SIMULATING LANDUSE CHANGES DRIVEN BY A 3rd BOSPHORUS BRIDGE

I. E. Ayazli [a, *], F. Batuk [a], B. Kleinschmit [b]

[a] Department of Geomatic Engineering, Yildiz Technical University, Faculty of Civil Engineering, 34220, Davutpasa, Istanbul, Turkey - (eayazli, batuk)@yildiz.edu.tr
[b] Department of Geoinformation Processing for Landscape and Environmental Planning, Technische Universität Berlin, Institute of Landscape Architecture and Environmental Planning, 10623 Berlin, Germany – birgit.kleinschmit@tu-berlin.de

Commission VI

KEY WORDS: Spatio-temporal Geodatabases, Urban Sprawl, Remote Sensing, Cellular Automata, Simulation

ABSTRACT:

Istanbul, which joins two continents-Asia and Europe, is an important city with its cultural, natural and environmental heritages. In the past and today, increasing population has caused an enormous transportation problem. To overcome this problem, two bridges were built on the Bosphorus and a third bridge will be built on the north side of Bosphorus. Although zone plans made in the 1960s suggested the urban growth to east-west direction, urbanization was triggered to northward by Bosphorus Bridges. Main research questions of this study are: What is the influence of a third Bridge on urbanization processes in Istanbul? Which protected areas will be damaged? To find out the influences of 3rd Bosphorus Bridge on the urbanization in Istanbul, four Landsat satellite images were classified. First bridge was built on the Bosporus in 1973 and the second bridge in 1988. Therefore, time periods of the images were determined as 1972, 1987, 2002 and 2009. SLEUTH simulation software was used to predict the urban sprawl of Istanbul for the year 2030. The result of the prediction map was shown that 28.88 % forest and 71.43 % agricultural areas and open spaces will be transformed to urban area.

1. INTRODUCTION

Urban sprawl is unplanned and uncontrolled urban expansion. The European Environment Agency (EEA) has described sprawl "as the physical pattern of low-density expansion of large urban areas, under market conditions, mainly into the surrounding agricultural areas" (EEA, 2006).

To determine urban sprawl, several theories have been developed such as the Monocentric City Model, the Tiebout Local Public Finance Model (Nechyba and Walsh, 2004), the Concentric Zone Theory, the Sector Theory, and the Multiple Nuclei Theory (Yu and Ng, 2007). However, urban sprawl is a dynamic system that contains physical, ecological and environmental parameters, all of which focus on economic and social factors. Therefore, complex systems are used to model urban sprawl (Clarke et al, 1997; Cheng, 2003).

Several data are utilized for monitoring urban sprawl, such as satellite imagery, land use/cover maps, digital elevation model (DEM), digital terrain model (DTM), administrative boundary, topographic maps, aerial photos, ortophoto, geological maps, socio-economic data etc. (Cheng, 2003; Çelikoyan, 2004)

CA is one of the simulation methods which runs subdivided cells of a regular lattice. Future state of each cell is determined by its adjacent cell's state. CA has five main elements, including, space, state, neighborhood, transition rules and time. Each automaton is defined by a set of state , neighborhood of automaton and transition rules.

Various software based on CA algorithm were created to simulate urban sprawl. SLEUTH is one of them and has been used in a lot of projects.

SLEUTH, which was written in C programming language and working under UNIX, has two components; urban growth model (UGM) and land cover deltatron model (LCD). The UGM uses the standard gnu C compiler (gcc) and the LCD is embedded in the code and driven by the UGM (URL 1).

Simulation model is created by four growth rules and five growth coefficients. In the Table 1, relations are shown between growth rules and growth coefficients. Each coefficient value must be between zero and 100 (URL 2 and Sevik 2006).

Growth Rules	Growth Coefficients
Spontaneous Growth	Dispersion, Slope
New Spreading Center	Breed, Slope
Edge Growth	Spread, Slope
Road Influenced Growth	Breed, Road Gravity, Slope, Spread

Table 1: Growth Rules and Coefficients

Self-modification is second level of growth rules. It "is prompted by an unusually high or low growth rate. The limits CRITICAL_HIGH and CRITICAL_LOW are defined in the scenario_file" (URL 3).

SLEUTH is based on CA algorithm and used Monte Carlo Iteration for simulation that is completed in three modes; test mode, calibration mode and prediction mode. Data are tested in test mode to see whether or not they are ready for calibration. In calibration mode which is finished in four steps (coarse, fine, final and derive forecasting coefficients), SLEUTH uses Brute Force Calibration methodology and determines the best fit value for each coefficient at the end of the process (Candau, 2002; Sevik, 2006).

Because of SLEUTH's self-modification qualities, coefficient values that initialize the model for a date in the past (Start_Date) may be altered by the simulation end date (Stop_Date). *"Therefore, for forecast run initialization, the coefficient values at the simulation end date are used to initialize a new simulation into a future date"* (Candau 2002).

After computing the best fit values determined for each coefficient in forecasting mode, prediction mode starts to create simulation model.

The increasing population of Istanbul causes an enormous transportation problem in the city. Overcoming this problem is desired with constructing a third bridge. This bridge joins not only two sides of Istanbul but also the center line of motorway from Edirne to Ankara.

Main purpose of this study was to determine how Bosphorus Bridges and their access roads have an impact on urbanization in Istanbul. Although zone plans that made in the 1960's, suggested the urbanization east-west direction in Istanbul, Bosphorus and Fatih Sultan Mehmet (FSM) Bridges led urban sprawl through northward of them. Most important natural areas that are located in the north side of Istanbul will be under threat if the 3rd Bridge is constructed. The other Bosphorus bridges experiences show that only constructing bridges does not overcome transportation problem, on the contrary each bridge created their own traffic.

In this paper, an alternative route of 3rd Bridge's effect on urbanization was examined using satellite images and created simulation model to predict urban sprawl for the year 2030 using Cellular Automata (CA). The change detection analysis was made to find out land transition from natural area to urban area between the years 2009 and 2030.

Input data were arranged and analyses were made using ArcGIS and Erdas and SLEUTH3.0_beta was used for creating simulation model.

2. MATERIALS AND METHODOLOGY

2.1 Study Area

At the beginning of this study, the 3rd bridge route could not be obtained from concerned institutions and hence announced routes by media were used. In this study, the simulation model was created for red route (Figure 1).

Figure 1: 3rd Bridge Routes (Kabadayı, 2008)

2.2 Data

Only to determine the effects of the 3rd bridge on urbanization in Istanbul, some factors were eliminated, such as socio-economic factors, inner city problems, housing preferences etc. Therefore, four main data were used for this paper, shown in the Table 2.

The historical land use maps were generated by automatic classification of Landsat satellite imagery for the years 1972, 1987, 2002 and 2009 using ERDAS software. Classified satellite imagery and master plans were used to create urban and excluded area (Figure 2). Water bodies, military zones and airports were selected as Excluded Area. DEM data obtained from Istanbul Metropolitan Municipality were utilized for creating Hillshade and Slope maps. Landsat data for the years 1972 and 1987 were manually digitalized for producing road maps. Digitized red route of 3rd Bridge (as shown Figure 1) was integrated with motorways obtained from JICA to create road map for the year 1997.

Data	Year	Data Type	Data Class	Data Source
Satellite Imagery	1972	Raster	Urban Excluded	Landsat 60 m
	1987	Raster	Urban Excluded	Landsat 30 m
	2002	Raster	Urban Excluded	Landsat 30 m
	2009	Raster	Urban Excluded	Landsat 30 m
DEM	2005	Raster	Slope Hillshade	SPOT 20 m
Plans	1980	Vector	Excluded	Master Plan
	1995	Vector	Excluded	Master Plan
	2009	Vector	Excluded	Master Plan
Route and Motorway	1972	Vector	Road	Landsat
	1987	Vector	Road	Landsat
	1997	Vector	Road	Yildiz Technical University

Table 2: Data Structure

A special joint symposium of ISPRS Technical Commission IV & AutoCarto
in conjunction with
ASPRS/CaGIS 2010 Fall Specialty Conference
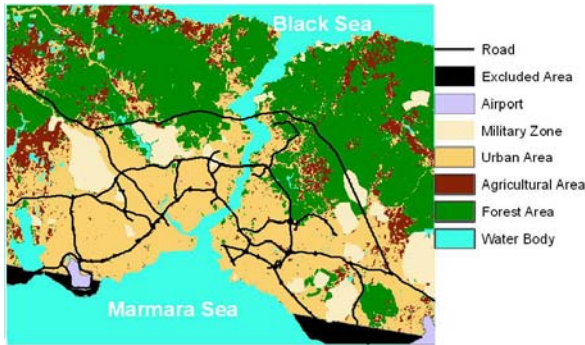November 15-19, 2010 Orlando, Florida

Figure 2: Land Use Map for the Year 2009

2.3 Software and Hardware

The name of SLEUTH was derived from the first letters of the required input data: Slope, Land Use, Excluded, Urban, Transportation and Hillshade. All data must be grayscale GIF images, in the same projection, same map extent and same resolution (row x column count is consistent) and the required naming format as "*istanbul.urban.1972.gif*" (URL 4).

All input data (except land use data) are arranged using with ArcGIS in the Acer Aspire 5920G notebook that has Intel Core 2 Duo processor 2.2 GHz and 2 GB DDR2 RAM. Because of being optional, land use data were not used in this study.

2.4 Creating Simulation Model Using a Cellular Automata

SLEUTH3.0_beta has 14 metrics that were used to evaluate the best fit value of growth coefficients for using prediction mode. These are; Product, Compare, Pop, Edges, Clusters, Cluster Size, Lee-Sallee, Slope, % Urban, X-Mean, Y-Mean, Rad and F-Match. There is no consensus about the metrics to be used during the calibration mode. The compare, population and Lee-Sallee statistics were used in the Washington-Baltimore metropolitan area (Jantz et al. 2004); Dietzel and Clarke (2007) used Optimal SLEUTH Metric (OSM) technique; Sevik (2006), Oguz et al (2007) and Silva and Clarke (2002) used only the Lee-Sallee metric in their applications.

Lee-Sallee metric "*the ratio of the intersection and the union of the simulated and actual urban areas*" (Dietzel and Clarke, 2007) was used in this study.

SLEUTH can be run under Microsoft Windows operation system if Cygwin is used. Cygwin provides that the programs work under UNIX running with Windows.

3. RESULTS

After the calibration mode, the best fit value of five growth coefficients computed as shown in the Table 3. These parameters were used in the prediction mode and simulation stop date was set to 2030. Prediction mode was finished 12 minutes and 42 second and SLEUTH generated urbanization map for the year 2030 in the GIF format. This image was arranged in ArcGIS and created sprawling map of Istanbul (Figure 3).

Growth Coefficients	Value
Dispersion	7
Breed	70
Spread	100
Slope	1
Road Gravity	66

Table 3: Computed Growth Coefficients

To find out transition lands from forest and agricultural and open spaces (Agr + OS) to urban area, change detection analysis was made between land use map for the year 2009 and sprawling map for the year 2030. Transformed area was calculated by multiplying pixel size with pixel counts. The areas are shown as hectare (ha) and percentile area in the Table 4.

As is shown in the Table 4, after constructing 3rd Bridge, min 28 % forest and 71 % agricultural areas and open spaces will be transformed to urban area. This transformation will cause for plundering natural areas.
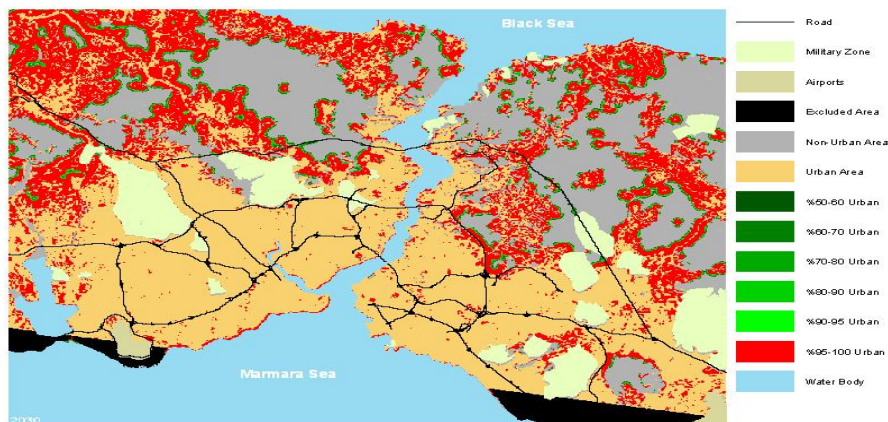

Figure 3: Urbanization of Istanbul for the Year 2030

A special joint symposium of ISPRS Technical Commission IV & AutoCarto
in conjunction with
ASPRS/CaGIS 2010 Fall Specialty Conference
November 15-19, 2010 Orlando, Florida

Year 2009	Year 2030 (%)	Transformed Area (ha)	% Area
Urban Area	Urban Area	67738.68	-
Agr + OS	Agr + OS	18007.92	-
Forest Area	Forest Area	71249.76	-
Agr + OS	50-60	31.32	0.17
Agr + OS	60-70	39.96	0.22
Agr + OS	70-80	68.04	0.38
Agr + OS	80-90	119.52	0.66
Agr + OS	90-95	120.96	0.67
Agr + OS	95-100	12863.16	71.43
Forest Area	50-60	700.56	0.98
Forest Area	60-70	738	1.04
Forest Area	70-80	883.08	1.24
Forest Area	80-90	1239.48	1.74
Forest Area	90-95	1142.64	1.60
Forest Area	95-100	20580.12	28.88

Table 4: Transition Lands from 2009 to 2030

4. CONCLUSIONS

Determining of the effects on urban sprawl has been studied for a long time. In this study, it was aimed to find out the effects of Istanbul Bosphorus Bridges on the urbanization through classifying satellite images into four time periods and to create simulation model for the year 2030. Landsat images, DEM, master plans and digitized route and motorways were used to determine transition lands from natural areas to urban areas

According to change detection analyses between the years 2009 and 2030, if the 3rd Bridge is built on Bosphorus, the most important natural areas will encounter with urbanization threats. This transition is lead to population growth and thus it cannot overcome Istanbul's complex transporting problem because it will create its own traffic problem. To generate a permanent solution, primarily seaway and railway transportation must be supported.

REFERENCES

Candau J. T., 2002, *Temporal Calibration Sensitivity of the SLEUTH Urban Growth Model*, Master of Arts Thesis, University of California, Santa Barbara

Cheng J., 2003, *Modelling Spatial and Temporal Urban Growth*, PhD Thesis, Utrecht University Faculty of Geographical Sciences, Utrecht

Clarke K. C., Hoppen S., Gaydos L., 1997, A Self-Modifying Cellular Automaton Model of Historical Urbanization in the San Francisco Bay Area, *Environment and Planning B: Planning and Design*, 24, pp. 247-261

Çelikoyan, T. M., 2004, *Monitoring and Analysis Of Landuse Changes In Historical Periods For The City Of Istanbul By Means Of Aerial Photography and Satellite Imagery*, PhD Thesis, Istanbul Technical University Institute of Science and Technology, Istanbul

Dietzel, C., Clarke, K., 2007, Toward Optimal Calibration of the SLEUTH Land Use Change Model, *Transactions in GIS*, 11(1), pp. 29-45

EEA, 2006, Urban sprawl in Europe, The ignored challenge, EEA Report No 10/2006, European Environment Agency, Kopenhag

Jantz C. A., Goetz S. J., Shelley M. K., 2004, Using The SLEUTH Urban Growth Model to Simulate The Impacts Of Future Policy Scenarios on Urban Land Use in The Baltimore/Washington Metropolitan Area. *Environment and Planning B*, 31, pp. 251–71

Kabadayi E., 2008, Sadakat İstanbul, Boğazını Koru, Atlas, Vol. 180, Istanbul

Nechyba T. J., Walsh R. P., 2004, Urban Sprawl, *The Journal of Economic Perspectives*, 18(4), pp. 177-200

Oguz H., Klein A. G., Srinivasan R., 2007, Using the Sleuth Urban Growth Model to Simulate the Impacts of Future Policy Scenarios on Urban Land Use in the Houston-Galveston-Brazoria CMSA, Research Journal of Social Sciences, 2, pp. 72-82

Sevik O., 2006, *Application Of SLEUTH Model In Antalya*, MSc Thesis, METU Geodetic And Geographic Information Technologies, Ankara

Silva E. A., Clarke K. C., 2002, Calibration of the SLEUTH Urban Growth Model for Lisbon and Porto, Portugal, *Computers, Environment and Urban Systems*, 26, pp. 525–552

URL 1: SLEUTH Web Page, Overview

http://www.ncgia.ucsb.edu/projects/gig/v2/About/bkOverview.htm (accessed August 2010)

URL 2: SLEUTH Web Page, Growth Rules

http://www.ncgia.ucsb.edu/projects/gig/v2/About/gwRules.htm (accessed August 2010)

URL 3: SLEUTH Web Page, Self-modification

http://www.ncgia.ucsb.edu/projects/gig/v2/About/gwSelfMod.htm (accessed August 2010)

URL 4: SLEUTH Web Page, Input Data

http://www.ncgia.ucsb.edu/projects/gig/v2/About/dtInput.htm (accessed August 2010)

Yu X. J., Ng C. N., 2007, Spatial and Temporal Dynamics of Urban Sprawl Along Two Urban–Rural Transects: A Case Study of Guangzhou, China, *Landscape and Urban Planning*, 79, pp. 96–109

A special joint symposium of ISPRS Technical Commission IV & AutoCarto
in conjunction with
ASPRS/CaGIS 2010 Fall Specialty Conference
November 15-19, 2010 Orlando, Florida

ACKNOWLEDGMENTS