Planning support systems and planning across scales: Comparing scenarios using multiple regional delineations and projections

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Abstract

Planning support systems often employ urban models that simulate and evaluate impacts of plans. Their application to plan making is however, challenging when issues transcend local jurisdictions, and model assumptions are contested by the stakeholders. Neglecting the role of such specifications, especially when they are important *and* uncertain, can diminish the efficacy of plans. In this paper, we use the principles of scenario analysis to illustrate the impacts of two such important considerations – forecasts and regional boundaries – on model outcomes and related decisions. We use Montgomery County, MD as a case and leverage a model developed for a larger region, i.e. the state of MD and vicinity. We develop two sets of scenarios – one where the county (a local government) freely competes with its neighboring jurisdictions for development and another where a higher (i.e. a regional or state) level agency controls the extent of development that the county can receive. The scenarios are constructed using different specifications for regional boundaries and also results in different amount of growth in the County – both rare practices in scenario analysis with models. We then compare the outcomes on a set of indicators and draw implications for planning. We conclude with the argument that planning agencies should compare future scenarios not just with different desirability but different sets of assumptions and regional formulations.

Keywords: planning support systems, scenario analysis, uncertainty, regional planning, assumptions

INTRODUCTION

Debates on the value of urban models in metropolitan plan making are not new. Throughout this debate, however, modelers and planners have developed techniques that have improved 1) the predictive abilities of models, 2) the integration of multiple models such as, land use and transportation, and 3) the visualization of outputs and development of useful indicators. These efforts have added to the toolbox and the value of tools in assessing and communicating impacts of plans and decisions.

Many classifications of models and modeling approaches have been made (Klosterman 2000, Batty 1994). According to Batty (1994), *modeling as a science of planning* and *modeling as a strategic tool to further cooperation* are distinct approaches. While one is driven to better explain the relationships between the components and characteristics of the built environment, the other should facilitate decision-making in a public process by illuminating various complexities of urban systems and stakeholder values. In this paper, we focus on the latter by establishing and addressing a gap between modeling and practice.

A lot of work has been done in this area particularly, in the development of *planning support systems* that can capture a range of plans and policy specifications, *multi-criteria decision analysis* models that compare outcomes according to stakeholders' values, and *scenario planning* approaches that provide a framework for the process. In practice, these approaches are used in combination to generate and compare alternative visions of the future (Chakraborty 2010). From these analyses, often a single desired, or preferred, future is selected. Policies are then developed to help achieve that future (Hopkins and Zapata 2007, Avin and Dembner 2001).

In case of large regions, implementing resulting policies coherently requires buy-in from a wide variety of stakeholder that can be difficult to achieve, and inability to do so can leave the plans less effective than desired. Moreover, when such unitary plans or policies are based on important and yet uncertain assumptions, their effectiveness can vary a great deal on the actual variations in assumed trends. This limits achievability of preferred futures due to lack of decision-makers control on external forces (Chakraborty et al. 2011) can also cause decisions to produce unintended or undesirable outcomes. Another aspect of the conventional practice to identify and make policies for a preferred future as that it is a useful tool to mobilize community support towards a shared vision. A process oriented to such ideas can bring divergent interests together. While this purpose has merit, it has been argued that given the political nature of plan making, urban models should also be used to illuminate the complexities of urban systems. This includes evaluating the impacts of competing and alternative choices made by different actors[1], and in turn providing each stakeholder unique insights in how plans and decisions, under different assumptions and conditions can affect each of their own specific interests and overall regional outcome. A way to advance this purpose, as we argue and demonstrate, is to recognize the role of

[1] Actors are the decision-makers and stakeholders at city, county, state and federal levels.

assumptions and other specifications in the model outcome. We develop alternative scenarios to illustrate how considering different assumptions and model specifications can help identify useful strategies suitable to heterogeneously governed regions. This, we conclude, adds value especially to large regions and planning process with multiple stakeholders.

Problem Statement: We posit the following:

> *When models attempt to address challenges that transcend jurisdictional and other boundaries, specifications can limit the outcome of an analysis, sometimes to the detriment subsequent decisions and plans. Developing and examining scenarios that represent outcomes of the different assumptions and specifications can illuminate these limitations and allow identifying and equipping us with necessary strategies for multiple possible futures. Furthermore, identifying and adopting suitable, and complementary, strategies within the existing fragmented jurisdictional set-up can be a better approach for regionally coherent policies that attempting to implement a consensus-based plan for all agencies in the region.*

In the rest of the paper, we proceed as follows. In the next section, we establish the limitations of current approaches to modeling and scenario planning in multi-stakeholder processes. Then we explain the objective of the paper. In following section, we discuss our dataset and models and choice of study area. Then we present our analysis and results. We offer some concluding thoughts in the final section.

THE GAP BETWEEN URBAN MODELING AND PLANNING PRACTICE

Multiple studies over the years have reviewed and critiqued the role of urban models and planning support systems in planning practice (see, for example, Klosterman and Brail 2001, Geertman and Stillwell 2003, Geertman 2006, Hopkins and Zapata 2007). In this section, we establish how they wrestle with the complexities of planning practice in large regions, specifically, those surrounding forecasting growth and selecting regional boundaries. We organize the relevant literature into three streams: 1) potential of scenarios to address complexities of plan making processes; 2) limitations with respect to the use of planning support systems and 3) their underlying modeling approaches; and 4) spatial planning and the confounding effects of institutional rigidity.

Scenarios, Complexity and Plan-Making Processes

In the United States, most urban plans are outcomes of strategic decision-making processes involving multiple actors. Planning processes have attempted to engage these actors through evaluation of alternatives that consider a range of choices, interests and viewpoints. Planning support systems have provided analytical and visual mechanisms to structure these processes. As a framework, evaluation of alternative outcomes of decisions, i.e. scenario analysis, has been central to the practice of plan making (Chakraborty et al. 2011). From a strategic standpoint, scenario analysis has been used to think about multiple facets of the problem simultaneously and as a tool for addressing the uncertain future in light of the limited cognitive and computational capacity of individuals and organizations. In particular, it is a tool that fosters imagination as well as critical thinking about how a future might unfold. Since its pioneering application by the RAND Corporation as epitomized by Kahn (1962), it has been used widely in various disciplines ranging from businesses to military applications (Van der Heijden 1996).

Smith (2007) argued that scenarios can be used in a number of ways and in the regional planning context should be used mostly as a tool for prioritization, oversight, and conversational. Where a participatory paradigm is important, using scenarios as a means of thinking collectively about what to do in different futures should foster thinking of a contingency nature, i.e. if _____ then _____. Neuman (2007) has discussed how scenario planning can encourage planners to dissolve geographic and conceptual boundaries and consider impacts and solutions that extend beyond them. Avin (2007) suggests that scenarios should inform urban plans by creating a platform for public engagement of various groups. Building on earlier work, Avin articulates a 12-step mechanism that includes constructing possible futures as distinct from desired futures. He suggests that these futures with intervention options will provide a framework to evaluate them. Nevertheless, the case studies that follow these prescriptions of the process do not make clear how these interventions are different and distinct from the forces that are producing uncertain effects and how one should make plans, given these interactions.

In the practice of metropolitan planning however, the use of scenario planning has been skewed towards formulating an argument for picking a ‘preferred future’ as opposed to the status quo or business as usual (see e.g. Council of Fresno County Governments 2009), in direct contrast with the contingency framework of scenario planning. Also, as this review will demonstrate, the participatory framework should be not only capable to compare alternative scenarios, but also serve other purposes such as, create plausible alternatives, facilitate questioning institutional rigidities, and radical changes in external forces. The planning support systems used in these approached should also be able to handle these considerations effectively.

Planning Support Systems and Complexity

In metropolitan planning with its interacting temporal and spatial phenomena, it is almost implausible to think about scenarios without resorting to some version of a planning support system (PSS). Many of these tools offer planners the ability to view complex data, to forecast potential outcomes of decisions and anticipate their implications, and more recently, to communicate these to the wider public. Despite their promise however, PSS have been largely used to – and designed to – facilitate plan evaluation, not plan making (Batty, 2004).

This disconnect is evident in many of the critiques of PSS. Avin (2007) warns that they should only be used to aid planning processes and create a platform for engaging with diverse stakeholders, not define the process. He adds that indeterminate factors are they key and those most likely to influence future outcomes should be included. Such considerations should be generated through the planning process, and multiple sets of variables should be tested. In practice however, the indeterminate factors are often given less than due consideration and are usually externally specified. For example, the Metropolitan Planning Organizations are required to identify the most likely 25-year growth forecasts within their region, evaluate its impact on the infrastructure and then, plan for them. The processes are often separated and developing specifications are a precursor to, and not a part of, the planning process. At other times, they are arrived at too rapidly or too early in the process and once estimated they are termed “givens”. The *givens* then carry through the rest of the process, in effect solidifying and multiplying the potential for error.

Scenarios analysis literature shows us how to tackle this separation and linearity by using the notions of *strategic thinking* (van der Heijden, 2006). For example, Hopkins and Zapata (2007) suggest that planners should move away from the idea of *preferred* futures and replace it with analysis of *possible* futures that incorporate more than the most likely future conditions. Such a move can ensure that a wider set of uncontrollable effects and conditions can be considered (e.g. supra-regional factors). They admit that such approached would need planners to make multiple plans. Another aspect of this is balancing increasing technical sophistication of models with the needs of communicating model outcomes in ways that can facilitate decision-making, For example, Batty (2004) has argued that the development of most models has been driven by advancement in GIS and remote sensing technologies but are still only abstractly related to cities as emergent complex systems. Practical applications for planning processes need to be driven by bottom-up driven concerns. As Batty writes: “[T]echnology interacts with policy in diverse, symbiotic ways which develop tensions that get resolved by changes in culture and context as much as by adaptation of the science behind the technology or the technology itself” (p 329). Thus “good” models are those that can be adequately adapted to the problems at hand in the local or specific context.

Klosterman (2001) reviewed a specific GIS based PSS called *What if?* While he notes the utility of PSS for decision makers seeking to broaden and inform public dialogue, he adds that its effectiveness is ultimately limited by the user-specified assumption. Similarly, Geertman (2006) has suggested that technology can often outpace planners capabilities and framing of problems requiring a dynamic interconnected with each informing the other in an adaptive utilization, ultimately dependent on a conceptual framework sensitive to context. The above critiques, and there are many others, suggest that it is critical to recognize the capacities and limitations of PSSs and, ultimately, chose an approach that captures the important complexities of the context.

Land Use Models in Planning Support Systems

Planning support systems are often at the interface of underlying models and the decision-making processes. The underlying models are characterized by their heterogeneity, hierarchical structuring of urban phenomena and approaches to deal with exogenous factors. They can be organized into two broad categories: top-down and bottom-up models. Top-down models employ regression, econometric and statistical approaches represent system relationships between aggregate variables depicting best fit of the data. Because of its generalized nature, top-down models are useful for revealing relationships in land use data and used for forecasting purposes. On the other hand, bottom-up models such as agent-based or cellular automata models start from a general understanding of the low-level processes and elements, and generate aggregate system behavior by simulating the individual entities in the system.

Top-down models often estimate regional growth projection first, and then allocate it among the constituent sub-geographies. In the US, this practice is employed to develop metropolitan or state level projections that are then allocated down to county level and sometimes further down to traffic analysis zones. Top-down models have been used in management of natural resources (Castella et al. 2007), simulation of system dynamics in multi-scalar land use variables (Veldkamp and Fresco 1996, Brown et al. 2000), and a host of other applications (see Hensher and Button 2004). On the other hand, Bottom up approaches can take top-down outputs as given and look at spatial impacts of them. They have also received significant attention in local lvel analysis and decision-making (for applications see, Landis 1994; Landis and Zhang 1998; Waddell 2002; Deal and Schunk 2004; and for reviews see, Hensher and Button 2004, Kim and Hewings 2011). The choice of a particular model depends on many factors, such as the needs of the project, availability of data and user discretion. Still both kinds are needed to some extent in many planning processes and their insularity can be problematic and deserves careful consideration.

Spatial Planning and the Confounding Effect of Institutional Rigidity

Finally, since models attempt to imitate real world phenomena, they can easily duplicate, and perpetuate, some of its limitations. For example, institutional rigidity, an often discussed barrier to regional planning (Teitz and Barbour 2007), has become a part of how many models specify and test policies. For example, land use impacts are often tested last and at a locality level. The high likelihood of these impacts to change as regional policies are changed, and their interdependence with other regional and local forces are often ignored at the local level analysis. Though these considerations sometimes simplify decision-making, they can also limit our anticipation of potential challenges and opportunities.

To address these challenges, advancing models alone will not be sufficient. To anticipate adequate variety in future conditions and implementation frameworks, planning approaches will also need to encourage and sustain participation. They will have to provide a platform for sharing divergent viewpoints in a pluralistic society, and when combined with evolving tools, helps us develop multiple visions for the future that look beyond the traditional limits of scale, time-horizon, and disciplinary and institutional boundaries. The literature provides many examples where attempts have been made to bridge this gap between empowered advocacy and comprehensive rational planning. It does so most often by utilizing technical tools to empower the stakeholders in the planning process through imagining a normative future (Borjeson et al. 2006, Myers & Kitsuse 2000, Porter 1985). These principles have been used worldwide in many planning processes including, Norwegian Long Term Program (NLTP), Sustainable Seattle, Oregon Shines, Metropolitan Tunis, and Envision Utah (AtKisson 1996, Barbanente et al. 2002, Grow & Matheson 2006, Kissler 1998).

In addition to unstructured deliberation, several other methods can be applied. One approach sensitive to different stakeholder values is multi-criteria decision analysis (MCDA). Malczewski (2006) shows how GIS and MCDA allows diverse (but interdependent) decision makers to insert value judgments and receive feedback on their implications, allowing policy makers to highlight trade-offs between alternatives. Innes and Booher (1999) looked at the need for consensus building planning processes to cope with complex adaptive systems. They suggest that such a framework allows for experimentation, building shared meaning and change.

Still additional considerations may be necessary. For example, metropolitan planning organizations in the US need to follow a single set of growth projections for transportation planning as per federal requirements for funding. As a result scenarios (both land use and transportation) have to accommodate one set of projections – no more and no less. Unless these requirements change, such agencies have little choice but to use unitary forecasts. They can however, attempt to consider the wider interactions with other agencies and interdependencies between land use, transportation and other systems when arriving at their assumptions.

In summary, much has been written about how planning processes use of scenario analysis, planning support systems and urban models and how their use many be limited by the nature of approaches and institutional consideration, among others. In order to overcome the resulting challenges, planners will have to balance the sophistication of their tools with accessibility and nimbleness. We argue that some of these challenges can be addressed by systematically considering complexities such as multiple sets of projects and inter- and intra-regional interactions by moving beyond the traditional static definitions of a model region. Scenarios have specific implications for plan making and, as we show next, how they are constructed affect the outcomes and subsequent plan making considerations. Understanding a broader range of uncertainties, as we will show, can allow for better assessment of varying future challenges and as a result can lead to more effective plans.

ANALYTICAL FRAMEWORK

Research objective

In this paper, we use the principles of scenario analysis to illustrate the impacts of two such important considerations – forecasts and regional boundaries – on model outcomes and related decisions. We use Montgomery County, MD as a case and leverage a model developed for a larger region, i.e. the state of MD and vicinity. We develop two sets of scenarios – one where the county (a local government) freely competes with its neighboring jurisdictions for development and another where a higher (i.e. a regional or state) level agency controls the extent of development that the county can receive. The scenarios are constructed using different specifications for regional boundaries and also results in different amount of growth in the County – both rare practices in scenario analysis with models. We then compare the outcomes on a set of indicators and draw implications for planning.

Data and Methods

The models used here have been developed over time by a number of partnering organizations (for details, please see Knaap and Frece 2006, Chakraborty 2010, Mishra et al. 2010, Chakraborty et al. 2011). Our entire modeling area covers the state of Maryland in U.S. and some surrounding counties (Figure 1). One of the purposes of our modeling effort has been to explore alternative futures for the state of Maryland with the intent to identify policies that maximize the likelihood of more desirable future outcomes.

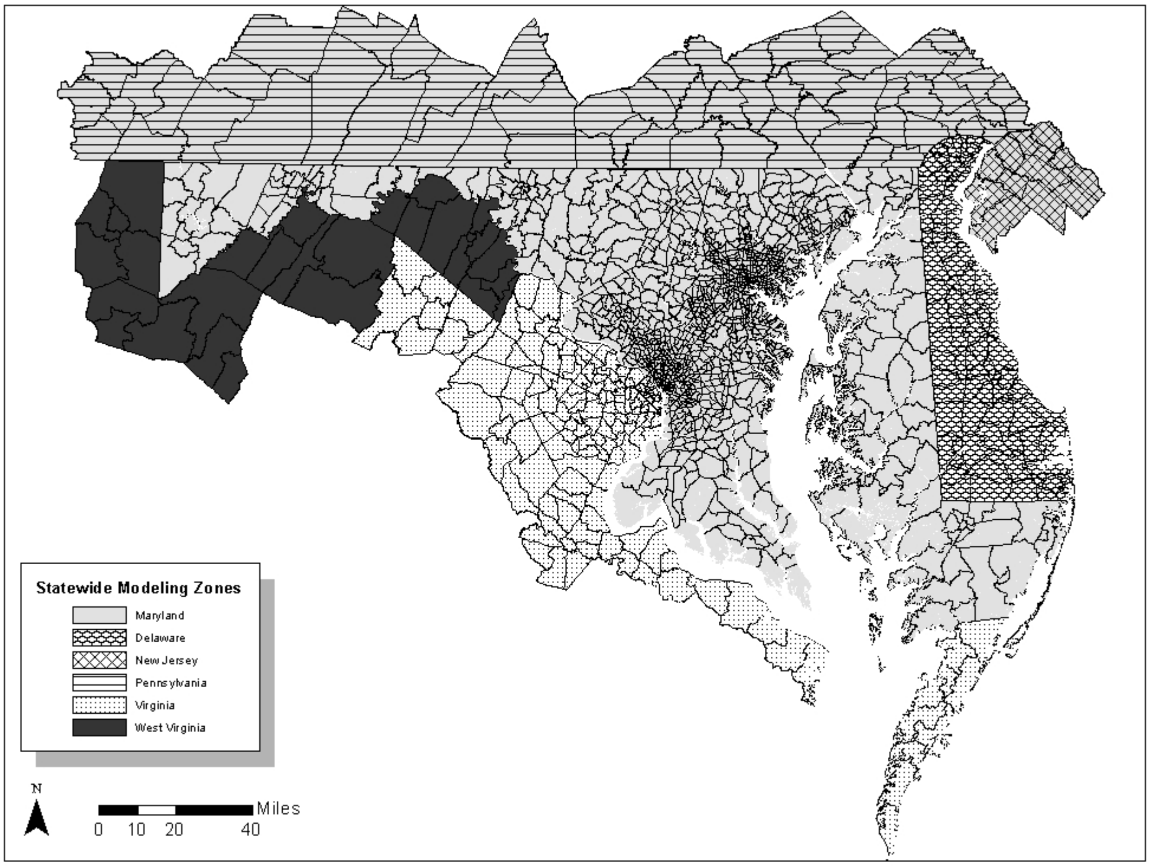


Figure 1 Broader region for which model tool has been developed (Source: National Center for Smart Growth Research and Education at the University of Maryland)

We briefly summarize the modeling framework and methodology below. The framework is of a loosely coupled set of models that work at different scales (national to local), in different areas of specialization and for different purposes. They interact however, as shown in Figure 2 and explained below, and allow us to generate different sets of forecasts, look at their effect on land use and transportation networks and they assess their impact using a set of governmental services and quality-of-life indicators.

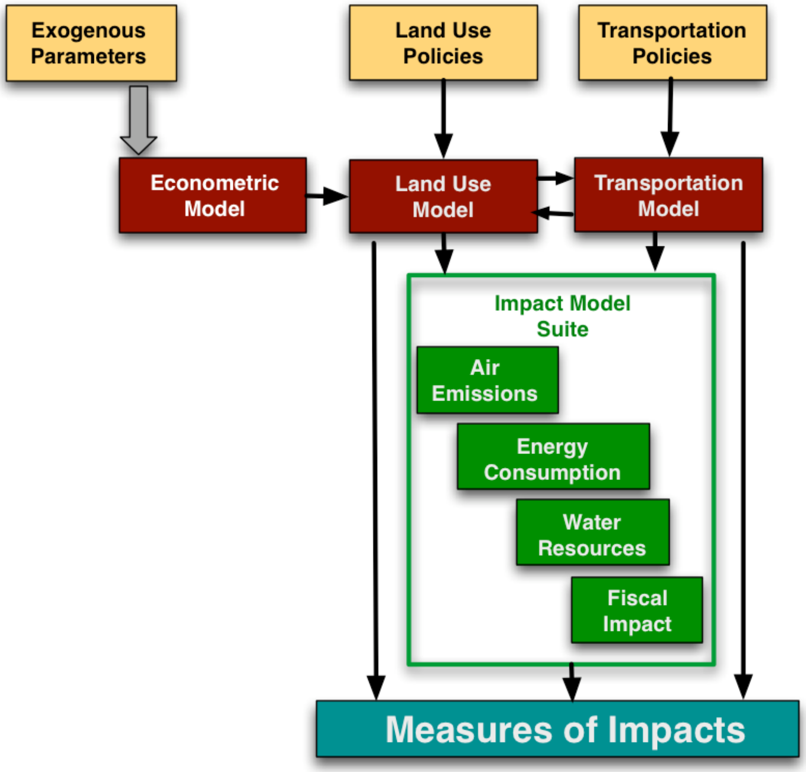


Figure 2 Loosely coupled modeling framework

- National econometric model: The national econometric model consists of two sub-models: (1) Long term Inter-Industry Forecasting Tool (LIFT), a macroeconomic input-output model operating at the U.S. national economy level forecasts more than 800 macroeconomic variables; that are then fed into (2) State Employment Modeling System (STEMS) to calculate employment and earnings by industry for all 50 states and the District of Columbia. Output from LIFT serves as input to STEMS. Results from the STEMS model are then allocated by region (political boundaries are imprecise predictors of boundaries of labor markets and economic regions) using current proportions of state level forecasts for each sector. A detailed description of LIFT and STEMS can be found in the literature (McCarthy 1991, INFORUM 2010).

- Regional Model: The regional level model depicts land use variables at the county level. At the regional level, the forecasting approach is based on a near-total reliance on empirically calibrated relationships. The calibrated model involves 40 equations using progressively more inclusive sets of predictors. The allocation model incorporates review of the benchmark forecasts (Hammer 2007).

- Local Model: The local model, titled Land-use Evolution and impact Assessment Model (LEAM), uses a state-change structured gridded surface whose conditions evolve over time, similar to other Cellular Automata (CA) technologies (Deal and Pallathucheril 2003).[2] The LEAM grid surface is not flat, however, but gains a "hilly" topography based on both physical and socioeconomic constraining factors. It incorporates techniques that calculate a probability to represent the potential of each cell (900 m^2 or 0.25 acre) to change from one land-use category to another. This probability of change is influenced by local interactions (e.g., the accessibility of the cell to a predetermined characteristic of its neighborhood or an "attractor"), global interactions (e.g., the state of the regional economy), and other causal mechanisms (e.g., social forces). These produce suitability scores that contribute to the grid surface relief and affect subsequent allocation.

Agencies that use models such as those listed above often work with specific requirements. For example, Metropolitan Planning Organizations (MPOs) use the most likely 25-year employment and household forecasts to test the stresses on travel network. Similarly, local governments updating their land use plans may use projections from state economic agencies as given to make policies that accommodate that growth, or affect it. The purpose of this paper, in part, is to demonstrate that while current approaches are useful for the purposes they serve, additional understanding can be gained by relaxing constrained projections and testing multiple regional extents.

We specify two scenarios – one where the County (local government) freely competes with neighboring jurisdictions and another where the regional/state government controls the extent of development that the locality can receive. For the first scenario, using our econometric model, we generate county-by-county projections, further detailed into various housing and employment categories using our regional model. For the second, we aggregate county level projections to the state level. We also specify our land use models at two scales: one at the level of each county and another at the statewide level.

We selected the case of Montgomery County, MD to demonstrate our point. We could have selected any county for our analysis but Montgomery County was selected for its rich and varied

[2] For more on LEAM, See: www.leam.uiuc.edu/maryland

planning history, its large size and high projected growth in the county. To develop the first scenario, we run the land use model only for Montgomery County and use the projections that are generated for Montgomery County alone, without regard for any interaction with neighboring jurisdictions. We argue that this closely represents a state imposed growth constraint and call it Constrained-Development Scenario. For the latter, we use the aggregated state level projections and run the state-level land use model. We argue that this represents competing behavior among counties for new growth and call it Competitive-Development Scenario. This scenario forces competition among municipalities for growth without regard to the specific amount of growth projected for each of these jurisdictions by the economic model. From this run, we extract the outcome for Montgomery County and compare with the stand alone run for Montgomery County. We compare the outcomes on a few simple indicators. All the models use year 2000 as the base year and are run for every 5 years intervals, up to 2030.

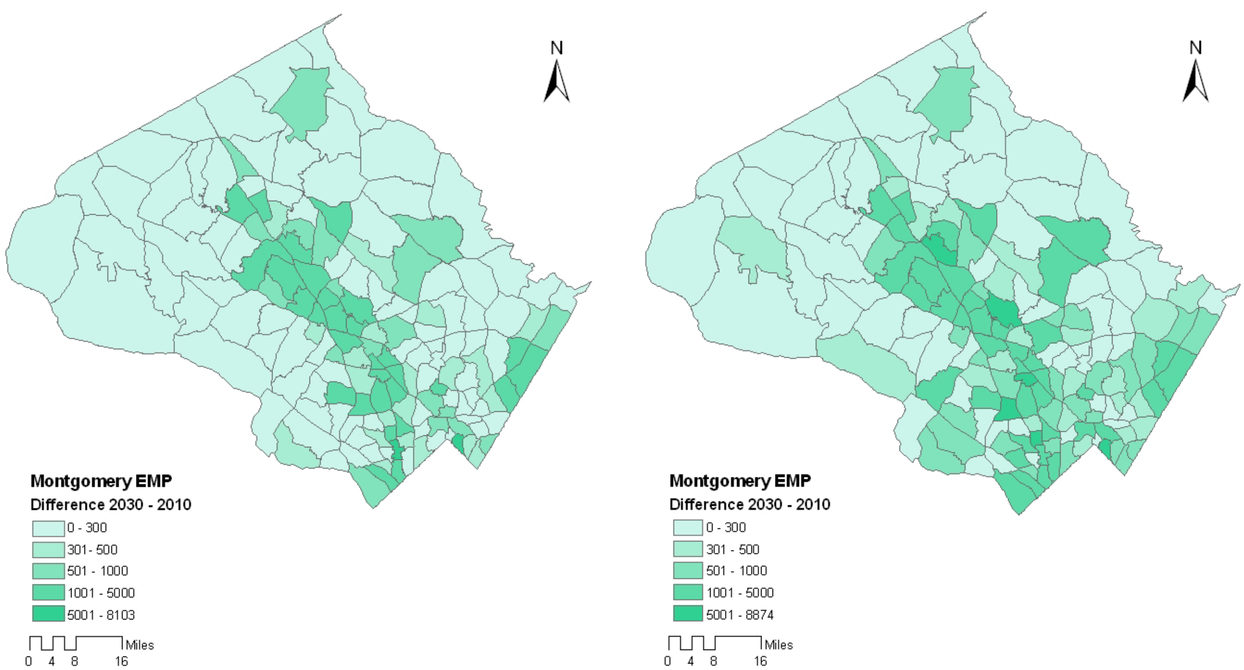
ANALYSIS

The results of model runs are summarized in table 1. Two sets are household, and employment totals at a county level, for each of the two scenarios – Constraint-Development Scenario, and Competitive-Development Scenario. These results were also available at a cell level of size 90m x 90m (discussed later). The employment data is also presented by four detail categories – retail, office, industrial, and other. Each scenario run is modeled for two time horizons on year 2000 data 1) most recent year or 2010 and 2) for the planning horizon 2030. The future year is identified in conformance to the constrained long-range plan for the county and state. The model results show that Montgomery County will receive higher amount of households and employment in the Competitive-Development Scenario run than in Constraint-Development Scenario (Table 1). The results suggest that given flexibility of growth across all counties, and the possibility of moving to a new locality, Montgomery County will attract more households, and employment Competitive-Development scenario. This comes at the expense of our counties and happens because of Montgomery County’s higher attractiveness in terms of land use and accessibility.

Table 1: Temporal Development Patterns

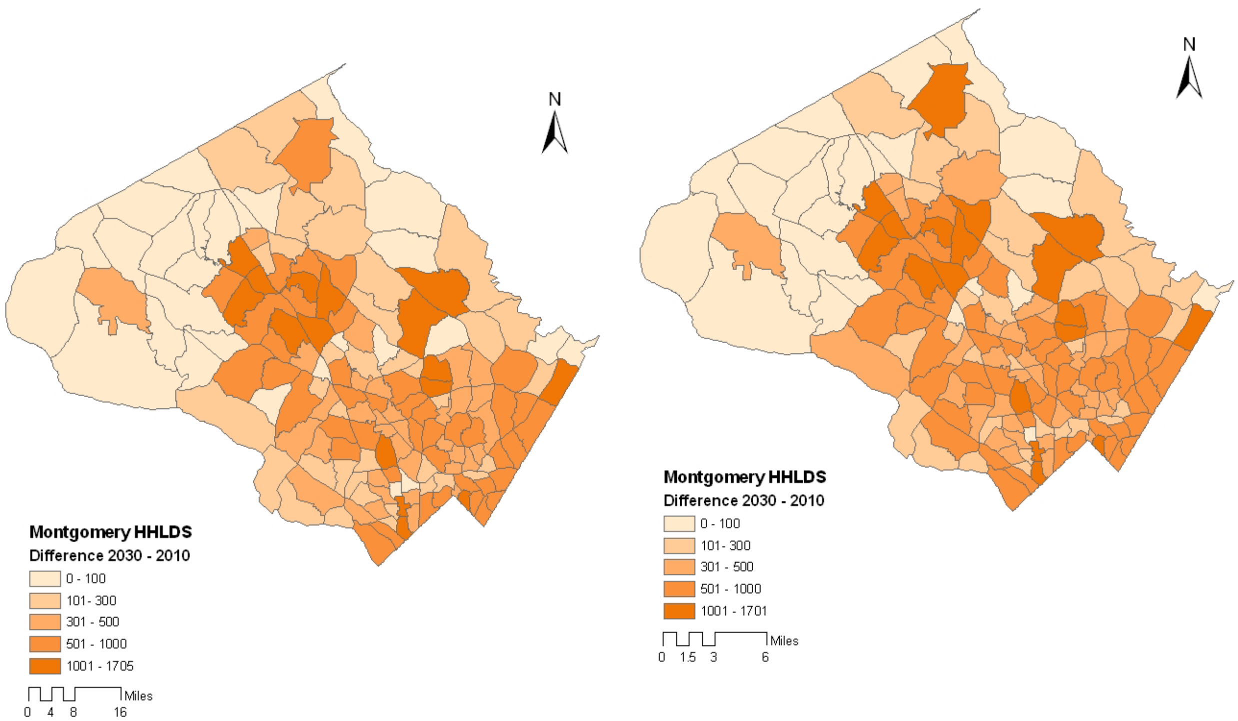
Attributes	2010		2030		(2030-2010)	
	Constrained-Development	Competitive-Development	Constrained-Development	Competitive-Development	Constrained-Development	Competitive-Development
HH	363,285	357,418	437,464	435,057	74,179	77,639
Retail (a)	72,097	72,208	87,268	94,147	15,171	21,939
Office (b)	275,831	276,415	333,797	361,792	57,966	85,377
Industrial (c)	43,283	43,276	52,391	56,838	9,108	13,562
Other (d)	152,268	152,992	184,198	202,266	31,930	49,274
Tot. Emp. (a+b+c+d)	543,479	544,891	657,654	715,043	114,175	170,152

The spatial distributions of household and employment growth in these two time periods for both scenarios are shown in Figures 3 and 4 respectively. The polygons in Figure 3 and 4 represent Traffic Analysis Zones (TAZs), showing the numbers estimated from aggregation of the cell level results.



Constrained-Development Competitive-Development

Figure 3: Employment Growth



Constrained-Development Competitive-Development

Figure 4: Household Growth

The new developments in both scenarios for both land use types happen as expected. The most growth goes in areas closer to the urban centers and next to existing modes of transportation. Areas next to transit stations as well as those with high possibility of redevelopment get a high share of new employment. Nevertheless, due to overall higher attractiveness and, as a result, overall higher demand for land, and the location of nearby counties where that new development is getting transferred from can be attributed to the differences seen between the two scenarios.

These differences in total amount and location of new development can be seen in the land use change indicators. For example, the loss of agriculture and forest land for both model runs are presented in Table 2. As expected, we find the loss to be greater in the Competitive-Development scenario than County-Constraint scenario. The loss in agriculture and forest land estimation is built into the modeling tools which further uses the land cover data in the CA based allocation process. In Figure 5 shows the grid level variations in the scenarios. The grid that are organized according the amount of new growth received as follows: (1) higher growth on County-Constraint scenario, (2) higher growth on Statewide Scenario, and (3) higher growth under both scenarios. The grid level results can be used as a tool to visualize difference more specifically.

Table 2: Montgomery County Loss of Forest and Agriculture Land (in Square Meters)

Attribute	County Constraint	Statewide
Forest land	36,620,100	62,677,800
Agriculture land	47,279,700	83,268,000

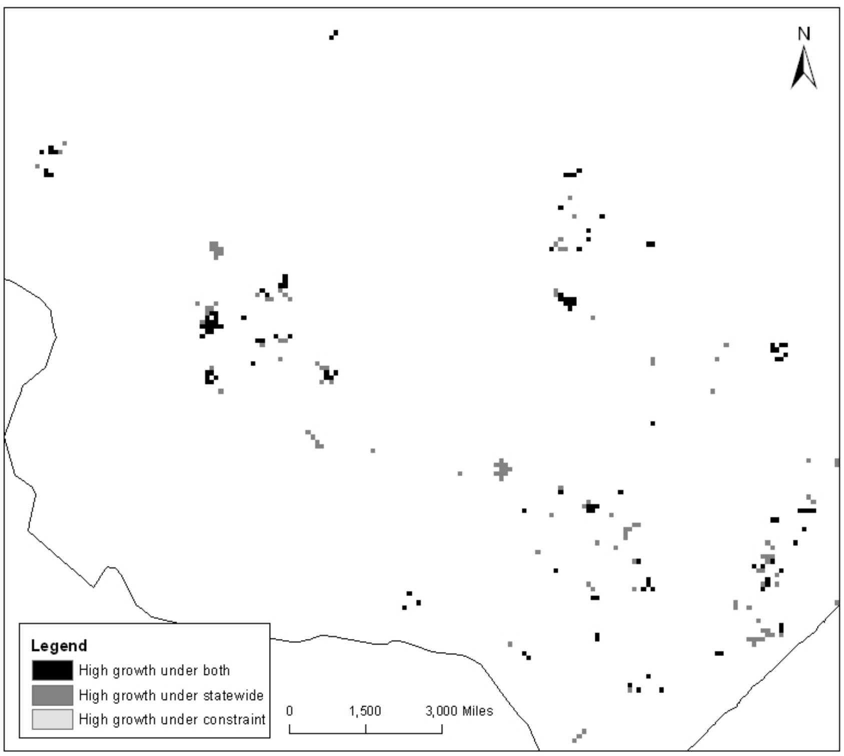


Figure 5: Comparison of Growth at Grid Level for Both Scenarios

CONCLUSIONS

Futures are not necessarily given; they are also not necessarily created solely through purposeful action. They are a product of complex interactions of forces that we cannot control as well as decisions, we make. Many authors have noted that even the most sophisticated and integrated models are not able to incorporate all variables of interest. Hopkins [2000] explains that numerous urban models have been developed based on different perspectives and theoretical foundations. Some simulate markets for land, housing and labor using preferences of households and firms based on past behavior with respect to prices. Still others rely on past probabilities of land conversions and seek an equilibrium solution. Some are dynamic, usually in discrete time intervals in which actions depend on the results of previous time intervals. In this paper, we use a combination of approaches to develop two sets of scenarios – one where a county freely competes with neighboring jurisdictions (Competitive-Development scenario using a statewide run) and another where the regional/state government controls the extent of development that the locality can receive (Constraint-Development Scenario). The scenarios are constructed using different specifications for regional boundaries and also results in different amount of growth in the County – both rare practices in scenario analysis with models.

Our analysis has a number of general implications. It shows that assumptions are important and should be carefully chosen. And, if possible, multiple plausible sets of assumptions should be compiled to tests the robustness of policies despite variations in assumptions. While similar in concept but different in application, our study also shows that the choice of regional extents at which models are run affects the outcomes. This is important for a number of reasons. While many studies on limitations of local governance suggest regional coordination as a way to address multiple issues, the scales and composition at which such coordination should happen is often unclear. Metropolitan areas have often been used as an appropriate scale for most purposes but with the evolving literature on other scales (for example, watersheds, megaregions etc.), care should be taken in understanding how these ideas are used in formulating the study region. Or more importantly perhaps, care should be taken that critical areas are not excluded from the modeled region.

More specifically, our findings suggest that a state imposed constraint on Montgomery County might be too low in its magnitude, and hence difficult to implement. It also suggests that in the lack of such constraints, higher amount of undeveloped lands will be lost resulting in different challenges. The detailed location of development can also be used to argue for certain arguments for or against each set of policies. For example, though it is beyond the scope of this study, it is possible to imagine that a fixed development constraint might be difficult to implement without added political compromise that benefit the county in some ways. Presence of such conditions might complicate the outcome and can indeed change the cost/benefit equation for an agency choosing whether to support the *constrained* or the *competitive development policies.*

Lastly, the scenario analysis proposed in the paper has practical implications in the state of Maryland. One of the examples is the potential residential and commercial land use for the greater Life Science Center (LSC) proposed in Montgomery County. Based on existing, approved, and proposed development, LSC could yield a maximum of 9,012 additional dwelling units to complement a projected total of 52,500 jobs. The resulting ratio of 5.8 jobs per dwelling unit is based on the existing housing in the greater LSC area (MNCPPC 2010). The Maryland Department of Transportation has concerns over such large scale development as it might lead to insufficient transportation infrastructure to support such mixed land use development. This is an example of the differences between the vision of the county planners and of the state planners for future of Montgomery County. Such differences, depending on the outcome of a process, can lead to a range of outcomes, two of which have been modeled in the two scenarios presented in this paper. Recognizing these possibilities are important to the planning process.

Another example is Prince George's county’s Konterra Town Center, a planned mix-use regional activity center that will include more than 4,500 residential units and over 5.5 million square feet of office, retail and hotel uses to produce more than 10,000 jobs (PGCPD 2009). In contrast to Montgomery County, the state agreed for this development as it supports the construction of Inter County Connector (ICC), a major east-west access controlled highway corridor connecting the two North and South Interstates-95 and 270. The new development will have access to ICC, will in turn become more attractive.

These examples illustrate the kind of decision-making conflicts and uncertainties that exist between land use and transportation planning agencies in a large region. Our results show that considering a wider range of possibilities can provide better tools for those working on these challenges. This includes comparing future scenarios not just with different desirability but different sets of assumptions and regional formulations.

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