# Cellular Automata Modeling for Accessibility Appraisal in Spatial Plans (UrbCA)

Nuno N. Pinto, Bruno F. Santos

To cite this report: Nuno N. Pinto and Bruno F. Santos (2012) Cellular Automata Modeling for Accessibility Appraisal in Spatial Plans (UrbCA), in Angela Hull, Cecília Silva and Luca Bertolini (Eds.) Accessibility Instruments for Planning Practice. COST Office, pp. 153-158.

# Cellular automata modeling for accessibility appraisal in spatial plans (UrbCA)

Authors of the report: Nuno N. Pinto, Bruno F. Santos

Organization: University of Coimbra

Address: R. Luis Reis Santos, Pólo II da Universidade, 3030-788 Coimbra

E-mail: npinto@dec.uc.pt

## Background

The interactions between land use and transportation are one of the most addressed topics in planning and transportation, both from the academic and from the practice standpoints. The use of computers to simulate these interactions is also a very important research topic since the early 1950s when computers were introduced to civilian research and large scale urban models were developed and applied to several urban areas. With the development of the personal computer in the mid 1980s, which led to the democratization of its use in planning research and practice, land use simulation models gained an even greater attraction, as every researcher could develop, at very low cost, solutions to support planning practitioners in their decision-making processes.

Cellular automata (CA) models were introduced to urban studies at that time and are, since then, among the most popular modeling concepts used to simulate land use change, taking into account the influence of transportation and accessibility in a more or less explicit way. This report will present a CA model that uses some innovative concepts to simulate land use change taking into account accessibility by including this driver as an endogenous phenomenon, allowing a simulation that effectively conjugates land use change and transportation.

## Conceptual framework and theoretical underpinnings

The use of dynamic models such as CA is often considered a powerful tool to simulate and understand complex systems and complex behaviors of stochastic nature which depend on different variables and have different temporal and spatial scales. With regard to accessibility, the CA model reported aims to simulate in a single simulation environment the effects of transport systems (from which accessibility is evaluated) as one of the main drivers of land use change. The main goal is to capture the effects of accessibility in land use by parameterizing some traditional transportation models (e.g. the gravitational model) in conjugation with other parameters regarding other drivers, such as land use interaction/neighboring effects, or land suitability. The interdependences of all these drivers, which are important features of the complexity of urban phenomena, are taken into account so that all the partial parameters can be calibrated under the influence of all the observed phenomena.

## Operational aspects

UrbCA is a dynamic model that simulates land use change over a space divided into irregular cells designed from the traditional census blocks. Cells have at each moment a given cell state (or land use) from a finite cell of cell states which change through time taking into account the cell states of a given number of neighboring cells. This evolution is provided by a set of transition rules that parameterize the behaviors of all the drivers at stake. The calibration of the model is done using an optimization procedure that provides an efficient search of the space of solutions for the optimal set of parameters of the model. The very simple concept of CA allows the creation of a very powerful tool to capture complexity and emergence from simple transition rules that can be easily linked to common planning rules and restrictions. UrbCA incorporates some innovations when compared with the ones reported in the literature. Irregular cells are drawn taking into account both urban form and the information that is spatially referenced to them. The neighborhood size is a calibration parameter and not an input value defined by the user. The effect of the transport system (and accessibility) is explicitly considered.

The evaluation of the influence of accessibility in land use change is made by considering that land use change occurs as a consequence of a set of transition rules that accounts a transition potential for each cell (each location in space) in every moment in time. This potential is a function of the land use drivers, such as accessibility, land use suitability, or neighborhood effects. The model calculates accessibility taking into account the road transport network for private car mode. Although possible, the consideration of other transport modes is not yet implemented in the model (it will probably be implemented by the time the WU will have their workshops during 2013).

Detailed information about the modeling concepts, options, and formulation of UrbCA can be found in Pinto and Antunes (2010).

The use of UrbCA in the appraisal of accessibility in planning focuses on the possibility of simulating different planning solutions under different planning parameters taking into account different accessibility conditions, which are a result of the investments on the road network. Rather than focusing on measuring accessibility as a primary goal, the model simulates the direct effects of accessibility in land use. The model provides the calibration of some accessibility parameters, as the friction parameter of a gravity transportation model, along with the calibration of other land use parameters. The model is also able to simulate future land demand values by simulating future demographic and employment distributions. Input data includes the transport network configuration and attributes, as long as data on land use, demographics, employment, and other relevant data to constrain land use change. All the datasets refer to a common spatial structure based on irregular cells that take into account urban form. All these datasets are made publicly available by traditional data providers such as municipalities or statistics agencies.

UrbCA is implemented as a stand-alone software application developed in Visual Basic to run in Windows-based machines. The running time for a standard problem vary from a few hours to one and a half days, depending on the configuration of the dataset and on the desirable threshold for calibration. Some GIS expertise is required to preprocess data in order to create the datasets for the UrbCA. No specific expertise is needed to interpret the results as the model provides a fully descriptive set of easy-to-use text files that only contain readable information.

## Relevance for planning practice

The use of modeling in common planning processes is many times a very demanding task as both common planning offices and practitioners are not technically prepared for it or do not have the necessary budget to acquire sophisticated consultancy support that could provide this kind of approaches. There is also a latent tension between modelers and practitioners, on the one hand, and between modelers and decision makers, on the other hand. Traditional practitioners (planners, architects, and also engineers) are many times suspicious of the capacities of models to effectively provide any kind of valuable help, which many times undermines the possibility of using sophisticated modeling approaches. Decision-makers, by the contrary, tend to be very keen of having solutions provided by advanced tools that help them to support their decisions by using state-of-the-art knowledge.

The main goal of UrbCA is to simulate different planning scenarios of land use evolution taking the influence of the transport system (and therefore accessibility) explicitly into account. This simulation is expected to help practitioners to evaluate these scenarios under different parameters in order to test their feasibility and to inform both the citizens in the participatory process and decision-makers in the planning process itself. UrbCA aims to be a simple-to-use, simple-to-understand decision support tool that can be used in any kind of planning process by any planning structure, regardless of financial or even technical requirements. It is designed to be a simple tool that can be used by planners with no specific background on modeling, by decision-makers who are not necessarily skilled to understand the mechanics of the model, and also by citizens who are also not skilled in participatory processes for evaluating different planning scenarios.

This modeling approach to planning is therefore relevant for providing informed solutions to different stakeholders at various stages of the planning process.

CA models have been used to support planning processes, being one of the most used models the MOLAND model which is used by the Joint Research Center of the European Commission to support long term regional planning under the influence of climate change. UrbCA was not yet fully used in real-world planning processes, as it still is under development. It was already used in a research context for providing a test-bed for strategic scenario planning in a research project that included several planning officials from different planning agencies. The Action will provide the proper test-bed for its application to a real world planning process in conjugation with the Coimbra municipal planning department. The model is expected to evaluate, within the work of the Action’s Working Unit of Coimbra, the impacts of new transport investments and the consequent new accessibility conditions in municipal plans.

## Strengths and limitations

The use of CA models for assisting planning processes is useful as they allow the simulation of prospective planning scenarios under a fairly good variation of the parameters that are considered by the model. The calibration of the model allows planners and decision-makers to understand the main drivers and the main trends that took place in their territories, which is very useful for cross analysis with other kinds of quantitative and qualitative indicators that are usually part of the planning toolsets. The use of this model is expected to be very suitable to forecast feasible and plausible future land use/transportation scenarios rather than to point out what will be future urban design solutions. The model is very good at identifying areas of potential change rather than indicating what are the exact plots which will be developed. These models are also strongly linked to GIS which allows a good use of visualization techniques, a powerful mean to explain different options to non-skilled interlocutors.

UrbCA was already used in a research project that simulated a practice environment in which several practitioners and decision-makers were present. Simple outputs of the model were very useful for launching the discussion over very simple planning options, proving the value of the model.

There are, however, important limitations as the application of any kind of models has always some degree of limitations. Models are meant to capture trends that are more or less accepted as good descriptors of a given reality under a very well-known set of conditions. The ability to simulate futures based on the calibration of models is always dependent of the capacity of researchers and practitioners to understand the complexity of systems making use of some abstraction. Many assumptions must be made in order to be able to work with available data, to feasibly model a given phenomenon, or even to be able to identify the proper scale of simulation. Models are many times not able to cope with decisions that break up historical trends, which reduce their use especially when practitioners are not properly informed about the use that can be made of the model.

The underlying complexity of the model is many times referred as a potential problem. The CA concept is, nevertheless, quite easy to understand and very intuitive in the way it models reality. The natural sense of complexity associated with this model may be reduced for elucidation purposes by (1) taking into account only variables which depend on available datasets which are commonly used in planning (mainly from censuses), and parameters which are simply to understand by the agents to understand by the agents and (2) by strengthening the visualization capacities of the outcomes of the model, explicitly linking the results to maps and associated data.

UrbCA is under development and the main goal is to create a low cost tool that is expected to be used in common planning processes by a wide range of planning agencies, from municipal departments to regional/national planning agencies.

## References

Pinto, N. and Antunes, A. (2010). *A cellular automata model based on irregular cells: application to small urban areas*. Environment and Planning B-Planning & Design, 37(6): 1095-1114.

# Figures

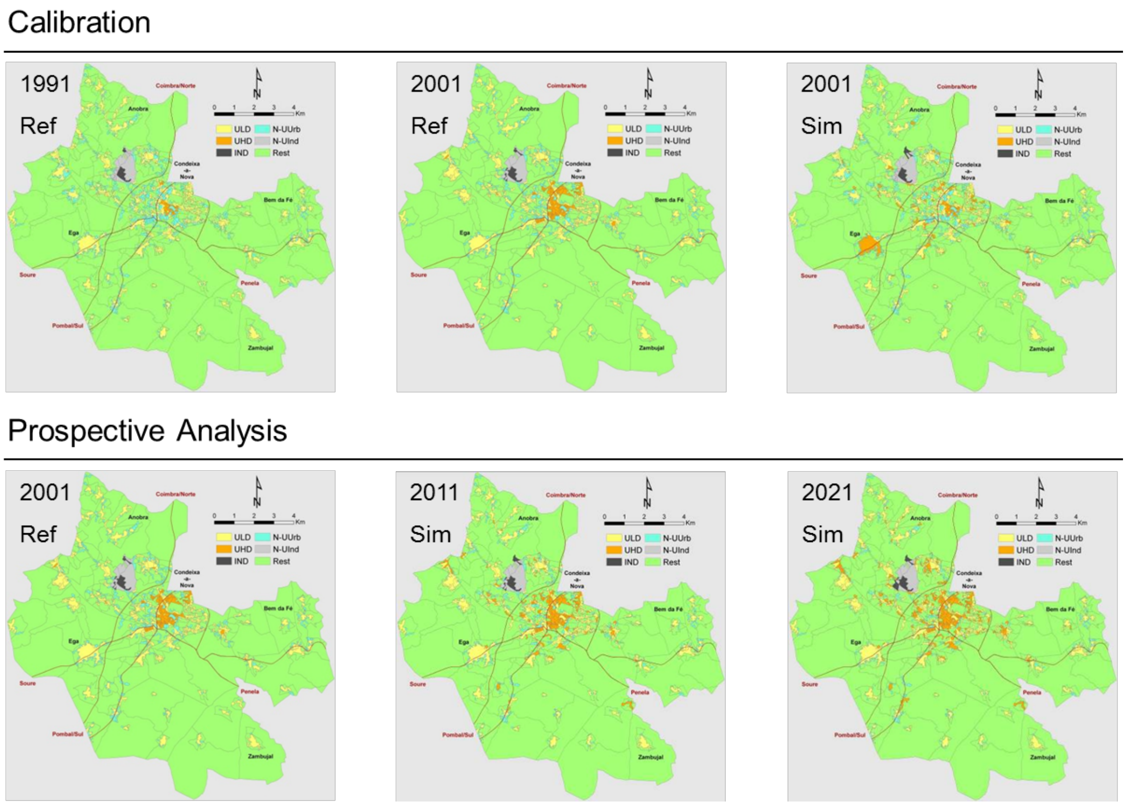


Figure 1 Application to Condeixa-a-Nova, Portugal

Growth Rates

| | 2001-2011 | 2011-2021 |
|---|---|---|
| Population | +3% | +2% |
| Employment | +2% | +2% |

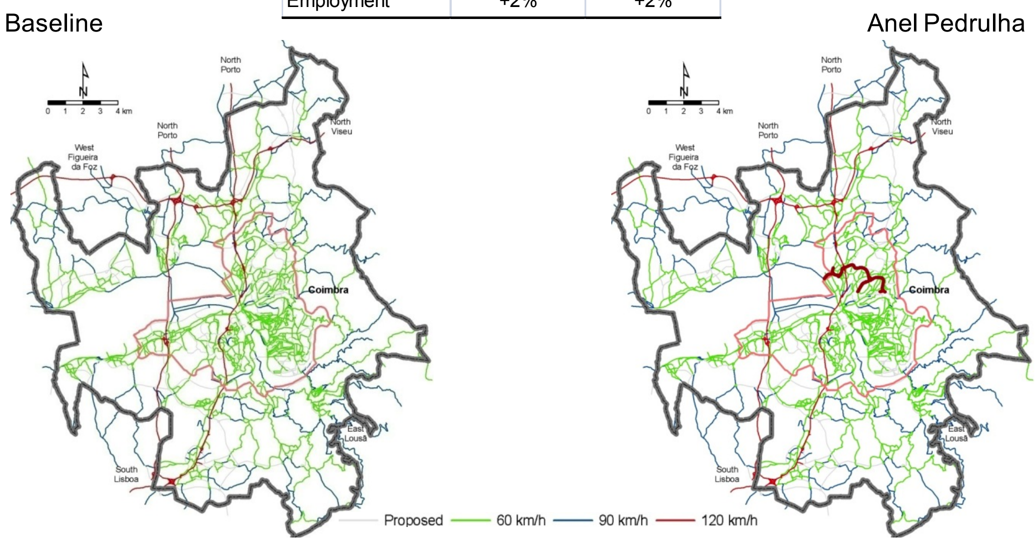


Figure 2 Alternative scenarios for road investment in the municipality of Coimbra

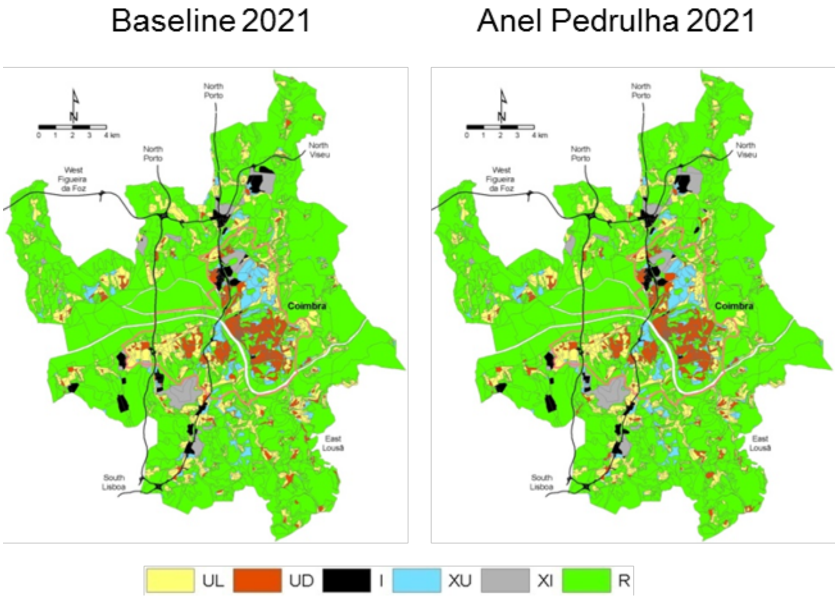


Figure 3 Land use maps for alternative scenarios for road investment in the municipality of Coimbra