Enhanced understanding of Cellular Automata land use models by sensitivity analysis of key parameters

Charles P. Newland [a,*], Hedwig van Delden [a, b], Jeffrey P. Newman [a], Holger R. Maier [a], Aaron C. Zecchin [a],

[a] Department of Civil, Environmental and Mining Engineering, University of Adelaide, Adelaide, South Australia

[b] Research Institute of Knowledge Systems, Maastricht, the Netherlands

Cellular Automata (CA) land use models serve as decision-making support tools for urban areas, as they simulate urban growth. This is important for decision makers who need some representation of urban change over time. Such models allow for the exploration of future scenarios with the capacity to assess a number of spatial (local, regional, country) and temporal (months, years, decades) scales.

To widen the applicability of CA land use models requires the development of an automated calibration procedure. At present the calibration of CA land use models is often a manual process, which is (mostly) assessed by a combination of the visual inspection of modelled and actual maps, and one or more quantitative comparison metrics. However, an overall assessment methodology combining the different methods is lacking. Such a method is desirable because the manual procedure used currently presents a few challenges; it is time consuming and requires expert knowledge to parameterize the system and define the relative importance of the various assessment metrics.

To address this, significant recent research effort has been directed towards the development of metrics that can be optimised during calibration. The primary focus of such metrics has been the evaluation of predictive accuracy (correct land use allocation). There is, however, a need to assess the current metrics that evaluate process accuracy, and whether greater research focus is required to determine alternative metrics for achieving this assessment.

The assessment of process accuracy requires an evaluation of the extent to which real world processes have been represented accurately. CA land use models are driven by equations that represent certain processes, a component of which are input parameters. These parameters provide a quantifiable basis for generating realistic processes. There are numerous parameters that can be considered; such as neighbourhood rules, which are the core of the CA land use model, and parameters relating to other processes such as accessibility, suitability and zoning.

There is a correlation between the processes within land use models and the spatial patterns that a model generates. Thus realistic processes should generate realistic spatial patterns. There already exist a number of methods to quantify spatial patterns. What is required is a more detailed examination of how well changes in simulated land use, as a result of changes in parameters affecting modelled land use processes, are reflected in evaluation metrics.

* Corresponding Author: Tel: +61 408 476 231
Email: charles.p.newland@adelaide.edu.au

The objective of this research is thus to determine the degree of sensitivity of current evaluation metrics to adjustments in model parameters that in part govern model processes. Three distinct questions will be investigated:

1. What are the dominant variables driving sensitivity across the metrics;
2. What are the most sensitive metrics across the variables;
3. Is there a pattern in the relationship between an evaluation metric and the driving variable to which it is most sensitive, and is this related to additional external drivers and policy measures?

Answering these questions requires a sensitivity analysis of the currently available spatial pattern evaluation metrics to adjustments in model parameters. The analysis will be performed using the modelling framework Metronamica (www.metronamica.nl). Metronamica is a generic forecasting tool with the ability to interactively simulate the impact of a variety of external influences (e.g. macro-economic changes, population growth) and policy measures (e.g. land use zoning, conservation policies, densification policies) on the regional development of an urban area. It has been applied extensively in over 30 countries. Testing will be performed on the previously investigated region of Randstad, a conurbation of the four largest and most populous cities within the Netherlands (Amsterdam, Rotterdam, The Hague and Utrecht) and the surrounding area.

The sensitivity analysis is conducted by applying the Sobol method. As part of the sensitivity analysis, the model parameters available within Metronamica, such as neighbourhood rules, accessibility and zoning parameters will be varied. The corresponding output will be evaluated to determine the sensitivity of evaluation metrics, such as the Clumpiness index and Fuzzy Kappa Simulation, to these perturbations. In order to determine how well process adjustments are reflected by the evaluation metrics, the sensitivity analysis will be repeated for a number of different scenarios. Scenario variations allow for different future realisations by adjusting the social, environmental and economic drivers.

The key outcomes obtained from this research are to determine the dominant parameters that evaluation metrics are most sensitive too, by evaluating the relative sensitivity of evaluation metrics to certain input parameters. This will potentially provide a framework for which current metrics can be applied in combination to best characterize the process accuracy of land use models, which will serve as the basis for an automated calibration procedure.