MIT Portugal

Transportation Systems

Working Paper Series

Qualitative Analysis of UrbanSim as a Modeling Test-Bed for the SOTUR Project

Paper# TSI-SOTUR-09-02

January 2009

Cristian Angelo Guevara
Massachusetts Institute of Technology

Qualitative Analysis of UrbanSim as a Modeling Test-Bed for the SOTUR Project

MIT Portugal Program
Transportation Systems Focus Area

Research Domain:
Transportation Systems Integration
Research Project:
Strategic Options for Integrating Transportation Innovations and Urban Revitalization (SOTUR)

Paper#:
TSI-SOTUR-09-02

January 2009

Cristian Angelo Guevara
Research Assistant
ITS Lab, Massachusetts Institute of Technology
crguevar@mit.edu

This publication was made possible by the generous support of the Government of Portugal through the Portuguese Foundation for International Cooperation in Science, Technology and Higher Education and was undertaken in the MIT-Portugal Program.

Comments and edits to this publication were made by Jorge Tavares from MIT.

Abstract

This working paper conveys a qualitative review of UrbanSim model in the light of general equilibrium theory of land-use and transportation systems, and regarding its suitability for addressing SOTUR modeling needs. Advances on mounting a prototype version of the UrbanSim model for the city of Lisbon are also reported.

1 INTRODUCTION

The aim of the SOTUR project is to identify measures which may contribute both to urban development patterns and innovative transportation solutions, with a special emphasis in the revitalization of areas with limited street space. One critical step required to achieve this goal is to have a modeling tool or "test bed" able to account for urban systems dynamics at a micro level, detailed enough to, for example, account small impacts of innovative transportation projects in reduced urban areas.

The state of the art modeling micro-simulation tool which would achieve those goals corresponds to UrbanSim (CUPSA, 2008). This is an open-source software on which many researchers had been collaborating with during the last decade. The goal of this working paper is to make a qualitative review of UrbanSim model, in the light of general equilibrium theory of land use and transportation systems theory and regarding its suitability for addressing SOTUR modeling needs.

The paper is organized as follows. The next section conveys a general summary of general equilibrium theory of land-use and transportation, as theoretical framework with which micro-simulation models of land use can be contrasted. In section 3, the components of UrbanSim software are concisely but comprehensively analyzed. In section 4 the advances in the development of an UrbanSim prototype for the city of Lisbon are reported. Finally, general conclusions of this working paper are summarized followed by the list of references used.

2 GENERAL EQUILIBRIUM MODELS OF LAND-USE: A MICRO-ECONOMIC FRAMEWORK

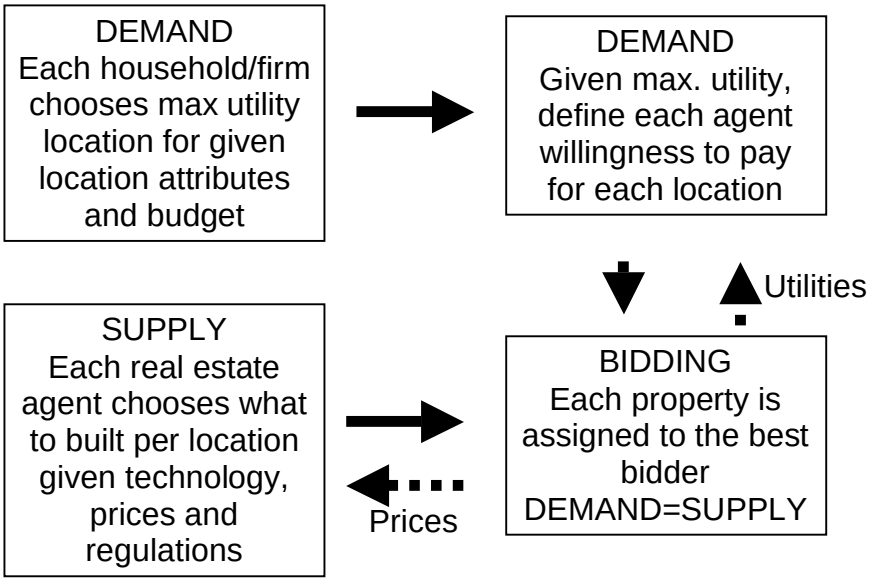
Land is a special market. The value of a particular dwelling unit is not only the result of its physical characteristics but also of its location. This fact makes each dwelling unit quasi-unique, placing important difficulties in modeling this market. On one hand, the price of each dwelling unit will be the result of an auction process in which the dynamic behavior of the potential buyers, households and firms, plays a relevant role. On the other hand, real estate developers have to make long term lump decisions based on the potential behavior of the agents. Finally, the society as a whole may be interested in shaping the behavior of this market to avoid the externalities derived from an inefficient use of space.

Given exogenous forecasts on aggregated population and economic growth, land-use models should be able to generate forecasts on lot size and construction types used by households and firms, land price for each location and even the evolution of the real

A good review of the general equilibrium framework to achieve these types of forecasts is given by Martinez (2007). This process is summarized in Figure 1. Within this framework, each agent places an offer for each dwelling unit according to their willingness to pay. Since each location and dwelling-unit is quasi unique, the owner has certain degree of monopolistic power and thus the market is cleared by assigning each dwelling-unit to the best bidder (Alonso, 1964). Then, these assignments will affect the agent's utilities and willingness to pay which correspond to the inverse of the indirect utility function, conditional on the location choice (Solow, 1973; Rosen, 1974; Martinez, 2003). In theory, this bidding process is repeated until equilibrium is attained and the market is cleared.

General equilibrium models could potentially also consider the prices by which each real estate agent chooses what to build, given the technology available and the land prices resulting from the auctions and the zoning constraints imposed by the authorities. Some classes of models are based on modeling the reaction of suppliers to the surplus of previous periods, but without representing their behavior explicitly (Simmonds 1999, Waddell 2002 and Wegener 1985). This has the advantage of reducing the modeling burden but at the cost of reducing the behavioral consistency of the agents involved in the land-use and transportation system. In turn, Martinez and Henriquez (2007) is an example in which real estate supply is fully determined by a microeconomic behavior corresponds to.

Figure 1. General Equilibrium Models of Land Use



Finally, general equilibrium is attained, in theory, when demand for dwelling-units and supply provided by the real estate agents attain consistency.

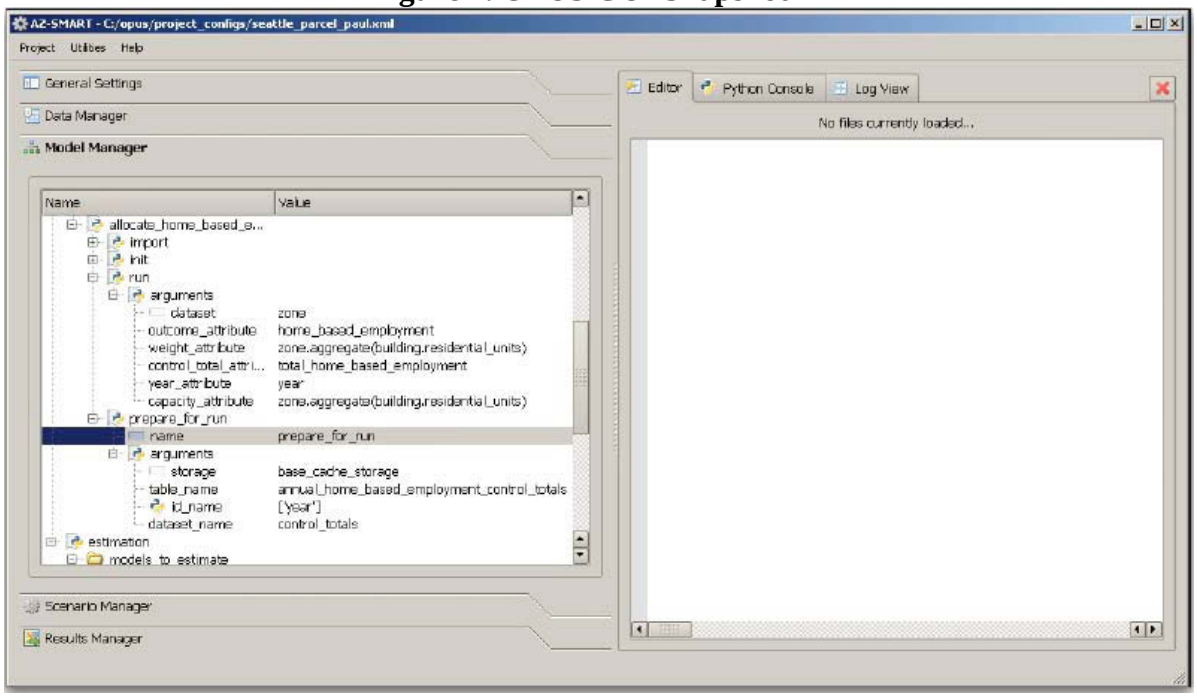
3 MICRO-SIMULATION OF LAND USE WITH OPUS-URBANSIM

Although general equilibrium models of land-use offer a consistent and conceptually robust framework to model this market, practical applications of these models have been only partially successful. In addition, they have only been circumscribed to model aggregated classes of users and to consider large modeling zones. Since the objective of the SOTUR project is to influence transportation innovations by taking advantage of the interaction between land-use and transportation, the analysis of the land use market at a micro level is imperative. Thus, an alternative venue should be followed.

The state of the art in microscopic simulation models of land-use corresponds to Urbansim (CUPSA, 2008). This open-source software has been developed by a group of contributors which have been continuously enhancing it. The goals of making UrbanSim as an open-source software were first to make this model productive and allow users to transform and update the software's capabilities to increase flexibility in supporting valuable experimentation, speed and scalability in supporting multiple production runs, and accessibility so that users can create additional packages and others can benefit from the collaborations.

To achieve these goals, UrbanSim was coded in a general purpose simulation platform named OPUS which includes some potentialities that are useful for micro-simulation purposes, such as population generation procedures, data sharing and processing capabilities. The latest version of the software has a graphic user interface (GUI) which considerably reduced the data management and modeling burden in general. Figure 2 shows a snapshot of the GUI.

Figure 2. OPUS GUI Snapshot



The UrbanSim model is conceptually similar to the general equilibrium models in terms of input needs, the outputs produced, and the overall internal processes. The main difference is that it does not attain equilibrium. Instead it applies a sequence of models to represent a city's conditions in subsequent periods of one year. Another important difference is that it does not model firms but only the number of employees by location.

UrbanSim needs an estimation of the total number of households and employments by sector as well as trips and generalized costs by origin and destination pairs as inputs. Additionally, the user can provide information regarding special events such as important real estate developments or relocations. Modeling outputs correspond to the number of households and employments by sector, real estate developments and land price.

The model can be developed at the level of a grid, at minimum, 150 by 150 meters or by parcel, depending on the availability of data and the purpose of the study. The model has nine modeling components which are applied sequentially. In the following paragraphs, each sub-model of UrbanSim is described in order of application. Additionally, comments on its potential strengths and weaknesses in light of the objectives of the SOTUR project and a comparison to the general equilibrium framework are included.

- Economic/Demographic Transition Model

These two sub-models are the first to be applied. They use the previous year's grid of households and employments by type and sector for each location as inputs. Then, based on aggregated forecasts of this features at the level of the whole city for the following year, these sub-models compute, respectively, the number of households and employments which should be added or dropped from the previous year's grid to match the forecast of the previous year. The households and employments which would have to be dropped are randomly chosen and eliminated in this stage.

- Employment/Households **relocation** model

These two sub-models convey the identification of a set of households and employments which would or would not be participating in the housing market in the next modeling year. This model is just as sophisticated as a binary logit which would depend on housing attributes (potentially including accessibility) and household characteristics. This model should capture the households moving inertia, in terms of whether or not they are willing to move based on the utility differential.

These sub-models imply a potentially substantial difference with the general equilibrium models since, for them, all households always participate in the housing market until equilibrium is attained. Since equilibrium households are treated as groups and individuals are not differentiable, an equilibrium for which a certain number of households of a certain class that continue to be located in the same area does not necessarily mean that the same households actually remained static. Whether one or another approach is more suitable would be a matter of potential future research.

- Employment/Households **location** model

This sub-model uses new households and employments resulting from the Economic/Demographic Transition models as well as those who are relocating in the modeling year according to the relocation model, as input. It additionally considers the information regarding available spaces derived from the real estate model (described afterwards), the price and other attributes of the dwelling units and employments.

Given this information the sub-model proceeds to locate households and employments across the city using a multinomial logit model which is applied using random sampling. The attributes considered in the model could range from dwelling unit price to aggregated zonal attributes, potentially including accessibility.

The specification and estimation of this model represents an important challenge to be addressed in future steps of this research. First of all, it should address endogenity issues caused by the omission of attributes which could be correlated with price, as well as spatial correlation issues derived also from the omission of attributes.

- Real Estate development model

This sub-model provides the forecasting of the real estate developments by type and location. It is comprised of two parts: The Development Project Location Choice Model and the Development Project Proposal Sampling Model. The first one is built as a multinomial logit model which depends on attributes of the location and market conditions. The second provides the process by which each potential development seeks respective funding in the financial market. This is modeled as a binary logit as a function of specific costs.

This sub-model considers development constraints in terms of size or locations that cannot be used for certain types of constructions. It relies also on the assumption that developers use “templates” as limiting examples or portfolios of potential types of developments to build.

- Land price model

The land price model predicts residential and non residential land value. It is basically a linear hedonic price model which depends on diverse attributes of the land. The Land price model constants are then adjusted as a function of the vacancy rates in the market.

This sub-model is susceptible to relevant improvements. Following the modeling framework of the general equilibrium model, it should be expected that the price of the dwelling units should be a function of the demand for them. Therefore, potential improvements of this model, following Martinez (2007), will be studied in future stages of research.

- Accesibility model

The final model corresponds to the link between the transportation model, which is exogenous, and the land-use model. It simply corresponds to the evaluation of a function for each location *i*, depending on the generalized costs of visiting other zones $L_{\alpha ij}$ and the attributes of the zone D_j.

$$A_i = \sum_{j+1}^{J} D_j e^{L_{\alpha ij}}$$

4 ADVANCES IN THE IMPLEMENTATION OF A LAND-USE MODEL WITH URBANSIM

The minimum data required to build the UrbanSim Model is still not yet available. However, verbal confirmation that such minimum data exists for the city of Lisbon made it advisable to start with this city.

First, wrap-up stages considered the installation of the software in a server and a personal computer and the application of modeling examples already available. Critical procedures which are already working correspond to data processing tools and model running tools. In turn, procedures which are still not working properly are the population synthesizer tools which are available with the software. Problems have also been identified in the application of the parcel version of the software and with the real estate development model

The main issue delaying the project is related with the availability of data. Three main sources of minimum data are required. The first corresponds to the transportation model needed to calculate accessibilities. Rather surprisingly, despite Lisbon being the capital city of an European country, it does not use a strategic four stage transportation model. However, another team which belongs to the SOTUR project (Martinez and Viegas, 2009), developed their own private car transportation network for Lisbon using VISIM. Such a network was made available for the project. For the first stages of this research, it is going to be used to couple the land-use model developed in UrbanSim for the calculation of accessibilities. In future stages, it will be necessary to add a multimodal network and eventually turn to traffic micro simulation using DynaMIT.

The second major source of data is mainly CENSUS data for control totals. Table 1 exposes a summary of the data required to build an appropriate UrbanSim model and the data currently available. Critical data on land prices and developing constraints are unavailable. Since there is no sign indicating that this data exists, the model will be performed using approximations based in existing data for the rest of the city.

Table 1. Data Availability for Developing an UrbanSim Prototype for Lisbon

Urban Sim Data Requirements		Urban Sim Data Availability for Lison	
Base Data		Availability	Comment
Overall Model Parameters	Gridcell Dimension	Ok	User defined
	Measurment Units	Ok	User defined
User Defined Parameters	Target Vacancy Rate	Ok	User defined based in Census DATA
	Yearly rate of relocating jobs and households	Ok	User defined based in Census DATA
Control Totals	Population and Employment Proyections	Ok	User defined based in Economic exogenous proyections for the city
Primary Data		Availability	Comment
Gridcells Table	Spatial Coordinates	Ok	User defined based in Census DATA
	Political Characteristics	Ok	User defined based in Census DATA
	Trafic Analysis Zones	Limited	Limited to Lisbon Minicipality
	Geographical Characteristics	Partial	General for all but specific, limited to Lisbon Minucipality
	characterizartion of land Use	Partial	Limited at a parcel level, limited non-residential information
Households Table	Socioeconomic Atributes per household	Partial	At an agregagted level by census parcel
	Location	Partial	At an agregagted level by census parcel
Jobs Table	Location	Partial	At an agregagted level by census parcel
	Industrial sector, building type per job offered	Partial	Limited business activity for Lisbon Municipality
Buildings Table	Location	Ok	footprint shapefiles
	Construction Year, Type, number of res. Units	Partial	footprint shapefiles
	price	Limited	Asking price for Lisbon Municipality
Develoment event History	Historical Real Estate Developments	Partial	Partially from Census data
Development Constraints	Zoning, Physical Constraints	Limited	Physical cosntraints derivable from maps
Transporation Model			
Network	Topology	Limited	Only Lisbon Minicipality
Demand	Gen/Dist/Msplit/Assign	Not Available	

The third source of data required are micro data used to perform the population generation for the UrbanSim model. The population generation stage basically consists of the following stages. First, a control total by zone is drawn from the CENSUS and then combinations of it are calculated using some type of iterative proportional fitting method. Afterwards, a number of individuals are drawn from an available micro-data source such that the control totals match.

The problem is that the micro-data is definitely not available from the CENSUS. Formal confirmation of this fact has been received from INE, the Portuguese organization in charge of the CENSUS. The alternative is to use data from surveys. Despite oral confirmation of the existence of data from an Expenditure survey and a Household survey for Lisbon, after months of waiting, this information is not yet available. As soon as it becomes available, the core part of the implementation of the UrbanSim model will really begin.

5 CONCLUSIONS

This working paper considered a qualitative review of UrbanSim model in the light of general equilibrium theory of land-use and transportation systems, and regarding its suitability for addressing SOTUR modeling needs. The main conclusion is that this software is a suitable tool for modeling land-use in the SOTUR project, although, in the light of general equilibrium theory, is seems necessary to explore the sophistication of some of its components.

Additionally, the preliminary steps on the process of developing a prototype version of UrbanSim for the city of Lisbon are reported. In this case, lack of micro data to develop the first stages of synthetic population is remarked as a critical issue which precludes substantial modeling advances.

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