

A Mega-region Framework for Analyzing a High Energy Price Future

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ABSTRACT: Mega-regions are a new geography that may well form the “nation’s operative regions when competing in the future global economy. A challenge is to determine how to foster greater efficiencies in these mega-regions by creating a stronger infrastructure and technology backbone in the Nation's surface transportation system,” according to the March 2010 FHWA Strategic Plan. To meet this challenge these regions will need analysis tools to evaluate scenarios and their regional impacts, analysis tools covering areas larger than covered by the typical Metropolitan Planning Organization (MPO) or State Department of Transportation (DOT) models. This paper describes what makes mega-regions different and identifies analytic issues mega-regions may need to address, identifies the Chesapeake Mega-region and provides a framework for analyzing issues within the Chesapeake mega-region. Finally, the framework is tested through a proof of concept scenario which assumes a sudden price rise in gasoline prices and the likely effects on travel. A brief summary of further work and additional scenarios planned is provided.

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1. INTRODUCTION

This paper presents preliminary findings on the development of a comprehensive economic, land use and transportation framework to be used for mega-region technical analyses. The paper covers the impact of an energy price surge on the future transportation system. Future work will include linking changes in travel time and impedance to the mega-region economic models and Using land use models to forecast the location of population and employment.

2. DEFINITION OF MEGA-REGIONS

Mega-regions have been emerging as viable entities throughout the world. Within the United States, areas such as the Boston-Washington megalopolis, Southern California, and Southern Florida are prime examples. One of the best known mega-regions outside the United States is the “blue banana”, an arc stretching from Manchester in Northern England to Milan in Northern Italy. The blue banana was later rejected as too simplistic (it covered most of the highly rural Alps) and it was decided a more fruitful name would be the European Grape (1) While no formal definition of a mega-region exists, there are factors which can be considered when linking together elements of a mega-region. Some of these factors include environmental systems and topography, common infrastructure, economic linkages, settlement patterns or shared cultural history. Ross and Woo (2) propose that mega-regions be defined by identifying core areas, identifying the boundaries of areas of influence, applying local characteristics and finalizing the boundaries.

Three key factors make mega-regions different from either traditional MPOs or, in many cases, states. These factors include the issues defining the mega-region, the economic and transportation interactions with other mega-regions and the rest of the country, and the scale of the problems addressed.

Issues – mega-regions are defined by issues, rather than explicit political boundaries. Examples of issues linking mega-regions are provided below:

- Environmental – Specific environmental issues may create a mega-region. For example, the Great Lakes Commission is a consortium of eight states addressing water resource issues (3). The Chesapeake Bay Commission, composed of Pennsylvania, Maryland and Virginia, is concerned with water quality in the Chesapeake Bay (4). In each of these instances the regional coverage is defined by environmental factors rather than economic or political factors.
- Transportation – Mega-regions, particularly those containing major corridors, may have concerns which span multiple subareas. A prime example is the Northeast corridor stretching from Boston to Washington. This corridor is linked by air travel, auto travel on I-95 and AMTRAK. All of the areas within the corridor are affected by the performance of the transportation system.
- Economic linkages – The size of economic problems addressed by mega-regions are typically larger than those addressed by MPOs or even by states. A mega-region may be concerned with economic growth and must explicitly address not only growth within the area but also in the country as a whole. As an example, a mega-region dominated by manufacturing would be concerned not only about manufacturing within the region but also with changes in manufacturing activity within the United States and possible

1 structural changes in the world economy. Further, the mega-region is likely large enough
2 that changes in its economic activity will impact the rest of the country.

- 3 • Scale of the Problem – The scale of problems may be larger than those addressed by
4 others. For example, mega-regions may be concerned with travel throughout the region,
5 at a scale larger than that addressed by typical MPOs. In a mega-region with multiple
6 MPOs, there may be more concern about travel between MPOs than travel within
7 individual MPOs. The mega-region may also be concerned with economic activity and
8 that the transportation system within the mega-region can support the mega-region's
9 economic development.

10
11 With mega-regions facing these issues, there is a strong need for an analytic framework which
12 can be applied to address these issues. Existing planning model frameworks, while addressing
13 transportation issues, fall short in addressing economic issues or the interactions between local
14 and regional economies with other regions and the national economy. Therefore, a mega-region
15 framework must have the capability not only to address traditional transportation issues but also
16 to go beyond transportation issues to address the national and mega-regional economy, the
17 economic and transportation interactions between a mega-region and other mega-regions, the
18 impact of long distance travel changes on the mega-region and environmental issues such as
19 water quality. In particular economic linkages and flows within a mega-region can be critical to
20 its economic health and of major concern to a mega-region oversight agency.

22 3. CHESAPEAKE BAY MEGA-REGION

23
24 The Chesapeake Bay mega-region comprises the portion of the eastern seaboard extending from
25 Norfolk, VA to Wilmington, DE and from West Virginia to the Atlantic Coast. The region is
26 home to 6 major metropolitan areas anchored by the Baltimore-Washington-Richmond corridor
27 (Figure 1a), along with numerous smaller urban and rural hinterlands. These communities house
28 a complex mix of industries including government, military, health, and manufacturing. The
29 economic connections within the region for transport sectors are shown spatially in Figure 1b.
30 This figure represents the dollar value of transportation shipments between different areas of the
31 CBM. As can be seen the greatest flows are along the northeast corridor, from Wilmington to
32 Richmond and then to Norfolk. Urban and rural connections are bolstered by agriculture,
33 fisheries, and recreation-tourism. A significant highway, rail and port infrastructure support the
34 region's dominant goods movement industry, housing a critical portion of the northeast corridor
35 shipping as well as a gateway to the world. The region is expected to grow faster than other
36 parts of the northeast, with Norfolk as one of the major east coast ports, poised to capture
37 increased traffic with the expansion of the Panama Canal and opening of northwest trade routes.

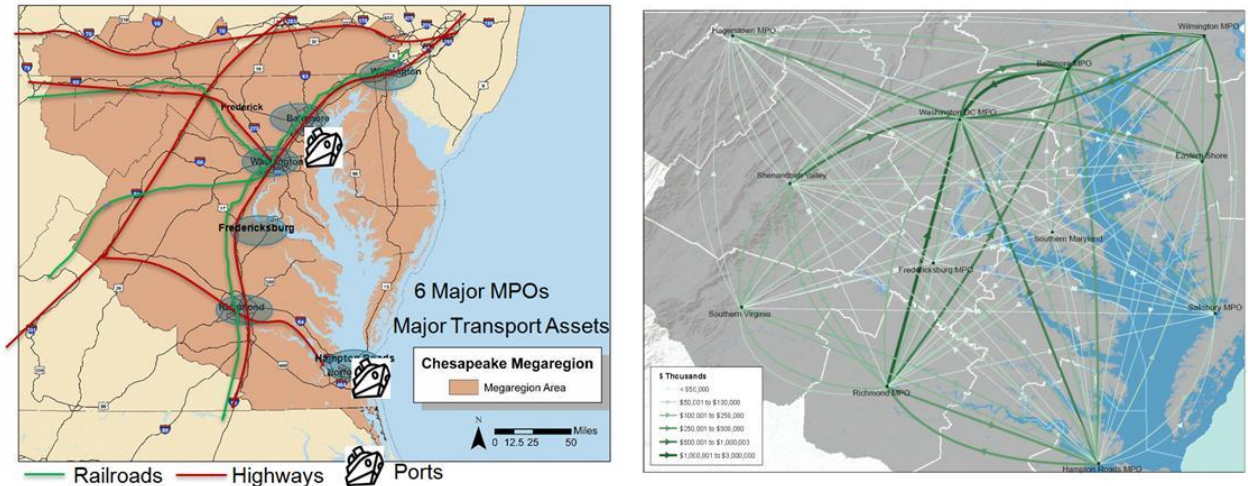


FIGURE 1a Major transportation infrastructure in the CBM
FIGURE 1b Dollar value of shipments between areas within the CBM (6)

Existing political linkages beyond the state, regional MPO, and county jurisdictions include the I-95 Corridor coalition to tackle freight movement and the Chesapeake Bay Commission to ensure stewardship of the Bay, the unifying economic and environmental heart of the region (4). Other common issues in the region include congestion and various discussions on congestion pricing solutions, growth in port traffic, land use planning to balance urban and agricultural interests, and environmental concerns about Bay water quality and sea level rise due to global climate change. In addition, a mega-region board would be concerned about the resilience of the region and its economic competitiveness under alternative futures, such as high gas prices.

Worker flow analyses and cluster analyses have been conducted on the mega-region. Projections of commuting patterns have shown strong linkages within the CBM (7). Cluster analyses have also shown that linkages within the CBM are stronger than those with other areas in the Northeast Corridor. In addition the CBM is projected to grow faster than other areas within the Northeast corridor.

4. FRAMEWORK DESCRIPTION AND APPLICATION TO THE CHESAPEAKE MEGA-REGION

4.1. Framework Description

The framework focuses on the technical issues associated with mega-region analysis. There are also political issues and management issues which would be involved both in analysis and bringing results to practice. These issues are beyond the scope of the paper.

A framework for mega-region analysis should be capable of addressing the following:

- Economic growth – economic growth, port expansion, employment, improved workforce and industry clustering, local production and consumption, major employer changes
- Land Use – Changes in the location of population and employment, the response of land use to changes in transportation and the economy.

- Transportation – High speed rail and highway transportation, pricing, freight, multi-urban area policies, disaster response, change in travel behavior
- Environment – climate change and resource management

A modeling process to address these issues can be formulated in four phases: (1) National Economic Changes, (2) Integrated land use model, (3) development of a travel demand model, (4) indicator models, such as emissions or economic impact models.

Figure 2 below provides a flow diagram of the modeling framework. To be useful, the framework must also smoothly interact with national models and local MPO or state DOT models. The global economy will impact the mega-region as well. More detailed knowledge on land uses and traffic flows from relevant MPO models in the area can be fed upwards into the mega-regional analysis tool.

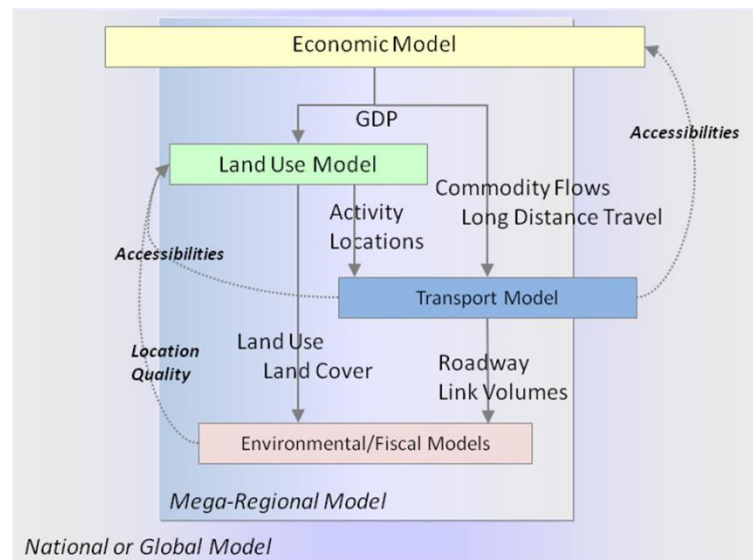


Figure 2 Analytic Framework for Mega-region Analysis

The framework begins with a national economic model which provides estimates of state population and employment as well as national freight flows. Statewide Population and employment are then used to model activity locations of population and employment. This formation is combined with commodity flows and used as input to the transportation model. Finally the results can be used to determine indicators of the economic and environmental impacts.

4.2. Chesapeake Mega-Region Demonstration

The framework will be used to develop a model to address scenarios within the CBM. This will focus primarily on the development of a proof of concept, thus the initial results will not be subject to an extensive validation effort.. Figure 3 below illustrates the interfaces between multiple layers in the mega-region framework. The model interfaces both with a national model and the models of individual MPOs. In this case the Wilmington MPO is not shown.

A multi layer model system is presented in Figure 3, below. The multiple are: (a) national, (b) state, (c) county and (d) mega-region model zones (MMZ)

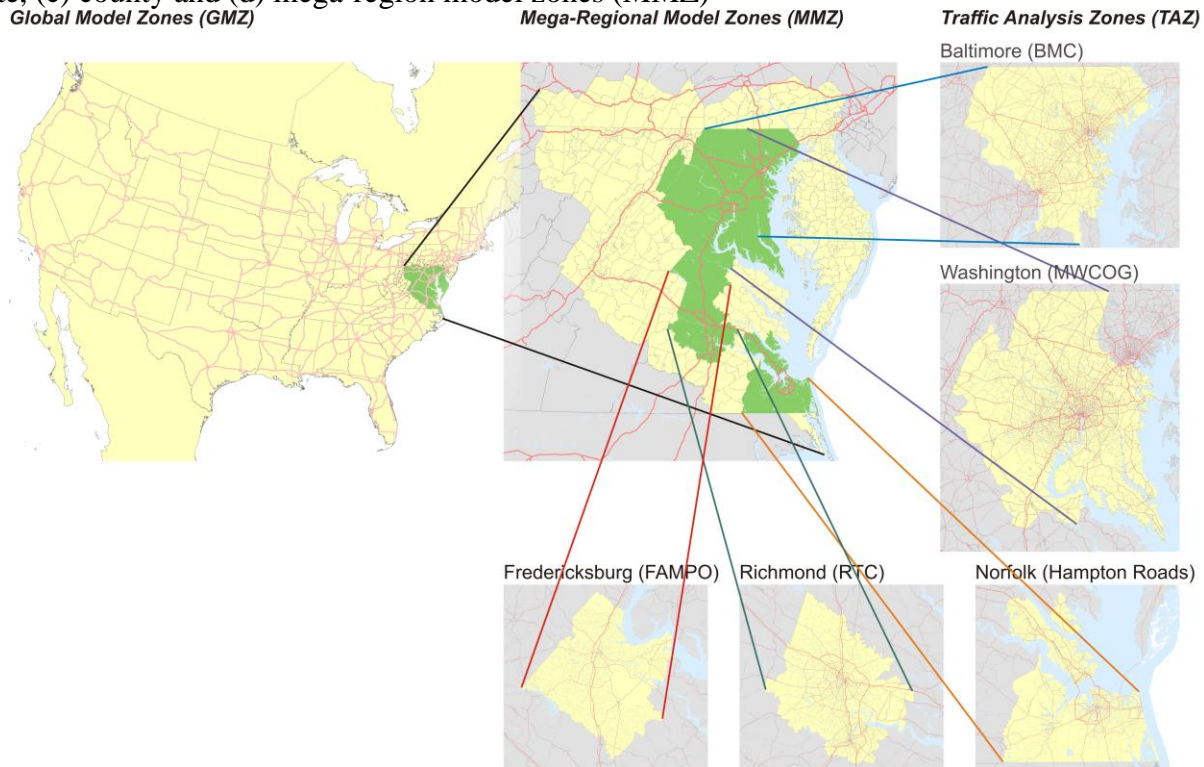


FIGURE 3 Multi - layer approach: Global, mega-regional and urban scales

Data Preparation

The socio-economic (SE) data reconciliation is an important part of establishing the inputs to the mega-region model. As the modeling region consists of multiple states, the SE data is collected from numerous sources such as metropolitan planning organizations (MPO), state DOTs and local agencies. The data sources do not follow the same definition and are not in the same format. A reconciliation procedure was developed to integrate all the data sources to provide a unified set of inputs to the mega-region model. A complete description of the methods can be found on the Maryland Statewide Transportation Model (MSTM) User's guide (8), a predecessor of the CBM model. The methods used resulted in the base year (2007) and future year (2030) SE data. The transportation network used was the combined 2007 Virginia and MSTM transportation networks. Reconciling the networks was a major effort, since the zone system and node numbering systems for Maryland and Virginia did not readily correspond. Airport and seaport traffic can have a major effect on the mega-region. We do not specifically model changes in airport and seaport traffic but do reflect estimated flows through the ports into the zones where they are located.

A modeling process to assess the outcome of the future regional scenarios can be formulated in four phases: (1) National Economic Changes, (2) Integrated land use model, (3) development of a travel demand model, (4) indicator models, such as emissions or economic impact models.

The economic and land use scenarios use a four layer system as presented in Figure 5. The four layers are: (a) national, (b) state, (c) county and (d) mega-region model zones (MMZ)

National Economic Changes

The national econometric model consists of two sub-models: (1) Long term Inter-Industry Forecasting Tool (LIFT), a macroeconomic input-output model operating at the U.S. national economic level, forecasts more than 800 macroeconomic variables that are then fed into (2) State Employment Modeling System (STEMS) to calculate employment and earnings by industry for all 50 states and the District of Columbia. Results from the STEMS model are allocated by region using current proportions of state level forecasts for each sector. Based on the state employment forecasts from STEMS and using the Census estimates of population for the entire country, Population is then allocated to individual states. A detailed description of LIFT and STEMS can be found in McCarthy (9) and INFORUM (10).

Integrated land use model

Figure 4 presents the land use model disaggregation procedure.

National Model: The national economic model disaggregates national forecasts of employment and population to states.

Regional (County) Model: The regional model disaggregates state level forecasts to the county level. This disaggregation is based on accessibility, land availability and previous employment located in the county.

Local Model: The local model allocates county level forecasts to mega-region modeling zones (MMZ¹). The allocations are made based on transportation costs and the basic employment distribution. A Lowry type model is used for this process.

¹ MMZs are the polygon structures used in the mega-region model and can be considered similar to TAZs in transportation planning. MMZs in the mega-region model are equivalent to TAZs in high density development areas, or TAZs are nested in MMZs in the low density development areas.

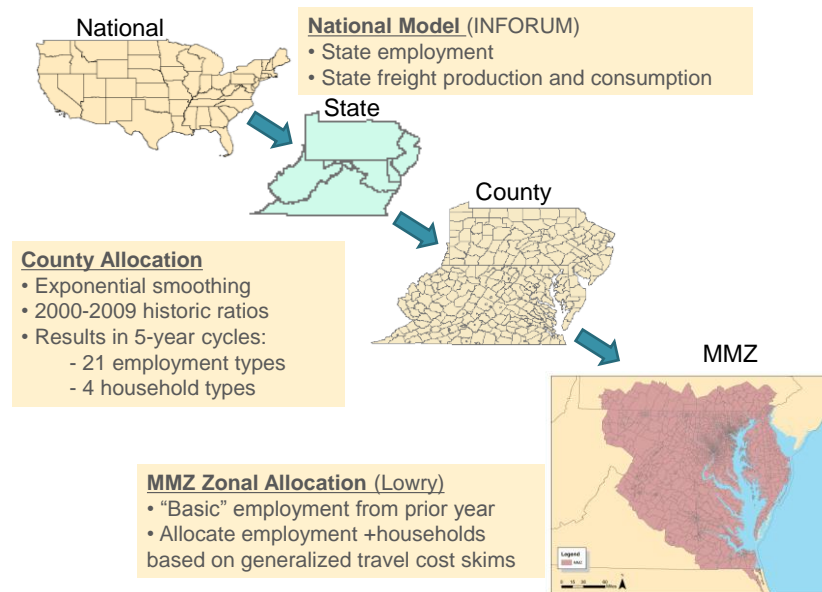


FIGURE 4 Land Use Model Disaggregation Procedure

Development of a Travel Demand Model

The travel demand model has been borrowed from the Maryland Statewide Transportation Model (MSTM) (8). It is designed as a multi-layer model working at national, regional and local levels. The MSTM originally covered Maryland and surrounding areas. The expanded mega-region version covers all of Maryland, Delaware, and Washington D.C.; along with portions of Pennsylvania, Virginia, West Virginia, and North Carolina (it covers 121 counties in the region). The Chesapeake Bay Mega-Region consists of 2,075 MMZs and 127 regional modeling zones (RMZs). The RMZs cover the complete US, Canada, and Mexico. A five-step travel demand model is developed to forecast passenger travel demand by various travel modes and time-of-day periods.

Freight movements in this framework are estimated through the FHWA Freight Analysis Framework (FAF) 3.1. Each of the 43 commodities employed in the FAF is defined according to the Standard Classification of Transported Goods (SCTG)². These classification codes were compared to the commodity detail employed in the macroeconomic with the industry detail derived from data published according to the North American Industrial Classification System (formerly the Standard Industrial Classification system). For each commodity defined in the FAF, the proposed model provides productions and consumptions for each FAF zone (11). The calibrated model forecasts productions and consumptions for the future year.

Indicator Models

In addition to transportation measures such as vehicle miles traveled (VMT), hours of congestion or number of trips, indicator models can identify impacts on other aspects of the mega-region. The indicator models in the framework include air quality, water quality, fiscal impacts and economic impacts:

² Information on SCTG can be found at <http://www.statcan.ca/english/Subjects/Standards/sctg/sctg-class.htm#19>.

- Air quality – The EPA MOVES model estimates emissions from mobile sources, including greenhouse gases and toxic emissions.
- Water quality – Water quality is determined in part by the types of land use in the relevant watershed. Land use types can include industrial, residential, commercial agricultural and others. As the land use changes and evolves the effect on water quality will be estimated.
- Fiscal Impact – New development will impact the expenditures of local and county government. These impacts are related to new transportation needs, school needs and sewer and water needs. The fiscal impact estimates the capital cost of these activities related to new development.
- Economic – The ability of a mega-region to be economically viable will be determined in part by intraregional connectivity. Using data obtained on economic flows within the mega-region, key linkages between different parts of the mega-region can be identified. If anything occurs which degrades these linkages the mega-region economy may be threatened.

4.3. High Energy Price Scenario

The framework will be used to conduct a scenario test on a high energy price future, demonstrating the ability of the framework to support ‘real world’ applications. Some of the effects of a scenario, such as changes in travel cost, are captured first at the local level then filter upward to land use and economic impacts. Others, like changes in the economy or land use patterns, are first captured at the national level then filter down to the local level. A mega-region view would seek to foster greater efficiencies within its borders by identifying and addressing regions, industries and populations most vulnerable to changes under different scenarios. Work on this study is underway and expected to be completed in February of 2012.

With the current volatility of the price of petroleum, a rise in energy prices has been selected as a way to demonstrate the capabilities of the framework. A petroleum price rise can occur in a variety of ways but generally the possibilities fall into two types, a slow steady rise due to the inability of supply to keep up with increasing demand and a sudden price surge due to disruptions in supply. The sudden price surge was experienced by the United States in the winter of 1973 – 1974 and in the spring of 1979.

Different types of prices rises would have differing impacts on the economy, land use and transportation. In general the most immediate impacts will be felt on the transportation sector while the economic and land use sectors would feel more long term impacts.

Steady Price rise

A steady price rise would be slow enough that impacts reflect the complex interactions of the economy, land use and transportation. The following are likely specific impacts on each sector:

Economic Impact

Higher petroleum prices will affect the economy generally, shifting employment from one sector to another, changing the amount of employment in each state. However, the shifts will be mitigated by substitution of energy sources (e.g. natural gas for gasoline), gains in efficiency and

changes in behavior. If petroleum prices rise, economies all over the world will be affected and the relative efficiency of the United States economy to other economies will also modify the impact.

Land Use and Travel Behavior

Land use and travel behavior are heavily influenced by auto operating cost (AOC). AOC has two major components, the cost per gallon of gasoline and the fuel economy (mpg) achieved by each vehicle. Each of these is discussed below:

Gasoline Prices – In early 2007 the U.S. had an average price of gasoline of \$2.12 per gallon. The Energy Information Administration (EIA) recently the projected price for gasoline in 2030 under normal conditions would be \$3.64 per gallon in constant dollars (12). . However, gasoline prices have been very volatile in the last three years, ranging anywhere from \$2.50 per gallon to \$4.50 per gallon. Price surges have occurred and price declines have also occurred. Forecasting the future price of gasoline is very risky at best.

Fuel economy/MPG – Estimates of future year MPG are at best risky, since they depend on the cost of fuel, advances in technology, mandated CAFÉ standards and the rate of turnover in the vehicle fleet. Currently the standards for 2016 are 27.5 mpg and 56.2³ mpg has been proposed for 2030. In terms of the feasibility of achieving these standards, the Argonne National Laboratory has produced a report describing the potential for internal combustion engine technology to achieve increases in mpg by up to 30%, and when combined with hybrid technology, plug in hybrids and other innovations it would be possible to achieve an efficiency of 100 mpg or more (12). Estimating fleet efficiency is also complicated by the rate of vehicle turnover. If the fleet turns over rapidly the average MPG will be close to CAFÉ standards, while if the turnover is slow the average MPG will lag the CAFÉ standards.

As can be seen above, forecasting future auto operating cost is a very uncertain process. Nevertheless, the impacts of a potential change in AOC can be estimated.

Land use

A steady price rise in AOC would likely bring activities closer together in clusters, allowing trips to shorten. If the AOC rose steadily intermediate applications of the land use model would be required to reflect the changes in land use patterns which occur as prices rise.

Travel Behavior

The overall effect of an increase in AOC would be to shorten trips, possibly eliminate some trips, increase ridesharing and, where available, increase the use of transit. In the longer term fuel efficient vehicles would replace vehicles currently in service, thereby mitigating the impacts.

Price Surge

A price surge would have an impact on the economy, land use and transportation but the immediate effects would be focused on the transportation sector. The economic and land use sectors are slower to change than the transportation sectors and would take longer to show a

³ On the date this was prepared a CAFÉ standard of 56.2 mpg for autos had been proposed for 2030.

response. Within the transportation sector the primary initial response would be in the form of changes in travel behavior. Likely responses would include fewer trips, more ride sharing, shorter trips and, where available, greater use of transit. Within driving patterns more direct routes may be preferred to faster routes.

4.4. Scenario Definition

In this case study we estimate the impact of a sudden price surge in gasoline on travel. Due to the uncertainty of forecasts for both mpg and the cost of gasoline, we have chosen a base auto operating cost of \$0.12 per mile and a high price auto operating cost of \$0.42 per mile. The high price AOC is equivalent to gasoline being priced anywhere from \$12.00 per gallon to \$16.00 per gallon and fuel economy between 28 and 38 mpg. The scenario assumes that auto operating cost jumps from \$2.90 per gallon in 2029 to a much higher price in 2030. Because of the sudden price surge the scenario assumes there is not sufficient time for land use or the economy to respond to the price change. The scenario compares travel behavior from three alternatives:

1. The 2007 land use and transportation systems
2. The 2030 constrained long range plans for counties in mega-region with an AOC of \$.12 per mile
3. The 2030 constrained long range plans with an AOC of \$.42 per mile.

5. HIGH ENERGY PRICE SCENARIO FINDINGS

There is a wide range of possible analyses which can be conducted using the framework and also a wide range of possible indicators which can be used. The specific analyses conducted and the indicators used will depend on the issues to be addressed and the time frame for viewing results. The mega-regional framework for the Chesapeake Bay Mega-Region contains a number of different modules which can be analyzed for each scenario run, including economic, land use, transportation, environmental and fiscal modules. A matrix has been developed to illustrate the range of indicators which can be applied. The matrix is presented in Table 1, below.

Theme	Area	Indicator
National Economy	Economy	Change in regional output & activity (employment/population) Change in commodity flow forecast (which drives truck trips)
Land Use	Relocation	Sub-regional activity growth (relocation/sprawl) Change in population and employment
Transport	Truck travel	Number of trips by purpose
	Passenger travel	Trip lengths Mode choice by purpose (for passenger travel only) Vehicle miles traveled (VMT) Travel costs and regional patterns
Indicators	Air quality	Greenhouse gas emissions
	Water quality	Nutrient emissions
	Fiscal costs	Public infrastructure costs
	Potential regional economic impact	Effect of energy costs and changes in travel costs on local economy

Table 1 – Multi-Dimensional framework analysis

Using the high energy price as an example, a long term analysis of the effects of a price rise would involve changes in the economy, changes in land use, changes in transportation and Changes in indicators such as air quality, water quality, local fiscal impacts and mega-region economic impacts. An which focused on national economic growth policy might begin with changes to the nation economy and model the flow of those policies into the mega-region economy, land use and transportation.

The proof of concept uses Vehicle miles traveled (VMT) and Vehicle hours traveled (VHT) as indicators of the impact of a sudden surge in energy prices. While a range of other indicators would be informative, these represent the magnitude of an initial response to an energy price surge.

Figures 5 and 6, below, present the preliminary results. The results are presented by state. As can be seen the largest changes are in Maryland and Virginia since these states comprise most of the mega-region. From these results it is apparent that both VMT and VHT increase between 2007 and the 2030 baseline due to the population and employment increases between these years. Of greater interest is the decline in 2030 of both VMT and VHT in a high energy price scenario. In all cases VMT decline to a greater degree than VHT. While further analysis is called for to fully understand these results, it would appear that under a high energy price scenario drivers become more concerned with the distance of the trip than the travel time involved. The transportation module is heavily influenced by changes in the auto operating cost. Likely effects include shorter trips and, where available, shifting from highway to transit or shared ride. The shift to transit and shared ride is not likely to be significant given that the only transit service readily available is in the Baltimore-Washington area, which covers a small portion of the mega-region.

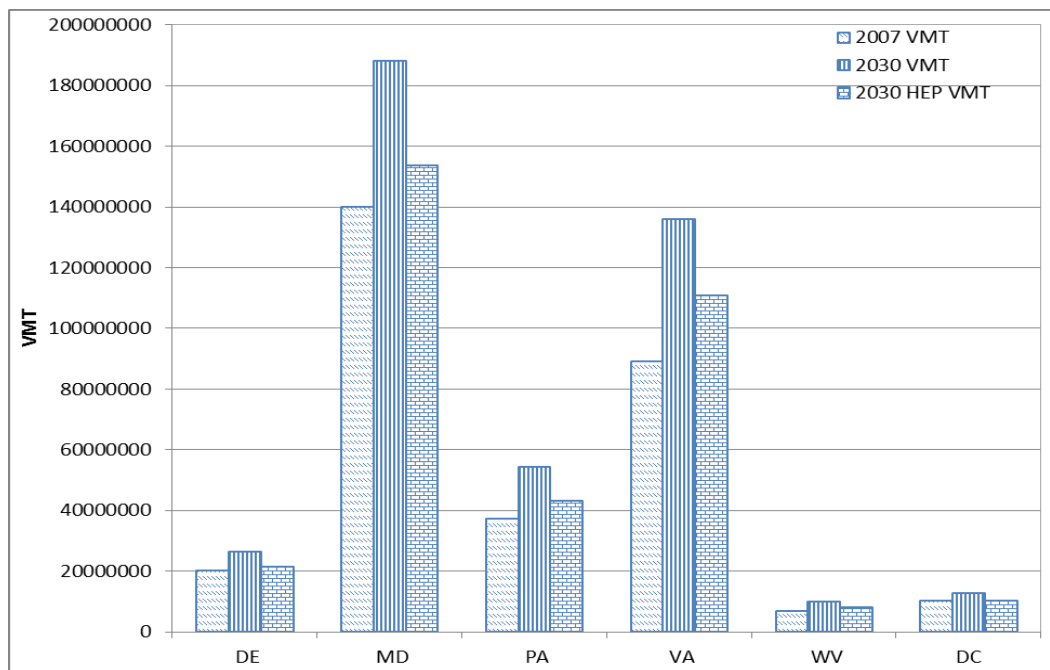


FIGURE 5: Comparison of VMT for the 2007, 2030 baseline and 2030 High Energy Price Alternatives

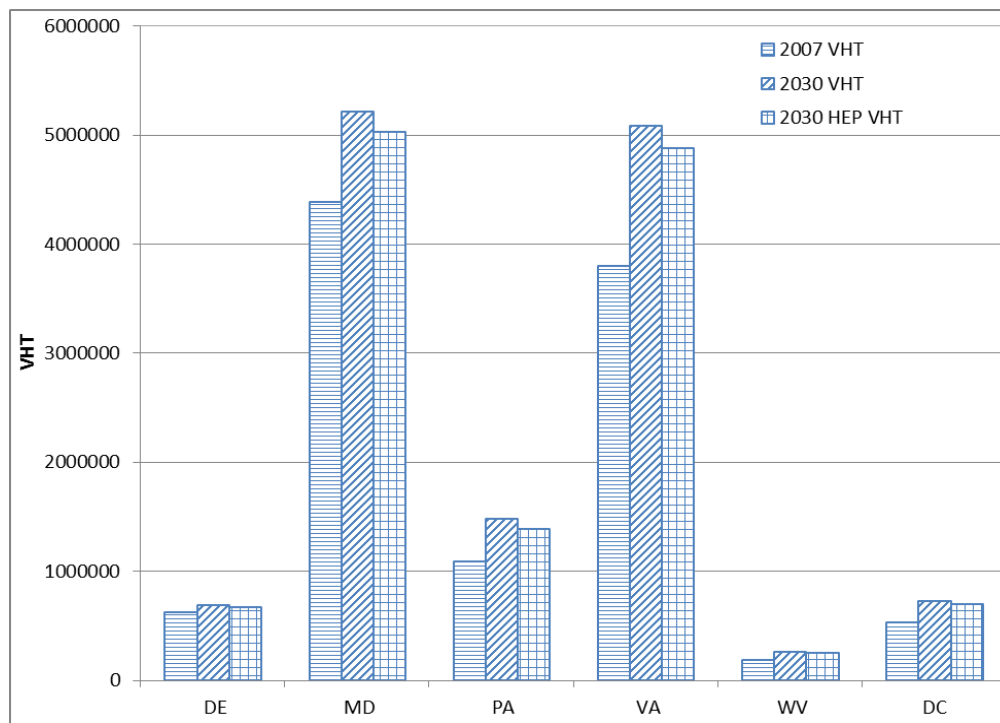


FIGURE 6: Comparison of VHT for the 2007, 2030 baseline and 2030 High Energy Price Alternatives

The results presented above are preliminary. Future research will include analyzing mode choice, testing the land use model in coordination with the travel models and examining the impact of changes in travel time on the mega-region economy.

6. IMPLICATIONS FOR A MEGA-REGIONAL PLANNING BODY

The scenario analyses suggest that higher energy prices will be a burden on the economy, personal travel and freight flows. However, the negative impact of higher energy prices may be mitigated by appropriate advance planning. A sudden and unexpected price spike, however, results in a significant burden and turns into a challenge for society to maintain the same standard of living. Planning for higher densities, improving public transit and reducing auto-dependency may help setting up a region for future energy price surges that are likely to exceed current price levels by far. A region that is prepared and adjusts economic, land-use and travel behavior over time is likely to cope with higher energy prices more easily than a region that is taken by surprise.

A mega-region is defined by close interactions between different metropolitan areas, often covering several states. If each planning authority within the mega-region pursues an individual strategy to prepare for higher energy prices, the concept will be less efficient. If a neighboring metropolitan planning agency continues to develop land for low-density urban

sprawl, a transit-oriented denser development may not be as successful before the energy price increase hits. A transit system that does not well integrate across all metropolitan areas in the mega-region is less efficient, and therefore, is likely to attract less ridership. Congestion management strategies, such as tolling, HOV lanes or freight corridors that end at the border of one jurisdiction and are not continued across the entire mega-region are certain to be less effective. A mega-regional planning approach offers the unique opportunity to strengthen economic, societal, transportation and environmental conditions throughout the entire region.

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