Smart City Research Cluster

Final Research Report, Part 1

FedEx Institute of Technology

Prepare a report that includes the following elements and submit to casanto@memphis.edu or smishra3@memphis.edu by December 31, 2017.

A Planning Support System for Comprehensive Planning and Zoning: A Geospatial Simulation Model of Land Use, Land Cover Change for the Memphis Metropolitan Region

Reza Banai, PhD, Professor, Department of City and Regional Planning,
Co-Principal Investigator
Youngsang Kwon, PhD, Assistant Professor, Department of Earth Sciences,
Co-Principal Investigator

1. **Provide a Research Executive Summary that includes the purpose of your research, your methodology, and key findings.** (500 words)

Urban sprawl in the Memphis metropolitan region is the impetus for our smart cities research project. Arguably, blight, crime, liter, and government inefficiency, among central issues identified by the Memphis Mayor, have sprawl as a principle cause. However, in order to counter sprawl it is essential to first determine its extent.

That first step was taken by a Faculty Research Grant (2016-2017) at the University of Memphis titled, "Mapping the Morphology of Urban Sprawl: A Pilot Study of the Memphis Metropolitan Region," with Reza Banai and Youngsang Kwon as principal investigators. That research motivated a continuation and a proposal to Smart Cities Research Initiative, supported by the City of Memphis and the FedEx Institute of Technology.

We have mapped the morphology of sprawl in the Memphis metropolitan region at three geographical scales—census block group, city and county. Remotely sensed land cover (satellite) and parcel-level land use from county assessor GIS provided spatial data. We mapped both land cover and land use transitions over a decade to determine the spatial pattern of sprawl with an index: Shannon entropy (Fig.). This binary index is considered as a robust measure of sprawl in applied geographical analysis and remote sensing literature. It is commonly computed at the metropolitan regional scale that facilitates comparisons of the extent of urban sprawl in different metro regions. However, the metropolitan-wide entropy index reveals little about the extent of sprawl and how sprawl is differentiated within the city-region—a spatial structure which is unique to each city-region. To surmount this limitation, we compute entropy index at multiple spatial scales that show the differentiation of urban pattern for the Memphis metropolitan region, from block group, to city, and county. As well, we compute the change in entropy values over a period of a decade that indicates whether the urban pattern from the block to the regional scale resembles more or less sprawl. The decade worth of the transitions in the seven land cover types shed additional light on the pattern of sprawl, particularly form greenfield sites to built-up areas.

The suburban and exurban expansion of the City of Memphis into the greenfields of Shelby County and beyond is commonly known, but rarely measured. Our mapping shows the extent of land cover conversions for the period from 2001-2011. It turns out, “planted/cultivated” is the largest proportion of land converted to “developed” or built-up land. Add forest, shrub land, herbaceous, and even wetland and water (0.64), then the proportion of “nature” to development conversion is 1.74%. The significance of this value is realized as a proportion of total land area of the city and county. (Table)*

Land use/land cover change (LUCC) is a critical element of urban growth pattern; hence also gauging future transitions that characterize smart urban development. The metropolitan region is vulnerable to the consequences of urban sprawl, particularly in the impervious, built-up areas in proximity to rivers, creeks, and wetlands posing the risk of local flooding during intensive-rain events in neighborhoods, damaging both ecosystem and property.

The longitudinal land use/cover inventory and conversion transitions facilitated by timely remote sensing and geospatial mapping technologies are a fundamental part of an evidence-based planning process that informs and guides environmentally sustainable future urban growth through comprehensive, long-term planning and zoning.

We used a modified version of Land Change Modeler (LCM) to run multi-layer perceptron (MLP) neural network algorithm in IDRISI’s TerrSet Geospatial Monitoring and Modeling software originally developed by Clark lab, Clark University. The variables (or drivers) tested included land cover maps from National Land Cover Dataset (NLCD) compiled for years 1992, 2001 and 2011, demographic variables at census block group level for 2000 and 2010, road network for 1990, 2000, and 2010, housing and employment density for 2000 and 2010, and parks and open space for 2000 and 2010. Three development intensities (low, medium, high) were determined by percent of impervious area from NLCD and used as a response variable. The potential explanatory power of each variable in transition potential modeling was evaluated by a measure of accuracy rate and skill score. MLP generates predicted class memberships for each of the validation pixels at each iteration and reports the aggregate accuracy as well as a “skill” score. The skill score represents the difference between the calculated accuracy using the validation data and expected accuracy if one were to randomly guess at the class memberships of the validation pixels. The skill score varies from -1 to +1 with a skill of 0 indicating random chance. We ran 10,000 iteration of training and testing with an accuracy of 60.8 %. As a result, the most significant driver in Memphis area was road networks (skill = 0.42) followed by housing density (0.34). Other drivers exhibited skill score less than 0.1 indicating little influence on the transition potential model. As a result, the prediction for year 2040 using business as usual scenario indicated that urbanized pattern consistently spreads outwards (eastwards) with noticeable new development along the road networks (I-385) and periphery of existing developed area.

[Note*: Tables and Figures cited throughout are available upon request.]

2. **Describe any next steps in your research agenda that have emerged from this project. (E.g., Revisions to methodology, new research questions, etc.)** (250 words)

We would like to examine further the forecasting accuracy of the GIS machine learning model in replicating observations for a known year, i.e., extrapolation vs. interpolation to 2040. Since housing density is determined as a significant driver, in a future study we plan to examine an alternative to BAU. Developing future scenarios that depart form BAU, for example, with housing weighted in favor of high density (smaller single family lots, multifamily, duplex) instead of low density single family housing that is prevalent in the Memphis region are plausible applications of the IDRISI- planning support system, with (re)zoning implications.

LCM algorithms simulate the spatial pattern of LUCC over time with 1) Change Analysis, 2) Transition Potential Modeling, and 3) Change Prediction. For economy of calibration, we used only two categories of urban land: "undeveloped" and "developed." In Change Analysis step, the locations of the transitions from undeveloped to developed land are determined in a grid. In Transition Potential Modeling step, a suitability map determines the land development potential. Land development potential is determined by a set of variables (opportunities and constraints) that indicate likely "smart growth." Smart growth drivers are identified in *regional* planning for smart growth which include: A hierarchy of centers (neighborhood, city, and regional) that are connected with multi-modal corridors; mixed use centers and districts; and preserves that connect open/green spaces with trails, and avoid natural area constraints e.g., floodplain, floodway, steep slopes, woodlands, and wetlands. Transition potentials using machine learning algorithms within IDRISI software aid in future investigation of such "drivers" of smarter metropolitan growth.

We would like to extend our planning support tool to develop a scenario that determines what future likely holds for Memphis and Shelby County for the 2040 forecast of land cover/land use particularly given the impact of climate change. Specifically, we would like to incorporate in the planning support model updated floodplain and floodways data that reflect the increased frequency and intensity of flooding in Memphis and Shelby County. This application of our planning support system that reflects natural, ecosystems (constrains) as drivers of a smarter growth recognizes the importance of enhancing the resilience of the Memphis metropolitan region that safeguards both neighborhoods and ecosystems.

During the course of this research we set out to determine if sprawl, which is regarded as a cause of regional inequity--from housing and neighborhood to education and taxation--is also related to blight, which is one of the priority areas identified by the Office of the Mayor. We used data from a recent (2015) survey of the Memphis blighted properties at the census block group level and determined a statistical relation of blight and sprawl. It turns out that blight decays exponentially with distance from Memphis CBD. This finding supplements the algorithmic, albeit aspatial, approaches to measure blight. (Insert two figures). We would like to build upon this investigation with multivariate spatial statistical analysis of blight and sprawl including socio-economic as well as environmental and neighborhood characteristics. Finally, also during the course of our research, we determined something more about sprawl pattern. We used Shannon entropy index for sprawl and Simpsons index for diversity. It turns out that in built-up areas of Memphis and Shelby County in 2010, sprawl and diversity are correlated: In general, when sprawl increases, diversity increases also. (Figure). This observation is helpful in planning and (re)zoning to toward a smarter mix of land use that provides an alternative to sprawl.

3. **List external funding that has been/could be leveraged by this project. Include grants/contracts awarded as well as pending funding opportunities.**

We have identified above substantive areas of future applications of our planning support system. Given the planning and policy relevance of this research project to the ongoing comprehensive planning as well as related current initiatives of the office of the Memphis Mayor, we remain actively engaged in smart cities research with every expectation of the continuation of funding from the City of Memphis as well as other public and non-profit organizations with a mission to further the cause of sustainable, resilient cities and regions. The Assisi Foundation of Memphis is among the non-profit organizations to be contacted.

4. **List any publications / conference presentations that have stemmed from this project.**

Dr. Reza Banai presented preliminary research findings from this smart cities project in November 2017 meeting of the North American Regional Science Association in Vancouver Canada. We are planning to disseminate final results at national and international urban planning and smart growth conferences including forthcoming meeting of the Urban Affairs Association in spring 2018.

5. **Summarize any student involvement in the project (e.g., classes that participated in the project, graduate assistants, PhD students, etc.) and list the number of students involved. Note whether the project has been connected to any doctoral dissertations.**

A Ph.D. candidate from the Department of Earth Sciences has participated in this research project and received partial funding. This participation started with Faculty Research Grant (2006/2007) and its extension with the current Smart Cities Initiative. In addition, the subject-matter of this smart cities research project has spurred a dissertation proposal currently under approval. Both principal investigators are on dissertation committee.