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ENHANCING POLICY DECISIONS USING INTEGRATED MODELS

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ABSTRACT

Policymakers are increasingly asking questions about the wider impacts of transport policy, expanding consideration beyond the transport system to include land use and the larger economic system. Integrated transport land use economic models support this trend, recasting travel and transport as by-products of economic activities and representing the connections between transport policy and economic impacts in a spatial context. As such, they help in addressing complex policy questions that models with a more limited transportation-only scope of representation – from the oldest traditional 4-step models to the latest tour-based microsimulations – cannot address, at least not well. This paper highlights some of the support provided by integrated models, based on applications of the Oregon TRANUS and Sacramento MEPLAN and PECAS integrated models. It outlines how these integrated models have been found to add value, helping land use forecasting, cumulative and indirect impact analyses, evaluation of economic impacts and communications across disciplines.

Keywords: Land Use Transport Economic System Modelling; Spatial Economic Modelling; TRANUS; MEPLAN; PECAS; Oregon, USA; Sacramento, USA

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1. INTRODUCTION

Initially transportation modelling was almost entirely just about travel. Traditional four-step transportation demand models represented roadway traffic loadings in order to make informed transportation investment decisions. But evolving government policies and regulations arising with increased expectations brought new challenges to travel modelling professionals. Models began to need to do a better job of representing the feedback effects of travel costs (i.e. induced demand) and policy-makers started looking beyond transportation supply and demand – taking into account land use responses to changes in travel conditions and the travel behaviour responses to various land use assumptions and policies. The most recent new integrated models go even further, recasting travel and transport as a by-product of economic activities separated in space; allowing an understanding of how transport investment affects the economy, particularly with regard to the movement of freight.

This paper explores some of the advantages of the integrated model framework, based on actual applications. It begins by summarizing the technical differences between transportation demand models and integrated models and the evolutionary path that has been followed in many regions. It then identifies how some common problems faced by modellers are enhanced through the use of integrated modelling; and also outlines some less obvious, but equally valuable, benefits arising with the use of integrated models.

Integrated models address complex policy questions that earlier transportation models could not address, or could not address well. Examples of questions that can now be asked include: What transportation policies/investment will promote compact land development? How do different transportation/land use policies affect the jobs-housing balance and hence the commuting patterns in a region? What are the economic impacts if region-wide freight movement is restricted by inadequate infrastructure? How are different regions and industries affected by different land use and transport policies? How do gas prices and zoning laws affect community growth, traffic patterns and the regional economy?

Several real-world examples are discussed, including recent applications of the Oregon1 statewide integrated model (Weidner *et al*, 2004) and the Sacramento MEPLAN model (Johnston *et al*, 2005; SACOG, 2005). These applications serve to highlight how integrated models have been found able to address policy and transportation investment questions asked by regional decision-makers. The paper highlights the value-added by integrated models to inform the consideration of these questions and to provide measures to help policy-makers make difficult trade-off decisions. The paper also offers some more general conclusions.

2. DEFINITIONS AND DIFFERENCES

People travel and goods and services are transported because of interdependencies. The arrangement of activities in space is a result of the conflict between the need for space and the desire to reduce this travel: if there were no need for space, all activities would locate in exactly the same location and there would be no travel; if there were no desire to reduce travel then activities would spread out in a way that simply maximizes the allocation of land. An integrated model of land use and transport represents this conflict explicitly, and thus considers the allocation between space use and travel that motivates both location and travel.

Figure 1 is a schematic of the full spatial economic system and the components of the system considered in land use and transport modelling. The transport component includes elements of both demand and supply along with transport flows and the 'price-like' travel time signals representing the interactions between these elements. The land use component includes much of the rest of the full system. In this sense the term 'land use' is highly inclusive, stretching to incorporate a spatial representation of the economy. This includes the production and consumption activities in the economy as well as the size of the economy itself, well beyond just the areas of floor space and/or land in different uses as the locations of these production and consumption activities. The use of the term 'land use' in this sense is somewhat of an anachronism: it initially referred to the data on land areas by use (square feet of residential, commercial, industrial, etc) required by older 4-step transportation demand models but it has stuck around as a common reference to the entire economic system giving rise to this data.

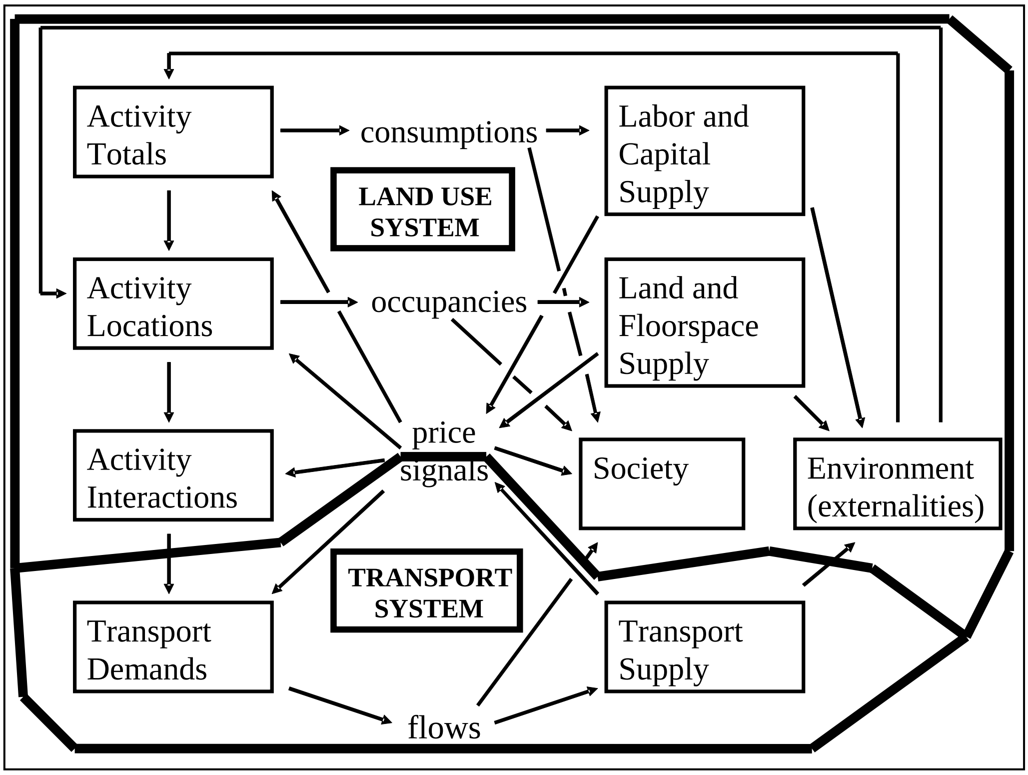

Figure 1: Elements and interactions in the full spatial economic system and the transport and land use components of this system.

Transportation systems models – whether they are basic 4-step models or state-of-the-art tour-based or activity-based microsimulation models – seek to represent the behaviour of the transportation component, with inputs to this component determined exogenously. The result is a 'line process' where the transportation system is seen to react to the land use system, in particular the distributions of activities, which are classically expressed as population and employment quantities in geographic zones. In general, there is no representation of transport conditions 'feeding back' to impact the land use system or the spatial distributions of activities in this system. This 'line process' engenders an approach to spatial planning (regarding both the transportation and the land use components) where the transportation system is designed to serve the forecast land use system without any corresponding consideration of how the land use system is constrained or otherwise influenced or impacted by the transportation system – thereby severely limiting the scope of consideration of both the impacts of policies and the types of potential policies.

The essential defining attribute of a land use transport model is some form of explicit representation of the 'feedback' where transport conditions impact the land use system and the spatial distributions of activities within it. This explicit representation can take several forms, as follows:

- generalized costs or (dis)utilities of transporting goods, services and labour between activities at specific locations: These generalized costs are numerical measures of the comparative difficulty of travelling between locations, incorporating the times and money costs for the available modes. Land use transport interaction models that include this form of representation use outputs from the transportation model at the level of zone-to-zone interchanges – usually the composite utility (or 'log-sum') determined at the 'top' of the mode choice sub-model of the transportation model. Mode-specific (usually auto) travel times between zones are sometimes used as a simplified form of this measure, but this is becoming less common. Land use transport models using this form are sometimes labelled 'integrated' models (de la Barra, 1989);
- accessibilities to activities at specific locations, incorporating generalized costs of transportation and the spatial distributions of these activities: These accessibilities are numerical measures of the overall ability to access some or all types of destinations from a given location. Land use transport interaction models that include this form of representation use outputs from the transportation model at the level of zones – often the composite utility values determined at the 'top' of the destination choice model, which are equivalent to a specific form of accessibility measure (Wilson, 1974). Land use transport models using this form are sometimes labelled 'connected' models;
- transport money costs generally: The money costs associated with travel and goods transport are incorporated into representations of the total money cost of living or operating at specific locations and this resulting total cost is one of the factors influencing spatial distributions of population and employment. This separate treatment of money amounts and the implications of budgets and expenditures is different from the use of the generalized cost and related composite utility associated with travel behaviour and the perception of the journeys themselves; and
- environmental impacts of transportation, acting differentially across space: This includes representation of the effect of differences in traffic noise or air quality on the desirability of residential locations and hence on population distributions.

Different land use transport modelling frameworks use different combinations of these explicit representations. MEPLAN (Hunt and Simmonds, 1993) and TRANUS (de la Barra *et al*, 1984; Modelistica, 1995) are 'integrated' and also include use of transport model costs explicitly. UrbanSim (Waddell, 2002), MUSSA (Martinez, 1996) and DELTA (Simmonds, 1996) are 'connected'. PECAS (Hunt and Abraham, 2005) is both 'integrated' and 'connected'. The Oregon1 model (Costinett *et al*, 1999) uses TRANUS, whereas the Oregon2 Transitional Model uses a variant of PECAS.

3. INTEGRATED MODELS HELP WITH COMMON PROBLEMS

3.1. Land Use Forecasting

Transportation models are essential tools for transportation planning. The results from these models are critically dependent on land use (i.e. socioeconomic) inputs. Model calibration problems can often be traced to land use input errors such as the employment inventory. Similarly, forecasts from transportation models can be no better than the land use forecasts on which they are based. Just as faulty land use inputs can cause calibration errors, land use forecasts that are not based on adequate behavioural models and/or do not take account of transportation feedback can result in counterintuitive or unreasonable transportation modelling results (Condor and Lawton, 2002).

Land use forecasts are perhaps the most difficult and time consuming inputs to generate. A large number of tools and methods have been developed to assist the process including relying on comprehensive plans, using expert knowledge, applying allocation rules or decision rules, developing statistical models, using geographic information systems, applying regional economic models, and finally employing formal land use models (PBQD, 1999). The method that is probably the most common involves drawing on a combination of (a) expert opinion or consensus forecasting, often by political jurisdictions, to distribute land uses at a fairly large geographic scale together with (b) a set of explicit rules for allocating land use quantities among the transportation model zones. This sort of combination of consensus forecasting and allocation rules does not tend to produce very reliable results, even though the participants may feel good about them. These results can be skewed by wishful thinking, politics, limitations of trending analysis, and the lack of consideration of how transportation and land use interact. The 'litmus test' in this regard is whether it is likely that a different group of experts on a different day would produce the same or different values. Using the Delphi method (Seskin *et al,* 2002) can reduce the effects of politics and group-think, but fundamentally, the quality of the results depends on the degree to which such forecasts are based on data that comprehensively embody local land use-transport interactions (Deakin *et al*, 1993) and use explicitly stated rules and/or equations about the assumptions and relationships being employed.

The Sacramento regional transportation planning agency (SACOG) used a MEPLAN model to forecast future growth patterns under scenarios with relaxed zoning regulations (SACOG, 2005). These scenarios showed the need for policies to encourage more concentrated and targeted growth. A multi-jurisdiction land use planning process, called the Blueprint project, was then used to identify desired, or 'aspirational', land uses that would provide for the economic growth that is forecasted to occur, without overloading the transportation system. The combination of the forecasts from the land use model and the studies from the Blueprint project allowed the transportation planning agency to show the various constituent groups in the region that future transportation problems could be managed, at least in part, through land use policies. In the near future the PECAS model will be used to determine how best to bring about 'aspirational' land uses; in particular what transportation policies can be combined with zoning restrictions to make the vision from the Blueprint project occur in reality.

3.2. Analysis of Cumulative and Indirect Impacts

Properly accounting for transportation and land use interactions is also important in the evaluation of the cumulative and indirect impacts of transportation projects. In the United States, the Clean Air Act, NEPA and ISTEA requirements for major investment analysis stipulate that land use interactions are to be evaluated as part of transportation planning analyses (Garrett and Wachs, 1996). It is no longer sufficient in such situations to assume that land use and travel patterns remain fixed when evaluating the impacts of major projects. Instead it is necessary to consider that projects may induce additional travel. Standard 4-step models can address some of these induced traffic effects such as from redistribution or rerouting. More advanced travel models can address trip generation and timing effects. But only connected or integrated models can address the land use changes (Hunt, 2002).

Integrated models add important capabilities to the analysis of induced travel effects. Much of the research that has been done on induced travel has little practical applicability to the assessment of individual projects or plans because it is seriously limited by its aggregate nature, problematical data, and severe difficulties in establishing causality (Gregor, 2004). In addition, the induced travel effects of a transportation project can be expected to vary significantly depending on the project context: is it a new road or widening of an existing road, is it a radial or circumferential road, how congested is the road and the road system, how is land zoned in the area and how strong are the land use laws? Integrated models address the particular environment in which transportation projects are planned and the interactions between the economic, transportation and land use elements of that environment. Moreover, integrated land use-transport models provide a wealth of information that can help planners to understand who is affected and by how much and the causal connections (Hunt, 2002). This gives decision-makers much more information to help them decide what should be done and how adverse impacts may be mitigated.

Integrated models can be used to help evaluate the indirect and cumulative effects of large-scale bypasses on cities in a region. The Oregon1 integrated statewide model was used to evaluate the regional effects of several small and medium-sized cities expected under a proposed highway bypass outside of Portland, OR. The modelling analysis, including the type location and magnitude of land use growth and resulting commuting patterns, figured prominently in complex state land use approval deliberations as well as documentation for the project environmental impact statement (ODOT, 2002).

3.3. Evaluation of economic impacts

On the basis of a more inclusive definition of ‘land use’, many integrated models provide another advantage arising because they are based on standard economic theories and approaches – including Input-Output or Social Accounting Matrices, and the relationship between prices, supply and demand – which facilitates economic analyses of the impact of potential policies from both efficiency and equity perspectives.

Prices for goods and services, and rents for land and floorspace, are outputs from many integrated models. Many transportation effects are capitalized into land values, so including land rents allows a better representation of the beneficiaries of transport policy.

Benefit measures from transportation models alone are sometimes incorrect in effect and sign. For instance, transportation improvements can lead to more options for location, and the ability to consume more space. In this situation travel can increase as production activities and households choose to consume more distant and larger amounts of land. A transportation model operating on its own alone would either not represent the increased land consumption (and hence measure the benefits incorrectly) or would report only the increased travel without the associated effect of increased land consumption.

In the Oregon Bridge Options Study (ODOT, 2003), economic outputs from the Oregon1 model formed the ‘headlines’ used by the Oregon DOT to secure a 10-year $2.5 billion transportation finance package in the 2003 Legislature. The ability to quantify the impact on jobs and the economy (measured in state goods and service production value) arising with differing strategies for sequencing the repairing of over 600 deteriorating bridges across the state was critical in garnering support for the program. The selected strategy was evaluated in terms of its ability to keep freight moving in support of the state economy, and as a tool for shaping the spatial and 'sectoral' distributions of economic development. In particular, the model indicated that the historical resource-based industries of agriculture and logging would be the most affected, and that the impacts on rural economies, while smaller in absolute magnitude, would be larger in proportion because of the greater reliance on shipment of heavy goods. The study was also able to consider significant equity issues related to the differential impacts on specific industries and regions in the state, which led to valuable statewide discussions. This transformed the study from one dealing with a technical bridge design problem to one considering economic issues of statewide importance.

3.4. Aiding Communication

Transport policy impacts a multi-faceted system that includes the transport system, land use and the economy. With all of these areas involved, the discipline-based 'silos' that have historically been built around them separately need to be bridged in the search for a consistent set of policies. An integrated model provides the common framework and language for accomplishing such bridging. Additionally, objective quantitative information from an integrated model can be useful as a starting point for conversations among opposing stakeholders. Instead of relying on history, 'gut feelings' or the 'squeakiest wheel', a more objective and systematic basis for decisions can be built around an integrated model.

In many cases, with an integrated model, the transportation analysts and engineers, land use planners, and economists involved have to learn some new terms and concepts. For the transportation analysts and engineers, this means understanding zoning, land consumption, and gross state product terms and metrics. The benefits arising with bridging in this way can be many-fold. Conversations that identify impacts and tradeoffs across many disciplines can result in much broader support for a project or program, aiding in its political success. The range of potential solutions to problems can also be broadened by the larger dialogue, extending beyond just transport investment, services, or tolls, to zoning for or against growth, taxes and subsidies on land development and taxes and subsidies on vehicle use. Thus it is no longer just the transportation planners and engineers advocating for projects - candid trade-off discussions can result in support from a broader base of interests.

Another benefit that has been observed is the encouragement of trust and dialogue among participants in public processes – including stakeholders, decision-makers, technical and non-technical staff – which can help encourage the identification of a common vision among these participants. An integrated model can help create a climate where stakeholders focus more on policy options and less on their judgments of what will happen. The model can help those involved to establish a more complete understanding of the tradeoffs involved, and how potential policy options can be (and perhaps even need to be) reinforcing in order to achieve the wider shared vision. Many of the arguments arising among stakeholders stem from differing 'mental models', where the different stakeholders see matters differently in a situation where they are not forced to be consistent. In such situations, a given stakeholder view can have at least some merit, but the stakeholder holding the view does not have to acknowledge the shortcomings or the view or acknowledge the merits of other views. An integrated model can confirm the merits of different views – helping those involved to see the situation more fully and to appreciate what the others are seeing, possibly leading towards a solution based on a cooperative combination of views and skills.

This is precisely what happened with the Oregon1 integrated model in one of the first situations where it was applied, in a high-profile transportation and land use visioning study of the Willamette Valley in Oregon. The study considered several land use and transportation alternatives. The model showed considerable urban sprawl arising with alternatives containing substantial highway investment, which was consistent with the views of several of the stakeholder groups involved. This consistency led these groups to a greater acceptance of the model and its broader indications – which helped foster a better understanding among the stakeholders of the interrelationships between land use and transportation policies and their effects, leading to richer and more productive discussions about the issues and reduced much of the speculation about the effects of policies that otherwise tends to exacerbate disagreements among stakeholders (ODOT *et al*, 2001). The apparent end result was a greater willingness to participate in the difficult process of compromising among the differing objectives of the different groups in the development of a shared vision.

A coalition of environmental and social equity citizens groups used the MEPLAN model of Sacramento to evaluate transportation policy scenarios (Johnston *et al*, 2005). Although constrained to some extent by the limited spatial resolution of this particular model, these scenarios served to highlight the need for comprehensive planning. Despite the technical complexity of the model, its broader comprehensive nature was well suited to an outreach setting among citizens with varying levels of technical expertise. Residents were able to understand roughly how the model works, identify the important policy, and learn the tradeoffs of the policy decisions being proposed. The conclusions from these studies will be evaluated, along with other alternatives, in the SACOG's transportation plan update process using the PECAS model, which has more spatial resolution and greater behavioural fidelity.

4. CONCLUSIONS

Integrated models allow policy makers to avoid a 'line process' in transportation planning, where transportation plans are designed to serve land use forecasts, in favour of more holistic planning, where land use regulations, economic policy and transportation policy work together to influence the shape of the spatial economy and the performance of the transportation system that serves the economy. They allow this by forecasting the distribution of activities and buildings in space (the 'land use') by considering the influence of travel conditions on location decisions.

An integrated model can make land use forecasting more consistent and realistic (and even easier, at least in the long term) and can help in addressing any integration requirements. Integrated models are more theoretically correct and inclusive than transportation demand models alone, correcting a number of deficiencies associated with planning using only transport models. This inclusiveness extends into the institutional framework, bringing different disciplines, agencies, professions and interest groups together, and facilitating communication and agreement between them. Policy solutions can be broader, incorporating taxation and subsidy as well as land use regulation. Economic analysis can be more complete and consistent with standard economic theory with the use of integrated models. The benefits of transportation policy can be quantified with more detail and theoretical consistency and more appropriately attributed to specific industries, household categories and landowners.

Appropriate directions for future work in integrated modelling can be sorted into two broad categories: 1) making the models and required data more affordable, with established forecasting toolkits available for initial adoption by agencies; and 2) determining ways to add detail and further behavioural sensitivities without overwhelming the systems. Planning agencies will hopefully play important roles in both these directions – with some seeking of more affordable entry-level models that are still sophisticated enough to provide the advantages described here and others looking for ways to extend the ability to address complex policy questions.

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