Economic Scenarios and Development Patterns in the Baltimore-Washington Region[1]

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Abstract

This paper illustrates the use of scenarios in land use, environmental and transportation planning in and around the State of Maryland. Different assumptions about futures result in different patterns of growth with differential impacts on particular sectors of the economy. Such different patterns require formulation of contingent plans as well as robust plans. In this paper, we illustrate the quantitative modelling methodology of loosely linked economic demographic, transportation and other impact assessment models in constructing two scenarios; one of which represented the best possible guess about the continuation of the future and other involving rapid changes to energy prices and Federal spending. We illustrate the spatial development outcomes and the transportation and environmental plans that are necessary to deal with these different outcomes. Further, we illustrate that different planned actions have different efficacies in different futures and thus multiple futures should be carefully considered. Finally, we illustrate the notions of contingent plans and robust plans.

[1] This paper describes work done jointly with Jeffery Werling and Douglas Meade of INFORUM and Thomas Hammer. The transportation model development is joint work with team at Parsons Brinkerhoff led by Rick Donnelly and Patrick Costinett. Nutrient loading model is an application of GISHydro work by Glenn Moglen at University of Virginia. Residential Energy Consumption Model is primarily developed in conjunction with Mattias Ruth & Andy Blohm. Various land use models are developed jointly with Brian Deal, Arnab Chakraborty at University of Illinois, Peter Claggett at USGS and Charles Towe. Xin Ye provided invaluable support throughout the project. The research assistance of Shuo Huang, Gregory Vernon is gratefully acknowledged.

Introduction

Plans should be contingent on futures, or at least should be responsive to the range of futures over which the plan maker has only partial control over. This paper illustrates that different assumptions about likely futures will point to different sets of decisions that need to be considered. Furthermore, the challenge of co-ordination between various governments and its agencies becomes more complicated in consideration of different futures. Decisions that span multiple jurisdictions, such as counties, states as well as functionally disparate agencies such as transportation, environment

To enhance the planning in and around the State of Maryland, the National Center for Smart Growth Research and Education with various partners have created various population and employment scenarios that are outputs of changes to large scale macro economic variables and test the efficacy of various proposed plans under these scenarios. This paper describes an on-going work called the Maryland Scenario Project and presents some preliminary results.

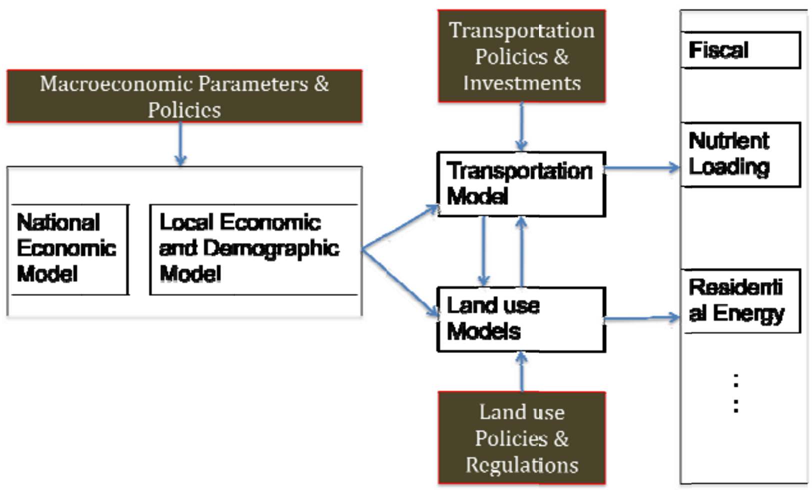

Figure 1 Loosely coupled modelling framework for scenario planning in Maryland

The Maryland Scenario Project is an exercise led by the National Center for Smart Growth (NCSG) designed to explore alternative futures for the state of Maryland and to identify what policies should be adopted today to maximize the likelihood of more desirable future outcomes. The project began with a public participation exercise called Reality Check Plus that engaged over 850 Maryland residents in four corners of the state. In these exercises participants were asked to identify principles that should guide long-term decision making and to indicate by placing legos on maps where future growth should take place. Shortly after these exercises, a Scenario Advisory Group (SAG) was formed to consider in more depth the critical driving forces and public policies that will shape the future economic, social, and environmental characteristics of the state. With the information obtained from the SAG, the NCSG is now developing formal scenarios that can be evaluated using quantitative evaluation methods.

For the Maryland Scenario Project to help shape public policy and inform the State Development Plan, which is currently under works, the scenarios constructed and subsequently evaluated must be plausible, internally consistent, sensitive to key uncertain parameters or events, and capture the effects of policy decisions. For this reason, the NCSG is now developing economic, transportation, land use, and environmental models (seeFigure 1). This modelling infrastructure will be used not only to develop distinct alternative futures, but also for computing quantitative indicators of those futures and identifying policy decisions that increase the likelihood of more desirable outcomes and yet preparing for those futures that are still possible.

Set up of the Modelling Framework for Scenario Analysis

In the next few subsections, we describe the economic, demographic, transportation and land use models at a generic level to give context to the scenario construction and evaluation of investment and policy options.

Economic and Demographic Models

As described in Figure 1, the modelling framework drives its inputs from exogenously specified parameters, such as interest rates, energy prices, exchange rates which are largely outside the realm of control by the state and local planners. The national economy is modelled using the INFORUMLong term Inter-Industry Forecasting Tool (LIFT) which has an I/O model at its core and builds the macroeconomic forecasts from the bottom up by using 97 industry sectors[2] and 3 government sectors.

Despite its industry basis, LIFT is a full macroeconomic model, with more than 800 macroeconomic variables determined either by econometric equation, exogenously or by identity. The econometric equations tend to be those where behaviour is more naturally modelled in the aggregate, such as the personal savings rate, or the 3-month Treasury bill rate. Hundreds of identities are used to collect detailed results into aggregates, and then to form other aggregate variables by equation or identity. For example, total corporate profits are simply the total of corporate profits by industry. An equation for the effective corporate tax rate is used to determine total profits taxes, which is a source of revenue in the Federal

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[2] Enumeration of these sectors are available at http://inforumweb.umd.edu/papers/inforum/products/LiftSecCategories.pdf

government account. Equations for contribution rates for social insurance programs and equations for transfer payments out of these programs can be used to study the future solvency of the trust funds.

The Inforum State Employment Modelling System (STEMS) provides projections of employment, output and earnings for 65 industries, for 50 states and the District of Columbia. STEMS also calculates regional aggregates for the 8 BEA regions. STEMS uses exogenous variables at the national level from the Inforum LIFT model of the U.S. STEMS relates the employment by industry in each state partly to national employment of that industry, and partly to the level of personal income in that state. Industries that are assumed to mainly serve national markets are called “basic” industries, and industries that mainly serve local markets are “non-basic” industries. The degree to which an industry is basic (national in scope) is defined by a coefficient between 0 and 1. In this version of the model, the co-efficient is fixed.

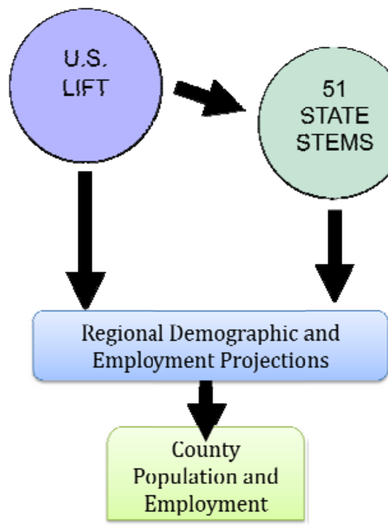


Figure 2 Using National Economic Forecasts for State & Local Demogrpahic and Economic Futures

Once employment has been calculated, real output is derived using national ratios of output to employment by industry. STEMS also calculates earnings by industry based on employment. The STEMS historical data includes earnings and employment for each industry by state. STEMS moves the state earnings to employment ratios forward in time by the movement of the ratio of (proprietors' income plus labour compensation) to employment in the forecast of the national model.

The next step in the calculations is to calculate total personal income in each state. Personal income is formed as a function of the following six components: Total income, dividend and rental income, social insurance, residence adjustment and personal income. The last of these, personal income has substantial influence on the employment and output of the given state in the industry categories whose basic coefficient is less than 1 (i.e. industries whose market is at least partly local). STEMS iterates until convergence each year, and personal income is the variable on which convergence is tested. The model is considered solved in any given year if the difference of personal income in every state for this iteration minus the value in the previous iteration must be very small.

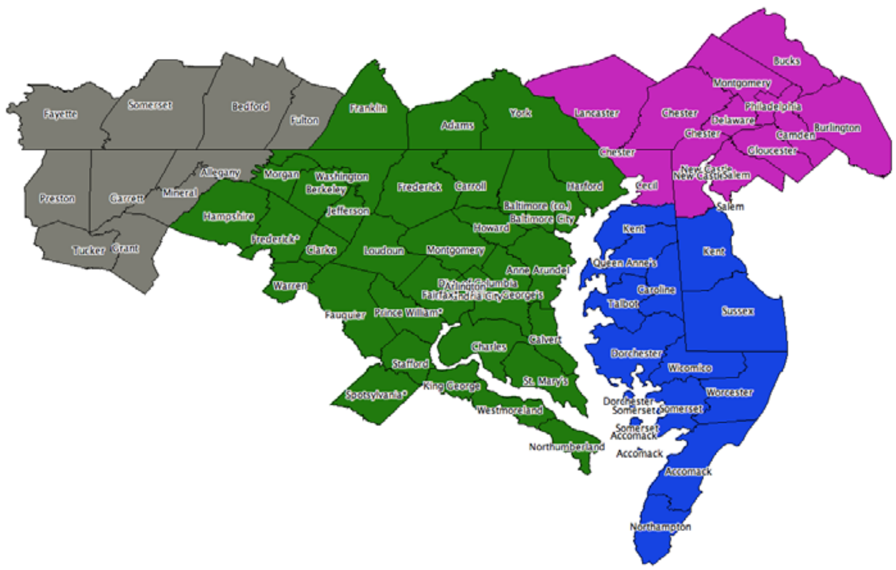


Figure 3 Spatial Scope & Regions of County Level Economic and Demographic Forecasts

However, planning within the state of Maryland does not stop at its borders, especially when it is co-dependent on the futures on regions like Northern Virginia and District of Columbia. Thus to study the impacts of decisions that cut across jurisdictions the area delineated for study comprises of 69 counties that includes all of Maryland, Delaware and District of Columbia and parts of New Jersey, Pennsylvania, Virginia and West Virginia. Political boundaries are imprecise predictors of labour markets and economic regions. As such proceeding from State to County level forecasts are not very viable. To account for these, are distinct regions which comprises of the Washington Baltimore region, the Peninsula (Eastern Shore & parts of Delaware and Virginia), Western Maryland and the Phildalephia region. These are shown in different colours in Figure 3. Evidence and justification for these regions are provided in Table 1. Whereas the United States grew at an annual rate of 1.2 percent between 1990 and 2005, individual region's growth rates ranged from declines of 0.25 to 1.7 percent.

	Actual			Forecast
	1990-95	1995-2005	1990-2005	2005-40
United States	1.14%	1.25%	1.21%	0.73%
Wash.-Balt. Region	0.09%	1.64%	1.12%	0.90%
Western Region	0.83%	0.67%	0.72%	0.37%
Philadelphia Region	-0.25%	1.09%	0.64%	0.37%
Peninsula Region	1.18%	1.70%	1.52%	1.05%

Table 1 Annual Employment Growth Rates for Different Regions in the Study Area

The regional economic scenarios are then derived as proportions of state forecasts based on the current proportions of the state level forecasts in each sector. These form the basis for deriving the demographic scenarios for the regions and then allocating the demographic variables to the counties, along with the economic variables, using a system of equations.

Figure 4 describes the allocation model in more detail. To simulate urban dynamics realistically, the allocation model incorporated the following features: 1) express interactions among all combinations of economic sectors and household groups; 2) capture the influence on each county on nearby areas; and 3) register the growth-retarding effects of reductions in land availability for development. Thus, explanatory variables for each county contained measure of allthe above where as thetarget variables are employment in 20 NAICS based industry groups and households in the region specific income quintiles. The independent variables are past changes in the predicted variable, current levels of other variables and a host of proximity and land availability measures. These equations have been calibrated in using a sample of 348 counties across the nation that represented roughly one-third of the nation's population and employment and are estimated for the period 1985-1995.

Furthermore, 2/3 of households growth is allocated using a variable expressing a county's access to employment throughout the region, multiplied by the county's value of the land availability index. For the lack of better term, this is called employment access variable given by equation

$$EA_i = \sum_{c \in R} \frac{(E^c * L^c)}{(D_{ic} + g + f)^r}$$

Where i and c are counties in region R, D is the distance between them, L is the land availability index and g is a measure of internal travel distance within the county which depends on the size of the county and f is a constant that is assumed. The parameter r is the gravity exponent that determines the decay. It is computed using total (i.e., all-industry) employment in the initial year of a given forecast interval, using the same type of gravity computation that the model deploys in obtaining access measures.

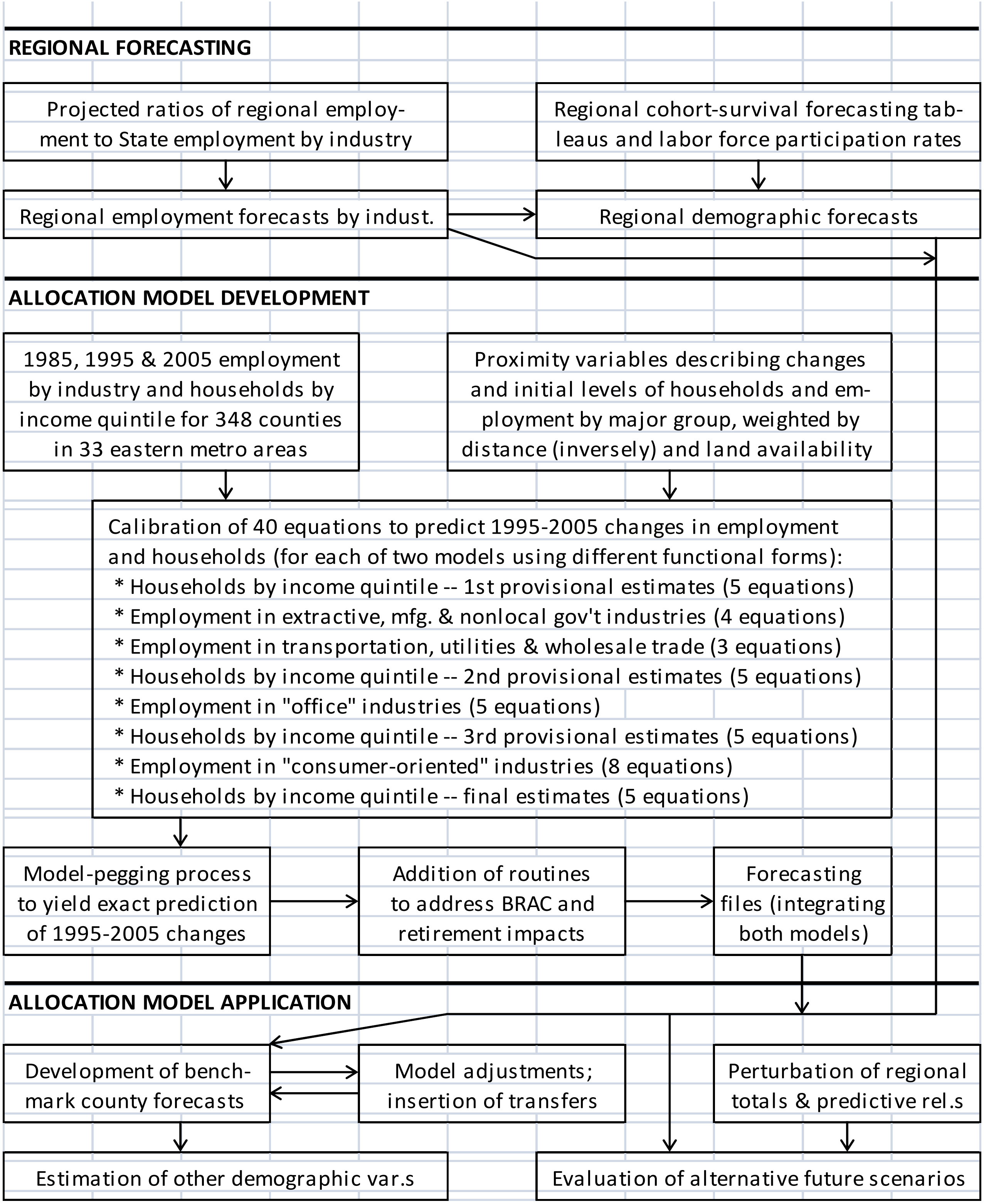


Figure 4 Regional and County level Economic and Demographic Model

This explanatory variable is assumed to be in effect only in one scenario. This is tantamount to assuming that the tendency of high fuel cost to concentrate future development will be driven by the attempts of households to reduce commuting distances, rather than by independent attempts of employers to stay close together. Given the tight integration of households and employment achieved by the new allocation model, this assumption is believed to yield adequate modification of employment patterns, which remain more concentrated than household patterns in any case

Transportation Model

The transportation model consists of at least 2 levels (in geography) that interact with each other. The first is a regional level of the model that includes the whole of United States. It is at this level long distance and visitor person trips is modelled at this level, as well as commodity flow movements into, out of, and through Maryland. Regional model zones (RMZs) cover Maryland and the surrounding states at the county level, at the state or Freight Analysis Framework Version 2 (FAF2) zone level further out, and eventually Census regions for the Western USA. There are 189 RMZs used in the model including 69 counties specified earlier. While the current version of the modelling framework does not incorporate national level forecasts of INFORUM, work is underway to link these up so that scenarios at the national level would directly impact the commodity flow through the region and thus resulting in different traffic patterns.

The second is a statewide level will be the central focus of the model. Only Maryland, the District of Columbia, Delaware, and parts of adjacent states is included in this level of the model. Statewidemodelling zones (SMZ) cover the entire statewide level. These zones are aggregations of traffic analysis zones (TAZ) in areas covered by Baltimore Metropolitan Council (BMC) and Metropolitan Washington Council of Governments (MWCOG) and adjacent state models, and defined by Census geography elsewhere. Person and truck travel within Maryland is modelled at this level. The modelling region is divided into 1607 SMZs.

The model is a traditional four step model that includes Trip Generation, Distribution, Mode Choice and Assignment. The key innovation in this model is that the trips of different populations (such as long distance visitors, commodities) are modelled separately but the final assignment to the network is done in one step. So increase in commodity movement through the port of Baltimore that goes to Florida will affect the congestion levels on I-95 and would be reflected in the person travel choices.

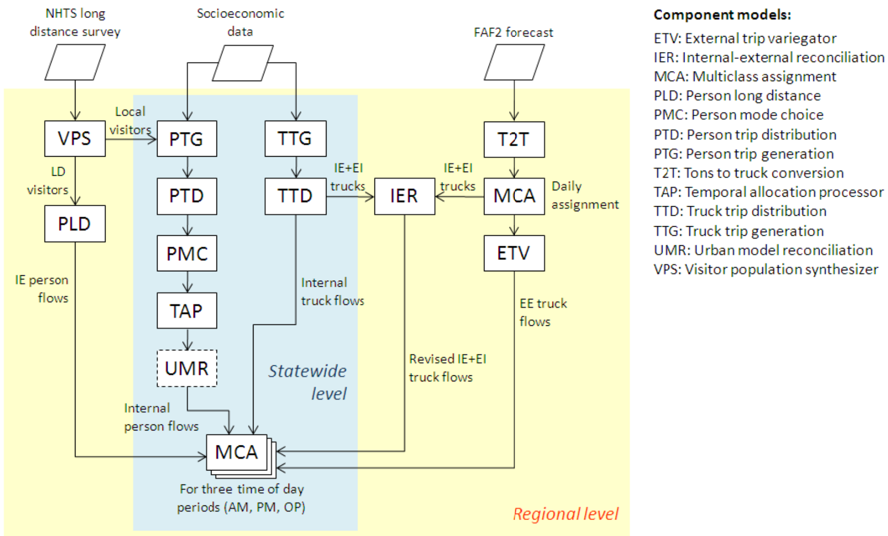


Figure 5 Schematic of Transportation Models

Landuse Models

Multiple land use models are used in this project and are chosen according to the relevance of the question at hand. At the very least, a simple Lowry model is used to disaggregate the County level employment and Population into SMZs so that the transportation model can use those as inputs so that the trip generation and attraction matrices can be created. This model simply uses travel time between two zones in a county as a determinant of new employment and household location in a particular zone. Since the county disaggregation model has already accounted for inter-county migration, we ignore the edge effects at this level. The four employment categories are Retail, Industrial (which is taken as basic employment), Services and Other. The Households are disaggregated by income quintiles.

On the other hand, cellular automata models developed by partners at University of Illinois and USGS are also being used for specific questions, though the geographies they are applicable at, are different. While Land use Evolution and Impact Assessment Model (LEAM) operates at 30 m resolution level and covers the region described in Figure 3 Spatial Scope & Regions of County Level Economic and Demographic ForecastsFigure 3, the Chesapeake Bay model, based on SLEUTH covers the whole of Chesapeake Bay which extends to New York.We also developed a bottom up land conversion in the state of Maryland at a statewide level using an economic framework using a multiple discrete continuous extreme value (MDCEV) framework. The whole state of Maryland is gridded into ¼ sq mi grids and treat them as economic agent that maximise the utility based on choice of conversion to residential single family and residential multifamily and non residential use in 3 year time increments. The results of these two models are not presented in this paper.

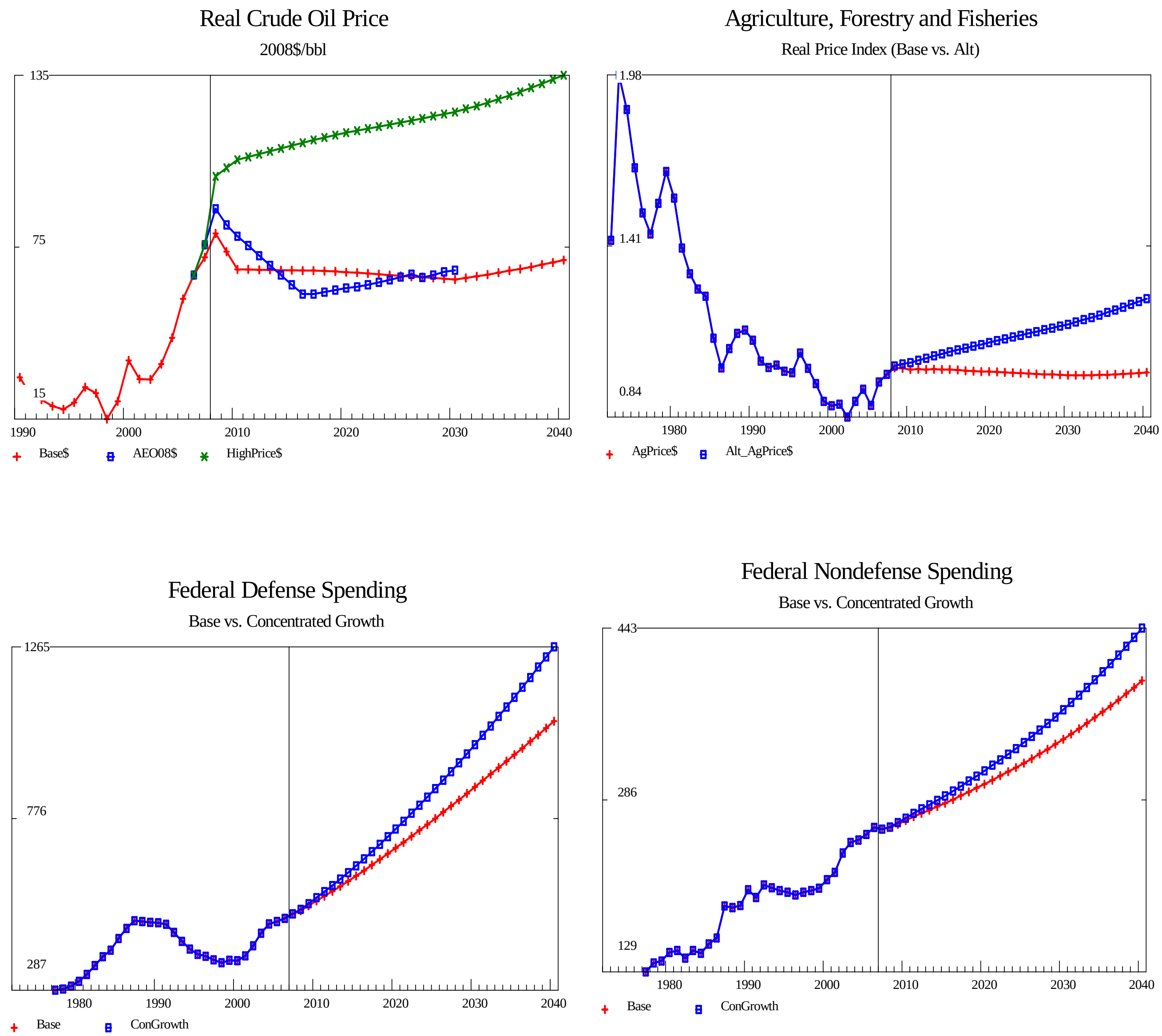


Figure 6 Selected Input Assumptions into Economic Models

Scenario Construction

The differences in the exogenous inputs to the LIFT Model between the scenarios are laid out in Figure 6. The assumptions of future price and consumption paths are contrasted in these two scenarios. These scenarios are called Business as Usual (BAU) and the High Energy Price scenario (HEP). The Business as Usual is the best guess about the future based on how the current relationships between economy and demography play out and can b termed a forecast.Further explanations are below. The purpose of the scenarios is to hypothesize about a plausible and interestingly different future not necessarily the most likely one.

Oil Price Assumption - Figure 6 shows the paths for the real ($/bbl) crude oil price for BAU and HEP. These are also compared to the Energy Information Administration of the U S Department of Energy (DOE)/Energy Information Outlook (EIA)*Annual Energy Outlook 2008,* released in June 2007.

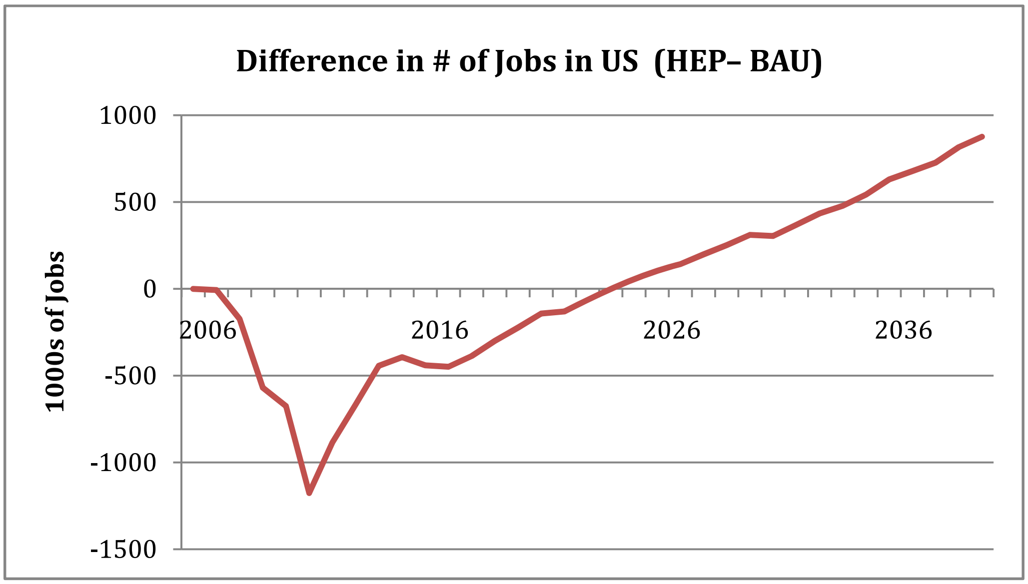
Assumption on Agricultural Prices - The assumption for the HEP is a price index for Agriculture, Forestry and Fisheries that is 25 percent higher than the base by 2040 in real terms, that is, adjusted for general inflation. The real agriculture, forestry and fisheries price index has been generally falling over time, since about 1975. The BAU assumption was for an Agriculture sector prices that rose slightly slower than general inflation, remaining almost constant in real terms. This is consistent with the USDA Baseline (although their projection only goes to 2017.)

Biotech / Infotech / R&D - These activities are concentrated heavily in two industries: 48: Miscellaneous professional, scientific and technical services 49: Computer systems design and related services. Both of these industries sell a large portion of their output to other industries (intermediate). To model the increased activity, the input-output coefficients of each industry to the major consuming industries were increased relative to the base case. The coefficients were assumed to become 20 percent higher than the base by 2040, indicating more intensive use of these industries by other industries.

Finance and Insurance (41-44) - Slightly more than half the output of these industries is sold to personal consumption. The major part of the remainder is sold to intermediate demand. Intermediate demand was increased in the same way as for industries 48 and 49. Finance and insurance consumption categories were also made to rise faster than the base.

Comparing Outcome Indicators

The differences in the national employment as produced by LIFT is shown in theFigure 8Figure 9. Predictably Maryland economy does better than the nation as a whole because of heavy concentration of the Professional services and other industries that are not entirely dependent on fuel prices. However, the shock of the fuel and agricultural prices are felt in both economies though due to the equilibrium nature of the LIFT model the economy performs corrects itself and reverses the decline by 2011, but actually has an increase in output by 2030 for the US and 2015 for Maryland. This difference is primarily due to heavy concentration of increases of Federal defense and non defense funding and its implications on DC, MD and northern VA region. Increases in agricultural prices may result in lower rates of urbanization, however, decreases output in the farm sector due to competition from international food prices that are kept fixed in the model.



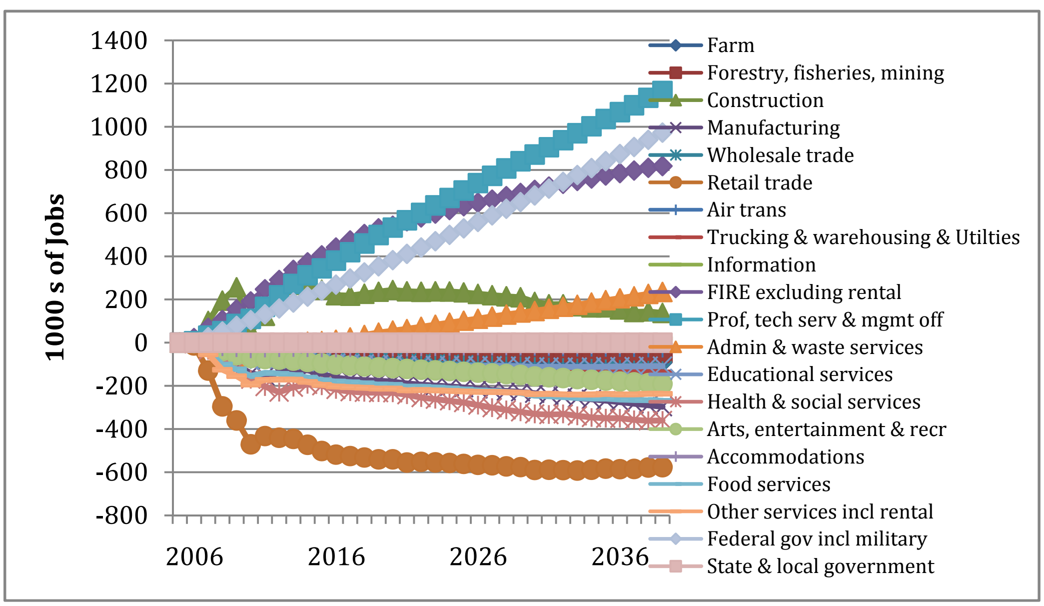


Figure 7 Difference in Number of Jobs in US between HEP and BAU scenarios

Being a General Equilibrium models, LIFT and STEMS reverts to equilibrium path even in the presence of shocks at times over correcting. This explains the reason why the economy performs better than the BAU in the HEP scenario even with higher than usual fuel prices. Furthermore, increases in federal spending also buoys the economy though affects Maryland and DC disproportionately compared to the rest. This is apparent from the annual employment growth rates (see Table 2) in both scenarios. The decline in the FIRE sector is attenuated in the HEP than in BAU due to the increase in the personal consumption equations of this particular sector.

Industry	U.S.		Maryland	
	BAU	HEP	BAU	HEP
Farm	-0.90%	-1.14%	-0.86%	-1.06%
Forestry, fisheries, mining	-0.76%	-0.89%	-0.97%	-1.10%
Construction	1.07%	1.10%	1.12%	1.20%
Manufacturing	-0.07%	-0.13%	0.14%	0.10%
Wholesale trade	0.00%	-0.06%	0.13%	0.12%
Retail trade	-0.56%	-0.69%	-0.44%	-0.51%
Air trans	2.18%	2.11%	2.25%	2.22%
Trucking &Utilties	0.43%	0.36%	0.59%	0.56%
Information	0.24%	0.26%	0.21%	0.27%
FIRE excluding rental	-0.46%	-0.15%	-0.39%	-0.09%
Prof, tech serv& mgmt off	0.09%	0.38%	0.25%	0.56%
Admin & waste services	0.40%	0.46%	0.45%	0.55%
Educational services	0.68%	0.60%	0.86%	0.82%
Health & social services	2.14%	2.11%	2.34%	2.36%
Arts, entertainment &recr	0.93%	0.75%	1.00%	0.86%
Accommodations	-0.31%	-0.32%	-0.29%	-0.27%
Food services	0.22%	0.15%	0.34%	0.31%
Other services incl rental	0.26%	0.19%	0.38%	0.35%
Federal govincl military	0.26%	0.74%	0.61%	0.71%
State & local government	0.46%	0.46%	0.61%	0.64%
TOTAL	0.47%	0.48%	0.63%	0.71%

Table 2 Annual Growth Rates between 2006-2040 in Employment in Different Scenarios

Figure 8& 9 show the spatial implications of these employment and demographic scenarios. Predictably, the central Maryland experiences much higher employment and population growth in the HEP scenario than in the BAU scenario, drawing them from the outer ring counties around the Washington Baltimore region. Furthermore, the counties around the city of Philadelphia draw the residents and the jobs away from the outer ring regions. The employment is much more concentrated than the population as can be evidenced from the Figures 8 & 9. These employment and population projections have different implications for the transportation planning process across the region.

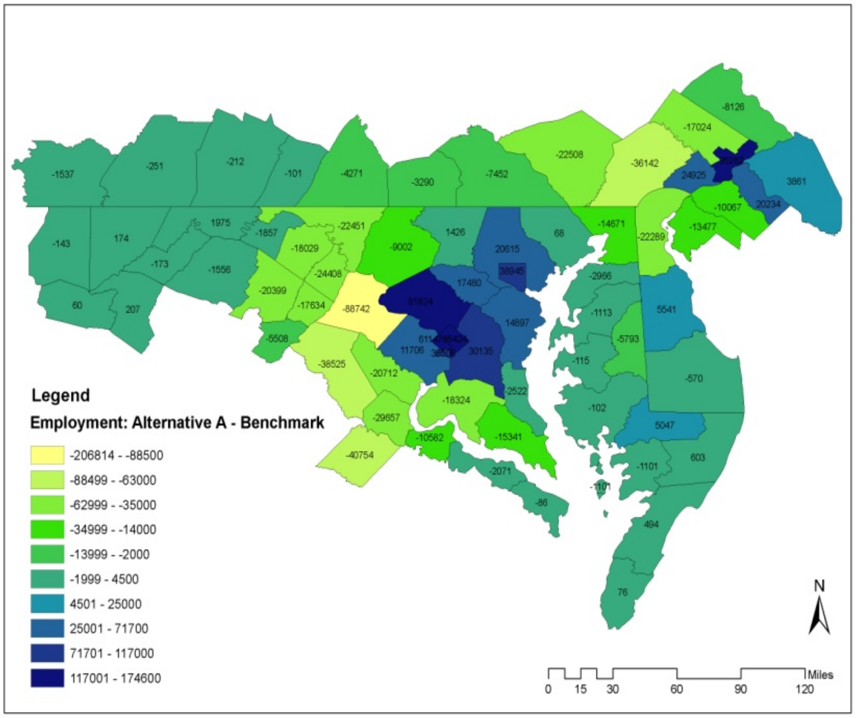


Figure 8 Difference in Employment Projections between HEP and BAU

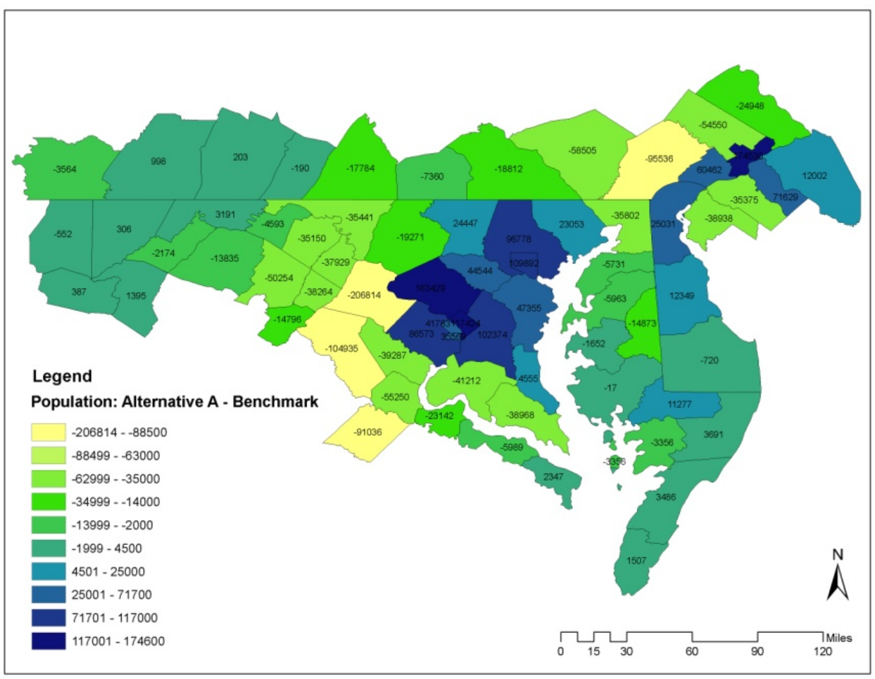
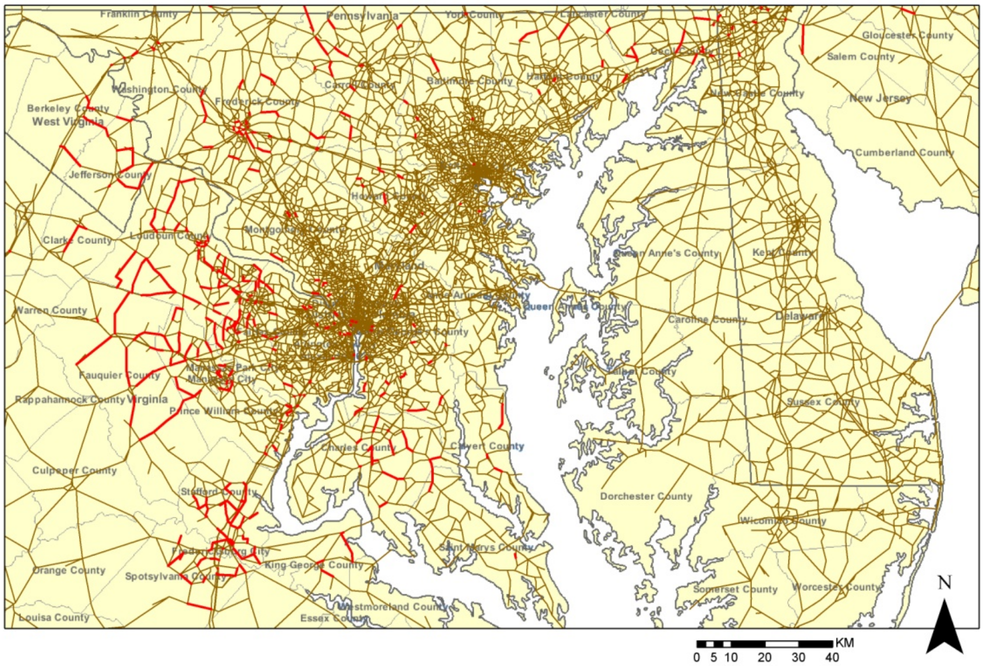


Figure 9 Difference in Population Projections in HEP and BAU

Congestion in BAU but not inHEP



Congestion in HEP but not in BAU

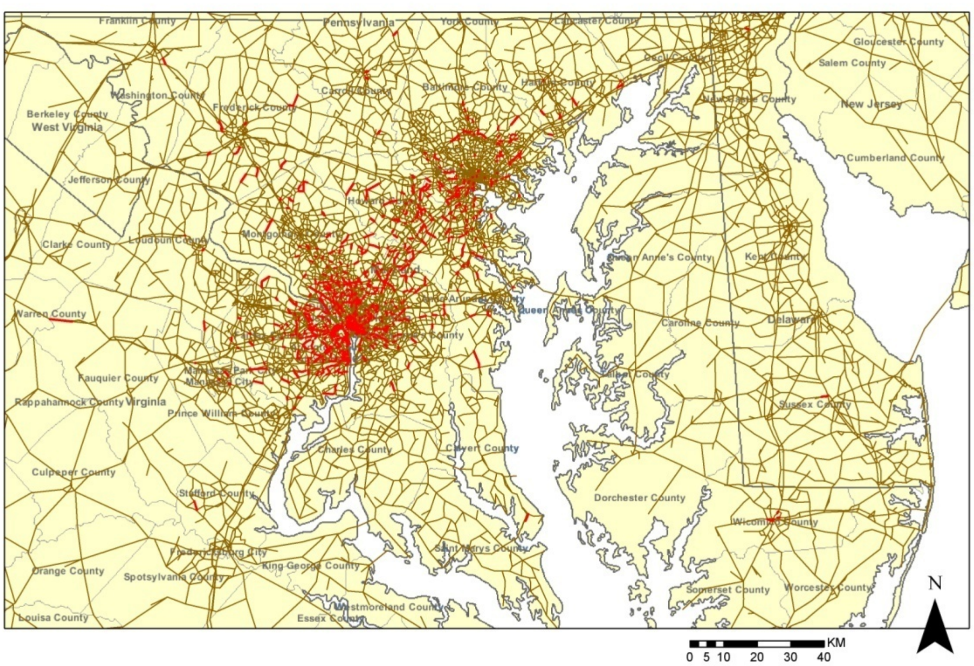


Figure 10 Congestion Patterns in 2040 Different Scenarios (Contingent Actions)

Figure 10 illustrates the differences in the congestion patterns evident in the Washington Baltimore region in the different region. The Volume to Capacity ratio of greater than 0.9 are considered congested. As expected, even though the trips are shorter, more highways with the Central Maryland and Northern Virginia region are congested in the HEP scenario but not in the BAU scenario. However, more roads in the outer ring counties are congested in the BAU scenario, where as they are not in the HEP scenario.

A *Contingentplan* wouldconsider these likely futures and plan to either expand capacity in the targeted links in different futures. This plan would require constant monitoring of which future is happening, not just in terms of the inputs to the models but also various intermediate indicators that provide clues about the futures. In other words, even if energy prices do not follow the path as described in Figure 6, plans that would consider the different projections of demographic and employment would in fact be prepared to deal with these futures.

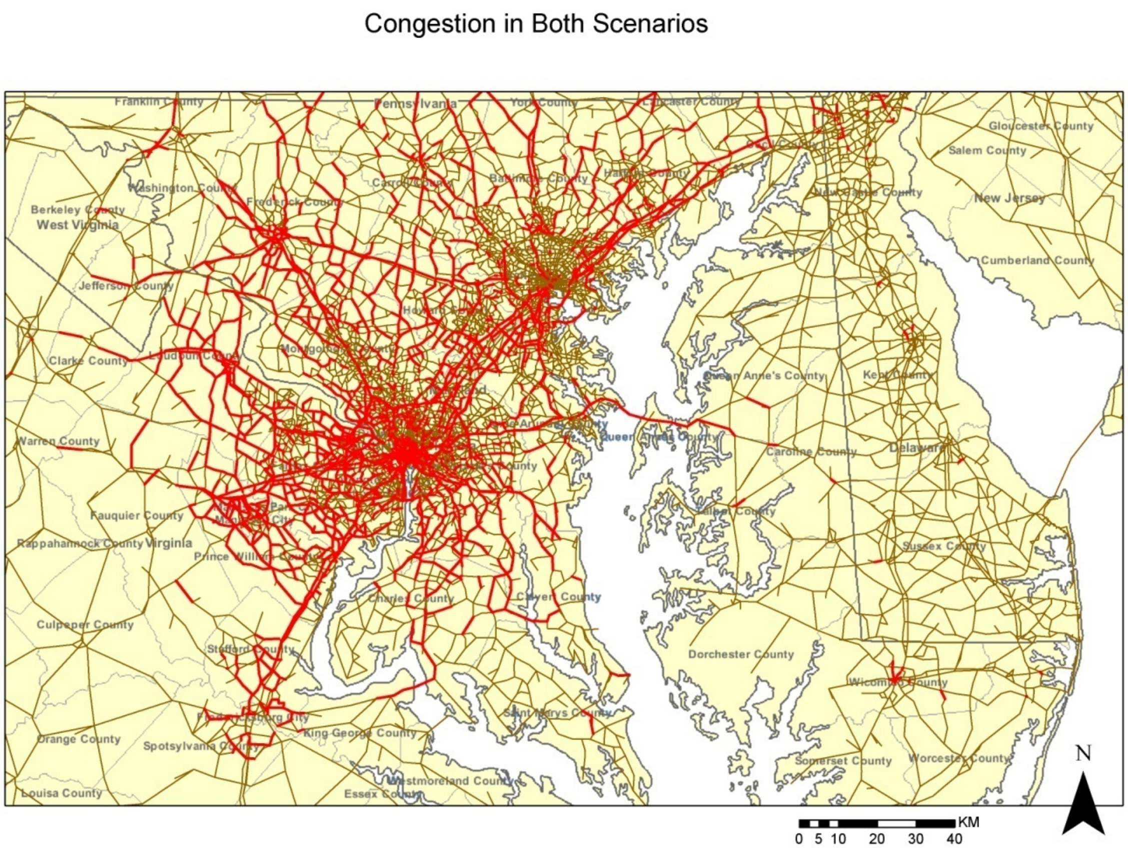


Figure 11 Congestion Pattern in 2040 inBoth Scenarios (Robust Actions)

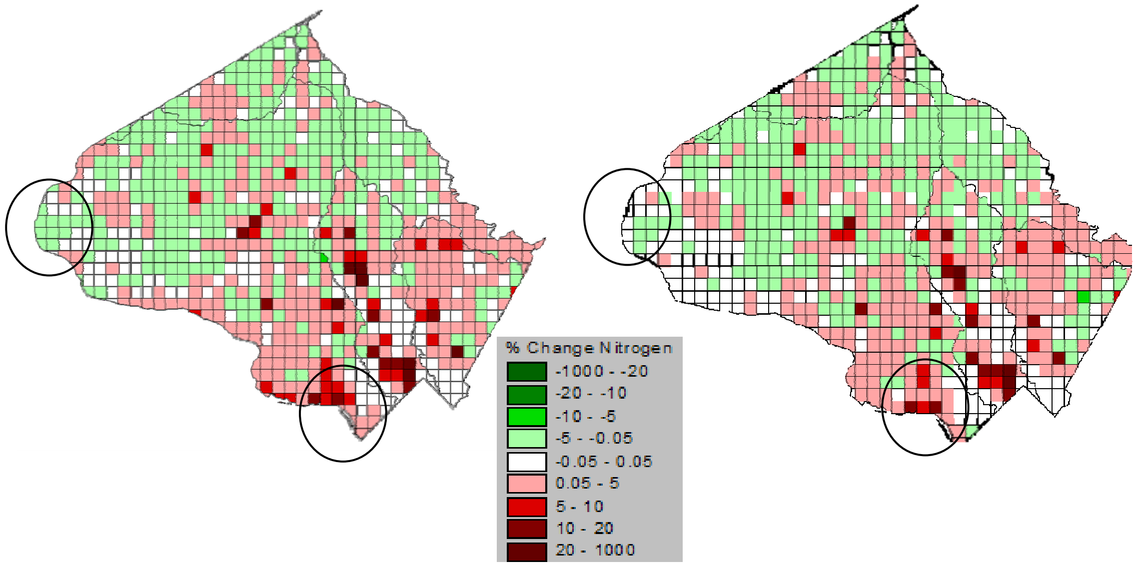


Figure 12 Percentage Change in Nitrogen Loading based on a 1 mi grid between 2000-2040 in Montgomery County (Left is BAU, Right is HEP)

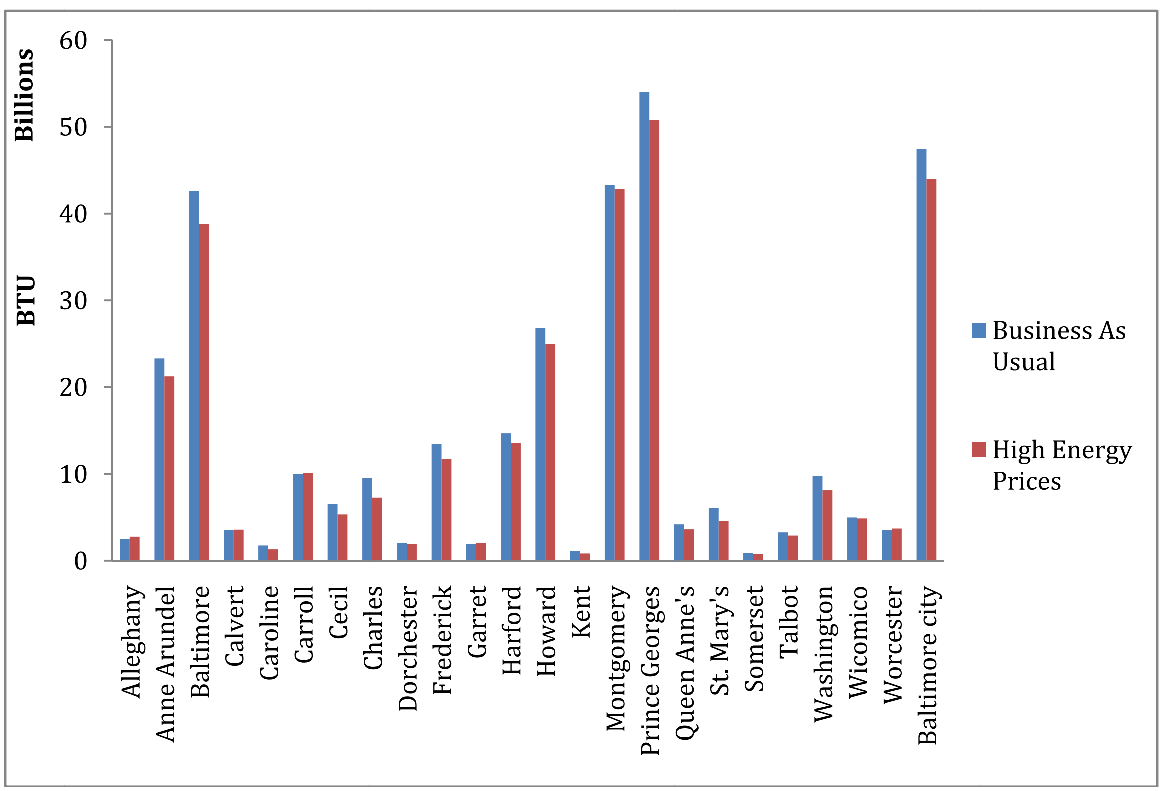


Figure 13 Annual Residential Energy Consumption in BAU and HEP

On the other hand, Figure 11 shows the roads that are congested in both scenarios. Thus, a *robust plan* would plan to deal with congestion on these roads. Irrespective of likely future, any policies or investments that deal with congestion on these roads would be effective in both the futures. Scenario planning would thus help to find actions that effective across a range of futures as opposed to a single future.

Figure 12 describes the changes in the nutrient loadings (in Nitrogen) in Montgomery County. The changes between 2000-2040 are illustrated in BAU scenario on the left and the HEP scenario on the right on a mile grid. The green represent the reduction in loadings between 2000 and 2040 where as the red represents the increases. These loadings are a function of changes to the land cover. Land conversion from Agriculture to Urban usually decreases the nutrient loading where as the land conversion from Forest to Urban increases the nutrient loading. Contingent on where the urbanisation happens, different scenarios have spatially differential impacts even within a single county, as illustrated in the two highlighted circles.

Figure 13 shows the energy consumption patterns in various counties. The energy consumption is forecasted using the estimated equations for the Department of Energy's Residential energy consumption survey data (RECS) and is a function of density, type of dwelling and climate variables. Different counties have different propensities for types of housing and different scenarios change the density in various 1 mi grids in different ways that except in few counties such as Alleghany, Carroll and Calvert, which are primarily rural counties, HEP scenario on average generates about 4 percent reduction in the residential energy consumption. Note that these reductions do not really come from the reduction in demand due to prices (prices are insignificant variable in the regressions) but due to changes in the types of dwellings, densities and moving households from highly variable climate zones to more temperate climate zones.

Conclusions

Thus any planning effort in and around the state of Maryland has to account for the likelihood of various plausible futures and choose policies that work well in these scenarios. We show that different futures require different sequences of actions that need to be taken. We distinguish between contingent plans that are useful only in the future that they are dependent on, and robust plans that are useful in various likely futures. More work is necessary to validate the models that are useful in more than one future, and are not entirely dependent on past relationships. The backward linkages between various indicator models and the economic and demographic models need to be strengthened.