Modeling and Predicting of Future Urban Growth in the Charleston, South Carolina Area

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In the 1970's migration from state to state largely began to take the place of variations in natural increases (changes in birth rates and death rates) as the major force of local population changes (Brown and Wardwell 1980). Migration has continued to increase in the 1980's and 90's and coastal states have become the new melting pots for these movers. Population experts predict that of the 20 states with the largest population growth rates, 17 will be coastal (Beatley et. al 1994). Along with this coastal growth trend, coastal population densities are now four times greater than the national average.

The American Association of Retired Persons (AARP) lists South Carolina as the second fastest growing state in terms of in-migrant retirees and in the top seven retirement locations in the nation. In the late 1970's, South Carolina was still considered primarily rural. It has taken just over a decade to change that status along with the myriad of issues that accompany burgeoning growth. A large proportion of this growth is taking place and will continue to take place along the coast.

Many institutions, agencies and citizens in South Carolina have become concerned about urban sprawl along the coast as well as other high growth areas of the State. While urban growth is economically necessary and unavoidable, uncontrolled growth will lead to urban sprawl and its resultant problems such as: increased cost of living, rising taxes and pressure on infrastructure and urban services, traffic congestion and increased travel time, environmental degradation, loss of farm/forest land, habitats and rural landscapes as well as declines in the urban core with potential community segregation.

This growth projection study, a partnership with the South Carolina Coastal Conservation League and funded by the NOAA Coastal Services Center through the South Carolina Sea Grant Consortium, builds upon another study completed by the Berkeley-Charleston-Dorchester Council of Governments (BCD COG), the University of South Carolina and the South Carolina Department of Natural Resources. That study investigated urban growth in the greater Charleston metropolitan area from 1973 to 1994 and found that over the 21-year period, urban land use growth has exceeded population growth by a 6:1 ratio (BCD COG, 1997).

Theories and Issues

Conflicting views of urban systems: simple vs. complex, static vs. dynamic, ordered vs. chaotic, physical vs. information, close vs. open, have led to a variety of different growth theories and models. Components of models include elements such as, physical urban forms, social characteristics, economic characteristics, cultural characteristics, etc. The question that remains is what represents urban or city, a few key variables or multiple variables? However, no matter what view a modeler holds, there are rules or relationships existing even in a random and chaotic system (behavior of the urban area follows certain rules). It appears that many of the spatial models use only limited numbers of variables or components to represent urban and all the modeling highly relies on computer analysis.

Methodology

The conceptual model involves two basic procedures to predict future urban growth in the BCD/Charleston region. The first one is to predict urban transition probabilities with an array of spatial (with geographic coordinates) data. The second procedure is to set urban growth scenarios with aspatial (without geographic coordinates) data. The combination of these procedures will yield maps of future urban growth as well as scenario series (different growth ratios) and temporal series (growth in each successive year) maps. The data used in this study to build the growth prediction model is listed in Table 1.

Growth Scenario

For the growth scenario, there are two assumptions involved. First, it is assumed that the ratio of overall urban land use change (255%) over overall population growth (41%) over the last 21 years, a ratio of 6:1, will remain the relatively stable for the next 35 years. After much discussion with planners and other interest groups, a more conservative ratio of 5:1 was selected for the final model. Since this ratio is an important index of urban growth, it is used here to determine the urban size for the future. Secondly, it is assumed that population will grow as predicted by the BCD COG with information from the U.S. Census Bureau and the South Carolina State Budget Control Board. In other words as population increases by 49% from 532,688 persons in 1994 to 795,879 persons in 2030, the total urban area should grow by 245% from 250.07 square miles to 868.55 square miles over the same period. National growth rates for population and urban area expansion support this notion. According to Rusk (1997), many metropolitan areas such as Detroit (13:1), St. Louis (7:1) and Baltimore (5:1), not necessarily targeted as high growth areas, have seen similar or higher ratios between 1960-1990 which is even a longer term than the current study used.

Table 1. Database Construction / Data Preparation
Source data

Data Name	Data Type	Scale	Spatial Resolution	Date	Data Source
Nature Environ					
Digital Elevation	Grids	24,000	30 m	Variable	SCDNR
Hydro/Water	TIGER/Line File	100,000		1990	Census Bureau
Soils					
Land Use					
Urban Land Use	Images		30-69 m	1973-94	BCD COG
Land Use76	GIRAS	100,000	90 m	1976	USGS
Land Use89	Images (Classified)		60 m	1989	USC
Incorporated Areas	TIGER/Line File	100,000		1990	US Census 90
Expert predicted	Polygon			1998	SCCCL
Population/Housing					
Population	TIGER/Line File		Census Block	1990	Census Bureau
Projected Pop	Table		County	1999	BCD COG
HU Mean Value	TIGER/Line File		Census Block	1990	Census Bureau
Infrastructure/Facilities					
Roads	TIGER/Line File	1:100,000		1997	Census Bureau
Improved Roads	Line	1:100,000		1998	BCD COG
Planned Roads	Line	1:100,000		1999	BCD COG
Planned Bridges	Line			1999	BCD COG
Water Line	Line			1994	Dept of Commerce
Sewer Line	Line			1994	Dept of Commerce
Approved W	Points			1999	BCD COG (Not Available)
Policy/Social					
Forest Boundaries	Polygon	24,000			SCDNR
Wetland	Polygon	24,000		1989	SCDNR (NWI)
Protected Areas	Polygon	24,000		1983	SCCCL
Zoning Districts	Polygon				Not available

Transition Probabilities

For the prediction of urban transition probabilities, four techniques including logistic regression possibility modeling, rule-based modeling, focus group mapping, and integrated GIS modeling were used in the project. Because the size of the region is too big for high-resolution modeling (parcel level), analysis units were set to 250X250 meters. All the source data were resampled at this resolution before further processing.

Logistic Possibility Model

For the statistical modeling, a multivariate logistic regression model was selected because of the non-linear nature of urban growth problems. Urban growth was measured here only in terms of change in urban area or urban land use.

Rule-Based Model

A rule-based model was developed to further enhance the relative transition probabilities of urban growth. This model was designed to complement the pure statistical model. The rule-based model utilizes various rating, weighting, and ranking techniques through map overlays and map manipulation (map algebra) to create a map of ranked suitabilities or relative probabilities of urban transformation. Table 2 shows the detailed information of layers or significant variables used.

Focus Group Mapping

The third technique used in growth modeling process was focus group mapping. A group of experts, local officials, planners, developers, conservationists and other people who have a profound knowledge of the area and urban growth issues were invited to a number of meetings, or interviewed individually to express their opinions on where the urban area is going to expand during next 30 years.

Table 2. Parameter Estimation of Logistic Regression and Rule-Based Models

Variable Name	B	Standard Error	Wald	Df	Sig	R	Exp_B
Population Density	0.4009	0.0175	522.8579	1	0.0000	0.0934	1.4932
Incorporated City Boundary	1.1701	0.0382	939.8772	1	0.0000	0.1254	3.2222
Road Density	0.0741	0.0018	1737.0420	1	0.0000	0.1705	1.0769
Proximity to Urban	-0.5397	0.0199	734.0140	1	0.0000	-0.1100	0.5829
Wetland Area	-1.4977	0.0515	844.8242	1	0.0000	-0.1180	0.2237
Proximity to Sewer Line	-0.3645	0.0185	389.6267	1	0.0000	-0.0800	0.6945
Proximity to Water Line	-0.0697	0.0191	13.2453	1	0.0003	-0.0130	0.9327
Slope	0.3330	0.0442	56.7579	1	0.0000	0.0303	1.3951
Forest Land	-1.4422	0.0374	1490.7720	1	0.0000	-0.1580	0.2364
Cost Distance to Downtown	-0.0022	0.0003	51.7239	1	0.0000	-0.0280	0.9978
Proximity to Road	0.1221	0.0099	153.0000	1	0.0000	0.0503	1.1298
Constant	-1.6240	0.0801	411.0710	1	0.0000	0.0000	

Integrated GIS Model

An integrated GIS model is designed to fully take advantages of the above three models by integrating them into one. This process can also be treated as a subsequent procedure following the above three because it relies on the results of the first three predictions. In this model, the focus group prediction was weighted 10% while the other two predictions weighted 45% each.

Results and Implications

Spatially, suburban areas closer to the previously developed urban area were well predicted, while the possible development in the periphery areas particularly in Dorchester and Berkley Counties might be slightly under-predicted.

If the current treads of growth in the Charleston metropolitan area continue and the predictions hold true, the future urban growth will mainly take the pattern of urban sprawl. This has several significant economic, environmental, and social implications in policy-making and urban planning.

Economically, there will be an increase of pressure on urban infrastructure and a decrease in efficiency of use of natural and urban resources. As the urban area sprawls, population density and housing density will decrease significantly. The wider spreading residential, commercial, industrial, and service centers require more intra-urban roads, bridges, water and sewer lines as well as other civil services such as fire stations, schools and hospitals. How to balance this need for urban growth with the efficient use of resources is a daunting issue for policy makers and urban planners.

Environmentally, this land conversion often involves destruction, damaging or alteration of natural environments by physically removing the elements of ecosystems, building barriers to natural processes, disposing pollutants to alter natural geo-chemical processes and cycles, and so on. Even if policies and regulations are implemented to protect some areas from being developed, they can not guarantee that these protected areas will not be polluted, especially by surrounding urban runoff.

It should be understood that there are virtually no stringent physical constraints for urban sprawl except for water and wetlands. The developments along the coast and the expansion toward inland areas are expected as long as any driving forces of urban growth exist. A proactive and preventive environmental consideration will be a crucial component for sustainable development in this metropolitan area. High-density or median density or cluster development strategies could be one of the solutions in the future. How to make an urban plan that will protect the wetlands, endangered species, unique landscape, waterfront, and prime land is a great challenge of the city and regional planners and citizens of this area.

References

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