Stepping Away from Trend Analyses for Regional Integrated Planning and Modelling

Pascal Perez[1*], Rohan Wickramasuriya[1], Nam Huynh[1] and Hedwig van Delden[2]

[1] *SMART Infrastructure Facility, University of Wollongong, NSW, Australia.*

[2] *Research Institute for Knowledge Systems, 6211 BV Maastricht, The Netherlands.*

ABSTRACT

Strategic regional plans formulated by authorities aim to achieve aspirational objectives such as vibrant and connected communities, accessible and affordable transport, innovative and productive economy, and protected natural environments. But planners often lack decision support tools capable of tracking complex dynamic interactions between these various components.

Many current regional planning models rely on feed-forward trend analyses. These trends are based on demographic or economic assumptions that lock-in regional growth into a unique pathway. The weaker the initial assumption is, the less plausible the evolution of other components of the regional development. In fact, useful regional planning models need to reproduce the co-evolution of land use, transport, economic and demographic dynamics.

We have developed a dynamic model that includes five interconnected modules: (1) a cellular automata-based land use module, (2) a 4-step transport model with dynamic allocation of traffic, (3) a dynamic input/output economic model, (4) a synthetic population-driven demographic model, and (5) a utility module to capture the evolution of demand for energy and water as well as production of sewage and solid waste. We use a sophisticated simulation platform called GEONAMICA to build and integrate foregoing modules for the Illawarra region in New South Wales, Australia. This paper presents the ongoing development of the model, as well as preliminary results from scenario analysis. We conclude the paper by discussing intended future work.

Keywords: Regional Planning, Integrated Modelling, Land Use, Transportation

INTRODUCTION

Strategic regional planning concerns long term projects that aim to bring about sustainable development through shrewd investment in and management of public and private resources[1]. This is often a challenging process as it requires careful balancing of competing priorities such as vibrant and connected communities, accessible and affordable transport, innovative and productive economy, and protected natural environments[2].

Although modelling offers an attractive solution to this problem, many current regional planning models rely on feed-forward trend analysis. These trends are based on demographic or economic assumptions that lock-in regional growth into a unique pathway. A weaker initial assumption can result in a less plausible evolution in other aspects of

1 United Cities and Local Governments. Policy Paper on Strategic Urban Development. (2010).

2 Geerlings, H. & Stead, D. The integration of land use planning, transport and environment in European policy and research. *Transport Policy* 10, 187-196 (2003).

the regional development. Regional planning models need to follow observed patterns to become useful. To this end, such models should incorporate land use, transport, economic and demographic factors that interact with each other and co-evolve in a simulation environment[3].

We have embarked on a project that aims to develop an integrated model encapsulating five interconnected modules: land use, transportation, econometric input/output model, synthetic population-driven demographic model and a utility module. This paper entails the first phase of the model development that features integrated land use and transportation models.

METHODOLOGY

Study area

The Illawarra, a coastal region located south of Sydney in Australia, is our study area that consists of four Local Government Areas (LGAs): Wollongong, Shellharbour, Kiama and Shoalhaven (Figure 1). These four LGAs occupy the coastal plain limited on the east by a forested escarpment, hence geographically well-demarcated as a region. According to the 2011 census[4], the population of the Illawarra region stood at 368,814 persons, 52% of which lived in Wollongong LGA only.

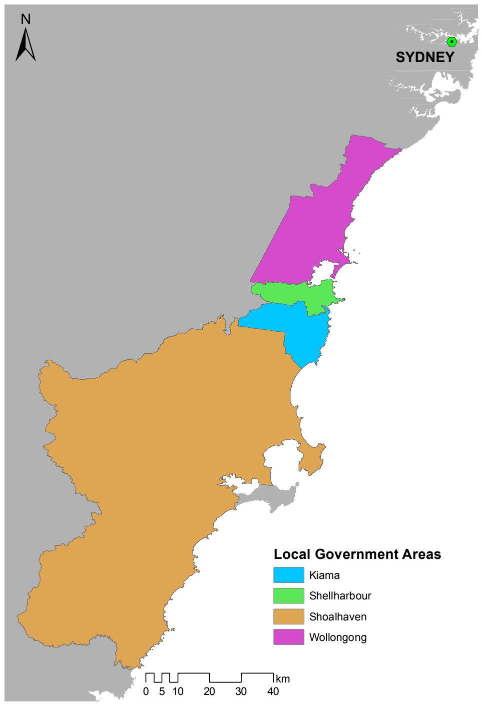

Figure 1. The Illawarra Region, New South Wales, Australia

Software framework and models

We use a sophisticated simulation platform called GEONAMICA[5] to build and integrate identified modules. The constrained Cellular Automata (CA) based land use model in Geonamica has been used in many applications around the world, both in the original form and its variants[6,7,8]. The main variable of the land use model is a land use map in raster format which is iteratively updated in yearly time steps over the course of the simulation. In the fully-integrated model, the demands for land uses are passed on by the economic and demographic models. However, in the absence of those two models in this phase of the model development, those demands are provided exogenously. The land use transitions are driven by endogenously calculated transition potential for which neighbourhood effect, physical suitability, accessibility (mainly to transport) and zoning contribute as key factors. A complete description of the land use model is available elsewhere[6,9].

Transport model is based on a classical four step approach[10], but has been made dynamic[9]. The land use model

3 van Delden, H., Seppelt, R., White, R. & Jakeman, A.J. A methodology for the design and development of integrated models for policy support. *Environmental Modelling & Software* 26, 266-279 (2011).

4 Australian Bureau of Statistics. Australian Statistical Geography Standard (ASGS). Volume 1 – Main Structure and Greater Capital City Statistical Areas (2011).

5 Hurkens, J., Hahn, B. & val Deleden, V. Using the GEONAMICA software environment for integrated dynamic spatial planning modelling. Proceedings of the International Congress on Environmental Modelling and Software 751-758, (2008).

6 Wickramasuriya, R. C., Bregt, A. K., van Delden, H. & Hagen-Zanker, A. The dynamics of shifting cultivation captured in an extended Constrained Cellular Automata land use model. *Ecological Modelling* 220, 2302-2309 (2009).

7 Stanilov, K. & Batty, M. Exploring the Historical Determinants of Urban Growth Patterns through Cellular Automata. *Transactions in GIS* 15, 253-271 (2011).

8 van Vliet, J., Hurkens, J., White, R. & van Delden, H. An activity-based cellular automaton model to simulate land-use dynamics, *Environment and Planning B-Planning & Design* 39, 198-212 (2012).

9 RIKS BV. METRONAMICA Documentation, RIKS BV Maastricht NL, (2005).

10 McNally, M.G. The Four Step Model. In: *Handbook of Transport Modelling* 35-52, (2000).

provides input to determine origins and destinations of trips, while transport model influences land use change by means of accessibility. This two-way communication provides the dynamic basis to the transport model.

SETTING UP THE INTEGRATED MODEL

Land use model requires a number of geospatial datasets. The main input, which is the land use dataset, is derived from the catchment-scale land use maps collated by the Australian Collaborative Land Use and Management Program (ACLUMP). The land use classification used in this study includes 23 classes out of which 6 are dynamic (Figure 2). The dynamic classes include urban residential, rural residential, industrial/commercial, horticulture, grazing land and forests. A slope layer is used as the only input for the physical suitability component, while three datasets (Local Environmental Plan, conservation areas and Strategic Regional Land Use Policy-SRLUP of NSW) are used as inputs for the zoning component. Road network and railway stations are used to determine accessibility. Spatial resolution used in the land use model is 100m.

The same road network serves as a major input to the transport model. Travel zones as identified by the Bureau of Transport Statistics (BTS) NSW are used as transport zones, which is the other major input to this model. We model 5 time periods of a typical weekday (midnight, morning, noon, afternoon, evening), two modes (car and public transport) and 4 purposes (work, shopping, social and home). A multi-dimensional Origin Destination (OD) matrix for 175 travel zones in the region is prepared using the Household Travel Survey data gathered by BTS.

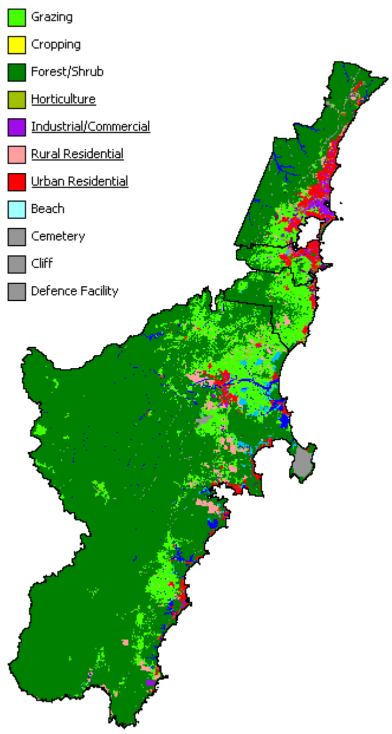

Figure 2. Land use classification

Calibration, validation and scenario exploration

The calibration period used is from 2006 to 2012. As such, land use and transport models start with initial data (2006), and dynamically update these in yearly time steps until 2012. The simulated land use map, OD matrix and road network assignment layer for 2012 are saved for comparing against the observed data for 2012. Observed land use data for 2012 is prepared using a feature extraction procedure applied on very high resolution satellite imagery. Only two land use classes (urban residential and industrial/commercial) are extracted by this method. Hence, the detailed calibration of the land use model is limited to only these two classes in this initial phase.

When the agreement between simulated outputs and observed data is not sufficient, a number of model parameters are systematically changed and the model is re-run for the same period until a reasonable match is achieved. Calibrated model parameters include neighbourhood rules (attraction and repulsion between land use classes), accessibility parameters, trip distribution during the day, cost sensitivity of trips for different purposes and transport mode aversion costs, among many others.

Once the model is sufficiently calibrated, the model is then run to the future (2012 – 2022) using the calibrated parameters. Only the baseline scenario is explored in this study to identify potential outcomes if observed patterns continue into the future.

RESULTS AND DISCUSSION

Calibration of the land use model is limited to only two land use classes namely, urban residential and industrial/commercial. Figure 3 depicts comparisons between observed and simulated land use for these two classes in 2012. The agreement between observed and simulated outputs is acceptable both visually (Figure 3) and statistically as evident by Kappa coefficients of 0.9 and 0.73 for urban residential and industrial/commercial land uses, respectively.

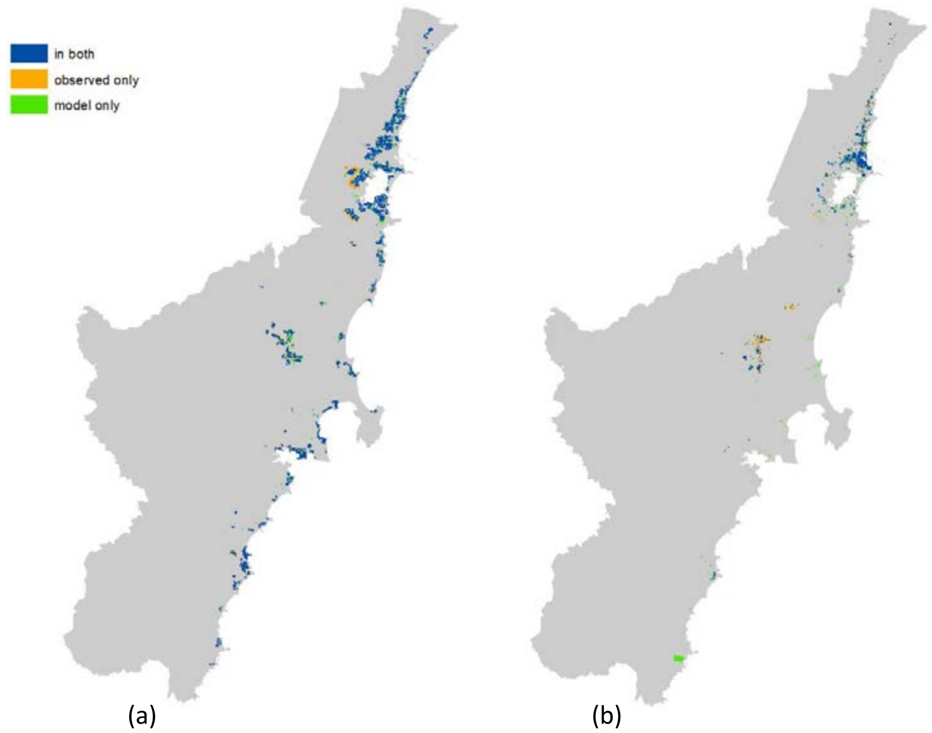

Figure 3. Comparison of observed land use and simulated land use for 2012, (a) urban residential, (b) industrial/commercial

However, a higher Kappa coefficient could also suggest that land uses are inert, as is the case usually for urban residential, industrial and commercial land uses. In such cases, a contingency table (Table 1) could be used to gain deep insights into model's performance. Values along the diagonal in Table 1 indicate areas where the model performs well. For example, our land use model is able to correctly identify 13579 urban residential cells. However, 213 industrial/commercial land use cells are incorrectly labelled by the model as urban residential.

Table 1. Contingency table for observed and simulated land use classes in 2012

Model / Observed	Urban Residential	Industrial/Commercial	Other
Urban Residential	13579	673	801
Industrial/Commercial	213	3751	1357
Other	1438	516	178160

Performance of the transport model is established mainly by comparing observed and simulated OD matrices at an LGA level (Table 2 and 3). While the transport model has predicted correct magnitude in terms of the number of trips between all LGA pairs, the absolute difference between observed and simulated values call for further calibration.

Table 2. Observed trip origin-destination matrix for transport mode 'car'

Trips	D			
O	Kiama	Shellharbour	Shoalhaven	Wollongong
Kiama	36369	11833	4059	4919
Shellharbour	10322	132140	1625	51671
Shoalhaven	3335	827	303351	5018
Wollongong	7261	52781	5108	565712

Table 3. Simulated trip origin-destination matrix for transport mode 'car'

Trips	D			
O	Kiama	Shellharbour	Shoalhaven	Wollongong
Kiama	24866	17786	7876	10307
Shellharbour	16637	94960	6701	60894
Shoalhaven	12015	4909	247010	3091
Wollongong	10679	64449	6121	435528

Our transport model records the speed at which vehicles move in the network during chosen time periods of the day for all simulated years. Figure 4 illustrates network speeds during morning peak on a typical weekday. Observed network speeds in Figure 4 are extracted from Google traffic maps. This comparison shows that the transport model is able to identify key network links that are subjected to significant congestions, thus adding to the confidence in using this model.

Baseline scenario (Figure 5) suggests a potentially significant urban growth to the left of the 'Lake Illawarra' which is an area identified and promoted for residential development in the SRLUP prepared by the NSW Government. It is important to note that this growth can lead to higher network congestion, thus reminding us the importance of combining the growth plan with an appropriate transport plan for the region.

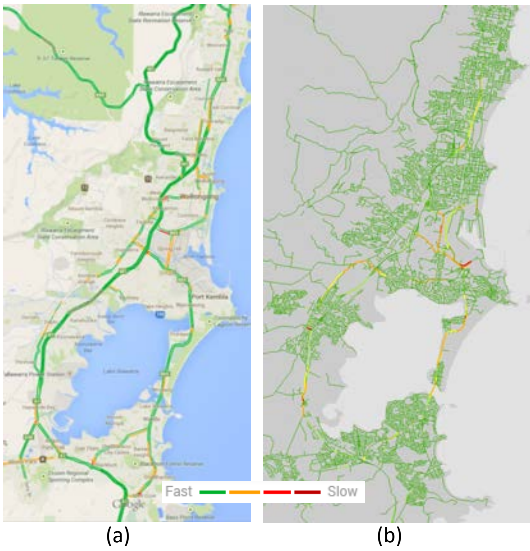

Figure 4.

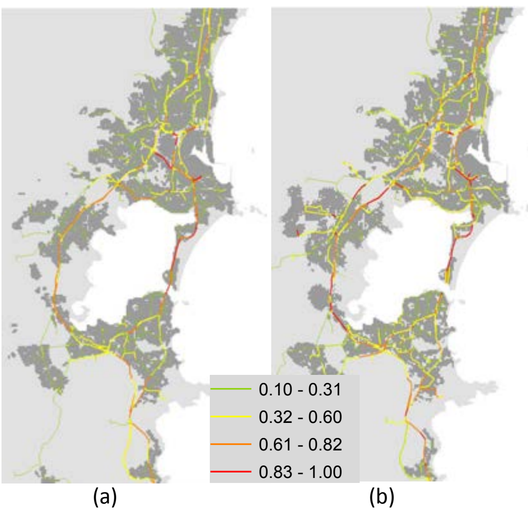

Figure 5.

CONCLUSION

This study marks the first phase of a larger project that aims to develop an integrated dynamic model in support of regional planning. In this phase, we have set up, calibrated and validate integrated land use and transport model. Calibration and validation results give confidence in using the model for scenario exploration, although there is room for improvement. In particular, residential land use could be further disaggregated into density-based classes. Same goes for industrial/commercial class which should be split into two classes. Land use model should also be calibrated for other land use classes. Number of trips produced by the transport model between origins and destinations needs further calibration.

In additon to improving calibrated model parameters, we are currently in the process of integrating an econometric input/output model and a synthetic population-driven demographic model into our framework. A conceptual model for utility consumption and network performance is also being developed.

ACKNOWLEDGEMENT

Authors would like to acknowledge the stakeholders of this project; Wollongong, Shellharbour, Kiama and Shoalhaven City Councils, Department of Planning and Environment NSW, Sydney Water, Endeavour Energy, REMONDIS, Illawarra Business Chamber, Cardno and People care.