policies under consideration in Perth:

- passenger demands, by time period during the day;
- trips by mode—the basic mode choices giving share 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;
- public transport patronage: system wide and at particular locations;
- impacts of specific policies:
  - traffic management;
  - price changes (including road pricing and tolls, congestion charges, fare changes and differentials, operating cost changes due to rising fuel prices, mobility charging);
  - parking;
  - reduced crowding through the provision of more rail cars or buses;
  - reduced variability in freeway travel times though, e.g., ramp metering;
- cost-benefit ratios; and
- measures of accessibility.

3.2 Assessment of Current Modelling Practice in Perth

There are essentially two strategic transport models in operation in Perth, each operated by separate modelling teams in different state government departments. The Strategic Transport Evaluation Model (STEM), at the Department of Planning, is used to assess the impacts of alternative land-use scenarios on Perth's multimodal metropolitan transport systems. STEM is a model used for land-use and transport policy assessment. There are currently two versions of STEM in existence—one using the established strategic network travel demand analysis package EMME/2 software platform and the other, the CUBE VOYAGER platform. It uses 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. STEM also produces several accessibility indicators.

The Regional Operations Model (ROM24), hosted at Main Roads, is a strategic network model, suitable for more specific studies of traffic impacts of road infrastructure projects, land-use developments and metropolitan-wide area traffic management measures. It provides traffic volume data for use in the planning and design of elements of the road traffic system, such as interchanges and intersections. It is further used to study regional traffic impacts of land-use development projects 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. The ROM24 outputs are flows of vehicles at the network link level, and measures of metropolitan road network performance in terms of economic efficiency. Outputs may also be used in evaluating social and environmental impact.

A key input to the STEM and ROM24 is the land-use forecasts provided by the Department of Planning's Metropolitan Land Use Forecasting System (MLUFS). MLUFS currently provides estimates of population, dwellings and employment at five yearly intervals to 2031. MLUFS is used to forecast dwellings and population and employment by industry for small areas within the Perth Metropolitan Region. Small areas are Census Collection Districts (CCD) but the MLUFS outputs can be aggregated to traffic and other zones (Government of Western Australia, Department of Transport 2013). The dwellings/population module estimates dwellings by type and population by age and sex. The employment module estimates employment by industry. Each module is controlled by reference to global dwelling, population and employment projections made independently of MLUFS. MLUFS allocates total population, dwellings and employment to spatial areas (CCD) based on a combination of trend analysis and analytical procedures which iteratively adjust allocations to balance capacities and growth trends in each area (Government of Western Australia, Department of Transport 2013).

3.3 Assessment of Stakeholder Requirements

A consultative process to assess current and anticipated future transport modelling needs of government stakeholders was undertaken (Government of Western Australia 2013, p. i). Key stakeholder groups comprising Main Roads, the Department of Transport, the Public Transport Authority, the Department of Planning, local government and the private sector, participated in a needs assessment survey and a series of stakeholder workshops held for each stakeholder group. The purpose of the survey questionnaire and workshops was to determine: current use of modelling outputs, whether current modelling outputs are considered fit for purpose, anticipated future modelling needs and suggested areas for improvement.

The key findings were:

- There was a broad level of support shown for the development of one integrated strategic level transport model for the Perth region.
- The current suite of transport modelling outputs from current strategic models was generally considered to be fit-for-purpose.

- Land-use inputs and feedback were an issue of concern and were considered a significant risk in the successful implementation of a new strategic level transport model.
- The need for mesoscopic traffic modelling was expressed, especially for the modelling of congested areas.
- State government should take a lead role in developing mesoscopic modelling and microsimulation modelling expertise through a Centre of Excellence approach.

Stakeholder requirements for the strategic model included:

- capability to provide fit-for-purpose transport modelling outputs for policy analysis, strategic and operational uses;
- multimodal capability, with the ability to calculate accurate mode split shifts;
- incorporating longer-term (2041 and 2051) land-use and transport scenarios;
- time of day modelling capability—peak period modelling, peak spreading, departure choice;
- improving quality, timeliness and consistency of land-use inputs, particularly in relation to the land-use forecasts;
- interactive land-use and transport modelling;
- appropriate application of macroscopic, mesoscopic and microscopic models;
- improved freight modelling capacity;
- achievable transport modelling data requirements;
- enhanced level of detail—disaggregation and segmentation—scale, zonal, socio-economic and modal attributes;
- predict behavioural responses to policies and demand management measures; and
- incorporating dynamics (treatment of time).

3.4 Review of International Best Practice Advances

In order to find best practice solutions to meet the stakeholder-identified requirements, a review of international and in particular Australasian developments in strategic transport modelling practice was undertaken. In terms of best practice, the focus of the review was on production as opposed to R&D models. The production model is defined as that available for use by or on behalf of users outside the model development-management group, currently being employed in applications on real world plans and projects. The review identified a number of recent advances:

- Replacement of the trip-based modelling approach by a tour-based schema, while remaining in the overall four-step modelling system.

- Introduction of a time of day modelling capability, certainly for production of 'n-hour' origin-destination 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, including a 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 models for large networks, covering entire metropolitan areas, and including a hybrid modelling capability so that small parts of the entire network can be modelled microscopically in the mesoscopic model, on a case by case or project specific basis.
- Land market economic theory-based land-use models, connected to transport models (as opposed to being fully integrated) with feedback to land-use choices through accessibility/composite utility values.
- [Re]Develop models within a GIS environment for data handling capabilities, enhanced visualisation and user-interfacing and spatial aggregation and disaggregation capabilities.
- Freight model development continues to be hampered by the lack of suitable and reliable freight-specific data.

The review concluded that no one city or one model combines all of the features collectively forming current best practice. It did, however, indicate that different cities and regions have included best practice features in their production models. Extracting and combining best practice features from different cities into a general purpose production model of metropolitan travel demand yields an 'ideal' tour-based strategic model which also:

- includes departure time choice, and possibly extending into peak spreading;
- has extensive segmentation for modelling of destination, mode and trip timing choices;
- has the opportunity to provide feedback to land-use;
- is supported by a freight modelling capability which provides separate vehicle origin-destination matrices;
- is possibly (but not necessarily) using quasi-dynamic macro assignment;
- most certainly works in conjunction with a mesoscopic traffic network model for the entire study region;
- is connected to a land market economic theory-based land-use model with feedback to land-use choices through accessibility/composite utility values;
- is developed within a GIS environment with enhanced visualisation and user-interfacing; and
- is part of an integrated modelling suite.

3.5 Development of Options

On the basis of the literature review of current state-of-the-art international advances in transport modelling, stakeholder requirements and importantly, accounting for the unique current modelling practice situation in Perth, three feasible options for model development were identified and evaluated:

- *Option 1*—continued (separate, parallel) development of both STEM and ROM24 models, providing specialised services to current clients, but with improved integration.
- *Option 2*—gradual development into a single modelling system, which incorporates the top features of the current two models, plus additional best practice developments.
- *Option 3*—development of a new best practice modelling system, 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 a freight component.

3.6 Evaluation of Options

The analysis of best practice of production models, highlighted a number of commonalities, summarised in the form of assessment criteria:

- 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.

Each of the options was evaluated in terms of the criteria (Table 1). In the case of Option 1 (Parallel Models), it was concluded that duplication of functions wastes resources and that special services to particular clients could be provided by a combined modelling system. Although they both use sound methods, neither model could be claimed to be best practice by world or Australian standards. The main advantage of Option 2 (Closely Associated Models) is that the ROM24 team could cover the whole range of road-based 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, providing greater productivity and bringing the two modelling teams back into collaboration.

Table 1 Summary of option evaluation against 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 modelling	Gradual adoption	Slightly faster adoption	Extended tours with deviations
Simultaneous mode-destination choice; logsum benefits	Depends on STEM achieving destination choice	May achieve destination choice more quickly	Full development of mode-destination choice 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
Mesoscopic 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

The prognosis for Option 3 (Integrated Models) would be reaching and even surpassing the best practice transport modelling standard already reached in some major cities. 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 workflow and resource utilisation.

3.7 Selection of Preferred Modelling System Approach

The third option was recommended as the preferred solution for addressing the modelling needs of WA.

The proposed Perth LAnd and Transport INtegrated Urban Model (PLATINUM) is a closely coupled, system of models, exchanging information among them, comprising:

- a five-step, tour-based, multi-modal strategic transport model, supported by a land-use model and outputting to a regional impacts model, for use in longrange planning, scenario analysis and system wide transport policy analysis, also providing road passenger/vehicle origin-destination matrices, by time of day and for planning horizon years to the road transport model;

- a hybrid meso-micro assignment, road transport model of the metropolitan road network including all road-based travel by time of day, and delivering results to a local area impacts model, for use in road project planning and evaluation, traffic management and control, congestion management, local area traffic impacts, event planning and incident management planning, as well as providing information on network travel times, delays and queuing as input to the strategic model;
- an external travel model, interacting with the WA State-wide Transport Model; and
- a freight transport model, comprising an improved Freight Movement Model and a separate model for light goods vehicles.

3.8 Proposing an Implementation Strategy

The implementation strategy contains specification of elements to be developed, linkages and feedbacks to be established, human and financial resourcing to be mobilised, risks to be managed, data to be acquired, maintained and managed, model validation and managing the transition process.

Implementing the preferred approach entails transport modelling for Perth being 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 (Fig. 2). 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 and medium-term studies, with an emphasis on congestion management, traffic management and road project evaluation.

The development of PLATINUM requires the implementation of the following elements:

- the specification or re-specification of several current model components and alignment of data (consolidate the current 1500 zones STEM and ROM24 networks, re-develop and integrate the land-use model);
- 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
- creation of new component models (including departure time, using a hybrid meso-micro dynamic traffic assignment model of all road-based travel by time

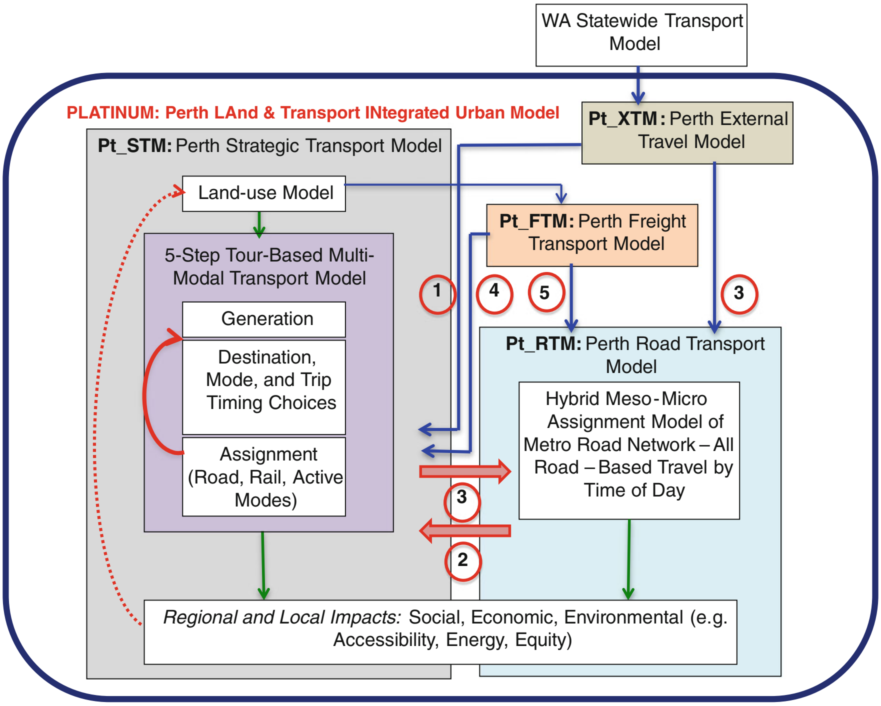

Fig. 2 Structure of the proposed Perth LAnd and Transport INtegrated Urban Model (PLATINUM)

of day, considering quasi-dynamic traffic assignment as a better starting point for meso-simulation, a new model assessing wider benefits of projects, feedback to land use, and authentic integration of all components).

Successful implementation of the strategy will depend to a considerable extent on the functioning of linkages and feedbacks (Fig. 2). Four of these are concerned with land-use and transport interaction. The feedback from regional transport impacts to the land-use model will include the accessibility measures. Between the component transport models, feedback (perhaps iterative) on network travel times, delays and queuing will have substantial impacts on the enhanced mode choice model.

Implementation further requires investment 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, public transport smart ticketing information, household travel survey and census data should be aligned with regular traffic and public transport monitoring, supplemented with some automatically collected data using mobile phones, GPS, etc.

The new modelling suite should remain 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.

4 Discussion and Conclusion

In common with worldwide trends, key emerging modelling requirements in Perth include the ability to model seamlessly at macro-, meso- and micro-scopic scales, greater levels of disaggregation and segmentation, land-use and transport interactions, behavioural responses, freight movement and time in a dynamic way. These modelling requirements have largely been driven by growing complexity in urban systems throughout the world in relation to changing planning objectives, policies and approaches (Waddell and Ulfarsson 2004). Consistent with worldwide trends, in Perth, objectives have shifted from a rather singular focus on improving road capacity for private vehicles to a much wider array of objectives, developed in response to issues of congestion and environmental consequences, with a much wider and diverse range of multi-modal, demand-side and land-use strategies as alternatives to meet growing transport needs.

While the need for modelling to become less of a 'black box', more open and participatory, has been recognised as a growing pressure (Waddell and Ulfarsson 2004), that modelling be facilitative of participation in the testing and evaluation of alternative policy strategies did not arise as a major requirement in Perth. This is most likely related to the strong role of the state government in planning with local government having little decision-making power and the associated approach of consultation rather than engagement with stakeholders and communities. It may also be a consequence of recognised existing under-application of (modelling in) strategic planning and scenario development processes.

Similarity of modelling requirements across the world has resulted in a wide range of best practice solutions available to draw upon in designing a new modelling system for Perth. Advances in tour-based schemas, time of day modelling, segmentation of demand, dynamic traffic assignment, mesoscopic traffic assignment, 'hybrid' modelling, land market economic theory-based land-use models, freight modelling, quasi-dynamic macro assignment and feedback to land-use choices through accessibility/composite utility values, have all been incorporated into the requirement-responsive design of a modelling system for Perth.

Unique to the development context of Perth, and influencing the development of design options, are:

- the existence of two modelling teams and two different models;
- the modelling teams are relatively well-capacitated and experienced; and
- there is a strong tradition of modelling and use of modelling outputs in transport operations and in evaluation of specific projects and local plans, but not for strategic planning.

Vonk (2006) identified the primary reason for lack of uptake, in particular, of analytical PSS (such as land-use and transport models), is lack of experience, which affects awareness of innovation and judgement of instrument quality. Accordingly, due to the high level of experience of the modelling teams in Perth, the expectation of uptake of the new model design would be positive. However, Vonk (2006) additionally identifies the bottleneck of resistance to change. He ascertains that the more radical the PSS innovation, like many analysing PSS, the higher the resistance. Incremental innovations, as in the case of the more simple information PSS, where planners, managers and specialists essentially continue doing the jobs they are used to, but with greater ease, face less resistance (Vonk 2006). He asserts that only watershed changes in planning context or planning system have the potential to instigate uptake of more radical innovations.

This last point is echoed in Waddell (2011) when he poses the question as to why advanced/innovative activity-based travel and land-use models are placed under such intense critical scrutiny by practitioners when the limitations of four-step travel models in widespread use, particularly in relation to limited degree of validation, are well established. He suggests that users become accustomed to standard practice, finding (incremental) ways around these limitations rather than embracing new innovations, which require a higher burden of proof by practitioners. Waddell (2011) maintains that the challenge in selling a new model is that not only should it perform better empirically but must also be deemed to be worth the effort in terms of overcoming potentially larger costs of data, computation and complexity.

The interpretation for the Perth context is that experience is a two-edged sword. On the one hand, it results in greater awareness and appreciation for the advances being made in practice around the world and their potential to enhance local model development. On the other hand, experience can lock in continued use of existing standard technologies, with ongoing incremental adjustments made to deal with limitations, resulting in a high level of path dependency and resistance to more radical innovations. This is exacerbated in Perth with the existence of two, almost competing, modelling teams and the propensity for modelling output to be used almost religiously, in planning.

For these reasons, and to maximise the opportunity for uptake of best practice advances, the development of model system options and the design and implementation specification of the recommended option for Perth, in addition to incorporating technical advances to meet model requirements, involved a detailed proposal for 'getting from where we are to where we want to be'. Cognisant of recent incremental innovations made by the two modelling teams, and in cases where they are aligned with best practice advances, these were incorporated into the new model design.

In conclusion, the recommendation for future model system design processes is that an explicit step in the assessment process should be devoted to understanding the existing modelling and PSS in use. Neither the model development process of Waddell and Ulfarsson (2004) nor the conceptual frameworks developed to enhance the uptake of PSS (Biermann 2011; Geertman 2006; Geertman and Stillwell 2004; Vonk and Geertman 2008), explicitly incorporate this as a step or a criterion or sub-criterion. Existing modelling considerations could either be undertaken as part of the development context assessment or as a stand-alone step. Designing model system options should explicitly acknowledge current systems in use and solutions should strongly account for the pathway from the existing situation to the new model system. In addition, the two-edged sword of experience should be recognised as both a positive influence in terms of innovation awareness but carefully dealt with in relation to potential negative influences of path-dependent, 'incrementality' at the expense of embracing more radical innovations.

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