CHAPTER 15

BOUNDARY OBJECTS AS TOOLS FOR INTEGRATED LAND USE–TRANSPORT PLANNING

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INTRODUCTION

The increasing complexity of cities with multiple layers of interacting systems and agents has resulted in unpredictable and emergent behaviour, increasing the need to understand relationships and feedbacks between the various components of the urban system. This is particularly true within the interconnected systems of land-use and transport, where a reciprocal influence is well-recognised, with the arrangement of land-uses and transport in a city defining movement patterns of people and goods. Wegener (2004) described this relationship as the land use–transport feedback cycle. Land-use activities influence transport by creating a demand for travel. Meeting this demand through the provision of transport infrastructure results in differential accessibility which in turn influences land-use. Motivated by policy objectives of urban efficiency, productivity and sustainability, urban planners and managers have sought to reduce the friction of distance and travel demand in urban areas by the co-location of activities and improving transport infrastructure links between activities. The complex interplay between land-use and transport has increased as planning and policy environments shift from a narrow focus on meeting transport demand through simply expanding road capacity to a more nuanced approach involving multiple modes, travel demand management and land-use policies (Waddell & Ulfarsson, 2004; see also chapter 25).

Challenges in implementing integrated land use-transport policies are well recognised (Curtis, Scheurer & Burke 2010), attributable to lack of shared vision and understanding of complexities, inability to communicate the vision, institutional path dependency and failed governance arrangements (Hull, 2008; Low & Astle, 2009; Te Brömmelstroet & Bertolini, 2008, 2010). In Australia, policy makers and researchers have developed and tested mechanisms to address these challenges, with solutions including strongly regulated networked governance arrangements (Legacy, Curtis & Sturup 2012), integrated plans and planning processes (Rhodes, Milliken & Thomas, 2013) and New Urbanism, Smart Growth and Transit-Oriented Development strategies (Curtis & Scheurer, 2010; Gleeson, Darbas & Lawson, 2004). Others have focussed on more technical solutions. Urban simulation models and accessibility tools (Curtis et al., 2010; Curtis, 2011; Biermann Olaru, Taplin & Taylor, 2015a; Biermann, Pettit & Brits, 2015b) and integrated indicators to target and monitor the achievement of travel-reducing patterns of land-use, such as measures of co-location of work and workers (Yigitcanlar, Dodson, Gleeson & Sipe, 2007; Biermann & Martinus, 2013), are amongst the more quantitative tools proposed for better integration.

Many of these mechanisms employed to enhance integration between land-use and transport planning can be considered as boundary objects (Star & Griesemer, 1989) or the objects which sit at the 'tension' line between the divergent viewpoints of diverse actors. Boundary objects support connections and build bridges between different practices and groups, being applied predominantly in the fields of management and social sciences, as well as information systems, sustainable development and natural environmental studies. They are 'tools which open up dialogue, information sharing, learning and consensus-building across different policy boundaries' (Holden, 2013, p. 89), so it is surprising that they are not considered in literature investigating the integration of land-use and transport planning.

This chapter presents a critical review of the effectiveness of two boundary objects between land-use and transport planning as applied in Perth, Western Australia. It firstly introduces the concept of boundary objects and presents criteria for measuring their effectiveness in bridging the land use–transport planning boundary. This is followed by a description and assessment of the two boundary objects – employment self-sufficiency target and land use–transportation modelling. Each object is evaluated according to the three key criteria (cf. Cash et al., 2003; Holden, 2013) of salience, credibility and legitimacy. The chapter concludes with recommendations of possible improvements to the objects to enhance their effectiveness in integrating land-use and transport planning.

BOUNDARY OBJECTS AND THEIR EFFECTIVENESS

Star and Griesemer (1989) first introduced the concept of boundary objects in the social sciences literature in relation to the establishment and development of a natural history research museum, recognising different types of boundary objects including repositories (e.g. library) and ideal (e.g. atlas), coincident (e.g. political state boundaries) and standardised (e.g. forms) types. Briers and Chua (2001) further identified 'visionary' objects which have 'such high levels of legitimacy to the extent that it is difficult for any 'rational' person to be against them' (p. 242). Boundary objects have been defined as artefacts, discourses or processes, operating at the intersection of different communities (e.g. disciplines, organisations, interest groups), facilitating connection, coherence, convergence, a shared space for action, knowledge transfer and translation (Benn, Edwards & Angus-Leppan, 2013; Cohen, 2012; Doolin & McLeod, 2012; Star, 2010; Star & Griesemer, 1989; Wenger, 2000). They have a unique ability to be simultaneously a shared, agreed and common concept but also used and interpreted by different groups in very different ways as they satisfy the informational requirements of each (Bowker & Star, 1999; Cohen, 2012; Sapsed & Salter, 2004; Star & Griesemer, 1989). It is agreed that it is not so much the object itself as the process of creating, using and managing the object which will 'open up dialogue, information sharing, learning and consensus-building across different policy boundaries' (Star & Griesemer, 1989; Holden, 2013, p. 89). Chapters 20 and 21 refer respectively to an organisation and a tool which could, in these respects be considered boundary objects.

Cash et al. (2003) proposed three criteria of salience, credibility and legitimacy to assess the effectiveness of the translation process between scientific knowledge and policy and practice. Holden (2013) tested these in a 'usability analysis' of sustainability indicator systems. Salience refers to the relevance of a boundary object and whether it adequately responds to policy questions, purposes or needs. Credibility relates to the perceived robustness of object outputs (Holden, 2013), being the 'scientific adequacy of the technical evidence and arguments' (Cash et al., 2003, p. 8086). Legitimacy is the degree of 'procedural fairness' (Holden, 2013) in the process of creating and using the object, the unbiased and fair treatment of opposing stakeholder views and interests in the production process, or transparency of the information production process (Cash et al., 2003). These three criteria are interrelated, and in some cases contradictory as the enhancement of one may incur costs and trade-offs with the others (Cash et al., 2003).

Considered boundary objects, employment self-sufficiency targets and land use–transport models are widely employed in planning, policy and practice in Perth, Western Australia, to improve land use–transport outcomes. The next sections describe the application of the three criteria of salience, credibility and legitimacy to assess the efficacy of these two boundary objects in bridging the boundary between land-use and transport planning.

BOUNDARY OBJECT 1: EMPLOYMENT SELF-SUFFICIENCY TARGETS

Object Description

The quest for self-sufficiency in some form or other has preoccupied urban planners and managers since Ebenezer Howard (1898) first espoused his ideal of the 'Garden City' with jobs and housing co-located in self-contained units, separated by green belts (Cervero, 1996; Curtis & Olaru, 2007). Jobs–housing balance has since continued to be pursued in cities in Australia as a land-use strategy to achieve transport outcomes, that is, to reduce the need to travel; and across the world, for purposes of environmental sustainability, economic efficiency and social benefits (Naess, Rue & Larsen 1995; Forster, 2006; Niedzielski, Horner & Xiao, 2013). In support of these policy efforts, a range of metrics have been developed and applied to target and monitor the achievement of some form of jobs–housing balance. There are essentially three related measures used for assessing the performance of a region with regard to the balance between working residents and jobs (Yigitcanlar et al., 2007; Biermann & Martinus, 2013). First, employment self-sufficiency (ESS) being the proportion of local jobs filled by local residents and indicating inward commuting flows, with higher rates equating to less work travel into the local area from other regions. Second, employment self-containment (ESC) being the proportion of residents working locally with higher rates pointing to lower levels of outward commuting flow. Finally, jobs–housing balance (JHB) being the ratio of local jobs to resident workers with no consideration of commuting flows, indicates the 'potential' balance of local employment and locally working residents (Biermann & Martinus, 2013; Cervero, 1996; Cervero, 2001; Sams & Beed, 1984; Yigitcanlar et al., 2007).

All five of Perth's metropolitan planning strategies since 1955 have advocated a balanced development approach in the number of jobs to working residents, to reduce the impact of commuting (Curtis and Olaru, 2007; Western Australian Planning

Commission (WAPC), 2010). The 1955 *Stephenson Hepburn Plan* promoted a compact metropolitan region through self-contained communities of residence adjacent to employment (Alexander, 2003). The 1970 *Corridor Plan* proposed four corridors surrounded by urban residential wedges, with sub-regional centres providing local employment to counter-balance rising congestion in the Perth CBD (Curtis & Olaru, 2007). The 1990 *Metroplan* widened these corridors to facilitate greater outward growth, with the 2004 *Network City Plan* aiming to accommodate a predicted two-fold population increase through the planning of a more compact, less car-dependent city, with concentrations of employment and higher density residential development in transit-oriented activity centres (Curtis & Olaru, 2007). In *Directions 2031* (WAPC, 2010), the preferred 'connected city' future growth scenario targets 'improv[ing] the relationship of where people live and where they work…deliver[ing] improved levels of employment self-sufficiency across the outer-sub-regional areas…[with an] equitable distribution of jobs…' (p. 30). Its clear objective is 'to reduce commuting time and cost, and the associated impact on transport systems and the environment' (WAPC, 2010, p. 30). A hierarchy of activity centres differentiated by role and function are used to increase the diversity and mix of land-uses, with higher-order centres aspiring to 'attract higher-order jobs such as business-to-business services, as distinct from population-driven jobs' (p. 49), to 'other centres in the upper levels of the hierarchy….[to] encourage higher levels of [employment] self-sufficiency outside the capital' (p. 49). The objective to reduce work travel through better integration of land-use and transport planning is also evident in the latest metropolitan land-use plan, the draft *Perth and Peel@3.5million* (WAPC, 2015) with explicit aims to:

> '… enhance employment self-sufficiency… bring[ing] work opportunities closer to where people live, reducing the need for long and costly commutes and increasing the economic sustainability of individual sub-regions' (p. 38)

> '…increase the number of people who live and work within sub-regions' (p. 23)

Since the 1990 Metroplan, Perth's metropolitan plans have used employment self-sufficiency targets of around 60 per cent as a mechanism by which to balance outer sub-regional metropolitan jobs and housing development and growth. This includes the latest *Perth and Peel@3.5million* which sets targets for each of the five metropolitan sub-regions for a series of horizon years to accommodate the 2050 predicted 3.5 million population (WAPC, 2015, p. 37). Defined as 'measure[ing] the quantity of jobs in a given area as a proportion of that area's resident labour force' (p. 38), these targets are actually a simple JHB measure with self-sufficiency per se based on assumptions that *all* local workers will fill local jobs irrespective of commuting flows. Figure 1 and Table 1 demonstrate the differences between the three measures between Perth metropolitan sub-regions. Perth Central has a substantially higher JHB (148 per cent), meaning that there is an excess of job opportunities in relation to the local resident labour force). Given the substantially lower number of jobs in sub-regions other than Perth Central, there are potentially less employment opportunities for residents and lower JHB ratio. The highest JHB outside the central sub-region are found in Peel (86 per cent), North East (74 per cent) and South West (72 per cent).

However, in reality, only 59 per cent of Perth Central jobs are filled by locals (ESS) with the remaining 41 per cent by commuters from other regions. The ESS of North West (80 per cent), South East (67 per cent) and Peel (84 per cent) sub-regions are all higher than their respective JHB ratios, signifying the greater number of resident workers which fill local jobs in these areas. The disparity between the ESS ratio of North East (55 per cent) and South West (66 per cent) to their respective JHB ratios underlines the propensity for the JHB ratio to underestimate the number of actual jobs filled by local workers in outer metropolitan largely residential areas. Furthermore, in all outer sub-regions, except for

Peel, a low ESC indicates most resident workers do not work locally. For example, 88 per cent of North West workers travel to other regions for work. Using the JHB ratio in these areas tends to overestimate the proportion of local residents actually working locally (by 10 per cent in North West, 33 per cent in North East, 15 per cent in South East, 25 per cent in South West and 14 per

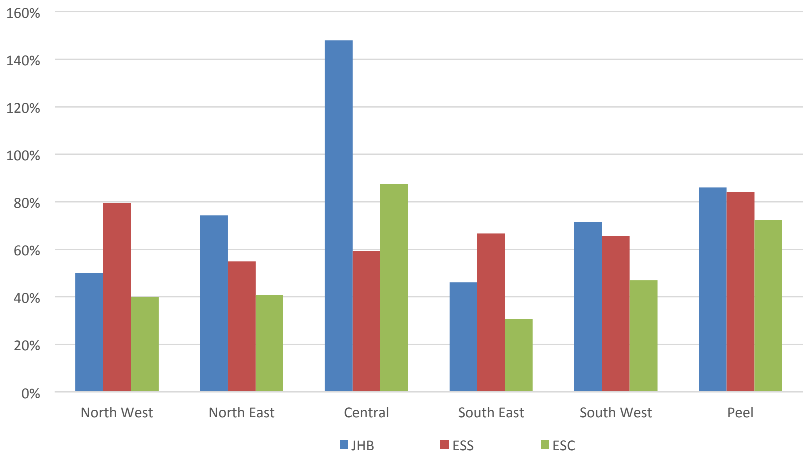

Figure 1: Perth sub-region comparison of alternative measures to assess local job and worker balance (ABS, 2011).

		Destination Sub-region (Work)										
		North West	**North East**	**Central**	**South East**	**South West**	**Peel**	**Total**	**% of Workers**	**JHB**	**ESS**	**ESC**
Origin Sub-region (Home)	**North West**	41,909	7,374	54,604	458	862	4	105,211	**18%**	**50%**	**80%**	**40%**
	North East	2,788	28,969	36,766	1,870	791	16	71,200	**12%**	**74%**	**55%**	**41%**
	Central	7,449	12,036	230,748	4,747	8,530	91	263,601	**45%**	**148%**	**59%**	**88%**
	South East	270	3,323	34,517	18,873	4,259	213	61,455	**10%**	**46%**	**67%**	**31%**
	South West	253	1,054	31,098	2,131	32,511	2,197	69,244	**12%**	**72%**	**66%**	**47%**
	Peel	37	80	2,139	239	2,614	13,356	18,465	**3%**	**86%**	**84%**	**72%**
	Total	52,706	52,836	389,872	28,318	49,567	15,877	589,176	**100%**			
	% of Jobs	**9%**	**9%**	**66%**	**5%**	**8%**	**3%**	**100%**				

Table 1: Perth sub-region comparison of alternative measures to assess local job and worker balance (ABS 2011 Journey-to-work data).

cent in Peel). ESC then is a better measure to target and track progress on how well increases in local employment opportunities have reduced out-commuter flows in sub-regions with the objective to minimise out-bound commuting.

Further to implications relating to how self-sufficiency is calculated, using aggregated employment totals in the formula also masks variations in commuting patterns of different types of employment. An initial disaggregated analysis of commuting and jobs in the Perth North West sub-region found that occupations associated most with intra-sub-regional travel are labourers, sales workers and community and personal service workers (Biermann & Martinus, 2013). Occupations most related to outward flows are professionals, clerical and administrative workers, managers and technicians and trades workers. Industries of employment most strongly related to outward commuting of North West sub-region residents are mining; electricity, gas, water and waste services; financial and insurance services; information, media and telecommunications; professional, scientific and technical services; public administration and safety; and wholesale trade. Agriculture, forestry and fishing, education and training, accommodation and food services and retail trade are the industries most linked to internal travel within the North West sub-region (Biermann & Martinus, 2013).

Assessment and Opportunities for Improvement

Salience: Does the object adequately respond to the policy questions, purpose or needs?

In as far as responsiveness to stated policy imperatives of balanced growth, improving the relationship of where people live and where they work, the levels of employment self-sufficiency across the outer-sub-regional areas and creating a more equitable distribution of jobs (WAPC, 2010), the object could be considered salient. At face value, employment self-sufficiency targets as defined, measured and applied in the Perth metropolitan planning context, are internally consistent with the stated planning ambition of increasing the number of people who both live and work within sub-regions. It provides planners with a means to target, monitor and communicate aspirations of co-location.

This object fails the salience test, however, when it comes to the question of adequacy. The measure used is in effect that of JHB, calculated simply as the ratio of sub-regional resident labour force to number of local jobs. This measure is inadequate in so far as it does not explicitly account for commuting between sub-regions making the object incapable of effectively and directly contributing to the achievement of the stated policy objective of reducing commuting (Biermann & Martinus, 2013).

While the JHB measure could still be considered useful for land-use planners in promoting sub-regional employment growth, it is less useful to transport planners. As noted above, in comparison to measures which include commuting, the JHB measure underestimates actual intra-regional travel and therefore does not answer questions of relevance to the purpose and needs of transport policy makers. By not accounting for commuting, JHB assumptions could result in under-investment in strategic transport infrastructure (Biermann & Martinus, 2013). ESC has been found to be the more appropriate measure to use in the case of outer metropolitan regions incorporating out-commuting (Biermann & Martinus, 2013).

Credibility: Is there a scientific robustness in object outputs?

Even if the right measure, explicitly incorporating commuting, was to be used, the object is still not scientifically robust as it remains in its most simple form, originally developed in the 1970s and 1980s. It is argued that the credibility of the object is in question as it does not incorporate recent scientific advances in the field. Measures such as self-sufficiency have been criticised as being an over-simplification of what is in reality an extremely complex issue, for the purpose of delivering 'achievable' outcomes or performance indicators to planning agencies (Forster, 2006). In particular, a more nuanced and disaggregated view of the complex trends and patterns of commuting, firms, housing and employment is called for (Bill, Mitchell & Watts 2007; O'Conner & Healy, 2004). Bill et al. (2007) emphasise the importance of a more disaggregated consideration of self-containment ratios for different occupations, given that self-containment rates are higher for some low-skilled occupations relative to those in advanced business and professional services, as well as knowledge-intensive industries.

Although employment complexities are acknowledged in recent Perth metropolitan land-use plans and are integral to the concept of the activity centre hierarchy, there is no direct or transparent translation of these strategic ambitions into sub-regional employment self-sufficiency targets (Biermann & Martinus, 2013). It is argued that the credibility of ESS and ESC as planning targets would be enhanced by accounting for variations in commuting dynamics of different industries and occupations (Martinus & Biermann, 2016).

Legitimacy: Has the process been respectful of and unbiased in divergent stakeholder views? Is there transparent access to the information production process?

The legitimacy of Perth sub-regional self-sufficiency planning targets was assessed with reference to the process evident in a recent research project to examine strategic directions for public mass rapid transit to serve the Perth metropolitan areas when the population reaches 3.5 million (Planning and Transport Research Centre (PATREC), 2016). Demographic and employment projections at a detailed scale, aggregated to sub-regions for the purpose of calculating self-sufficiency targets, were generated by land-use planners, consistent with the chosen 'connected city' growth pattern (WAPC, 2015). Transport planners were supplied with these employment and population projections as input for their travel demand estimation as the basis for designing a transport system to accommodate that demand. During the process of assessing the implications of these projections on travel demand, there were questions raised about the wisdom and achievability of the present urban planning growth path, especially of its targets for employment and residential intensification particularly in outer sub-regions (PATREC, 2016), given the poor record of success of previous self-sufficiency targeting in Perth as indicated earlier in this chapter. International literature has indeed shown that despite good intentions, there have been more failures than successes in increasing self-sufficiency rates in practice (Cervero, 1998; Hui & Lam, 2005; Yigitcanlar et al., 2007) and that policy initiatives aimed at self-containment/self-sufficiency on their own, appear to offer little potential for significantly improving commuting or employment outcomes (Parolin, 2005; Curtis & Olaru, 2007, 2010; Li, Corcoran & Burke, 2012).

Despite these express views of transport planning stakeholders, the brief to transport planners remained that of advising on infrastructure requirements for the given policy and related distributions of population and employment, without recourse to explore other alternatives as part of the current process. The implications of desired land-use policy outcomes not eventuating, especially in relation to higher self-sufficiency rates in outer sub-regions, is that transport infrastructure, planned on the assumption that fewer inter-regional trips would be made, particularly to the central area, could be insufficient to meet real demand and would need re-planning (PATREC, 2016). The conclusion is that the process was biased in favour of land-use planning views, less respectful of the views of transport stakeholders. This assessment has not considered other stakeholders in the process such as local councils responsible for implementation. With regard to transparency of information to those outside the formal institutions responsible for planning, all that is publicly available on self-sufficiency rates is current rates and targets for interim years and the design year of 2050, published in a summary table, with no back-up and disaggregated numbers provided (WAPC, 2015, p. 37). Neither is there any explicit information about how self-sufficiency rates were derived provided in the plans made available for public comment, making it very difficult for stakeholders outside the formal process to engage meaningfully with the material presented. The object is thus not considered legitimate in as far as there is transparent access to the information production process.

BOUNDARY OBJECT 2: LAND USE–TRANSPORT MODELS

Object Description

Traditional land use–transport models forming the core of so-called large-scale system models have been used since the 1960s in metropolitan planning to forecast potential urban system impacts before committing to policy interventions and infrastructure investment. Impact assessment supported by land use-transport modelling is often a requirement for infrastructure funding applications across all levels of government. Predicting these impacts is difficult due to the complex interrelationships and speed of change differences between urban system variables. The further into the future the predictions, the more difficult the task and uncertain the results. Despite this, transport models are often linked with associated land-use models to predict and evaluate urban impacts by simulating human decision-making and its consequences. Land-use models are mathematical representations of functions, dynamic processes and interactions which generate (mostly urban) spatial structure in terms of land-use; to analyse and forecast the development of urban land-use systems (Batty, 2009; Waddell & Ulfarsson, 2004; Wegener, 1994). Transport models simulate travel on transport networks in response to land-use patterns, travel behaviour and network capacity in order to analyse and forecast development of the urban transport system. Land-use and transport models are interdependent requiring inputs and outputs from the other. In practice, in only a few cases some models are truly integrated, but in most cases land-use and transport models are loosely coupled.

Transport modelling, together with its land-use inputs, forms an important part of transport planning and operations in Perth. There are essentially two strategic transport models applied, both based on the traditional four-step transport modelling approach but supporting different functions (Biermann et al., 2015b). The Strategic Transport Evaluation Model (STEM) is used for broadbrush assessment of the impacts of land-use scenarios and transport policy options on Perth's multimodal metropolitan transport system. The outputs of STEM are flows of vehicles and travellers per mode 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. The Regional Operations Model (ROM24), hosted at Main Roads WA, is 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.

In Australian cities, in practice, land-use inputs to infrastructure planning are mostly derived through some form of population and employment trend forecasting, not strictly regarded as land-use modelling as it does not attempt to simulate an urban system (Biermann et al., 2015b). There are a limited number of land-use modelling applications in Australia at the local government or city scale reported in the academic literature (Brits, 2013; Brits, Burke & Li, 2014; Chhetri et al., 2007; Pettit, 2005; Pettit et al., 2008; Pettit et al., 2015; Stimson, Bell, Corcoran & Pullar, 2012; Wilson, 2011). In Perth, land-use inputs to both transport models are from the Metropolitan Land-use Forecasting System (MLUFS; Department of Planning). MLUFS 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. Smaller areas are Census Collection Districts (CCD) but the MLUFS outputs can be aggregated to traffic and other zones (Government of Western Australia, 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 dwellings, 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, 2013).

Assessment and Opportunities for Improvement

In order to harness recent modelling advances to address the unique contextual and growing challenges of transport modelling and to improve modelling operational efficiency, a review of transport modelling in Perth was commissioned (Government of Western Australia, 2013). As part of the review process, stakeholder engagement to determine modelling requirements and a review of international, and in particular Australasian developments, in strategic transport modelling practice were undertaken with a view to providing design options for a new and more responsive model system. The following object evaluation draws substantially on the assessment of modelling requirement and the international best practice review undertaken as part of that review of transport modelling in Perth (Biermann et al., 2015a; Government of Western Australia, 2013; Taplin, Taylor, Biermann & Olaru, 2014). The object is assessed from the perspective of opportunities for enhancement rather than dwelling on deficiencies of the current object.

Salience: Does the object adequately respond to the policy questions, purpose or needs?

The ability of urban models to be flexible in responding to shifts to a more complex, nuanced and demand-management policy environment has been recognised as an important challenge in model development worldwide (Waddell & Ulfarsson, 2004). Policy objectives have generally 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. The ability of models to test and evaluate demand management policies and their interactions including travel demand management policies, such as congestion pricing, and land-use policies, such as urban growth boundaries, is becoming more important. In addition, greater complexity must be addressed in the form of multi-modal transport systems including non-motorised and transit modes (Waddell & Ulfarsson, 2004). Unsurprisingly, Perth strategic land use–transport modelling, while generally salient in many respects, was considered by stakeholders to be inadequately responsive to a similarly changing policy environment, consistent with worldwide trends.

As part of the Perth transport modelling review process, a consultative process to assess the current and anticipated future transport modelling needs of government stakeholders was undertaken to determine current use and efficacy of modelling outputs, anticipated future modelling needs and suggested areas for improvement (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 were held. The results of this engagement process have been used to assess the policy responsiveness and relevance of the Perth land use–transport models.

The engagement process indicated a strong tradition of land use–informed transport modelling in Perth in support of policy and infrastructure investment decisions, with a high degree of confidence placed in modelling results. A number of improvements in the form of policy-supportive, modelling needs were identified:

- passenger demands, by time period during the day;
- trips by mode – the basic mode choices giving shares of trips between modes;
- travel times and link speeds;
- trip forecasts including metropolitan region flows, flows resulting from particular land-use developments and/or particular highway or railway extensions;
- road traffic flows by link or at screen lines and vehicle queue lengths;
- public transport patronage – system wide and at particular locations;
- impacts of specific policies including 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, – through, e.g. ramp metering;
- cost-benefit ratios; and,
- measures of accessibility.

While both the current strategic models were generally considered by stakeholders to be salient and fit-for-purpose, adequately meeting the modelling requirements listed above, three related primary areas for improvement were identified in relation to enhancing responsiveness of the models to the current policy environment:

- multimodal capability with the ability to calculate mode shifts;

- predicting behavioural responses to policies and demand management measures; and
- interactive land-use and transport modelling (Taplin et al., 2014).

Credibility: Is there a scientific robustness in object outputs?
The reliability of Perth land use–transport models in terms of scientific rigour employed to produce outputs was assessed with reference to the review of international best practice modelling advances, conducted as part of the modelling review (Taplin et al., 2014). The review identified a range of technical innovations being applied in practice across the world which could be applied to improve the scientific credibility of land use–transport modelling in Perth, many of which are related to enabling better policy responsiveness.

Enhancing credibility of strategic transport modelling in Perth would be achieved through:

- replacing the trip-based modelling approach by a tour-based schema, while remaining in the overall four-step modelling system;
- introducing a time of day modelling capability, certainly for production of 'n-hour' Origin-Destination (O-D) matrices to cover the hours of the day, possibly extending into 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;
- supporting a freight modelling capability which provides separate vehicle O-D matrices;
- 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; and

- working in conjunction with a mesoscopic traffic network model for the entire study region 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 (Taplin et al., 2014).

Land-use inputs and feedback in relation to quality, timeliness and consistency, particularly in relation to land-use forecasting, was considered by Perth modelling stakeholders as a significant risk to credible modelling outputs (Government of Western Australia, 2013). According to Biermann et al. (2015a), enhanced credibility of land-use modelling would be achieved for Perth by adopting: a behavioural theory-based approach with a strong grounding in land market economic theory (Hunt, Kriger & Miller 2005; Waddell, 2011); a higher degree of spatial resolution to minimise model bias, maximise statistical efficiency and improve policy sensitivity and model transferability (Miller, 2003); reducing uncertainty in long-term forecasting incorporating path dependency using dynamic equilibrium microsimulation (Miller, 2003; Waddell, 2010); and enhanced empirical validity through rigorous calibration and validation, with predictions corresponding reasonably well to observed reality (Waddell, 2010).

Land use–transport integration is important so that interactions between transport network performance and land development/location choice behaviour are captured within the model system (Hunt et al., 2005). In line with international best practice advances in integrated modelling, enhanced credibility in Perth would be achieved through having a system of ‘connected’ land-use and transport models with well-established feedback mechanisms to influence land-use choices through accessibility/composite utility values (Hunt et al., 2005; Ortúzar & Willumsen, 2011). Connected models are where the O-D matrix is generated in the transport model and feedback to the land-use model is via composite utility values from logit models in the transport destination choice model.

The benefit of connected models is that any (new) land-use model can theoretically be 'bolted' onto an existing transport model, whether the transport model is a traditional four-step (Ortúzar & Willumsen, 2011) or even an agent-based model. While the fully integrated approach (where the O-D matrix is generated on the land-use side of the model, using spatial economic flows generated from composite utilities in the mode choice model) is theoretically 'elegant' and ensures internal consistency, the connected approach is more flexible, accounting explicitly for the fact that accessibility is only one of a number of factors which influences residential and firm location (Hunt et al., 2005 p. 343).

Legitimacy: Has the process been respectful of and unbiased in divergent stakeholder views? Is there transparent access to the information production process?

Transparency, ease of use and communication in the process of using and interacting with models are increasingly being considered as critical to enhance legitimacy. The urban modelling fraternity has responded through the development of more simple, open and interactive collaborative planning support systems with enhanced mapping and visualisation capabilities (Glackin, 2012; Klosterman, 1999; Kwartler & Bernard, 2001; Stock et al., 2008). Attempts to improve behavioural responsiveness of transport and land-use models have increased their complexity, making them more difficult for users to interact with while simpler models inadequately inform city development as they do not incorporate behaviour change (Batty, 2015, p. 192).

While the need for making modelling less of a 'black box', more open and participatory, has been recognised as a growing pressure worldwide (Waddell & Ulfarsson, 2004), participation in the testing and evaluation of alternative policy strategies did not arise as a major requirement for modelling in Perth (Taplin et al., 2014). This is most likely related to the strong role of the state government in planning, with local government having little decision-making power, as well as the associated planning approach of consultation rather than engagement with stakeholders and communities (Biermann et al., 2015a). Nevertheless, in line with best practice advances in modelling, identified as part of the Perth modelling review, it was recommended that to enhance legitimacy, the integrated land use-transport modelling suite in Perth should be developed within a GIS environment for data handling capabilities, enhanced visualisation and user-interfacing and spatial aggregation and disaggregation capabilities (Taplin et al., 2014). This recommendation addresses the 'dilemma' by retaining behavioural complexity, i.e. scientific credibility but improving legitimacy through user interfacing and visualisation.

CONCLUSION

In this chapter, the performance of two boundary objects, ESS targets and land use–transport modelling, operating between the land-use and transport planning domains, were assessed according to the well-established criteria of salience, credibility and legitimacy. Explored within their application context in Perth and Peel Metropolitan Region, opportunities for improvement were identified as a means to enhance land-use and transport planning integration outcomes.

Although the policy intention is to reduce commuting through co-location of jobs and housing in Perth metropolitan plans, the measure used to calculate ESS targets, does not explicitly account for commuting nor for variations in the employment commuting dynamics of different industries and occupations. The data source and calculation method for the targets are not transparent and, therefore, difficult for stakeholder communities to engage with and influence, for example transport planners who use land-use projections as vital inputs into transport modelling. This leads to the conclusion that Perth and Peel planning ESS targets do not perform highly in terms of salience, credibility or legitimacy, providing a very weak bridge for those working at the land use–transport planning boundary. Such boundary objects need to be reviewed in the context of recent scientific findings regarding the derivation and monitoring of such targets, using an open stakeholder participatory process involving those in transport and local implementation planning.

In contrast, there is a strong tradition of land use–transport modelling in Perth and a high degree of confidence placed in these results when planning and funding key infrastructure projects. As a result of this and a more open on-going review and improvement process, land use–transport modelling is found to be highly salient, credible and legitimate as a boundary object linking land-use-transport domains. The modelling review process pointed to the importance placed on collaborative state and local implementation transport-land-use stakeholder engagement by object custodians. This included the need to incorporate scientific advances as a means to improve response mechanisms appropriate for a highly complex policy environment involving multi-modal, demand-side and land-use strategies as alternatives to meet growing transport needs. However, though land use–transport modelling is largely considered by stakeholders as fit-for-purpose, land-use inputs and transport modelling feedbacks to land-use planning are not deemed adequate. As such, its role as a boundary object can be enhanced by placing greater emphasis on its land-use modelling component and its interaction with the transport model to improve its salience, credibility and legitimacy.

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