A Review of the Development and Application of UrbanSim Integrated Land-Use and Transportation Model

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To analysis and mitigate the accelerated growth of urban complexity, dynamic urban growth simulation modeling techniques have long been considered by planner and related stakeholder. However, most of the existing techniques to study dynamic urban growth have lack of accuracy at the level of household or land parcel and majority of them remain highly aggregate despite the use of disaggregate calibration methods and essentially static in nature. It is with this in mind, to anticipate the future changes of Seoul Metropolitan Area, dynamic micro simulation model "UrbanSim" has undertaken into consideration on Korean perspective since it is operational and have been implemented and used for policy analyses. This paper provides an overview of UrbanSim model conception, its development, a list of application to date, as well as our experiment through Yongsan-Gu in Korea.

Keywords: UrbanSim, integrated land-use and transpiration models, urban growth simulation

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1. INTRODUCTION

1.1 Research Background

Urban system are complex enough included many interactive system like transportation, housing market, labor market, real estate market, commercial, industrial etc. Every system is closely interconnected with complex relationship. Predominantly, land use and transportation are strongly linked in reality since patterns of land use and available transportation systems play a critical role in determining the economic vitality, liability and sustainability of urban areas (Pinnel et.al 1999). However, traditionally, land use and transportation planning have been conducted separately and very rarely acknowledge any response or effects from transportation improvements on land use. In order to recognize these relationships between transportation and land use, their characteristic, growth, demand and distributional pattern in future as well as intervention in turns of compound outcome are major policy agenda in many metropolitan organizations. Another possible way and might be powerful techniques to understand these interdependency and complexity through simulation modeling. In recent research has thrown up many prospective modeling techniques like cellular automata, discrete choice modeling, multi agent simulation and linear programming. However, most of the recent modeling techniques have been criticized due to their insufficient theoretical background (Lee 1973 Wegener 2004), aggregate behavior (Wegener 2004, Wilson 1997) and static in nature. Even to date there is little evidence of accurately simulating and predicting dynamic urban growth at the detailed spatial location of land parcel or household level (Terarojanarat 2004). Therefore the objective of this paper is to investigate the UrbanSim, its functionalities, model structure and the link with GIS and finally finds significant issues for feasible PSS (Planning Support System) application to Korea through case study in Younsan-gu land price model.

1.2 UrbanSim : Overview

UrbanSim was developed in the face of subsequent lawsuit, the Intermodal Surface Transportation Efficiency Act (ISTEA 1990) and Clean Air Amendment Act (CAAA 1991) which was given a legal mandates and demand for comprehensive, interactive planning of land use, transportation and environment (Waddell 2000, Haghani 2002).The inter-modal planning as a new key concept in planning is regarded as an interactive and dynamic process which incorporates all components involved with (Meyer, 1993) and land-use and transportation system should be treated in a unified model (Haghani et al., 2002). In addition almost existing models has been criticized for its aggregate nature(Iacono et al., 2008), complicated in behavior, expensive in software (Hunt 2004) as well as lack of proper theory or inadequately connected to existing theory (Lee 1973, Wegener 2004). The initiative of UrbanSim was to systematically address the above shortcoming of existing land-use modeling and emerging needs to better coordination in transportation and land-use planning (Waddell 2003). Although, UrbanSim simulation approach differs from prior urban simulation models (Noth et al., 2003) but it has been benefited and substantially extended to prior modeling approaches. UrbanSim is called integrated modeling approaches because it use micro-simulation for individual choice, discrete choice modeling to determining the agent location choice, GIS techniques to integrate input data and visualizing simulation results, cellular automata for cell based representation and multi agent simulation method to interact with individual agent. The model is still in progress, and so far, it has been implemented more than two dozens of cities across the world and being developed through international collaborative research.

2. RECENT RESEARCH TREND IN URBANSIM

The recent progress in UrbanSim, which is a rapidly evolving integrated transportation land-use model that has been under development since 1996, can be classified into five categories as follows.

2.1 Descriptions of UrbanSim

Some literatures include a description and analysis of UrbanSim in comparison with other models (Waddell et al.; Waddell and Borning, 2004; Davis et al., 2006; Waddell, 1998; Waddell, 2001 and Waddell, 2000; Hunt et al., 2005).

2.2 Software and User Interface

Papers in the computer science literature describe UrbanSim and various aspects of the UrbanSim system in the context of software and user interface development (Noth et al., 2003; Freeman-Benson and Borning, 2003; Schwartzman and Borning, 2007 and Waddell et al., 2003).

2.3 Discrete Choice Innovations Related to Location Choice as a Tool to Test Hypotheses

A literature on methodological developments has used data relating to, or resulting from, UrbanSim to investigate improvements in two broad areas. The largest number of these articles have looked at discrete choice innovations relating to household location choice (de Palma et al., forthcoming; de Palma et al., 2007 and de Palma et al., 2005), and joint household location choice and mode or workplace choice (Waddell, Bhat, Eluru, Wang and Pendyala, 2007 and Pinjari et al., 2007). The other articles have looked at sensitivity analysis of variation in UrbanSim results (Pradhan andKockelman, 2002) and methods to quantify the amount of uncertainty in UrbanSim results (Sevcikova et al., 2007).

2.4 UrbanSim Applications

A number of UrbanSim applications have been reported. Half of these have been written by the developers of UrbanSim. They show that UrbanSim can be used successfully (Waddell, 2002) and that the integration of land-use can have an important impact on transportation system performance results (Waddell, Wang and Charlton, 2007). Waddell, 2002) shows that for the case of Eugene, Oregon, UrbanSim produced good results for predicting land-use evolution (e.g. where households and jobs will locate in the future). This is demonstrated using correlations of UrbanSim predictions against actual development in 1995. Waddell, Wang and Charlton (2007) provide a detailed description of an application for the region of Salt Lake City, Utah. Among other things, it shows that compared to a system analysis using a traditional transportation modeling approach that total vehicle miles traveled (VMT) are 5% higher and that total congestion delays are 16% higher. A more recent, although final model of San Francisco not, Waddell shows how a recent version of UrbanSim has been used with an activity based model (Waddell, Ulfarsson, Franklin and Lobb, 2007).

2.5 Independent UrbanSim Applications

There have also been three independent reports of UrbanSim applications. Joshi reported on the application of UrbanSim to analyze the effects of a planned light rail system in Phoenix, concentrating primarily on land-use implications (Joshi et al., 2006). Nothing is mentioned about the effort required for model implementation. The number of authors in the paper suggests the resources required were significant. Zhao is the most detailed independent analysis of an application of UrbanSim in Volusia County, Florida (Zhao and Chung, 2006). They report success in implementing UrbanSim and that it is feasible, although there is not much detail about the resources required. They report that the main challenges were related to data collection and preparation and parameter estimation. Loechl describe the results of modeling efforts for the region of Zurich (Loechl et al., 2007). The model was not fully implemented and the paper describes problems encountered in data collection and how these were overcome. It also reports on the simulation results obtained in this effort. Another report has just been released by IAURIF in Paris that itemizes ten lessons learned after four years of modeling efforts for the Paris region (Nguyen-Luong, 2008). They report that theirs is the first full implementation of UrbanSim outside of the United States and it provides practical lessons that they were able to derive from their efforts over the past four years. They also provide interesting insights into the factors that are required to develop a well-functioning, UrbanSim model.

3. DATA AND MODEL IN URBANSIM

3.1 Key Features of UrbanSim

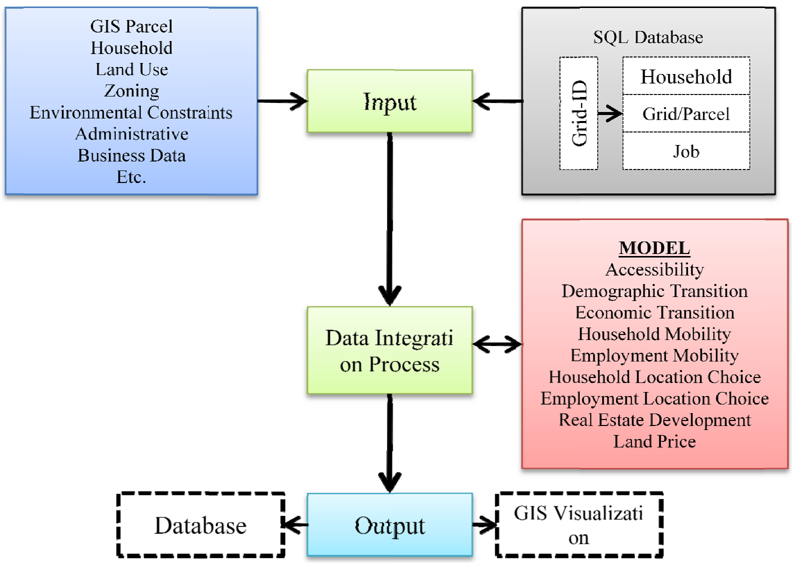
UrbanSim is a new simulation tool of urban areas (Waddell 2007) including land use, transportation and environmental impacts, over periods of twenty or more years under different scenarios (Noth et al., 2003). The software can be downloaded at www.urbansim.org at no cost. UrbanSim supports both a graphic user interface (GUI) and a command line interface to run the software. From software perspective, it is a large, complex application, with heavy demands for excellent space efficiency and support for software evolution as well as it has interfaced to a range of databases and flat files are available (e.g. MySQL, MS SQL Server, ArcGIS, Postgres, PostGIS, SQLite, DBF, CSV, and Tab-delimited ASCII files). On the output side, the simulation results can be exported to external ASCII text files or Gedatabase file and additional GIS program can be incorporated to interactive visualization. The model till now implemented to Eugene-

Springfield, Oregon; Salt Lake City, Utah; Honolulu, Hawaii, Seattle, Washington, Houston, Texas, Phoenix, Arizona; with other application in process. Internationally, it is being applied in Paris, France; Tel Aviv, Israel; Amsterdam, The Netherlands; and elsewhere (Borning et al., 2005). As an integrated modeling technique, UrbanSim has received a fair bit of attention in the modeling community (Patterson and Bierlaire 2008) and well know due to its disaggregated approaches (Iacono, Levinson, & El-Geneidy 2008).

3.2 Architecture of UrbanSim Model

3.2.1 Model structure and processing of UrbanSim

UrbanSim is not a single model rather an urban simulation system, which consist of a family of models interacting with each other, not directly but through a common database, (Joshi et al., 2006) representing different actors and process in the urban environment such as residents, business, land developers and transportation networks (Noth et al., 2003).



〈Figure 1〉 UrbanSim model structure and data flow

The main model components in UrbanSim, in the order of their execution, at the accessibility model, the economic and demographic transitional models, the household and employment mobility models, the household and employment location choice models, the real estate development model, and the land price model.

Demographic transitional model accounts for changes in the distribution and compute births and deaths of population by household type over time. Economic transitional model compute the job creation or loss by employment type (accounts for sectoral growth or declines of jobs).

In household location and relocation model, simulates household decision about whether to move or remain in the current residence, and, if they choose to move, their housing type and zone.

The Employment Mobility Model determines which jobs will move from their current locations during a particular year and the Employment Location Choice Model is responsible for determining a location for each job that has no location.

Exploiting the Random Utility Maximization theory, UrbanSim implements the Residential location choice, employment location choice and real estate development choice models as discrete choice models.

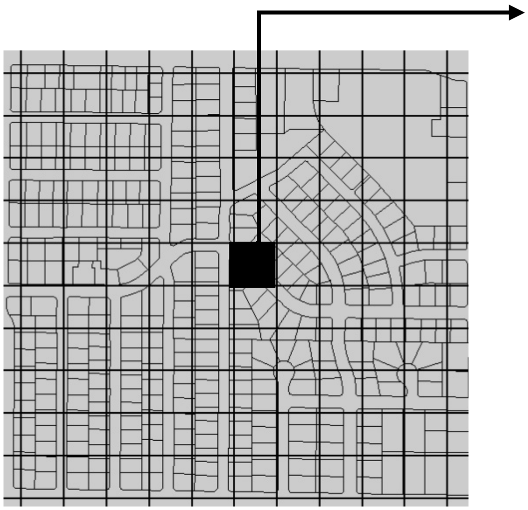
The Land Developer Model simulates the action of a developer making decisions about where and what kind of construction to undertake (if any), including both new development and redevelopment of existing structures.

The Land Price Model simulates the evolution of land prices at each grid by using a hedonic regression of land value on characteristics of the land and its environment.

UrbanSim allows user to specify policy and generate assumptions that can be input to the model to examine their potential consequence on outcomes such as urban form, land-use mix, density, and travel pattern etc.

3.3. Development UrbanSim Database and Methodology

Database is the backbone of UrbanSim specially the relational database (usually mySQL) that contains exogenous data, primary data, model coefficients, model specification and data classification. Database usually maintains concurrent relationship with the sub-model. In UrbanSim modeling, three types of geographic units are considered as a unit of analysis; these are Gridcells, Parcells and Zone. In gridcell-based approach, a city or study area is divided into grid cells (150/150 or user defined) and each cell is associated with different characteristics which are aggregated into grid. Another alternative data structure that UrbanSim supports is Zone. This approach can be used with less geographic detail with coarser resolution.



Column Name	value
Grid_id	44
City_id	1
County_id	23
Development_type_id	12
Plan_type_id	1072
Zone_id	125
Commercial_sqft	1850
Governmental_sqft	0
Industrial_sqft	0
Commercial_improvement_value	5000000
Governmental_improvement_value	0
Industrial_improvement_value	0
Nonresidential_land_value	182000500
Residential_land_value	25000000
Residential_units	1
Year_built	1982
Distance_to_arterial	225
Distance_to_highway	550
Relative_x	200
Relative_y	45
Prevent_water	3
Percent_wetland	0
Percent_floodplain	0
Percent_roads	0

〈Figure 2〉 One grid cell records in database table

In UrbanSim modeling, data requirement is huge including household data merged from multiple census sources, employment data, in the form of geocoded business establishments, parcel database with acreage land use, housing units, nonresidential square footage, year built, land value, improvement value, city general plans and various GIS overlays and environmental features.

All inputs to the model must be re-structured, geo-coded in raster grid cells and stored as tables in the SQL database. These data are loaded into base year which called "the base year data base" and the simulation run on the base year data. Although, developing the input database is a difficult challenge, owing to its detailed data requirements and still data collection for a simulation has remained a major efforts of metropolitan (Wegener 1999). Particularly GIS based parcel data, detailed information on individual household are not readily available.

Some data are very sensitive like taxation and employment data and not easy to get by from government organization. However, synthetic data could be used in case of individual household.

3.4 Case Study: Applying Land–Price UrbanSim Model into Korea

This research project develops a land price model for Youngsan-gu by using UrbanSim simulation software. There are obvious some important issues to choosing both land price model and particular site. First, the study area (youngsan gu) has been under experiment by several land use model and thus we wanted to know the behavior of UrbanSim compare to other model. Another reason equally important is to exploiting the existing data base which is readily available or constructed or used for other model. Secondly, the area is comparatively small in size and low population which is extremely tractable from a modeling standpoint. Further, the study area is an excellent place to study patterns of Urbanization because it has diverse possible future courses due to the large, open space and actively developing area.

This study focused only land price model since Land Price model provides a key inputs to the other land development, household and employment location choice models. As is mentioned that UrbanSim data requirement is huge and we found that our supplied data was not enough for running all module at this time. Additionally, this type of study is somewhat new in Korea and our attempts were whether to adopt this methodology with an alternative environment on available country data. Clearly, this is a very rough and pragmatic approach, but sufficient for the first runs of UrbanSim. Further efforts should be put either in modeling of all sub-models or in acquiring suitable data.

3.4.1 Land price model:

In UrbanSim, Land price are modeled using a hedonic regression of land values on attributes of the land and its environment, including land use mix, density of development, proximity of highways and other infrastructure, land use plan or zoning constraints, and neighborhood effects. A hedonic regression approach, as described in this working paper.

$$Pilt = a + \delta \left(\frac{V_i^S - V_{it}^c}{V_i^s} \right) + \beta X_{ilt}$$

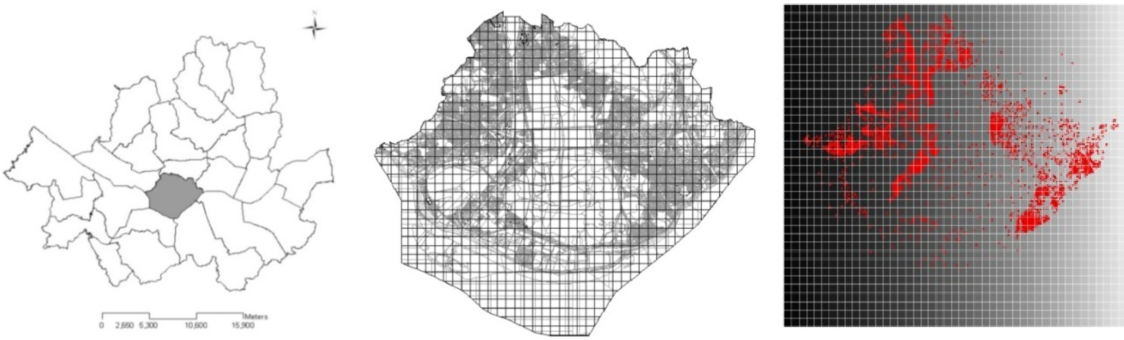
Where, P_{ilt} is the price of land per acre of development type i at location l at time t, V_{it}^c is the current vacancy rate at time t, weighting local and regional vacancy, V_i^s is the long-term structural vacancy rate, X_{ilt} is a vector of locational and site attributes, and α, δ and β are estimated parameters. Prices are updated annually, after the construction and market activity is completed.

The independent variables influencing land price can be organized into site characteristics, regional accessibility, urban-design scale effects, and market conditions.

3.4.2 Data construction

Much of the work of this research revolved around developing the required data inputs for UrbanSim land price model of which there is a long list. Some required data were publicly available and required only minimal processing (e.g. wetlands, floodplain boundaries). Other data sets required several months of manual labor to conflate, impute, and join, quality control, and process to achieve the required input format. Spatial data processing and analysis was performed using ESRI's ArcGIS 9.2, while tabular data was processed and assembled using a combination of Microsoft Excel and Geodatabase. Initially, the study area was portioned into a set of 150m x 150m grid cells which are commonly used in UrbanSim models. Then road network, general planning boundaries and other environmental features such as wetlands, floodways, steep slopes, or other sensitive or regulated lands were overlaid and analysis was made through ArcGIS environment.

We obtained data from various sources for example Household data (except income) came directly from the household Travel Survey Data (2002, 2006). The main gridcell table was developed by the Cadastral Map (1999, 2001, 2006), residential and non-residential land value were used as a proxy for land price and uses of commercial and residential square footages was obtained from Building Register (2002, 2003, 2007).



〈Figure 3〉 Location of the study area, geographical portions and data aggregation process into grid cell.

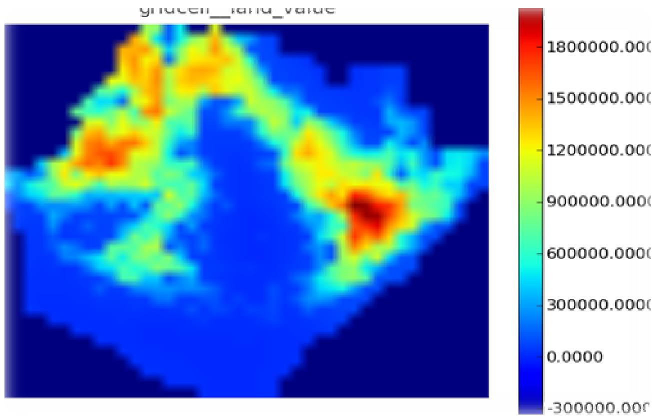
The primary use of this model in a core model in UrbanSim is the prediction of property values. UrbanSim does require land prices as input. The only land price data available are manually provided figures by which do reveal average land price per square meter per land use (residential and commercial use) and per region. In this case the dependent variable (land price) is estimated by a set of proxy measures that characterize the grid cell and its surrounding neighborhood. Data is summarized at the grid cell scale for a variety of cell scale for a variety of attributes (commercial square feet, housing units, industrial square feet, distance to arterial and highway etc.)And the value of a gird cell is regressed against a subset of these characteristics.

3.4.3 Simulation and analysis of land price model

Once the data have been prepared the model does run reasonably fast and may make good sense over the longer term for interested region.

gridcell__land_valu

Within several minutes one can visualize the outputs either in instance map or tracking in to service database. In our study the simulation process took only a few seconds and the following map produce instantly. For more precise analysis the simulated result (indicators) was exported to GIS environment. Finally the simulation result was compared against the actual data.



〈Figure 4〉 UrbanSim land price simulation map (Yongsan-gu) in opus

As we expected and the simulation result indicates that an increase in commercial square feet, total employment, population density, access to population, percentages of commercial and developed lands, and high-income households are associated with higher land prices. Conversely, land values are lower where the cell is located within a block of conserved land (park, open space, wetland), presence of industrial space and the travel time to the Central Business District is greater. This makes sense because land in a conservation area is likely to have more restriction on the type and amount of development that is allowed and the further one travels from the CBD the land price per acre is expected to decrease.

4. CONCLUSIONS

UrbanSim is an integrated transportation and land-use model that is increasing in popularity. UrbanSim conducts its analysis at 150 by 150 meters gridcell more recently parcel allows a much finer-grained approach and a great deal of flexibility in analyzing many aspects of an urban system. In addition, conceptually and theoretically UrbanSim is sound, robustness and reflects actual agent choice. Potential infinite indicators within the model domain and user enjoy unlimited flexibility in model specification and more substantive question related to policy can be addressed. However, UrbanSim specification limitations are multiple and its data requirements are serious and may be impossible for almost any planning agency to meet.

This study introduced not only the UrbanSim functionalities but also address the shortcomings of existing data repository particularly when we are interested to deal with grater urban complexity through sophisticated methodology. Although there are number of limitations of this study, Nevertheless, the applied methodology has proved to be useful and sufficient in the first application of UrbanSim for the Korea. It is planned to further enrich and improve the land price model as well as other sub model in the near future with current data as it become available.

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