A Planning Support System for Comprehensive Planning and Zoning:

I. Mapping the Morphology of Urban Sprawl and Blight

II. A Geospatial Simulation Model of Land Use, Land Cover Change for the Memphis Metropolitan Region

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Introduction

To aid the City of Memphis comprehensive planning process, we first diagnose historical pattern of sprawl that a long-term comprehensive plan aims to counter.

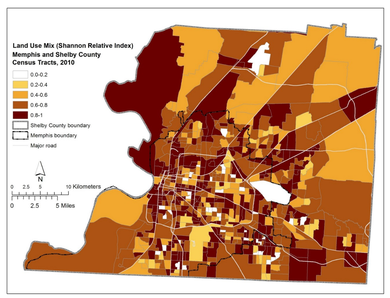
We do this in two parts. We map the sprawl-and, its phenomenally-related, blight- morphology of the Memphis metropolitan region in part I. In part II a geospatial model maps land use trend or "business as usual" projected to 2040. This model provides a decision support system for planning smarter growth alternatives, with efficient public transportation, walkable communities, viable centers, open space, natural resource conservation.

Morphology of Urban Sprawl

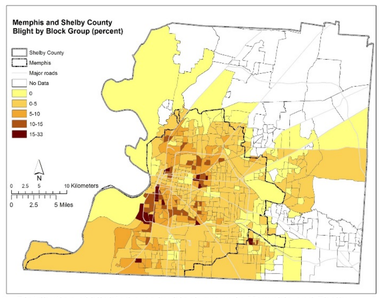
Shannon's entropy index is used to quantify the degree of dispersion.

$$H_n = \sum_{i}^{n} p_i \log(\frac{i}{p_i})$$

where p_i is the probability or proportion of occurrence of a phenomenon in the i^{th} spatial unit out of n units.



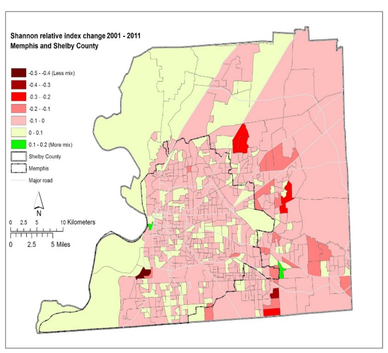
Shannon Entropy Index of Built-up Areas of Memphis and Shelby County by Block Group, 2010.



Distribution of blighted area by block group in Memphis and Shelby County, 2016

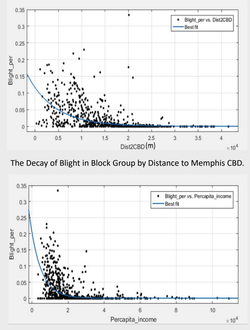
Land cover Transitions

The suburban and exurban expansion of the City of Memphis into the greenfield of Shelby County and beyond is commonly known, but rarely measured. Our mapping shows "planted/cultivated" is the largest proportion of land converted to "developed" or built-up land. The significance of this value is realized as a proportion of total land area of the city and county.



Thus the entropy (H) value can be treated as a critical limit or threshold to the expansion of area. If entropy values can be monitored over years, it can provide quantifiable description of the urban situation to policy makers.

Correlation of Sprawl and Blight



The Decay of Blight in Block Group by Distance to Memphis CBD.

If distance to city center (CBD) is an indicator of sprawl, then it is logical to assume that blight is a consequence of the sprawling metropolis "naturally" expanding outward while the declining infrastructure is left behind.

We observe that the incidence of blight measured by proportion of blighted properties per census block group *y* decreases exponentially with distance *x* from the city core.

Figure (left): The decay of blight with income. Regression between per capita income (as independent variable) and blighted properties area percentage (as dependent variable) for block groups in Memphis and Shelby County 2016

Multi-Layer Perceptron (MLP)

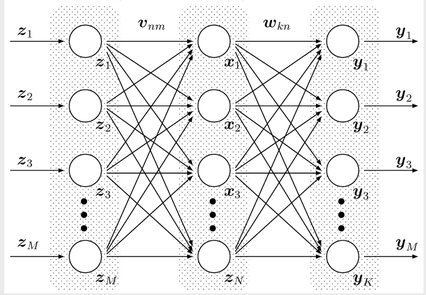
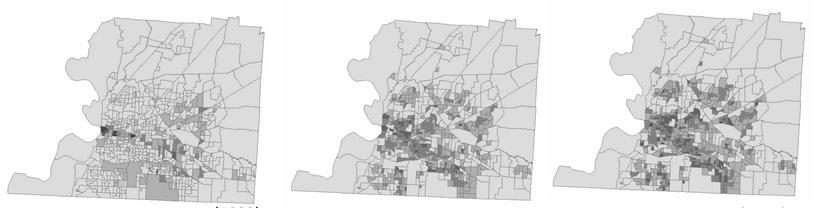


Image source: Isokawa et al. 2012 doi:10.3390/info3040756

List of potential drivers

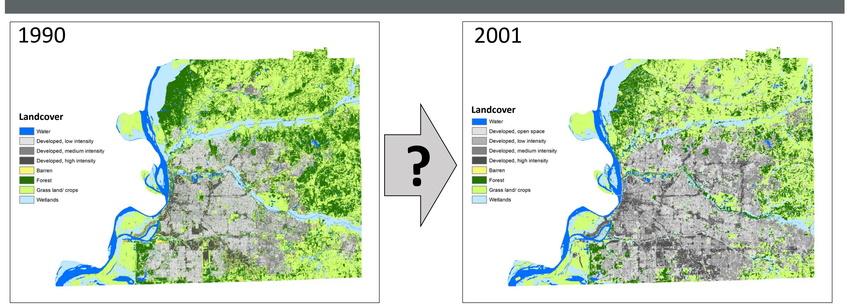
- Land-use mix (in developed areas) per census block
- Employment-to-residential worker ratio per census block
- Housing density
- Parks and open space
- Mode of transportation to work (% auto trips)
- Transit routes and stops
- Areas of natural constraints (growth deterrent): Floodways/Floodplains
- Major roads and highways

Drivers (selected)

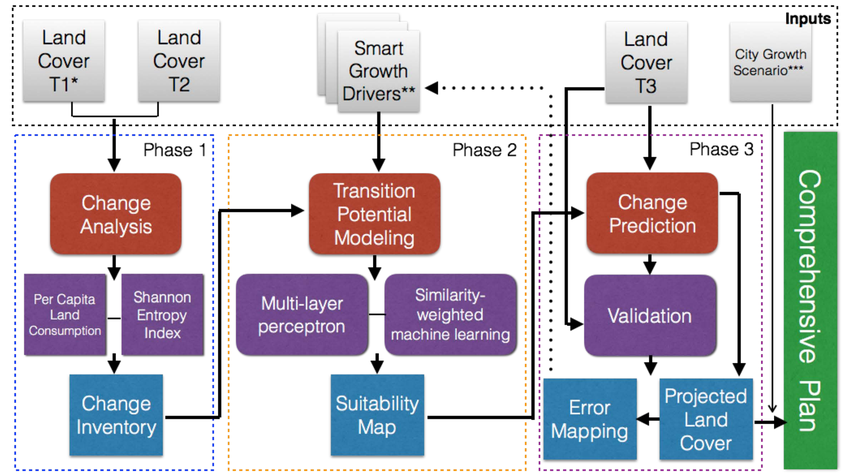


Employment Density (1992) Housing Density (1990) Population Density (1995)

Transition Potential Modeling



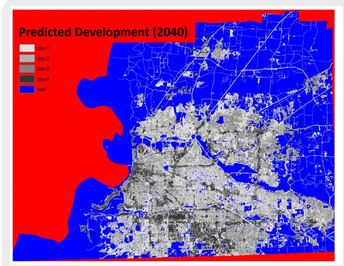
Modeling Work Flow



* Land cover T1 and T2 denotes land cover maps from year 1970 to 2010 at 10-year interval and T3 denotes the latest land cover map used for the model validation.
** Smart Growth Drivers include presence of multi-modal corridors (transit corridors), centers (urban and regional), districts (industrial; mixed use), and preserves (floodplain, floodway).
*** City Growth Scenario is from the 9-month visioning process by the city of Memphis under the New Comprehensive Plan

Legend: Input | Output | Methods

Prediction 2040



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.
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.

Further Research

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.