Data and Technology Base Planning
Connecting GIS Technology and Smart Growth

Geographic information systems (GIS) are some of the newest tools being used to plan and manage the development of cities and suburbs, but are rarely discussed as a driver of smart growth. This session focuses on the technological advances being used to shape compact, pedestrian-friendly communities and multi-modal accessibility to jobs and services. Experts will identify the areas in which GIS is potentially a viable, smart-city technology.

Makeover Montgomery4
Montgomery County Planning Department
National Center for Smart Growth
Silver Spring, MD, May 10, 2018

Advanced GIS Technology and Smart Growth Drivers: A MetaThematic Framework

Reza Banai

Professor of City and Regional Planning

University of Memphis

rbanai@memphis.edu

https://blogs.memphis.edu/rbanai/

Smart Growth Drivers:
A Paradigm Shift with GIS and Geodesign Technologies

Introduction

- From large-scale transportation and activity-location modeling on an IBM computer in the 1950s and 1960s—Detroit, Penn-Jersey, and Chicago Area Transportation Studies—to envisioning the twenty-first century's city and region on desktops and wireless mobile devices.
- From "drivers" of urban growth in the first-generation urban models—**major roads, increased auto ownership, population growth, and decentralization of jobs and housing** (Boyce 2013)--to smarter alternatives--**compact urban form, jobs/housing balance, land-use mix, pedestrian-friendly**, "**shared streets**," **multi-modal accessibility to jobs and services**, **preservation of open space**, conservation of resources, and a resilient city-region in the face of population, economic, and climate change, and natural hazards (Calthorpe and Fulton 2001)
- From low-resolution, auto-centric traffic analysis zones (TAZ) to high-resolution, parcel-level, context sensitive geospatial, planning, and visualization (Landis 2001, McElvaney2012).

Why (GIS) Technology Meta-Framework for Smart Growth

- Smart growth is characterized by multiple, interrelated pillars (themes) of urban sustainability.
- **Smart growth drivers** are organized by GIS thematic features holistically: **Density, Pedestrian-Friendly, Multimodal Access, Land Conservation**.
- GIS technologies facilitate high-resolution, parcel-level, context-sensitive, pedestrian-scale geo-design, planning, and visualization—from the building site to the region.
- GIS- and Geodesign technologies (analysis, simulation, visualization) enhance planning decision making that depends on politics and public's (stakeholder's) active engagement for implementation (Wachs 1985, Waddell 2001).
- Geo-design applications that address smart growth features are scattered in emerging decision-support systems literature.
- GIS technological advancements are rarely systematically discussed in deference to the drivers of smart growth.
- We show how this gap is bridged with a meta-thematic framework.
- Limited scope. We do not include a comprehensive review or assessment of GIS as an urban modeling technology of smart growth.
- We focus on GIS and geodesign technologies implemented with smart city outcomes, rather than those which are in R & D phase.

A Meta-Framework for Thematic Mapping Applications:
Selective Criteria, but not Exhaustive Case List

- Organized by smart city features e.g., density, mixed land use, transit-oriented that are thematically mapped and implemented with (GIS) geodesign technologies.
- Limited to GIS applications that target smart city drivers (sustainability's 3-Es, resiliency, climate change)
- Decision-support systems (DSS) and geodesign technologies that have been implemented and resulted in smarter city outcomes are highlighted, rather than those that are in design or refinement phase.
- First generation technology of large-scale, computer-aided transportation and activity location that resulted in mainly sprawling, car-dependent urban form are not included.
- Are cities or regions placed on a smarter, sustainable trajectory by using geodesign technology judging by outcomes realized or expected?

Cases and Outcomes

Environmentally-Sensitive Urban Form

- *Woodlands (Montgomery County!) TX*. Environmentally-sensitive suburban master planning.

The master plan is framed by storm drainage systems; protected hydrological corridors function as “green ribbons” that shape the urban form (Steiner 2014). Ecological planning and design principles with McHarg’s (1969;1994) *Design with Nature*—are conceptual foundation of GIS with map overlays that determine land suitability for urbanization or conservation.

Woodlands Town Center (Wikipedia)

Cases and Outcomes

TOD, Pedestrian-Friendly Accessibility

- *Portland OR*. Land Use, Transportation, Air Quality Connection (LUTRAQ)—Portland's light-rail extension, feeder bus service, and TOD (Calthorpe and Fulton 2001). LUTRAG filled a gap created by computer models insensitive to walkable, bikable, transit-friendly urban form. Spatial Enhancements:
    - Pedestrian Environment Factor (PEF): street crossing, sidewalk continuity, local street network, topography
    - Urban Index: Density of jobs (walkability of local destinations), and street intersections density.
    - Not a GIS, however, the spatial scale is GIS-like, high resolution.

Portland OR (web image)

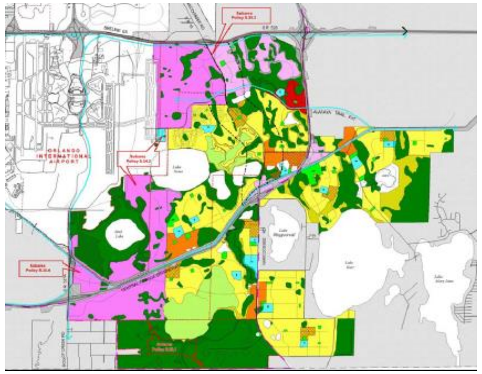
Cases and Outcomes

Environmentally-Sensitive Urban Form

- *SE Orlando*. Mapping SE Orlando's greenfield site, wetlands, habitat, greenbelts mapped as preserves in a network of connected open space, drainage, and habitat protection. The open space network and circulation system (rail transit) frames the design of preserves, infrastructure, mixed use, districts, neighborhoods, village centers, and town centers (Calthorpe and Fulton, 2001).

Drivers:

- Preserves (wetlands, habitat areas)
- Open space network
- Transit
- Mixed-use
- Density



SE Orlando
www.cityoforlando.net/greenworks/wp-content/uploads/.../SEOSPwebNov2012.pdf

Cases and Outcomes

Multi-Modal Mobility

- *Medley, and Miami Dade County.* Integrated land-use /transportation planning is aided with GIS data analysis of traffic and pedestrian routes, and identification of suitable transit corridors.

  Drivers:
  - Jobs Growth
  - Land Use–Transportation Connection
  - Transit
  - Biking
  - Connected open space
  - Walkable urban thoroughfares
  - Complete streets

Sources: http://www.miamidadetpo.org/smartplan-land-use-planning-visioning.asp
http://www.miamidadetpo.org/library/studies/medley-multimodal-mobility-study-2017-11.pdf

Cases and Outcomes

<u>Climate Change-Compact Urban Development</u>

- *Visioning Florida 2050.* GIS-aided modes of regional urban form with stakeholder participation and collaboration, evaluation of scenarios and choice (McElvaney 2012; myregion.org).

  <u>Drivers:</u>

  - Population Growth; ecosystem preservation
  - Mixed Land-Use (retail, commercial, multi-family-residential)
  - Centers (growth in urban cores)
  - Corridors (high density, mixed-use rail)
  - Conservation (regional connection and preservation of ecosystems)

Source: East Central Florida 2060 Plan
www.cityoforlando.net/wp-content/uploads/sites/12/.../2010-08-30_2060plan.pdf

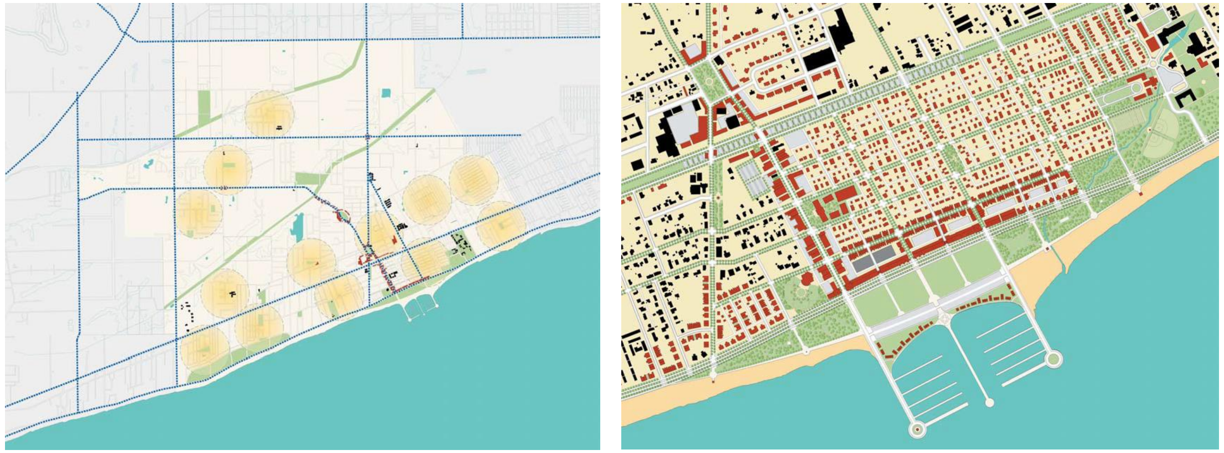
Cases and Outcomes

Compact Urban Development

Long Beach, D'Iberville, MS. GIS identifies parcels for coastal redevelopment planning and design after Katrina (Nicholson 2014; www.mississippirenewal.com 2015). The mater plan and smart code rezoning are implemented partially; Urban development is faster in rural rather than urban lands (Nicholson 2014).

Drivers:

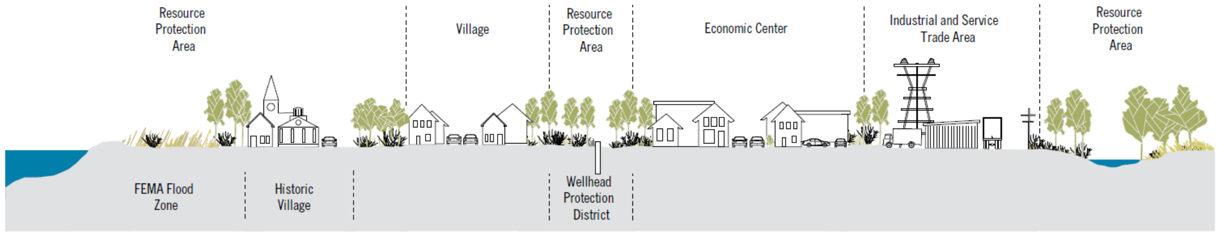
- Hurricane Katrina
- Compact urban form
- Walkable downtown; mixed use, open space
- Housing type variation
- Access to nature; Sustainable Development



Long Beach, Pedestrian sheds & thoroughfare proposed framework; Master plan proposal.www.mississippirenewal.com (2015)

Climate Change-Compact Urban Development

- *Cape Cod*. A GIS to design a compact future growth that is responsive to climate change (McElvaney 2012; capecodcommision.org). Geocoded spatial information and computation: distances, densities, networks; geodesign-aided participatory planning. Drivers:
  - GHG, Sea-Level Rise
  - Population Growth
  - Ecosystem preservation
  - VMT Reduction
  - Residential and employment Density
  - Neighborhood Design
  - Land Use Diversity
  - Proximity to Destination
  - Distance to transit



Cape Cod Regional Policy Plan, Source: www.capecodcommission.org

Cases and Outcomes

Infill- Brownfield/Greyfield Sites

New Haven, Connecticut. Socio-economic index, smart growth index, and environmental index with a GIS to identify Brownfield redevelopment sites (www.cfgnh.org; see also Wheeler 2014).

Drivers:

- Existing infrastructure
- Savings in local government infrastructure
- Expansion of housing, service types and densities, land use mix
- Proximity to jobs and services, amenities
- Multi-modal accessibility
- Alternative to greenfield sites/ Open space preservation
- Urban revitalization incentives

Source: www.cfgnh.org

Cases and Outcomes

Equitable Growth- Housing in the Urban Core

Nashville, TN. Maximizing affordability and minimizing dislocation in the urban core. Mapping opportunity in neighborhoods comparatively with GIS (Housing gentrification equitable development, 2014).

Drivers

- Transit and auto access
- Healthy food access
- Proximity to parks and open space
- Distance to toxic sites
- Housing and Neighborhoods
- Education
- Poverty
- crime


Source: www.Nashville.gov/housing gentrification equitable development pdf

Cases and Outcomes

Climate Change-Green Infrastructure

Richmond California. A web-based tool integrates technical and community input

<u>Drivers</u>

- Urban heat island reduction
- Carbon-free, trail and transit access from residence to connected destinations
- Water-smart parks, percolating green alleys, ground water recharge
- Coastal shoreline parks and natural lands for protection of neighborhoods from coastal and riverine flooding

Richmond CA's core objectives of a strategic, web-based tool.
Source: https://web.tplgis.org/richmond_csc/; For Boston's, Nashville's and Cleveland's climate-smart planning and decision support systems, see The Trust for Public Land, Planning and GIS.

Cases and Outcomes

Climate Change-Compact Urban Development

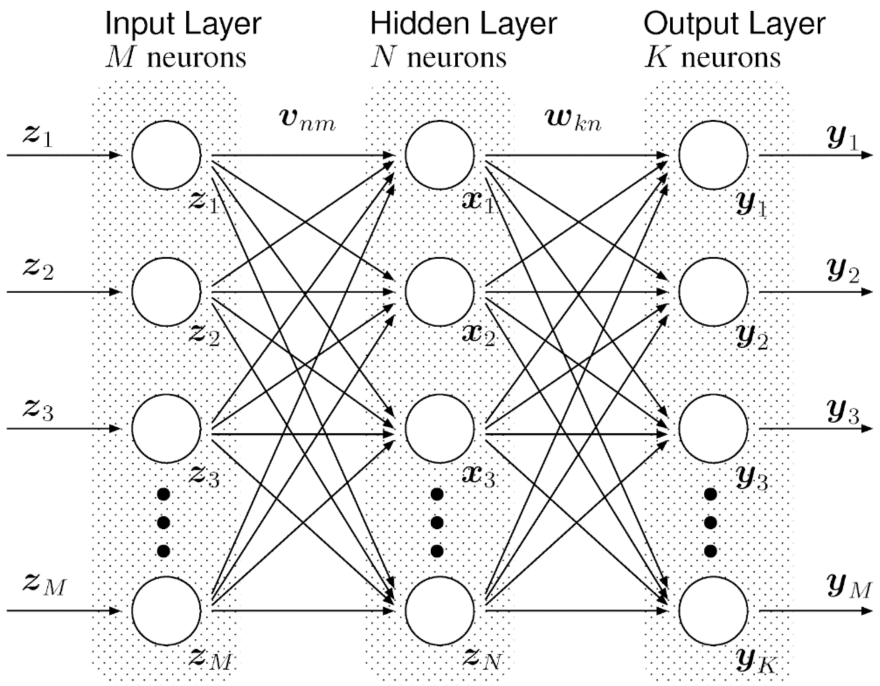
- *Singapore's Jurong Lake District*. District-level master planning with 3-Es (McElvaney 2012). GIS-aided evaluation of urban form alternatives.

  Drivers:
  - Rapid urbanization; Climate change
  - Land use balance
  - Access (parks, local services—retail, medical)
  - Shading (building/landscape pedestrian space)
  - Place making (access to quality gathering place)
  - Operational synergy (access with venues to Lakeside)
  - Ecological integration (connected parks)
  - Carbon footprint (% reduction)
  - Urban heat island

Jurong Lake District, Source: web image.
See also https://www.youtube.com/watch?v=Q8TT9y4Ge7M

Projecting Land Use Futures with a Smart (Machine Learning) GIS

Multi-Layer Perceptron (MLP)



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

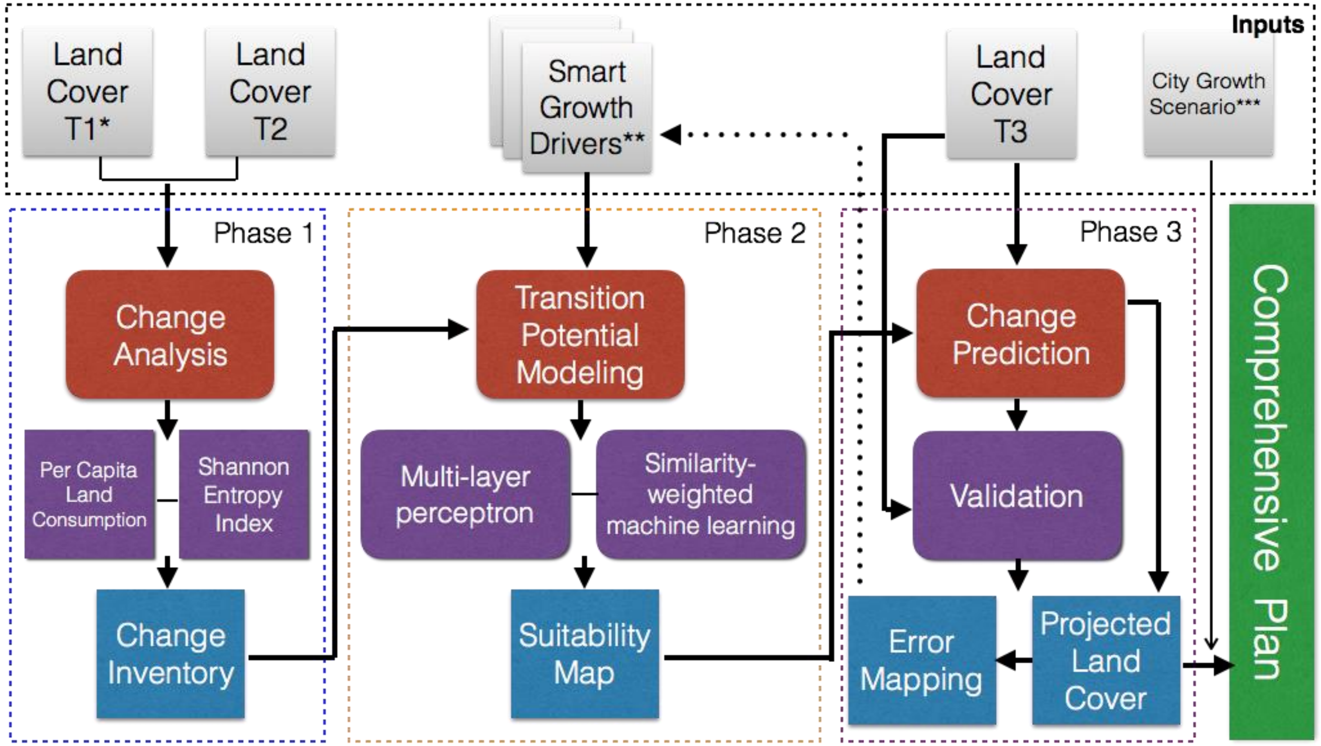
Selecting Drivers of Urban Growth

Employment Density

Housing Density

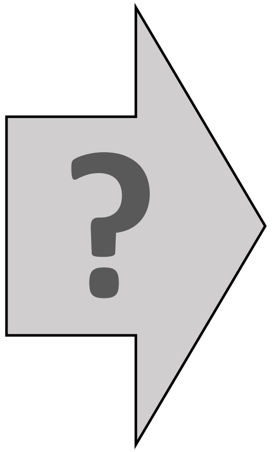
Population Density

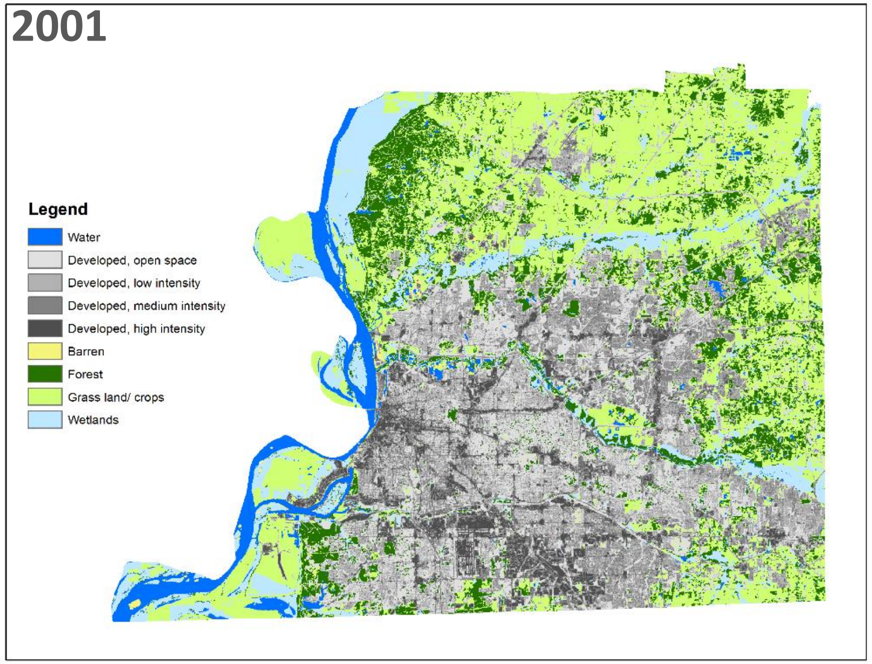
Modeling Process



* 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

Modeling Transition Potential





Land Development "Business as Usual" Projected to 2040 for Memphis and Shelby County

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 (Banai and Kwon 2018).

Takeaway

- Drivers of urban growth have evolved from major roads, increased auto ownership, population growth, and decentralization of jobs and housing (Boyce 2013)--to smarter alternatives--compact urban form, jobs/housing balance, land-use mix, pedestrian-friendly, “shared streets,” multi-modal accessibility to jobs and services, preservation of open space, conservation of resources, and a resilient city-region in the face of population, economic, and climate change (Calthorpe and Fulton 2001).
- GIS technologies have evolved from a basic inventory and mapping toolkit for multi-criteria land suitability assessment (e.g. TOD) to smart, “machine learning” GIS prediction of future land use to facilitating interactive, online, real-time public decision making among alternative, sustainable urban and regional futures.
- Multicriteria thematic features of GIS are particularly suitable for smart growth drivers that are inherently spatial (e.g. density, intensity, proximity) from small scale of “complete streets” to the larger regional scale of districts, multi-modal corridors, mixed use centers, and connected preserves and open spaces(Calthorpe and Fulton 2001).
- Smart growth outcomes are not achieved with GIS and geodesign technology or data alone. Environment, (market) economy, and social and political context of planning and decision-making matter.
- Public planning, legislation (state-enabled), community support are instrumental to fulfilling smart city goals. Ex: 1000 Friends (OR), Portland’s Transportation Rule, Urban Growth Boundary, Minnesota’s (Minneapolis-St. Paul Metropolitan Area) sales tax for transit, Maryland’s Funding Priority Areas.

Takeaway

- GIS-based DSS inform “stakeholdes” about the rational, technical steps of the planning process--analysis, simulation, visualization--inclusively and transparently, and thereby reconcile the technical and political dilemma in a planning decision making and implementation process that depends on politics and empowered, engaged public (interest) (Wachs 1985, Waddell 2001).
- A fundamental tension between incremental (project) and comprehensive (master plan) poses anew in planning for smart growth as “all of a piece,” e.g. TOD, or TND (Banai 1988, 2013; Nicholson 2014).
- Comprehensive view of smart growth is beneficial with long-term outcomes. For example, joint transit-land use-planning and zoning that averts gentrification; density and mixed land use that supports transit which promotes walkable neighborhoods.
- Smart growth features mutually beneficially interrelate: A compact, pedestrian-friendly city is good for public safety and transit, and land conservation. A GIS is particularly suitable technology to “map” the multiple features of smart growth thematically, which are weighted differently in different context, reflecting local priorities.
- GIS technology meta-framework informs local planning and decision making to fine-tune smart city pillars that are context-specific, reflective of community values and priorities.

References

Banai, R. 2013. Plan vs. Project Dilemma in Urban and Regional Studies Revisited: A Progress Review of Urban and Regional Studies *Urban Studies* 50, 4: 807-824 http://usj.sagepub.com/content/50/4/807

Banai, R. 1988. The New Urbanism: An Assessment of the Core Commercial Areas, with Perspectives from (Retail) Location and Land Use Theories, and the Conventional Wisdom *Planning and Design* 25: 169-185

Banai, R. 1988. Transit-Oriented Development Suitability Analysis by the Analytic Hierarchy Process and a Geographic Information System: A Prototype Procedure *Journal of Public Transportation* 2,1: 45-67

Banai, R, Kwon Y. 2018. A Planning Support System for Comprehensive Planning and Zoning: A Geospatial Simulation Model of Land Use, Land Cover Change
for the Memphis Metropolitan Region, Smart Cities Research Initiative FedEx Institute of Technology, Memphis, TN

Boyce, D. 2013, Urban Travel Forecasting: A 60 Year Retrospective

Boyce, D., and H. Williams 2015, Forecasting Urban Travel, Edward Elgar

Calthorpe P and Fulton W 2001 *The Regional City:,* Island Press, Washington

East Central Florida 2060 Plan, Implementing the Regional Vision,

www.cityoforlando.net/wp-content/uploads/sites/12/.../2010-08-30_2060plan.pdf

Landis, J 2001, CUF, CUF II, and CURBA: A Family of Spatially Explicit Urban Growth and Land-Use Policy Simulation Models In *Planning Support Systems* Brail R. K. and Klosterman R.E. eds., ESRI Press, Redland, CA

Long Beach Gulf Coast MS *(2005)* Ayers, Saint, Gross, http://www.mississippirenewal.com/documents/Rep_LongBeach.pdf

McElvaney, S. 2012, *Geodesign: Case Studies in Regional and Urban Planning*, Esri, Redland CA

References

McHarg I. 1969/1994. *Design with Nature* Natural History Press, Doubleday, Garden City, New York; second edition, John Wiley and Sons, New York

Nicholson, H. 2014. "Smart Growth and New Urbanism: The Implementation of Development Plans Eight Years after Hurricane Katrina on the Mississippi Gulf Coast" (2014). *Honors Theses*. 260. https://aquila.usm.edu/honors_theses/260

Southeast Orlando Sector Plan--Transforming Suburbia (2012) East Central Florida 2060 Plan

www.cityoforlando.net/wp-content/uploads/sites/12/.../2010-08-30_2060plan.pdf

TerrSet Geospatial Monitoring and Modeling System - Clark Labs www.clarklabs.org

www.cityoforlando.net/greenworks/wp-content/uploads/.../SEOSPwebNov2012.pdf

Waddell P. 2001 Between Politics and Planning: UrbanSim as a Decision-Support system for metropolitan planning In Planning Support Systems Brail R. K. and Klosterman R.E. eds., ESRI Press, Redland, CA

Wachs, M. 1985. Management vs. Political Perspectives on Transit Policy Making *Journal of Planning Education and Research* 4,3:139-147

Wegener, M. 1994. Operational Urban Models *JAPA* 60,1: 17-29

Reading further

Brownfield: For GIS applications of brownfield inventory and redevelopment in Piedmont Triad Regional Council and South Bend Indiana, see:

http://www.ptrc.org/index.aspx?page=461

http://www.esri.com/news/arcnews/spring11articles/south-bend-indiana-uses-gis-for-brownfields-inventory.html

Equitable Development: Mapping "opportunity" in Nashville's Urban Core, see:
https://www.nashville.gov/Portals/0/SiteContent/Planning/docs/NashvilleNext/ResourceTeams/Housing_Gentrification_EquitableDevelopment.pdf

Climate Change- Planning for Resilience: For GIS applications for Resilient New Orleans, with park, open space, and green infrastructure, see:

https://web.tplgis.org/nola_csc/ The Trust for Public Land, Planning and GIS

Climate Change- Planning for Resilience. For a web-based decision support tool for collaboration and science-based prioritization of green infrastructure for Boston MA, see:

https://web.tplgis.org/boston_climate/ The Trust for Public Land, Planning and GIS