

Smart City Initiative Research Proposal

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

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Overview

Urban sprawl is commonly identified by the spread of population and jobs from city center to the urban edge, disproportionate consumption of land relative to population, leapfrog or disjointed development pattern that induces increased vehicle mile traveled, gridlock on highways and major roads, divested and blighted neighborhoods, reduction and conversion of green fields to impervious land prone to hazardous urban flooding. Emerging research identifies the wide-ranging consequences of the essentially human-made sprawling city - including but not limited to regional (income) inequality, inequity of regional mobility and accessibility to jobs and services in the absence of reliable public transit, physical inactivity (obesity) of an auto-dependent population, increasing demand on city services and infrastructure outpacing ability of local government to supply, finance, and manage services efficiently, and greenhouse gas emissions and climate change. The menacing consequences of human-made urban sprawl are comparable to those of the naturally occurring disasters like floods, hurricanes, and earthquakes.

Our Smart City Research proposal is informed by two developing strands of the literature on smart urban growth and remote sensing/geographic information systems (GIS) science. First, “smart growth” emerged as a movement in the US in the 1990s to counter urban sprawl by promoting compact development (smartgrowthamerica.org). Second, geospatial modeling tools of geographic information science (GIS) with satellite-based remotely sensed imageries facilitate the mapping and modeling of urban development pattern with increasing flexibility and accuracy.

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 unmanaged growth i.e., 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 recent grant from the US Department of Housing to Shelby County is evidence of importance of the resilience of the metropolitan region that safeguards neighborhoods in relation to natural systems. By mapping LUCC, particularly from undeveloped land to urban development, with per capita consumption of land and Shannon entropy index over a period of

decades we determine quantitatively the magnitude and pattern of urban growth—whether closer to a compact form, or to sprawl.

For the purpose of this Smart City Program, we develop a geospatial simulation model of LUCC for the City of Memphis and Shelby County (Figure 1). This model a) describes spatial patterns of LUCC over a period of several decades, and b) anticipates future urban patterns with likelihood of land use/cover conversion based on machine learning science. We measure the magnitude of sprawl longitudinally by per capita consumption of urban land for each decade starting in the 1970s, and the (Shannon) entropy index, which indicates the degree of urban sprawl. A key statistic - consumption of land relative to the growth in population over a forty year span - indicates how the Memphis metropolitan region compares with other U.S. cities with and without an urban growth boundary (UGB) that limits expansion of urban development of the urban, suburban and exurban green fields. The City of Portland OR, which is similar to Memphis in population size and is considered as a model of urban sustainability, designated an UGB in the 1970s to promote conservation of green fields and rural land at the urban fringe, and redevelopment of vacant land within the city limit with access to existing infrastructure.

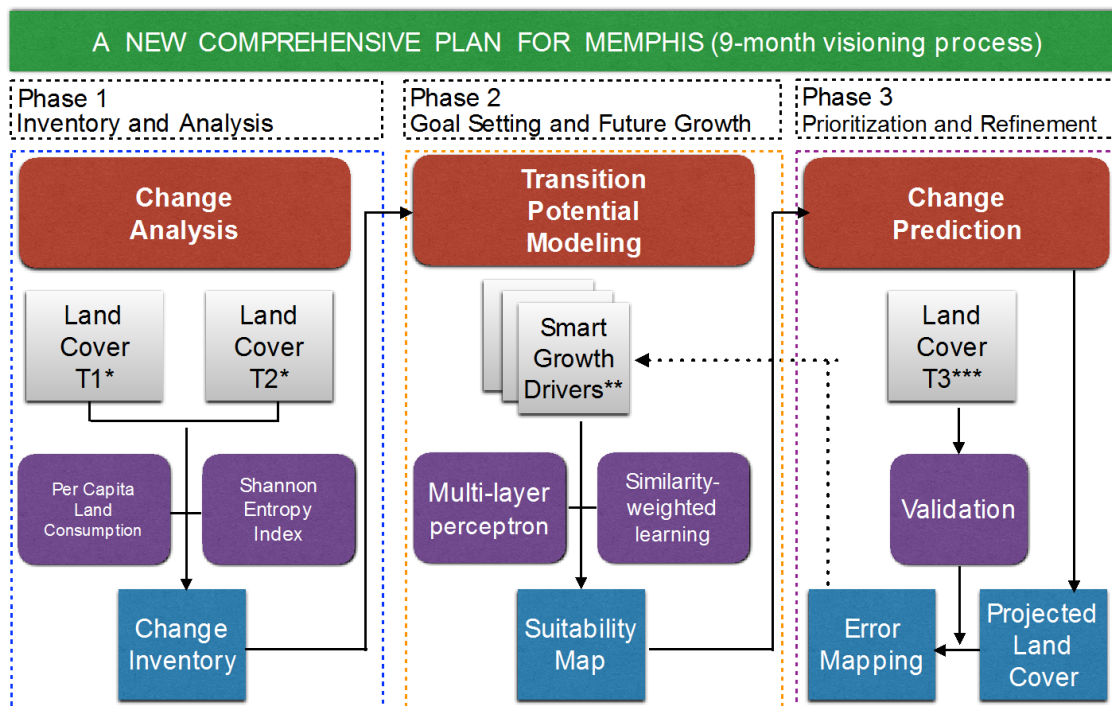
Above all, a longitudinal land use/cover inventory and conversion transitions facilitated by timely, remote sensing and geospatial mapping technologies that predict future growth informs planning for environmental sustainability, and is a fundamental part of an evidence-based planning process that guides efficient future urban growth through comprehensive, long-term planning and zoning.

We are co-principals with expertise in city and regional planning and spatial science in an ongoing University-funded research project titled “Mapping the Morphology of Urban Sprawl: A Pilot Study of The Memphis Metropolitan Region”. We consider the Smart City Program as an ideal vehicle for building on the kind of research that uses technology to inform urban sustainability and public policy we have already initiated, particularly in a potential partnership with the City of Memphis, which is getting ready to prepare a Comprehensive Plan. Funding will make possible a logical next phase of our research protocol, a geospatial simulation model that identifies factors impacting the form of urban growth, and projects transitions into the future, briefly outlined below.

Planning Support System: A brief overview

We use a modified version of Land Change Modeler (LCM) in IDRISI’s TerrSet Geospatial Monitoring and Modeling software originally developed by Clark lab, Clark University. Earth Sciences Department of the University of Memphis purchased multi-seat campus license for teaching and research purposes. LCM is a grid-based empirically driven, stepwise modeling process. 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 use 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 variables are

identified in the new comprehensive planning process by the planning team and community, in alignment with key existing plans including the Greenprint. The presence of multi-modal corridors (transit corridors), hierarchy of centers (urban and regional), districts (industrial; mixed use), and preserves (floodplain, floodway) are commonly identified in planning for smart growth. Finally, transition potentials are modeled using machine learning algorithms within IDRISI software including a multi-layer perceptron (MLP) neural network or a similarity-weighted instance-based machine learning tool. The calibrated transition potential models determine the probability (Markov Chain) and the magnitude of land use/ land cover transition at a future date. LCM accommodates constraints and incentives, such as those identified by planning and zoning, planned infrastructure changes, new roads or built-up land. By using historical rates of land cover change, with Transition Potential Modeling we will construct a future land use/ land cover scenario in deference to the City of Memphis long-term comprehensive plan. The architecture of (IDRISI) Planning Support System is shown in Figure 1.



Notes: *Land cover T1 and T2 denotes land cover maps from year 1970 to 2010 at 10-year interval. T3 denotes the latest land cover map used for model validation. This mapping contributes to phase 1 of the comprehensive planning process, Inventory and Analysis.

**Smart Growth Drivers include multi-modal corridors, hierarchy of centers (urban and regional), districts (industrial, mixed use), and preserves (floodplain, floodway). The Suitability Map aids phase 2 of the comp. planning process with Goal Setting and Future Growth, with “growth, stability, rebirth, and no growth” scenarios.

***Land Cover T3, with Projected Land Cover contributes to Prioritization and Refinement (phase 3) in decision making and (transect) zoning with the choice of desired growth scenarios.

Figure 1: The architecture of IDRISI model of land cover, land use transitions, Memphis and Shelby County.