

ABSTRACT

Title of Dissertation: AN EXPERIMENT IN STATEWIDE SCENARIO ANALYSIS: TOWARDS AN EVEN SMARTER GROWTH FOR MARYLAND

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Using scenario analysis, this dissertation explores the impacts of alternative development patterns on quality-of-life indicators for the state of Maryland. It compares existing conditions and six alternative scenarios using a set of planning-relevant indicators, such as open space protected, vehicle miles traveled, and proximity to highways and transit. The scenarios are – 1) extension of past trends, 2) build-out of local government zoning, 3) a regional vision developed through representative, participatory process, and three rule-based experimental scenarios (4, 5 and 6) developed through a land use allocation model.

This experiment in scenario analysis adds to the literature in two respects. First, it offers a rare experiment in scenario analysis at the statewide level. In that respect, it offers new insights concerning the influence of geographic unit of analysis, methods of aggregation, and the choice of performance indicators. Second, it offers new insights into the performance of alternative state-level land use policies. It shows, for example, that by most measures of performance land use planning by local government yields the poorest outcomes. The smart growth strategy in which growth is contained in state approved Priority Funding Areas yield better outcomes. Even better outcomes are

possible, however, by containing growth in urban corridors, an urban core diamond, or as recommended by the public in a “Reality Check” exercise. Whether there is sufficient political support to implement these better performing outcomes, however, remains uncertain.

AN EXPERIMENT IN STATEWIDE SCENARIO ANALYSIS: TOWARDS AN EVEN SMARTER
GROWTH FOR MARYLAND

By

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Dissertation submitted to the Faculty of the Graduate School of the
University of Maryland, College Park, in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
2007

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Dedicated to my parents Purnima and Dipankar Chakraborty

Acknowledgements

This dissertation could not have been successful without the enthusiastic and unending support of my wife Shilpa, my advisor Dr. Gerrit-Jan Knaap, my dissertation committee members and my colleagues at the National Center for Smart Growth. Especially, I would like to thank Jung Ho Shin and Dr. Doan Nguyen for providing valuable critique every step of the way including sitting through rehearsal presentations and commenting on really crude drafts. I am lucky to have so many past colleagues and affiliates of the Center who provided their help in developing this work, especially, Prof. Chengri Ding, Prof. Sidney Brower, Prof. Vikas Mehta, Elana Messner, Terry Moore, Laurel Davis, Megan Rhodes, Selma Lewis, Laura Cole, Stephanie Martins and Nam Seok Kim.

To all of you...again, Thank you!

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Glossary of Acronyms

BMC	Baltimore Metropolitan Council
LULC	Land Use and Land Cover
MDP	Maryland Department of Planning
MPO	Metropolitan Planning Organization
MWCOG	Metropolitan Washington Council of Governments
PFA	Priority Funding Areas
RCP	Reality Check Plus
TAZ	Transportation Analysis Zones
USGS	United States Geological Survey
UGB	Urban Growth Boundary
VMT	Vehicle Miles Traveled

Chapter 1: Introduction

Planning serves a range of interests at various overlapping scales (local, regional and national), fields (physical, social, economic) and degree of influences. Thus many functions of planning such as zoning, comprehensive planning, transportation planning, etc. are often disconnected leading to suboptimal or undesirable outcomes. As planning faces many challenges related to growth, or decline or performance of plans, scenario planning provides a tool that allows planners to ask questions that cross conventional boundaries. As a result, scenario planning has a potential to play an increasing and more meaningful role in the planning process.

Planning strives for rigorous analysis and public participation in all aspects including identification of issues, evaluating alternatives and decision making. Yet, in practice, planning is often conducted as government action with short-horizons of election cycles or without adequate critique of assumptions or consideration of impacts beyond the particular field in question. Scenario planning, on the other hand, can greatly advance planning ideals as it not only incorporates political and participatory processes that are interesting but also sophisticated technical analysis.

Porter (1985) defines a land use or development scenario as “an internally consistent view of what the future might turn out to be – not a forecast but one possible future outcome.” In a scenario analysis process, many such outcomes are generated based on a set of questions using a variety of methods. Due to recent advances in mathematical models and participatory tools, scenario analysis has gained increasing interest among planners. Such efforts have common ties, including – understanding past trends, projecting variables into the future, having spatial components to any analysis, and asking questions regarding the scale at which certain planning problems should be addressed. The nature of such efforts, especially their scale and general outlook, makes it possible to aggregate variables and

evaluate the resulting scenarios regionally in addition to locally. Advocates of scenario analysis generally argue that looking at issues regionally internalizes the interdependence among neighboring areas for an overall regional benefit. Development scenarios represented through maps also allow planners to test their efficacy against other scenarios using objective indicators.

This research uses the spatial distribution of existing households and jobs, and relationships drawn among their quantities, locations and various impacts of development, to generate and compare a set of land use scenarios for Maryland. The scenario analysis also includes comparison of build-out of current zoning in the state and outputs of a participatory visioning process. This experiment in scenario analysis adds to the literature in two respects – it offers a rare experiment in scenario analysis at the statewide level. In that respect, it offers new insights concerning the influence of geographic unit of analysis, methods of aggregation, and the choice of performance indicators. Second, it offers new insights into the performance of alternative state-level land use policies. It shows, for example, that by most measures of performance land use planning by local government yields the poorest outcomes. The smart growth strategy in which growth is contained in state approved Priority Funding Areas yield better outcomes. Even better outcomes are possible, however, by containing growth in urban corridors, an urban core diamond, or as recommended by the public in a “Reality Check” exercise. Whether there is sufficient political support to implement these more preferred outcomes, however, remains uncertain.

Maryland is rapidly growing, and is already the fifth densest state in the country. In the past, a number of efforts that have tried to address growth issues regionally, such as the Priority Funding Areas Act of 1997 and the Baltimore Vision 2030, a visioning process. In spite of such efforts, the existing regulatory framework, competing interests of jurisdictions, and tax-base and property rights issues

have kept land use planning restricted largely in the domain of local governments. Scenario analysis allows relaxing some of these constraints, asks “what if” questions, and attempts to answer them through quality-of-life indicators.

In a broader sense, land use planning has received attention with heightened concern recently in the context of climate change, particularly its interaction with the transportation network and its environmental impacts. With Maryland slated for significant growth in the near future, the possible impacts on transportation, environment, quality-of-life, etc. have been placed high on the political agenda. These conditions, multiple ongoing planning-relevant efforts in Maryland and elsewhere, as well as relative lack of empirical and conceptual foundation for regional planning, particularly at the state level, make this research timely and important.

1.1 Research Questions

The objectives of this research are –

1. To explore the utility of statewide scenario analysis
2. To explore, using scenario analysis, the impacts of alternative development patterns on quality-of-life indicators in the state of Maryland

Through the process, this research addresses the following issues:

1. *How can a wide set of plausible scenarios be generated?*
2. *What are the differences between scenarios generated through different methods and assumptions?*
 - *What are the measurable indicators in each scenario?*

3. *How much difference do the components of a scenario, such as geographic unit of analysis, control totals, etc. make in the outcome of the analysis?*

1.2 Background

As this research is structured as a case study of Maryland, it is important to understand the background of recent growth-related planning practices in Maryland at various levels in the state and their impacts on development. Maryland is nationally recognized as a leader in enacting growth management policies. The State's Priority Funding Areas (PFA) Act of 1997 is one of the more recent statewide statutes with several programs, including – demarcation of certain areas that have preexisting sewer and road networks as eligible for additional funding, tax credits to live near the place of work, and funding local governments to protect prime farmlands. Additionally, at the local level, policies in certain jurisdictions such as Montgomery County have promoted preservation of agricultural land through Transfer of Development Rights (TDR) and creation of affordable housing opportunities through Moderately Priced Dwelling Units (MPDU) programs¹. Many local governments in Maryland also have Adequate Public Facilities Ordinances (APFOs) that reduce availability of building permits in areas lacking infrastructure capacity for new developments.

Although it is difficult to separate the individual effects of these policy measures, certain facts stand out²:

1. The development footprint in the state has grown considerably in the last 10 years, and has created leapfrog development patterns in the region.

¹ Montgomery County Department of Housing website:
http://www.montgomerycountymd.gov/dhctmpl.asp?url=/content/DHCA/housing/housing_P/housing_p.asp (accessed 05/30/07)

² Appendix G includes further details of the following observations including figures

2. Since the enactment of PFAs, more development has happened outside the PFA (even at an increasing rate) than inside the PFA (in terms of acres developed)³.
3. The population of almost all suburban (not rural) jurisdictions has increased while population in central cities declined (Central cities refer to Baltimore, and just outside the study scope of this research, Washington D.C.).
4. The health of the Chesapeake Bay, a major factor in the state's economy, continues to decline.
5. Transportation planning in the state, now regarded as intrinsic to land use decisions [Waddell, 2001], continues to be conducted separately for Baltimore Metropolitan Region and Washington Metropolitan Region⁴.

Many related occurrences such as movement of defense-related jobs into Maryland due to recent Base Realignment and Closure⁵ (BRAC), predictions of rise in sea level⁶ and potential inundation of parts of Maryland shoreline, regional integration of multiple economic entities in the larger mid-Atlantic region, and perception that northern Virginia economy is growing faster than Maryland have all contributed to the rising interest in being proactive for future growth.

1.3 Conceptual Framework

Many efforts, such as Portland 2040, Chicago 2020, California Urban Futures model, New Jersey State Plan, etc., are underway to understand and estimate the future supply and demands of land use and related resources and their consequences (Landis, 2001; Burchell et al. 2003). Scenario analysis contributes to these efforts as a framework to analyze and compare alternative representations of the future. Thus, based on certain explicit assumptions, it helps planners prepare for the uncertainties of

³ State of Maryland Priority Funding Areas website:
http://www.mdp.state.md.us/msdc/PFA/Resid_Growth/PFAAnalysis_2004Summary.ppt#315,1,PFA and Residential Single-Family Development in Maryland, 1990 – 2004 (accessed 05/30/07)

⁴ Metropolitan Planning Organization for Baltimore area is Baltimore Metropolitan Council (BMC); whereas that for Washington area is Metropolitan Washington Council of Governments (MWCOG)

⁵ BRAC transportation action plan (last accessed 6/10/07
<http://www.marylandtransportation.com/Planning/brac/index.html>)

⁶ DNR Answers Questions about Sea Level Rise In Response to IPCC Report (date accessed: 6/10/07
http://www.dnr.state.md.us/dnrnews/infocus/sealevel_rise.asp)

increasingly complex urban and regional structures in an organized and simplified fashion. When scenario analysis is done with a spatial and a visual component, it also facilitates conveying complex information in a simple format to the decision makers and the public-at-large and incorporate their feedback into the planning process. The objective of scenario analysis is not to decide on the likeliest future, or even a normative one, but to make strategic decisions in the present that will serve all plausible futures (Moore, 2005). “The standard for scenario-building must be effectiveness rather than accuracy; the outcome of the process should be better decisions in the future.” (Schwartz 1996)

In such a process, different assumptions on policies, drivers, etc. lead to different outcomes or new scenarios, which are compared to the baseline conditions. Specifically, land use scenarios in this study are defined as distinct spatial combinations of households and jobs. Stated differently, new scenarios are changes in spatial distribution of households and jobs, resulting in a net change in the magnitude of total population and employment for the region. Six such scenarios are developed using different methods and are compared for the policy assumptions and outcomes. In addition to the baseline conditions, this research compares the following scenarios:

1. COG 2030 scenario [household and jobs allocation in year 2030, as projected by official forecasts of the Councils of Governments (both Washington and Baltimore)]
2. Build-out of existing zoning [build-out analysis of the state’s zoning ordinances, and sometimes comprehensive plans without specific time horizon]
3. Reality Check *Plus* (RCP) 2030 scenario [household and jobs allocation in year 2030, as envisioned by Reality Check *Plus* participants in the regional exercises] (Reality Check *Plus*⁷: A representative participatory process)

⁷ “Reality Check *Plus*” was the name given to a series of growth visioning exercises that were held in four different regions in Maryland in late spring 2006. The events were designed to help elected officials, government leaders, business executives, civic organizations, environmentalists and Maryland residents become more aware of the level and pace of

4. Scattered Urban Clusters scenario [rule-based scenario, conditions are experimental, year 2030]
5. Urban Diamond scenario where growth is restricted inside a region defined as an Urban Diamond with Washington, Baltimore, Annapolis and Frederick at the vertices [rule-based, experimental, year 2030]
6. PFA-oriented Smart Growth scenario [rule-based, a test on the state's smart growth policy, year 2030]

The assumptions, methods and contents of the scenario together try to cover a wide range of options that are yet simplified and context-sensitive. The baseline conditions are based on the most recent Census data (year 2000) on households and employment and the COG scenario is based on Council of Government forecasts for the year 2030. The build-out of existing zoning provides an evaluation of existing plans of the jurisdictions in the study area⁸. The Reality Check scenario is based on a participatory process. The last three scenarios are created on a rule-based model and are experimental in nature, developed to test the efficacy of certain, otherwise untested, development patterns. As the subsequent chapters explain in detail, the scenarios were developed through a set of methods and processes, but many common themes help make their comparison possible. The qualitative differences in outcomes of the scenarios and their consequences are also discussed.

One common theme is the data resolution or unit of analysis. Although different datasets are available at different levels of aggregation (census tracts, transportation analysis zones or TAZs, block groups, parcel points, etc.), all data is converted into 1 sq. mi. grid. As subsequent chapters will illustrate, the benefits of a grid-based unit of analysis, which is comparable across scenarios generated through different methods, outweighs the aggregation error this entails. Also, household and employment

growth that is projected to come to Maryland by 2030 – and to ask them to think about the potential challenges and consequences Marylanders will face as a result of such dramatic change.

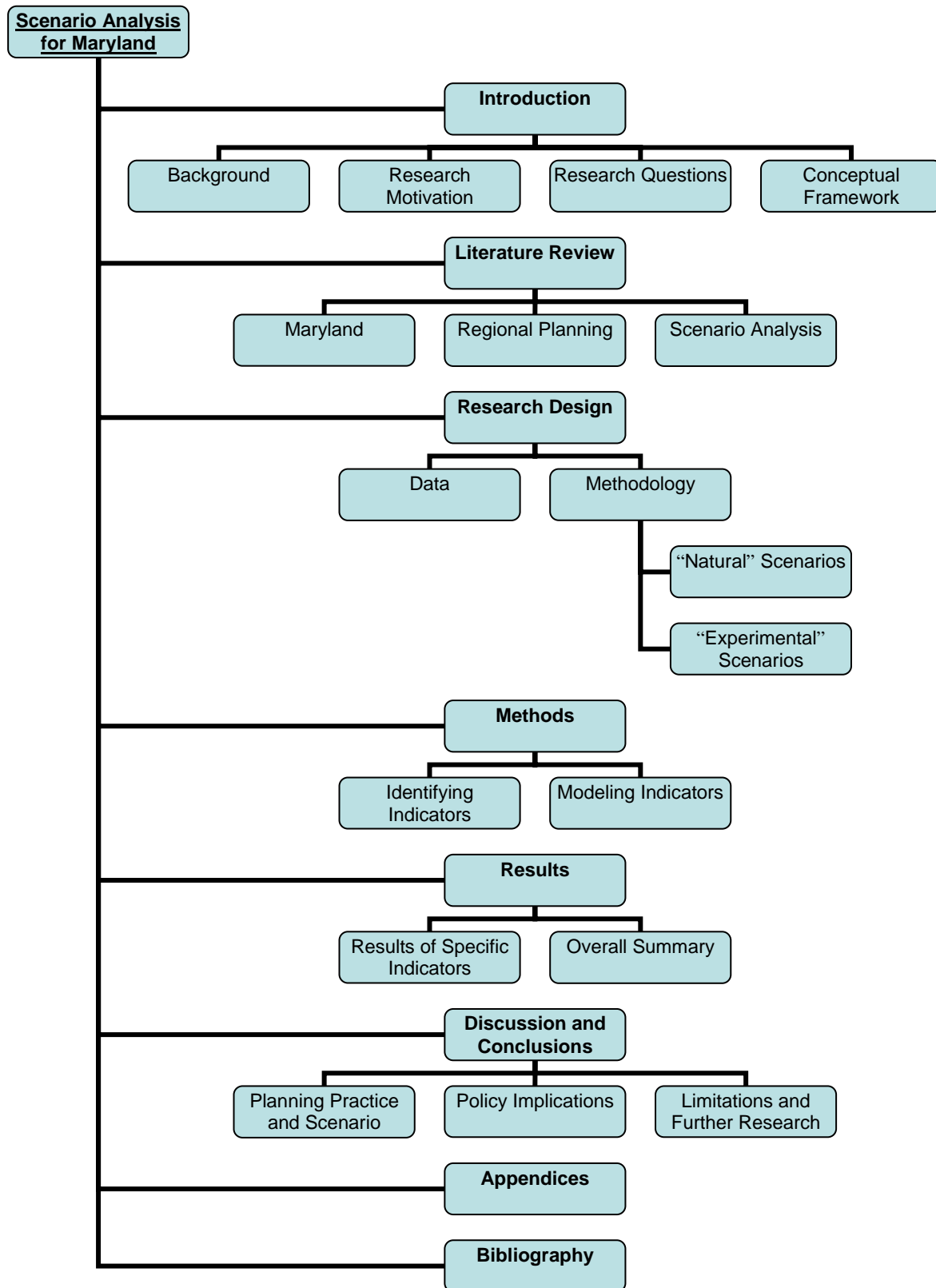
⁸ As explained in Chapter 5, a collection of local zoning maps is representative of local governments' land use plans

projections through 2030 (an exception to this was the build-out scenario) are used as demand side variables in the scenarios.

The scenarios are compared using a set of planning-relevant indicators, such as proximity to transit, acres of new development, vehicle miles traveled (VMT), development inside the beltways, etc. Some of these indicators are developed using spatial or statistical methods while others are based on models from existing literature. All of the indicators presented in this research are a function of variables that can be effectively predicted or dictated in a future scenario. The indicators are also sensitive to spatial arrangements of population and households. However, the indicators presented here are a small set of potentially large and diverse set of consequences. For example, this dissertation does not address the impact of development patterns on energy consumption or equity issues. Although some correlations could be drawn from the existing literature, the future scenarios developed here looks at only those variables and their effects which are also projected in the future. For example, this research does not look at household type (single-family, multi-family etc.) and hence any indicator that may be a function of splits in household types or correlated to it (such as income, equity etc.) are not directly computed.

In developing and evaluating scenarios, many additional questions that arise are either discussed or listed under assumptions and explained. These include issues related to supply of land in already developed areas, how to define a set time horizon, etc. Trying to evaluate an uncertain future in certain, quantitative terms is a challenge. This research is, thus, an exercise in overcoming this challenge by developing scenarios through multiple methods, such as extension of past trends, visioning, models based on existing relationships, and sometimes, simple heuristic choices.

1.4 Research Organization



Chapter 2: Literature Review

Scenario analysis of development patterns is based on the foundation that how and where the development happens makes an impact on the quality of life and understanding these choices help make better planning decisions. Such analysis involves looking at precedents, collecting data and doing technical analysis and an understanding of the institutional context of the case under investigation. There is extensive literature on the various cause-and-effect models that relate development with its consequences and scenario analysis processes that bring together many such models into an overarching framework. There is also a lot of material on how the regional planning process has evolved over time. There is some material at the intersection of the two fields and few that looks at these questions at the statewide level. The literature review presented here looks at three bodies of work – scenario analysis, statewide and regional planning, and the physical and institutional context of land use planning in Maryland.

2.1 Scenario Analysis

This section summarizes the scope and application of scenario analysis, through various models that develop and analyze future development patterns and their impacts. It compares the mathematical and normative principles involved in some of the more popular models with respect to specific regions or metropolitan areas where they have been applied. Finally, it summarizes why scenario analysis as a tool is appropriate for this study.

Douglass Lee (1973) criticized mathematical models used in land use change forecasting that they are simplistic, top-down, and are based on unrealistic assumptions. More than three decades later, planning has become arguably more diverse in its model applications, more rigorous in its methodology and sophisticated computations are now possible with the click of a button. With the

improvement in GIS and other analytical software packages, there have been a flood of data that are readily available to serve any need, and the primary concern has changed from data availability to data usability, organization and update. Mathematical models have also come a long way in becoming much more sophisticated with the developments in other fields such as economics, regional science, ecology and transportation. However, the increased complexity of these models have not convinced all their critics, and new ways of “planning” urban systems have emerged over time which are more participatory and/or user-friendly and/or more locally adaptable. Moreover, there is no single state-of-the-art model and modeling continues to diversify. Such models of developing future growth patterns have been collectively termed here as *Scenario Analysis*.

In a broader sense, models that try to generate future development patterns are roughly categorized as *simulation* or *scenario-based* models. Simulation models generally have explicit time paths, detailed in their application and are generally deterministic in nature. Scenario-based models may include planning support systems, such as *WhatIf?*TM, or visioning exercises, such as *Reality Check Plus*. Some processes such as Chicago Metropolis 2020, uses both approaches. Although there are some models that go beyond the broad definitions of these categories (involving stochastic, heuristics and linear programming), the broad categories of inputs (supply side inputs – vacant land, current zoning; demand side inputs – growth projections) are similar in many models and what varies are the approaches and the outputs.

Simulated Models are comprehensive, operational and integrated (Hunt et al. 2005). Hunt explains each of these terms as *comprehensive* – “the model must include a reasonably complete range of spatial processes, notably land development, location choices by both households and businesses, and travel”; *operational* – “the model must be used in one or more practical urban planning operations”

and *integrated* – “feedback exists between transport and urban activity systems, so that short- and long-run interactions between transport network performance and land development/location choice behavior are captured appropriately within the model”. Examples of simulated models are DRAM/EMPAL and UrbanSim™ (Hunt et al. 2005).

Compared to simulated models, the outcomes of scenario-based models are more evaluative and policy-oriented and less deterministic. Leaving the decision-making to users and just providing the background and the support system, scenario-based models stop short of giving a single “exact” prediction. The objectives for designing such a model are to provide the user with basic information, underlying assumptions and maximum flexibility. These models also have fewer data requirements. Still, the wider appeals of scenario-based models lie in their collaborative and collective decision-making assisting role rather than being purely analytical.

The two categories of models are also intended for different users, situations, budgets and audiences. Scenario-based models provide a structural framework on which policy alternatives are analyzed, and since it is relatively simpler to understand how to use these models, it could be opened up to different stakeholders in a planning process to collect their input. In other words, as long as the background information are provided these models can be used by a wide group of people to quickly and easily visualize the results of different policy measures. The outputs of scenario-based models are in the form of maps (*WhatIf?*™) or 3D visualizations that make their use with a large audience attractive (Hunt et al. 2005).

Simulation models, on the other hand, need expertise to handle, need to be calibrated for regions where they are applied, (as lots of assumptions are based on local conditions such as land use and

local economy) and their outputs need expert interpretation as the format may vary from being a map, chart or tables. But due to their mathematical sophistication, and policy relevance, simulation models are suitable for extensive cost-benefit analyses, impact assessments and micro-level cause-effect phenomena.

Alternatively, scenario-based models are useful in forming long-term visions, broader coalitions among stakeholders in partnership projects and generating public support. But it would be simplistic to say that scenario-based models are bottom-up as opposed to top-down simulation models. Many variations exist within these broad categories. For example, there is literature that compares visioning exercise as a further third category. Avin and Dembner (2001) say that scenarios are a set of reasonably plausible but structurally different futures. This is in contrast to visioning, which often raises false expectations and masks the trade-offs. There are other authors who talk about integrating multiple approaches as complementary to each other (Bartholomew, 2005). For example, as opposed to being a standalone task, scenarios could also be integrated with smaller scale spatial models. Hopkins (2000) notes how using multiple approaches to modeling could lead to better plans. For a large region where it is difficult to incorporate all variables into one sophisticated model, multiple models tied with scenario building approach could lead to more plausible results. The following table summarizes a few scenario building processes around the country and how mathematical and/or scenario-based processes were integrated.

Table 1 Summary of Scenario Building Processes across U.S.

	Utah	Portland	Chicago	Sacramento	Beijing
Organization	Envision Utah Public/Private Partnership	Portland Metro	Chicago Metropolis 2020	Sacramento Area COG	National Center for Smart Growth
Period	1997-1999	1990-1994	1996-1998	2002-2004	2004
Base Year	1995	1990	1996	2000	2000
Horizon	2020	2040	2030	2050	2020
# Scenarios	4	4	3	4	3
Scenarios	Sprawl Baseline Medium Compact	Sprawl Baseline Medium “new-urbanism”	Baseline Compact Medium	Baseline Medium1 Medium2 Compact	Compact Eastward- directed Sprawl
Land Use Model	Spreadsheet method	Spreadsheet method	Spreadsheet method	MEPLAN	
Integration of LU and Tran.	Loose	Loose	Loose	Integrated	Integrated
Software	N/A	N/A	N/A	I-PLACE3S	INDEX

Klosterman (2005) has categorized tools for scenario analysis (also called *planning support system*) on the basis of their technical roles rather than policy focus. He categorizes them as *large scale urban models, rule-based models, state change models, impact assessment models* and *cellular automata models*. While large-scale urban models have been in use for decades mainly for transportation

planning purposes, California Urban Futures (CUF) model (Landis, 1994) was the first GIS-based urban development model. Instead of using spatial interaction and market processes as drivers for growth, CUF and other rule-based models allow users to specify explicit decision rules that guide the models' behavior.

Rule-based models such as CUF were followed by CUF II (Landis and Zhang, 1998) are categorized as state-change models (Klosterman, 2005) that project future land uses "...without attempting to simulate the demographic and economic processes which cause that growth." Such models, arguably, expand the role of planning by allowing more flexibility to decision makers in making their policy choices and for stakeholders to understand and comment on their implications, thus also adding a normative role for planning through the scenario analysis process.

In development and evaluation stages, scenario analysis involves developing alternatives that are evaluated against criteria, leading to the selection of optimum alternative. The three main steps in the process involve – determining how to develop the scenarios, what criteria will be used to evaluate scenarios, and how those criteria will be weighted. Moore (2005) says that there is "...hope at the heart of all policy evaluations that most of the significant impacts [efficiency and equity] of policy can be identified, described and compared..." to make rational choice. Moore (2005) lists four criteria – internally consistent and feasible, thought-provoking, visually appealing, and proximate to people's interests.

It is interesting to note that 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. Others rely on rules for the likelihood of land

conversions from one use to another. Some consider preferences of households and firms based on past behavior with respect to prices. Others rely on past probabilities of land conversions, and some seek an equilibrium solution. Some are dynamic, usually in discrete time intervals in which actions depend on the results of previous time intervals. Some model trip-behaviors given locations; others locate housing based on accessibility. When not developed from scratch, these models are always calibrated to a local area.

To summarize, testing the future impacts of present policies and plans creates many challenges. Myers and Kitsuse (p. 32, 1999) in their review of theories and tools to construct future say: "... what is needed today is a new synthesis of skills that includes all of the lessons of the modern era – political relevance, public inclusiveness, quantitative technique, narrative, openness of communication and more..." Doing that needs a set of tools that can create alternative representations of the future arrived at through various means, and analyzed and evaluated through a wide set of measures.

2.2 Regional and Statewide Planning

Despite the presence of multiple studies on the impacts of development patterns at jurisdictional or metropolitan scales (Jantz et. al., 2003; MWCOG, 2003; Roberts, 1975; Basolo, 2003; Downs, 1994 etc.), none looks at statewide scenarios spatially and using multiple models. Burchell et al. (2000) studied the impact of statewide development plan for New Jersey by comparing two scenarios – one, where the state development according to the plan and the other, where it developed according to the trends. Burchell concludes: *"No impact assessment can measure every variable, but overall, the assessment has carefully and consistently measured all relevant areas for which it has been charged, and the results are clear. The goals, policies, and strategies of the State Plan will produce noticeable improvements in the state's economy, environment, infrastructure, community life, and*

intergovernmental coordination.” Still, the New Jersey analysis does not look at alternative scenarios, and is limited in its spatial scope.

Another question associated with scenario analysis is its relevance to land use policy. Scenario analysis methods deal with the questions of scale, resolution, time horizon, and control totals, but their wider application has to consider the institutional framework of planning, both at local and regional level. This section summarizes application of land use planning at the state level in three states, reviews theories as they apply to regional planning, and discusses literature on costs and benefits of different approaches.

Background

The basic theoretical basis for regional planning is that regional government can internalize all costs and benefits. Campbell (1996) and others (Konishi, 2000; Cervero 2005; Downs, 1994) argue that many decisions influence regional development. They may include location of land uses, their integration with regional infrastructure development plans, and adding spatial components to taxation. Also, as an argument for a more regional approach to planning, Cervero (1996) and Levine (2005) highlight the existing disconnect in city-suburb relationship through job-housing mismatch, congestion, and degradation of environmental resources. The regional housing literature (Basolo, 2003) looks into housing interdependence among jurisdictions. Such studies link job-housing mismatch, travel distance, congestion, (Cervero, 1996; Levine, 2005) and lack of affordable housing for lower income people, (especially close to their employment) resulting in income and racial segregation and inadequate physical conditions (Downs, 1994; Davis, 1991; Schneider, 1989).

Recent History of Statewide Planning

One aspect of the regional approach to planning has been the adoption of plans and/or policies at the state level. Rhode Island, New Jersey, and Connecticut are three states which have implemented state land use plans and future land use maps to supplement current plans.

In the case of Rhode Island, the state plan was first implemented in 1975, reviewed in 1989⁹ and updated in 2006¹⁰ as *Land Use 2025*, Rhode Island's State Land Use Policies and Plan. In creating this plan, Rhode Island conducted telephone surveys, town meetings, regional workshops, interviews with planning leaders, and a *Land Use 2025* Brainstorming Session¹¹. Indicators included are: land use, housing, economic development, natural and cultural resources, services and facilities, open space and recreation, and transportation. *Land Use 2025* depicts a preferred pattern of land that is consistent with the vision, goals, and policies of the State Plan. The map is intended to be a policy guide to direct growth to areas that are most capable of efficiently supporting current and future development.

There were multiple steps in designing Rhode Island's Future Land Use Map – 1) Completion of a Land Suitability Analysis (LSA), 2) Land Availability Assessment to identify committed and available land within the state, 3) identification of land qualities and development constraints with regard to existing State Guide Plan policies, 4) Land Intensity Potential Classification (LIC) to examine the current land use patterns and existing infrastructure in combination with LSA, 5) creation of four scenarios: Trends, Centers and Corridors, Infill, and Composite, and 6) the final step,

⁹ State Land use Policies and Plan Land Use 2025. <http://www.planning.ri.gov/landuse/121/part1.pdf> (accessed October 18, 2006).

¹⁰ State Land use Policies and Plan Land Use 2025. <http://www.planning.ri.gov/landuse/121/cover.pdf> (accessed October 18, 2006).

¹¹ State Land use Policies and Plan Land Use 2025. <http://www.planning.ri.gov/landuse/121/techappend.pdf> (accessed October 18, 2006).

evaluation and scenario selection. Rhode Island selected the Composite Plan after evaluating each scenario for the projected amount of land to be consumed versus the projected growth needs and future land use patterns that best balanced the ecological and economic concerns.

In the case of the New Jersey State Plan, the measures of performance for scenarios or indicators included were: economic, environmental, infrastructure, community life, and intergovernmental coordination. The Plan's Statewide Policies are applied through five Planning Areas that reflect distinct geographic and economic units within the State. Each Planning Area is a large mass of land with tracts that share certain characteristics and strategic intentions. These are categorized as: Metropolitan, Suburban, Fringe, Rural/Environmentally Sensitive, and Environmentally Sensitive/Barrier Island. Where a municipality has more than one Planning Area within its jurisdiction, growth should be guided in that order.

Connecticut's statewide plan is designed to influence municipal land use decisions through state infrastructure plans and capital investments in transportation, water and sewer lines. The following six "Growth Management Principles" are included in Connecticut's State Plan: redevelop and revitalize regional centers and areas with existing or currently planned physical infrastructure; expand housing opportunities and design choices to accommodate a variety of household types and needs; concentrate development around transportation nodes and along major transportation corridors to support the viability of transportation options; conserve and restore the natural environment, cultural and historical resources, and traditional rural lands; protect and ensure the integrity of environmental assets critical to public health and safety; and promote integrated planning across all levels of government to address issues on a statewide, regional and local basis.

The “Locational Guide Map” categories are assigned a relative priority value for both Development Area Policies as well as Conservation Area Policies. They are as follows – Development Area Policies (in order of priority): 1) Regional Centers; 2) Neighborhood Conservation Areas; 3) Growth Areas; and 4) Rural Community Centers, and Conservation Area Policies (in order of priority): 1) Existing Preserved Open Space; 2) Preservation Areas; 3) Conservation Areas; and 4) Rural Lands.¹²

In summary, following themes emerge from this review. It is a difficult exercise to relate scenario analysis to planning implementation. The states that went successfully through this process had integrated approaches including both technical and political tasks. At the background or technical level, each state used various land use or analytical categories and computed indicators to demonstrate costs and benefits or impacts of alternative scenarios. The scenarios that were developed evaluated multiple policy options and were evaluated using planning-relevant indicators. At the procedural level, there was both a public process as well as attempts at regional coordination among various entities at multiple levels.

Regional Planning Background

In addition to the above cases, multiple efforts have attempted to evaluate and implement regional development plans with spatial components. Portland’s pioneering urban growth boundaries (UGB) and the recent legal challenges it faces are well-known. Apart from direct policy measures like UGBs, other actions had regional impacts on land uses. Examples include development of the Interstate Highway systems, the Clean Air Act and more recently the Transportation Equity Act for the 21st Century. The application of a direct regional planning framework, however, has occurred with mixed

¹² Conservation and Development Policies Plan for Connecticut 2005-2010.
<http://www.opm.state.ct.us/igp/cdplan/cdplan2.htm> (accessed October 19, 2006).

success. When applied, their impacts on development patterns are diverse, difficult to measure and overall effects are controversial.

A strong empirical basis of implementing of regional policies remains elusive although with recent technological advances, researchers have tried finding positive economic and environmental effect of enacting policies at a regional scale (Hannick et al. 2005), Historically, the proponents of regional reform have largely argued from theoretical and normative perspectives rather than a base of empirical findings (Levine, 2001). Such arguments have found many advocates in the proponents of affordable housing and critics of suburban growth. As early as 1920s, Regional Planning Association of America (RPAA), the nation's first regional advocacy group, had identified the region as an organic entity (Friedmann and Weaver, 1977). Levine (2001) cites planning authors from 60s and 70s who argue that urban region is an appropriate arena for dealing with a variety of contemporary problems, including equity, race, education, taxation and economic development.

With the advent of regional science as a new field in the 1960s, regional planning retracted into a more abstract form and the focus of attention shifted from bounded regions to open city systems (Berry, 1970) – where each city performs certain functions within a system of cities, not as an isolated growth center of its own. Public choice theory, political fragmentation, and the relationship among cities and suburbs received significant attention in literature during this time. This wave was complemented by Tiebout's theory of 'voting with one's feet'. More recently, the 'new regionalism' literature considers economic growth and regional competitiveness rather than public-sector efficiency alone, thus reinforcing the need for regional *planning* not just regional *governance*. Researchers, over time, have also explored the relationship between central cities and their

neighboring suburbs, hypothesis ranging from suburban dependence to independence to interdependence.

Researchers (Voith, 1994; Frisken, 2001) in recent decades have questioned the system of local governments regulating land uses through zoning and public financing mechanisms as having adverse effects on the central cities in particular, and the region in general. The increasing poverty and declining tax bases of central cities due to a range of factors in the latter half of last century have fueled multiple efforts to advocate for regional solutions to such problems, especially financing public services such schools, roads and policing. The scale and scope of local governments have also changed over time. Before the 1960's, multiple suburban governments did not pose a serious threat to central cities as central cities were the primary economic, political units in a region (Voith, 1994).

Since 1960s, many social and technological changes contributed to significant loss in tax base for the central city, resulting in lower level of services in the city and further out-migration. The smaller suburban jurisdictions (in population terms) started growing larger and became more politically influential. The increasing economic wealth of these out-migrating residents resulted in adoption of many personal and policy choices and in-turn a suburban fabric that many have dubbed – the 'urban sprawl'.

Although quantitative studies of regional growth were limited until recently by technology, this body of research has grown in past decade (Hanink, 2005). A number of researchers (Xiang et al. 2003, Avin et al 2001, Yeh et al. 2002) have tried to quantify the benefits that may be accrued by planning at a regional scale. Since the 1990's researchers working with refined analytical models have found conflicting, and even negative outcomes of inter-jurisdictional competition (Dolan 1990; Foster 1993;

Lewis 1996). Recent research (Voith, 1994) has also shown that a healthy city has a positive effect on its suburbs where as a declining city has negative effect on its suburbs suggesting greater regional coordination in public services. Public transit services that are usually provided on a regional level, are showcased as models for such regional cooperation. Their coordination efforts may include policies on revenue sharing, creation of special service districts, and more cooperative and symbiotic economic development practices. However, there are also skeptics who claim that evidences that suggest regional cooperation are inconclusive (Levine, 2005). Levine (2001) concluded a regional planning literature review with three broad categories that need to be modeled – economic, quality of life and quasi-governmental. Such a framework could then be evaluated on the basis of economic, land use, fiscal, environmental and other such indicators. Also, as the review of the initiatives in planning at the state level shows, there is value in asking questions about benefits of state level planning.

2.3 Maryland

In the United States, local governments are generally responsible for land use plans and policies. Federal mandates and incentives exist (mostly in metropolitan areas) to form regional entities (such as Metropolitan Planning Organizations) to deal with regional issues, but mostly focused on transportation. Related to planning activities, such organizations are also generally responsible for forecasting growth (employment and households), and to modeling certain impacts of changes.

In Maryland at sub-state level, the counties (and Baltimore City, which has the status of a county) have land use authority. Certain municipalities (Laurel, Salisbury etc.) also have jurisdiction over land use. At a regional level, the Baltimore Metropolitan Council (BMC) and the Metropolitan Washington Council of Governments (MWCOCG), provide a platform for counties and municipalities to discuss

cross-cutting themes. Various departments of state government such as Maryland Department of Planning, Department of Business and Economic Development, etc. also coordinate regional efforts and propose acts that they deem to be of regional significance and value.

In the historical context, first documented evidence of regional planning in Maryland is the 1937 Regional Planning Report produced by the Maryland State Planning Commission. It recognized three major centers in the region – Washington, Baltimore, and Annapolis. It anticipated the “suburban flows” and offered directions to residents in the region on land use, transportation, and public services. The report also documented spatial growth of the developed areas between 1750 and 1937. The report used such trends to create two scenarios for 1950 – ‘without planning control’ and ‘with planning control’. This document provides significant historical evidence of interest in regional planning in the region. The recommendation of the “plan” included transportation corridors, preservation of open space and directing development along target development areas.

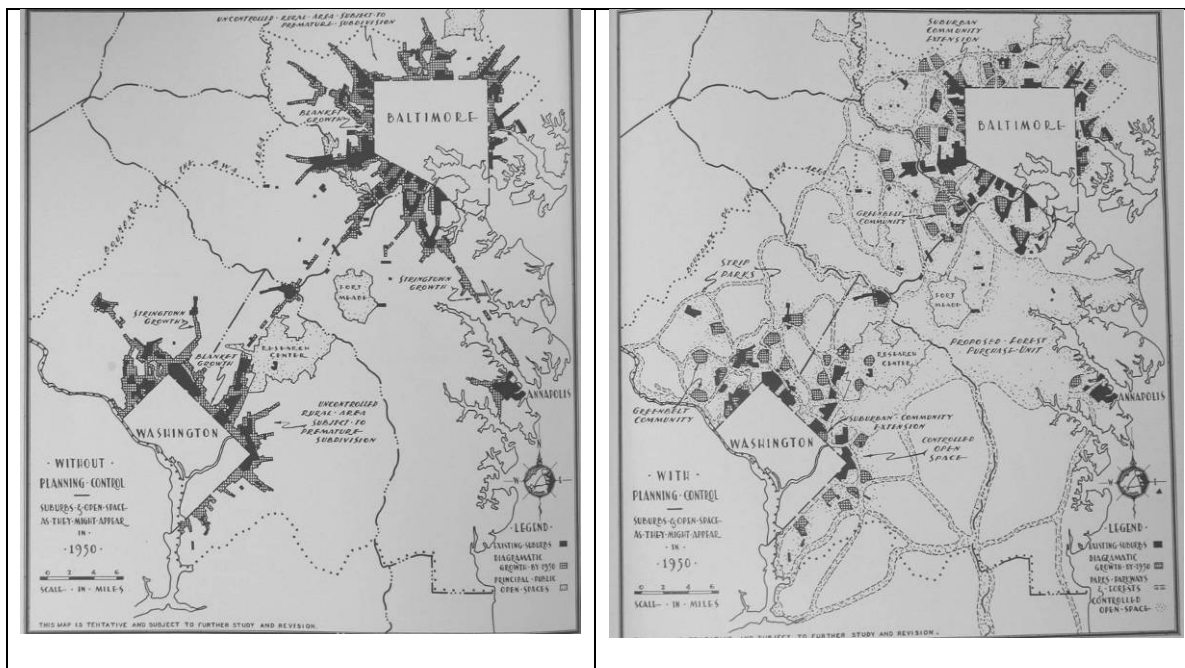


Figure 1: Planning Projections for the region in 1937 (‘without’ and ‘with’ planning controls)

In the 1960s, Maryland National Capital Park and Planning Commission developed the “On Wedges and Corridors – a general plan for the Maryland-Washington regional district”. This plan talks about “pleasant places to live”, a mix of densities with segregated spaces for industrial and commercial uses, and accessibility to highways and mass transit. Around the same time (1963), Baltimore and vicinity created the regional planning council – a multi-county body including Carroll County, Baltimore County, Baltimore City, Harford County, Howard County and Anne Arundel County. This regional body was multi-disciplinary (planning, natural resources, public health etc.) and democratic (nominated by Governor, but decisions made by voting).

More recently, the Maryland Smart Growth Act of 1997 created an incentive-based program in the state with many objectives – demarcate Priority Funding Areas to direct growth in areas that met multiple criteria (areas with existing infrastructure, within Census-defined urbanized area, etc.), ensure funding for protecting Rural Legacy Areas (prime farmland, extraordinary aesthetic value etc.), live-near-your-work program and brownfields redevelopment programs. Various local governments have also enacted laws and programs such as Montgomery County’s Moderately Priced Dwelling Units (MPDU) program and the Transfer of Development Rights (TDR) to create opportunities for affordable housing, protected open-space etc.

Still, as the Land Cover Images of 1973 and 2002 show, there has been significant dispersed development around the state and although some efforts (such as MPDU and TDR) may have created denser development in the inner-ring counties, regionally the development footprint resembles a leap-frog pattern.

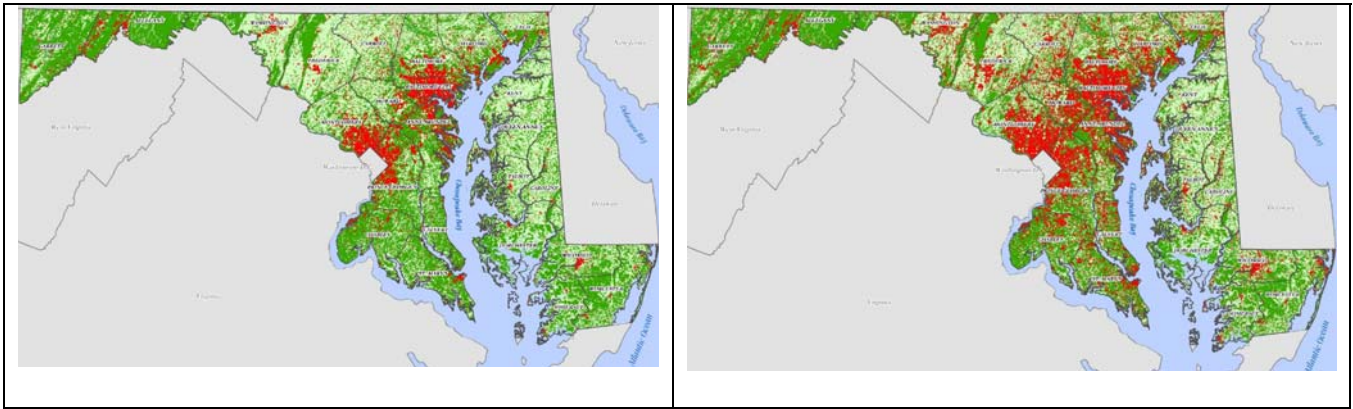


Figure 2 Land Use Land Cover 1973 and 2002 (Source: MDP, USGS). Urban areas shown in red.

Recently, many regions have become interested in scenario analysis. But this has typically been restricted to metropolitan or urban areas. Baltimore Vision 2030¹³ is such an example of regional visioning and scenario planning for the Baltimore Metropolitan Area. More recently, the Reality Check *Plus* effort has expanded the analysis to the entire state of Maryland. This work attempts to address the research objectives by building on some of the past scenario planning efforts. It does so by creating scenario as the state level, that are developed using diverse methods and are then evaluated using a set of indicators.

2.4 Summary

The basic question this dissertation seeks to answer is how scenario analysis can facilitate the planning process. Specifically, in the context of Maryland – what lessons can be learnt by looking at statewide scenarios that are developed by following separate paths but, when completed, are comparable. As the literature review shows, there are many clues to be learnt from the past. The evolution of scenario analysis, land use models and their application in many states, as well as the connection to advocates of regionalism in the past and the “smart growth”er’s of the present – all

¹³ Baltimore Vision 2030 website (last accessed July 26, 2007 <http://www.baltometro.org/content/view/94/176/>)

provide lessons on how to think about development patterns of the future. The literature review also shows that there is no single path towards achieving an accurate representation of the future. A desirable future can be pursued more effectively by properly analyzing the trends in the past, the present policies and the unforeseen challenges of the future.

Planning continues to search for tools and means of representations to arrive at a “solution”, one that is legitimate, based on solid analysis, and has political and economic feasibility. Although regional efforts, such as Envision Utah, have successfully attracted the public’s attention to the region’s future, the results of such exercises are rarely linked to studies that further analyze impacts of change using multiple models. “Visions too often lack an explicit time path connecting historical realities and present trends to viable outcomes” (Helling, 1998). Scenario analysis using multiple models offer methods that planners can use to address future with greater understanding, incorporating elements for successful planning and implementation – political relevance, public inclusiveness, quantitative technique, narrative, openness of communication and more.

As this literature review demonstrates, no one theory or tool alone is usually adequate to create a good plan. Scenario building is a framework which planners have used in the past to combine various models throughout the planning process.

Chapter 3: Research design: Scenarios

“...[P]lanning is intervention with an intention to alter existing course of events” (Campbell and Fainstein, 1996). Although non-exclusive, the above definition is representatively overarching, just like the field of planning. To that end, the role of scenario analysis is to assist in identifying the areas of development and related fields where an intervention may be warranted to create a more desirable future. Accordingly, developing scenarios should need a combination of all that information which is relevant towards understanding the present conditions and help us make our best effort in judging the future. As that makes scenario analysis a potentially unending task, past literature provide clues on how to be selective. Most scenario analysis efforts of the past choose population (or households) as their basic variable and the finest resolution at which such data may be obtained (census tracts, block groups, etc.) as the units of analysis. The choice of other variable such as infrastructure, policies, physical features, climate, economy, demographic mix etc. are then added to the list depending on the questions that a particular exercise is trying to answer.

Some recent models have added employment, in addition to the population, as the basic changes among scenarios. Although this could be attributed to increasing recognition among planners of looking at jobs and households and their respective locations in relation to each other, another fact is that employment data is now available at almost as fine a resolution as population. This research design is based on using both as the basic variables of change.

Additionally, scenario analysis needs identification of other relevant data, selecting variables of interest such as infrastructure supply; a process for developing alternative scenarios and evaluation tools. This chapter first covers background information on the study area, growth horizon, growth (control) totals, data and tools. The next section covers scenarios that are available to be tested

followed by new models to develop additional scenarios, and why and how additional scenarios were developed. The next chapter will discuss the indicators – what makes a good indicator, how they were selected, calibrated and applied in the context of this research.

3.1 Data

The study area (state of Maryland) consists of 23 counties¹⁴ and the City of Baltimore. Though an independent city, Baltimore is considered a county equivalent for most state related purposes. Many of these counties include incorporated municipalities (some of which are responsible for land use planning) and other fragmented forms of institutional structures exist for various purposes. Two major regional agencies in the state are Baltimore Metropolitan Council (which houses the Metropolitan Planning Organization or MPO for Baltimore area) and Metropolitan Washington Council of Governments (which houses the MPO for Washington Area). MPOs' tasks include long range transportation planning and while the rest of the regional agencies tasks include generating transportation analysis zones (TAZ) level household and employment projections and technical assistance. BMC's jurisdiction includes – City of Baltimore, Baltimore County, Howard County, Carroll County, Harford County and Anne Arundel County. MWCOG jurisdiction within the scope of this study includes – Montgomery County, Prince George's County and Frederick County, Charles County, Calvert County and St. Mary's County (MWCOG's region also includes the District of Columbia and multiple northern Virginia Counties).

¹⁴ Allegany County, Anne Arundel County, Baltimore County, Calvert County, Caroline County, Carroll County, Cecil County, Charles County, Dorchester County, Frederick County, Garrett County, Harford County, Howard County, Kent County, Montgomery County, Prince George's County, Queen Anne's County, St. Mary's County, Somerset County, Talbot County, Washington County, Wicomico County, and Worcester County

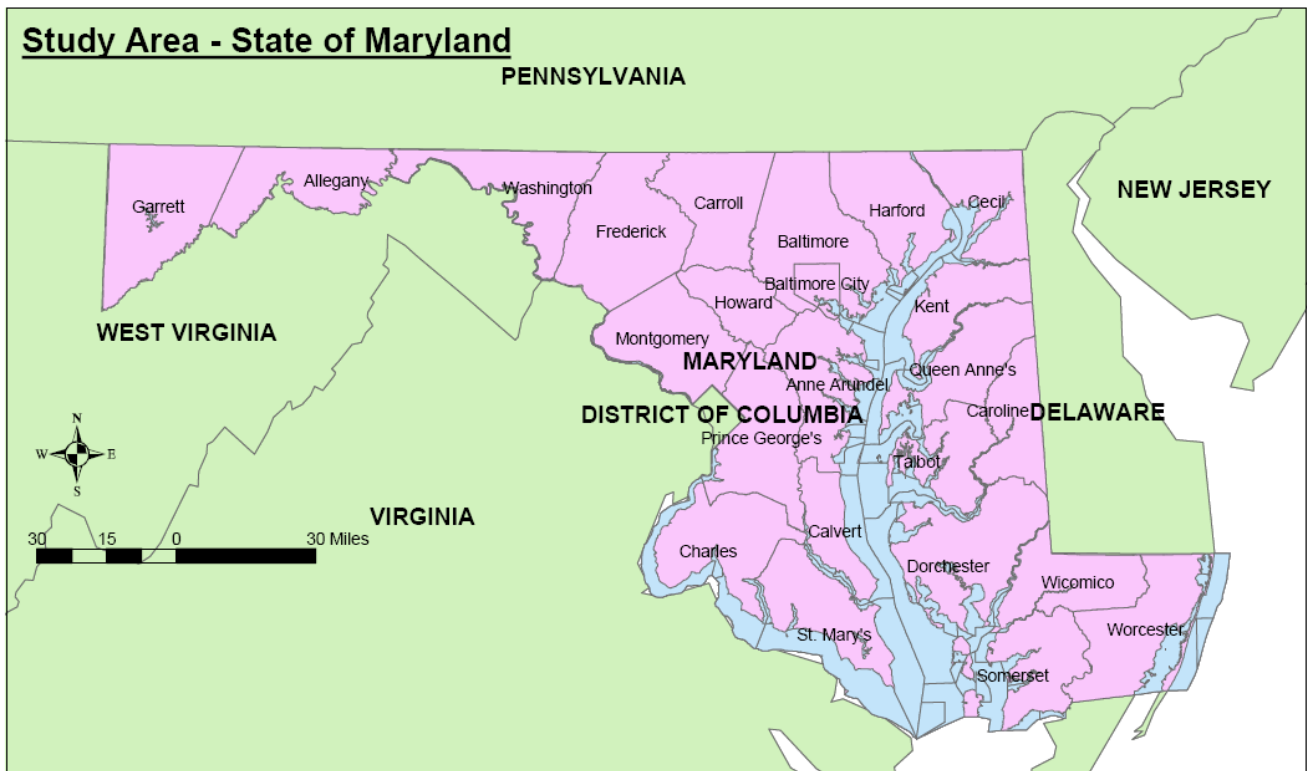


Figure 3 Map of study area

Any analysis is only as good as the data it is based on. A scenario analysis process needs data on past trends, present conditions and future projections and also numerous other physical and policy variables that allow investigation of cross-cutting relationships. The datasets used in this dissertation were collected from a number of sources and when they were not available for the entire state of Maryland, different datasets were joined. Certain datasets for which geographies did not match were altered based on assumptions detailed later in this section¹⁵. The data includes population and employment information, infrastructure and policy information, outputs of multiple surveys on travel, travel models, local and state government related information and projections for 2030¹⁶. A detailed

¹⁵ The Census Bureau uses multiple characteristics to define different geographical units. Within the study area of this research, there are Census-defined Metropolitan Statistical Areas (MSAs), MPO regions, urbanized areas and more with overlapping, non-exclusive boundaries.

¹⁶ The research uses 2030 as planning horizon based on the rationale that a scenario analysis needs one and using 2050 (the other choice for which forecast data is available) takes away the sense of urgency from the planning process. Although the projections of 2030 are much lower than that of 2050 and hence are a lesser stress on existing capacities, yet it is large enough to raise significant interest in promoting change. This 25 year horizon is also consistent with other parallel planning initiatives in the region such as the Reality Check and the MPO planning efforts.

list of preliminary data used (to build the base line scenario and program the indicators) is included in Appendix D.

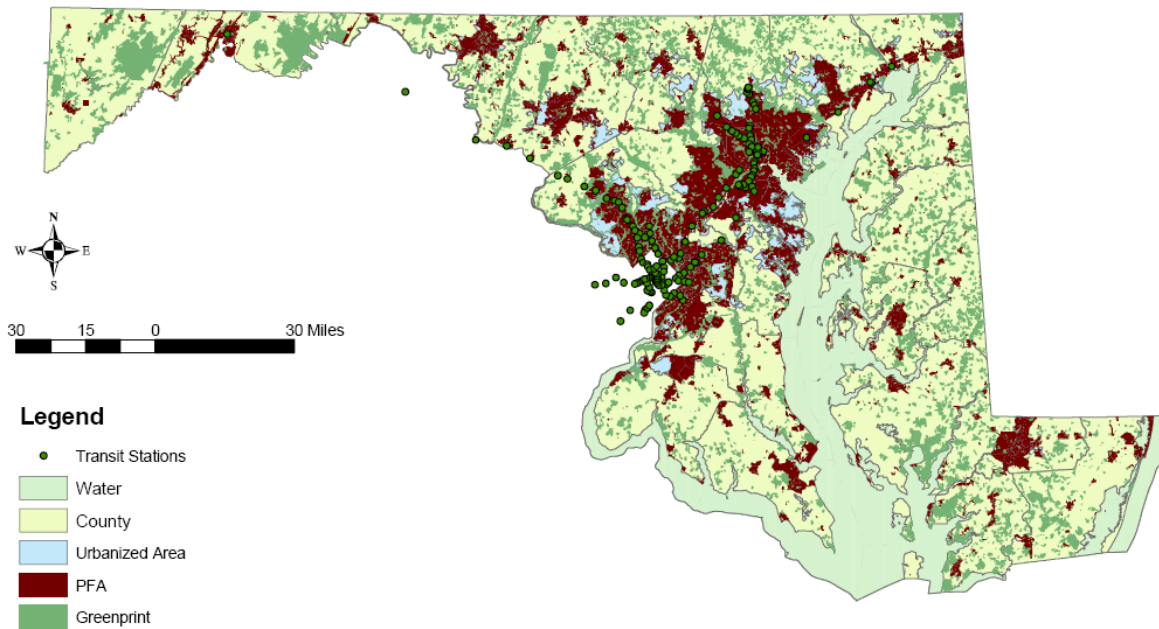


Figure 4 Map showing a few of the background layers that were used in the analysis

The above datasets¹⁷ primarily acted as inputs to the baseline conditions and were used to model measures such as the relationship between density and demand for new lane miles. In the next step, the above datasets were brought together into a common format that facilitates both the scenario planning process and modeling and computing indicators.

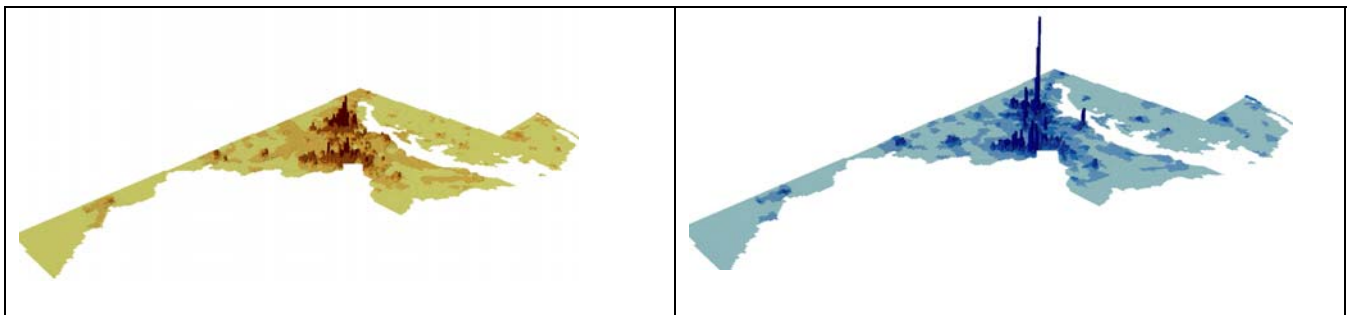


Figure 5 Baseline conditions (built on grids) of households (yellow) and employment (blue)

¹⁷ Data in addition to those mentioned above were sometimes collected for small areas to test the validity of indicators during their development stages.

3.2 Methodology - Scenario Planning

Klosterman (1999) says that scenario-based models evolved with the wider planning ideology of “plan-with” instead of “plan-for” public. Instead of “objective unsupervised analysis” these models allow for “adversary or counter” modeling. The process developed in this dissertation works within the following constraints: they use only those variables that may be projected into the future, they use a common unit of analysis and they use the same horizon and control totals (except the Build-out scenario). Yet, the process provides a fair analysis of state’s zoning, builds in a successful tool for participatory regional visioning and a foundation on which to create many more experimental scenarios reflecting a wide range of plausible questions.

The scenarios developed for this research can be broadly grouped into two sets. The first set, which can be called “*natural*” scenarios are extensions of existing conditions; plans; or developed through a set of participatory exercises. The second set of “*experimental*” scenarios use lessons from the first set to develop and test additional ideas and alternative scenarios.

The initial stage of this research compares the following set of scenarios to each other and to existing conditions:

1. COG 2030 scenario [jobs and household allocation in year 2030, as projected by official forecasts of the Council of Governments]
2. Build-out of existing zoning [build-out analysis of local zoning ordinances within the state, no time horizon]
3. Reality Check *Plus* (RCP) 2030 scenario [jobs and household allocation in year 2030, as envisioned by Reality Check participants in the regional exercises]

The second set is discussed later in this section.

Relative to the baseline conditions the other scenarios serve the following role – COG 2030 is a scenario based on current trends; a build-out arguably presents a close proxy of a composite of local government plans; and the RCP 2030 represents a regional vision¹⁸.

Before describing how the individual scenarios were created, it is important to note the common threads between them. As described in the data section, background data comes in the form of tabular, spatial (vector and raster data) and aspatial information. To translate the data into a format that is consistent to other data layers and allow computation of indicators – a spatial grid¹⁹ (1 sq. mi. in size) was overlaid on the state. All existing information and data layers such as population, employment etc. were apportioned to the new unit of analysis. Additional infrastructure, policy and physical features data were then overlaid on the baseline grid to compute additional attributes by aggregating the values of individual layers with respect to each grid. For example, a spatial analysis of road network on top of a grid when passed through the above analysis created a new attribute of every grid cell as “number of lane miles of roads in the grid”. This process was then repeated for all the other layers to add more attributes on top of the baseline conditions into the 1 sq. mi. grid. This format also helped the data to be visualized consistently across scenarios.

¹⁸ The argument for this is presented in the next section.

¹⁹ The choice of grid and its 1 sq. mi. scale had additional advantages as discussed in the Reality Check Process section.

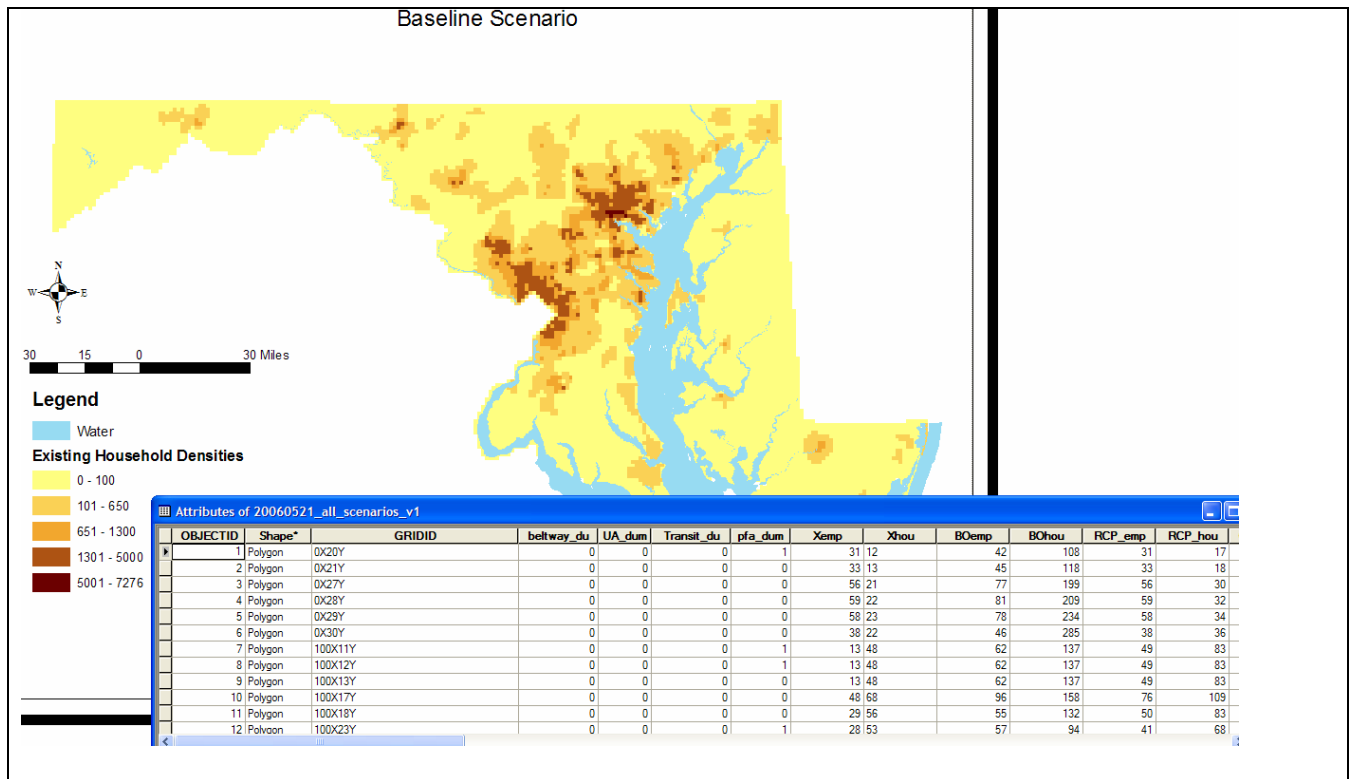


Figure 6 Baseline conditions with a background attribute table

The baseline conditions in grid format were the starting point of all further analysis. It had three main roles:

1. It acted as the foundation on which future scenarios were built
2. It was used to compute baseline spatial indicators and model future indicators based on existing relationships such as those between household density and lane miles²⁰.
3. Individual grids were used as building blocks in defining the rules that were later developed for the allocation model and creating experimental scenarios (detailed in the next sections)

²⁰ More on these indicators in the next section

3.3.1 Developing the first set of scenarios

The remaining 3 scenarios in the first set were developed based on the following methodology, assumptions and processes –

Build-out scenario

“Build-out” usually refers to the total capacity – meaning when you build-up to total capacity as defined by current zoning, you have exhausted all opportunities for further development. Multiple assumptions went into creating the “build-out” scenario – primarily that the existing zoning and policy measures stay the same. The indicators computed for the “build-out” scenario gives a measure on multiple scales if all the existing plans/policies were to be realized. Although, development capacity and actual development, especially outside urban areas, may be widely different, a build-out analysis gives a method to rate existing plans and may explain some of the planning-related issues of the day. Build-outs for households and employment were estimated separately.

In the case of Households – The “build-out” scenario for households was based on the output of Residential Development Capacity Analysis²¹. This analysis was based on the following set of information – parcel-level data on land uses, zoning maps and estimates of zoning yield, protected land and land with constraints, and local water and sewer plans.

The analysis included computation of total residential zoned acres by subtracting acres of non-residential acres from total acres. The next step computed capacity by subtracting acres already developed to allowable limits, protected lands and environmentally sensitive parcels (such as agricultural easements, wetlands etc.) and tax exempt land. New Housing Capacity was computed as a

²¹ Maryland Department of Planning’s Growth Model

function of zoning yield of total available *residential* land. The parcel based estimates were finally aggregated to the statewide grid.

In the case of Jobs – Census (2000) provides employment data at the census tract level for the entire state. Land area devoted to various categories of existing land uses can be estimated from Land Use Land Cover (USGS, 2000²²), also at the census tract level. The build-out analysis uses linear regression to model a relationship between employment numbers and land areas under different categories. Since the intensity of use varied significantly across the state, the coefficients of land use categories were separately estimated by dividing the state into four regions. The regions were created according to the definitions adopted in Reality Check *Plus* (discussed in the next section).

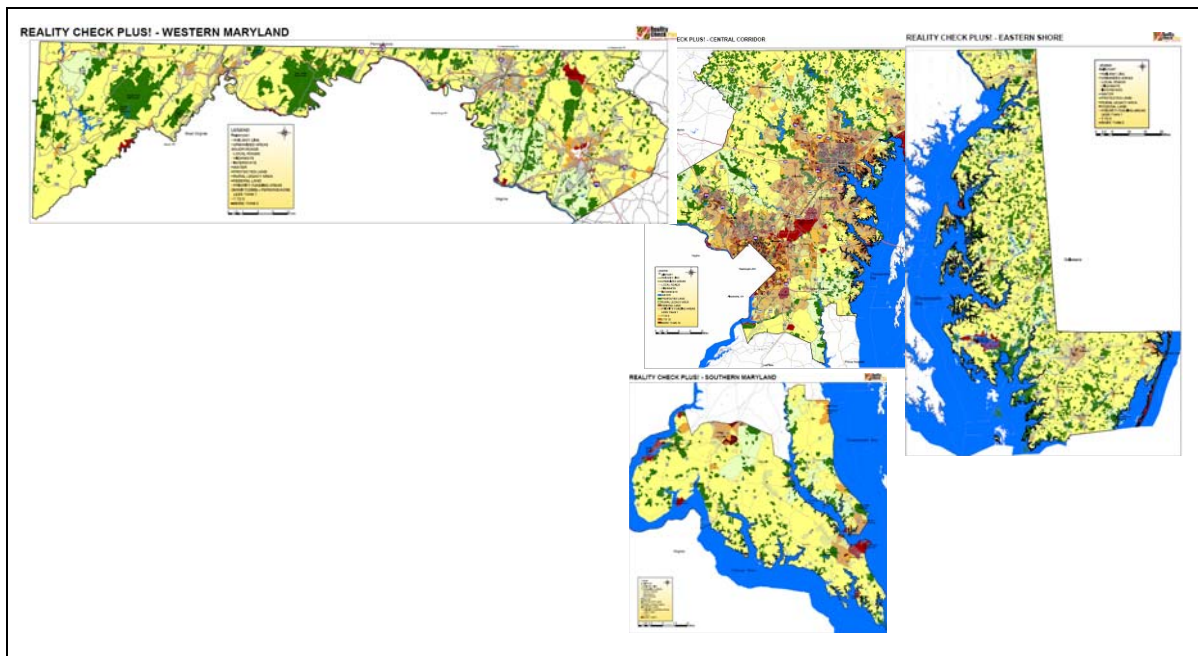


Figure 7 Map of four Reality Check regions

²² Land use categories in USGS' Land Use Land Cover Data layers are usually different from land use categories in zoning documents. The two were matched using the closest available categories.

The general equation used to compute the employment at build-out –

$$\text{Employment (for each census tract at build-out)} = A1*(\text{zoned commercial acres}) + A2*(\text{zoned industrial acres}) + A3*(\text{zoned low-density residential acres}) + A4*(\text{zoned medium-density residential acres}) + A5*(\text{zoned high-density residential acres}) + A6*(\text{zoned mixed use}) + A7*(\text{zoned municipality})$$

The following table summarizes the estimated coefficients used in the above equation for predicting future employment.

According to the Table 2, one additional acre that is zoned commercial will create 10 additional jobs in the Western Maryland region of the state.

Table 2 Coefficients (employment multiplier) of areas under different land use types in different regions (land use codes refer to the above equation)

Land use type	Western	Southern	Central	Eastern
Commercial (A1)	10	7	20	6
Industrial (A2)	7	7	7	7
LDR (A3)	0	0	0	0
MDR (A4)	1	1	1	1
HDR (A5)	20	20	6	6
Resources / VLD	0	0	0	0
Mixed (A6)	3	3	6	6
Municipalities (A7)	2	2	2	2
Other	0	0	0	0

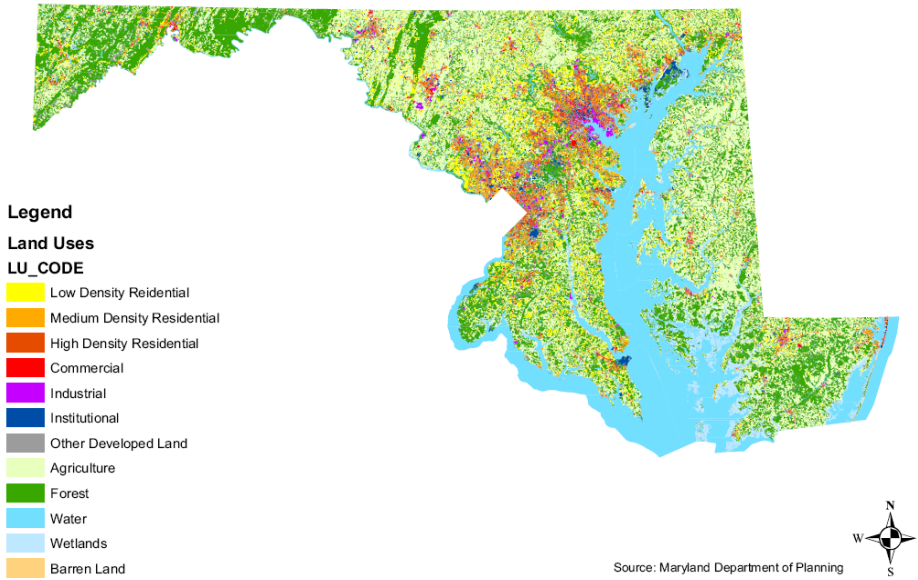


Figure 8 Land use categories in Maryland were regressed with employment numbers from Census Transportation Planning Package data to estimate the relationship between land use type and employment

In the next stage, acres of different land uses under existing zoning were assumed to be in their final state. The coefficients from the above tables were then used to compute the employment by various census tracts in “build-out” scenario.

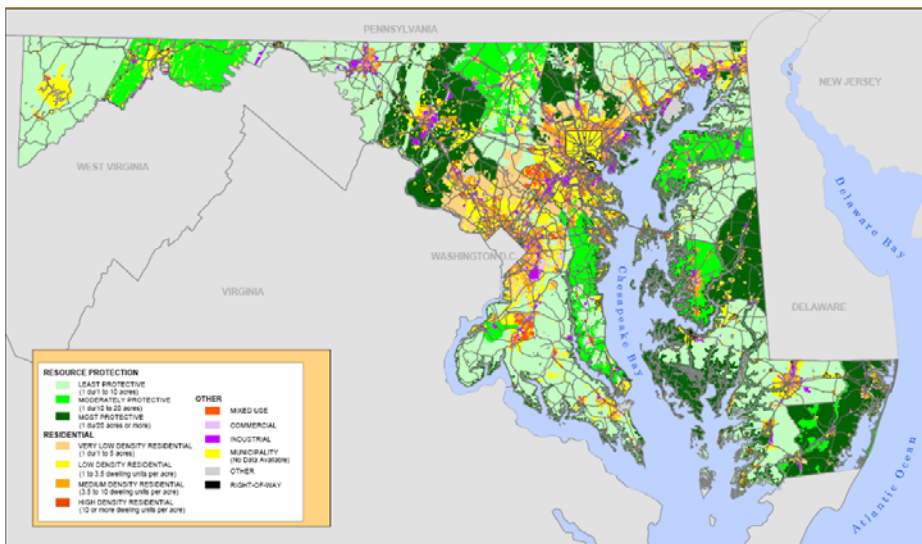


Figure 9 Generalized zoning map of Maryland was used to compute build-out estimates of zoned areas which were then multiplied by pertinent coefficients (Source: Maryland Department of Planning)

The data was then reaggregated into the baseline grid. An important point to keep in mind is that, although the “build-out” scenario is not based on a future point in time, all other scenarios are defined as development pattern for a particular time horizon (2000, 2030 etc.)²³

COG 2030 Scenario

The Council of Government “scenario” is created from combining the 25 year forecasts done by 2 separate MPOs responsible for different regions in the state of Maryland. The forecast for the Maryland suburbs of Washington DC were obtained from the Metropolitan Washington Council of Governments and that of the six Baltimore Area Counties were obtained from the Baltimore Metropolitan Councils. *Together*, these forecasts cover the entire Central Maryland and Southern Maryland regions²⁴ and Frederick County in Western Maryland. The process of creating these forecasts by the councils generally includes a Cooperative Forecasting and Data Subcommittee (CFDS), a technical subcommittee to the Planning Directors Technical Advisory Committee (PDTAC) and the Metropolitan Development Policy Committee (MDPC).

The COG data provides spatially disaggregated (by TAZs) projections up to 2030. The net number of growth in jobs and households are also the finest (in terms of resolution) available estimates of total growth coming to the region by year 2030. But the COG scenario is limited to the Baltimore-Washington corridor, and growth projections were needed for the rest of the jurisdictions to arrive at total projections for the state. MDP provided data on jobs and households projections for the rest of the state but they were only available at the aggregated county level.

²³ Another point to note is that a “build-out” scenario is not a projection of how much growth is expected statewide or in any given jurisdiction, but rather is an assessment of how much growth is allowed under existing zoning constraints.

²⁴ As per Reality Check Plus regional definitions discussed in the next section

The aggregate of COG projections plus MDP projections for the rest of the state are hereon called “control totals”. These numbers are used as the demand side variables for the rest of the scenarios.

This was important for two reasons: any scenario building process needs control totals at an aggregated or disaggregated level and the control totals among scenarios need to be consistent. These numbers meet both the criteria. The household and employment totals in 2000 and (projected) in 2030 are:

Table 3 Population and Employment totals in different scenarios

Scenarios	Number of Household	Number of Employment
Baseline (2000)	1,867,394	2,892,851
COG (2030)	2,236,889	3,531,655
Build-out	3,207,597	4,859,336
RCP (2030)	2,751,783	4,443,897

RCP 2030 Scenario – (Reality Check *Plus* Envisioning Process²⁵)

Reality Check *Plus* consisted of a series of visioning exercises organized throughout the state to give the audience, which included elected representatives, community and business leaders, a sense of projected growth in the state. They were given tools to develop spatially explicit scenarios of growth and certain impacts of growth (such as transit proximity) were computed and presented back to the group during the one day event.

The state was divided into 4 regions where 4 separate events were held to generate an overall vision.

Splitting the state into 4 parts was important for many reasons. It was logistically easier than a single

²⁵ As discussed earlier, Reality Check *Plus* (RCP) events were organized outside the purview of this dissertation. However, as many assumptions and tools used in the process were similar to those used here, the results of RCP present an opportunity to further investigate the impacts of a scenario developed through visioning exercise and compare it to other scenarios.

visioning exercise as events could be held closer to the participants and assured higher participation. It allowed for more time being devoted to the exurban and rural areas of the state and their issues. And it allowed larger maps of each region where they could be scrutinized in greater detail. Splitting the state also led to a few issues, such as how the regions should be defined, how the control totals should be sub-allocated, and should the audience treat the control totals as given. Additional issues included differences in mean densities and development types between urban and rural regions (which affected uniform assumptions across regions). The state was divided into 4 regions as shown in the Reality Check map. Control totals were divided up into 4 parts which were sum projections in all the counties within these regions.

Table 4 Projected population and employment growth in four regions of Maryland by year 2030

Region	Number of New Households	Number of New Employment
Eastern Shore	86,188	74,711
Western Maryland	87,191	82,508
Central Maryland	409,469	582,305
Southern Maryland	77,843	70,629

At each event, participants were divided into groups of eight to 10 and assigned to tables representing both the geographic and interest group diversity of the region. At each table, participants gathered around large table-top maps of their region, colored to represent the existing population and employment density, major highways, subway and commuter rail lines and stations, parkland or other protected conservation areas, airports, military bases, and other government installations, and rivers, floodplains, and other bodies of water.



Figure 10 Scene at one of the Reality Check visioning events

To encourage participants to think regionally, rather than locally, all jurisdictional boundaries were intentionally omitted, although place names of cities and towns helped orient each group. Each table was staffed by a scribe/computer operator and a trained facilitator to lead the three-hour exercise. Before considering where to accommodate growth, participants were asked to reach consensus on a set of principles to guide their decisions about where to place the new development – ideas such as protecting open space, making use of existing infrastructure, or maintaining jobs-housing balance or building new highways.

The exercise used Lego® blocks of four different colors to represent the growth projected to come to each region: blue blocks represented jobs; white blocks represented the top 80 percent of new housing units in the region based on price, or essentially market-rate housing; yellow blocks represented the bottom 20 percent of new housing based on price, essentially a stand-in for non-subsidized affordable housing; and, black blocks represented lower density housing development that could be exchanged for higher density white blocks at a ratio of 4:1. Each table was given a box of Lego®, which

represented the total growth projected to come to the region. The task on each table was to allocate all the Lego® blocks to the map while trying to build consensus with the rest of the group.

Maps of baseline conditions were used with a grid overlaid on them such that a single Lego® block fit on a single square of the grid. Participants who wanted to add more housing or jobs to a single square than what was represented by a single block simply needed to stack the blocks. Those who wished to propose mixed-use development could represent that by stacking housing and job blocks together.

Once all the Lego® blocks were placed on the map, the result²⁶ yields a three-dimensional representation of where participants at each table said they hope future growth in their region will – or will not – be located.

Since the outputs varied by tables and region, a method was devised to aggregate everything into a single, statewide scenario. For each region, all the tables were averaged to create a final, aggregate regional scenario. This was done by adding the final population and employment numbers in each grid cell and dividing the sum by the total number of tables in that region. All the regional scenarios (the grid in which they were built in) were finally joined and the resulting statewide grid was named the Reality Check scenario.

The next set of figures represents densities of households and jobs under each scenario across the state.

²⁶ Once the four regional exercises were completed, the results were aggregated and analyzed.

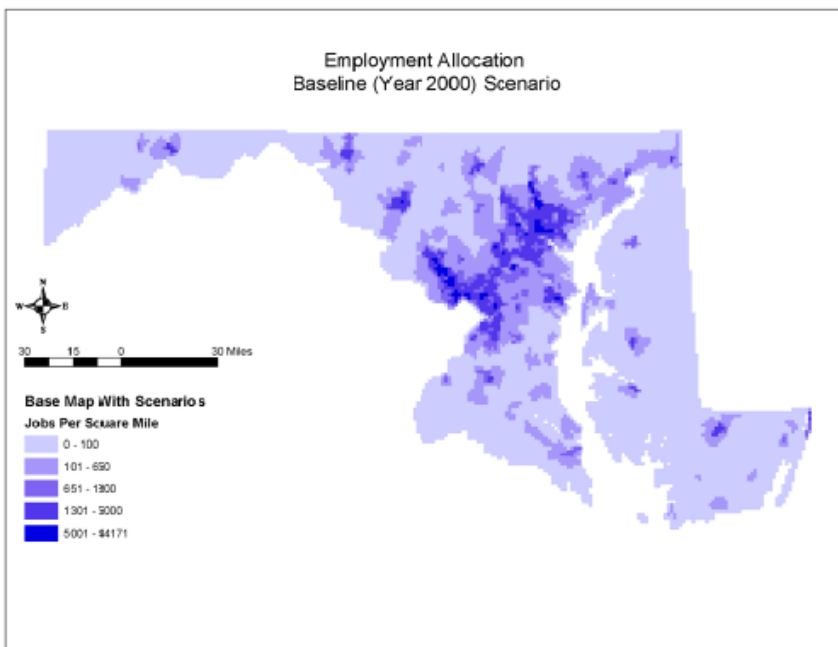
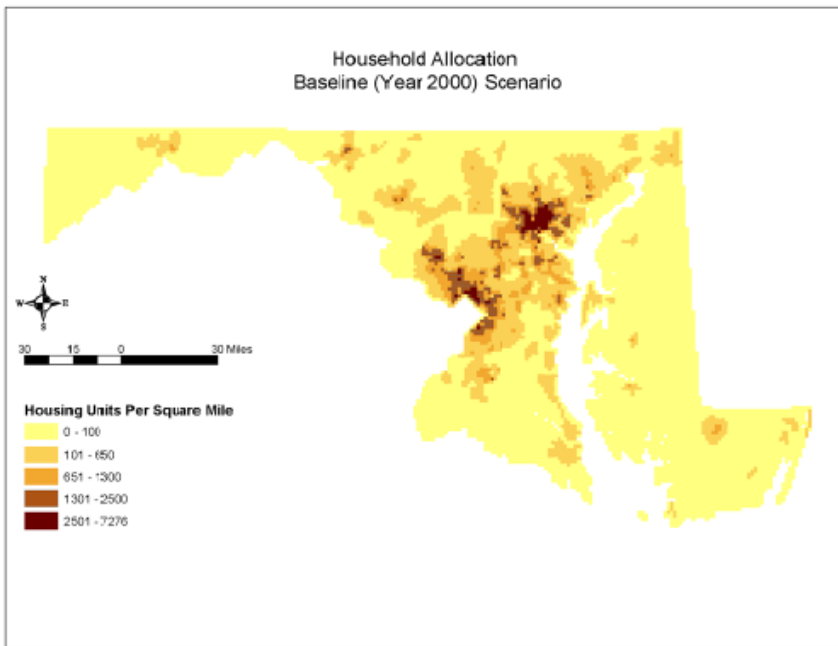


Figure 11 Household and Employment distribution in baseline conditions

The baseline conditions map for household and employment reinforces the conventional wisdom. The household and employment are both concentrated towards the urban centers with more concentration for employment. Concentration outside the Baltimore-Washington corridor is due to secondary cities such as Hagerstown and Salisbury, and some outside the urban area employment center such as St. Mary’s City.

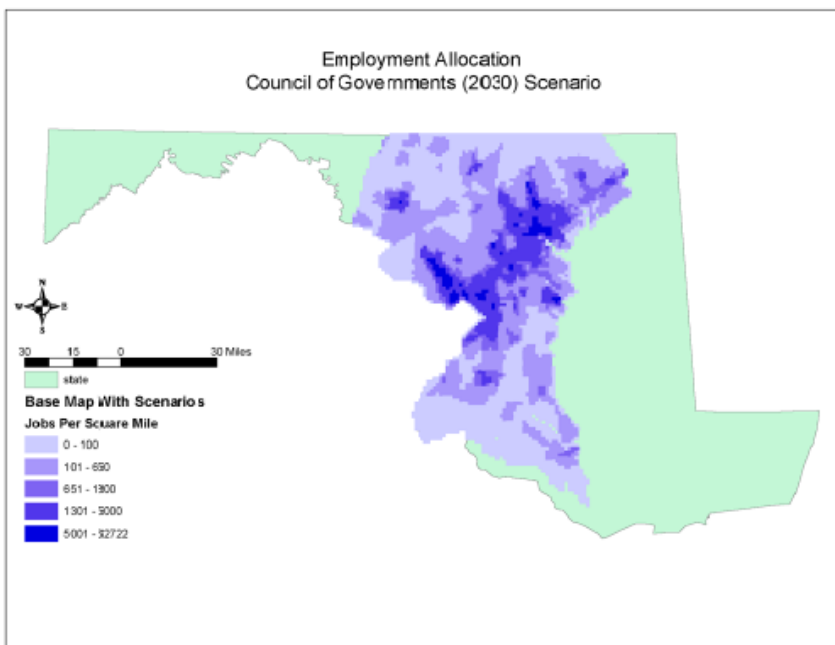
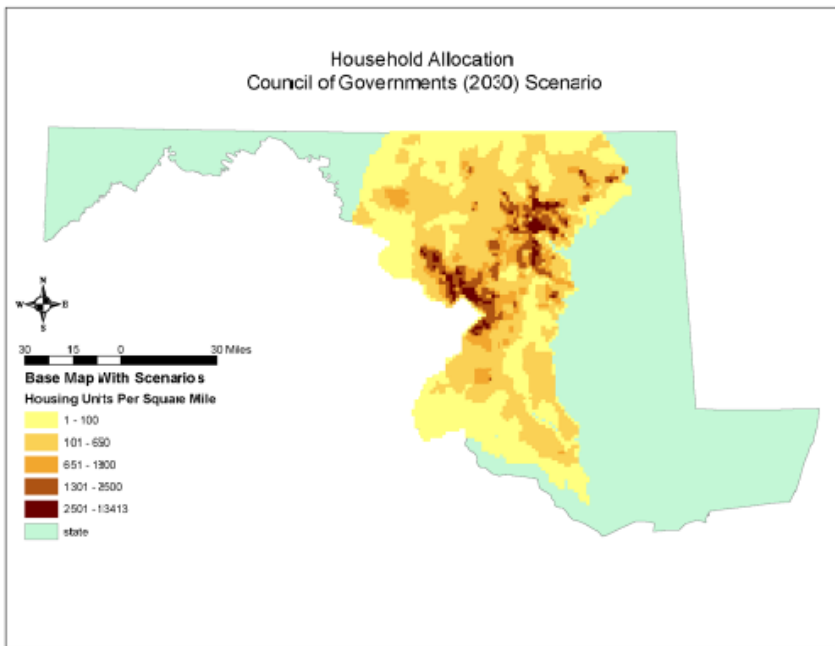


Figure 12 Household and Employment in COG scenario

COG scenario, as noted earlier, is restricted only to those areas for which the MPOs do cooperative forecasting. The COG forecasts tend to follow the existing conditions with some dispersal outside the currently urbanized areas. Yet, much of the future dispersal seems to be in the areas along the highways or that currently have infrastructure.

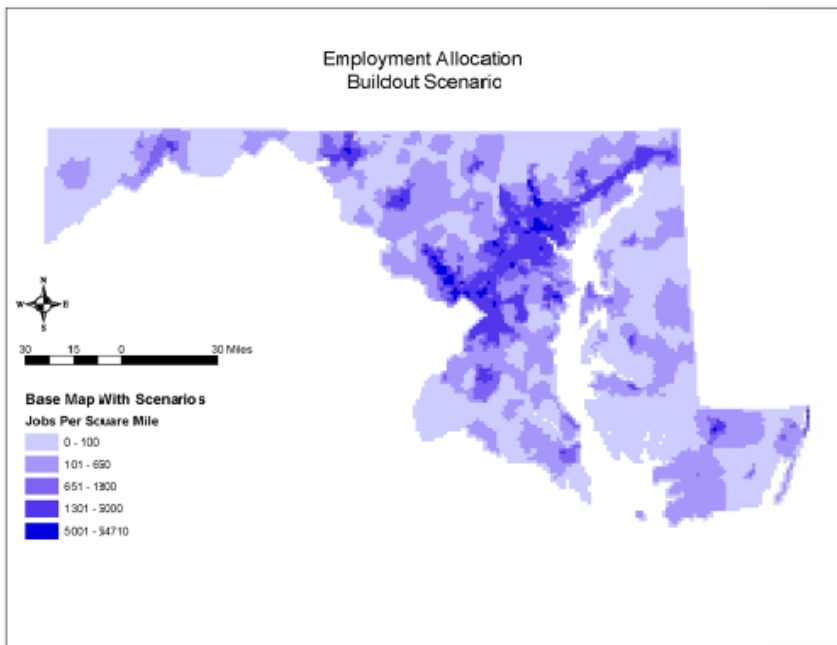
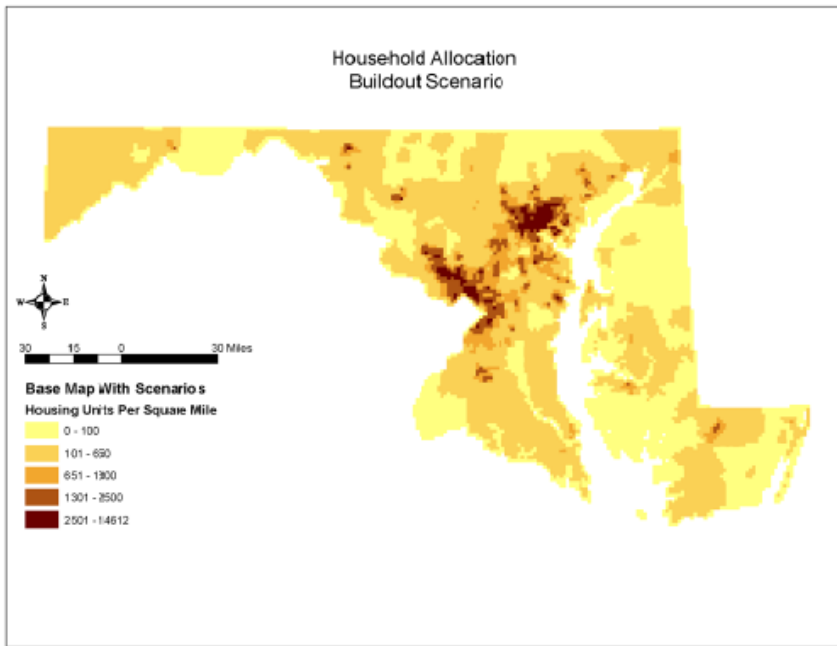


Figure 13 Household and Employment distribution in build-out scenario

The Build-out scenario produces interesting outputs, especially in the case of households. As the map shows, there is significant dispersal in households over the entire state. This shows that there is lot of capacity outside the existing urban areas. In case of employment, the dispersal is not that high, as most of the undeveloped land in rural areas are generally zoned for non employment generating land uses.

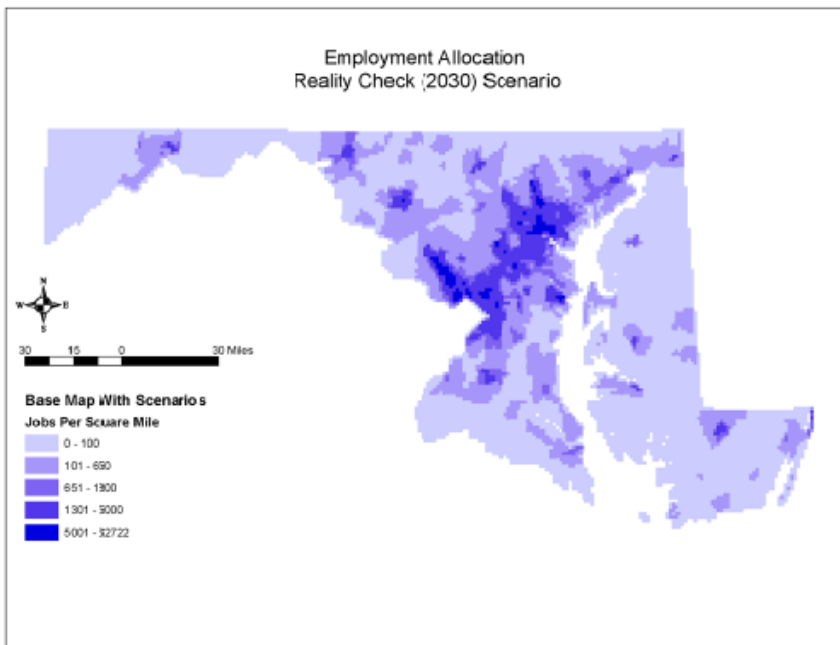
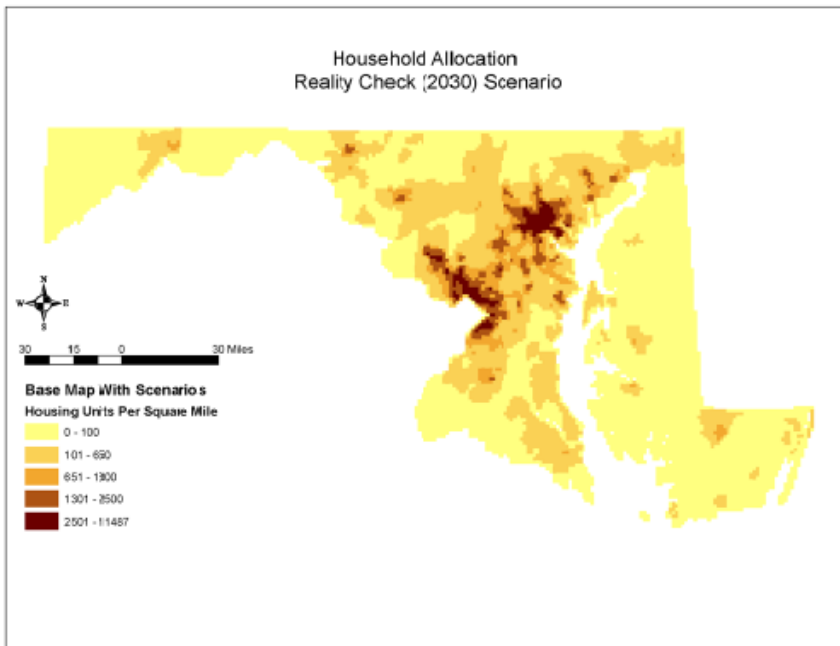


Figure 14 Household and Employment distribution in RCP scenario

The Reality Check *Plus* scenario contains the projected growth mostly inside the currently urbanized area. The participants also expressed a desire to place more jobs on the eastern side of the Baltimore Washington corridor (a part that is relatively underdeveloped), put more households and jobs close to the metro stations and protect much of the environmentally sensitive land on the eastern shore and the

farmlands of the eastern shore and western Maryland regions. It should be noted here that the Reality Check *Plus* scenario was developed by aggregated results from multiple tables and as a result it “washes-out” many extreme cases of development.

Summary

The three scenarios discussed so far evaluate impacts of three different land use patterns based on different set of ideas and assumptions. In addition to the Reality Check *Plus* scenario, which presents a regional vision, the other two scenarios present the extension of trends or capacity under current zoning, and in themselves, leave many questions unanswered (for example, what are the consequences of certain, specific policy measures). Also, the Reality Check and the Build-out scenario suffer from aggregation issues that “wash-out” strong impacts of possible extremes. There are other limitations that are discussed in the final chapter. But, as a scenario process that tries to consider multiple plausible options, this next step in this research was to look at additional ways to develop scenarios that pushes the envelope on the constraints of the earlier processes.

3.3.2 Experimental Scenarios

The literature review chapter discusses many models of developing additional scenarios. One of them, the California Urban Futures II model (Landis 1994) describes how various decision rules may be used to develop future scenarios. Such a model allows the use of established framework of baseline grids along with the opportunity to quantitatively use the information on neighborhood level variables (that are within coded into the grids) to develop additional scenarios. Such a method also allows creating comparable scenarios that can be varied by choosing different policy options as decision rules.

The first set of scenarios tries to answer questions related to development patterns, growth projections and future allocation of land uses. To restate the context – the scenarios show how the jobs and households are distributed under existing conditions, how they will be distributed in 2030 if the current trends and projections were to continue, how they will be distributed in the 2030 if the current overall projections and regional visions in reallocating them were to be successful, and finally, without regard to a time horizon, what the build-out of all the existing zoning will look like. Prior to evaluation of indicators, these scenarios:

1. Indicate distribution of jobs and households if local government plans were to be fully realized (build-out)
2. Indicate distribution of jobs and households if a regional vision were to be implemented (Reality Check *Plus*)
3. Provide data to compute, using various physical layers (such as roads, water etc.) and policy layers (such as PFA boundaries), how each of the above two scenarios (and extension of trends or the COG scenario) vary from the existing conditions.

However, additional spatially relevant questions need to be asked in a scenario analysis exercise. For example – what if the local governments continue to exercise land use authority but do so with increasing local constraints? What if the state started taking more control on growth issues and imposing stricter development controls? What if cost of commuting falls? How does an aging population affect growth? How does climate change affect growth? Or what if the region develops a high-speed rail system? More specifically, what if there is a new Chesapeake Bay Bridge to connect to the Eastern Shore or an up-zoning of Columbia leading to its expansion into a major regional center, or more relocation of military jobs in the region. Each of these questions deserves careful examination in order to assess their true costs and benefits. Thus, though these questions are both speculative and complicated, they are plausible possibilities, and hence valuable to ask in a scenario analysis framework. While many of these issues have come to attention in past planning processes (like Reality Check *Plus*), their effects cannot be identified with the four scenarios discussed so far. This section describes how three additional experimental scenarios that are more flexible to accommodate additional growth-related questions were developed to be compared to the first set of scenarios.

Beyond the trend and the baseline conditions, many archetypes exist for creating additional scenarios. The study of past scenario analysis exercises (Bartholomew, 2005) lists five main ones – center/satellite, compact, dispersed/highway-oriented, corridor, and infill/redevelopment. However, instead of using the archetypes as a guide for developing additional scenarios, this research asks more direct and context-specific questions. Also, to ensure that the experimental scenarios are comparable to earlier scenarios in scale, scope, and general vocabulary, all the scenarios are built on the baseline grid and use the same proximity and dummy variables as the baseline conditions. Also, household and employment growth accommodated in the new scenarios are based on projections for the year 2030.

Another reason for not using the prevalent archetypes of scenarios is the conflict within standardized definitions of planning terminologies that become less relevant as land use in the region diversifies. For example, what is the “right” distance for a development from a major infrastructure for it to be considered in close proximity? For transit oriented development, it is generally ¼ mile from a station, for highways, it is a mile; but for a residential facility that may be too close. Then, there are resolution-related issues that may render a 1 sq. mi. grid too crude for certain assessments as it will not distinguish differences at a smaller scale.

Finally, though beyond the immediate scope of this exercise, the prevalent archetypes lack political relevance and accommodation of the institutional context. Hence, the approach for this research in selecting the scenarios comes from a balance of two main themes in scenario planning – policy-oriented and visionary.

Policy-based components of a scenario are those that incorporate certain local and regional policy measures that are plausible in short-term and long-term future. Policies that have been pertinent to land use impacts have come from a wide variety of fields – environmental, planning, transportation, economic development to name a few. Past stages of work with stakeholders and existing literature offer some direction. Some policy measures that could have wide ranging impact on the future of land use in the region are –

1. establishment of Urban Growth Boundaries (UGBs)
2. creation of a regional planning authority
3. regional economic authority that promotes some form of tax sharing agreements among local governments

4. external conditions that may impact housing and transportation costs to change dramatically or impose stricter environmental restrictions
5. creation of a regional transit system that takes away a significant share of riders from the highway network
6. federal government and/or military related/enacted policies

Visionary components of scenarios or visionary scenarios should go beyond the limits of direct policy relevance (as long as they meet the basic criteria for scenario planning) and are usually spatial.

Certain visionary ideas that have been derived over the course of past research in Maryland are –

1. Densify urban core, create rural clusters (accommodate a lot of growth in few rural areas)
2. Build-up the Baltimore Washington corridor (particularly Columbia), put high-speed rail in the corridor
3. Control development on the Eastern Shore and build-out Baltimore
4. Protect open spaces in local jurisdictions – but without creating leap-frog patterns

It is important to identify sets of policies and visions that fulfill the objectives of scenario planning exercises, such as representing a plausible but diverse future. The following table shows a list of policies and visions in each axis to identify consistent sets. Experimental scenarios are then derived as a synthesis of these sets –

Table 5 List of plausible visionary and policy ideas

Policies → Visions ↓	UGB, Strict open-space control	Regional COG/MPO	Regional transit system	Federal/military impacts
Urban/rural clusters	☒	27	☒	28
Buildup corridor/Columbia, high-speed rail	☒	☒	☒	☒
Eastern shore as retirement/tourism community	☒	☒	29	☒

☒ - Consistent vision and policy measures

The above table notes some of the most common³⁰ “big picture” issues in Maryland today. The columns denote various policy choices, mostly related to the level of authority (UGB and regional transit system at the regional level, strict open space policies both at the regional and the local level and federal impact through investment choices such as military, Base Realignment and Closure or BRAC, etc.). The rows are longer term vision of the region which may or may not be related to direct policy choices (urban/rural cluster type development may be a result of policy choice or market forces such a high gasoline prices). As potential combinations of such policies and visions are endless, this dissertation tries to identify three combinations (or stories) that are distinct yet address important policy choice related questions. The following three scenarios present outcomes of policy choices and visions and describe how the region may look like in the year 2030.

²⁷ Urban/rural clusters defined as local governments retaining planning authority (not a greater influence of MPOs)

²⁸ Irrelevant as military facilities tend to be outside of urban areas

²⁹ Irrelevant as there are no plausible plans of transit development in Eastern Shore.

³⁰ Based on summary of Implementation Discussion at Reality Check *Plus*: Reality Check *Plus* report at <http://www.realitycheckmaryland.org> accessed 7/27/07

1. Scattered Urban Clusters -

- a. Local government retains land use controls but exercises strict restrictions on containing growth outside the urban areas. This leads to higher density development not only in the existing urban centers but also creation of centers all around the state where additional growth is concentrated. Most of the additional demand on the transportation system is met by the highways. Open spaces outside the urban clusters are protected.

2. Urban Diamond -

- a. Annapolis, Baltimore, Washington D.C. and Frederick are the vertices and Columbia is the center of the regional core that may be conceptually considered an “urban diamond”. Infrastructural spending is consolidated along the corridors connecting the nodes and within the diamond where most of the projected growth is directed. The new demand on transportation is supported through investment in high-speed rail infrastructure. Some development goes into the greenfields currently inside the diamond but greenfields outside the *diamond* is protected. Employment is concentrated inside the urban diamond as well.

3. Smart Growth/PFA -

- a. If the state considers development inside the priority funding areas as “smart growth”, then this is the Smart Growth scenario as all growth up to the year 2030 is directed inside the PFAs. In this scenario the government invests heavily inside the PFAs to develop and improve infrastructure and provide additional incentives to developers to develop within PFAs. There is strict zoning outside the PFAs. Protection of farmland in eastern shore and natural environments in western Maryland is also a top priority.

The scenarios described above may be considered “extreme” but are worth investigating through the same yardstick as the other scenarios at the statewide level. The following figures show sketch representations of the above scenarios.

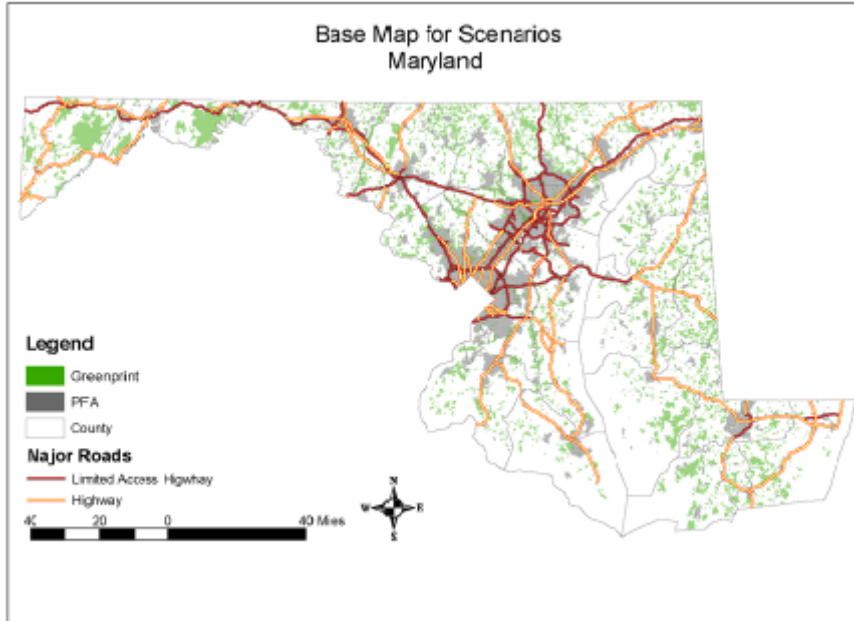


Figure 15 Base map on which experimental sketches were developed

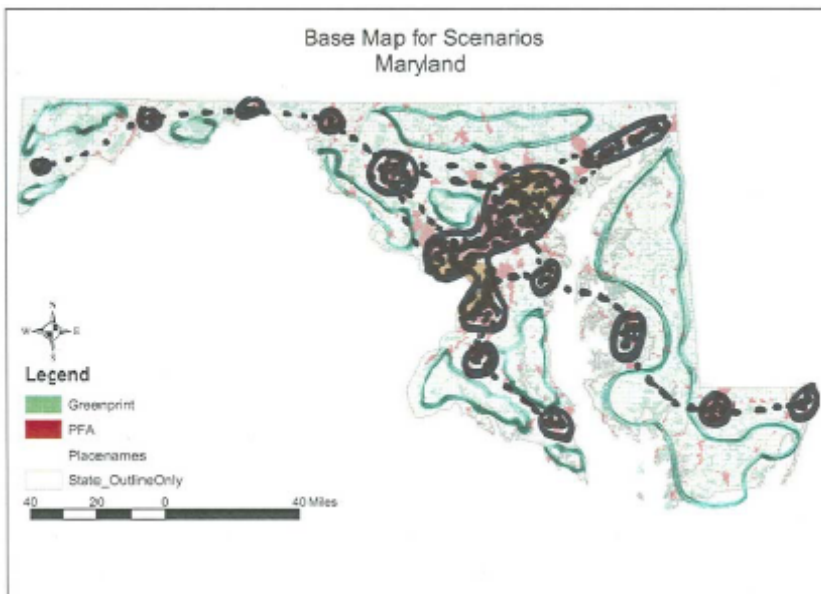


Figure 16 Sketch of Scatter Urban Clusters scenario

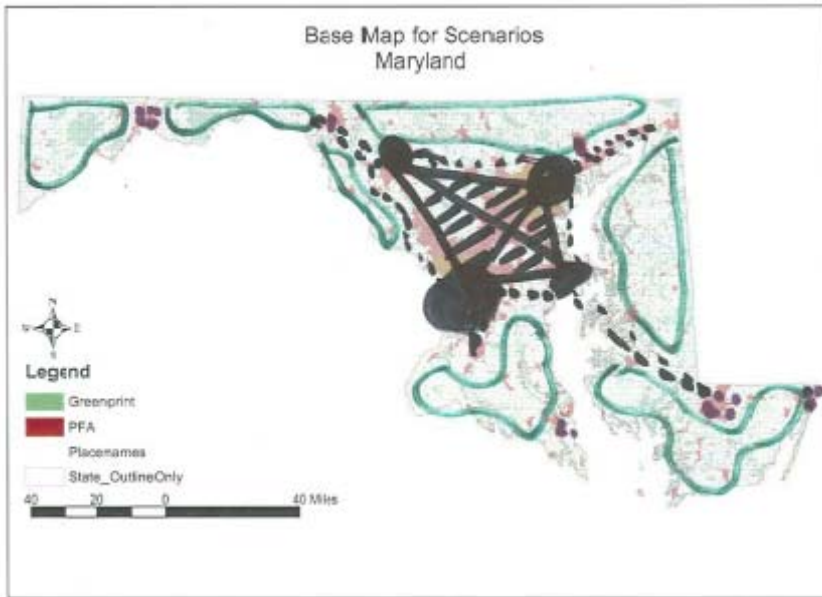


Figure 17 Sketch of Urban Diamond scenario

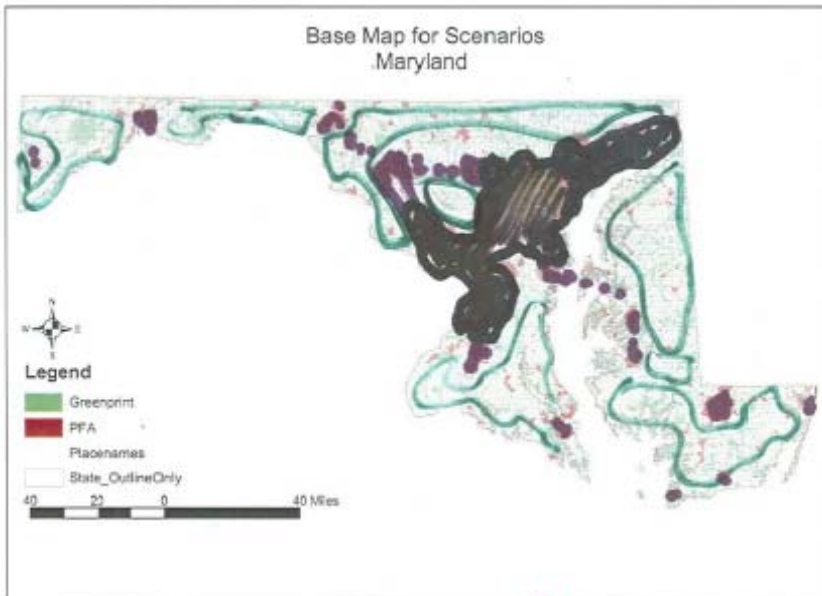


Figure 18 Sketch of PFA/Smart Growth scenario

The resulting scenarios have the same control totals as Reality Check *Plus* scenario as they are based on the same projected number of households and employment (as projected by MDP) and allow

consistent comparisons. The following table shows the total figures of jobs and households and the net growth to be allocated in the experimental scenarios.

Table 6 Specific numbers in each scenario

Scenarios	Household	Employment
Baseline (2000)	1,867,394 (H0)	2,892,851 (E0)
COG (2030)	2,236,889	3,531,655
Build-out	3,207,597	4,859,336
RCP (2030)	2,751,783* (H1)	4,443,897** (E1)
Urban Cluster	2,751,783* (H2)	4,443,897** (E2)
Urban Diamond	2,751,783* (H3)	4,443,897** (E3)
PFA/Smart Growth	2,751,783* (H4)	4,443,897** (E4)
<i>Additional growth in experimental scenarios</i>	<i>~900000 (H1 – H0)</i>	<i>~1600000 (E1 – E0)</i>

*, ** Scenario uses control totals for 2030 and hence, have the same control totals.

The allocation model uses information on existing and past characteristics of each grid to generate a score (called allocation index, described later) for the likelihood of the grid to develop further and the magnitude of such development. The following table lists the background variables attributed to each grid on the basis of the grids' location, existing features in the grid and its neighborhood characteristics that are used to model the equation behind the score –

Table 7 List of attributes of each grid

FIELD	DESCRIPTION
GRIDID	Unique identity for the grid on the statewide map
COUNTY	county within which the specific grid is located
Xemp	employment in 2000
Xhou	households in 2000
BOemp	employment under build-out scenario
BOhou	households under build-out scenario
RCP_emp	employment under reality check scenario
RCP_hou	households under reality check scenario
90emp	employment in 1990
90hou	households in 1990
Prototype90	Prototype in 1990
Prototype00	Prototype in 2000
beltway_du	1 for grids whose centroids are within the beltway, 0 otherwise
UA_dum	1 for grids whose centroids are within the urbanized area, 0 otherwise
Transit_du	1 for grids whose centroids are within a mile of transit, 0 otherwise
pfa_dum	1 for grids whose centroids are within the priority funding areas, 0 otherwise
GPrnt_Acre	acres of protected (or designated to be protected) areas inside the grid
Roadmiles	miles of major roads within the grid
Xhouden	existing household density
Xempden	existing employment density
area of each grid	1 sq mi or 640 acres

Unlike the Build-out, COG and RCP scenarios (where jobs and households were used as continuous variables added to the baseline conditions to create additional scenarios), these scenarios were built on the basis of past trends, lessons learned through the development of prototypes (see Appendix C) and review of experimental scenario building methods. The ideas behind conceptual sketches were operationalized through “decision rules” which guide how the projected growth may be accommodated in the baseline grids. This was done in following steps –

1. *Create conceptual ideas that guide additional scenarios* – This step was discussed earlier in this section as identifying sets of policies and visions followed by sketches of where the development may go.
2. *Select grids that will receive any growth under each scenario* – This step selected those grids that are eligible to receive *any* growth (and conversely, those grids that will not receive any growth)

3. *Create effect and weighting table (with positive or negative effects), assign weights, compute allocation indices* – this was done through an extensive process discussed later in this section.
4. *Allocate 900,000 households and 1,600,000 jobs* – This step refers to the final task of actual allocation of the projected growth.

The assumptions behind each scenario are a collection of assumptions made in each of the above steps.

The next few paragraphs elaborate on this discussion.

Selecting grids that may receive growth:

Allocation models, in part, rate growth potential of an area on the basis of a set of rules and assumptions. One important such rule is separating-out (growth potential = 0) grids that will not get any future growth on the basis of their protected status, current development pattern, physical characteristics etc. This model chooses grids that will be considered eligible for growth (because of rules or assumptions) by default choose those that may not get any growth. The set of criteria are defined by each scenario. These principles were derived from the earlier steps and they guided the selection of grids that receive any new growth –

Urban Cluster – The Census Bureau defines urbanized areas and urban clusters as pieces of land that meets a set of criteria based on density, contiguity, development in its neighboring geographic unit and so on. This scenario assumes that the projected growth is accommodated in the existing urban areas and urban clusters (with some adjustment on the edges). In this step, any grid that is within an existing urbanized area or urban cluster (as defined by Census Bureau, 2000) or within a *3 miles* buffer of them is considered eligible to receive growth.

Urban Diamond – A quadrilateral (“diamond”) was drawn by joining 4 vertices – Baltimore, Annapolis, Washington D.C., and Frederick. The center of each city was buffered relative to the size of their current population (selected grids had their centroids either within the 20 miles buffer of Washington D.C., or within the 15 miles buffer of Baltimore or within the 10 miles buffer of Annapolis or Frederick or located within the quadrilateral connecting the center of all four cities).

PFA/Smart Growth – In this scenario, all grids whose centroids lie inside an existing PFA area will be eligible to receive growth. It is assumed that over-counting the total area inside PFA (as not all grids whose centroids fall inside the PFA layer will be completely inside the PFA layer) will be balanced out by those grids which have their parts inside the PFA layer but will not be counted as their centroids will fall outside the PFA layer.

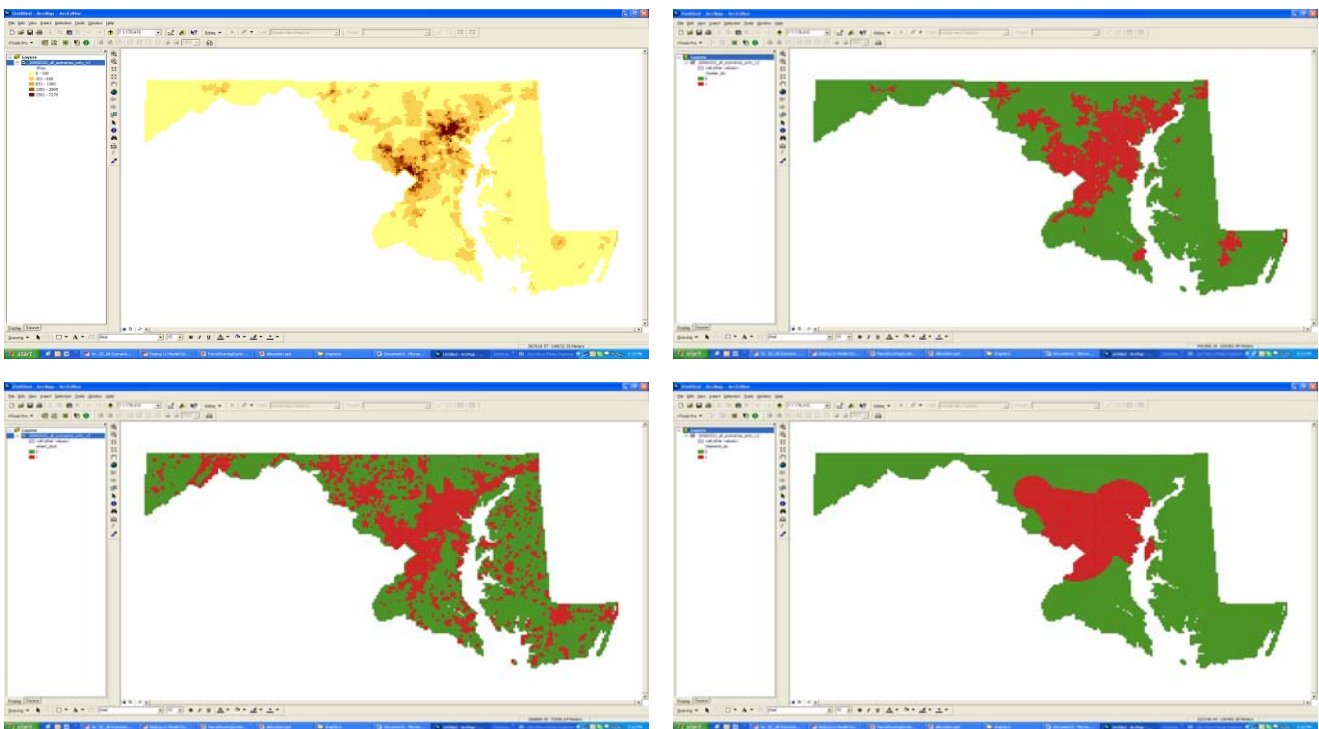


Figure 19 Selecting grids that receive any growth, shown in red (clockwise from top-left: existing densities, urban cluster, urban diamond and PFA/Smart Growth)

After executing the above steps in GIS, the above maps show, in red, the grids which are eligible to receive growth under different scenarios. Also, the total numbers of grids that are eligible under each scenario are: *Urban Cluster: 2509; Urban Diamond: 2474; PFA/Smart Growth: 3762; Also, the total number of grids in the whole state: 11159.* This information will be used in the next subsection on allocation rules.

Effect and weighting table

Once the grids which may receive growth were identified, a set of allocation criteria was needed. The intent of this research was to develop a simple linear model that is based on past trends. Largely modeled on the concept of gravity and existing conditions, the basic principle behind the criteria is that the existing built environment, physical conditions and policies have an effect on the pull (and push) to new growth, both household and employment. The magnitude of this attractiveness (positive) or unattractiveness (negative) vary among different attributes and also have different effects with respect to household and employment.

Households and employment for each grid were estimated for the year 2000 and year 1990. The other characteristics of the grid were estimated based on physical and other conditions of each grid or its neighborhood. Two linear regressions were run, one with change in households (1990-2000) as the dependent variable and the other with change in employment (1990-2000) as the dependent variable. The following table summarizes the effects among a set of variables and changes in the number of households and jobs in that grid from 1990 and 2000 with respect to other variables –

Table 8 Attractiveness and weighting table for various attributes of the grid with regard to new household and employment

ATTRIBUTE	WEIGHTS	Effect on Households	Effect on Employment
Empden_dum ³¹	1 if above mean employment density, 0 otherwise (controls for builtout land)	+	+
Houden_dum	1 if above mean household density, 0 otherwise (controls for builtout land)	-	+
Transit_dum	1 for grids whose centroids are within a mile of transit, 0 otherwise	+	+
Proportion multi-family	1 if proportion above mean, 0 if not	+	+
pfa_dum	1 for grids whose centroids are within the priority funding areas, 0 otherwise	+	+
Green_dum	1 for grids whose centroids are within the greenprint layer, 0 otherwise	-	-
UA_dum	1 for grids whose centroids are within the urbanized area, 0 otherwise	+	+
Beltway_du	1 for grids whose centroids are within the beltway, 0 otherwise	-	+

The results of the linear regression (OLS) are included in Appendix G. The transit dummy and green dummy are were not included in the regression but are expected to have strong positive and negative influences respectively on both household and employment development.

The signs from the above table were useful in creating an equation for allocation index but the coefficients from the linear regressions were not used. This is due to two reasons – first, the development drivers in the year 2005 are expected to be different from drivers in year 1990 and second, although some of the signs in the above equation came out as expected (existing employment density having a positive effect on future housing growth) changing preferences and diminishing capacities in already developed areas may have quite the opposite effect.

³¹ All the variables in the above table have been discussed earlier as attributes of each grid except the Houden_dum and Empden_dum. They are dummies that were developed on the basis of variation of existing densities in the grids from the mean density in the region.

As mean housing density in the region = 167 HH/sq. mi. and mean employment density in the region = 260 jobs/sq. mi., hence –

If [Xhou] > 167 Then houden_dum = "1"; else, houden_dum = "0"

And

If [Xemp] > 260 Then empden_dum = "1"; else, empden_dum = "0"

The approach, hence, followed in this model is based on sum of signs rather than the OLS coefficients. The signs also put a growth constraint on grids, if they are too dense (and act as proxy for zoning and other regulatory barriers). Thus,

$$\text{Allocation Index} = \Sigma(\text{aggregate weights and effects of all dummies})$$

The attractiveness of each grid for new households is called household allocation index and is given as (HH_allo_idx) –

$$\text{HH_allo_idx} = [\text{transit dummy} + \text{multi-family dummy} + \text{pfa dummy} + \text{urban area dummy} + \text{houden_dum} - \text{empden_dum} - \text{green_dum}] + 1$$

- “+1” assigns some growth to rural areas where all other dummies may be zero, except in greenfields where the overall effect will be no growth, all negative values are converted to 0

The attractiveness of each grid for new employment is called employment allocation index and is given as (Emp_allo_idx) –

$$\text{Emp_allo_idx}^{32} = [\text{transit dummy} + \text{pfa dummy} + \text{beltway dummy} + \text{empden_dum} + \text{houden_dum} - \text{green_dum}]$$

Allocation index values were then computed using GIS for each grid. Although the households (and employment) allocation index values for each grid were same under each scenario, when the actual allocation was done, each grid got a different share of projected growth due to a method discussed next (total fixed across state but number of cells receiving growth and the share of growth in those cells vary by scenario) –

³² All negative values are converted to 0 as on the basis of the above equation negative values come from high density residential developments or from protected areas-related variable. And, though they may slow the growth they will not lead to decreasing densities in the absence of other variables.

For Urban Cluster scenario, the following steps were performed to allocate jobs and households, independently and based on existing conditions –

1. Total Number of grids in the region = 11159
2. Total number of grids in the area that may receive growth = 2509 (area = 2509 sq. mi.)
3. Sum of all household indices in the grids that are eligible to receive growth in this

$$\text{scenario (i.e. } \sum HH_allo_indx) = 4091$$

4. Sum of all employment indices in the grids that are eligible to receive growth in this

$$\text{scenario (i.e. } \sum Emp_allo_indx) = 9987$$

This means that the control totals will be allocated to a max of selected 2509 grids proportional to their allocated indices –

Within the subset:

Formula for household growth received by each grid

$$(hhgro_Cluster) = (HH_allo_Indx) X (totalprojectedhouseholdchange) / \text{Sum}(HH_allo_Indx) = (HHallo_Indx) X 900000 / 4091$$

Similarly, for employment, growth in each grid

$$(empgro_Cluster) = (Empallo_Indx) X (totalprojectedemploymentchange) / \text{Sum}(Emp_allo_Indx) = (Emp_allo_Indx) X 1600000 / 9987$$

Then, for ALL grids, the new allocation were added to the existing jobs and households in each scenario

$$ClusterHH2030 = hhgro_Cluster + Xhou$$

$$ClusterEmp2030 = empgro_Cluster + Xemp$$

Where *Xhou* denotes existing housing in the grid and *Xemp* denotes existing employment.

ClusterHH2030 and *ClusterEmp2030* are the final number of jobs and households in the Urban Cluster Scenario for each grid. Also, since the total number of grids eligible to receive growth (2509 sq. miles for urban cluster scenario) and the sum of all allocation indices (household and employment indices (4091) were different for each scenario, the allocation results (*hhgro* and *empgro*) and the final output for 2030 will be different for each scenario.

In the case of other two scenarios –

Urban Diamond scenario:

1. Total number of grids in the area that may receive growth = 2474
2. Sum of all household indices in the grids that are eligible to receive growth in this scenario = 3170
3. Sum of all employment indices in the grids that are eligible to receive growth in this scenario = 8198

This means that the control totals will be allocated to a max of selected 2474 grids proportional to their allocated indices –

Within the subset:

$$\begin{aligned} &\text{Formula for household growth received by each grid (hhgro_Diamond) =} \\ &HH_allo_Indx * totalprojectedhouseholdchange / Sum(HH_allo_Indx) = \\ &HH_allo_Indx * 900000 / 3170 \end{aligned}$$

$$\begin{aligned} &\text{Similarly, for employment, growth in each grid (empgro_Diamond) =} \\ &Emp_allo_Indx * totalprojectedemploymentchange / Sum(Emp_allo_Indx) = \\ &Emp_allo_Indx * 1600000 / 8198 \end{aligned}$$

For ALL grids –

$$DiamondHH2030 = hhgro_Diamond + Xhou$$

$$DiamondEmp2030 = empgro_Diamond + Xemp$$

PFA/Smart Growth scenario:

1. Total number of grids in the area that may receive growth = 3762
2. Sum of all household indices in the grids that are eligible to receive growth in this scenario = 7437
3. Sum of all employment indices in the grids that are eligible to receive growth in this scenario = 11439

This means that the control totals will be allocated to a max of selected 3762 grids proportional to their allocated indices –

Within the subset:

$$\begin{aligned} &\text{Formula for household growth received by each grid (hhgro_SG) =} \\ &HH_allo_Indx * totalprojectedhouseholdchange / Sum(HH_allo_Indx) = \\ &HH_allo_Indx * 900000 / 7437 \end{aligned}$$

$$\begin{aligned} &\text{Similarly, for employment, growth in each grid (empgro_SG) =} \\ &Emp_allo_Indx * totalprojectedemploymentchange / Sum(Emp_allo_Indx) = \\ &Emp_allo_Indx * 1600000 / 11439 \end{aligned}$$

For ALL grids –

$$SGHH2030 = hhgro_SG + Xhou$$

$$SGEmp2030 = empgro_SG + Xemp$$

Once the allocation run was completed and the scenarios were organized into a single framework, they were visualized by household and urban densities and fit into the larger template of all scenarios

from which the indicators were computed. The next set of figures represents densities of households and jobs under each of the experimental scenario across the state.

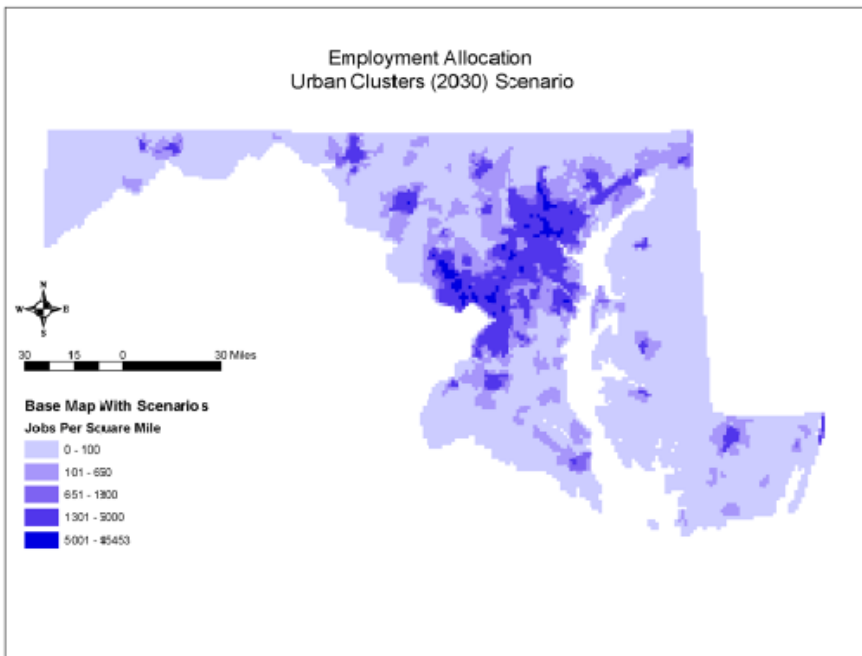
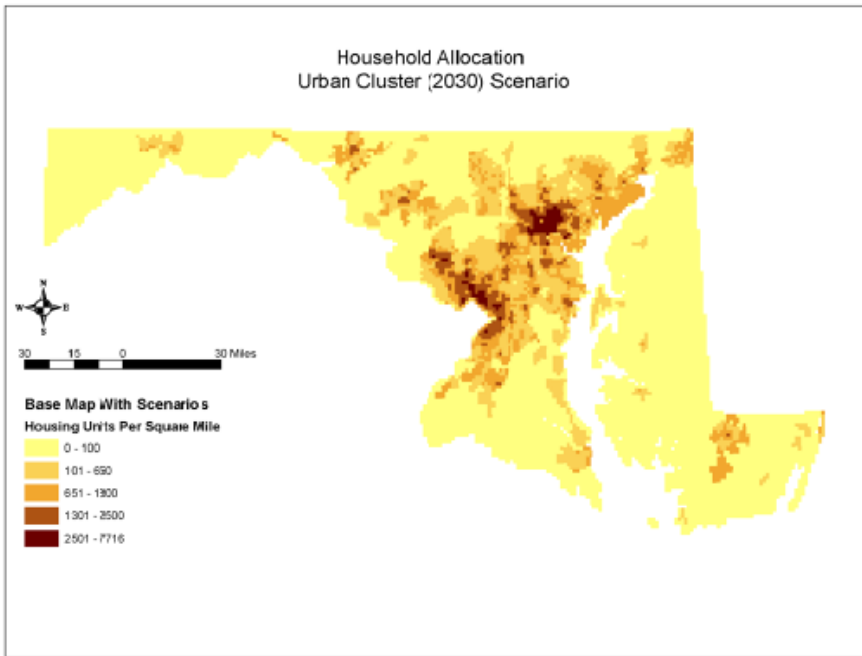


Figure 20 Household and Employment distribution in Urban Cluster scenario

In the above scenario, all new growth goes inside the grids identified as urban clusters. Hence, in terms of densities, this scenario closely resembles the existing conditions, with higher densities in almost all developed grids. The clustered nature of the development and the allocation criteria keeps most of the undeveloped land intact.

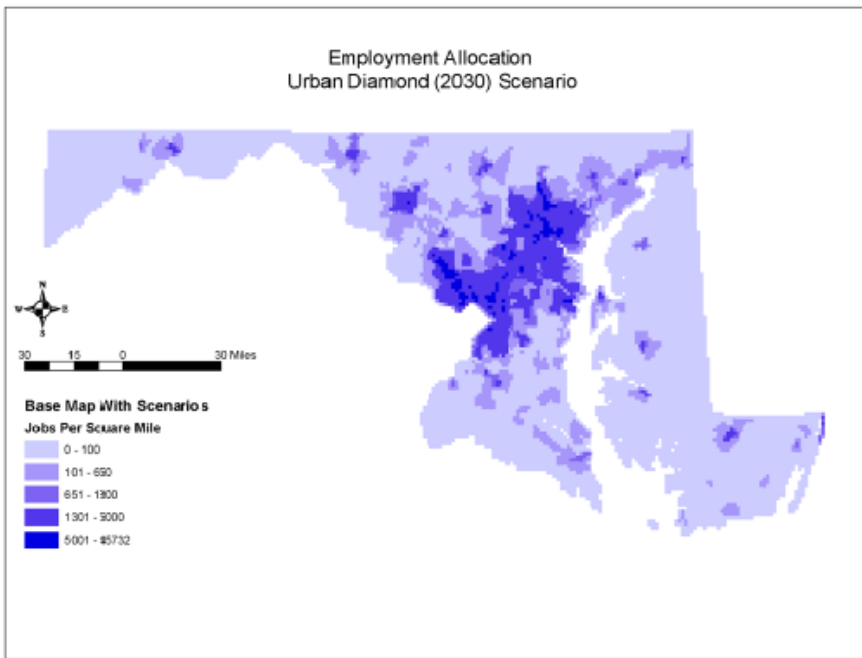
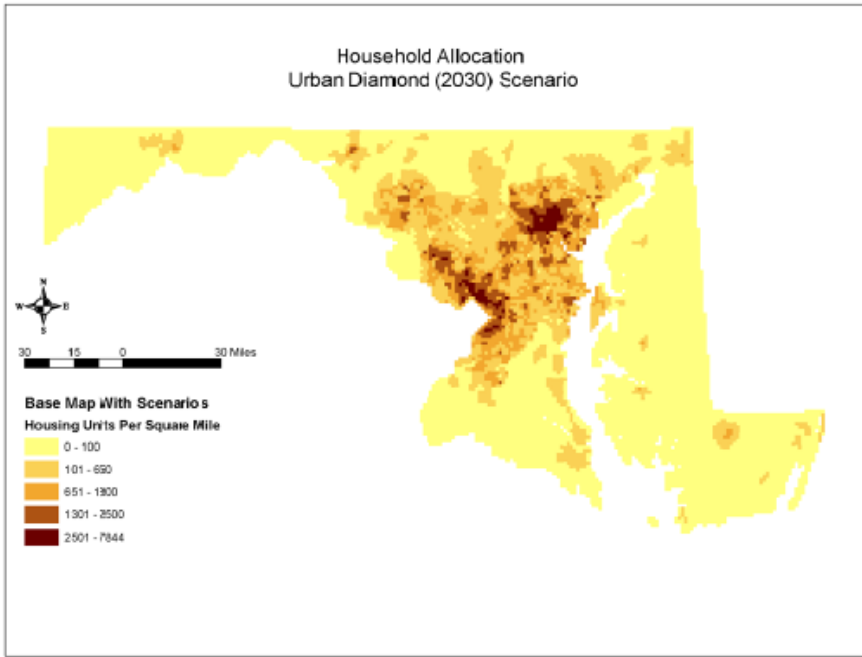


Figure 21 Household and Employment distribution in Urban Diamond scenario

The Urban Diamond scenario ends up developing all the protected areas inside the “diamond” and resulting in a new density and development pattern. However, the areas outside the diamond do not receive any growth. Also, within the areas that receive growth, the areas with high density under existing conditions get more employment whereas the other areas get more housing.

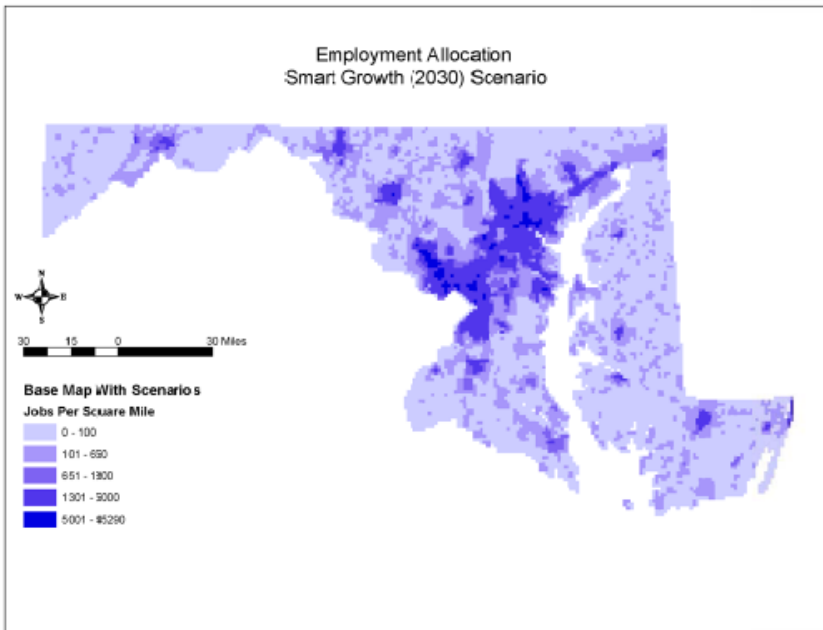
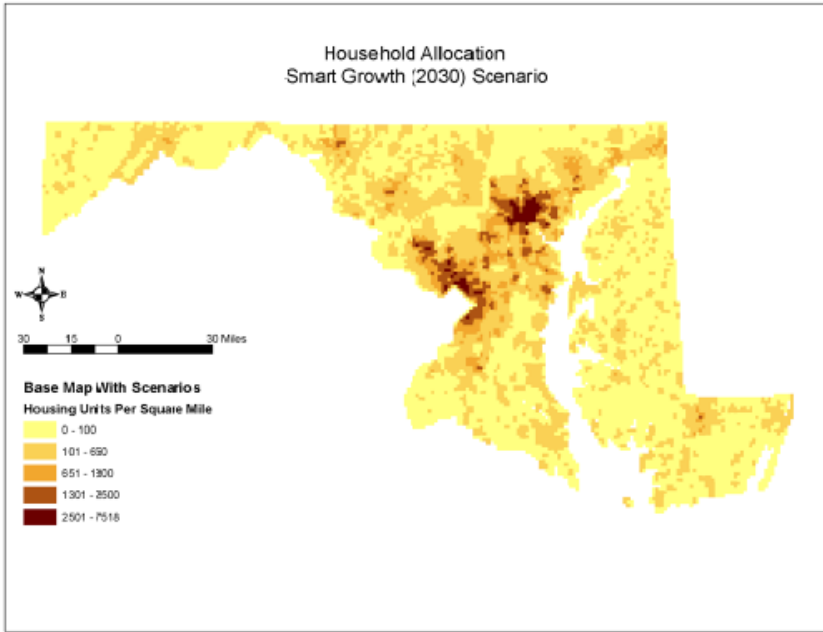


Figure 22 Household and Employment distribution in PFA/Smart Growth scenario

The PFA scenario demonstrates the fragmented nature of the PFAs in the state. Although growth is restricted within the PFAs, the dispersed nature and ample amounts of grids that qualify to receive growth in this scenario create an overall dispersed pattern of development. Compared to the other two experimental scenarios, this scenario receives much growth outside the central corridor.

Chapter 4. Indicators

4.1 What makes a good indicator?

The process of developing objective measurements to compare six scenarios is not independent of the task of developing the scenarios themselves. The choice of scale, size of the region, unit of analysis, growth horizon and control totals, all dictate the indicators that can be successfully computed.

Indicators should also be a function of variables among scenarios – number of jobs and households and their relative location (and what that means for infrastructure, policy etc.).

Impacts of development can be wide-ranging. The indicators that capture those impacts (positive or negative changes) reliably and reasonably with the help of available variables and resources are the ones paid most attention to in this work. Most comparative scenario analyses, depending on their goals and constraints, select a subset of these major categories –

- Land Use – developed and undeveloped areas (inside or outside PFAs, inside or outside greenfields), urban density, rural density, land use types (high density residential, commercial etc.)
- Economy – employment type, income, poverty rate
- Population/Demography – age, income, race, education
- Housing – new housing units, housing type (single family, multifamily, apartment etc.), housing units/job
- Transportation – vehicle miles traveled, lane miles, bus route miles, transit ridership
- Infrastructure – government expenditure per capita, new schools capacity needed, new park space needed, new sewer capacity needed
- Environment – change in sensitive land, change in impervious surface, air quality violations

Although many of these indicators could be estimated as functions of population and employment densities and their relative locations, others need additional assumptions and estimations. Also, some indicators use functions developed in past studies (impervious surface and VMT) and others were developed for this study. Still, every indicator was calibrated for the region in which they are applied. The following list includes indicators that were computed for each scenario. The methods used to compute all the above indicators are discussed in the next section.

Spatial Analysis based Indicators:

- Development (jobs or households) inside priority funding areas
- Development (jobs or households) inside the beltways and urban areas
- New development (jobs or households) in Greenprint areas
- Development (jobs or households) within a mile of highways
- Development (jobs or households) within a mile of rail-transit

These comparisons also permitted estimates of the change in:

- The amount of impervious surfaces that would result from increased development;
- The change in the number of “lane miles” of highways;
- The way such development might have an effect on the state’s remaining “green infrastructure”; and,
- Vehicle Miles Traveled

The following table lists these indicators along with the data on which they were calibrated, the units in which they were computed and the general method used in the process.

Table 9: Preliminary list of indicators

Name	Available data	Units	Method
Proximity (1 mi. to highways, transit)	1990, 2000	% change	Spatial analysis
Inside (or outside) PFAs	2000	% change	Spatial analysis
Developments in greenfields	2000	Acres	Spatial analysis
Inside urban areas and beltways	1990, 2000	% change	Spatial Analysis
Jobs-housing balance	2000	Index, fraction	County level (spatial)
Impervious surface	1990, 2000	% change, mean	Log-linear regression
New lane miles (infra. cost)	2000	Miles	Linear regression
Vehicle miles traveled	2000	Miles	Cluster Analysis
Avg. land area per person	2000	Acres	Spatial Analysis

4.2 Methods to estimate indicators

Development inside priority funding areas

In 1997, Maryland enacted “Smart Growth” legislation that generally restricted the use of state funds for growth or development projects to municipalities, areas inside the Baltimore and Washington beltways, and other areas specifically designated by local governments. These areas became known as Priority Funding Areas. One way of assessing the results of the scenarios is to determine if more or fewer households and/or jobs were allocated inside the Priority Funding Areas.

Effect on Green Infrastructure

Since 2000, the state of Maryland has maintained a mapped inventory of the state’s “green infrastructure” – an inventory of about 2 million acres of the state’s most ecologically significant

lands. These lands were mapped as part of a state program known as GreenPrint. To gauge the effect of future development on the state's green infrastructure, the inventory of GreenPrint lands was overlaid with map layers showing the location of existing households and employment and, where they were placed as part of various future development scenarios. For example, the value for build-out scenario will show the impact on GreenPrint lands of the development that would be permissible under existing zoning.

Development Inside the Beltways

Circumferential highways around Baltimore and Washington (I-695 and I-495/I-95 respectively) define already heavily developed areas adjacent to these two major cities. As such, these areas were designated as Priority Funding Areas under the state's Smart Growth Act. One measurement of support for more intense development, therefore, is how much new growth each scenario allocated inside the Baltimore and Washington beltways.

Development near Rail-transit

Another indicator of relevance and interest among many scenario exercises is how much growth is proposed near transit stations. As with measurements of growth inside the beltways around Baltimore and Washington, measurement of development near transit was primarily an issue in the central corridor region, where most of the existing transit stations are located. This indicator assumes that there will be no change in transit stations and routes.

Jobs/Housing Balance

The distance between housing and employment opportunities is important in the development of communities as well as for its effects on commuting time, commuting patterns, and public as well as

private transportation costs. Change in the jobs/housing ratio, however, is not a statewide issue, but rather an issue that plays out at the local level.

Space per person indicator

An indicator inversely proportional to density is a valuable measure for any development scenario. As land is considered a normal good (urban economic theory; people demand more of it as their income increases), it is interesting to measure various statistics (mean, standard deviation etc.) related to space per person under different scenarios.

New Lane Miles

The study tried to look at the relationship between lane miles and various physical attributes of the grid. Only those variables from existing conditions are used that can reasonably be predicted for a future scenario. The regressions done on existing conditions show a correlation between population, population density and the amount of roads necessary to support that population (please see appendix H for details). As the population increases, the need for more roads goes up; but higher density population requires fewer roads than low density population. The relationship used in estimating future lane miles³³:

$$\text{RoadDens} = 0.259 * \text{PopDens}^{(0.569)}$$

Vehicle Miles Traveled

³³ This relationship is based on work done by staff at the National Center for Smart Growth, particularly doctoral student Jung Ho Shin and his comments on the relevance of his work on this research. Further research, beyond the scope of this dissertation, is ongoing in this area to estimate roads by functional class.

Projecting VMT needs a framework that combines future land use and demographic variations to changes in travel demand³⁴. It is customary to use TAZs or census tracts as their units of analyses but this study will use grids³⁵.

The adopted framework modeled VMT per household per day as a function of 4 census variables - income, vehicle ownership, employment rate and urban-suburban-rural classification. These variables are used to identify unique clusters of census tracts under the premise (or hypothesis later proven in the cited study) that unique clusters share travel characteristics. Once they are grouped, each cluster is related to National Household Travel Survey (NHTS)-based VMTs for that type of cluster and then multiplied by its household population.

The first set of analysis involved 3-steps -

1. Identification of very high or very low income clusters and separating them
2. Then the remaining grids are clustered by density-based community characterization (urban suburban, rural)
3. Finally, each community-based cluster is subdivided into three sub-clusters based on income, employment rate and vehicle ownership

The model that allocates average VMT to each cluster was derived from NHTS surveys on connecting actual surveyed VMT to type of census tracts. This serves as a multiplication factor to the number of households in each grid to derive an estimate of total daily VMT.

³⁴ This research uses a framework developed by researchers at the Oak Ridge National Laboratory (ORNL) to support the derivation of census tract level travel statistics from national travel survey data, and [extends] the ORNL method to estimate future vehicle activity in response to a small set of demographic variables.

³⁵ This study uses a similar framework with grids as the units not census tracts for which the model was originally developed. The size of census tracts vary greatly over an urban area (std. dev. of census tract areas in sq. mi.s within urbanized areas of Maryland = 2.54) limiting the accuracy of the model. Grids which have identical areas (1 sq. mi.) are close to the average census tract size within urbanized areas of Maryland (1.66 sq. mi). A similar rationale was used while using the impervious surface modeled of census tracts on grid data.

It should be noted the scenarios developed on the baseline grid have information on present and future data on households and employment and only present information on demographic variables. As a result, an exact adoption of the above model is not possible. Two variables were completely left out – income and vehicle occupancy rate. Though these variables were available for baseline conditions, the current research framework does not allow predicting those variables in future. Normative assumptions could be made on the basis of existing condition and desirable futures, but because all the scenarios are based on changes of population and employment density – adding such assumptions will needlessly complicate other indicators. This research therefore uses the other two variables – employment rate and urban-suburban-rural character. The clusters are then defined as:

- U1 – Urban High – high household density, high employment density
- U2 – Urban Medium – high household density, medium employment density
- U3 – Urban Low – high household density, low employment density
- S1 – Suburban High – medium household density, high employment density
- S2 – Suburban Medium – medium housenhold density, medium employment density
- S3 – Suburban Low – medium household density, low employment density
- R1 – Rural High – high household density, high employment density
- R2 – Rural Medium – high household density, medium employment density
- R3 – Rural Low – high household density, low employment density

Additional variables such as proportion of multi-family housing were also considered in adopting the model for the purpose of this study but were later dropped as they could not be predicted without making additional normative assumptions.

Table 10 Identifying Clusters that are used as basis for characterizing VMT

Cluster	Housing Density	Employment Density	Multiplication factor (VMT per capita)
U1	HH Density > $2 \overline{H}_i$	Emp. Density > $2 \overline{E}_i$	44
U2	HH Density > $2 \overline{H}_i$	$2 \overline{E}_i > \text{Emp. Density} > \frac{1}{2} \overline{E}_i$	37
U3	HH Density > $2 \overline{H}_i$	$\frac{1}{2} \overline{E}_i > \text{Emp. Density}$	20
S1	$2 \overline{H}_i > \text{HH Density} > \frac{1}{2} \overline{H}_i$	Emp. Density > $2 \overline{E}_i$	65
S2	$2 \overline{H}_i > \text{HH Density} > \frac{1}{2} \overline{H}_i$	$2 \overline{E}_i > \text{Emp. Density} > \frac{1}{2} \overline{E}_i$	52
S3	$2 \overline{H}_i > \text{HH Density} > \frac{1}{2} \overline{H}_i$	$\frac{1}{2} \overline{E}_i > \text{Emp. Density}$	41
R1	$\frac{1}{2} \overline{H}_i > \text{HH Density}$	Emp. Density > $2 \overline{E}_i$	78
R2	$\frac{1}{2} \overline{H}_i > \text{HH Density}$	$2 \overline{E}_i > \text{Emp. Density} > \frac{1}{2} \overline{E}_i$	68
R3	$\frac{1}{2} \overline{H}_i > \text{HH Density}$	$\frac{1}{2} \overline{E}_i > \text{Emp. Density}$	61

\overline{H}_i = mean household density in *i*th scenario.

\overline{E}_i = mean employment density in *i*th scenario.

The indicator is run through a sub-routine within GIS that identifies different clusters for every scenario (except COG scenario, for which this indicator was not tested). The clusters were identified by running a rule-based code in GIS according to the above table individually for each of the six scenarios and existing conditions:

And finally, VMT measures are computed by multiplying the household population of the grid with per households' VMT for each cluster. The following figure shows results of running cluster identification subroutine for the Build-out scenario. The results are discussed in the next section.

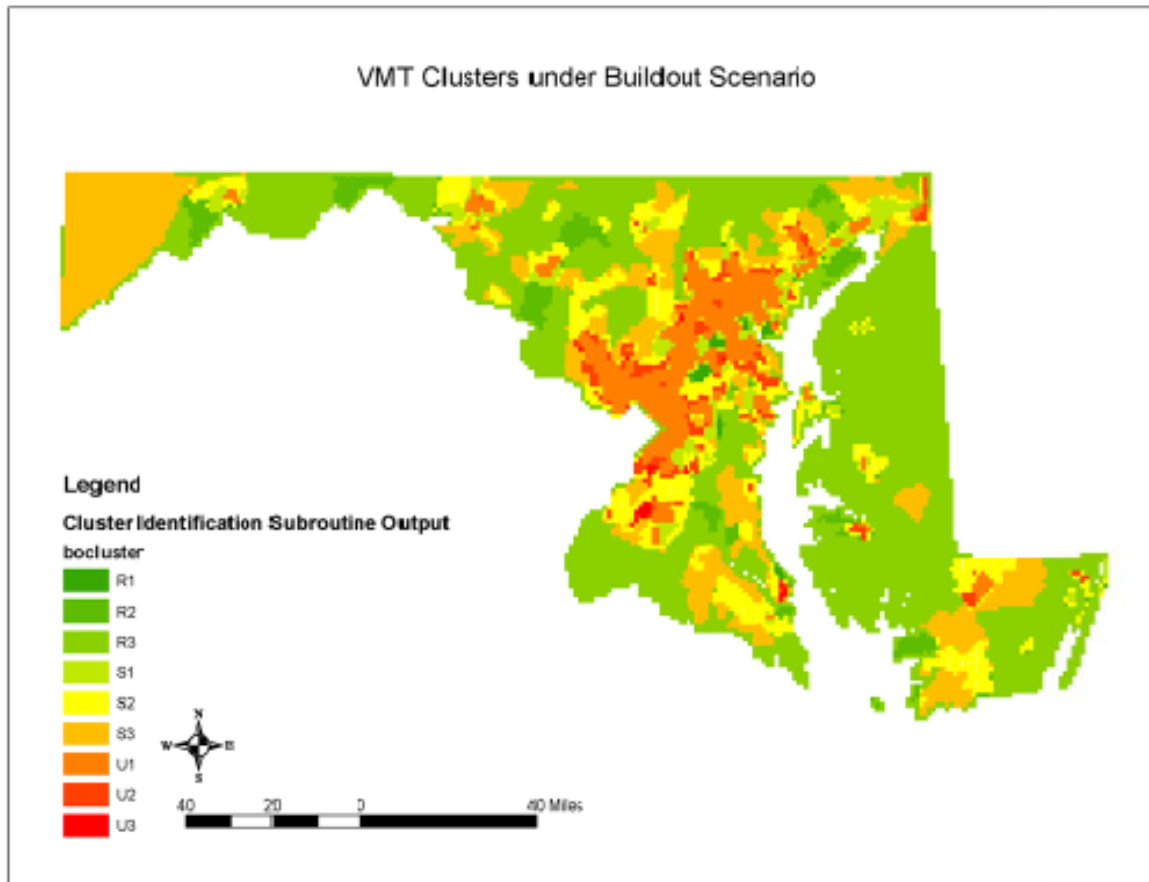


Figure 23 Output of cluster identification routine for computing VMT

Impervious surfaces –

Impervious surfaces are areas in which water cannot permeate through the ground. As the amount of impervious surfaces increases in a watershed, studies have shown that the quality of the environment decreases. This is because water quality decreases as the ability of the land and vegetation to filter the water decreases. Flooding also increases as water runs off impervious surfaces in large quantities and at fast rates. This flooding damages the shape of stream channels and their stream life. In addition, groundwater levels are severely impacted because the impervious surfaces prevent underground aquifers from recharging. Scientific literature generally agrees that watersheds with over 10% of their areas covered in impervious surface begin to experience environmental degradation (USEPA, 1997).

In this study, the year 2000 was used as a baseline. Three main steps were performed in this analysis:

- Determining 2000 percent impervious surface levels through raster satellite imagery developed by RESAC;
- Using a regression equation developed by Hicks and Woods (2000) and 2000 population density data, to compare the equation's performance at estimating percent impervious levels to the 2000 RESAC data; and
- Using Hicks and Wood's regression equation to determine the percent impervious surface levels for future scenarios by each grid.

The first step in this analysis was determining actual percent impervious surface levels, as estimated by the University of Maryland's RESAC. This data was created using satellite imagery for the year 2000. Using this data in GIS and using the Spatial Analyst tool, the percent of impervious surface for each grid in the state was estimated. This provided an estimate of the amount of impervious surface throughout the state in 2000.

Once these estimates were calculated, the regression equation developed by Hicks and Woods was used to estimate the percent of impervious surface for the same year of 2000. The equation is:

$$\%TIA = 94(1 - e^{-0.02833 * population \ density}) + 1$$

The variable %TIA is percent of Total Impervious Area (or surface). The variable *population_density* is the population density per hectare. The results show that the regression equation tended to slightly overestimate the percentage of impervious surface by grids as compared to the RESAC data (on the basis of sensitivity test on 2000 data compared to actual 2000 numbers). However, the difference between the regression's results and RESAC's results were not noteworthy. In fact, when a

correlation was run on the two data sets, it was found that they were significantly correlated at the 95% confidence level with a correlation of 80%. In addition, other studies have shown this equation to be a fairly good estimate of impervious surface. Bird et.al. (2002) tested its accuracy in Frederick County, MD and found that there was only an average absolute error of 1.4% of impervious surface.

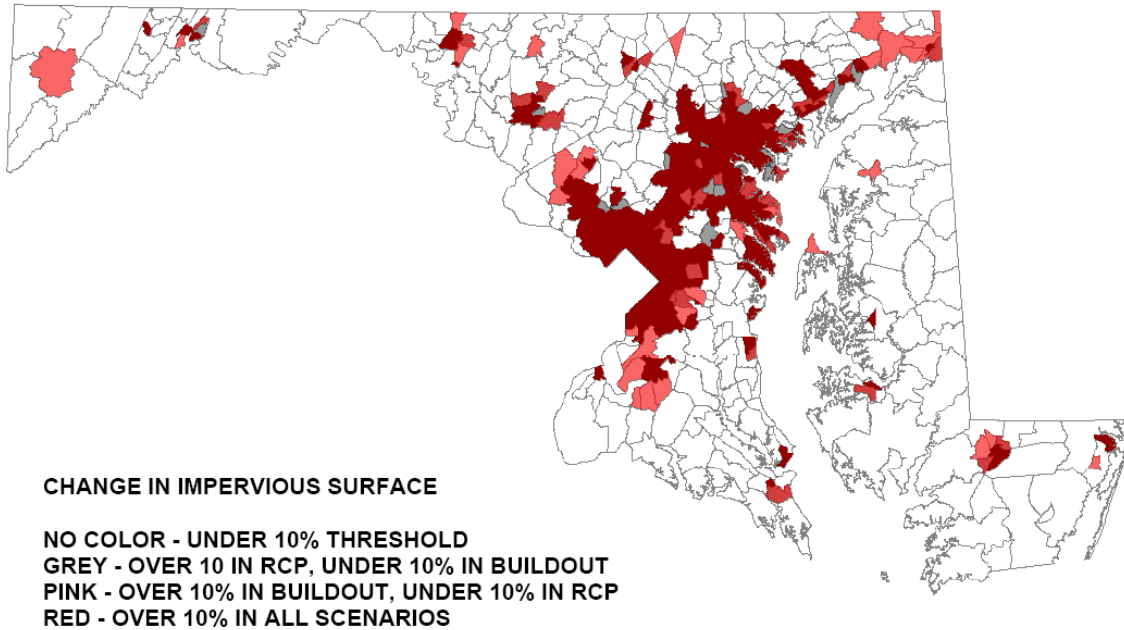


Figure 24 Impervious surfaces under Reality Check versus Build-out scenario

Summary

In summary, Chapter 3 and 4 together achieve the following objectives:

1. creates an overall research framework for scenario planning
2. selects relevant data sets, horizons, region and control totals
3. sets scenario building constraints and specifies tools, especially
 - a. baseline conditions grid with coded information for existing employment and households, infrastructure, policy measures and proximity and character of the grids' neighborhoods

- b. 6 additional scenarios – a build-out of local plans, a trend forecast, a regional vision and 3 experimental scenarios
- 4. arranges all the above in a consistent format for effective analysis and evaluation
- 5. develops and discusses indicators

The next chapter discusses the indicators with respect to each scenario and compares them across other scenarios.

Chapter 5. Results – Comparing Scenarios

Scenarios developed in this study are distinguishable fundamentally on the basis of following variables –

- amount of growth in a given period
- spatial allocation of that growth
- transportation and other infrastructure investment
- other key policies (e.g. regulations or incentives that restrict or encourage growth)

This chapter discusses the results of comparative analysis of each of the six scenarios and existing conditions using the indicators discussed earlier. For every indicator, the chapter details how each scenario performed, tabular or graphic representations of scenarios, a brief description on how it relates to the research question, other indicators and, limitations and caveats (to be discussed in the next chapter in detail). The final section will summarize these results and look at the overall impacts of different scenarios.

It should be noted here that despite many similarities such as format and control totals, (except build-out and COG³⁶ scenario) multiple facts and assumptions make them distinct and restrict outright comparisons. It is in this regard that most of the indicators discussed here are presented as percentages or changes with respect to the baseline conditions.

5.1 Results of Specific Indicators

The indicators developed in the research design section deals with multiple methods. Some of them are based on spatial analysis such as development inside the priority funding areas while others are based on statistical relationships developed through testing multiple hypotheses of relationships among variables in the baseline conditions, while still others have been adopted from literature or

³⁶ An important point to be noted here is that as COG scenario did not cover the entire region, and as one of the purposes is to compare indicators across scenarios, many of the indicators discussed here are not relevant for the COG scenario.

earlier studies tested under different but similar contexts. To repeat the main research question, this study is about exploring impacts, using a wide set of so-called quality-of-life indicators. A wider variety of indicators than presented here were tested during the course of this research (for example projecting demographic change, housing type splits and projections of sewer services and demands of public parks). However, due to restrictions on the availability of relevant data and models, many of those indicators were dropped. Still the research tries to present a wide variety of measures of urban form, travel demand, environmental impact, broadly termed as quality of life indicators.

1. Development inside priority funding areas

Percentage inside PFA

	JOBS	HOUSING
Baseline	81%	76%
COG³⁷	n/a	n/a
Build-out	73%	62%
RCP	82%	78%
Urban Cluster	91%	81%
Urban Diamond	91%	79%
Smart Growth	93%	89%

The scenarios were tested by the amount of jobs and households that were located inside the priority funding areas (land demarcated by the state government to provide additional development incentives). The PFAs are spread all over the state generally based on pre-existing supply of infrastructure. Under existing conditions 81% of jobs and 76% of housing, respectively, are located inside the PFAs. Every scenario except the build-out scenario increases the percentage of both jobs and households inside PFAs. The smart growth scenario stands out in putting the highest percentage, 93% jobs and 89% of households inside the PFAs.

³⁷ COG scenario measures are only noted in tables of indicators for which they were measured. However, the results are not discussed in most cases as the COG scenario just covers part of the state and therefore cannot be compared with other scenario in terms of performance measures.

The last observation is primarily because of the way the smart growth scenario is defined (under this scenario all *new* developments go inside the priority funding areas). The build-out scenario stands out on the lower end of the spectrum because of the existing zoning regulations in the rural areas of the state and the assumption/condition that all land gets developed to capacity.

2. Development close to transit (and highways)

Percentage close to Transit

	JOBS	HOUSING
Baseline	37%	27%
COG*	n/a	n/a
Build-out	28%	22%
RCP	37%	28%
Urban Cluster	33%	25%
Urban Diamond	34	26%
Smart Growth	32%	23%

Percentage close to Major Road

	JOBS	HOUSING
Baseline	82%	72%
COG*	80%	79%
Build-out	76%	65%
RCP	82%	74%
Urban Cluster	84%	73%
Urban Diamond	84%	73%
Smart Growth	83%	75%

The scenarios were tested for two proximity measures – 1. proximity to existing transit infrastructure and 2. proximity to existing highway infrastructure. It should be noted that the data layers used to compute both these indicators are based on present conditions. Although new infrastructure will be

developed that will either follow or foster development, such predictions remain beyond the scope of this research.

Under baseline conditions 37% of the jobs and 27% of housing are within a mile of transit. These percentages fall significantly under the build-out scenario and are somewhat under the three experimental scenarios. They stay constant or change nominally under the Reality Check scenario. With regard to proximity to a major road baseline conditions numbers are 82% and 72%. In this case Build-out is again lower while other scenarios show slight increases as compared to the baseline conditions. These results need to be carefully interpreted. In the case of transit the experimental scenarios and the build-out scenario show decreases because some development (a higher share than current conditions) goes outside the immediate proximity to the Baltimore Washington Corridor. But the transit system, assumed to mostly stay the same, is largely within the Corridor. In the case of major roads this is not the case and hence the shares remain largely the same. This somewhat echoes the assumptions of higher attractiveness index of grids close to highways that went behind developing these scenarios.

3. Development inside beltways

Percentage inside beltways

	JOBS	HOUSING
Baseline	36%	33%
COG*	n/a	n/a
Build-out	28%	25%
RCP	35%	31%
Urban Cluster	39%	31%
Urban Diamond	42%	33%
Smart Growth	38%	28%

This measure tries to capture the compactness of the region. A good measure of urban form within a metropolitan area, it is still valid in the context of the whole state as a region because Baltimore and Washington surroundings are the nuclei of the state. Also, as the above table shows more than a third of both jobs (36%) and housing (33%) are located inside the beltways. As expected, the percentages of both go down under the build-out scenario as areas inside the beltway tend to be highly developed and have low development capacity under current zoning. The experimental scenarios, however, are not constrained by zoning and show a rise in the employment levels inside the beltway. All three scenarios, Urban cluster, Urban Diamond, and Smart Growth – have 39%, 42% and 38% jobs inside the beltway. Again, as household development is negatively affected by higher densities and presence of jobs (implying presence of conflicting land uses) the percentages of households inside the beltways in all three scenarios are lower than other scenarios.

4. Effect on green infrastructure

Percentage in Greenprint

	JOBS	HOUSING
Baseline	2%	3%
COG*	3%	3%
Build-out	3%	5%
RCP	2%	4%
Urban Cluster	2%	2%
Urban Diamond	2%	3%
Smart Growth	2%	3%

“Green Infrastructure layer” is areas designated by the state as protected or marked to be protected. Since the development scenarios assigned growth numbers to the grids and the grids cover the entire state, according to the assumption of development being uniformly distributed inside the grid, it is impossible to measure the impact on the green infrastructure layer. Therefore, the method used for

making these comparisons produces more of an index than a measure of development. But as the above table shows, only the Build-out scenario makes a high impact.

5. Jobs/housing balance

Jobs/Housing (ratios) By County³⁸

County	Baseline	COG	Build-out	RCP	Urban Cluster	Urban Diamond	Smart Growth
Allegany	1.45	n/a	1.98	1.20	1.72	1.45	1.06
Anne Arundel	1.68	1.81	1.95	1.70	1.98	1.87	2.22
Baltimore	1.60	1.82	1.73	1.60	1.81	1.76	2.05
Baltimore City	1.81	1.76	1.52	1.92	1.96	1.98	2.03
Calvert	1.00	1.00	0.94	1.29	0.94	1.00	0.88
Caroline	1.22	n/a	1.14	1.03	1.22	1.22	0.66
Carroll	1.27	1.12	1.19	1.20	1.15	0.99	1.13
Cecil	1.04	1.24	1.52	1.11	0.71	1.04	0.80
Charles	1.14	0.90	1.04	1.25	1.10	1.10	1.19
Dorchester	1.45	n/a	1.14	1.21	1.68	1.45	0.91
Frederick	1.46	1.50	2.08	1.33	1.22	0.80	1.21
Garrett	1.36	n/a	0.15	0.84	1.32	1.36	0.55
Harford	1.27	1.30	1.84	1.27	0.95	1.27	1.51
Howard	1.73	1.19	2.10	1.63	2.10	1.68	2.23
Kent	1.58	n/a	1.44	1.22	2.08	1.58	0.89
Montgomery	1.69	1.66	1.46	1.71	1.97	1.91	2.08
Prince George's	1.40	1.58	1.72	1.42	1.75	1.74	1.87
Queen Anne's	1.16	n/a	1.24	0.98	1.33	0.76	0.84
Somerset	1.11	n/a	1.19	1.05	0.35	1.11	0.47
St. Mary's	1.32	1.40	1.03	0.82	1.43	1.32	1.27
Talbot	1.94	n/a	1.09	1.67	2.25	1.94	1.15
Washington	1.60	n/a	2.12	1.53	1.35	1.60	1.28
Wicomico	1.51	n/a	1.21	1.40	1.25	1.51	1.29
Worcester	1.80	n/a	1.59	1.46	1.90	1.80	1.19

A large body of literature that advocates “smart growth” has argued for a need to balance the number of jobs and households for reasons such as accessibility, decreased commute times, more housing choice and choice of multiple modes of transportation. An opposite scenario is generally one that congests highways going in one direction, creation of bedroom communities and higher

³⁸ Most values in the table are greater than. This is because the table shows jobs/households not jobs/population. Overall regional value for jobs/household ratio is around 1.6.

environmental costs resulting from longer commutes. Although urban economic theory suggests such mismatch in patterns of development, this indicator is worthwhile to get an idea at least from a tax base point of view. However the size of the region within which such balance is desirable is unclear.

The imbalance of jobs and households is self evident in the context of Maryland. As the above table shows the counties with the highest jobs per household ratios under the baseline conditions tend to be the urban counties in the Baltimore Washington Corridor such as Howard County, Montgomery County, Anne Arundel County and Baltimore City. Prince George's County, another county in the Urban Corridor has a much lower share of jobs per households (reinforcing the region divided hypothesis; Brookings, 1999). Interestingly, rural counties such as Talbot (with cities of Cambridge and Easton) and Worcester (with Ocean City) show relatively higher jobs per household suggesting that they may be sub-regional employment centers. Build-out scenario changes these proportions greatly, making counties such as Allegany, Frederick and Washington as counties with the highest share of jobs per household. Not surprisingly, it reduces the jobs per household in Garrett County to 0.15 showing primarily the huge housing development capacity largely due to absence of zoning.

The Urban Cluster scenario which creates compact clusters through the state reinforces the high jobs per household ratios in many of the existing urbanized areas. For example, it increases the proportion of jobs in Montgomery County from 1.69, under baseline conditions to 1.97, whereas, in Baltimore City it goes up from 1.81 to 1.98, and in Howard County it goes up from 1.73 to 2.10. Even in Prince George's County it goes up from 1.40 to 1.75. Although the baseline conditions looks most balanced overall (the ratio varying from 1.11 to 1.94), the Urban Diamond scenario comes next, where the range is from 0.99 to 1.94. The Smart Growth scenario, which is largely driven by the location of the PFAs shows the highest range of ratios from 0.47 to 2.22.

6. Effect on impervious surface

Impervious Surface Estimation

	# of grids with more than 10% impervious	Change (# of grids)
Baseline	1581	-
COG*	n/a	-
Build-out	2728	1147
RCP	2313	732
Urban Cluster	2392	811
Urban Diamond	2408	827
Smart Growth	2711	1130

This indicator shows the number of grids (out of a total of roughly 11000 in the entire state) that have more than 10% of their surface area as impervious (1581 under baseline conditions). Using the 10% threshold was chosen as an indicator because as a rule of thumb, watersheds with as little as 10% if their area covered by impervious surfaces begin to experience environmental degradation and as such this indicator becomes a proxy for measuring the effect of development on the environment, especially water quality.

The analysis found that there was a definite increase in impervious surfaces in every scenario when compared to the baseline. The build-out scenario added the highest number of grids (1147) to the list of grids which had more than 10% impervious surface. The so called Smart Growth scenario, which is the least densely packed of the other four scenarios added the next highest number of grids to the list. The other three scenarios made lower and comparable set of additions. With Reality Check scenario adding the least number of grids to the list (732).

7. Effect on vehicle miles traveled

VMT (per scenario per day)

	Total	Change
Baseline	86,373,911	
COG*	n/a	n/a
Build-out	151,613,752	65,239,841
RCP	123,600,785	37,226,874
Urban Cluster	121,112,996	34,739,085³⁹
Urban Diamond	121,805,927	35,432,016
Smart Growth	123438016	37064105

VMT proved to be the most elusive indicator to estimate largely as travel demand depends upon a wide range of variables and predicting behavioral indicators are more complicated than spatial ones. In the earlier chapter there was a discussion on the variables that the model adopted in this study used to make its estimations. Those variables were income, vehicle ownership, and employment rate and community type. However, this research does not forecast changes in income and vehicle ownership (although they could be included in the list of assumptions or estimated in a future study). This research uses population density and neighborhood dummy variables to estimate community type into urban, suburban or rural types. It further uses the employment density, available in all scenarios as the employment rate. Thus it assigns a combination of employment rate and community type into nine clusters of grids similar to the method used in the model adopted here. Thus the research could assign the characteristic VMT per household numbers from the adopted model into each of the clusters redefined here.

The above table shows total VMTs under each scenario – where the characteristic VMT of each grid (related through the cluster to which the grid belongs) is multiplied to the number of households in each grid and then added for the whole region

³⁹ The findings in the table are consistent with expectations of some researchers. For example, lower VMT per household per day in case of the Urban Cluster scenario is consistent with theories proposed by Gordon and Richardson (2001).

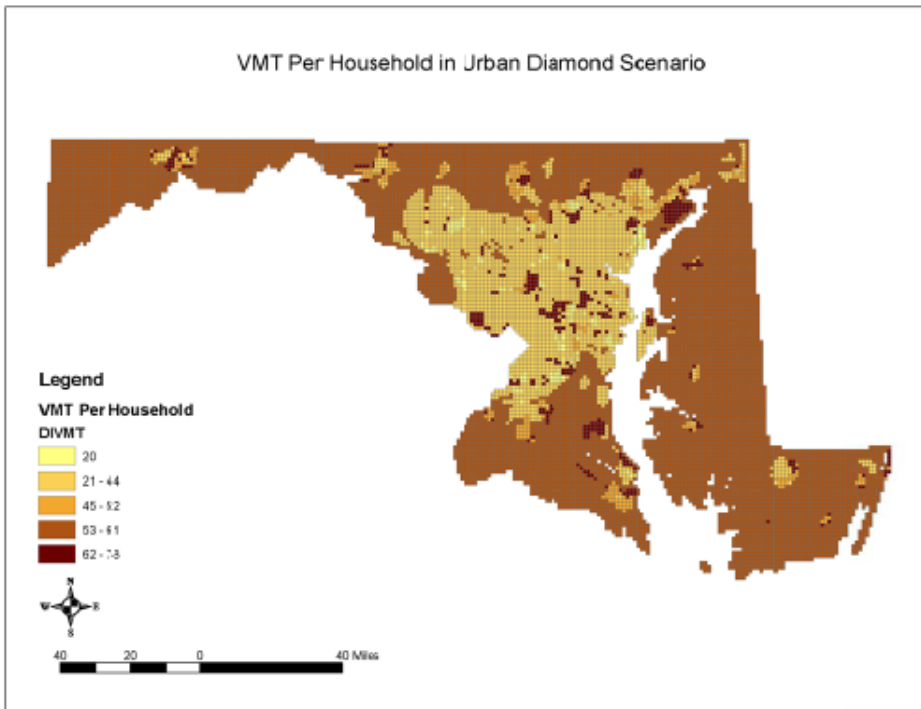


Figure 25 Illustration of VMT per household in Urban Diamond Scenario

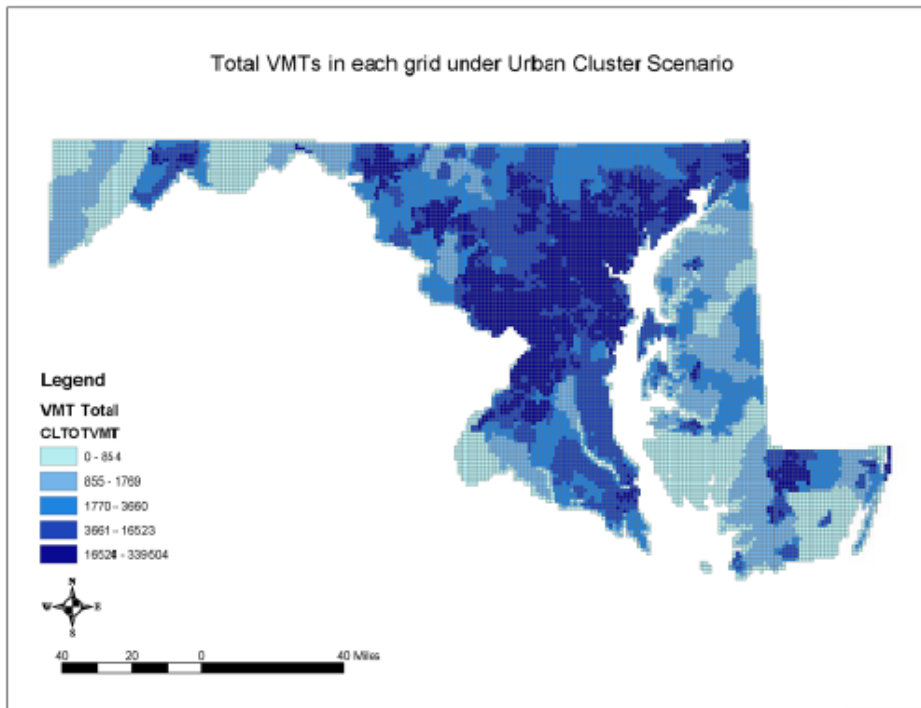


Figure 26 Illustration of total VMT per grid in Urban Cluster scenario

Thus, the total VMT for the state goes up in every future scenario as more households are added to the state. This increase is quite large under build-out scenario, roughly 85% whereas in other scenarios it

goes up comparably around 50%. This difference could be directly assigned to the dispersed nature of household developments in the build-out scenario as compared to all other future scenarios and the recognition of higher per household VMTs that lower density clusters seem to characterize.

Although VMT per capita is a usual measure of travel demand indicator, this model uses it as midpoint (as a cluster characteristic) and total VMT as an output . Thus the results are indicated as aggregate VMTs among various scenarios. Finally, the following table lists the total VMTs by individual counties in the state. It is difficult to interpret this table as the numbers are both a function of the total population of the respective county and the predominant cluster types of the grids that are in it.

VMT TOTALS BY COUNTY (in miles)

COUNTY	BASELINE	BUILD-OUT	REALITY CHECK	URBAN CLUSTER	URBAN DIAMOND	SMART GROWTH
Allegany	1,127,898	2,381,524	1,897,174	1,329,437	1,172,348	2,367,122
Anne Arundel	8,659,257	11,876,531	12,033,056	12,522,240	14,224,839	10,936,865
Baltimore	13,344,843	18,193,070	17,314,621	18,383,598	19,646,600	15,895,326
Baltimore City	8,664,502	13,143,985	12,271,410	9,730,550	10,062,073	9,262,987
Calvert	1,163,891	2,178,150	1,891,479	1,376,194	1,340,729	2,057,288
Caroline	664,779	1,938,916	1,192,221	664,107	664,107	1,359,252
Carroll	2,622,792	4,070,038	3,532,376	4,328,750	3,845,920	4,651,010
Cecil	1,543,801	5,075,957	2,242,515	3,389,818	1,719,277	3,222,482
Charles	2,188,060	5,916,893	3,807,021	3,443,380	2,361,913	3,964,493
Dorchester	615,349	2,344,896	1,130,325	627,866	627,866	1,528,208
Frederick	3,505,778	5,882,212	5,308,912	5,805,357	9,345,959	6,611,949
Garrett	583,892	6,457,992	1,176,202	601,772	583,892	1,283,907
Harford	3,342,401	4,913,608	5,204,011	6,998,863	3,479,105	4,911,944
Howard	3,582,748	5,288,480	4,991,427	4,620,722	5,989,657	4,247,726
Kent	448,567	1,650,728	818,813	481,126	442,647	1,333,016
Montgomery	13,130,420	17,924,913	16,734,895	16,173,501	17,870,008	15,149,911
Prince George's	10,443,034	15,352,893	15,301,077	14,022,179	15,519,378	12,949,187
Queen Anne's	778,881	2,394,419	1,349,220	801,414	1,377,159	1,589,445
Somerset	581,519	3,029,617	941,973	1,305,050	586,917	1,900,379
St. Mary's	1,680,773	3,357,473	2,705,597	2,102,028	1,767,839	2,696,446
Talbot	666,608	2,050,635	1,125,401	698,244	651,971	1,677,346
Washington	2,060,624	4,748,056	3,193,563	3,952,232	2,164,771	4,354,066
Wicomico	1,412,918	3,980,259	1,991,492	2,785,256	1,487,753	2,906,066
Worcester	853,483	2,107,086	1,456,425	945,400	860,054	1,853,593

8. Effect on lane miles

New Lane Mile Development Estimation

	Miles of Lanes (miles)	New Lanes (miles)
Baseline	4,171	-
COG*	3,812 ⁴⁰	-
Build-out	6,468	2,297
RCP	5,287	1,116
Urban Cluster	5,223	1,052
Urban Diamond	5,216	1,045
Smart Growth	5,559	1,388

The highway proximity indicator measures the amount of development within a certain distance of a major highway but, unfortunately, cannot capture the new highway development that will occur and inevitably put a higher percentage of developments close to highway than estimated here. The location of those highways in the future is hard to predict or assume, but the amount of new lane miles (not just highways) needed is easier to estimate. This was done, as explained in the previous section, by estimating the relationship between road density (in unit of new lane miles, dependent variable) and exogenous variables based on existing conditions. The significant exogenous variable used in the model is population density of the grid.

The above table shows how the demand for new lane miles varies by scenarios. The baseline conditions has about 4171 lane miles (based on the road data layer used). Using the model, the build-out scenario will need an additional 2297 miles of lanes (by far the highest amount). The other scenarios will need relatively comparable amounts new lane miles development with Urban Diamond scenario needing the least amount of new roads. This result make intuitive sense as part of the state inside the “Urban Diamond” boundary has the highest current density of roads, and though the level of service requirements were not included in this study, the generalized model tend to suggest this region has the highest absorption potential of future growth in terms of current infrastructure capacity.

⁴⁰ Lower total shows that COG scenario only covers a part of the state

9. Land area per person

Land Area Per Person (Acres per person)

County	Baseline	COG	Build-out	RCP	Urban Cluster	Urban Diamond	Smart Growth
Allegany	11.8	-	5.8	6.6	10.0	11.8	4.2
Anne Arundel	1.8	1.2	1.3	1.3	1.2	1.0	1.5
Baltimore	1.5	1.1	1.1	1.1	1.0	1.0	1.3
Baltimore City	0.2	0.3	0.2	0.2	0.2	0.2	0.2
Calvert	6.7	5.0	3.6	4.5	6.3	6.7	3.9
Caroline	20.6	-	7.0	11.5	20.6	20.6	6.9
Carroll	5.6	3.1	3.7	4.3	3.1	3.6	3.0
Cecil	8.1	-	2.5	5.5	3.1	8.1	3.3
Charles	8.7	4.8	3.2	4.9	4.6	8.0	4.5
Dorchester	41.5	-	10.1	22.7	41.5	41.5	12.6
Frederick	6.1	3.6	3.8	3.9	3.1	1.7	2.9
Garrett	39.0	-	2.4	19.4	37.3	39.0	9.2
Harford	3.9	2.1	2.8	2.5	1.5	3.9	2.6
Howard	1.9	1.5	1.3	1.4	1.5	1.1	1.6
Kent	30.6	-	8.1	16.5	27.3	30.6	7.4
Montgomery	1.0	0.7	0.7	0.8	0.8	0.7	0.9
Prince George's	1.1	0.8	0.8	0.8	0.8	0.7	0.9
Queen Anne's	18.4	-	6.3	10.8	18.4	8.6	7.3
Somerset	26.9	-	4.0	16.4	6.8	26.9	4.6
St. Mary's	9.1	5.8	4.0	5.1	7.0	9.1	5.3
Talbot	17.8	-	5.7	10.2	16.5	17.8	5.7
Washington	5.7	-	2.5	3.7	2.6	5.7	2.4
Wicomico	8.3	-	2.8	6.0	3.6	8.3	3.6
Worcester	20.7	-	8.6	12.7	17.2	20.7	7.6
<i>Standard Dev</i>	<i>12.0</i>	<i>1.9</i>	<i>2.7</i>	<i>6.4</i>	<i>11.8</i>	<i>12.3</i>	<i>3.0</i>

Urban economic theory suggests that more space per person is better, all other things being equal. The above table shows aggregated space per person in each county under different scenarios. This indicator is a simple measure based on population densities only (in a way, it is inverse of density aggregated at the county level). But there are many issues that warrant discussion (some of those covered in the next chapter), such as higher density could mean better urban spaces, housing choices, better environmental protection and lower infrastructure cost. Some of these causal models have been

demonstrated in this chapter as various indicators of different scenarios. And, though the overall space per person for the entire state remains same in the last four scenarios (as they have the same control totals) yet the share in various counties differ considerably in every scenario. For example, the space per person in Garrett County is 39 acres in baseline conditions and goes down to 2.4 in the build-out scenario. This is due to a much higher share of growth going into this particular county. As expected, the baseline conditions has the highest space per person for all counties compared to other scenarios as it has the lowest control totals (as no county loses population in the scenarios under consideration).

Summary

As expected, different scenarios seem to optimize on different performance measures, with the exception of build-out analysis, which performs poorly on almost all indicators. Land area per person and jobs housing ratio are disaggregated by counties and since in this case the overall jobs/housing ratio or land area per person remains the same when aggregated over the entire state, those indicators cannot be included in an overarching assessment. Only if an individual or a subset of counties is being investigated (such as a sub-regional assessment like the Baltimore-Washington corridor) that those indicators can be used to make a judgment on the scenarios.

The following table shows a synthesis of all the other indicators presented in this chapter –

Table 11 Synthesis table for indicators computed at the state level for all scenario

Scenarios	<u>Percentage inside PFA</u>		<u>Percentage close to Major Road</u>		<u>Percentage Inside Beltways</u>		<u>Percentage Close to Transit</u>	
	JOBS	HOUSING	JOBS	HOUSING	JOBS	HOUSING	JOBS	HOUSING
Baseline	81	76	82	72	36	33	37	27
Build-out	73	62	76	65	28	25	28	22
RCP	82	78	82	74	35	31	37	28
Urban Cluster	91	81	84	73	39	31	33	25
Urban Diamond	91	79	84	73	42	33	34	26
Smart Growth	93	89	83	75	38	28	32	23

Scenarios	<u>Vehicle Miles Traveled</u>	<u>New Lane Miles</u>		<u>10%+ Impervious Grids</u>		<u>Percentage in Greenprint</u>	
	Total	Total Lane Miles	New Lane Miles	Total	Change	JOBS	HOUSING
Baseline	86373911	4171	-	4171	-	<u>2</u>	<u>3</u>
Build-out	<i>151613752</i>	<i>6468</i>	<i>2297</i>	<i>6468</i>	<i>2297</i>	<u>3</u>	<u>5</u>
RCP	123600785	5287	1116	5287	1116	<u>2</u>	<u>4</u>
Urban Cluster	121112996	5223	1052	5223	1052	<u>2</u>	<u>2</u>
Urban Diamond	121805927	5216	1045	5216	1045	<u>2</u>	<u>3</u>
Smart Growth	123438016	5559	1388	5559	1388	<u>2</u>	<u>3</u>

The extremes in the above table are identified as bold for highest performance and italics for the lowest. Although, this study does not assign subjective judgments to the direction of the indicators' value, the outliers are identified in line with the ceteris paribus point of view. It is interesting that the Build-out scenario performs low in all indicators while the Urban Diamond scenario scores high in many and highest in seven of the 13 indicators (the GreenPrint indicator is a weak representation compared to others).

Many past studies in scenario analysis have tried to arrive at a unified score for the “best” scenario by placing weights on respective indicators (multi-criteria evaluation). There is, however, no generally accepted framework on assigning weights among the indicators used here. But, not assigning weights could implicitly mean equally weighting all indicators. Still, this dissertation does not present a multi-criteria evaluation to suggest the “best” scenario. Rather, it discusses the context sensitive nature of planning problems by discussing each indicator with respect to distinct scenarios separately. The next chapter discusses overall conclusions, and limitations of this research.

Chapter 6 Discussion and Conclusions

Urban planning by definition is an exercise in imagining and shaping the future. Scenario analysis provides a framework to simplify and operationalize the future using a set of diverse tools that allow us to ask and answer wide ranging questions about the future. This research also set out with a few questions. It was not about creating the best scenario but an experiment in understanding development patterns and their impacts at the state level. In the end, there are a few lessons to take away. The results have shown that different scenarios yield different results. But in many cases results are not too far apart, except in the case of build-out. Build-out is different to a large extent because it uses different control totals as it is not constrained by a fixed time horizon. The indicators are crude and in many cases do not show much difference from the existing conditions. This is, in part, because of the time horizon of only 30 years, which leads to a net change of around 30% of the state's total jobs and households. Still, the results show that 1) measurable differences exist in different scenarios, 2) there are deficiencies in current plans and 3) although it is not clear what exact steps are needed to get any desired output, this research indicates that greater regional coordination may be beneficial.

6.1 Planning Practice and Scenario Planning

Current development practices have been criticized for many deficiencies. Some practices have been accused of short-sightedness and some of being long-range but disconnected from past trends (Myers and Kitsuse, 1999). The issues generally arise from diverse nature of development practices and contexts in different places that evade simplification and one-size-fits-all solutions. As one of the practices that influence development, planning is an exercise that takes place in the public realm, and in theory, context sensitive. Thus it not only needs to be technically sound, but also politically inclusive. Scenario analysis as a tool has tried to balance these two aspects. In varying combinations, scenario analysis has brought together political adversaries, evaluated effects of current and

alternative policies, tied technical planning analysis of past trends with forecast and projected future course of actions. It has also provided a broader outlook than traditional planning, which have focused on local planning practices. Also, as this research shows, current technology provides the tools necessary to do such large scale analyses at a regional level.

There are many advantages to the local-level planning. They include neighborhood choices based on service demands and individual's willingness to pay, local political power to even the smallest jurisdiction, and innovative competition among cities to attract growth. However, as the literature review suggests, this has also helped create a short-sighted view resulting in overall inefficiencies in the region and discriminatory, exclusive policies such as exclusionary zoning practiced by many jurisdictions.

Scenario analysis presents a tool that provides a wider systemic understanding of the impact of development at different scales. This may include looking at some of the issues more regionally or from a statewide perspective, understanding the trends so that projections may be desirably altered, provide better measures of development patterns at micro and macro scales and tools of visualization and participation that can strengthen the role of planning in dealing with the challenges related to growth. It also provides the policymakers and stakeholders a way to look beyond short-range; budget cycles based programs and immediate horizons of political cycles. Also, perhaps most importantly, it provides a mode of public discourse by providing a wide variety of information that is technically sound, visually appealing and politically relevant to choose a desired course of action.

6.2 Policy implications of this study

In practice, scenario analysis has been sometimes used to “inform” public about the coming growth and its perils. This research does not take that approach and comment on total capacity for growth. Instead, it focuses on what the objective and computable measures are.

Growth generally has adverse environmental costs but many a times has positive socio-economic benefits. If planned properly, new communities provide increased opportunities of employment, wider housing choice and thriving socio-cultural atmosphere. The “quality of life” indicators presented here acknowledge both sides of the coin and show alternatives ways in which planning can play a role in reducing the costs while advancing the benefits.

The analysis shows that Maryland jurisdictions have zoned for more residential and employment capacity than projections suggest are coming to the state within the next 25-30 years. In 2000, the state had fewer than 2 million housing units, a level projected by Maryland Department of Planning to go up to 2.6 million by 2030. Under existing zoning (i.e., “build-out”), however, the state has a current capacity of nearly 3.2 million housing units. But the bigger issue here is how that capacity is distributed across the state. A build-out analysis, unlike the other scenarios, develops a piece of land only when there is capacity available. This means, as the indicators show, that urban areas with already higher density developments tends to push new growth out to places where there is capacity to absorb such growth. Also, as the indicators show, this strains the infrastructure network, creates additional demand for public services at an increasing rate, depletes the environment more than the other, more compact, scenarios and increases per household travel demand (and by extension increased commute times and reduced air quality). It also potentially underutilizes the existing infrastructure.

Also, when Reality Check, Urban Cluster and Urban Diamond scenarios are compared with what would be permissible under existing zoning (i.e., the “build-out” scenario), there are places throughout the state where alternative scenarios placed a denser level of housing and jobs than current zoning would permit (see red in Figure 30). This was particularly true in the vicinity of the I-95 corridor. This means that while the “build-out” scenario clearly shows there is much more capacity in the state to accommodate growth than current population projections demand. Still the other scenarios appear to demonstrate a mismatch between location of capacity and areas of high demand for growth.

A related problem highlighted by the “build-out” scenario is that the lack of regulatory restraint in some suburban and most rural counties means that current zoning would be more likely to foster a pattern of dispersed development than other scenarios.

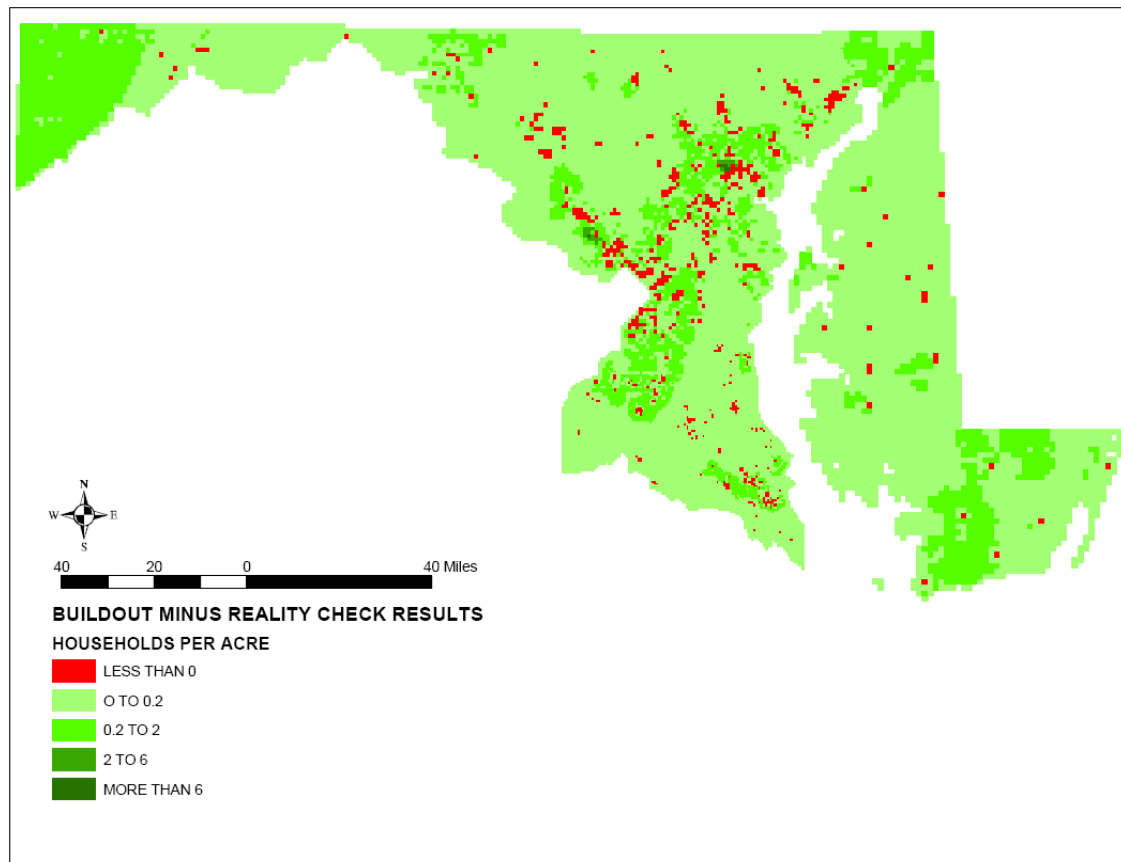


Figure 27 Map of Reality Check *Plus* scenario putting more than allowed households in the core

As the introduction and literature review section have discussed, the state and many local jurisdictions have policies to fulfill many of the so-called smart growth objectives. Though the jury is still out on the outcomes of many recently enacted policies, the PFA-based smart growth scenario helps demonstrate, there are possible perverse effects of well-intended policies.

Three of the six scenarios – Reality Check, Urban Clusters and Urban Diamond generally return higher measures of accessibility, environmental impact, demand for public facilities, travel demand and mode choice among other things than the Build-out or PFA scenarios. Within the constraints of the assumptions that went behind developing these scenarios – the results show that there are alternative development patterns that yield better results than Build-out. But it is not clear which

measures, whether state planning or not, can get us there. However, the assumptions also hint at the certain hypothetical conditions for achieving such positive results. They vary by scenario:

- For Reality Check scenario – provision for a stronger regional entity to manage growth as desired by the representatives of residents and stakeholders. Also, zoning and comprehensive plans updates for inner jurisdictions with stronger open space policies and investment in improved public facilities in already developed areas.
- For Urban Cluster scenario – the local governments will need take a stronger role in promoting compact development patterns that are more balanced in regional distribution of jobs and households, create incentives, fees and/or controls within each jurisdiction to contain growth in designated areas, promote transportation systems such as regional rail networks that connect such nodes.
- And for the Urban Diamond scenario – there needs to be strong investment in the urban core of the state in the form of additional highways and rail networks, reinforcing existing centers and promoting additional centers within the Diamond. Cities in this subregion – Washington, Baltimore, Annapolis and Frederick, with the possible inclusion of expanded subcenters such as Columbia, Bowie, Laurel, Gaithersburg etc. provide distinct forms of urban and suburban lifestyles due to different socio-economic and political contexts and physical attributes. Along with existing open spaces in the region (some of which may need to be developed to accommodate the projected growth) will make this scenario generate the lowest total VMT among many other scenarios.

To summarize, it is important to note that any scenario planning process that is geared toward policy needs to acknowledge the trade-offs. Any implementation of policies or decisions based on the scenario planning process should try to optimize on the desirable indicators. In Terry Moore's (2005)

words "...[P]lanning scenarios needs to fulfill two layers of requirements: 1) it has to be objective and analytical, with limits on the range of possible futures, and 2) it must reflect the desires of various interest groups. Additionally, long-term future depends on multiple temporal processes at work at present or that in near-future..." This research, while adhering to the above rules, thus takes a fresh look at scenario analysis at statewide scale using multiple models and computes a long list of indicators with the hope that they will contribute to the understanding of the development processes at multiple scales and allow for questioning existing practices so that new ones can evolve.

6.3 Limitations and Further Research

A major limitation of this study is its inability to project more variables, other than jobs and households, into the future scenarios. A wide set of information is available under the baseline conditions, ranging from demographic, spatial, infrastructure, and policy measures. Any future scenarios, 25 years or more in the future can have any degree of changes in each of those variables – such as a higher share of low income residents, their varying degree of spatial segregation, better technology to meet with environmental demands, political uncertainty etc. Taken in combination, there are infinite possibilities with varying degree of numeric and spatial changes. Thus scenario planning tends to hold one set of variables constant, assume predefined changes in another set of variables, along with calculated, varying degree of changes in yet another set variables. This allows estimation of yet another, fourth set of variables. For this study, the first set refers to demographic variables (such as race, income, education), market conditions etc., the second and third set could be interchangeably the population and employment control totals (demand side variables) and the policy variables such as zoning, open space preservation, PFA etc. (supply side variables). The last set is of the indicators which are computed as a function of the second and third set of variables (treating them as generally exogenous), *ceteris paribus*.

Scenario analysis is also about creating plausible alternatives that are interesting and thought provoking. It is about asking “what if” questions in order to evaluate alternative responses and in the process trying to find a path to reach a desirable “what if” scenario. In doing so, this research makes many simplifying assumptions in generating scenarios and estimating indicators, such as uniform densities within the baseline grid, defining many complicated processes into indicators that functions of population density and a few other variables. Additionally, there are limitations in defining variables, number of indicator that could be satisfactorily measured using a limited set of variables, proper unit of analysis and proper interpretations of results.

Similarly, another issue this research does not address is how to account for changes in regional landscape between the present time and the growth horizon. Although this can be theoretically achieved using a prototype-based model developed in this research (but not used in the analysis, please see appendix C), such a measure will have its own set of research question and could be a potential follow-up to this work. The example often used in this regard is transportation improvement plans. The issue here is that most of the infrastructure based indicator comparison such as highway accessibility now and in 2030 should be computed with two different set of basic infrastructure layers, namely a 2000 layer and one that approximates 2030 scenario.

Generating the scenarios

Spatial data comes in various forms – parcel level, aggregated by census tracts, raster data etc. To create a uniform dataset, such as the baseline grid, into which all the above forms of data can be reaggreated inevitably builds in a certain degree of aggregation error. This error continues through the analysis as successive data layers are added to the grid. Still the grid was adopted for various

reasons – 1) it originally presented an ideal participatory tool for the Reality Check exercise; 2) since this research dealt with a wide range of datasets and large region; 3) it provided the right scale for visualizing the information as well as reasonable data processing times. The allocation of growth into a 1 sq. mi. grid still presents interpretation challenges. 1000 households added to a sq. mi. grid could be put into a single apartment tower or 1000 half-acre lots with single family homes. The models used to compute the indicator generally do not distinguish between the two. This limitation, in part, led to the development of the prototype-method, where the new development is based on character of the community rather than continuous increases in jobs and households. Such models may provide a way to better visualize development at finer resolution with more control over the character of the final outcome.

The grid type and accessibility measures used in allocation index measurement relied heavily on highway infrastructure, location in the region and land use policy regarding open space, PFAs and sometimes zoning. However, as studies constantly suggest many other variables such as school quality, age and income groups, housing prices etc. play a role in those decisions. But those variables, as noted earlier, were not included in this study.

As the VMT model (and also the impervious surface and the road density models) and the brief discussion included therein suggests, the predictability is enhanced if additional variables such as income, vehicle ownership are taken into consideration. But each of those is important and interesting research questions in itself. This study has simply adopted established models into Maryland context to give an assessment of a set of impacts of a wide range of scenarios.

The allocation model used in the study can be improved in many ways – 1) using a feedback loop that re-computes the allocation indices after every unit of allocation, 2) using a finer resolution of the grid, 3) experimenting with non-linear allocation equation. Still, in many respects, the current model serves its purpose. Most importantly, it provides a way to create and visualize alternative scenarios and compute indicators within the research framework.

The limitations of the present study provide the strongest cue for future research. Although some limitations such as choice of unit of analysis and data aggregation, which are fundamental to the scenario planning process, are technically a trade-off rather than a limitation, other issues can be addressed more categorically, such as:

- Developing intermediate scenarios – not “what-if” but “how-to” models that represent incremental changes
- Assigning regulatory constraints to allocation models such as restricting new growth using zoning controls
- Forecasting additional variables such as demographic changes, infrastructure changes
- Improving existing models of indicator computations and creating better ones

Each of the above points raises their own set of research questions such as – 1) how temporally disaggregated the forecast data is; 2) which places not only have higher probability of developing but also a temporal model that changes probabilities over time; 3) what is a participatory mechanism that helps convey the more complex elements of such a scenario to stakeholders; and 4) to what degree the additional variables help in improving the quality of the indicators.

Much background information for answering those additional questions exist now, in part due to the work done in this research and the ongoing follow-up work in developing more sophisticated models investigating more specific analysis, such as, a statewide transportation model, a statewide water quality model, and energy cost model and a housing price model. Additional scenario development work that followed this research includes an ongoing focus group based scenario development process.

To summarize, despite many limitations, scenario planning using multiple models at a statewide scale provides a framework to test alternative development patterns. The scenarios may be developed in a participatory setting (Reality Check), as regulatory analyses (build-out), as analysis of current trends (COG), and as responses to certain basic heuristic questions such as “what if the local government retain land use control but enforce strict growth measure” (Urban Clusters) or in all of the above fashions and more (as done here) and then analyzed and compared. Such scenarios often demonstrate unintended, though extreme, effect of certain policies, for example, the PFA-based smart growth scenario. They also allow capturing a wide range of issues that cannot be addressed using a single (whether participatory or mathematical) method. The work reinforces the context sensitive nature of planning practice and also shows how optimization (rather than maximization) remains a key in planning when a large set of variables and potential measures of impacts are present.

###

Appendices

Appendix A. Explanation of some datasets used in this study

National Household Travel Survey - 2001

The National Household Travel Survey (NHTS) is the nation's inventory of daily and long-distance travel. The survey includes demographic characteristics of households, people, vehicles, and detailed information on daily and longer-distance travel for all purposes by all modes. NHTS survey data are collected from a sample of U.S. households and expanded to provide national estimates of trips and miles by travel mode, trip purpose, and a host of household attributes. The daily travel surveys were conducted in 1969, 1977, 1983, 1990 and 1995. This data series provides a rich source of detailed information on personal travel patterns in the U.S. Longer-distance travel was collected in 1977 and 1995. The 2001 NHTS collects both daily and longer-distance trips in one survey.

<http://nhts.ornl.gov/2001/index.shtml>

Land Use Land Cover - 2002

This dataset uses the Anderson Level 2 Classification System to display land use / land cover for each Maryland County and Baltimore City. Initially developed using high altitude aerial photography and satellite imagery. For 2002, land cover types were undated using 2002 aerial photography for Central Maryland. Urban land use categories were further refined using parcel information from the 2002 Edition of MDPropertyView.

Maryland Property View - 2004

ADS data from the State Department of Assessments and Taxation are a comprehensive data set that incorporates parcel ownership and address information, parcel valuation information and basic information about the land and structure(s) associated with a given parcel. These data form the basis

for the 2004 Database, which also includes selected Computer Assisted Mass Appraisal (CAMA) characteristics, text descriptions to make parcel code field data more readily accessible and logical True/False fields which identify parcels with certain characteristics, and can be used as a basis for performing various analyses based on parcel data.

Appendix B. Core Concepts, definitions and assumptions in scenario planning

While commonly used in scenario-building and planning processes, the terms projection, forecast and plan need clarification. The distinction among visioning, scenario writing and persuasive storytelling also need to be clear.

Projection, Forecast and Plan

Isserman(1984) explains that a projection is not a prediction, but merely the result of entering hypothetical assumptions into a mechanistic quantitative procedure. A forecast represents a best guess about the future, achieved by adding judgment about the most likely future rates of behavior and other assumptions. Finally, a plan requires evaluation of the forecasted future for its level of desirability and potential alterability. Plans can be constructed to avoid undesirable futures, to make desired forecasts come true, or to create new, more desirable futures. Isserman concludes that planners often treat projections either as the most probable future (truth) or as if they were desired (ideal).

Visioning, Scenario Writing, and Persuasive Storytelling

Visioning is a collaborative process whereby citizens' desires for their city or region are melded into an image of the locality in its ideal future state. Visions are a statement of the aspirations of a given group, which then acts as a benchmark for planning decisions and actions. If visioning is to be effective, the creative and collaborative aspects of the visioning process must be balanced by feasibility projections and grounding in action scenarios. In their absence, visions risk devolving into inconsequential and expensive wish lists for the future, as illustrated in Helling's evaluation of Atlanta's Vision 2020 Project. (Helling 1998, Myers and Kitsuse)

By contrast, scenario-writing and persuasive storytelling are processes that yield stories that explain the significance of events that have already or are likely to occur, and suggest how actions in the present will affect the future. (Myers and Kitsuse) Scenario-writing familiarizes planners and participants with the various possibilities of the future, which then can be planned for or against. Stories add unique richness to the plan, although they are often taken lightly. According to Throgmorton(1992), “Some view of the world can only be fully and adequately stated in ways that are more complex, more allusive, more attentive to particulars; in a word, through stories.”

Public participation, stakeholder led representative process

- A scenario planning process eventually compares scenarios obtained through various means. These are usually:
 - Past scenarios
 - Baseline (or present scenarios)
 - Public participation based – small-scale, locally oriented, simple variables
 - Stakeholder input based – large scale, regional, simple variables
 - Focus/expert group based – large scale, regional, more sophisticated than stakeholder input based
 - Experimental/heuristic – logic-based, follows basic laws of scenario building but nothing more
 - Spatially disaggregated forecasts done by someone else

Appendix C Developing the Grid-Prototype Method

What are the limitations of the previous models?

The models developed and used so far have a number of limitations in representation:

1. The grid used in the baseline and all successive scenarios developed on top of baseline conditions assume uniform development densities and patterns inside the 1 sq. mi. grid area. Development patterns tend to vary greatly over small distances, especially in metropolitan areas. For example, in terms of density alone (of population and employment), a suburban area with a small business district may be similar to a rural town center. Although all models tend to simplify by aggregation and assumption, it is important to understand the degree of distortion and address them in future scenarios.
2. The basic variables among scenarios are household and employment numbers. This limitation is partly linked to the above point that variations in development character and typologies are not captured. They also cannot predict the type of mix of uses, residential types (apartment, condominium, mixed use), housing type (single and multifamily units), or spatial aggregation or separation within the sq. mi. block. Also, in terms of other physical conditions such as infrastructure availability, very limited information and a lot of uncertainty exists. As a result, many indicators (for example, proximity to highways) as based on the current infrastructure conditions.
3. The new scenarios or the changes from the baseline conditions are represented as changes in households and employment numbers. Technically any change in these numbers will lead to a uniform change in the density of the grid. This fails to capture the many things:
 - a. According to the model, this leads to gradual changes in neighborhood character.

Though in practice, such changes mean that generally developed areas largely stay the

same over 25 years, or change marginally where as new developments occur in the greenfields.

- b. Unless neighborhood variables are taken into account, most of the indicators become functions of density.








The Grid-Prototype method developed and discussed here attempts to address these issues. A prototype is defined as a development type in a sq. mi. area. Typically they match the perceived predominant character of a place such as high-density residential area or a commercial corridor. Then a model was developed that identifies each grid in the state as one of the predefined prototypes (Table 3). The function related existing development types (such as high-density, mixed use area) with grid's variables such as population, employment, infrastructure and open space. This presented two immediate advantages – each grid could be characterized as a development prototype rather than variations in population and/or employment densities; and any change to create a future scenario could be a matter of changing prototypes. Thus, they are potentially easier to visualize and understand in a participatory setting and present unambiguous outputs (as opposed to Lego® blocks). Prototypes help demonstrate the changes needed to accommodate different degrees of growth (e.g. – a change to high density prototype can accommodate as much growth in a small area as multiple low density grid prototypes). Also, prototypes help compute preliminary quality of life indicators by basing them on existing standards of current prototypes.

The prototype based method is based on the premise that any existing development pattern in the 1 sq mile grid can be characterized using one of multiple pre-defined prototypes. Thus, all the existing grid cells on the map were characterized as one of the pre-defined prototypes and developing new

scenarios was a matter of changing many grids from one prototype to another⁴¹. Also, since each prototype stands for a certain number of employments and residences (and also – miles of roads, percentage impervious etc.), this method allows keeping note of the control total (or overall allocation).

The prototypes are based on a 2-digit nested model. As shown in the following figure, each prototype represents a certain density of employment and households.

Table. 1-digit and 2-digit Level Prototypes (1-digit level prototypes is be used for mapping as they are easier to visualize, the 2-digit level is for data analysis)

	VHDR More than 16 du/acre	HDR 4 to 16 du/acre	MDR 2 to 4 du/acre	LDR 1-2 du/acre	VLDR Less than 1 du/acre	
VHDE More than 100 jobs/acre	TYPE 1a	TYPE 1b	TYPE 1d	--	--	 • 1. Very High Density Urban Center (Baltimore, Bethesda)
HDE 50-100 jobs/acre	TYPE 1c	TYPE 2a	TYPE 2b	TYPE 5a	--	 • 2. High Density Urban Center (Silver Spring, Hagerstown)
MDE 10-50 jobs/acre	TYPE 1e	TYPE 2b	TYPE 3a, TYPE 6a	TYPE 5b	--	 • 3. Medium Density Urban Areas (Salisbury, Cumberland, Annapolis)
LDE 5-10 jobs/acre	--	TYPE 6b	TYPE 3b	TYPE 5c	TYPE 4a	 • 4. Residential Suburban (Inner and Outer ring – Germantown, Indian Spring)
VLDE Less than 5 jobs/acre	--	--	---	TYPE 4b	TYPE 7a (7% for non-residential, non-employment uses)	 • 5. Highway – Service Corridors (I-270, 95, US-301, Bowie)
						 • 6. Rural Centers (St. Mary's City, Funkstown, Cambridge)
						 • 7. Other Uses (developed-rural, undeveloped and un-developable land)

VHDE = Very High density employment, VHDR = Very high density residential, HDR = High density residential, etc.

The statewide grid level data for existing condition was analyzed for characterizing each grid as one of the pre-defined prototypes. Two issues arose when doing this – first, since the population and employment numbers represent gross densities within the grid, it was difficult to identify the concentrations of development *within* each grid. Second, many grids have higher service levels in terms of road, open space etc., which were considered important in characterizing the prototype. These issues were resolved by combining the above two conditions. Sensitivity tests were done to

⁴¹ It is important to note that existing grids will be made to fit prototypes based on a *range* of densities and other variables, where as future prototypes will be defined by absolute numbers. This reduces the complexity when changing from one prototype to another.

adjust gross densities to some measure of net densities that closely match the observed net densities within the grids.

This was done based on a measure of the level of services and open space available within each grid. Other GIS layers were used to code in dummy variables – PFA, Urbanized Area, Beltway, Within 1 mile of Transit and few continuous variables such as miles of major road lanes in the grid. Descriptive statistics were observed for additional layers – e.g. average numbers of road miles per grid. Next, the existing housing densities were somewhat limited in scope to capture all the urban form characteristics as they were averaged over 1 sq. mi. grid. Hence a function of existing densities was devised that adjusts existing densities to an index that gives a net measure of concentration of dispersion within the grid. This measure accounts for net increase in densities due to presence of high amount of open space, road miles and location with respect to urbanized area. This measure is shown below –

$$(\text{ProtoDenHou}) = (2X + \text{roadmiles}/0.66) + (\text{GrnDum}) (2X) + \text{UA_dum} * 3$$

X is the actual density of the grid, Roadmiles is the number of miles of existing highways within the grid, GrnDum is a dummy variable with a value of 1 if more than 50% of the grid is open space and UA is an urban area dummy. Since employment tends to be more concentrated than households, the net prototype densities for employment was computed by using a similar method but different coefficients that predicted steeper density slopes⁴².

⁴² An additional idea behind this is that once all the variables are encoded, the relationship between a prototype and the level of services (roads, schools etc.) provided it could be identified. Once the coefficients of such service variables are established for each prototype (and they are assumed to remain constant for that particular prototype), flipping prototypes in difference scenarios gives an estimate on new services required to accommodate the new growth.

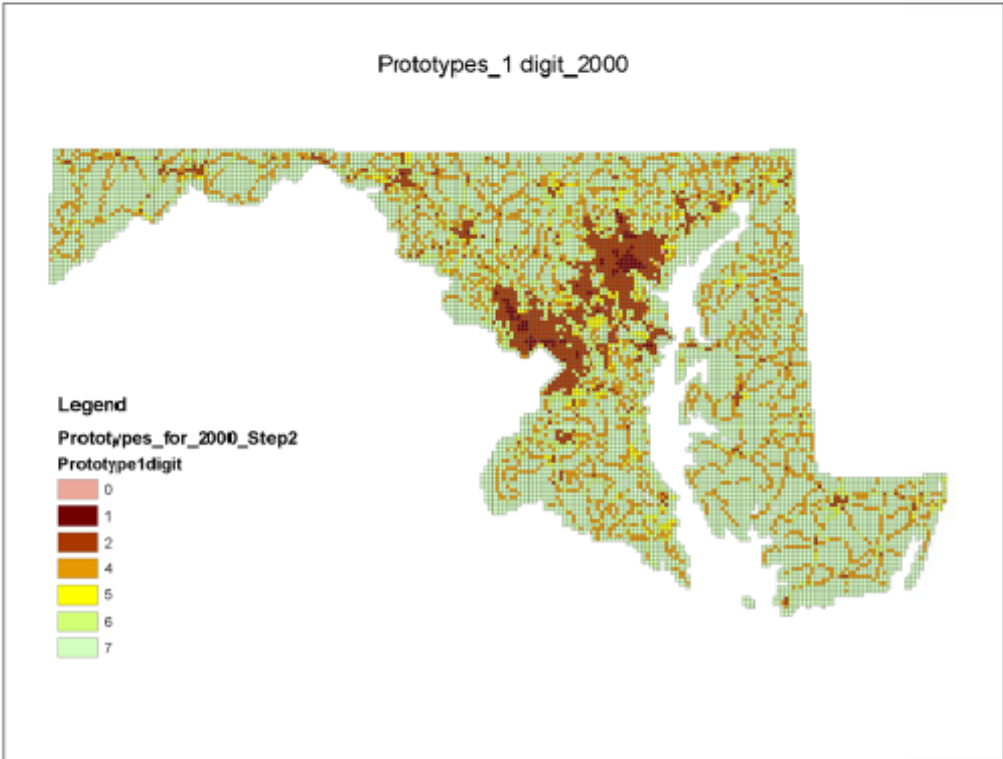
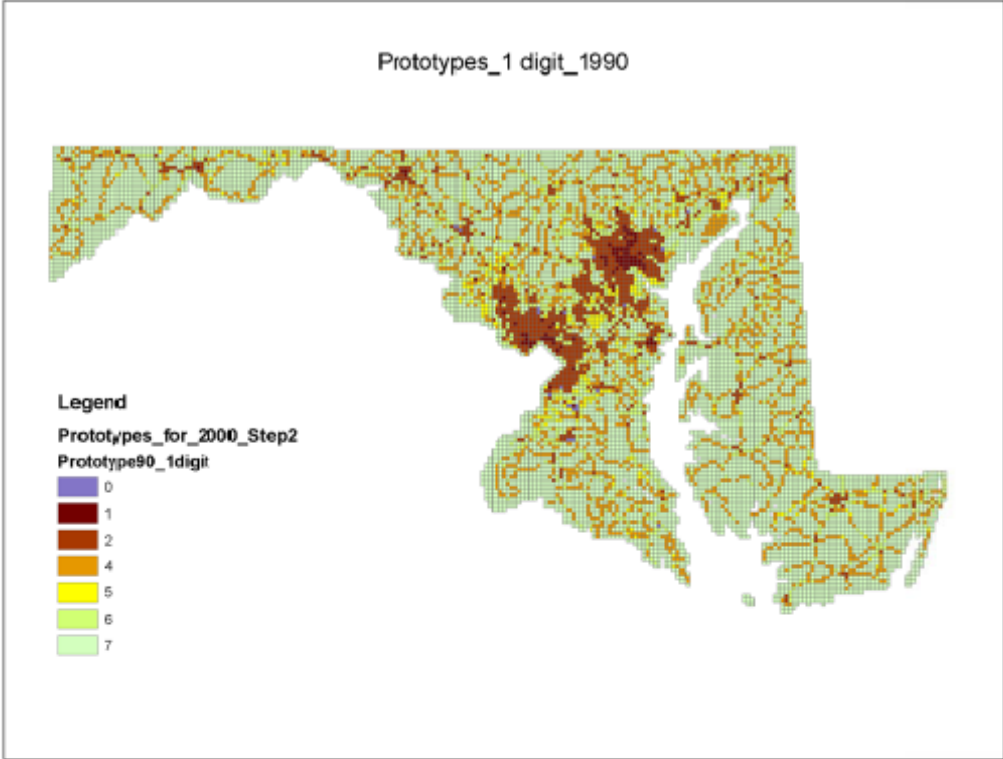


Figure 28 Statewide grid after 1-digit level prototype identification, 1990 and 2000

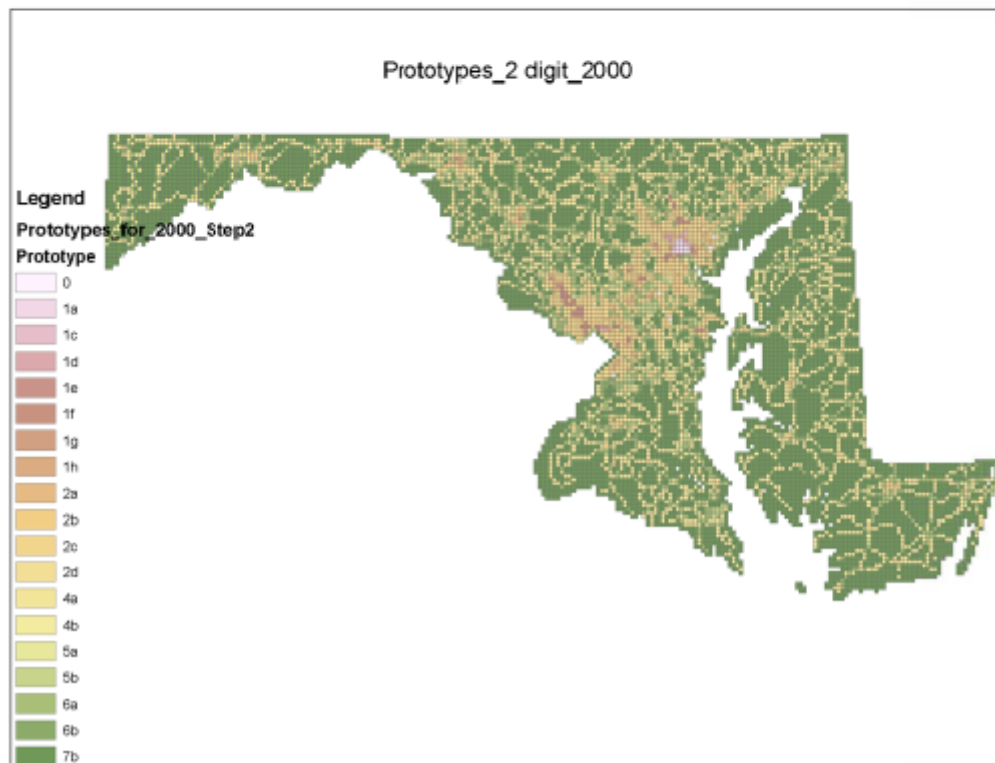
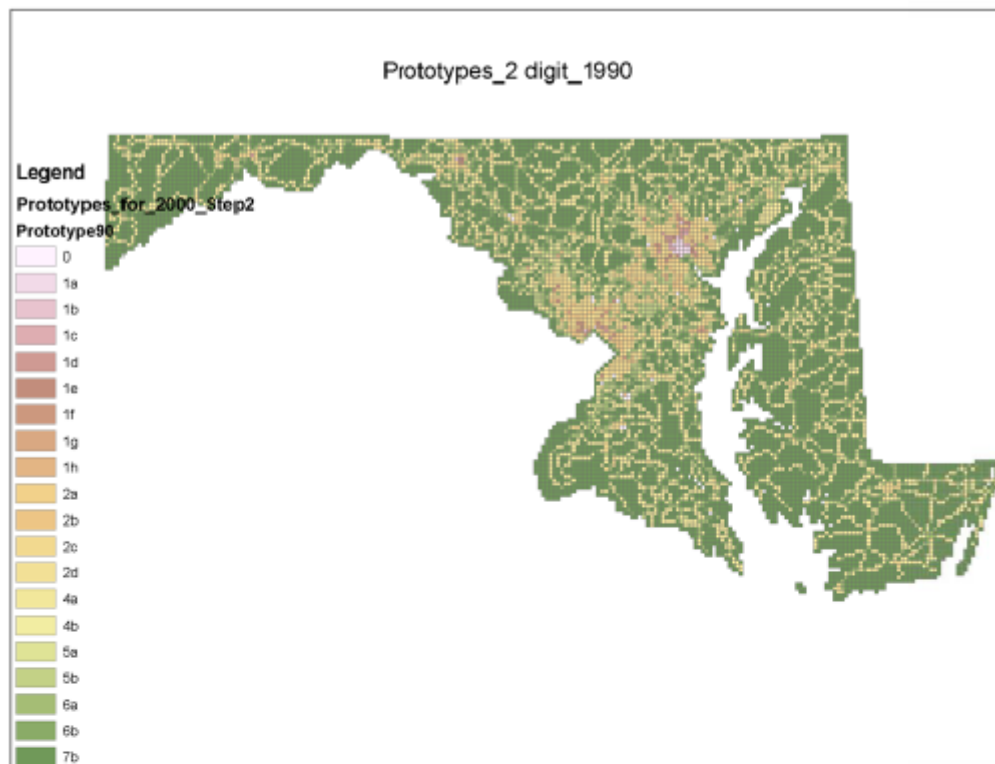


Figure 29 Statewide at 2 digit-level, 1990 and 2000

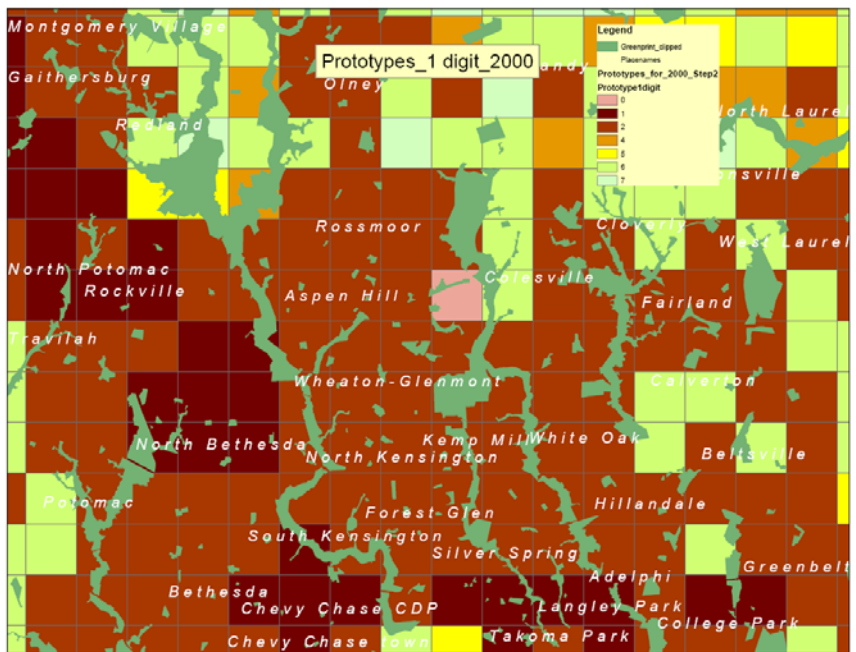
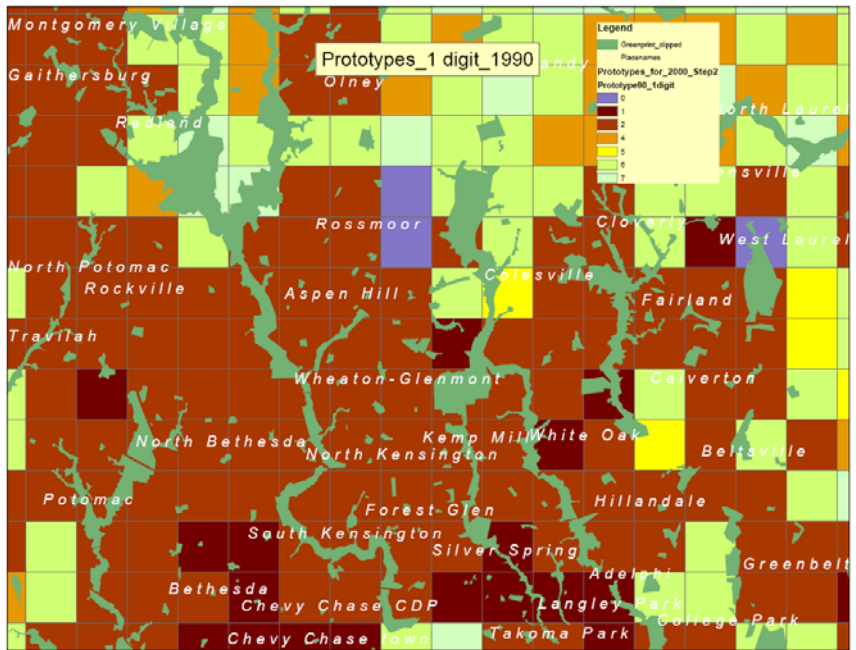


Figure 30 Zoomed in view of Washington vicinity after running 1-digit prototype identification code

Appendix D List of Data Layers

A detailed list of preliminary data used in the first phase of the research to create the base line scenario follows: [arranged as NAME (source, year, file type)]

1. Background data –

- a. Geographic boundaries (political, physical or census defined) such as census tracts, MSAs, block groups, urban areas, water, counties etc. (Census Bureau, yr. 2000, .shp)
- b. Population and households by Census Block Group (Census Bureau STF1, yr. 2000, .xls)
- c. Economic and social characteristics (median income, median age, percentage white etc.) by Census Block Group (Census Bureau STF1, yr. 2000, .xls)
- d. Physical characteristics (age of structure, multi-family/single family split etc.) by Census Block Group (Census Bureau STF3, yr. 2000, .xls)
- e. Number of jobs (by place of work) by census tracts and TAZs (Census Transportation Planning Package [CTPP] Part – 1 and 2 , yr. 2000, .xls and .shp)

2. Projections

- f. MPO cooperative forecasts through 2030⁴³ (MWCOG and BMC, yr. 2005, .xls)
- g. Household and employment forecasts by county (Maryland Department of Planning [MDP], yr. 2005, .xls)
- h. Activity centers projected by MPOs as future employment concentrations in the state (MWCOG, yr. 2004, .shp)

3. Physical features

⁴³ Available only for the 12 counties for which the MPOs currently do long-range transportation planning and cooperative forecasting

- i. Natural elements including rivers, lakes, reservoirs, streams, bay, oceans (ESRI, yr. 2000, .shp)
 - j. Landmarks including cities, places, schools etc. (ESRI, yr. 2000, .shp)
 - k. Existing infrastructure including roads, trains (stations), transit, sewer polygons (ESRI and local governments, yr. 2000 or later, .shp)
 - l. Public land including federal land, national park and other permanently protected areas (ESRI and local governments, yr. 2000 or later, .shp)
 - m. Aerial imagery (Maryland Property View, yr. 2005, .tif)
4. Modeled data
- n. Land use and land cover – raster data with information by land use categories (USGS w/ MDP edits, yr. 2002, .tif)
 - o. Impervious surfaces (Chesapeake Bay Program, yr. 2000, .tif)
 - p. Digital elevation models (USGS, yr. 2000, .tif)
5. Property and Policy layers
- q. Parcel point data for every property in the state with information on area, zoning, and if developed, building type, use, number of units etc. (Maryland Property View, yr. 2005, .shp)
 - r. Zoning types, detailed for some counties, generalized for others (local governments and MDP, yr. 2000-2005, .shp)
 - s. Policy layers – Greenprint (areas designated for future protection), Priority Funding Areas (MDP, yr. 2005, .shp)

A few of the background layers

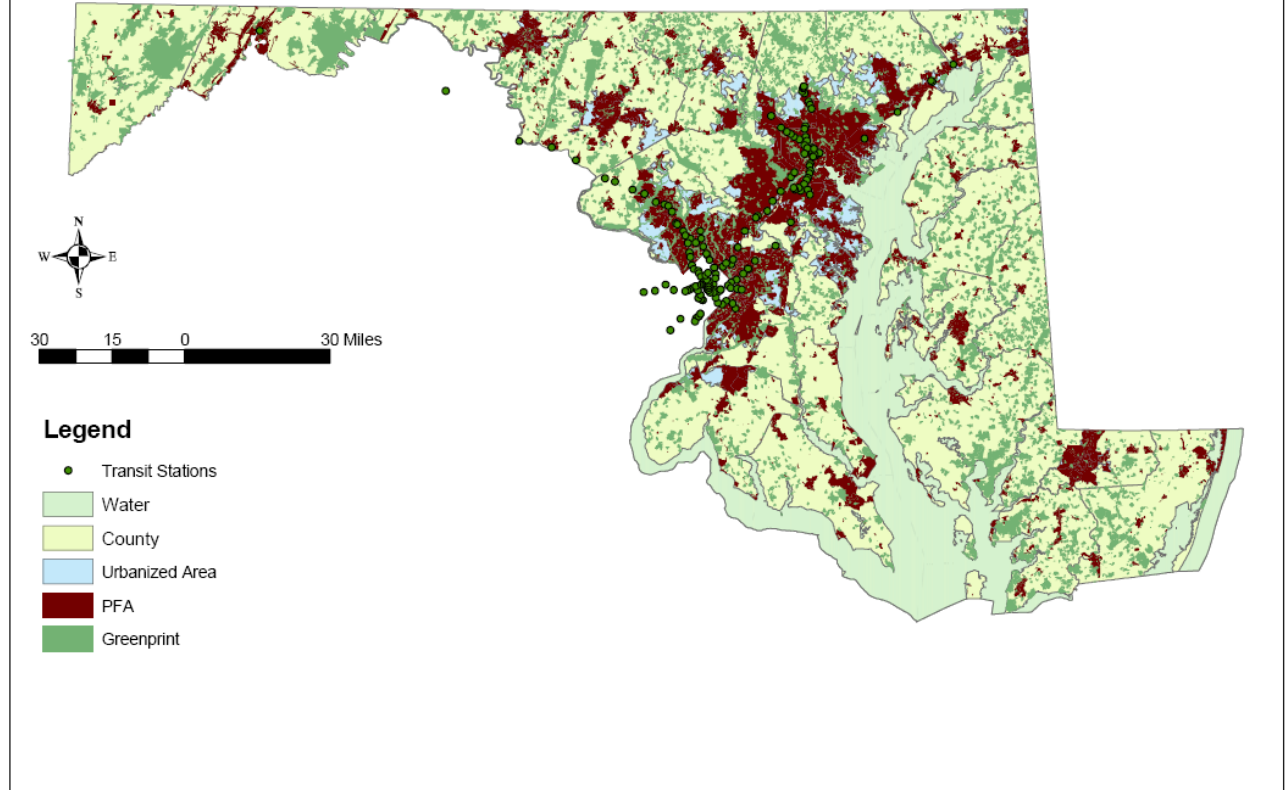


Figure 31 Background layers used in the analysis

Appendix E Identifying clusters and estimating VMT

This section explains the small routines that were used to identify clusters in GIS:

Mean Densities (per sq. mi.):

Scenarios	Household Mean Densities	Employment Mean Densities
Baseline (2000)	167	259
Build-out	287	435
RCP (2030)	248	402
Urban Cluster	248	402
Urban Diamond	248	402
PFA/Smart Growth	248	402

1. Identify baseline clusters –

Computing Coefficients:

$$2 \times 167 = 334$$

$$\frac{1}{2} \times 167 = 84$$

$$2 \times 259 = 518$$

$$\frac{1}{2} \times 259 = 130$$

Code:

Dim Xcluster as string

Dim Xemp as integer

Dim Xhou as integer

If [Xhou] > 334 AND [Xemp] > 518 Then

Xcluster = "U1"

ElseIf [Xhou] > 334 AND [Xemp] > 130 AND [Xemp] < 518 Then

Xcluster = "U2"

ElseIf [Xhou] > 334 AND [Xemp] < 130 Then

Xcluster = "U3"

ElseIf [Xhou] > 84 AND [Xhou] < 334 AND [Xemp] > 518 Then

Xcluster = "S1"

ElseIf [Xhou] > 84 AND [Xhou] < 334 AND [Xemp] > 130 AND [Xemp] < 518 Then

Xcluster = "S2"

ElseIf [Xhou] > 84 AND [Xhou] < 334 AND [Xemp] < 130 Then

Xcluster = "S3"

ElseIf [Xhou] < 84 AND [Xemp] > 518 Then

```

Xcluster = "R1"
ElseIf [Xhou] < 84 AND [Xemp] > 130 AND [Xemp] < 518 Then
Xcluster = "R2"
Else
Xcluster = "R3"
End If

```

2. Identify BO clusters

Computing coefficients:

$$2 \times 287 = 574$$

$$\frac{1}{2} \times 287 = 144$$

$$2 \times 435 = 870$$

$$\frac{1}{2} \times 435 = 218$$

Code:

```
Dim BOcluster as string
```

```
Dim BOemp as integer
```

```
Dim BOhou as integer
```

```

If [BOhou] > 574 AND [BOemp] > 870 Then
BOcluster = "U1"
ElseIf [BOhou] > 574 AND [BOemp] > 218 AND [BOemp] < 870 Then
BOcluster = "U2"
ElseIf [BOhou] > 574 AND [BOemp] < 218 Then
BOcluster = "U3"
ElseIf [BOhou] > 144 AND [BOhou] < 574 AND [BOemp] > 870 Then
BOcluster = "S1"
ElseIf [BOhou] > 144 AND [BOhou] < 574 AND [BOemp] > 218 AND [BOemp] < 870 Then
BOcluster = "S2"
ElseIf [BOhou] > 144 AND [BOhou] < 574 AND [BOemp] < 218 Then
BOcluster = "S3"
ElseIf [BOhou] < 144 AND [BOemp] > 870 Then
BOcluster = "R1"
ElseIf [BOhou] < 144 AND [BOemp] > 218 AND [BOemp] < 870 Then
BOcluster = "R2"
Else
BOcluster = "R3"
End If

```

3. Identify RCP cluster

Computing coefficients:

$$2 \times 248 = 496$$

$$\frac{1}{2} \times 248 = 124$$

$$2 \times 402 = 804$$

$$\frac{1}{2} \times 402 = 201$$

Code

Dim RCPcluster as string

Dim RCP_emp as integer

Dim RCP_hou as integer

If [RCP_hou] > 496 AND [RCP_emp] > 804 Then

RCPcluster = "U1"

ElseIf [RCP_hou] > 496 AND [RCP_emp] > 201 AND [RCP_emp] < 804 Then

RCPcluster = "U2"

ElseIf [RCP_hou] > 496 AND [RCP_emp] < 201 Then

RCPcluster = "U3"

ElseIf [RCP_hou] > 124 AND [RCP_hou] < 496 AND [RCP_emp] > 804 Then

RCPcluster = "S1"

ElseIf [RCP_hou] > 124 AND [RCP_hou] < 496 AND [RCP_emp] > 201 AND [RCP_emp] < 804

Then

RCPcluster = "S2"

ElseIf [RCP_hou] > 124 AND [RCP_hou] < 496 AND [RCP_emp] < 201 Then

RCPcluster = "S3"

ElseIf [RCP_hou] < 124 AND [RCP_emp] > 804 Then

RCPcluster = "R1"

ElseIf [RCP_hou] < 124 AND [RCP_emp] > 201 AND [RCP_emp] < 804 Then

RCPcluster = "R2"

Else

RCPcluster = "R3"

End If

4. Identify Urban Cluster cluster

Computing coefficients:

$$2 \times 248 = 496$$

$$\frac{1}{2} \times 248 = 124$$

$$2 \times 402 = 804$$

$$\frac{1}{2} \times 402 = 201$$

Code

Dim CL_cluster as string

Dim CL_emp as integer

Dim CL_hou as integer

If [CL_hou] > 496 AND [CL_emp] > 804 Then

CL_cluster = "U1"

ElseIf [CL_hou] > 496 AND [CL_emp] > 201 AND [CL_emp] < 804 Then

CL_cluster = "U2"

ElseIf [CL_hou] > 496 AND [CL_emp] < 201 Then

CL_cluster = "U3"


```

ElseIf [CL_hou] > 124 AND [CL_hou] < 496 AND [CL_emp] > 804 Then
CL_cluster = "S1"
ElseIf [CL_hou] > 124 AND [CL_hou] < 496 AND [CL_emp] > 201 AND [CL_emp] < 804 Then
CL_cluster = "S2"
ElseIf [CL_hou] > 124 AND [CL_hou] < 496 AND [CL_emp] < 201 Then
CL_cluster = "S3"
ElseIf [CL_hou] < 124 AND [CL_emp] > 804 Then
CL_cluster = "R1"
ElseIf [CL_hou] < 124 AND [CL_emp] > 201 AND [CL_emp] < 804 Then
CL_cluster = "R2"
Else
CL_cluster = "R3"
End If

```

5. Identify Urban Diamond cluster

Computing coefficients:

$$2 \times 248 = 496$$

$$\frac{1}{2} \times 248 = 124$$

$$2 \times 402 = 804$$

$$\frac{1}{2} \times 402 = 201$$

Code

```
Dim DI_cluster as string
```

```
Dim DI_emp as integer
```

```
Dim DI_hou as integer
```

```

If [DI_hou] > 496 AND [DI_emp] > 804 Then
DI_cluster = "U1"
ElseIf [DI_hou] > 496 AND [DI_emp] > 201 AND [DI_emp] < 804 Then
DI_cluster = "U2"
ElseIf [DI_hou] > 496 AND [DI_emp] < 201 Then
DI_cluster = "U3"
ElseIf [DI_hou] > 124 AND [DI_hou] < 496 AND [DI_emp] > 804 Then
DI_cluster = "S1"
ElseIf [DI_hou] > 124 AND [DI_hou] < 496 AND [DI_emp] > 201 AND [DI_emp] < 804 Then
DI_cluster = "S2"
ElseIf [DI_hou] > 124 AND [DI_hou] < 496 AND [DI_emp] < 201 Then
DI_cluster = "S3"
ElseIf [DI_hou] < 124 AND [DI_emp] > 804 Then
DI_cluster = "R1"
ElseIf [DI_hou] < 124 AND [DI_emp] > 201 AND [DI_emp] < 804 Then
DI_cluster = "R2"
Else
DI_cluster = "R3"
End If

```

6. Identify Smart Growth cluster

Computing coefficients:

$$2 \times 248 = 496$$

$$\frac{1}{2} \times 248 = 124$$

$$2 \times 402 = 804$$

$$\frac{1}{2} \times 402 = 201$$

Code

SGm SG_cluster as string

SGm SG_emp as integer

SGm SG_hou as integer

If [SG_hou] > 496 AND [SG_emp] > 804 Then

SG_cluster = "U1"

ElseIf [SG_hou] > 496 AND [SG_emp] > 201 AND [SG_emp] < 804 Then

SG_cluster = "U2"

ElseIf [SG_hou] > 496 AND [SG_emp] < 201 Then

SG_cluster = "U3"

ElseIf [SG_hou] > 124 AND [SG_hou] < 496 AND [SG_emp] > 804 Then

SG_cluster = "S1"

ElseIf [SG_hou] > 124 AND [SG_hou] < 496 AND [SG_emp] > 201 AND [SG_emp] < 804 Then

SG_cluster = "S2"

ElseIf [SG_hou] > 124 AND [SG_hou] < 496 AND [SG_emp] < 201 Then

SG_cluster = "S3"

ElseIf [SG_hou] < 124 AND [SG_emp] > 804 Then

SG_cluster = "R1"

ElseIf [SG_hou] < 124 AND [SG_emp] > 201 AND [SG_emp] < 804 Then

SG_cluster = "R2"

Else

SG_cluster = "R3"

End If

7. Computing VMT – using multiplies (one program fits all – *?not really*)

Table 12 Identifying Clusters

Cluster	Housing Density	Employment Density	Multiplication factor (VMT per capita)
U1	HH Density > $2 \overline{H}_i$	Emp. Density > $2 \overline{E}_i$	44
U2	HH Density > $2 \overline{H}_i$	$2 \overline{E}_i > \text{Emp. Density} > \frac{1}{2} \overline{E}_i$	37
U3	HH Density > $2 \overline{H}_i$	$\frac{1}{2} \overline{E}_i > \text{Emp. Density}$	20
S1	$2 \overline{H}_i > \text{HH Density} > \frac{1}{2} \overline{H}_i$	Emp. Density > $2 \overline{E}_i$	65

S2	$2 \overline{H}_i > \text{HH Density} > \frac{1}{2} \overline{H}_i$	$2 \overline{E}_i > \text{Emp. Density} > \frac{1}{2} \overline{E}_i$	52
S3	$2 \overline{H}_i > \text{HH Density} > \frac{1}{2} \overline{H}_i$	$\frac{1}{2} \overline{E}_i > \text{Emp. Density}$	41
R1	$\frac{1}{2} \overline{H}_i > \text{HH Density}$	$\text{Emp. Density} > 2 \overline{E}_i$	78
R2	$\frac{1}{2} \overline{H}_i > \text{HH Density}$	$2 \overline{E}_i > \text{Emp. Density} > \frac{1}{2} \overline{E}_i$	68
R3	$\frac{1}{2} \overline{H}_i > \text{HH Density}$	$\frac{1}{2} \overline{E}_i > \text{Emp. Density}$	61

\overline{H}_i = mean household density in *i*th scenario.

\overline{E}_i = mean employment density in *i*th scenario.

Allocated clusters and per household VMT's were added as attributes to the grid at the end of this step

For example for baseline conditions:

Households in each grid = Xhou

After characterizing clusters, per household VMT in each grid = XVMT

Other scenarios: BOVMT (buildout), RCPVMT, CLVMT, DIVMT and SGVMT

Code:

Dim SGVMT as integer

Dim SG_CLUSTER as string

If [SG_CLUSTER] = "U1" Then

SGVMT = 44

ElseIf [SG_CLUSTER] = "U2" Then

SGVMT = 37

ElseIf [SG_CLUSTER] = "U3" Then

SGVMT = 20

ElseIf [SG_CLUSTER] = "S1" Then

SGVMT = 65

ElseIf [SG_CLUSTER] = "S2" Then

SGVMT = 52

ElseIf [SG_CLUSTER] = "S3" Then

SGVMT = 41

ElseIf [SG_CLUSTER] = "R1" Then

SGVMT = 78

ElseIf [SG_CLUSTER] = "R2" Then

SGVMT = 68

Else

SGVMT = 61

End If

[BOVMT or RCPVMT for other scenarios with relevant additional variables]

Allocated clusters and per household VMT's were added as attributes to the grid at the end of this step

For example for baseline conditions:

Households in each grid = Xhou

After characterizing clusters, per household VMT in each grid = XVMT

Other scenarios: BOVMT (buildout), RCPVMT, CLVMT, DIVMT and SGVMT

8. computing aggregate VMT for each grid

Total VMT for each scenario = $\sum_i HH_j * VMT_j$

XTOTVMT = XHOU*XVMT

Appendix F OLS results from estimating weights and effects table

[DataSet1 - CHANGE IN HOUSEHOLDS]

Variables Entered/Removed(b)

Model	Variables Entered	Variables Removed	Method
1	Proportion_MF, roadmiles, beltway_du, pfa_dum, Xemp, UA_dum, Xhou(a)	.	Enter

a All requested variables entered.

b Dependent Variable: change in hh

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.744(a)	.553	.553	90.253

a Predictors: (Constant), Proportion_MF, roadmiles, beltway_du, pfa_dum, Xemp, UA_dum, Xhou

ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	112457610.556	7	16065372.937	1972.296	.000(a)
	Residual	90765519.861	11143	8145.519		
	Total	203223130.416	11150			

a Predictors: (Constant), Proportion_MF, roadmiles, beltway_du, pfa_dum, Xemp, UA_dum, Xhou

b Dependent Variable: change in hh

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients		Sig.
		B	Std. Error	Beta	t	
1	(Constant)	-7.223	1.455		-4.965	.000
	beltway_du	-44.611	5.187	-.070	-8.600	.000
	UA_dum	24.938	2.804	.074	8.895	.000
	pfa_dum	10.468	2.227	.037	4.700	.000
	Xemp	.018	.001	.141	17.111	.000
	Xhou	.175	.003	.556	53.751	.000
	roadmiles	2.383	1.086	.017	2.195	.028

Proportion_MF	79.985	5.676	.107	14.091	.000
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a Dependent Variable: change in hh

[DataSet2 - CHANGE IN EMPLOYMENT]

Variables Entered/Removed(b)

Model	Variables Entered	Variables Removed	Method
1	Proportion_MF, roadmiles, beltway_du, pfa_dum, Xemp, UA_dum, Xhou(a)	.	Enter

a All requested variables entered.

b Dependent Variable: change in emp

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.659(a)	.435	.435	562.779

a Predictors: (Constant), Proportion_MF, roadmiles, beltway_du, pfa_dum, Xemp, UA_dum, Xhou

ANOVA(b)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	271608856 8.840	7	388012652.69 1	1225.096	.000(a)
	Residual	352921441 2.097	11143	316720.310		
	Total	624530298 0.937	11150			

a Predictors: (Constant), Proportion_MF, roadmiles, beltway_du, pfa_dum, Xemp, UA_dum, Xhou

b Dependent Variable: change in emp

Coefficients(a)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	5.639	9.071		.622	.534
	beltway_du	-55.047	32.344	-.016	-1.702	.089
	UA_dum	178.543	17.482	.096	10.213	.000
	pfa_dum	88.493	13.887	.056	6.372	.000
	Xemp	.424	.006	.613	66.192	.000

Xhou	-.029	.020	-.017	-1.440	.150
roadmiles	-12.578	6.771	-.017	-1.858	.063
Proportion_MF	93.541	35.395	.023	2.643	.008

a Dependent Variable: change in emp

Appendix G Growth related trends in Maryland

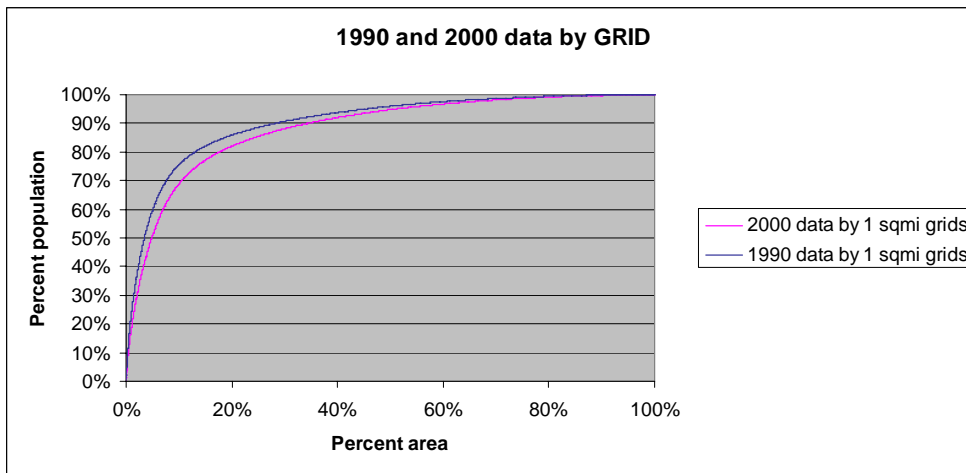


Figure 32 Representation of concentration showing percentage of aggregate population by percentage of aggregate area (flattening slope means dispersing population gradient)

Percentage of Residential Parcels outside the PFA

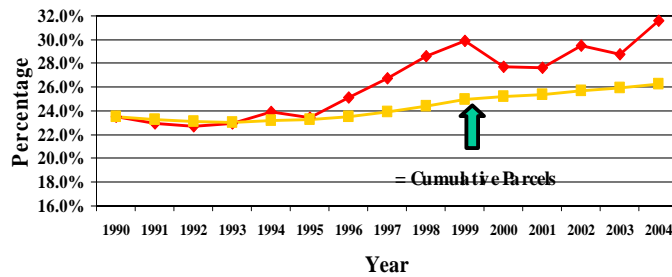


Figure 33 Residential Parcels Outside of PFAs as a percent of Total Residential Parcels in Maryland (Source: Maryland Department of Planning)

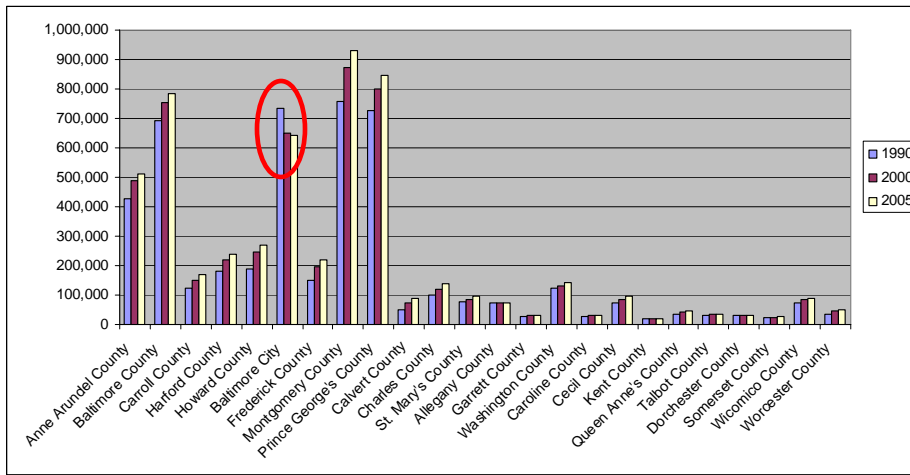


Figure 34 Population in Maryland counties 1990, 2000 and 2005 [estimated]

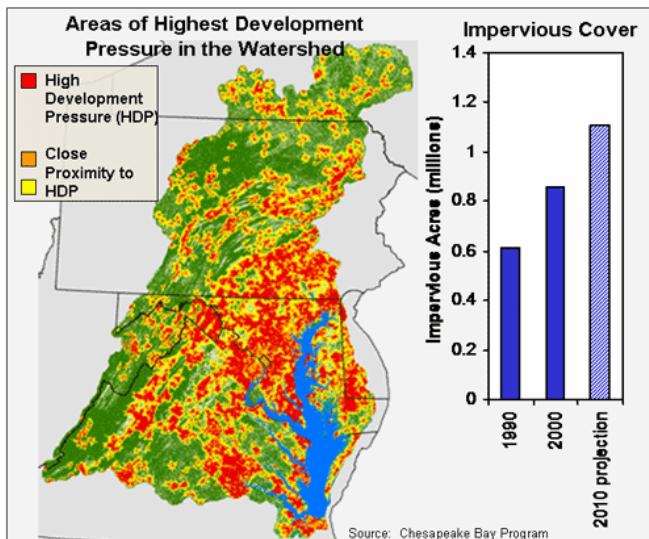


Figure 35 Chesapeake Bay Watershed showing the highest development pressure areas in Maryland (Source: Chesapeake Bay Program – Report on Bay Indicators)

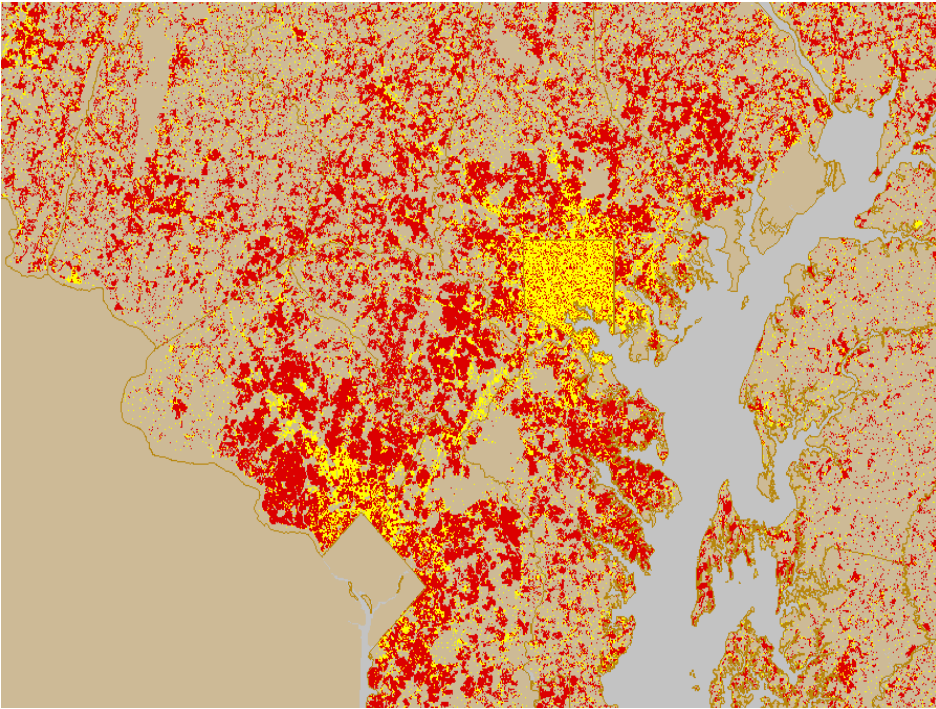


Figure 36 Growth in development footprint 1900 to 1997 (Source: MDP, USGS)

Appendix H Lane miles computation

Objective - Compare road impact of scenarios

Key Assumption

- There is a close correlation between [population density] and [road density]. Therefore by studying today's relationship between population density (persons per sq. mi.) and road density (lane per sq. mi.), we can forecast how much more road construction (in lane-miles) will be required by each of the scenarios.

Regression Formula

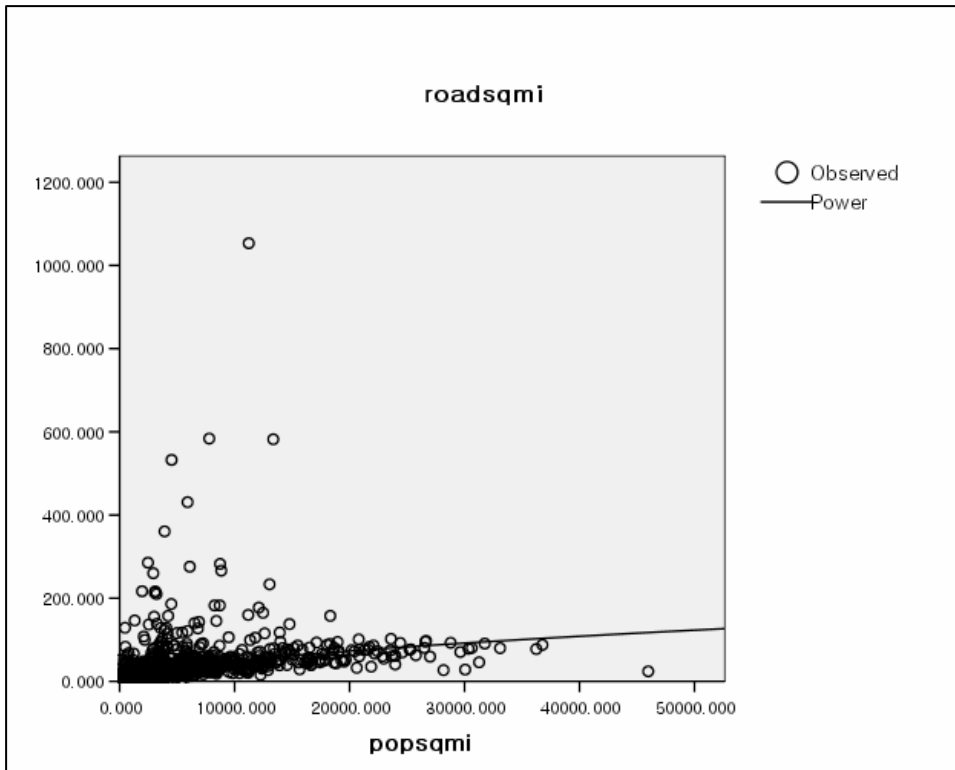
$$\text{RoadDens}=0.259*\text{PopDens}^{(0.569)}$$

ROAD CONSTRUCTION IMPACT

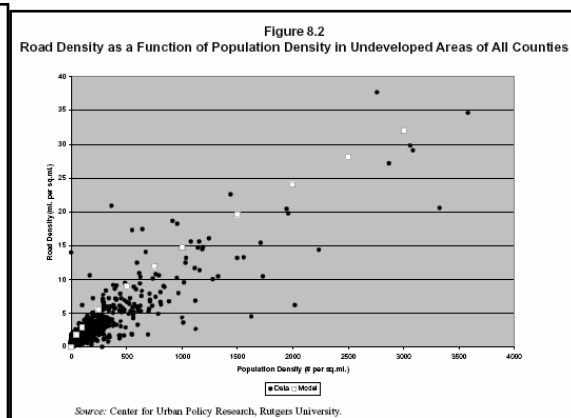
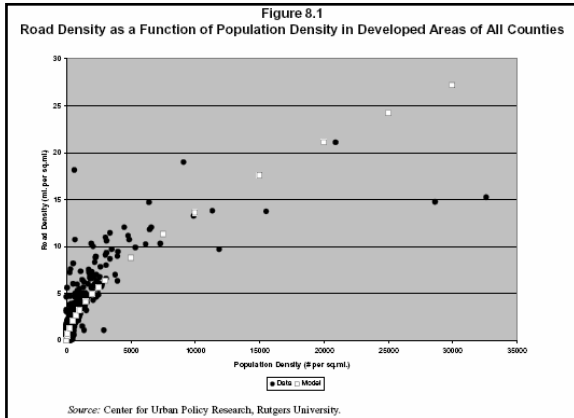
People need roads to make necessary daily and non-daily trips. While it is impossible to estimate 'where' new roads will be built due to population and employment increase, it is possible to estimate 'how much' new roads will be built, from past trends and data. This stems from the fact that road density (road length per square mile) is correlated to population density (number of people per square mile), which enables us to construct a regression model and thus, estimate future road length (in lane-miles) that will be constructed. From this future road length, road cost can be calculated assuming certain construction cost per mile.

From Census TIGER road data, different road categories were assumed to be either 4-lane roads or 2-lane roads. Since only paved roads were considered, bike trails and unpaved road categories were deleted.

An equation that depicts the relationship between road density and population density is derived from running regression using power function form. The scatterplot displayed below show the correlation relationship in Maryland. As expected, as population density increases, so does road density. But it does not linearly increase – the increase in road density slows down, until it is nearly flat along the horizontal axis. This is consistent with our common sense, that road length increases as more developments take place but not indefinitely. This is also consistent with Rutgers study, which examined this relationship in New Jersey.



$$\text{RoadDens} = 0.259 * \text{PopDens}^{(0.569)}$$



(Rutgers Study)

At buildout, it is assumed that all development capacity in the State of Maryland is depleted. This implies that currently undeveloped, rural areas will need significant amount of new road constructions.

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