

# Clothing the Emperor?: Transport modelling and decision-making in Australian cities

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**Abstract:** In no field of planning is there more reliance on technical-rational decision-making processes than transportation planning. In Australian cities transport planners still heavily rely upon complex, quantitative transport models, especially the four-step model (FSM) and its variants, used at the regional, metropolitan and corridor levels of analysis. While it is beyond the scope of this paper to provide a detailed critique of each stage of the FSM, there are numerous problems with its use that need to be addressed. This paper examines the empirical shortfalls of the technical-rational process, highlighting the reliance on a select few experts, limited public participation in modelling processes, and decision-makers who have little understanding of the methodological limitations inherent in transport modelling advice. Model deficiencies do not allow for, and may actually impede consideration of many of the most important emerging issues within cities, including road pricing, climate change and oil vulnerability, as well as long-held concerns such as land use changes, induced travel, the environment and sustainability. This paper identifies numerous inter-related concerns about the broader policy and political dimensions of technical-rational decision-making in the transport sector, and recognises the main tools used in technical assessments.

## Introduction

The paper explores the limitations of conventional transport evaluation and analysis and its position within a broader institutional landscape. The paper argues the technical complexity of conventional transport models is such that understanding of their internal capacities and limitations is, in most jurisdictions, restricted to a small number of specialists. When coupled with the inherent inadequacies of transport modelling, this technical complexity may be seen to create a form of institutional risk for transport planning. This observation has implications for the quality of transport planning in cities.

The paper first considers transport planning and the role of technical-rational evaluation. Issues pertaining to the broader political and policy dimensions of transport assessments are explored, highlighting recent research into these issues. The particular problems of transport modelling, especially the conventional four-step model (FSM), are then discussed, highlighting both the known and well-understood concerns, such as induced traffic, as well as a range of new and emergent issues that modelling may not be well suited to appraising. The paper concludes with an outline of further research possibilities in the Australian context.

## Transport planning: Techno-institutional views

Has any policy field relied on technical-rational evaluation methods more than transport planning? Since the 1950s there has been an intense focus in transport planning on technical appraisal and modelling to solve problems of movement, often at the expense of other potential influences. And at the heart have been large city-wide strategic transport models, used to forecast travel flows and to test project or policy scenarios.

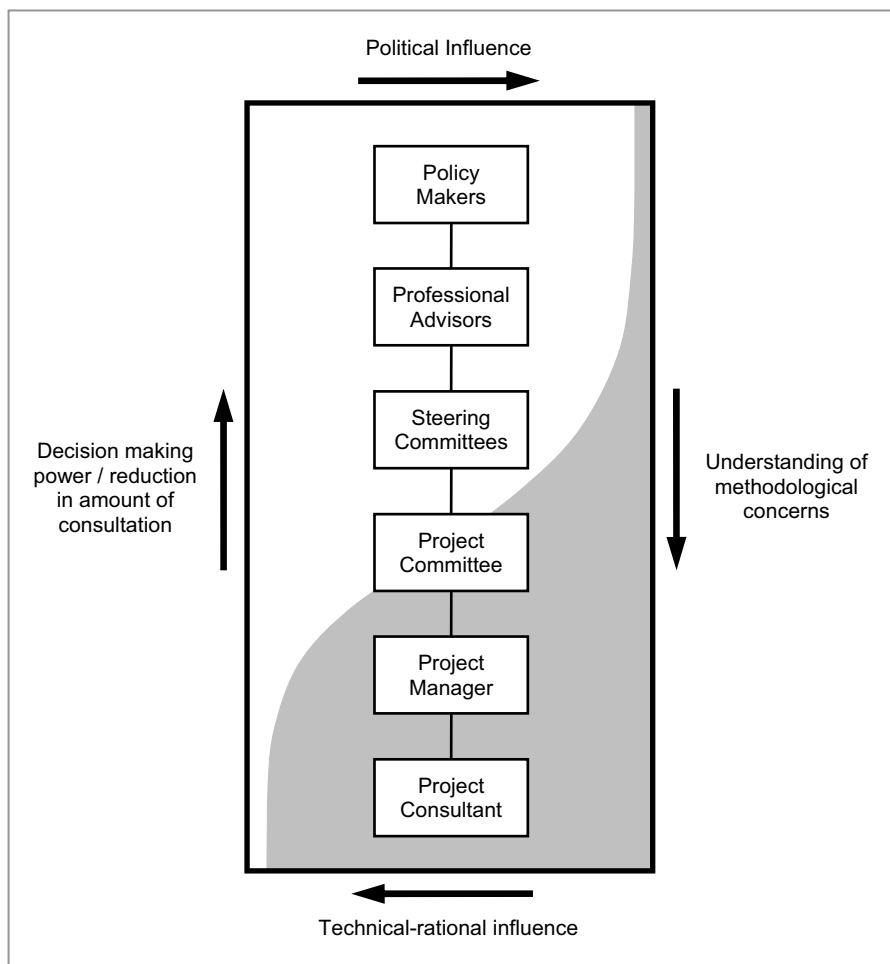
Modelling's influence on decisions is certainly less than during the excessively pro-roads 1960s, when land use and transport studies such as the 1965 Brisbane Transportation Study (Wilbur Smith and Associates, 1965) sought to reshape the inner-cities of Australian cities for urban motorway networks. Indeed, in recent decades both transport models and transport planners have receded somewhat from the public eye, their names generally unknown. But they are still used to inform every major transport investment or strategic plan. That is not to say that model outputs necessarily dictate transport policy and project decisions – models have 'an ambiguous role in the choice of transport plan or policy' (Talvitie, 2006, p.84). And they may serve to legitimate particular projects that have been selected on a political rather than technical basis. Most cynically, Abram (2005) suggests that the use of technical methods in government policy making is simply 'politics by other means'. There have been relatively few studies that seek to comprehend transport technical assessment as a broader process involving technical, social and political dynamics. Vigar's (2002; 2006) work is perhaps the most developed in this regard, demonstrating how technical assessments in the UK have been used both to design road schemes and also to frame debates, focusing discourse on highway capacities, on 'schemes' and on 'hard' engineering projects (Vigar, 2002, pp.106-107). Mees and Dodson (2007) have also

demonstrated how technical studies and the assumptions and calibrations underpinning them have been used to shape and distort political and public preferences in strategic transport analysis.

It remains the case that in Australian cities, the majority of strategic transport plans and project investment decisions are invariably developed using guidance from complex and highly technical computer-based models such as the Melbourne Integrated Transport Model (MITM), the Brisbane Strategic Transport Model (BSTM) and the Strategic Transport Model of Sydney (STM). These models assist in developing the future transport networks for the metropolitan strategies that now guide urban growth and investment in each of the Australian mainland capital cities. Models are also typically used to predict network flows, to develop local transport plans, to appraise specific investments, to identify 'corridor' opportunities, to provide the necessary inputs to environmental impact assessments of projects, and for many other purposes. The technical-rational processes inherent in such models mean that by their nature their use must be 'expert-led', and typically involve a narrow range of participants' using highly quantitative, complex modelling procedures (Vigar, 2006, p.269). Though the use of models is somewhat inevitable (Ortuzar and Willumsen 1990, p.2) the technical basis for such modelling processes and the level of understanding necessary to comprehend their internal functions means that knowledge of how the models work and their capacities, and in turn their biases and inadequacies, are often restricted to a small number of professional experts. The technical complexity of transport assessment methodologies imbues these systems with the appearance of objectivity and universality. Yet the policy context in which transport decisions are framed and the political circumstances surrounding these decisions also influence the way assessment is undertaken and the outcomes of that assessment. Traditional views held by decision makers, may heavily influence the assumptions that drive transport policy when selecting and creating new infrastructure and transport options (Low 2003).

Even aside from these broader dimensions, there has been much academic and institutional debate about the merits of conventional transport modelling per se (e.g. see Beimborn, 1995; Bureau of Transport Economics, 1998; Cervero, 2006; David Simmonds Consultancy et al., 2000; Litman, 1999; Noland, 1999; Supernak, 1983). Certainly, models have continued to improve with time – thanks to increases in computing power and model sophistication – though it is not certain that *in practice* much is changing (Noland, 2004, p.18). Indeed, the ruinous demand estimates for some recent Australian transport projects (e.g. Brisbane's Airtrain, Sydney's Cross City Tunnel) reinforce the view that improved precision isn't resulting. This isn't solely an Australian problem – technical analyses of transport projects are often inaccurate or wrong. Flyvbjerg's studies (Flyvbjerg et al., 2002; Flyvbjerg et al., 2003) have demonstrated a wide variation exists between the outputs of transport technical assessment and the eventual transportation outcomes generated by major roads, bridges, tunnels and rail links. Flyvbjerg et al (2003) have argued that the broader context for transportation decision-making influences the way technical assessment is performed. And he suggests that the 'ambitions' of project proponents may either explicitly or implicitly shape technical assessment processes with great potential for 'strategic misrepresentation' of the viability of projects. Flyvbjerg et al (2006) have also identified traffic forecasts as particularly susceptible to these strategic problems such that the reliance on models itself constitutes a form of risk.

The role of transport modelling in policy processes is represented in Figure 1, which illustrates the typical organisational hierarchy of a conventional transport planning project in the Australian context. The detailed technical knowledge of the modelling gradually decreases as the project moves up the institutional chain, with an inversely increasing amount of political influence affecting the outcomes of the project. Problems may arise for those higher in the chain where methodological concerns are not necessarily understood, or where limitations may be ignored.



**Figure 1: Typical organisation of a transport planning project and the influences upon it**

Given the influence that transport projects and schemes can have on the shape and function of cities and the prominence of technical-rational decision-making, the models and the assessment methods used can have an enormous bearing on urban trajectories. This influence extends to the investment cost of transport decisions, which can impose heavy burdens on both governments and private businesses (Flyvbjerg 2003). These issues suggest there are important aspects of transport technical assessment that deserve scholarly attention.

While the Flyvbjerg et al. (2003; 2002), Vigar (2002) and Mees and Dodson (2007) studies shed some light on the techno-political nexus of strategic transport assessment, more research is needed to fully comprehend these processes. An Australian perspective in particular is desperately needed. There is a further important task to extend inquiry beyond simply the analytical frame of scholarly investigation. Part of this task involves identifying the capacities and limitations of transport technical assessment and reporting these to planning and transport policy decision makers to assist with their selection of strategic and project alternatives.

The remainder of this paper commences this work, examining the technical capacities and weaknesses of conventional transport modelling, summarising known methodological concerns, and highlighting emergent issues for transport assessment.

### **Transport modelling and technical transport planning processes**

The predominant methodology used internationally in the technical assessment of urban transport networks is the 'Four Step Transport Model' (FSM), of which the Melbourne, Sydney and Brisbane models mentioned above are examples. Transport planners have 'traditionally considered the relationship between urban structure and travel patterns at the aggregate level' (Schwanen et al., 2005, p.17). The FSM uses this approach, seeking to identify future travel demand and predicting the measures needed to cater for it (Hensher and Button, 2000). The FSM has dominated transport modelling since the 1960s, and still resides in most comprehensive transport models in various modified forms (McNally, 2000). The FSM also typically supports cost-benefit analysis for the

purposes of making assessments and obtaining justification for policy decisions (Hensher & Button, 2000).

The operational sequence for the FSM is: 1) trip generation, 2) trip distribution, 3) modal split/choice, and, 4) route/traffic assignment (see Figure 2). It is beyond the scope of this paper to give an authoritative overview of the process, or to discuss the considerable issues of input data and network representation, or the use of model outputs for economic or environmental appraisal, important as those issues are. However a brief outline of the FSM is provided to identify the influence each may have on transport assessments.

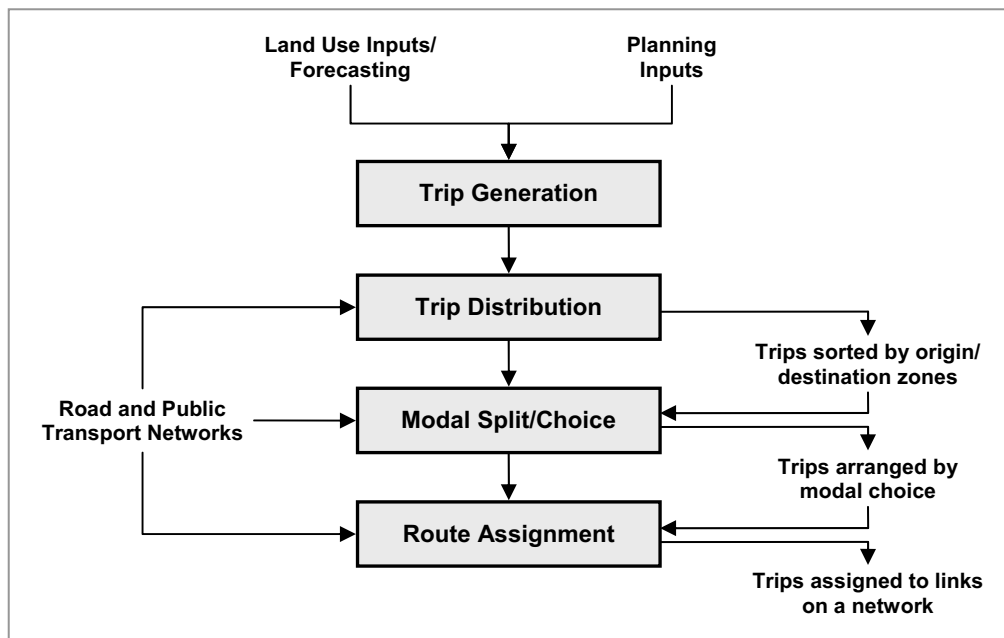


Figure 2: Traditional four-step transport model (adapted from Button, 1977, p.117)

### *Trip generation*

The trip generation step uses population and employment forecasting plus land use planning inputs to identify the magnitude of future total daily travel, calculated at either the household or zonal level (McNally, 2000). There are several different methods for calculating total daily travel within the FSM. These include linear and multiple regression analysis (multiple regression tending to be the most popular method), and cross-classification or category analysis (Ortuzar & Willumsen, 1990). Variables used to calculate the number of trips usually includes the number of jobs within zones, the number of residents, and sometimes other gross activity measures such as tertiary education attractors (Cervero, 2006).

Methodological concerns of trip generation models are many. Travel is grossly simplified into only few trip types (often only 4 or 5), with often no discrimination between pedestrian-likely trips and motor vehicle trips (Beimborn, 1995; Beimborn et al. 1996). Trip-chaining behaviours, whereby persons combine multiple destinations such as work and shopping into their travel from home, are ignored due to the complex nature of such trips (Beimborn, 1996, p.16; Lee and McNally, 2006, p.554). Spatial environmental variables known to influence travel behaviour, such as resident and employment density, land use mixing, and ease of non-motorised accessibility, are rarely considered (Cervero, 2006). Trip zones are often large, limiting any potential to consider short distance walking and cycling trips (Cervero, 2006). These concerns limit the predictive capacity of the FSM in general, but are of especial concern for modelling of contemporary land use and transport interventions, such as transit-oriented development, with which the FSM struggles.

### *Trip distribution*

Trip distribution takes the outputs from the trip generation stage of the FSM and allocates them to routes on a transportation network to develop a region-wide origin-destination matrix, better known as a 'destination choice model' (McNally, 2000). The most used method of allocation is the 'gravity' model, which assigns travel to various land uses based on their population or employment size and the separation (usually expressed as travel time) between them.

Methodological concerns include the singular focus on travel times to represent the 'friction' of separation and distance, and the failure to consider socio-cultural factors in destination choice, such as locality avoidance due to class preferences or crime (Beimborn, 1995). There is typically little consideration of congestion or other feedback effects when modelling distribution (Beimborn et al., 1996, p.19). Comparisons with observed data generally find significant errors in the predictions of gravity models (Ortuzar and Willumsen, 1990, pp.157-158). Intra-zonal trips are also poorly handled, with households and jobs either modelled as being at one centralised point in each zone, or ignored (Cervero, 2006). These issues further reduce the precision of the FSM – particularly in regards to the desired directions and destinations of travel, and considerably affect short trips made via walking and cycling.

### *Modal assignment*

The modal assignment step assigns the trip numbers derived from the results of the trip distribution analysis to mode-specific journeys (McNally, 2000). Mode choice models can be aggregate, if they are based on zonal information, or disaggregate, if based on household or individual data (Ortuzar and Willumsen, 1990, p.162). Most models today use behaviour-oriented approaches, the most common of which is the 'nested logit' model, that use complex probabilistic mathematical calculations to impute individual travel mode choices (McNally, 2000). Public transport, due its greater complexity (different stops, routes, possible interchanges, arrival and departure times of services, etc.) than car travel, is aggregated to simple networks and average journey and waiting times (Freidrich, 1998, p.12). Most modal assignment models use relative travel times for public transport modes, representing the time spent in accessing public transport, waiting time (including at interchanges) and time spent in-vehicle.

Methodological concerns include the naivety of most models to many qualitative features of public transport services (Beimborn, 1995), and the exclusion or very limited consideration of non-motorised trips. Most models are insensitive to travel options such as carpooling (Beimborn et al., 1996, p.28). The focus on interchanges and waiting times, rather than the quality of nodes, to predict the mode travellers will use is questionable (Cervero, 2006, p.286). The approach is generally seen as favouring the use of private motor vehicles over alternative modes, despite growing literature that suggests higher mode shares for public transport and non-motorised travel will result in cities which have designed quality public transport, walking and cycling infrastructure and systems (Newman and Kenworthy, 1999, pp.154-159, 162-164).

### *Route/traffic assignment*

The route assignment step assigns the zonal mode trips to specific transport network routes using complex mathematical operations (McNally, 2000). Performed separately for road and public transport trips (non-motorised trips are generally ignored) methods are used to assign traffic to specific routes, usually with capacity constraints modelled, relating the volume of flow to the costs (in travel time) of each link. Assignment processes generally seek to assign traffic flows to approximate an equilibrium condition whereby all travellers have minimised their travel costs within the network, such that no one traveller may further reduce their travel costs by switching routes (Ortuzar and Willumsen, 1990, p.254).

Methodological concerns include assignment methods generally focusing on link travel times, ignoring or placing less emphasis on intersection delays. Capacities are often over simplified, neglecting to allow for such things as heavy vehicle movements or highway geometry. Intra-zonal travel is ignored. Travel made at different times of day is often readjusted into the peak hour by applying an hour adjustment factor, and peak hour travel is overemphasised (Beimborn et al., 1996).

Other acknowledged problems of the FSM include poor trip generation assessments due to weak land-use projections, and limited (or more commonly nil) feedback between transport and land-use systems. Yet few of these limitations are given much attention in the reporting of transport assessments. There are both well-known and emergent issues with which transport planners have been confronted, and with which convention assessment and the FSM have thus far generally failed to accommodate, to which we now turn.

## **Further Challenges in Transport Technical Assessment**

Beyond the technical problems with the various steps in the FSM identified above, a number of additional issues have proven difficult for modelling to overcome. And new issues have emerged to

further confound the transport planning profession. This section briefly outlines some of these technical and empirical problems.

### *Induced traffic and travel*

The existence of induced traffic and travel has been debated for many years (Noland, 2001). However the SACTRA (1994) report on the generation of traffic through road construction led to the general acceptance of induced travel as an irrefutable problem of capacity expansion. Induced traffic refers to the phenomenon of additional road capacity generating new and generally unpredicted travel, additional to persons switching times and routes within the system (Luk and Chung, 1997; Litman, 1999; Ramsey, 2005, p.41). Induced travel comes in a variety of forms including new travel due to changes in land uses caused by shifts in transport network accessibility, mode shifts due to declining public transport services or increased car ownership as a city becomes more auto-focused, or driving substituting for other activities (Litman, 1999, p.5). Where the benefits of transport projects are calculated in terms of travel time savings, lower emissions and decreased road trauma, these benefits may be 'illusory' due to induced traffic effects (Newman and Kenworthy, 1999, p.297).

The FSM is often able to model changes in route and mode behaviour in the short term due to changes in transport networks, and some changes in scheduling or distribution of trips. But most models assume a linear relationship between population, land-use concentrations and transport demand in the longer term, and few are capable of adjusting trip frequencies, or to factor in longer term effects of automobility. In turn, models are also typically insensitive to the feedback effects identified by Mogridge (1997) in which rising congestion on roads increases travel times and shifts travel demand towards alternative travel modes. The failure of FSMs to account for induced traffic weakens their capacity to inform policy makers about the broader economic value and environmental impact of major transport projects.

### *Land use and transport interactions*

Changes to urban form alter the number, mode, and distribution of trips within a region. And regardless of assumptions that land uses are set by metropolitan strategies or other land use plans, the reality is that transport network changes are fundamental in shifting demand for land as accessibility increases (Ramsey 2005, p.40). Low (2003, p.7) argues that 'increasing transport infrastructure feeds back into more spatially dispersed patterns of land use'.

Most transport models in Australia have no land use feedback loops and thereby fail to consider the impacts of land use changes on travel. As a result, their outputs may inadvertently promote greater use of private motor vehicles (Beimborn et al., 1996). In addition, most models fail to identify any benefits of improved land use mixing, public transport quality (beyond travel and waiting times) or improved conditions for walking or cycling (Beimborn et al., 1996; Cervero, 2006).

Australian metropolitan strategies (e.g. OUM - QLD Government, 2005) generally seek to reduce land use separation and distance, to promote walking, cycling, and public transport, and to reduce the use of the private motor vehicles. The use of models unable to assess land use/transport interactions in order to determine and prioritise transport project investments within these strategies is therefore questionable.

### *Socio-economic status and transport*

Inability to access, afford or operate private transport imposes significant costs on many urban households especially the less socio-economically affluent (Kenyon et al., 2003). A lack of alternative modes such as public transport may limit household access to employment, education or community services (Herala, 2003; SEU, 2003). As we have seen, conventional transport models focus on urban mobility in ways that may bias towards car travel at the expense of public transport, walking and cycling. This may contribute to transport policies that fail to address the travel demands of socio-economically disadvantaged households, especially those without access to a motor vehicle.

### *Air quality, noise and transport systems*

Vehicle emissions are a major contributor to overall air pollution, with trends in transport indicating that emissions will continue to rise due to the increases in vehicle trips. And noise effects of transport vehicles are a major problem for health and well-being (Chapman, 2007; Lenzen et al., 2003; Lidskog

et al., 2003; Romilly, 1999). Many technical assessments use the outputs of transport models to assess the effects of increase motor vehicle use on air quality and noise. Typically travel time savings are used as the singular cost measure in transport assessment of this type. However, Affum et al. (2003, p.2) argue that 'much transport network planning still fails to consider environmental impacts at the time future road network scenarios are modelled and evaluated'. Evaluative methods are needed both at the link and at the system level, work that is rapidly progressing. Further, the costs of pollution should be considered during strategic network planning exercises, and not only within the confines of environmental impact statements for particular projects to which an agency has committed. Public transport (particularly using electric power) should be factored as a low-emission option for developing a sustainable transport system (Low, 2003; Yee, 2003).

### *Climate change/Greenhouse gas emissions*

Similarly, the transport sector generates 26% of global CO<sub>2</sub> emissions (Chapman, 2007) and a shift from cars to alternative modes may have a significant impact on transport CO<sub>2</sub> emissions (Chapman, 2007; Lenzen et al., 2003; Waterson et al., 2003). Further reductions could be achieved through walking and cycling, which are seen as 'zero carbon' alternatives (Chapman, 2007).

Means to incorporate carbon within technical assessments are many, including the UK approach of costing carbon emissions at a specific level. But this approach has yet to be incorporated into Australian project or plan assessments. There are further questions as to what may occur should government intervention be used to price carbon, increasing transport fuel costs, but this issue may pale in comparison to the issue of oil vulnerability.

### *Oil vulnerability and energy security risk*

Dependence on private automobiles for urban transport implies increasing dependence on petroleum. The global price of petroleum has more than doubled since early-2004, rising from around US\$25 per barrel to approximately US\$70 in mid-2007. Rising fuel costs have impacted on travel behaviour and have stimulated greater demand for public transport and changing composition of motor vehicle fleets toward smaller vehicles. Assessments of future petroleum prices suggest rising fuel costs over the long term as global petroleum demand exceeds global supplies.

Most technical assessments of transport systems are naïve to the issue of petroleum risk. Indeed, conventional transport modelling exercises typically involve linear projection of transport demand over the long term, assuming growth in travel will continue without interruption. Nor has there been much investigation in Australia to assess the likely travel demand patterns under higher fuel prices. Such petroleum risk evaluations should extend to comprehending the way in which rising fuel costs will impact not only on transport, but on housing and employment preferences, and on the communities at most risk. Assessment frameworks are needed to deal with travel demand volatility.

### **Where to for transport technical assessment?**

This paper has identified numerous inter-related concerns about the broader policy and political dimensions of technical-rational decision-making in the transport sector. It also recognises the main tools used in technical assessments, especially the FSM, and has identified continuing and emergent issues that cause further complications. These concerns open numerous opportunities for further research. Best-practice approaches developed elsewhere that in part address these concerns are not appreciably utilised in Australia, possibly due to inertia within the profession, resource constraints, and the use of proprietary products.

Whilst there have been a number of attempts in other jurisdictions to create either a superior land use and transport models or modelling frameworks (e.g. Hunt and Abraham, 2004; Lautso et al., 2004) or to create tools to address specific concerns, such as air quality or noise emissions (e.g. Brown et al., 2004), there is urgent need for research to inform and assist practitioners to improve technical assessments here in Australia.

A case study approach is suggested, taking one representative Australian city and exploring the use of technical assessments and main modelling tools *in practice*. This work may explore the overall technical assessment framework as used to assist transport policy decision-making, establish linkages between the various component land use and transport models, and identify specific methodological concerns, and possible means to address them. Brisbane is suggested for this work, primarily as the city (through state and local government agreement) has moved to standardise transport modelling

with the Brisbane Strategic Transport Model (BSTM), and there is strong institutional interest in both broadening the capacity of transport assessments, to explore new questions such as land use interventions, and also in improving the precision of such work. Further, Brisbane City Council recently made both the BSTM, and its necessary land use inputs, available for academic purposes – for which it should be commended. This work has commenced.

## References

- Abram, S. (2005) Introduction: Science/technology as politics by other means, *Focaal – European Journal of Anthropology*, 46, pp. 3-20.
- Affum, J. K., Brown, A. L. and Chan, Y. C. (2003) Integrating air pollution modelling with scenario testing in road transport planning: The TRAEMS approach, *Science of the Total Environment*, 312(1-3), pp. 1-14.
- Bates, J. (2000) History of demand modelling, In: Hensher, D. A. and Button, K. J. (Eds) *Handbook of transport modelling* (Oxford: Pergamon).
- Beimborn, E. (1995) *A Transportation Modeling Primer* (Milwaukee: Centre for Urban Transportation Studies, University of Wisconsin).
- Beimborn, E., Kennedy, R. and Schaefer, W. (1996) *Inside the Blackbox: Making Transportation Models Work for Livable Communities* (Milwaukee: Centre for Urban Transportation Studies, University of Wisconsin).
- Brown, A.L., Affum, J.K. and Chan, Y.C. (2004) *Transport Pollution Futures for Gold Coast City 2000, 2011, 2021, based on the Griffith University Transport Pollution Modelling System TRAEMS*, (Brisbane: Griffith University).
- Bureau of Transport Economics (1998) *Urban transport models: A review* (Canberra: Bureau of Transport Economics).
- Button, K. J. (1977) *The economics of urban transport*, (Farnborough: Saxon House).
- Cervero, R. (2006) Alternative approaches to modelling the travel-demand impacts of smart growth, *Journal of the American Planning Association*, 72(3), pp. 285-295.
- Chapman, L. (2007) Transport and climate change: A review, *Journal of Transport Geography*, Article in Press.
- David Simmonds Consultancy, Institute for Transport Studies University of Leeds, MVA, and John Bates Services. (2000) *New Look at Multi-Modal Modelling: report on modelling requirements*, (London: Department of Environment, Transport and the Regions).
- Flyvbjerg, B., Bruzelius, N. and Rothengatter, W. (2003) *Megaprojects and Risk: An anatomy of ambition*. (Cambridge; New York: Cambridge University Press).
- Flyvbjerg, B., Holm, M. K. S. and Buhl, S. L. (2006) Inaccuracy in Traffic Forecasts. *Transport Reviews*, 26(1): 1-24.
- Flyvbjerg, B., Holm, M.K.S and Buhl, S.L. (2002) Underestimating Costs in Public Works Projects: error or lie?, *Journal of the American Planning Association*, 68(3), pp. 279-295.
- Freidrich, M. (1998) A Multi-Modal Transport Model for Integrated Planning, *Presented at 8th World Conference on Transport Research, 12-16 July 1998, Antwerp, Belgium*.
- Hensher, D. A. and Button, K. J. (2000) Introduction, In: Hensher, D. A. and Button, K. J. (Eds) *Handbook of transport modelling* (Oxford: Pergamon).
- Herala, N. (2003) Regulating Traffic with Land Use Planning, *Sustainable Development*, 11(2), pp. 91-102.
- Holmen, B. and Niemeier, D. (2003) Air Quality, In: Hensher, D. A. and Button, K. J. (Eds), *Handbook of transport and the environment* (Oxford: Elsevier).
- Hunt, J. and Abraham, J. (2004) Design and Application of the PECAS Land Use Modelling System, *in 8th Computers in Urban Planning and Urban Management Conference (CUPUM '03), Sendai, Japan*.
- Kenyon, S., Rafferty, J. and Lyons, G. (2003) Social Exclusion and Transport in the UK: A Role for Virtual Accessibility in the Alleviation of Mobility-Related Social Exclusion?, *Journal of Social Policy*, 32(3), pp. 317-338.
- Lautso, K., Spiekermann, K., Wegener, M., Sheppard, I, Steadman, P., Martino, A., Domingo, R. and Gayda, S. (2004) *PROPOLIS: Planning and Research of Policies for Land Use and Transport for Increasing Urban Sustainability* (Helsinki, Finland: LT Consultants).
- Lee, M. and McNally, M.G. (2006) An Empirical Investigation on the Dynamic Processes of Activity Scheduling and Trip Chaining, *Transportation*, 33(6), pp. 553-565.
- Lenzen, M., Dey, C. and Hamilton, C. (2003) Climate Change, In: Hensher, D. A. and Button, K. J. (Eds) *Handbook of transport and the environment* (Oxford: Elsevier).
- Lidskog, R., Elander, I. and Brundin, P. (2003) Towards sustainable urban transportation in the European Union?, In: Low, N. and Gleeson, B. (Eds) *Making Urban Transport Sustainable* (Basingstoke, Hampshire: Palgrave Macmillan).

- Litman, T. (1999) *Generated Traffic: Implications for Transport Planning* (Victoria, British Columbia, Canada: Victoria Transport Policy Institute).
- Low, N. (2003) Is urban transport sustainable?, In: Low, N. and Gleeson, B. (Eds) *Making Urban Transport Sustainable* (Basingstoke, Hampshire: Palgrave Macmillan).
- Luk, J. and Chung, E. (1997) *Induced demand and road investment - an initial appraisal*, Research Report ARR 299 (Vermont South, Melbourne: ARRB Transport Research).
- McNally, M. G. (2000) The four-step model, In: Hensher, D. A. and Button, K. J. (Eds) *Handbook of transport modelling* (New York: Pergamon).
- Mees, P. and Dodson, J. (2007) Backtracking Auckland?: Technical and communicative reason in metropolitan transport planning, *International Planning Studies*, 12(1), pp. 35-53.
- Mogridge, M. (1997) The self-defeating nature of urban road capacity policy, *Transport Policy*, 4(1), pp. 5-23.
- Newman, P. and Kenworthy, J. (1999) *Sustainability and Cities: Overcoming Automobile Dependence* (Washington, D. C.: Island Press).
- Noland, R. (1999) *Relationships between highway capacity and induced vehicle travel*, edited by U.E.P. Agency (Washington, D.C.: US Environment Protection Agency).
- Noland, R. (2001) Relationships between highway capacity and induced vehicle travel, *Transportation Research Part A: Policy and Practice*, 35(1), pp. 47-72.
- Noland, R. (2004) Transport Policy and Assessment Procedures in the United Kingdom: lessons for the Federal District of Mexico City, In: *Seminario internacional hacia la creacin de una nueva legislacion para la calidad del aire (International seminar on the creation of new air quality legislation for Mexico City)* (Mexico City).
- Office of Urban Management (OUM - QLD Government) (2005) *South East Queensland Regional Plan 2005-2006* (Brisbane, Australia: Office of Urban Management).
- Ortuzar, J. and Willumsen, L. (1990) *Modelling transport*, (Chichester, West Sussex: Wiley).
- Ramsey, S. (2005) Of Mice and Elephants, *ITE Journal*, 75(9), p. 38.
- Romilly, P. (1999) Substitution of bus for car travel in urban Britain: an economic evaluation of bus and car exhaust emission and other costs, *Transportation Research Part D: Transport and Environment*, 4(2), pp. 109-125.
- SACTRA (1994) *Trunk roads and the generation of traffic*, (London: Department of Transport, Standing Advisory Committee on Trunk Road Assessment).
- Schwanen, T., Dijst, M. and Dieleman, F. M. (2005) The relationship between land use and travel patterns, In: Williams, K. (Ed) *Spatial Planning, Urban Form and Sustainable Transport* (Aldershot, Hampshire: Ashgate).
- Social Exclusion Unit (SEU) (2003) *Making the connections: Final report on transport and social exclusion*. (London: Office of the Deputy Prime Minister, UK Government).
- Stead, D. (2001) Relationships between land-use, socio-economic factors, and travel patterns in Britain, *Environment and Planning B*, 28(4), pp. 499-528.
- Supernak, J. (1983) Transportation Modeling: Lessons from the past and tasks for the future, *Transportation*, 12(1), p. 79.
- Talvitie, A. (2006) Experiential incrementalism: On the theory and technique to implement transport plans and policies, *Transportation*, 33(1), pp. 83-110.
- Vigar, G. (2002) *The politics of mobility: transport, the environment, and public policy*, (London: Spon Press).
- Vigar, G. (2006) Deliberation, participation and learning in the development of regional strategies: Transport policy making in north east England, *Planning Theory and Practice*. 7(3), pp. 267-287.
- Waterson, B. J., Rajbhandari, B. and Hounsell, N. B. (2003) Simulating the Impacts of Strong Bus Priority Measures, *Journal of Transportation Engineering*, 129(6), pp. 642-647.
- Wilbur Smith and Associates. (1965) *Brisbane Transportation Study: Summary Report* (Brisbane: Queensland Main Roads Department).
- Yee, C. (2003) Towards sustainable transportation policy in the United States: A grassroots perspective, In: Low, N. and Gleeson, B. (Eds) *Making Urban Transport Sustainable* (Basingstoke, Hampshire: Palgrave Macmillan).