

Robust Plans and Contingent Plans

Scenario Planning for an Uncertain World

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Problem: The practice of scenario planning is often too focused on developing a single preferred scenario and fails to adequately consider multiple uncertain futures. The U.S. Department of Housing and Urban Development recently awarded grants for scenario planning at regional and metropolitan scales that further promote this practice. However, a lack of systematic analysis of uncertainty limits the role of scenario planning.

Purpose: The purpose of this article is to demonstrate how to incorporate uncertainty into large-scale scenario analysis and then use that framework to identify contingent and robust plans.

Methods: We adapt the concepts of controllable internal options and uncontrollable external forces and consider their interactions in order to develop future scenarios and identify contingent and robust decisions. We then apply this technique using advanced econometric, land use, and transportation models developed for the Baltimore–Washington metropolitan region and its vicinity. Finally, based on the results of a hypothetical, yet plausible, exercise, we show how contingent and robust decisions can help local and regional governments develop contingent and robust plans.

Results and conclusions: Scenarios developed as a combination of internal options and external forces allow us to identify a wider range of future impacts than in traditional metropolitan scenario planning. Robust plans support choices that offer benefits across scenarios. Contingent plans can be tailored to specific futures.

Takeaway for practice: By providing a way to think systematically about uncer-

If scenario planning is defined generally as the exploration of alternative options before formulating a plan of action, then scenario planning has been central to the practice of land use planning for many decades. In the classic planning text, *Urban Land Use Planning*, Chapin (1965) suggests that plans should be “the culmination of the repeated tests and retests of alternative arrangements in the pattern of uses,” and should “[consider] location and space needs previously specified and the density and intensity of development prescribed in the course of deriving these trends” (p. 466). In the last two decades, scenario planning has reached a new level of prominence, especially at the metropolitan scale. Following the example set by Portland’s Land Use, Transportation and Air Quality plan, many metropolitan areas are now developing alternative future scenarios, exploring their virtues, identifying a preferred scenario, and adopting a strategy to attain it. The U.S. Department of Housing and Urban Development’s (HUD) recently announced Sustainable Communities Initiative all but requires such an approach (HUD, n.d.). However, as planners, we must

tainty, scenario analysis promises to improve the efficacy of large-scale planning.

Keywords: robust and contingent plans, internal options, external forces, land use and transportation models, uncertainty, strategic decision making

Research support: This article was not directly supported by any outside agency, but support for the modeling system was provided by the following organizations: Maryland State Highway Administration, Maryland Department of Transportation, Maryland Department of Planning, U.S. Environmental Protection Agency, and Lincoln Institute of Land Policy.

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not only evaluate the alternatives before us, we must also consider possibilities that we may not fully control.

Scenarios are generally thought of as cogent stories intended to aid decision makers. Their purposes determine their construction. Börjeson, Höjer, Dreborg, Ekvall, and Finnveden (2006) offer a standard typology that classifies scenarios as predictive (i.e., forecasts), normative (i.e., preserving, transforming), and explorative (i.e., external and strategic). Each type of scenario planning requires a different mode of operation. For example, construction of predictive scenarios may involve modeling, whereas normative scenario construction may involve workshops, backcasting, or Delphi methods. Irrespective of motivations and methodologies, however, scenario planning assumes that if decision makers consider multiple futures, they are more likely to make better decisions.

Despite the prominence of scenario planning in contemporary practice, some researchers question its efficacy. Postma and Liebl (2005) suggest that scenarios often fail to diverge enough from past trends and are unlikely to incorporate improbable but plausible extreme events. Similarly, Hopkins and Zapata (2007) argue that the practice of scenario planning is often too focused on developing a single preferred scenario and fails to adequately consider multiple, typically uncertain futures. Couclelis (2005) and Myers and Kitsuse (2000) suggest that many scenario-planning exercises often fail to use planning support systems that integrate models from different fields, and, thus, do not communicate their results effectively. Bartholomew (2007) criticizes the modern practice of scenario planning for including a strong planner's agenda and inadequately facilitating public participation.

To illustrate how scenario planning can more effectively address uncertainty, we craft and explore alternative scenarios for the Baltimore–Washington metropolitan area and its vicinity. We build these scenarios using a combination of internal options (decisions we may control) and external forces (factors over which we have little or no influence). By examining decision making under uncertain circumstances, we identify contingent and robust decisions. *Contingent* decisions depend on the outcome of multiple uncertain conditions; *robust* decisions produce preferred results within those conditions. However, the internal options and external forces differ for each actor in the metropolitan planning context. For this reason, each actor must consider these scenarios when formulating individual and collective plans (Kaza & Hopkins, 2009). Plans rarely involve one overarching decision: Both robust and contingent decisions need to be evaluated in order to create plans that are useful across multiple scenarios (robust plans) and in specific cases (contingent plans). Identifying

robust and contingent plans is a more advanced, and heretofore underdeveloped, use of metropolitan scenario analysis.

We begin by providing a brief overview of the practice of scenario planning. Second, we present the tools and methods we used to develop alternative scenarios under conditions of uncertainty. Third, we evaluate those scenarios in a decision-making framework to identify contingent and robust plans. We conclude by identifying lessons that will guide the burgeoning practice of scenario planning at the metropolitan level.

Scenario Planning in the United States

Following Bartholomew (2007) and Smith (2007), most scholars trace the origin of scenario planning to the RAND Corporation (Kahn, 1962) and its application to business to the Royal Dutch Shell (Wack, 1985). In its earliest stages, scenario planning was used as a way to consider multiple facets of a problem simultaneously, as well as a tool to help decision makers who had limited backgrounds and resources address the uncertain future. It fostered imagination and facilitated critical thinking about how a future might unfold. It has been widely used in disciplines ranging from business to conflict resolution to the military (Andrews, 1992; Bloom & Menefee, 1994; Bradfield, Wright, Burt, Cairns, & van der Heijden, 2005; Hall, 1986; van der Heijden, 1996). While scenario planning extended to land use–transportation and natural resources, urban planning as a field was slow to incorporate all aspects of scenario planning. Current land use–transportation scenario planning processes have their roots in the alternatives analyses mandated by the Federal-Aid Highway Act of 1962. Under the act, metropolitan planning organizations (MPOs) were required to adopt long-range transportation plans for entire metropolitan areas and for multiple modes of transportation. Planning was to be “continuing, comprehensive, and cooperative” (Federal-Aid Highway Act, 1962, 23 U.S.C. § 134).

Consideration of alternative outcomes became more common in transportation and resources planning under the National Environmental Policy Act of 1970. According to that act, “all agencies of the Federal Government [must include a]...detailed statement by the responsible official on...alternatives to the proposed action” (National Environmental Policy Act, 1970, 42 U.S.C. § 4332). As a result of this mandate for environmental impact statements, the practice of creating a series of possible actions and measuring their consequences has become

commonplace in public decision-making processes. As stated by Bartholomew (2005):

For much of the 35-year history of NEPA, this style of considering alternative courses of action has significantly differed from the business and military applications of scenario planning. In the latter contexts, the focus is on assessing the interactive causal relationships between external influences—such as environmental, political, or economic conditions—and one’s range of possible action strategies (Avin & Dembner, 2000). Most NEPA-style alternatives analyses, on the other hand, focus on a range of internally specified alternative actions, gauging their relative impacts on external resources and conditions, with little attention paid to internal/external interactions. (p. 7)

Portland Metro pioneered the explicit use of scenarios for planning at the metropolitan scale in the early 1990s. According to Landis (2008), the Portland 2040 plan “heralded a new and ongoing period in American metropolitan planning: the era of the regional vision plan” (p. 2). The practice caught on quickly. By examining 80 similar scenario exercises, Bartholomew (2007) found that scenario planning processes were usually facilitated by regional organizations, frequently MPOs. Often, the processes focused on regional-level, growth-related issues, such as spatial patterns and urban form. The scenarios used “center” or “cluster” archetypes to consider variations in development density and location of growth and their impact on transportation-related values.

In a set of case studies of six exemplary scenario-planning exercises, Knaap and Lewis (2011) found that, although most of these exercises were led by MPOs, they involved a variety of constituent organizations, they relied heavily on GIS and four-step transportation models, they considered a range of three to five alternative scenarios for a 30–50-year horizon, and they resulted in the adoption of a “preferred” scenario as the foundation for a metropolitan plan. Typical scenarios included “sprawl” or “business as usual,” “smart” or “compact” growth, and “satellite” cities. The preferred scenarios, the result of extensive quantitative evaluation and public participation, usually resembled the smart growth scenario.¹

Following this trend, on June 24, 2010, HUD issued a Notice of Funding Availability (NOFA) for the construction and adoption of regional plans for sustainable development. The prescribed goals of these plans are to foster the development of sustainable communities; to support multi-jurisdiction partnerships; to facilitate strong alliances of residents and interest groups; to build greater trans-

parency and accountability; to expedite the implementation of livability principles; to align local, state, and tribal capital improvement programs; and to help all regions move toward sustainability and livability (HUD, n.d.). To be eligible for these funds, applicants must “conduct scenario planning that allows the Regional Plan for Sustainable Development to project a variety of economic growth possibilities and anticipate responses to each of them” (p. 26). The specifics of this process were left undefined.

HUD’s lack of specificity about “scenario planning” enables metropolitan planners to define the task in ways that suit local problems and purposes. Some planners might interpret scenario planning as a visioning exercise, “creating images of the future to serve as goals or guides for planning decisions” (Shipley, 2002, p. 7). Others may define it as the development of a vision of “what could be,” thus, “[m]otivating people to take actions they believe will give the imagined result” (Hopkins, 2001, p. 36). Still others may “us[e] scenarios to anticipate the range of [possible] changes that may impact their communities and to develop adaptation strategies to address these impacts” (Quay, 2010, p. 496).

Despite the ambiguity of HUD’s NOFA, its two-fold intent is clear: a) to encourage metropolitan areas to develop plans, especially transportation plans, that do not simply accommodate recent development trends, and b) to provide a vision for the future that can galvanize and motivate a disparate and inclusive set of stakeholders. We agree that scenario analysis can serve these important purposes. Following Hopkins and Zapata (2007), however, we have found that scenario analysis at the metropolitan scale has largely ignored uncertainty and focused too narrowly on developing a single preferred vision for the future. Although that approach has value, advanced metropolitan scale models can also be used to identify robust and contingent strategies and thus more effectively incorporate the inherent uncertainty involved in long-term planning.

Contingent and Robust Decisions and Plans

Meeting the literal requirements of the 2010 NOFA will require planners to use scenarios in ways that have not been widely practiced in metropolitan scenario analysis.² Specifically, by requiring plans to anticipate and respond to a variety of growth possibilities, HUD’s NOFA requires contingent decision making or the formulation of contingent plans, plans tailored to specific futures. If a future outlined in the plan does not materialize, the plan will

remain unused; yet, without such a plan, one risks being unprepared. Perhaps, unintentionally, HUD's NOFA follows Dewar (2002), who stresses the importance of assessing the assumptions behind planning for the future. Some of these assumptions, he argues, are "load-bearing," and contingent scenarios should be developed in case the assumptions are not realized. These assumption-based plans should also contain "hedging actions" to protect against unforeseen results and the effects of uncontrollable and uncertain external forces.

Table 1 presents four scenarios as the outcomes of a 2×2 matrix of internal options and external forces in a simplified framework. The decision-making entity can choose option A or option B; it does not have the ability to choose external force 1 or 2, as these are uncontrollable forces. Thus, the decision maker must consider the possibility of external forces 1 and 2 when deciding among internal options A or B. If external force 1 comes to bear, the decision maker would choose (or plan to choose) option A if scenario 1A is preferred to scenario 1B, and choose option B if scenario 1B is preferred to scenario 1A. The decision maker would always choose option A if both scenario 1A and scenario 2A are preferred to scenario 2A and scenario 2B. Option A, then, would be a robust decision, a decision that yields preferable results under multiple external forces. If option A is preferred under one set of external forces but not the other, then option A is a contingent decision. Although one scenario may be preferred over all the others, decision makers cannot choose among all scenarios; they can only choose among available options. According to this framework, HUD's NOFA only requires the identification of contingent plans under external forces 1 and 2 (HUD, n.d.).³ In this article, we suggest that scenario analysis can be used not only to identify such conditional, contingent plans, but also to identify robust plans that produce preferable results under multiple external forces.

The above framework posits a unitary decision maker choosing among options A and B. However, such a decision maker rarely exists in practice; instead, decisions are made by coalitions of actors through collective choice procedures. We acknowledge these internal decision-

making dynamics and assume that this collective group has more control over its internal options than its external forces. As we discuss in more detail later, while federal spending and households' location decisions may not be within a regional agency's control, the agency can choose to expand the regional transportation network. Yet, a regional government also must consider whether or not federal funding will materialize. For various local governments, on the other hand, both federal spending and expansion of transportation networks represent largely external factors. A local government may prefer an option the regional authority considers, but might plan for a scenario in which a less desirable option is chosen by the regional authority. These assumptions do not imply that the regional authority lacks influence over federal spending or that local governments have little influence on the regional authority's transportation investment decisions. They merely highlight the interplay between contingent and robust decisions when more than one decision-making entity is involved.

Alternative Scenarios for the Baltimore–Washington Region

The tools and methods outlined in this section helped generate alternative scenarios for the Baltimore–Washington region and its vicinity. The tools were developed from the Maryland Scenario Project (MSP) led by the National Center for Smart Growth (NCSG) at the University of Maryland. Like other large-scale scenario projects, the MSP involved large-scale participatory visioning exercises, extensive dialogue with focus groups, advanced model building, scenario construction, and scenario evaluation. (For more on MSP, see Chakraborty [2010, 2011] and Knaap and Frece [2006].)⁴

The internal options and external forces we used to construct scenarios developed out of the Scenario Advisory Group, an MSP-affiliated group of nearly 40 land use and transportation planning experts from across the region. The group identified forces driving the region's future growth and crafted conceptual alternative scenarios based on the interactions between these forces and potential local and state policies and investments. To illustrate the efficacy of contingent and robust planning using scenarios, we drew upon the work of this advisory group and on a small set of alternative policy choices.

Modeling Framework

To build and evaluate alternative scenarios, the NCSG developed a suite of models that can be expanded and

Table 1. Scenarios as combinations of internal choices and external forces.

	External forces 1	External forces 2
Internal option A	Scenario 1A	Scenario 2A
Internal option B	Scenario 1B	Scenario 2B

modified to suit particular questions. This article focuses not on the adequacy and accuracy of these models, but on their use, that is, how model outputs can advance a different planning approach. One can substitute many other kinds of models that differ in scope, approach, and geographic resolution in order to make similar points. For this reason, we describe the models conceptually. For more technical details, refer to model documentation and published material elsewhere.

The connections among various models are depicted in Figure 1. The national economic model is based on the Long-Term Interindustry Forecasting Tool (LIFT), which considers various sectors of the economy at the national level and enables planners to forecast outcomes of various macroeconomic policies and changes such as energy prices.⁵ The outcomes of this model, in turn, influence the regional and local demographic model, which determines households' employment in various county-level sectors and provides inputs to the loosely coupled transportation and land use models.

As illustrated in Figure 1, the modeling framework derives its inputs from exogenously specified parameters

such as interest rates, energy prices, and exchange rates, which are largely outside the control of state and local decision makers. The national economy is modeled using LIFT, which has an input-output model at its core and builds the macroeconomic forecasts using 97 industry sectors and 3 government sectors (Henry & Stokes, 2006). We assume the output of these models drives the regional economy and demographic transitions. Using a calibrated set of equations that correlates relative change in employment in the county to demographic change, as well as a host of measures of accessibility and land availability, we distribute these regional economic and demographic changes across counties. At this stage, we estimate household income categories.

The transportation model is a traditional four-step model that operates nationally and locally. Freight and other long-distance travel components operate at the national level, whereas the passenger travel component operates in and around the Baltimore–Washington region. As its input, the transportation model uses national and local socioeconomic data to operationalize the origin–destination matrices; however, assignment of freight and

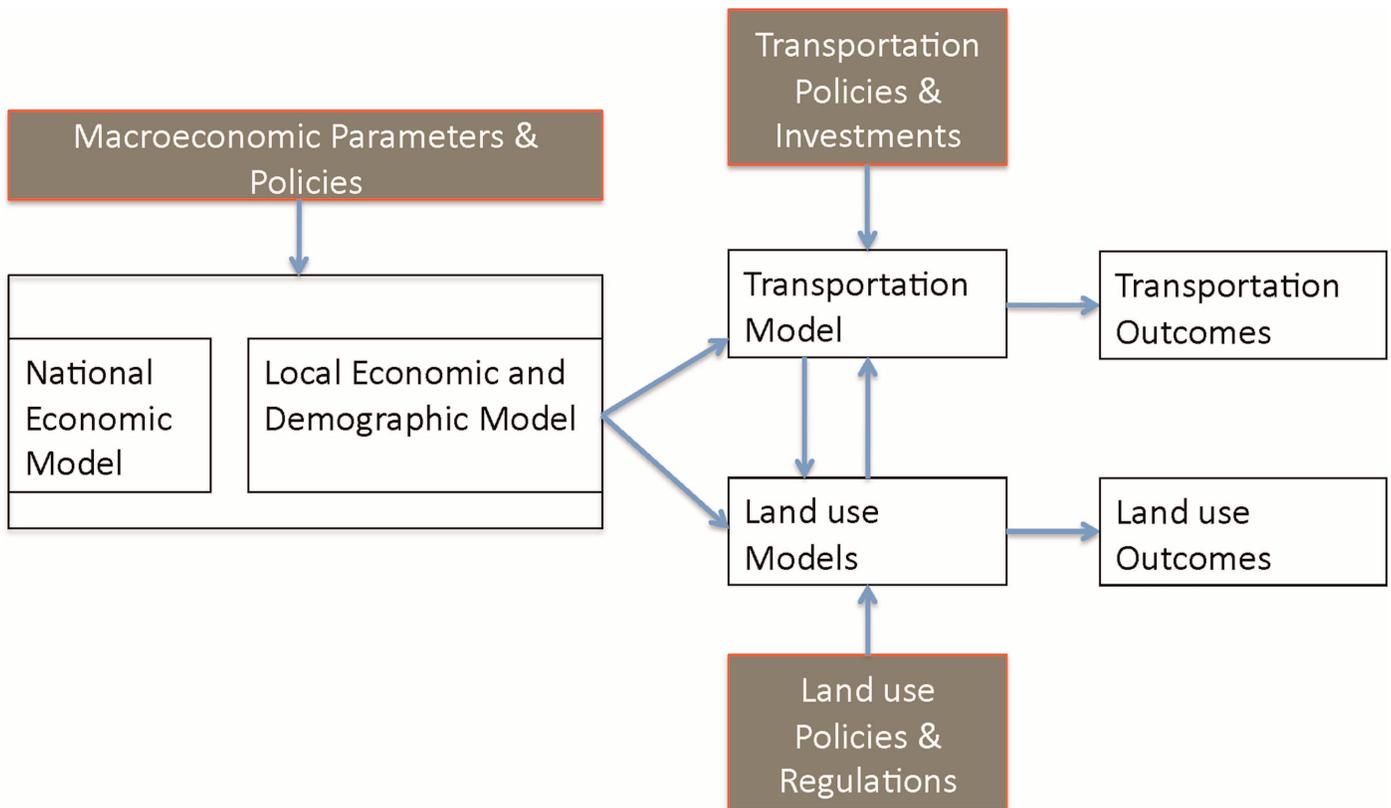


Figure 1. Loosely coupled modeling framework for scenario planning in Maryland.

(Color figure available online.)

passenger travel is done simultaneously on a national network. The national network used in the model is denser in the region around Maryland and sparser in the rest of the United States.

The land use model (Land Use Evolution and Impact Assessment Model, or LEAM) uses a state-change structured gridded surface (similar to other cellular automata), in which conditions evolve over time (Deal & Pallathucheril, 2003).⁶ The LEAM grid surface 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 square meters or 0.25 acre) to change from one land-use category to another. 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) influence the probability of

change. These produce suitability scores that help determine the grid-surface relief and affect subsequent allocation. The land use model also uses cell-level accessibility metrics from the transportation model.

Alternative Regional Scenarios

To generate alternative scenarios for the Baltimore–Washington region, we experimented with both internal options and external forces. We define internal options in terms of a set of major transportation investments. These proposed (or considered) investments include the addition of an outer beltway that extends the Inter-County Connector (currently under construction), the Silver Line extension of Washington Metro to Dulles Airport, the Purple Line extension of Washington Metro from New Carrollton to Bethesda, the Red Line extension of the Baltimore light rail system, and a new bridge extending across the Chesapeake Bay (see Figure 2). Ignoring the

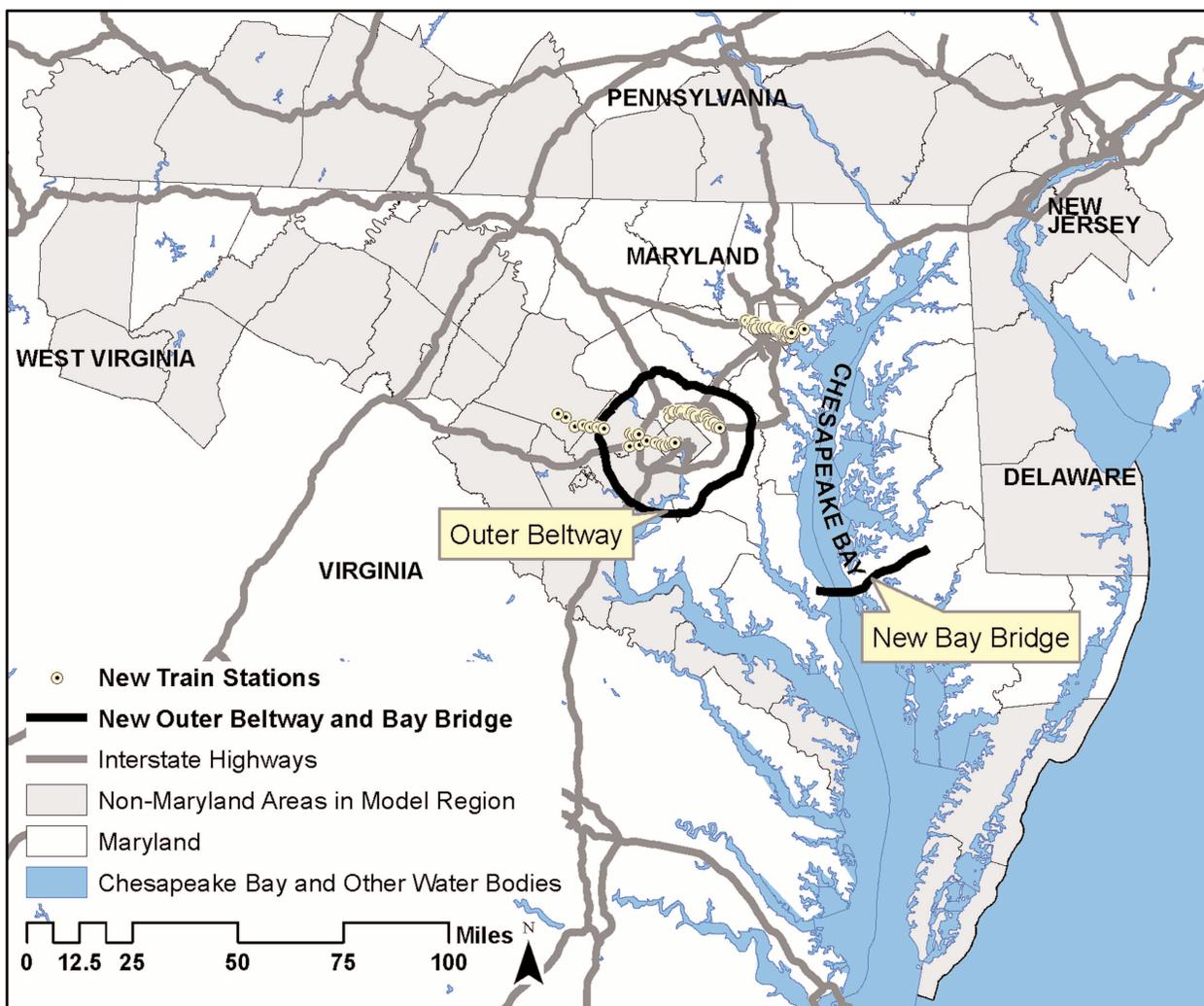


Figure 2. Transportation investments tested as internal choices.

(Color figure available online.)

region's institutional complexity for the moment, we define these transportation investments as internal options because choosing whether to pursue them lies within the purview of regional decision makers. While in practice it may be desirable to consider each investment individually, for purposes of illustration, we consider these transportation investments as a single decision.⁷

The Scenario Advisory Group identified the most important and uncertain external factors that would influence regional development patterns: growth rates of energy prices and growth rates of federal expenditures.

Building on these two uncertainties for scenario purposes, we define sets of external forces as a) Business As Usual (BAU), in which relationships between sectors, investment patterns, demographics, etc., continue unimpeded;⁸ and b) High Energy Prices (HEP), an alteration of energy prices in which some historical relationships will continue, but changes in energy prices will reverberate throughout the economy and change economic, land use, and transportation outcomes (see Figure 3). In BAU, real crude oil prices roughly follow the Energy Information Administration's short-term projections. Under HEP, oil prices rise faster than BAU at 1% above the projected inflation rate. The Scenario Advisory Group also determined that BAU and HEP would differ in their assumptions regarding federal spending.

The internal options to be considered are whether or not to invest in a new outer beltway, new transit stations, and a new bay bridge. We define the sets of internal options as a) current infrastructure (CI); and b) transportation investments (TI). We combine these internal options and external forces to construct four scenarios: BAU&CI, BAU&TI, HEP&CI, and HEP&TI.

Scenario Analysis at the Regional Scale

Using the framework above, we analyze these alternative scenarios from a regional perspective. Effects of the two external forces, BAU and HEP, are predicted by entering different inputs, including federal spending and energy price paths, into the econometric model. Based on each set of external forces, the model produces employment and population forecasts for the year 2040.

Because industries have different sensitivities to energy prices, the 2040 employment forecasts have different industrial compositions. As expected, U.S. federal employment and technical services grow more under HEP, but manufacturing declines more (see Table 2). Because industries have different location orientations, their spatial arrangements under the two external conditions differ. For example, the manufacturing sector in Maryland registers an annual growth rate of over 0.1%, unlike the rest of the

United States; the difference in growth rates of the service sector between the United States and Maryland is over 0.16 percentage points in both BAU and HEP. These economic projections drive the population and employment projections in various counties.

Differences in county employment and population projections for the year 2040 are shown in Figures 4 and 5, respectively. Counties in central Maryland, Philadelphia, PA, and Northern Virginia are projected to experience higher employment and population growth when energy prices are high, while outer-ring counties are projected to experience lower growth under the same conditions.

These population and employment projections drive the transportation model, which, in turn, readjusts population and employment and, therefore, land use consumption. It is in these iterative steps that the transportation investments are considered and that the reciprocal impacts on land use and transportation infrastructure are analyzed. Inner-ring counties, such as Salem, NJ, Fairfax, VA, and Montgomery, MD, experience a greater amount of residential development under HEP than BAU (see Table 3). Conversely, Prince William, VA, Franklin, PA, and Loudon, VA (all outer-ring or exurban counties), experience less residential growth. Loss of agricultural land corresponds to new residential development outcomes. The results also show that while the impact of rising energy prices, an external condition, is regional, the impact of infrastructure investment is more local, depending on where the investments are made. For example, Loudon and Fairfax, two counties in Virginia that currently experience congestion, are projected to grow more, as a result of significant transportation investments. They each gain substantial new residential development, regardless of external forces. Accordingly, the residential development rates of counties that did not receive new infrastructure, such as Salem, NJ, and Franklin, PA, do not vary much given either set of internal options. Montgomery County, MD, does not show much difference either, likely due to existing development in areas close to the proposed expansions and the county's overall attractiveness.

As the regional totals demonstrate, there is greater farmland loss in HEP than BAU, regardless of whether there is investment in transportation infrastructure (see Table 3). This is primarily due to the accessibility of farmland in the inner-ring counties.⁹ If the region invests in the set of transportation projects outlined above, the region loses less farmland, regardless of increases in energy prices. If farmland loss at the regional scale is the sole criterion for decision making,¹⁰ investing in transportation is a robust decision.

Considering land use patterns in the transportation model and examining congestion patterns yield additional insights. Under HEP, increases in employment and

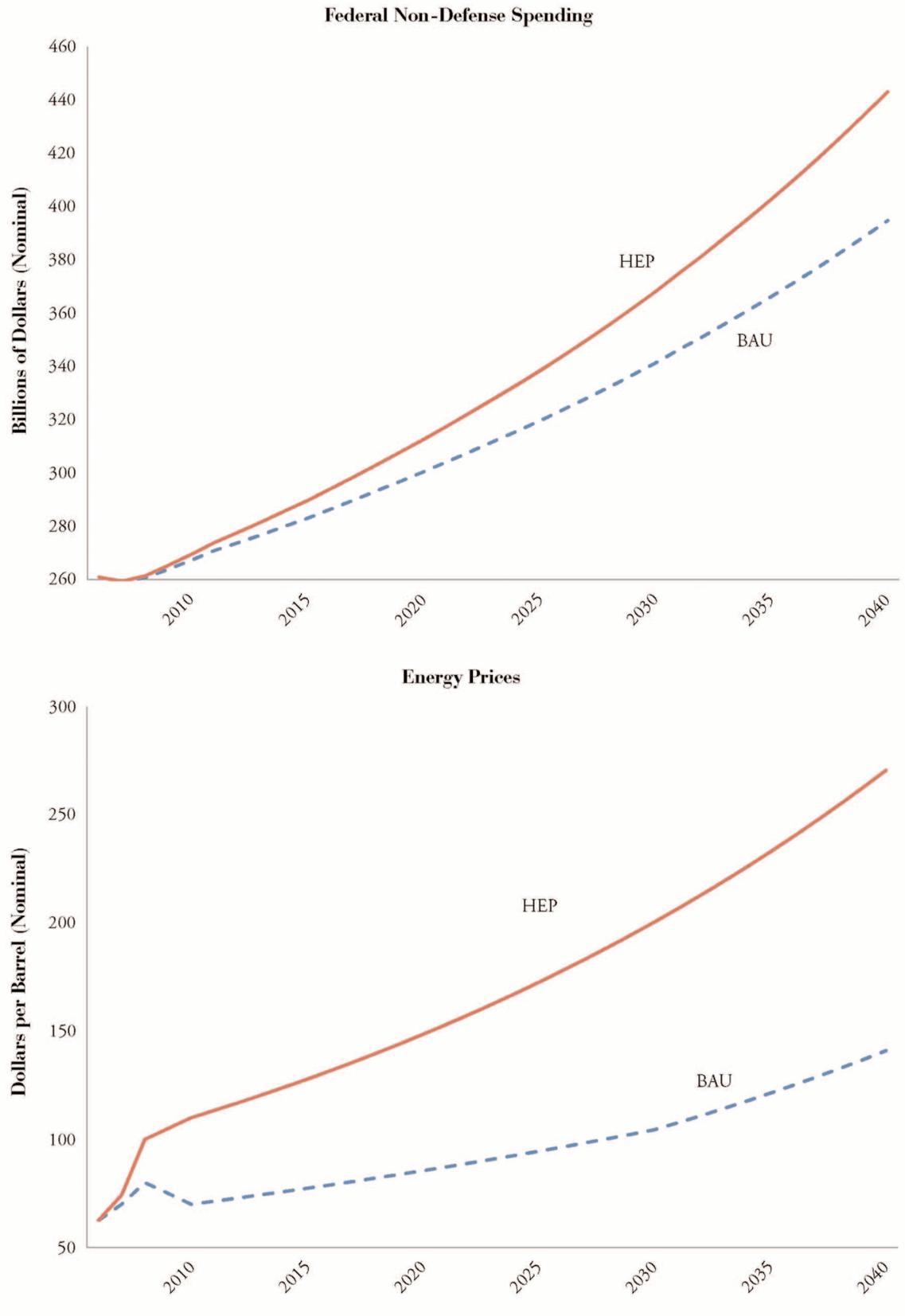


Figure 3. Trends in external forces as selected inputs for econometric models.

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Table 2. Projected annual growth rates in employment shares in 20 different industries under external conditions: Business as Usual (BAU) and High Energy Prices (HEP).

Industry	United States		Maryland	
	BAU %	HEP %	BAU %	HEP %
Farm	-0.90	-1.14	-0.86	-1.06
Forestry, fisheries and mining	-0.76	-0.89	-0.97	-1.10
Construction	1.07	1.10	1.12	1.20
Manufacturing	-0.07	-0.13	0.14	0.10
Wholesale trade	0.00	-0.06	0.13	0.12
Retail trade	-0.56	-0.69	-0.44	-0.51
Air transportation	2.18	2.11	2.25	2.22
Trucking and utilities	0.43	0.36	0.59	0.56
Information	0.24	0.26	0.21	0.27
Finance, insurance, and real estate, excluding rental	-0.46	-0.15	-0.39	-0.09
Professional, technical services and management offices	0.09	0.38	0.25	0.56
Administrative and waste services	0.40	0.46	0.45	0.55
Educational services	0.68	0.60	0.86	0.82
Health and social services	2.14	2.11	2.34	2.36
Arts, entertainment, and recreation	0.93	0.75	1.00	0.86
Accommodations	-0.31	-0.32	-0.29	-0.27
Food services	0.22	0.15	0.34	0.31
Other services, including rental	0.26	0.19	0.38	0.35
Federal government	0.26	0.74	0.61	0.71
State and local government	0.46	0.46	0.61	0.64
Total	0.47	0.48	0.63	0.71

Table 3. Land use model outputs in different scenarios for select counties.

County		Residential growth		Agricultural land conversion	
		BAU	HEP	BAU	HEP
Fairfax, VA	CI	29,926	33,278	4,064	4,464
	TI	32,153	35,457	4,332	4,771
Montgomery, MD	CI	21,378	23,997	3,909	4,299
	TI	21,367	24,012	3,876	4,330
Prince William, VA	CI	5,676	4,164	1,094	807
	TI	6,193	4,474	1,203	877
Franklin, PA	CI	4,224	2,978	1,593	1,115
	TI	4,117	2,944	1,609	1,095
Loudon, VA	CI	3,816	2,736	826	591
	TI	4,145	2,963	885	640
Whole region	CI	268,024	291,638	62,228	68,292
	TI	269,202	292,253	62,088	68,000

Notes: Acreages in the table. BAU = business as usual, CI = current infrastructure, HEP = high energy prices, TI = transportation investments.

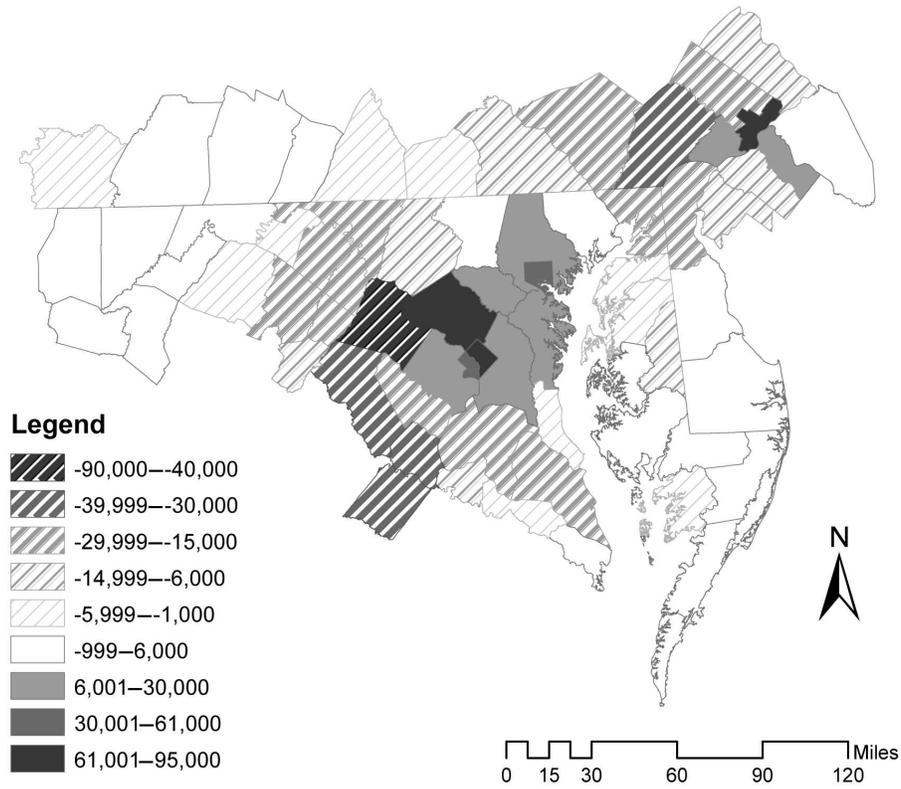


Figure 4. Difference in employment growth between external conditions HEP and BAU.

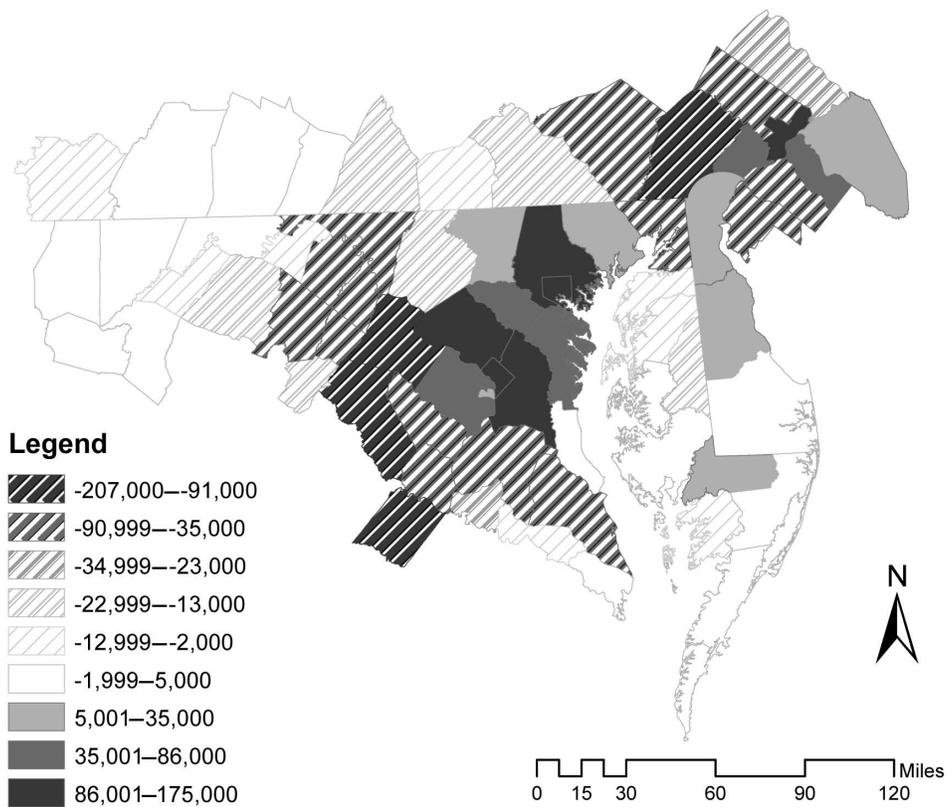


Figure 5. Difference in population growth between external conditions HEP and BAU.

population in the inner-ring and more urban counties cause greater road congestion (see Table 4). When there are no transportation investments, 15% of the lane miles are congested in both HEP and BAU, although the spatial pattern of congestion differs. This difference is small, but based on road congestion alone, TI is a robust decision. In sum, a scenario framework for analyzing transportation investments at the regional scale illustrates the contributions that scenario analysis can make to regional decision making. Whereas standard practice develops a limited set of scenarios, evaluates each one, and chooses a preferred scenario, the framework above illustrates how scenario analysis can be used to identify robust decisions under uncertain conditions. While reality complicates this picture, this decision-making framework provides space to consider additional real-world factors.

Scenario Analysis at the Local Scale

Compared with regional decision-making entities like MPOs, local governments have limited influence over large

transportation investment decisions. From a local perspective, both energy prices and transportation investments are external factors. As a result, a slightly different process must be used to identify robust and contingent decisions at the local level.

Using model outputs on land consumption and traffic congestion, we compare areas that receive significantly high new growth given two external forces (BAU and HEP) when no major infrastructure investments are made (CI) (see Figure 6). Significant new growth is defined here as more than 100,000 square feet of new building footprint per square mile. Higher energy prices will move development closer to the core (and, by extension, away from the urban edge). The lightest-shaded areas experience more development in BAU, and medium-shaded areas experience more development in HEP (see Figure 6). These areas could develop contingent land use plans for each future and adjust them depending on the likelihood of a specific future materializing. The dark areas experience high growth whether or not energy prices rise. For local governments accommodating growth in these areas would represent a robust decision with respect to energy prices.

In HEP, investing in an outer beltway around Washington and extending transit in suburban Northern Virginia would shift new development from the suburbs of Baltimore and the Baltimore–Washington corridor to areas closer to Washington and places with newer investments (see Figure 7). If both high energy prices and transportation investments are likely, these areas should plan for more development.

A regional agency interested in selecting a robust strategy (e.g., investment in major infrastructure or not) can combine land use and environmental impact information with transportation outcomes using multi-criteria analysis (Munda, 2006). Additionally, when regional decisions are dependent on local support, regional and local decision makers may come to a better understanding of the impacts and tradeoffs associated with different decisions. For example, if a locality loses projected (and desirable) development due to infrastructure investments (TI) regardless of external forces (BAU or HEP), it might decide to oppose the investments or argue for compensation.

The analysis can again be extended to include transportation impacts. Figure 8 illustrates which links will be congested under alternative scenarios. For example, in BAU, the outer-ring suburban counties have a higher population and employment share than they would in HEP; as a natural result of more growth, more roads in these areas become congested (see Figure 8). However, in

Table 4. Congested lane miles in different scenarios for select counties.

County		BAU %	HEP %
Delaware, PA	CI	46.3	47.5
	TI	49.4	50.9
Stafford, VA	CI	45.9	34.6
	TI	43.5	32.5
Prince William, VA	CI	43.8	40.6
	TI	42.7	37.9
Loudon, VA	CI	43.6	34.5
	TI	39.6	25.0
Fairfax, VA	CI	37.7	39.0
	TI	30.3	32.3
Arlington, VA	CI	35.8	44.2
	TI	28.6	37.2
Clarke, VA	CI	30.5	17.9
	TI	16.7	10.9
Spotsylvania, VA	CI	27.8	14.7
	TI	25.6	14.0
Frederick, MD	CI	27.5	26.5
	TI	20.0	18.6
Howard, MD	CI	25.7	28.2
	TI	15.9	19.4
Jefferson, WV	CI	25.2	14.4
	TI	20.3	8.8
Whole region	CI	15.1	15.0
	TI	12.0	11.7

Notes: BAU = business as usual, CI = current infrastructure, HEP = high energy prices, TI = transportation investments.

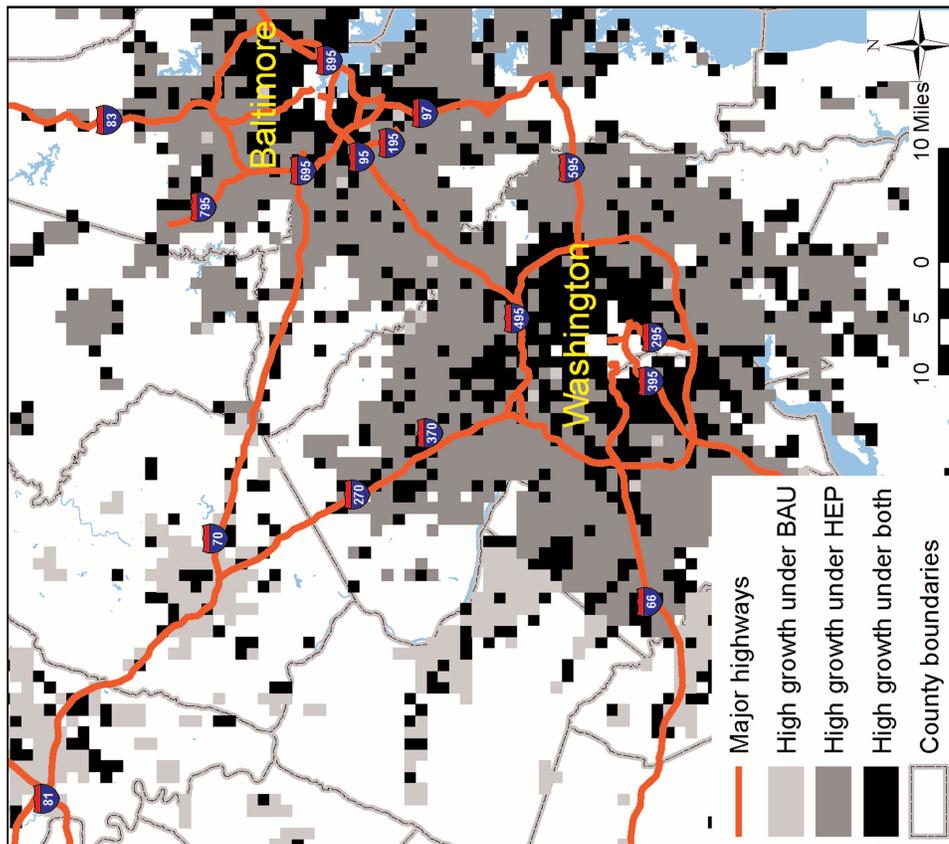


Figure 6. Comparing new developments across external futures under current infrastructure. (Color figure available online.)

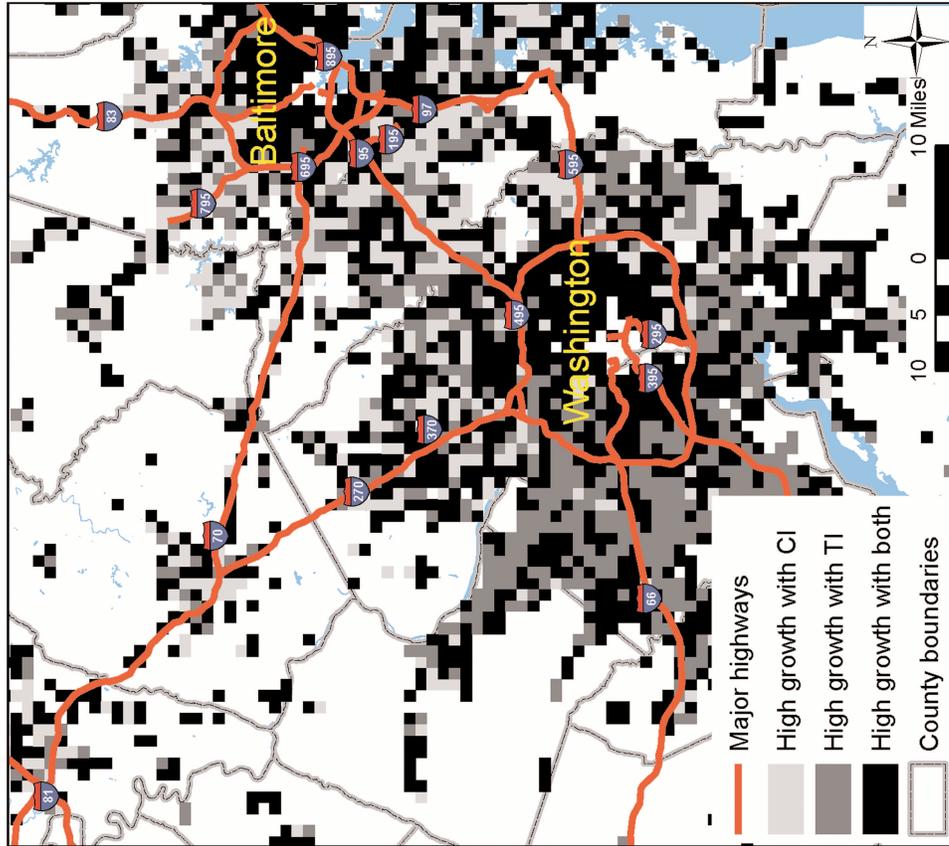


Figure 7. Comparing new developments in CI and TI under HEP.

Note: Darker areas require plans for high growth irrespective of CI or TI, while lighter areas require complementary plans depending on which transportation option is chosen. (Color figure available online.)

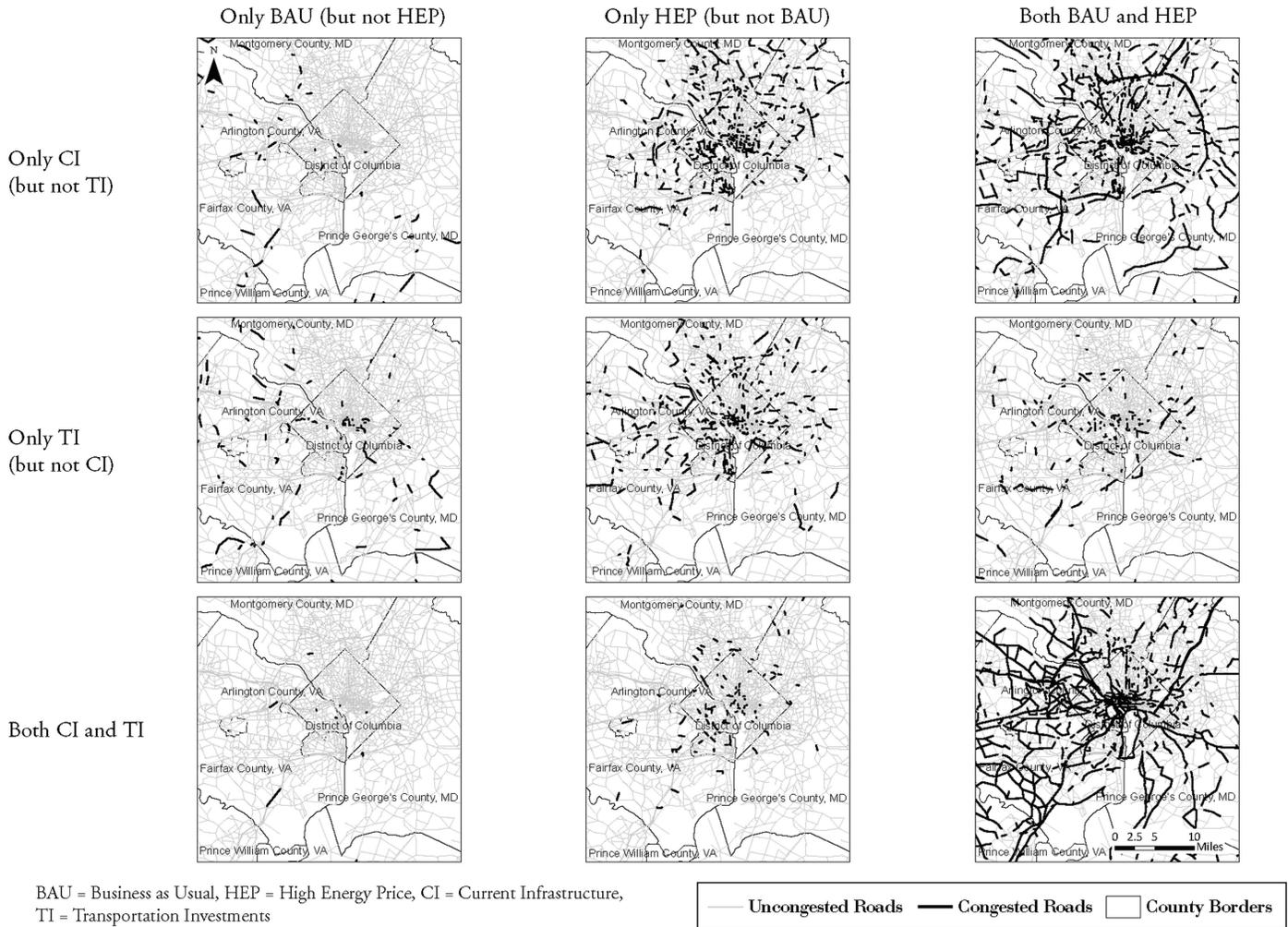


Figure 8. Congested roads in different scenarios.

Note: Roads congested irrespective of BAU and HEP require robust plans; those congested irrespective of CI-TI decisions require complementary robust actions. Links congested only in particular scenarios require complementary contingent actions.

HEP, the inner-ring suburban counties receive higher shares of employment and population, and therefore, are subject to higher congestion levels than in BAU. While the general pattern described above holds true across the two external forces (BAU and HEP), the extent of local impacts varies depending on transportation investments. For example, the existing beltway (Interstate 495) is congested when no investment occurs, but not congested (irrespective of the external forces) when investments are made. Congestion on other highways and local roads varies considerably. Addressing congestion in these areas may be viewed as a task for the localities, but because local governments cannot control energy prices or large-scale transportation investments, contingent plans are necessary.

If investment in major regional infrastructure represents a robust decision, additional challenges, such as links

that will remain congested to different extents under different external forces, could be addressed by multiple contingent plans. Figure 8 depicts the specific links that contingent plans must address. Depending on the jurisdiction, these plans may be local or regional. Local governments anticipating impacts such as high loss or gains in development might also take complementary actions, such as updating their land use plans. For example, as new infrastructure in Fairfax County, VA, improves accessibility and increases development capacity, the county will need to plan for more urban development. At the same time, counties that do not see much impact from internal options but see high differential impacts from external forces should consider developing contingency plans that identify a range of strategies to deal with uncertain future circumstances.

These stylized planning cases demonstrate an iterative process in which scenarios are further evaluated using additional choices and forces at other temporal and spatial scales in order to determine complementary actions and linked decisions. These cases also highlight the rich potential of scenario analysis in strategic decision making across varying scales. As noted earlier, they provide opportunities to discuss uncertain futures with multiple stakeholders and to conduct comparative analyses of interdependent decisions.

Caveats and Qualifications

The logic of our analysis is sound, and the products of our models demonstrate the use of metropolitan-scale tools to identify contingent and robust strategies, but we recognize the limitations of our work and the difficulty of using our strategy in practice. First, the distributive impacts of investment decisions require careful consideration. Second, many other factors warrant attention besides the rate of population growth and loss of farmland. Local values and a wide range of additional variables should be considered in any such large-scale investment decision.

As with any causal mechanism, the models presented in this article are subject to limitations and caveats. The econometric models are useful insofar as past structural relationships hold under different scenarios. The transportation models do not account for regional transit and trip chaining and the availability of consistent regional socioeconomic data. The land use model is also constrained by the availability of consistent data, is very sensitive to transportation investments, and does not capture urban redevelopment effectively. Despite these models' limitations, our analysis illustrates how their results can be used in the planning process in new ways. We also recognize that most metropolitan-scale decisions must be made in a complex institutional environment that involves local, state, regional, and federal decision makers and many other stakeholders. Sets of constituents may classify the same condition as an internal option or external force. This complexity, as well as the time and monetary costs associated with large-scale endeavors, may cause some to question the usefulness of scenario planning. Yet, other methods, such as choosing a preferred scenario without considering the uncertainty inherent in planning for a 30–50-year horizon, are also not without cost.

Finally, identifying external forces requires careful monitoring.¹¹ Nevertheless, because scenario planning considers many uncertain futures, planners are likely to be

prepared for a range of possibilities. In fact, robust plans can make preferred scenarios even more compelling by demonstrating their ability to work under a range of possible external forces.

Conclusions

Agencies that use scenario planning (especially agencies in large regions) typically use it to identify common regional issues and formulate solutions that serve multiple jurisdictions. In practice, scenario analysis has led to “choice” among archetypical futures, such as Business as Usual, Smart Growth, and others in between, on a somewhat linear scale of desirability. The intended result of this type of exercise is to publicly choose an already preferred scenario, usually a regression to the median (Kaza, 2006). In other words, planning agencies have not yet fully harnessed scenario planning's unique capacity to illustrate multiple futures and formulate contingent actions. Instead they have focused on articulating and choosing a preferred scenario.

Thinking about scenarios (or possible futures) as an interacting set of controllable internal options and uncontrollable and varying external forces allows planners to explicitly address uncertainty, thereby enabling the creation of multiple contingent plans and robust plans. As we demonstrate through a regional planning case, scenario planning offers a much richer perspective with which to confront uncertainty. Using the tools developed for the Maryland Scenario Project, we illustrate the logic of using this approach to develop multiple plans or strategies, robust ones that address more likely outcomes despite varying forces, and contingent ones that are perhaps more flexible and can address other possibilities. From a practical standpoint, this perspective may help local and regional governments consider uncertainty more effectively in their planning and investment decisions. The framework can also be used by the decision makers and affected stakeholders to identify complementary actions in specific futures.

While the temptation to choose a preferred scenario persists, in reality, a preferred scenario is often merely a commitment signal. Such signals may be important, to borrow Hopkins' (2001) canoe analogy, but the rower cannot choose to avoid hitting the rock. The choice is among steering directions under imperfectly predictable currents. In enabling us to think systematically about uncertainty, scenario planning promises to expand the usefulness of plans and the efficacy of planning.

Acknowledgments

The authors would like to thank Philip Berke, Lewis Hopkins, and anonymous reviewers of *JAPA* for making extensive comments on the manuscript; Shuo Huang, Anne Eshleman, and Yong Wook Kim for providing excellent research assistance and creating graphics; and Laura Searfoss for providing assistance with copyediting.

Notes

1. Most of the standard measures of performance (e.g., vehicle miles traveled, criteria pollution emissions, land consumed for residential use, etc.) decrease in accordance with increases in density and diversity, causing the smart growth scenario (compact urban form with high-quality transit and mixing of uses) to be chosen.
2. Scenario planning is quite common in military and natural hazard applications. See Bloom and Menefee (1994) and Moats, Chermack, and Dooley (2008), respectively.
3. Our reading of the projects that HUD funded, however, suggests that HUD did not literally require contingent scenario development and, instead, focused more on the community engagement aspects of scenario planning under a single, preferred scenario.
4. See the National Center for Smart Growth website at <http://www.smartgrowth.umd.edu/marylandscenarioproject> for more information.
5. For more on LIFT, see <http://inforumweb.umd.edu/services/models/lift.html>
6. For more on the LEAM model, see <http://www.lead.uiuc.edu/maryland>
7. Another reason for treating these investment decisions as a single set is to ensure that our example is not used to support particular investment decisions. The use of models for transportation decision making is a complex and often highly politically charged process. We aim to demonstrate a decision-making strategy, not enter into the decision-making debate. Furthermore, *ceteris paribus* exercises are not central to scenario planning, which is more focused on developing coherent story lines using interacting forces.
8. BAU acts as reference against which all other outcomes are compared. It is “as-usual” in name only. It presumes inertia: All variables remain in their current state or maintain the past trajectories or sustain past relationships posited in the model.
9. This issue relates to how land use controls are represented in the models and to the different regional attitudes toward agricultural preservation. Maryland has strong and stable zoning categorizations, but counties in Virginia do not. Because of these differences, while Maryland’s generalized zoning is considered in the model, no such controls are imposed outside the state. Nevertheless, these inputs are constant across all four scenarios.
10. Because planning problems are particularly wicked and multidimensional (Rittel & Webber, 1973), robust decisions are rarely solely based on a single criterion.
11. We have addressed the need for monitoring and the use of information in decision making over time in other books and articles. See Knaap (2001); Knaap and Hopkins (2001); Knaap, Donaghy, and Hopkins (1998); and Kaza and Knaap (in press).

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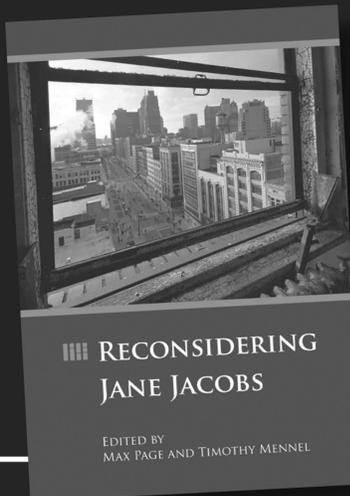
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