A Framework for Mega-Region Analysis: Development and Proof of Concept

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*The views expressed do not necessarily represent those of the University of Maryland, the Maryland Department of Transportation, or the State of Maryland.

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EXECUTIVE SUMMARY

In many parts of the world mega-regions, large agglomerations of metropolitan areas and their supporting hinterlands, represent an emerging development pattern. Examples in North America include the Northeast corridor in the United States covering Boston, MA to Richmond, VA and the industrial areas of the United States and Canada surrounding the Great Lakes. 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. To effectively function and to allocate scarce resources to infrastructure investment, mega-regions must not only understand their relationships with other mega-regions, but must also understand their own region's internal economic flows and the interactions between these flows and the transportation system.

Analytic methods are needed to address issues at the mega-region level. This report first proposes an analytic framework for analyzing mega-region issues, then develops a proof of concept application of the framework to the Chesapeake Bay mega-region (CBM)

MEGA-REGIONAL ISSUES

The recommended analysis framework applicable to any mega-region is structured in part based on issues which must be addressed at this level. Many planning decisions are more appropriately made at the mega-regional level than at the traditional MPO or state level. The larger scale is relevant in cases of spillovers between areas, economies of scale, demand heterogeneity, and administrative cost efficiencies. While the mega-region issues may be similar to those addressed by MPOs, the scale of the issues is significantly different from those faced by an MPO or even state government and the impact on economic competitiveness is also critical.

FRAMEWORK

An analytic framework for a mega-region would include three considerations not typically found in current Metropolitan Planning Organization (MPO) and statewide models:

- **Study area definition** –Mega-regions are defined by naturally occurring economic, demographic and environmental factors rather than political boundaries.

- **Economic issues** – For a mega-region economic competitiveness is paramount, with transportation, land use, and the environment means to support a vibrant economy. Thus, mega-region models should be driven by a national economic model, as well as including analysis of key industry sectors and goods movement flows within the mega-regional economy and linkages to transportation system. The transportation needs of these economic flows provide a key input in decisions regarding new infrastructure investment at the mega-regional level.

- **Interaction with other mega-regions** – Due to the geographic size of the mega-region, it is important to model the economic and long distance transportation interactions with other mega-regions and the rest of the country.

The mega-region analysis framework must include short- and long-distance travel and freight as well as passenger movements. As such, it is more appropriate to employ integrated models where travel is driven by economic and land use decisions, and employ a multi-level model where activities are assessed at an appropriate national, regional, or local context reflecting the scale at which the phenomenon occurs. Such a suite of models would aspire to address:

- Economic, Transportation, Land Use and Environmental Impacts.
- Multi-Modal Transportation Systems.
- Short- and Long-Distance Travel.
- Multi-Scale Projects.
- Diversified Mega-Region Context.

Since mega-regions encompass a larger area than typically covered by MPOs or DOTs, a larger analytic view is required. This requires the inclusion of economic motivations for travel and a focus on longer distance inter-city freight and person travel. Local detail must remain to enable sensitivity to policies where changes in local conditions may impact the region and where evaluation of performance measures requires such detail.

A multi-tiered approach with three layers represents the context for travel decisions by the market segments important to mega-regions. This approach facilitates the integration with existing local models. Probably most important is to tailor this framework to the policy questions of the particular mega-region.

Mega-region models must consider both short and long distance trips. The explicit distinction between short and long-distance travel has behavioral and technical implications for the framework. In terms of travel behavior, long-distance trips differ significantly from short-distance trips due to differences in travelers' income, mode and destination choice, and trip purpose. Limited information also affects time of day, mode selection and route selection; while longer trip lengths may reduce sensitivity to congestion and costs of travel.

Figure 1 Mega-region analysis framework

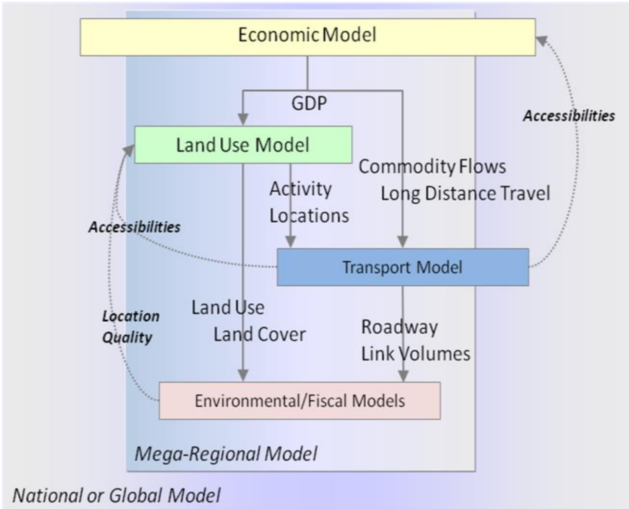


Figure 1 shows the model components recommended for mega-region analysis. The Mega-region analytical framework is built on the economy. The economy defines the region geographically and serves as a driver for activity locations and associated travel demands. A land use model allows the analysis of coordinated policies that can work towards efficiencies rather than competitions Indicator models are important measures of performance. The data flows and feedbacks between them that reveal the complex interplay of forces.

The level of detail, at which each element of the framework operates, very much depends on the policy questions that are likely to be asked. The following describes each of the framework components.

Economic model (yellow in Figure 1). Changes in the national economy will have effects on the mega-region, both with respect to growth in population and employment and trade with other mega-regions. Important economic interactions occur at geographies that are larger or smaller than political units, or at a scale comprising many smaller units. Larger and/or more complex geographies may better represent the spatial dimension of the most successful integrated economies. In addition, the economic model should interact with other mega-regions and the national economy.

Land-use model (green in Figure 1). The land use model forecasts the likely location of future population and employment.

Transport models (blue in Figure 1). Transport models forecast the number of trips made, origins and destinations and mode. They do this for short and long distance passenger trips and short and long distance freight trips.

Indicator models (pink in Figure 1). Indicator models are post-processor models which are used to address specific issues of a mega-region. Examples are air quality, water quality and local economic impacts.

Implementation

The specific policy issues and conditions of each mega-region will guide the application of this framework. In each application the region should carefully review the local conditions, issues to be addressed and data available, and design the analytical framework (models) with these in mind.

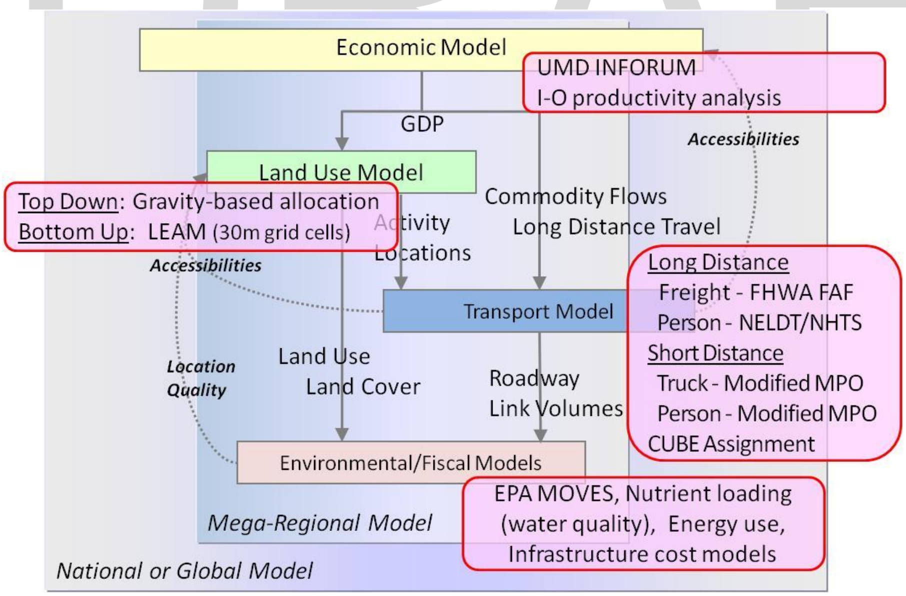
The framework as described includes the traditional gravity model for trip distribution and static assignment techniques for network analysis. More advanced methods such as activity based demand models and dynamic assignment techniques may improve theoretical accuracy particularly relevant for some policies, but should be carefully considered and weighed against the analytic needs (issues and performance measures) and the state of the art in modeling before being implemented.

Case Study Application

The Chesapeake Bay Mega-Region demonstration uses the Maryland Statewide Transportation Model (MSTM), originally developed for the Maryland State Highway Administration. In the MSTM a national economic model forecasts basic employment at the statewide level. This employment is further disaggregated to counties and then to zones. Local serving employment is then estimated from basic employment and finally residences are located. Short distance travel is estimated based on a local MPO model. The economic model also informs freight movements. Using data from the Virginia statewide model to cover the Chesapeake Bay Mega-Region area, the model was expanded to cover the eastern portion of Virginia. Transport models adopted from local MPOs were upgraded and indicator models added.

Figure 2 shows the implemented Chesapeake Bay Mega-Region analysis framework. A market analysis assessment of the CBM region revealed key issues, urban area strengths, industry clusters, and available data and models. The resulting modeling framework has been designed with sophisticated long distance person and freight components as well as strong short distance person mode choice and pricing components given the region's high transit usage and regional issues of interest. Upgrades to short distance models initially borrowed from MPOs has occurred based on needs identified in validation and sensitivity testing.

Figure 2 Chesapeake Bay Mega-Region Analysis Framework



The implemented components can be summarized as follows:

- **National Economic Model.** A proprietary national economic forecasting model built by the INFORUM group at the University of Maryland was applied. It forecasts marginal consumption and production in 65 economic sectors and allocates these forecasts to states. These allocations are also used to adjust the marginals of the FHWA Freight Analysis Framework multi-modal commodity flows.

- **Land Use Model: Zonal Level Allocation**. State level forecasts of basic employment are allocated to counties based on historic patterns of development. Population, followed by retail and service employment are then allocated to counties in 5-year increments. In the horizon year of 2030, a Lowry (gravity-based) top-down land use model then allocates county population and employment totals to model zones.

- **Land Use Model: Parcel Level Detail**. A Cellular Automata model, (LEAM model) calculates probabilities of the potential for each cell to change from one land-use category to another, influenced by adjacent cells. This model was used only for water quality estimates and is described further in Appendix D, indicator models.

- **Transport Model: Long-Distance Freight**. The truck portion of the economic model's commodity flow output is disaggregated from FHWA FAF zones to model zones using employment data and inter-industry input-output relationships. Truck trips are assigned to a U.S. network with flows within the mega-region added to traffic projected by other model components and assigned to a more detailed network. Exogenous adjustments to mode shares can be applied; reflecting commodity-distance specific rules and local market knowledge (e.g., rail capacities).

- **Transport Model: Long-Distance Person**. The Nationwide Estimate of Long-Distance Travel (NELDT) model using NHTS long-distance travel data and traveler attributes forms a national model of long-distance travel. This travel is assigned to a full U.S. network with flows within the mega-region added to traffic projected by other model components and assigned to a more detailed network.

- **Transport Model: Short-Distance Person**. A 4-step travel model from one of the local MPOs was transferred and applied region-wide. Trip purposes, mode choices, and socio-economic data were standardized and applied region-wide. The gravity-type trip distribution model was upgraded to a destination choice model to better address differences in trip lengths and to incorporate regional differences in modal options. The mode choice model may be updated to include a tolling option, and to cover both short and long distance modal choices, subject to policy scenarios.

- **Transport Model: Commercial Vehicles**. A local MPO model's commercial vehicle model (simulating both service-oriented non-freight trips and freight-carrying truck trips) was transferred and applied region-wide.

- **Transport Model: Assignment and Time of Day.** A local MPO model's roadway, transit networks and volume-delay functions (were borrowed and standardized. Additional US networks were pulled from GIS/travel assignment software packages and intercity rail/air modal options were added. CUBE software is used for assignment consistent with the state's MPO models. Time of day factors were developed from Maryland Department of Transportation traffic count data and MPO models.

- **Indicator Model: Greenhouse Gas Emissions.** The EPA MOVES model uses fleet assumptions, modeled VMT and link-level volumes and speed data output by the travel model to estimate GHG and other mobile emissions.

- **Indicator Model: Water Quality.** A nutrient loading model uses detailed land cover changes from the parcel-based land use model to identify changes in nutrient runoff experienced in each watershed. (Note: The current model estimates impacts only from Montgomery County and not from the entire Chesapeake Bay watershed.)

- **Indicator Model: Infrastructure Costs.** An infrastructure cost model forecasts needs based on relationships between urban/rural development and the provision of infrastructure required for the forecast development pattern. The fiscal indicator model has been developed to reflect conditions and costs in Maryland.

- **Indicator Model: Regional Economy.** An input-output analysis was used to determine the connectivity of economic sectors within the mega-region.

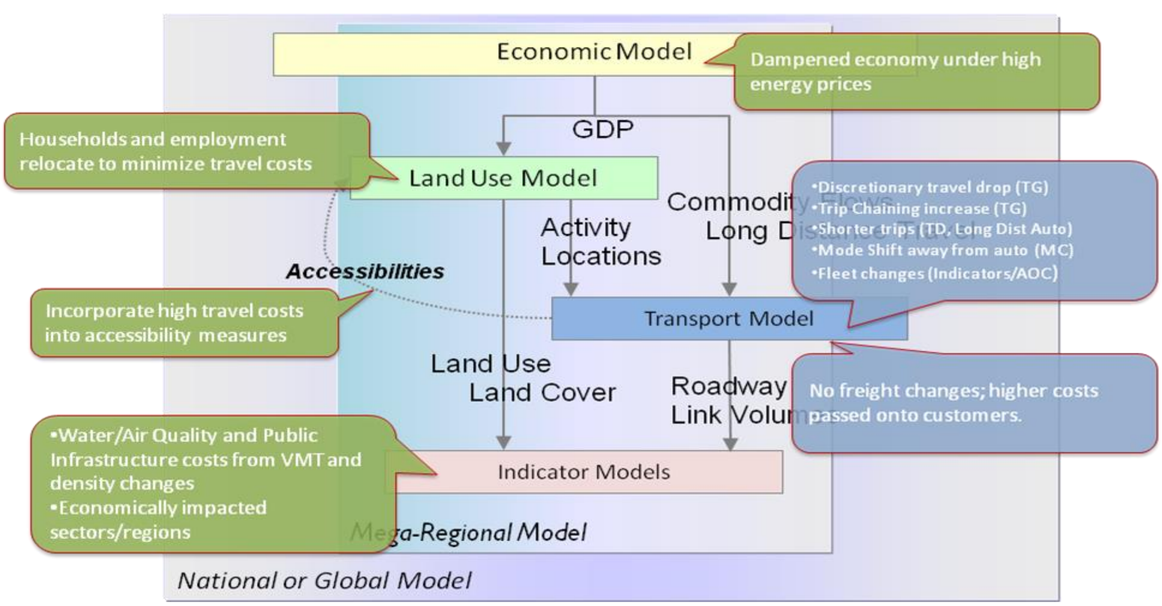
This enables assessing the feedback of how transportation improvements might affect the economy in particular corridors and industries. **NOTE:** This section will be updated at a later date.

HIGH ENEGY PRICE SCENARIO

To exercise the analysis framework on CBM issues, three possible future energy price scenarios were identified spanning the possible effects: **Reference**, in which the price of petroleum rises slightly and MPG remains the same; a slow **Steady Price** rise, in which the price of petroleum rises to a high level but slowly over a long period of time, allowing people and the economy to adjust; and a **Price Spike** in which the price of energy remains relatively constant through 2029, then jumps to a very high level in a very short period of time.

Several components of the basic Chesapeake Bay Mega-Region Model noted above were enhanced to test the scenario of an energy price surge. These changes are exhibited in Figure 3.

Figure 3 Chesapeake Bay Mega-Region Analysis Framework- High Energy Price Sensitivities

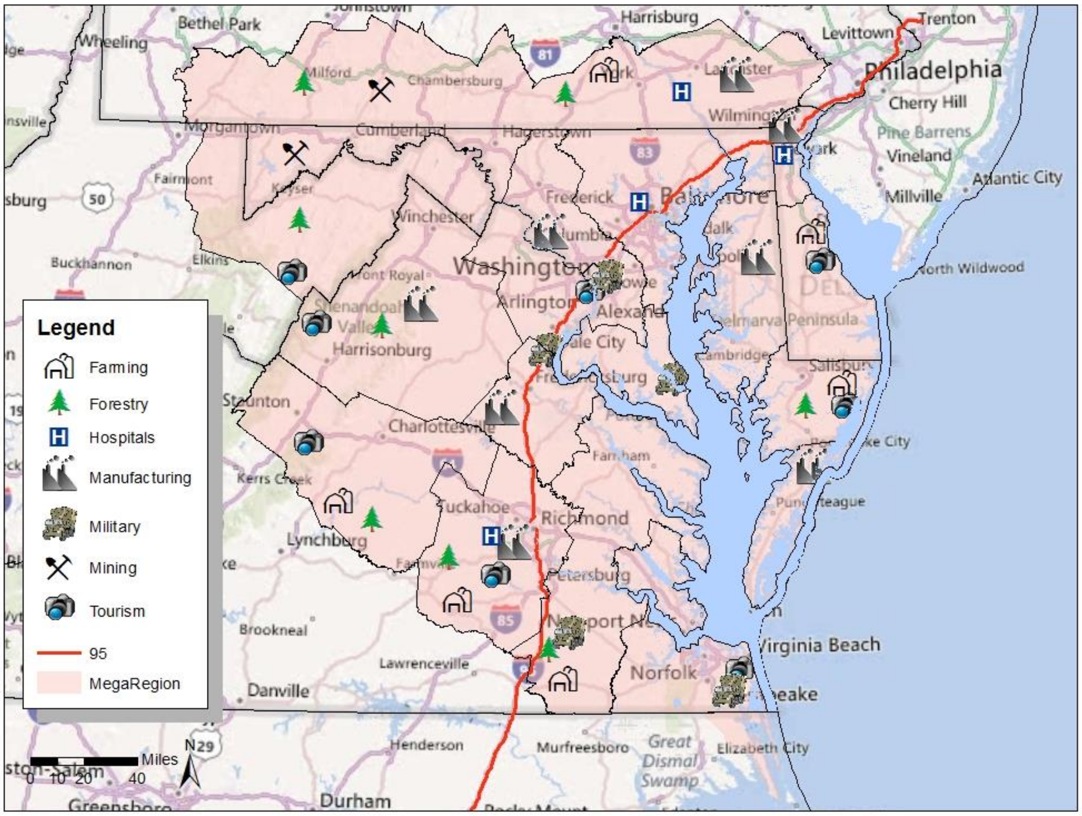


Regional Characterization 2007- 2030

The regional characterization of the CBM shows that the CBM economy is closely knit (Figure). The region has a dominant spine running north-south along the I-95 corridor from Wilmington, DE to Hampton Roads, VA, which houses the urban services of hospitals, military bases, and manufacturing. The manufacturing spills east and west into areas with supporting areas dominated by natural resource (farming, forestry, mining), and recreation services. Significant economic flows occur between subareas of the mega-region, as measured by the value of shipments. The north south movements, particularly along I-95, are historically important and likely to grow, highlighting linkages along the full north-south spine of the mega-region. At the same time, with the dispersed location of employment growth as transport costs remain low, the need for expanded transportation infrastructure to serve east-west economic movements increases in the future.

In 2030, due to growth under assumed continuation of low transport costs and the challenge of absorbing more growth in the dense urban areas, more development occurs in suburban and rural areas. Policies that encourage the development of more compact communities with mixed land use would allow for trips with multiple purposes to be satisfied within the same general area. Areas with densities high enough to support transit could partially accommodate future growth through additional transit service.

Figure 4 CBM Inter-dependencies



Steady Price Rise

While the case study focused primarily on the scenario of an energy price spike, a forecast of the effect of a steady price rise on employment sectors was conducted. The conclusion from this forecast is that with forewarning and appropriate energy price signals to influence long term decisions such as business and residential location and vehicle purchases, the mega-region's economy and transportation system is resilient to weather the long-term impacts of a steady energy price rise.

Sudden price rise

A sudden energy price spike, in contrast to the steady rise, would likely have a more immediate impact, primarily on travel but also on the economy.

Residents can be expected to reduce the number of trips, change trip destinations to allow for shorter trips, make more direct routes and chaining of multiple trips, as well as increase the use of any alternative transportation options available to them, such as carpooling and transit services.

In the Baltimore-Washington area, where a wide range of transit options are available, the analysis showed a significant increase in transit ridership. In contrast, outside the Washington D.C. suburbs urban areas in Virginia do not have a high level of transit service and instead shifted to carpools and shorter trips. The analysis highlights the non-urban and low-income communities are more vulnerable to rising energy prices. The resulting drop in personal auto vehicle miles traveled lead to congestion relief, with congested speeds an improvement relative to 2007 levels.

For freight movements, the economic impact of a price spike would be mixed. The case study makes two assumptions with respect to freight. First, the cost of shipping is borne primarily by the shippers, not the freight carriers, reflecting long-term contracts. Second, in industry processes, particularly those requiring assembly of intermediate goods and shipment for final assembly, destinations cannot be easily be changed. Thus, by lowering congestion the decrease in traffic can actually have a net benefit to freight and the economy. This benefit can be particularly important for shipments which are high value and /or time sensitive. Particularly in urban areas they were able to move more quickly due to the reduction in person travel, and associated congestion relief.

Combined Policy Impacts

A Mega-Region Board (MRB), a hypothetical body charged with planning for a mega-region, could use tools similar to those in the case study to analyze policies in isolation or combination, to determine their collective effect on the mega-region and on local jurisdictions. In the mega-region view, policies in one jurisdiction can have spillover effects on the rest of the mega-region. Individual areas can develop policies which are optimal for one area but have negative effects on adjacent areas. Within the mega-region, with the linkages spanning many jurisdictions, the spillover effects can be wide ranging. For example, policies that attempt to foster economic development in one area may have the effect of removing development from another area.

While this study did not address security issues directly, the threat is particularly severe in the Chesapeake Bay Mega-region, home to the nation's capital and numerous military bases. For example, an evacuation from Washington, DC would likely tie up the entire I-95 corridor, affecting traffic flows from Philadelphia to Richmond and beyond. In the event of a natural disaster such as a severe hurricane, travel through the CBM could be disrupted and it would also be critical to move relief supplies in and people out. This type of planning can only be accomplished at the mega-region level, and the CBM analysis tool would provide a great framework for such study.

NEED FOR MEGA-REGION VIEW

This case study identified other factors significant to a mega-region body; the fact that the CBM is tied together economically and that in addition to land use, transportation and the economy, the CBM should address specific policies at the mega-region level, such as emergency preparedness and the collective impact of individual local policies. The analysis framework has helped to identify these policies. The framework could also serve to test the impact of implementing such policies in a coordinated or uncoordinated way across the jurisdictions within the mega-region.

On a technical level, the project demonstrated that data from multiple sources can be combined to develop a multi-discipline, multi-level model and that the model can be applied on a large geographic scale encompassing a key US mega-region. On a policy level the project demonstrated the impacts of high energy prices on the economic, land use, transport, and environment of the region as a whole as well as highlighting vulnerable communities and industries. The case study characterization and scenario analysis of highlighted how the CBM is linked together economically and the value of analyzing a wide range of issues with a broad mega-region perspective.

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1 Introduction

1.1 Background

The Federal Highway Administration (FHWA) contracted with the National Center for Smart Growth (NCSG) at the University of Maryland to conduct research on "mega-regions."[1] A typical mega-region is defined as a set of interconnected central cities and their economically linked hinterland. The concept of mega-regions derives from the observation that as urban regions growth and transportation and communication links improve, it is in their best interest for multiple urban areas to act together as an economic unit.

The specific objective of this research project is to (1) recommend a framework for mega-regions to use in analyzing issues and (2) test the ability of the framework to provide a suite of forecasting and evaluation models using the Baltimore / Washington D.C. / Richmond / Norfolk mega-region (referred to here as a the Chesapeake Bay mega-region, CBM) as a case study. This report covers the results of this project. The report includes:

Mega-region Concepts and Framework

- What is the need for mega-regions? What issues do they faces and what is important about viewing issues from the mega-region perspective?
- How should an analysis framework for modeling of a mega-region be structured? What components should it contain and how should those components be designed and interact.

[1] The full research team includes ECONorthwest, Parsons Brinkerhoff, the LEAM Group of the University of Illinois at Urbana/Champaign, and David Simmonds Consultancy.

Mega-region Case-study/ scenario development

- How is the Chesapeake Bay Mega-region characterized? What are the boundaries of the mega-region, what are the economic land use, and transportation linkages? What other issues are of concern (e.g. greenhouse gases, health of the Chesapeake Bay and the local fiscal impact of growth).
- What are the key issues for this Mega-Region? How was the High Energy Price scenario selected and what are the assumptions behind it
- What is the analysis framework used for this case study? What modifications or adjustments are made to the recommended framework previously presented. How did the framework evolve for this region and to address the chosen scenario?
- What are the results of the scenario? What can be said about the current and future economic, transportation and land use results. What can be said concerning environmental impacts and impacts on the mega-regional economy.

Mega-region Board

The case study assumes that there is a mega-region board with concern about policies and developments within the mega-region.

- What would the case study tell the board about economic, land use and transportation policies and investments under a high-energy price scenario?
- What is the value and importance of the mega-region view of these issues.

Appendices

The appendices contain important supplemental information about mega-regions in general and the technical details the technical aspects of the case study. Appendices include:

Literature Review

- Mega-region Examples
- Mega-region issues and value

Case Study input data

- Zone system and networks
- Socio demographic data – economic and land use models

Case Study Framework

- Mega-region economic, land use, transport model methods
- Model adjustments and assumptions for the High Energy Price Scenario

Case Study Indicator Models

- Mega-region indicator model methods (Greenhouse Gas emissions, nutrient loading, public infrastructure fiscal costs, economic post-processor)

2 Mega-Region Concepts

2.1 The need for a mega-region view

The expansion of major metropolitan areas over the last several decades, facilitated in part by investments in auto-oriented transportation infrastructure, has resulted in the integration of large polycentric urban agglomerations, or "mega-regions." With the baby boom generation entering retirement at a time when this cohort has amassed considerable housing wealth and with the increased mobility of highly educated workers, mega-regions are becoming the typical urbanization pattern. By as early as 2050, they will contain two-thirds of the nation's projected 430 million residents (Amekudzi, Thomas-Mobley, Ross 2008; Carbonell and Yaro 2005). [2]

These new urban patterns create new opportunities and challenges for planners and policy makers. On the one hand, mega-regions offer distinct agglomerative benefits that make such areas more competitive in the global marketplace. Mega-regions have a sufficiently diverse economic and land supply base that the entire value chain of a given multi-national firm would be able to locate its different functions within the region rather than off-shoring activities for different functions (Sassen 2007). On the other hand, mega-regions extend beyond traditional

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[2] This paragraph is taken from the Literature Review, Appendix A

political boundaries, making policy implementation and coordination much more difficult, particularly given the dearth of mega-regional institutions.

2.2 MEGA-REGIONAL ISSUES[3]

Mega-regions comprise the economic engine of the US, forecasted to contain half the nation's population growth and perhaps up to two-thirds of its economic growth by 2050 (Amekudzi, et al. 2007). Supporting the economic competiveness of these regions domestically and abroad is a key concern given increasing global competition and international trade. A primary justification for addressing policy issues at a mega-regional scale as opposed to the metropolitan scale is that regional economic activities are increasingly linked in such a way that economic shocks to a given metropolitan area result in spillovers, both positive and negative, to adjacent metropolitan areas. As a consequence, the resultant environmental and social impacts associated with such activities likewise spill across metropolitan areas. Furthermore, as pointed out by Christaller (1933), Lösch (1954), and Ross and Woo (2009), individual cities are part of larger systems that are linked by inter-city trade hierarchies.

Mega-regions are a development pattern evident throughout the world. Examples in North America include the Northeast corridor in the United States covering Boston to Richmond and the industrial areas of the United States and Canada surrounding the Great Lakes. The Federal Highway Administration's Strategic Plan[4] states that mega-regions are likely to be 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

[3] Section 2.1.1 is based on the paper Mega-Regions develop as complex systems: Horizontal and vertical integration for a Mega-Region Simulation Model Submitted to ASCE by Moeckel, Rolf; Mishra, Sabyasachee, Ducca, F and Weidner Submitted to ASCE November, 2011 and the Literature Review

[4] Federal Highway Administration (FHWA) Strategic Plan, FHWA-PL-08-027. (Revised, March 2010)

system." [5] Indeed, the economic engines of European and emerging countries also reside in mega-regions often bound by high-speed rail.

Mega-regions now compete with each other for economic development as well as complement and connect each other. They also face internal economic issues and demands for infrastructure investment. Unlike states and MPOs which are defined by political boundaries, mega-regions are defined by unifying economic, demographic or environmental factors. Mega-regions may have significant effects on the national economy and connectivity within and between mega-regions will be a critical issue. Indeed, mega-regions dominate the coveted knowledge workers of the 'creative class', encompassing over 60% of U.S. counties with higher than average share of such populations.[6]

Many planning decisions are more appropriately made at the mega-regional level than at the traditional MPO or state level. The larger scale is relevant in cases of spillovers, economies of scale, demand heterogeneity, and administrative cost efficiencies. Through a comprehensive literature review as well as experience working on specific projects, issues and models, the team has identified issues that ought to be addressed at the mega-regional level.

Policy issues exhibiting the following characteristics are most appropriate for a mega-regional level of analysis:

- Issues involving large spillovers which extend beyond existing local, regional, and possibly state governance arrangements but not to the scale of the entire nation. Investments involving large-scale economies which are exhausted at the mega-regional scale.
- Issues for which public sector demand is relatively homogeneous at the scale of the mega-region.

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[5] Appendix A, the literature review, contains a detailed discussion of the evolution toward mega-regions and issues which Mega-regions face.

[6] From Lang, Nelson, Megapolitan America, (2011). It uses the USDA's Economic Research Service classification and data which expands on Richard Florida's 2002 book, The Rise of the Creative Class.,

- Issues which involve a redistribution of resources across metropolitan areas or states but which benefit from local (mega-regional) knowledge regarding the nature of the redistribution.
- Issues that can be addressed with low administrative costs at the mega-regional scale. If there are economies of scale in administration, then mega-regional governance would be preferred to local governance arrangements.

Specific examples of issues that are more appropriately addressed at the mega-region level are described below;

Environmental

The following environmental issues are best suited for a mega-regional policy framework:

Climate change. Air quality issues can go well beyond metropolitan borders. Greenhouse gases are a worldwide issue and larger units of analysis are critical to addressing the problem. The Regional Greenhouse Gas Initiative (RGGI) is an agreement among ten Northeastern states to regulate emissions from power plants through a "cap-and-trade" system, where limits are placed on the total pollution emitted from power plants, and emissions permits can be bought and sold to meet carbon emissions standards (Todorovich 2009). This issue is best addressed at the mega-region scale when heavy polluters cannot easily avoid cap-and-trade regulations by relocating to other mega-regions. Larger-scale climate changes produced by non-point source pollution, and the resultant impacts including sea-level rises and destruction of property and infrastructure along the coast, are also appropriate for mega-regional policy intervention.

Mega-region water resource management. Like air quality, water quality issues can be larger than a metropolitan area. If water quality is to be effective analyzed, the entire watershed of the body of water in questions must be included in the analysis. The Great Lakes Commission was established in 1955 to govern water resource management through a compact agreed upon by the eight states surrounding the Great Lakes. The Commission provides recommendations for the use and conservation of water, public works and improvements, improvements to navigation and ports facilities, and other strategies which serve to protect water quality within the Great Lakes Basin (Great Lakes Commission n.d.).

Transportation

Transportation is key to economic linkages within the mega-region.

High-speed rail. High-speed rail systems connecting metropolitan areas within a mega-region is frequently cited as a mega-regional issue. High-speed rail provides an intermediate form of transportation, faster than an automobile but slower than air travel. However for intermediate distance trips, those which require faster travel time than the auto but are not necessarily long enough require the boarding delays and access times associated with air travel, high-speed rail can be competitive. In Europe, high-speed rail unites mega-regions increasing their reach for labor expertise and agglomeration, thereby incurring competitive advantage for the region. The Southern California Mega-Region is currently developing plans for a high-speed rail system that relies on magnetic levitation (Maglev) technology to connect regional airports to urban centers such as Los Angeles, Riverside, San Bernardino, and Orange County. When finished, the system will cover 275 miles and move up to 500,000 riders per day (Kern County Council of Governments, et al. 2005). The introduction of new high-speed rail systems might also result in significant changes to other travel modes, such as regional air travel, suggesting a need for mega-regional coordination of multi-modal facilities.

Management of congestion on interstate highways through coordinated tolls and congestion pricing. Improvements in transponder technology now make congestion pricing important at a mega-region scale. If technologies differ between metropolitan areas, such pricing strategies will be more costly to implement and cumbersome for users (Glaeser 2007). For example, the E-Z pass toll collection system provides a uniform pricing technology for those traveling along I-95 in the Northeast. This technology was made possible through the I-95 Corridor Coalition, an alliance of state departments of transportation, metropolitan planning organizations, law enforcement agencies, and transportation industry associations that span the length of I-95 from Maine to Florida (Todorovich 2009).

- **Freight movements**. Much of freight involves long distance movement represented at the mega-region level, requiring a larger analysis area than a state or MPO model; particularly when analyzing tradeoffs between highway and rail.

- **Multi-urban area policies/investments**. Cumulative impacts of policies implemented across multiple urban areas, such as growth management or freight infrastructure investment. The planning efforts for the I-95 corridor on the east coast are a prime example. Disaster Response/emergency Preparedness planning involves multiple jurisdictions. Short-term disaster responses (e.g., Hurricane Katrina in New Orleans and 9/11 in New York and Washington) impact the regional transportation network. Long-term disaster responses (e.g., Hurricane Katrina and 2010 Gulf of Mexico oil spill) may have long-term effects on the economy, land use and the transportation system.

- **Port expansion.** The volume of international trade occurring through major U.S. ports is projected to be much higher in the future. Since most major ports are located in mega-regions, estimated trade volumes over the next 25 years are projected to be concentrated within mega-regions (Ross and Woo 2009). This is an issue of importance to mega-regions, because the increased volume of goods flowing into major ports will require significant upgrades to port facilities and freight distribution networks connecting ports to domestic markets.

Economic Development

Economic development often occurs at the mega-region level. Some examples follow:

- **Avoid competition among mega-region industry locations**. In complex manufacturing processes such as the automobile multiple firms may make parts of the final product, then ship them to the manufacturer for final assembly. At the same time Local governments often engage in "smoke-stack chasing," offering tax breaks and other incentives to lure firms from adjacent jurisdictions within the same mega-region. This form of local government competition wastes scarce tax base resources and often incentivizes inefficient firm location decisions. Mega-regional coordination of economic development incentives can help to minimize the incentives to engage in such inefficient local government competition.

- **Capture full supply chain job opportunities**. Mega-regional coordination of economic development incentives can also help to diversify the mega-region's economic base. Most economic development incentive programs focus on top-tier "knowledge economy" industries and ignore low-wage sectors, many of which have moved offshore. By focusing on the entire value chain within a mega-region, Sassen (2007) makes a case for diversifying the package of incentives offered to firms and attracting low wage industries that may have linkages to firms higher up the value chain. Activities such as low-cost manufacturing and back-office functions that are currently outsourced to other countries could be accommodated within a mega-regions' rural areas, because the urban cores of mega-regions are not competing with such functions due to their higher land values and labor costs (Ross 2008).

- **Buy Local keeps money in the regional economy**. Agriculture is another area where coordination at the mega-regional scale can reduce reliance on outside regions for imports, if locally produced foods can be integrated into the mega-regional food supply chain.

Cross-cutting Issues

Several issues appropriate for mega-regional policy intervention span each of the substantive policy domains mentioned above. These include:

- **Mega-regional natural disaster response.** Hurricane Katrina, which struck the Gulf Coast mega-region in 2005, caused massive property damage and widespread displacement in an area that stretches from Pensacola to greater Houston. The decline in population within the area affected by the hurricane and the influx of new residents into cities such as Houston placed heavy demands on public services. It is now widely acknowledged that pre-existing local, state, and federal disaster response systems were inadequate to address the full range of issues posed by the storm. Since the entire Gulf Coast mega-region lay in the path of Katrina's destruction, coordinating disaster prevention and response efforts at the scale of the entire mega-region would have allowed for an assessment of the extent to which assets and population were displaced from affected regions to neighboring regions (Lang 2006). Mega-regional coordination of disaster response networks would have facilitated both a more expansive short-term emergency response in addition to facilitating a more comprehensive long-term rebuilding effort.

- **Other man-made disasters** such as blackouts affecting large power grids and rises in sea levels induced by global climate change point to a role for mega-regional policy intervention.

2.3 MEGA-REGION BOARD

With the grow of mega-regions and the clear identification of issues which are appropriately addressed at the mega-region level, an oversight body or board with the ability to address mega-region issues would be of great benefit to many areas. This body would provide input to decisions which impact the entire mega-region and might have functions similar to those of an MPO, but with a wider coverage area. Depending on how it was set up the board could also have the ability to advise various levels of government on issues related to the mega-region. In particular the board would inform on policies or actions which would impact the entire mega-region. A mega-region board, empowered to address mega-region policy, would address issues which go beyond individual urban areas and which, if not properly addressed, would negatively impact the entire mega-region and the areas within the mega-region.

Such a board would need analytic tools to support their policy analysis. The analytic tools should be able to address issues which the mega-region board would face and be able to be modified to address new and emerging issues. The remainder of this report discusses a framework which can serve as a blueprint for mega-regional analysis.

Ideally, analytical tools (models) should be developed that respond to any of these mega-regional issues. Such a suite of models would aspire to address the following:

Economic, Transportation, Land Use and Environmental Impacts. Mega-Region models must support decisions related to the interactions of transportation, economic, land use, and the environment. Such models will quantify interactions between cities and counties, guide economic investment, the provision of new transportation infrastructure, the location or relocation of a large numbers of workers, and shape policies for mega-region environmental issues. Modeling at the mega-regional level quantifies connections to the economy and captures opportunities for regional shifts in land use. Additionally, environmental impacts and emission are important criteria to evaluate policies.

Multi-Modal Transportation Systems. The modeling framework must be able to evaluate both freight and passenger travel in a multi-modal transportation system. This includes freight modes and capacities (e.g., truck, rail, marine), as well as the various intercity transport modes (e.g., auto, commuter rail, high-speed rail, air travel),

Short- and Long-Distance Travel. The modeling framework should encompass all trip purposes and trip lengths. Besides the common purposes in short-distance travel, the framework needs to address long-distance business, personal, and commuting travel, both within and between mega-regions. Likewise, freight travel can be distinguished between long-haul commodity flow movements and short-distance distribution and service trips, typically by truck. Both short- and long-distance travel needs to be represented in a mega-region model for understanding actions under changing conditions and reflecting network demands and congestion. There are several differences between short- and long-distance travel requiring that separate analyses for each:

- **Timing**. Long distance travel may be made over a period of several days while short distance travel usually returns to a starting point at the end of the day. Long distance trips do not follow the typical AM/PM peaks of short distance trips.

- **Origin/Destination.** The frequency and end points for travel differ between long and short-distance travel. Person long distance travel is more frequently done by high-income households, with destinations ranging from business districts to recreation facilities and parks. Long distance freight is typically business to business commodity-flow based, with some warehousing and wholesaling, while short-distance freight is more retail focused, with home deliveries and services, more amenable to a tour-based approach.

- **Modes.** Long distance trips have different rules for mode choice than short distance trips. Long distance person trips may go by air and may not have public transit as an available mode. Long distance freight is more likely to have modal options.

- **Routes.** In selecting routes, short distance travelers typically have better access to local information about routes and congestion.

These different attributes make it technically challenging to model both short and long distance travel together, warranting separate models within the framework. Given the large number of long-distance trips in a mega-region, the separation of short- and long-distance trip distribution modules improve the overall model performance noteworthy.

Multi-level Projects. The modeling framework should permit evaluations of projects at the mega-regional scale. Examples of projects include high-speed rail, freight corridors, warehouse distribution centers, and port facilities, as well as the cumulative impacts of a broad implementation of smaller scale policy actions. Although the latter is a challenge at the mega-regional scale, the mega-region model should be sensitive to local projects, possibly done in collaboration with more detailed MPO models.

Diversified Mega-Region Context. According to Dr. Ross[7] and America 2050[8], about ten twelve emerging mega-regions in the United States have been identified. These mega-regions vary significantly in terms of size, economy, domestic and international trade partners, existing transportation infrastructure characteristics, available data sources, and policies of interest. The recommended analytical

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[7] Delineating Existing and Emerging Mega-Regions; Report to the FHWA; Georgia Tech Research Corporation. PI: Dr. Catherine L. Ross, Co-PIs: Jason Barringer, Jiawen Yang (2009).

[8] America 2050 Initiative. (http://www.america2050.org/publications.html).

framework needs to be flexible enough to be transferable to any of these emerging mega-regions.

2.4 Framework for Mega-Regional Analysis: Overview

The model framework must be able to respond to the requirements identified above. Since mega-regions encompass a larger area than typically covered by MPOs or state DOTs, a larger analytic view is required. This requires the inclusion of economic motivations for travel and a focus on longer distance inter-city travel by freight and persons. However, some of this local detail must remain to enable sensitivity to policies where changes in local conditions may impact the region and where evaluation of performance measures requires such detail.

Modeling for mega-regions is similar in many ways to the traditional travel models developed by MPOs and State DOTs; trip generation, distribution, mode choice and assignment procedures. However, due to the scope of mega-regions and the nature of issues to be analyzed, mega-region models can also have significant differences from traditional travel models. These differences include:

Interaction with other mega-regions and the nation – Due to the size of the mega-region, at a low level of detail a mega-region model should capture the economic and long distance transportation interactions with the national economy and with other mega-regions and the rest of the country.

Study area definition – Since mega-regions are defined by economic, demographic or environmental factors, these factors must be included in the definition of the mega-region study area. For example, an economic and transportation model addressing water quality in the Chesapeake Bay must include the Chesapeake Bay Watershed.

Economic issues – For a mega-region the economy and economic productivity can be critical issues. Mega-region models typically should begin with an economic model which identifies sectors of the mega-regional economy that would benefit from improved transportation linkages. Along with societal and environmental considerations, the impact of transportation changes on the mega-regional economy can be a key issue in deciding new infrastructure at the mega-regional level.

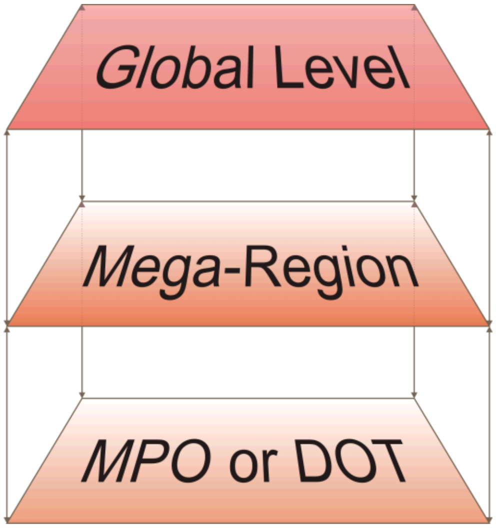
Distinction between short and long distance travel - A mega-region analysis framework must include short- and long-distance travel for both freight and passenger movements. As such, it is more appropriate to employ integrated models where travel is driven by economic and land use decisions, and employ a multi-level model where activities are assessed at an appropriate national, regional, or local context.

Market Analysis – At the beginning of the mega-region modeling process a market analysis should be conducted. The market analysis identifies the economic, demographic and environmental factors which tie the mega-region together and the issues which a mega-region model must address. The market analysis thus helps to shape the structure of the mega-region model.

This report develops a technically sound analysis framework addressing the issues described above. This framework provides a guideline which may be transferred to any mega-region and adapted for local use.

A multi-tiered approach with three layers is recommended to best represent the context for travel decisions by the market segments important to mega-regions (Figure 2.2-1). The top layer represents modeling and activity at the national and international level, the middle layer at the Mega-region level and MPO/DOT layer represents the state and MPO activity along with all other modeling and data sources. The arrows indicate that information flows up and down between each layer.

Figure 2.2-1 Multi-tiered approach



Policy analysis tools are often designed and operated at different spatial scales to make use of varying data scopes and support different types of decision-making. For example, economic models are more suitable for larger geographical areas to quantify interactions between states, cities and counties. In contrast, land use models have frequently been designed at smaller geographies for single cities or even single neighborhoods. Water pollutant emissions models may need to analyze an entire watershed, with boundary requirements different from the economic models. Transport models can be developed or applied at smaller or larger spatial scales depending on application needs. A multi-layer approach facilitates analyzing each component in the right context and scope, while facilitating integration with existing local models.

Figure 2.2-2. Mega-region analysis framework

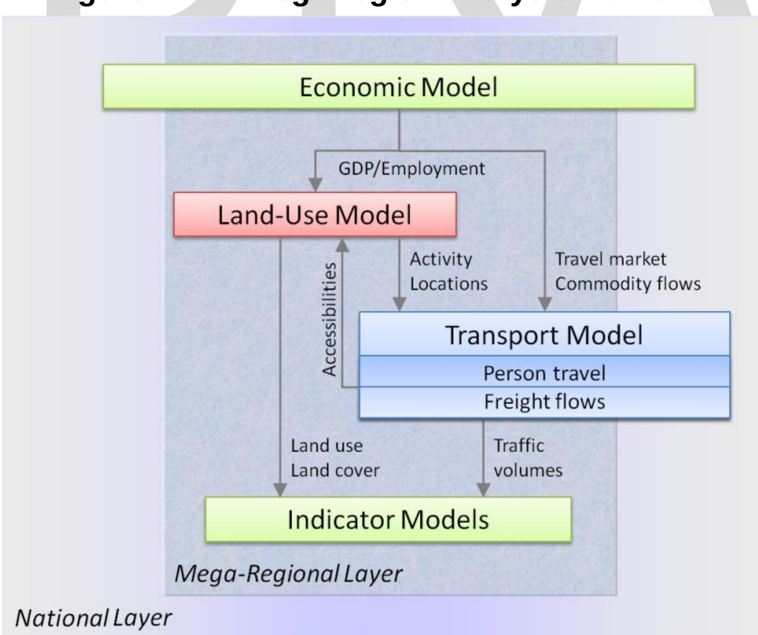


Figure 2.2-2 shows the model components recommended for mega-region analysis. In contrast to the analysis framework for typical transportation focused issues, the Mega-region analytical framework is built on the economy. The economy is crucial in defining the region geographically and its issues and metrics, and serves as a driver for activity locations and associated travel demands. A land use model becomes more important, as the location options within the mega-region are somewhat

interchangeable and coordinated policies can work towards efficiencies rather than competitions. Due to the larger geographic context, the framework must address longer distance travel for both people and freight. Indicator models are important measures of performance. And just as important as the individual model components are the data flows and feedbacks between them that reveal the complex interplay of forces. Probably most important is to tailor this framework to the policy questions of the particular mega-region.

Following, each module of the recommended framework is described in more detail.

Economic Models

Economic model (green in Figure 2.2-2). *How might the economy change in the mega-region over the forecast period? For example, how might different industrial sectors change in terms of output and employment, both in general and under special conditions? How do transportation changes affect the mega-region economy? The economic model works at the national/global level, as growth in other parts of the world affect growth in the mega-region.*

Economic data are typically generated and reported by political unit (country, state, county, etc.). But important economic interactions occur at geographies that are larger or smaller than political units, or at a scale comprising many smaller units. The notion of a mega-region, in contrast to conventional composite geographies such as metropolitan areas, is that even larger or more complex geographies may better represent the spatial dimension of the most successful integrated economies.

Additionally, all regional economies, even those of a mega-region, interact with other regions, the national economy, and even the international economy. This poses a challenge to a model charged with measuring the likely effects of policy changes such as improvements in the transportation infrastructure or changes in land-use policy. Representing a region as an isolated economic unit (when it is not) can lead to inaccurate measurement of the effects of policy initiatives on that region because of failure to incorporate competitive or complementary interactions with other economic units.

National Economy

Rationale – Captures the national economy influence on a mega-region's total population and employment (overall rise or fall, and economic productivity; especially if the region specializes in sectors that will change more than the economy on average).

Scope – National/International, providing economic forecasts for the mega-region and/or sub-regions (e.g., states).

Methods – Top-down approaches assume that the national economy influences the mega-region but that the influence of the mega-region on the national economy is minimal (e.g., Computable General Equilibrium models and Vector Auto-Regression models). The input–output components of these models may be used to examine flows between the mega-region and areas outside the mega-region.

Data – National economic data such as energy prices, government spending, commodity prices or imports and exports.

Sensitivities – Respond to economic variables such as wage tax rates, deficit spending, changes in productivity in other mega-regions, or any other macroeconomic variables in their structure.

Outputs – Population and employment (disaggregated by industrial sector) for the mega-region, possibly disaggregated to sub-regions.

Mega-Region Economy

Rationale – Interactions among sectors in the mega-region economy influence the mega-region's economic productivity. These interactions may be strengthened or weakened by changes in connectivity of the transportation system (accessibility).

Scope – Mega-region level (and sub-areas within the mega-region), with allowance for flows to other mega-regions.

Methods – Input-output analysis to determine interactions between sectors, influenced by accessibility (from transport model). State of the Art economic models may have feedback between the mega-region model and the national economic model.

Data – Input-Output inter-industry relationships and reliance on transport services. Data by employment sector, in the United States.

Sensitivities/Output – Identification of where the mega-region economy can be strengthened by improving transportation linkages.

Outputs – Changes in mega-region economy (e.g., Population and employment disaggregated by industrial sector). Advanced economic models may also make it possible to measure the gross mega-region product, with linkages to commodity flow and thus freight transportation.

Land-Use Models

Land-use model (green in Figure 2.2-2). *Where is future growth of population and employment most likely to locate? Which part of the population is likely to relocate due to changes in job market, real-estate market and accessibilities?*

A land use model must be able to allocate economic activities to zones, respond to changes in accessibility and cost, and provide sufficient detail on land cover changes to drive the environmental indicator models. The land-use model works at the mega-region level, as land-use changes outside the mega-region are largely irrelevant.

Rationale – Locations of population and employment provide origins and destinations for the transportation models. National as well as regional and local conditions affect the location of activities to model zones. The land-use model also needs to re-allocate activities among zones under changing local conditions.

Scope – Annual; Statewide control totals allocated/re-allocated to model zones. Parcel/grid-level as required by environmental models.

Methods – Allocation of regional control totals to model zones based on discrete choice theory or equilibrium-based input-output theory, sensitive to local development constraints and accessibility measures. State-of-the-art models would be sensitive to more generalized accessibility (time, cost, distance) and produce sufficient land use change details for air/water emissions models.

Data – Historic and current land use data and land use development constraints (zoning). Survey to derive location preferences of households and employment.

Sensitivities –Sensitive to accessibility and costs; sensitive to zoning and land use policies; indirectly influenced by sensitivities noted in the economic model.

Outputs –Population and employment forecasts by model zone.

Travel Models

Travel models (blue in Figure 2.2-2). *How many trips are made and where do they travel? Which modes of transport will be used based on congestion, pricing and available mode alternatives? Which route is chosen to reduce travel time? Travel demand is separated into long- and short-distance travel. Demand is then implemented at the relevant national/global or mega-region level. The assignment covers both layers, as some long-distance trips (often defined as trips of 50 miles or more) may have their origin and destination within the mega-region.*

There are multiple components to the travel demand model. Primarily, there is a core model, similar to a traditional MPO travel model that estimate short-distance trips. Additionally, long term passenger and freight models need to be included. All trips within the meg-region are assigned to common networks by time of day.

<u>Long-Distance Freight Travel</u>

Rationale – Larger geography and policy issues of mega-regions require a more comprehensive view of long distance freight movements. These trips are important to the region's economic competitiveness, and a growing share of congestion despite non-local drivers. The model should be able to test the impact of economic, land use, and transport policies on long-distance freight movements. Such a model should be driven by national economic policies and include industry-commodity connection to be sensitive to input and output changes of different industries.

Scope – Daily, National. Full US plus ports of entry. Multi-modal demand with multiple truck types.

Methods – Multi-modal commodity flow input captures economic drivers and connects to zonal employment data; can limit assignment to trucks on roadway network; desirable to have truck/rail diversion rule set to respond to pricing. State-of-the-art models would provide full linkages of commodity flow from and freight accessibility feedback to the economic model; and include tour-based or supply chain approaches.

Data - Commodity flow patterns (e.g., FHWA Freight analysis Framework); production and consumption by commodity and industry; truck types by commodity; time-of-day distributions; network travel level of service.

Sensitivities – Impact of economic policies, land use policies; pricing; truck-rail diversion and rail capacity limitations; other commodity-sensitive freight policies.

Outputs – Modal flows by commodity and truck trips by type with one or both ends in the Mega-region model area.

Long-Distance Person Travel (resident long-distance + visitor travel)

Rationale – As with freight, mega-regions scope and policies require capturing intercity and multi-day travel of residents and visitors. A national perspective is required to capture competing destinations within and outside the mega-region.

Scope – Daily, National. Full US plus key international destinations important to the mega-region. Multi-modal intercity demand including the modes auto, bus, rail and air.

Methods – Simulation based on surveys of long-distance travel attributes (e.g., FHWA National Household Travel Survey or NHTS). State-of-the-art models would have full linkages of overall inter-mega-region travel demands driven by the economic model as well as feedback of travel accessibilities and attractions back to the economic model.

Data – long-distance travel survey dataset (e.g., NHTS); visitor survey; hotel beds or employees by zone; tourist attractions inventory; annual airport passenger demand; network travel level of service.

Sensitivities – pricing (tolls, fuel price, and fares); intercity transit improvements, including high-speed rail.

Outputs – Long-distance person trips, domestic trips with specific origins and destinations, international trips with port of entry/exit.

Short-Distance Commercial-Vehicle Travel

Rationale – Captures local distribution of freight as well as service delivery for non-freight purposes.

Scope – Peak and off-peak period traffic volumes; intercity and local truck trips that are internal to the mega-region of multiple truck types.

Methods – Commonly a traditional 3-step model with trip generation, distribution and assignment. State-of-the-art models might include a tour-based model.

Data – Establishment survey; truck counts; employment; time of day factors, network travel level of service.

Sensitivities – pricing (tolls, fuel price), truck-only lanes, time of day congestion.

Outputs – Truck trips by vehicle type within the mega-region.

Short-Distance Person Travel Demand

Rationale – Captures short-distance person travel demand for all trip purposes. Urban transit is less detailed than in MPO models, especially if transit share is low.

Scope – Peak and off-peak period traffic volumes; short-distance person trips that are internal to the mega-region. Urban transit expected to only be reported at system-level or on intercity transit screen lines.

Methods – Commonly a traditional 4-step model with trip generation, distribution, mode choice and assignment; simplified urban transit options (inputs and forecasting) particularly for bus. In a State-of-the-art model a destination choice model replaces the trip distribution module and activity-based models could be applied to simulate tours rather than trips.

Data – Household Travel Survey, transit system ridership, traffic counts, socio-economic zonal data (from the land use model), network travel level of service.

Sensitivities – pricing (tolls, fuel price, and fares); network changes, urban transit improvements.

Outputs – Person and vehicle trips by purpose within the mega-region.

<u>Transport Supply/Time of Day</u>

Rationale – Required to assess congestion, vehicle and person miles travelled, and emissions. Time of day, if not explicit in demand models, captures peaking characteristics and associated congestion influence on travel behavior and activity allocation. Output accessibilities influence economic and land use models.

Scope – Peak and off-peak periods that sum to daily travel; a subset of the long-distance person and freight demand can be extracted and loaded on networks covering only the mega-region; multiple truck types, multiple drive-alone/shared-ride auto types. This typically will be limited to highway and transit assignments.

Methods – Time of day factors from traffic counts and survey data. Multi-class equilibrium assignment. In a State-of-the-art model, long-distance trips that cover multiple periods call for assignment in multiple periods or time dependent assignment methods.

Data – Traffic count data by time of day; household travel survey; roadway network and link attributes; transit networks and transit service attributes; transit fares; trip tables to be assigned; tolls and other restrictions such as truck-only lanes; volume delay functions; passenger car equivalent values for trucks.

Sensitivities – Network restrictions, such as bridges, tolls, network improvements, HOV lanes, or truck-only lanes.

Outputs – Roadway link volumes, volume-to-capacity ratios, speeds; VMT by speed (for GHG emissions estimation); transit boardings; network skims of distance, travel time, travel costs.

Indicator Models

Indicator models (pink in Figure 2.2-2). *What are the likely impacts of policy scenarios on local emissions, such as noise or particular matter, global emissions in form of GHG emissions, and fiscal revenue and infrastructure costs? The mega-regional level as where the necessary detail in land use and transportation is simulated.*

Multiple indicator models should be included that cover the sustainability triple bottom line of environment, fiscal, and social impacts. Three are proposed below and others may be used depending on the issue addressed. The indicator models are used to estimate specific impacts from various policies using outputs from the transportation, land-use and economic models. The results of the indicator models are typically not fed back to the other model components but may be used to identify additional scenarios to test, such as economic, land use, or transportation actions necessary to keep below targeted indicator values.

Air Emissions

Rationale – Captures estimates of air emissions resulting from various policy changes using the EPA Motor Vehicle Emission Simulator (MOVES) model or other emission models.

Scope – Adopts the boundary of the travel model assignment outputs.

Methods – MOVES has been documented elsewhere. [4] Other simpler Department of Energy methods used in pre-MOVES applications can be employed, as warranted (e.g., for sketch level analysis, freight).

Data –Trip tables, VMT, link volumes, and speeds (from the travel model) for running and cold start emissions; supplemental speed distribution data; local climactic conditions.

Sensitivities – Respond to changes in travel demand, VMT and/or speeds.

Outputs – Reports of regional quantities of various emissions.

Water Quality

Rationale – Captures the impact of alternative policies on water quality. For example, a nutrient loading model forecasts the annual loads of nitrogen, phosphorus and sediments on the watershed.

Scope – Covers the portion of the mega-region draining into major water bodies. In areas with outlets to multiple watersheds, a topographical model may be required.

Methods – Coefficients by land use type estimate nutrient emissions.

Data – Detailed ground classification for urban and agricultural land sub-classified into specific land cover categories. Changes to land use (from land use model)

Sensitivities – The model responds to changes in land cover, and thus any economic, transport, or land use policy. Detailed parcel/grid-based land use model typically required to provide sufficient detail on land use change.

Outputs – Estimated quantities of nutrient emissions produced by watershed.

<u>Infrastructure Costs</u>

Rationale – Estimates state and local governments' costs to provide public infrastructure in support of new development (e.g., roads, sewer, water).

Scope – The model may be applied at any scale; ideally at the local jurisdiction level

Methods – Established relationships between current development and the provision of infrastructure are applied to project future improvements needed to satisfy additional activity; assumes different levels of service for urban and rural areas. State-of-the-art models would apply locally-specific relationships rather than borrowed or national averages.

Data – Residential development classified by housing type; existing water and road infrastructure and capacities. Property value trends, tax rates, etc.

Sensitivities – Respond to economic, land use or transportation policies which impact land use.

Outputs – Public infrastructure costs and revenues of alternative land use patterns.

Model Component Options & Simulation Years

There are a variety of freely available and proprietary models and datasets that may be used to develop each component noted in the recommended framework. The most common options are listed below:

Economic. Exogenous/collaborative forecast, Computable General Equilibrium (CGE) models

Land use. Lowry-type model, micro-simulation models of household and firm location, economic allocation models

Transport: Long-distance freight. Models based on FHWA FAF[9] or TRANSEARCH datasets, supply chain models.

Transport: Long-distance passenger. Models based on NHTS or ATS[10] datasets

Transport: Short-distance freight. Trip-based or activity-based models, often using FHWA Quick Response Freight Manual.[11]

Transport: Short-distance passenger. Trip-based or activity-based models

Assignment. Static assignment models or time dependent network models

Indicator: Environmental. EPA MOVES (emissions)[12], Nutrient Loading (water quality), residential energy use.

Indicator: Fiscal. Customized tools written for local needs.

Emerging Methods – Multiple methods are emerging which can enhance the models; INRIX data on speeds and volumes and OD data collected via GPS are two examples.

Commonly, a base year is simulated to validate the model and thereby demonstrate that results replicate observed conditions. Integrated models are often

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[9] FHWA Freight Analysis Framework (http://ops.fhwa.dot.gov/freight/freight_analysis/faf/)

[10] FHWA National Household Travel Survey (NHTS) and pre-2000 American Travel Survey(ATS) (http://nhts.ornl.gov/

[11] FHWA Quick Response Freight Manual II (September 2007) (http://ops.fhwa.dot.gov/freight/publications/qrfm2/index.htm)

[12] US EPA MOVES model. (http://www.epa.gov/otaq/models/moves/index.htm).

run in an evolutionary scheme, replicating the time-dependency of incremental changes in land use, socio-economic growth, and transport capacity improvements interactions over time. In these cases it is common to start with a base year in the past (e.g. 1990) and run the model iteratively to a current year for which data are available (e.g. 2008). If the model reproduces the trend to current conditions reasonably well, there is confidence that the model is capable of simulated future developments similarly well.

Policy scenarios are simulated for future years. Common forecast horizons reach 30 to 50 years into the future. In state-of-the-practice transportation-only models, only the base year and a forecast year are necessary to evaluate policy scenarios. In the integrated models proposed for mega-region analysis, an evolutionary forecast is more appropriate where intermediate years are simulated. To save runtime, the land-use model could be run every year, while the transportation model is updated only every five years, for example, since the aggregate changes in transport accessibility change slowly, while land use changes evolve in a time-dependant fashion over many years. Choice of intermediate years may depend on key changes in the forecast economic, land use, demographic, or transport capacity.

2.4.1 Data

Mega-regional models require exogenous data for policy scenario inputs, establishing relationships and calibration. Additionally, data is exchanged endogenously among model components during model runs and output in performance metrics.

Inputs & Outputs

The proposed Mega-regional models require various types of inputs:

- **Policy Inputs**: Inputs modifiable by the user as policy levers, imposed in a scenario in order to evaluate the mega-regional impacts. These result from a specific policy action or anticipating variation in global/national conditions.
- **Outputs**: The likely output performance measures expected. The specific outputs of a mega-region model will depend on the region's issues of interest

A set of such inputs by module are noted in Table 2.2-1.

Endogenous Data Flows

Data flows between components from the top of the model chain to the bottom (economic-land use-transport-indicators) are strong. More difficult are data flows that feedback or push up the model change. Feedback flows will be critical between the network travel level of service and the demand models. Where significant changes in network accessibility occur they will also be critical between the land use and transportation models. The use of feedback shall be driven by mega-region policies and performance measures of interest (Figure 2.2-3). Specific recommended data flows are also listed by component in Table 2.2-1.

Figure 2.2-3 Data Flows

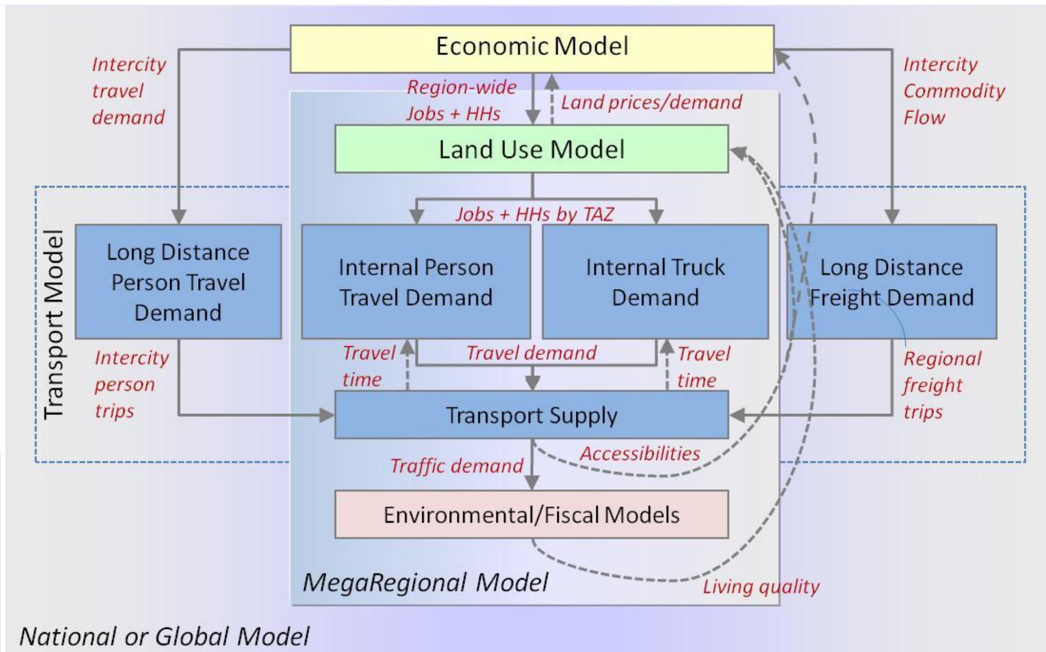

Table 2.2-1. Data Needs for Mega-Region Analysis Framework

Model Component	Inputs & Outputs		Data		Endogenous
	Policy Input	Output Measures	Exogenous Data	Calibration Data	
National Economy Regional Economy	Alternate economic forecasts (e.g., recession, energy cost), industry mix, technologies (e.g., shift to local consumption), change in global/national competitiveness.	Economic activity in US zones throughout the country; Commodity Flow; Demand for long-distance intercity travel.	Input-Output accounts and coefficients. National Forecast/Foreign Trade Data	Calibrated using inpurt data	*Uses*: National economic forecast. *Possible Feedbacks*: land prices/demand (land use model) and travel demand and accessibilities (travel model) impact changes in mega-region economy and national competitiveness.
Land Use	Zoning/ development restrictions/subsidies; Location of new development; Land consumption by sector	Population and employment zonal forecasts; Land cover by activity type; Segregation of land use (functional [residential/commercial/industrial] and socio-economically [income, race, household size, etc.]).	Parcel/grid land cover and usage (including vacant); Floorspace quantities by type and zone; Development restrictions and zoning; Base year geo-located household and employment; Floorspace consumption rates (e.g. sqft/employee)	Census data	*Uses*: Household and employment region-wide control totals (economic model). *Possible Feedbacks*: Environmental quality (environmental models) and accessibilities (travel model) impact land use.

Model Component	Inputs & Outputs		Data		Endogenous
	Policy Input	Output Measures	Exogenous Data	Calibration Data	
Transport-Freight	Commodity-specific shifts in freight modes.	Modal flows by commodity ($ and tons) Truck trip Origin-Destination matrices by vehicle type;	Input-Output accounts and coefficients	FAF/Commodity flow survey	*Uses*: Commodity flow (economic model), population and employment (land use model) *Possible Feedbacks*: Travel Level of Service (distance, time, cost, logsums; from the travel model) impacts freight demand.
Transport-Passenger	Urban or inter-city transit investment (new lines or service frequency); New roadway capacity; Auto operating cost/fuel price changes;	Person and vehicle trip Origin-Destination matrices by purpose; Commute distances; Auto-dependency	In regions with little transit, transit share by purpose in specific markets can be an input.	Household Travel Survey On-Board transit survey National Household Travel Survey Census data, American Community Survey	*Uses*: Intercity travel demand (economic model), population and employment (land use model). *Possible Feedbacks*: Travel Level of Service (time, cost, logsums; from the travel model) impacts demand for person travel.
Transport-Supply	Roadway and Transit network changes in capacity, service; Network restrictions (truck-only lanes, roadway capacity, speed limits, pricing/fares, transit frequency).	Roadway link volumes, volume-to-capacity ratios, speeds; VMT by speed (for GHG emissions); Transit boardings; Network skims of distance, travel time, travel costs.	Multi-model highway and transit networks; Existing toll roads and tolls; Intermodal and transshipment locations	Traffic Count Data HPMS	*Uses*: Travel demand matrices (auto + truck+ transit from travel demand models). *Possible Feedbacks*: Travel Level of Service (time, cost; from the travel model) impact trip routing and time of day.

Model Component	Inputs & Outputs		Data		Endogenous
	Policy Input	Output Measures	Exogenous Data	Calibration Data	
Indicators	Minimum thresholds; Or drive the analysis to meet performance targets (e.g.,air or water emission targets or thresholds). (1) Economic growth, support for specific industries	Reports of emissions by type; Estimates of nutrients produced by type; Infrastructure costs of alternative land use patterns. Cost of all types of freight	Air emissions rates Land cover, soil type Cost of providing infrastructure Cost of moving freight by value of cargo	Various	*Uses*: VMT by speed, roadway link volumes, land use. Air quality Water quality Cost of infrastructure provision Transport system support for economy *Possible Feedbacks*: None, since indicators are at the bottom of the model chain.

(1) Indicator models are typically employed as a post-processor, with limited feedback. If they fall below minimum thresholds, their results can indicate required changes to the transportation, land use, or economic model inputs need to be changed. If indicators are the policy goal used to drive the analysis, this become a complex scenario requiring multiple iterations of the full model and entailing many of the policies mentioned in the other modules in combination to reach an ambitious goal.

Exogenous Data

Exogenous data is used to develop inputs to the model and establish relationships critical to the methods of the component models. A few of these may be modified and also serve as scenario inputs. Some inputs describe base year conditions; others are used to establish relationships either through estimation (e.g., utility equations) or sampling (e.g., micro-simulation distributions). Once the inputs for each component are established, the component models can be calibrated in isolation, and then within the full model structure, with the goal of meeting observed calibration targets and exhibiting proper behavioral response and sensitivity.

Model calibration is an art as well as a science, no more so than with integrated model. Integrated models prove more difficult to calibrate as they have many moving parts that must attempt to match many different observed target datasets. Often datasets from various economic, land use, transport sources are not consistent (e.g., the census identifies households where land cover indicates no residential uses) or were collected in different years, making it impossible to meet all model targets simultaneously. However since models covering a region as large as a mega-region are most valuable in addressing strategic questions, relative magnitude and direction are more important than tight adherence to detailed calibration data. Sensitivity testing, discussed in some length in reference[13], which evaluates whether the model provides reasonable responses to policy variables such as changes in land use or transportation conditions, can be the most valuable test of a model's capabilities.

Noted below are key exogenous datasets valuable for use in the many phases of model development and calibration: model estimation and calibration to observed behavior; model validation against an independent data set; and sensitivity testing of the model under changes in likely policy variables. Critical data are noted by model component in Table 2.2-1.

Critical

Household Travel Survey (urban and rural).
Traffic Count Data. Observed truck and auto by time period,
On-Board transit survey (if transit use is significant)
National Household Travel Survey (NHTS), American Travel Survey (ATS)
FAF/Commodity flow survey
Census data, American Community Survey (ACS) micro-simulation records
Highway Performance Monitoring System (HPMS)
Regional Household Travel Survey (HTS)

Optional

Stated preference surveys
Visitor data & surveys
Land and/or floorspace price data
Special generator studies

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[13] NCHRP Synthesis 406: Advanced Practices in Travel Forecasting (September 2010).

Establishment survey
Truck intercept Origin-Destination surveys

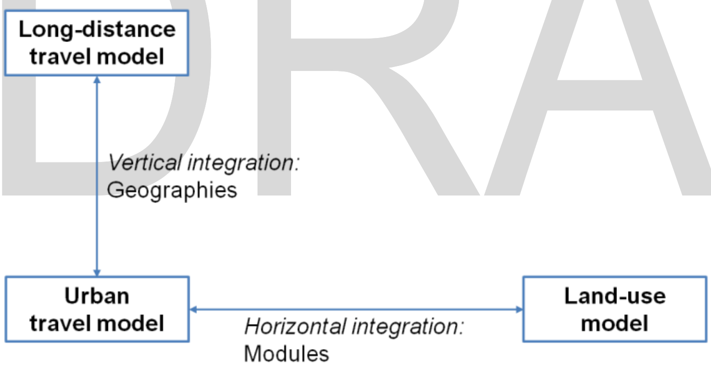
2.4.2 Integration

Mega-region models should relate both to national models (at a more aggregate level) and with state and MPO models (at a more disaggregate level). This integration should be bi-directional, with mega-region models utilizing information from other models and mega-region models providing information to other models.

Integration within a Mega-region Model

These flows of information also happen at two different geographic layers, the mega-regional and the national layer, as shown in Figure 2.2-4.

Figure 2.2-4: Two dimensions of model integration



First, Models of otherwise comparable phenomena may work at different geographical levels, such as integrating a typical travel model covering just the mega-region area with a long-distance travel model covering a national scope (geographical integration). At a minimum, the output of the two models needs to be combined, and often output from a model at one geographic layer directly influences the model behavior at another geographic layer.

Horizontal: Modules with the same geography but different modeling tasks need to be integrated horizontally, such as a transportation model and a land use model covering the same study area (component integration). The two modules are likely to improve by exchanging information. Each level is discussed separately in the following sections.

Vertical integration across geographies

Integrating a national with a mega-regional model requires close integration of modules to pass on data required by each model, avoid double-counting of aspects simulating, and develop smooth interfaces that facilitate integration even under extreme scenarios.

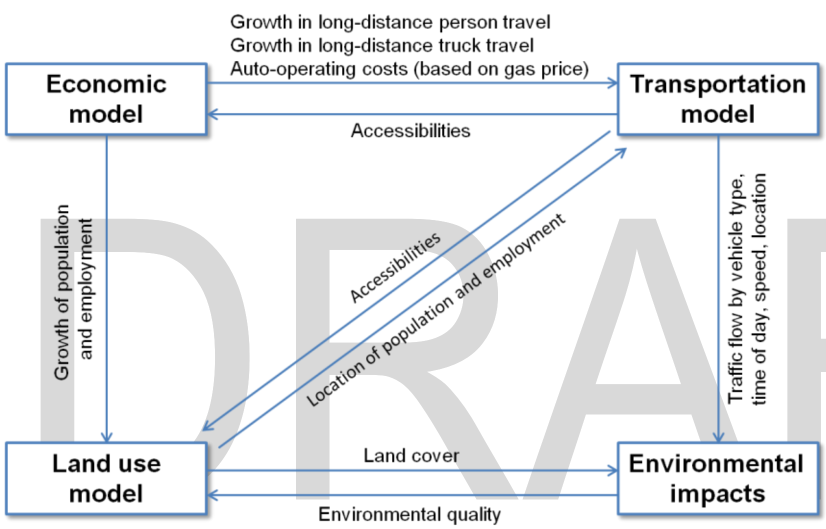
Building modules that work at different geographies allows simulating similar tasks (such as person trips) with different modeling approaches catered to each level. Each module may be designed differently, and the spatial resolution of different modules may differ to fit each model's purpose. For example, while a destination choice model works well to distribute person trips at the local level, this module becomes difficult to apply with both short-distance and long-distance trips using the same calibration results. Thus, the same task of a person trip may be simulated with different methods at the local and the regional level. The spatial resolution may be finer at the local level and much coarser at the regional level. For a trip that stays within the study area, the detailed locations of origin and destination are of interest. For a trip that leaves the study area to a destination a hundred miles away, the precise location of the destination most likely is irrelevant. While a geographic distinction in different model layers most likely is less relevant for urban models, this distinction is helpful when modeling larger study areas, such as a mega-region.

If trips are simulated at several geographic layers, special attention has to be given to minimize inconsistencies at the border between the layers. If the mega-regional model had very small zones, and the national model had very large zones as spatial representation, pathological behavior may be generated at the border. While outside the mega-region the model may only generate trips between zonal centroids that are fairly far apart, the model finds centroids that are close together inside the mega-region. This may lead to different trip length frequency distributions that are solely caused by the different resolutions in the zone system inside and outside the mega-region. One way to overcome this inconsistency is by applying separate models to the more detailed mega-regional zone system than are used with the coarser zone system at the national level. This way, each component can be calibrated to its respective zonal resolution, creating a more consistent trip length frequency distribution.

Horizontal integration across modules

At the same geographic layer, a series of model components need to be integrated horizontally, including an economic model, a land use model, a person-travel demand model, a truck model, and several environmental impact models. Every model is likely to benefit from (if not require) an integration with some or all other models. Figure 2.2-5 shows graphically an example integration of modules at the same level of geography.

Figure 2.2-5: Horizontal integration of modules



Source: Cheasapeake Bay Mega-Region Model

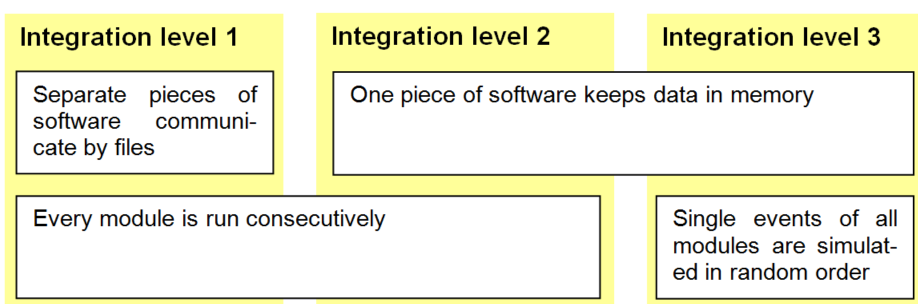
In the figure, the economic model provides population and employment for the land-use model based exogenously given overall growth. At this point, the economic model provides these data at the state level, and the land-use model allocates population and employment to the zonal level within these statewide constraints (or the economic model could provide the socio-economic control totals for the entire study are of the CBM model, allowing the land-use model to distribution population and employment entirely based on utilities of different locations, unconstrained by artificial state borders). The economic model also sets the stage for the transportation model, as it defines growth in long-distance person travel, long-distance truck travel and auto-operating costs based on exogenously given energy prices. The transportation model returns accessibilities to both the economic model and the land-use model. Accessibilities are considered to be one variable in predicting economic growth as well as the attractiveness of locations for households and firms to locate.

To calculate environmental impacts, the transportation model provides traffic volumes by vehicle type, time of day and speed at the link level. The land-use model provides land cover to the environmental impacts module, as different land cover types have different impacts on run-off water, fixed-source emissions and infrastructure costs. The environmental model could also provide feedback to the land-use model on environmental quality. Environmental quality is a relevant location factor, as households enjoy living close to well kept environmental amenities such as parks and shorelines, and away from highways and other sources of noise or pollution.

Tightness of model integration

There is a wide range of tightness when integrating models. Models may share the same modules that are fed with different data to work at different geographies. Or, models may share some data that are reconciled to ensure consistency across each model. There are also different levels of how closely different modules may be integrated technically (Figure 2.2-6).

Figure 2.2-6: Three levels of model integration



The most common is Integration Level 1. Every model runs independently. After a model has started, it reads the output data of several other models, does its own simulation, writes new output data, and is closed. After one model has finished another model can start. Building one single piece of modular software

(Integration Level 2) that contains all modules may be advantageous. Having all modules in one piece of software saves runtime because a large amount of data can be kept in working memory, saving read and write times. The integration into one piece of software that is likely to improve the runtime requires, on the other hand, a very close interaction between developers of all modules. The third level of integration runs all modules simultaneously. Events of each module are run in random order, such as a person makes a trip to work, another household moves, a truck delivers groceries, a child is born, a person goes to the cinema, etc. This very close integration resembles how events happen in reality. So far, however, this level of integration rarely has been achieved in applied models. Typically some combination of level 1 and 2 are employed, where some components are stand-alone modules run consecutively, while others are more tightly integrated together minimizing time-consuming reading and writing of intermediate results.

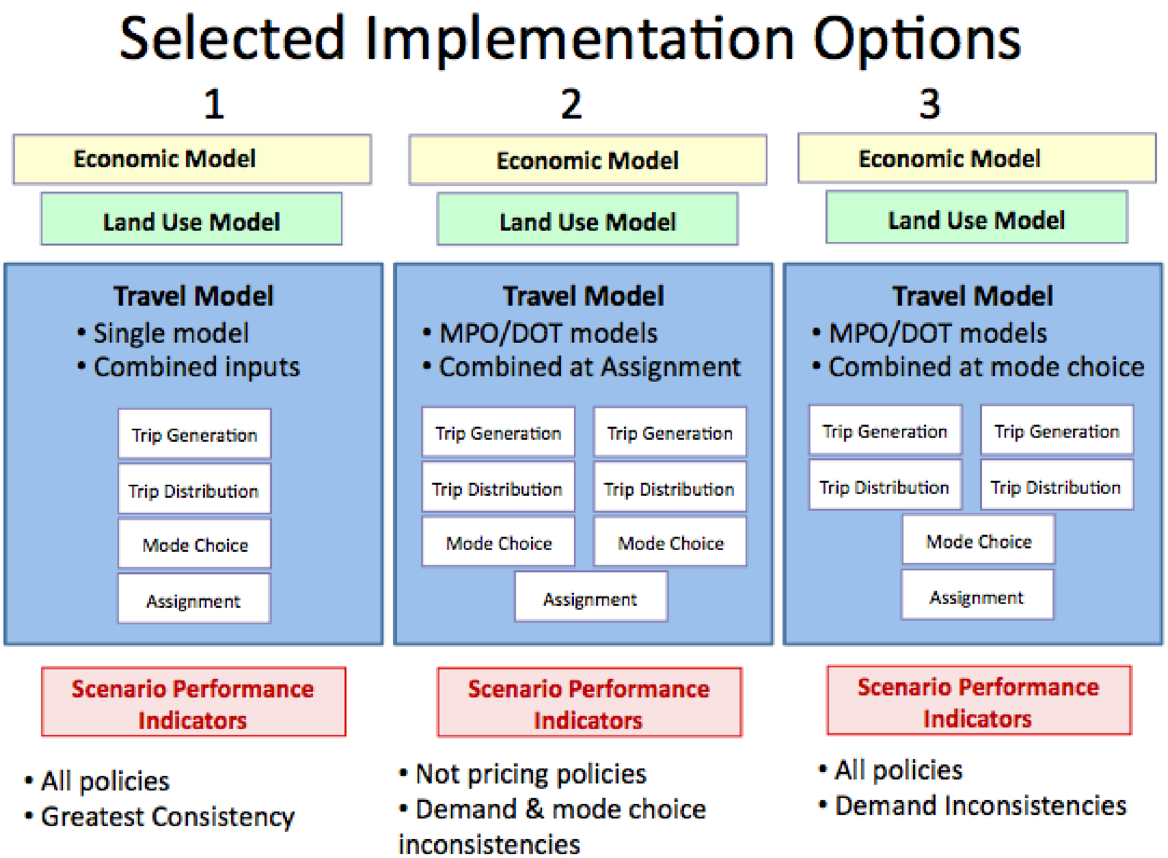
Integration and Coordination with other models

Mega-region models by their scope are most valuable in assessing strategic region-wide policy actions, and should not try to replicate the urban-level forecasts best left to MPO models, they are also not encumbered by the political boundaries of statewide transport models that miss key economic connections across state borders and often limit their view to transportation issues. The broad mega-region view that sees other mega-regions as global competitors also benefits from linkages with national models.

Combining Existing Models

From MPO/DOT models the mega-region models can use data (e.g., household and employment data, household survey, transit surveys, networks, traffic counts and screenlines) and in certain circumstances utilize these models directly. A few possible approaches are shown in Figure 2.2-7.

Figure 2.2-7. MPO/DOT Models Integration Options



Option 1 shows a situation where a new mega-region model is developed, borrowing inputs and potentially model components from other models and applying them to the full mega-region. This enables the greatest consistency within the mega-region model components and the greatest flexibility in which policies the model can be built to address. Option 2 and 3 show hybrid approaches where existing state or urban models might be run on their own with results combined either at the mode choice (OD tables) and/or assignment (vehicular trip tables) steps. Pricing and transit scenarios may require consistent mega-region modeling of mode choice. Although these hybrid options entail some inconsistencies, they likely can be developed more quickly, depending upon the scenario of interest.

In all cases, a reconciliation process between the mega-region model and other models can establish consistent inputs (e.g., socio-economic data, networks), model assumptions and temper unrealistic forecasts across the region's models. The reconciliation process also supports 'buy in' by local agencies and provides for further use of the mega-region model.

Information may also be shared from the mega-region models to the MPO or state model with the mega-region model providing improved understanding of external flows (inbound, outbound, and through) for local analytic efforts. The mega-region models can also provide a national economic model with better estimates of mega-region economic activity under various scenarios.

Integration with National Models

In developing the mega-region model, careful attention must be paid to the relationship between the mega-region and the national economy and the mega-region and the nation transportation network.

The national economy is critical to estimating employment and population in the mega-region and the overall economic health of the mega-region. If the mega-region relies on a particular economic sector for most of its employment, a change in that sector can have major impacts which ricochet through the model chain. A mega-region may also play a key role in the national economy and what happens in the mega-region can impact the rest of the country.

The national transportation system can also play a major role, not only in transportation within the mega-region but also in the mega-region economy. External trips can play a major factor in traffic congestion within the mega-region, not only affecting the flow of traffic but also, affecting the flow of freight. In addition to affecting traffic movements, significant changes to the national transportation network can affect the mega-region economy. For example, the Panama Canal is currently being widened to allow deep draft vessels to pass through. This will impact traffic in east and west coast ports and, with additional shipping capability, affect the economy in areas served by those ports.

Multi-Scale Evaluation

By integrating the mega region models with national and metropolitan level models the framework provides for a multi- level analysis, tying together all aspects of the mega-region. A new project can be evaluated based on its ability to move traffic through an urban area, how it supports the nationwide movement of freight and how it supports the development of the mega-region economy. This interaction also allows the framework to analyze the combined effects of policies in multiple sates and urban areas within the mega-region.

The framework also supports addressing economic and transportation issues in rural areas, although due to the high level view in mega-region models additional analysis at greater detail should be conducted when specific rural questions are addressed.

Implementation

A theoretically defensible framework for mega-regional analysis was presented in Sections 1-4 of this document. However, implementation may vary depending upon regional data, existing tools, and policy issues of interest. Additionally, any framework implementation will require data collection, and outreach to local institutions to be successful. This section discusses these implementation topics in tailoring the generalized framework.

2.4.3 Regional Characterization

A market analysis is part of an evaluation of a mega-regional economy. It can address questions like: What are the characteristics which define the mega-region, and how do these characteristics tie the mega-region together? The market analysis is key to determining the geographic area that a mega-region model must cover and identifying the policy issues of concern, which will then influence the structure of the model.

Unlike MPOs or State DOTs, mega-regions do not have fixed political boundaries. A marketing analysis should be conducted to determine the factors—environmental, demographic, economic, etc.—that tie a mega-region together. The market analysis may include a literature review, discussion of the roles and connections between major urban and rural areas within the mega-region, dominant industry clusters, major environmental concerns, common goals and values, and other relevant factors. For example, one aspect of a market analysis that the Chesapeake Bay mega-region demonstration project will address is intra-regional linkages among industrial sectors within the mega-region.

The specific policy issues and conditions of each mega-region will guide the application of this framework. In each application the region should carefully review the local conditions, issues to be addressed and data available, and design the analytical framework with these in mind. Table 1 illustrates for each of the mega-region issues previously identified how the framework should be modified. It specifically describes required capabilities of the framework as well as the ("data" column) inputs which must be modified in order to test each policy.

2.4.4 Framework Evolution

The market analysis and associated identification of mega-region specific issues will indicate what capabilities the model should strive for to best serve the region's interests. However, funding limitations will typically preclude the full vision from being implemented immediately. Instead, it is recommended that a multi-year vision/development plan be established at this point with milestones and associated criteria for success. This not only establishes the vision and feasible steps to reach it, but it also affords an opportunity to engage stakeholders and decisions-makers in a common understanding of analysis benefits, desired performance measures, data needs, and allows long-term planning to capture funding opportunities. The multi-year roadmap should recognize that individual model components might take different approaches than the generalized recommended framework due to regional data, tools, and policy issues of interest.

A staged approach implies compromises, but provides a tool that is able to bring value in a short time to assist policy decisions, while making the case for continued investment in long term improvement of analysis fidelity. Initial steps may involve the following compromises:

Evolutionary Approach. Initial components may serve as placeholders with enhanced functionality evolving with the region's scenarios of interest. In some cases, full functionality may never be required (e.g., sophisticated mode choice models are likely not to be required where no viable transit alternative exists).

Minimum Requirements. Identify initial desired performance measures and issues and work backwards to identify model capabilities to output them. Identify initial desired policies and build just enough to capture their integrated impacts. In computer science, this approach is called the 'Agile' paradigm. It starts with simplest model possible and continually evolves (instead of the big design up front). This provides intermediate tools to show value.

Feedbacks. It is easiest to travel down the model chain from national economics allocated to zones that drive travel and impacts. Feedback up the model chain is more difficult, such as the impacts on the economy size and location changes from accessibility changes and travel costs. Such feedback mechanisms may not be fully functional in initial capabilities.

Data Collection. In some cases, additional data collection is needed to build a tool with the required functionality. For example, surveys may be required to understand the sensitivity of travelers to a new high-speed passenger rail service relative to existing modal options. As such, simpler or borrowed models maybe put in place until the additional data is obtained.

2.4.5 Other Implementation Issues

Other factors important to all aspects of implementation include the following:

Data Collection. Is the data readily available, are there any proprietary issues, are local sources available, can data from multiple sources be easily merged? How is mega-region data reconciled with MPO or statewide data and with national data?

Network and Zone Detail – The level of detail in the network affects the implementation. Decisions must be made on which roadway functional classes will be modeled, how transit will be represented and the zone size. In general the more detailed the network and zone system the more accurate the model. At the same time the data collection costs and run times and model development cost increase, often significantly, with the level of detail. If transit is a major factor there should be sufficient detail to adequately capture the effects of transit. The level of detail must also be weighed against the policy questions being addressed.

Outreach. Outreach to local and state governments is critical to the successful use of the model. Outreach supports the integration of the mega-region model with other decision tools and provides feedback for improvement of the model. Outreach will also support the sharing of data and experience.

Resources. Staffing to run and maintain the model will be required. In addition to training staff, training should also be provided to others such as MPO staff or state DOT staff who may have an interest in using the model. Funding will be required to support ongoing maintenance of the model and updating of data.

Peer Review. Effective use of an external Peer Review panel can pay high dividends. Such a panel can oversee the project over its lifespan, playing a key role in model design and acceptance. A good point for engaging a peer review is after issues and goals have been established and initial model capabilities have been demonstrated. At this point, a panel can help prioritize future evolutionary development to meet the regions evolving policy issues. Membership on the panel should be focused primarily on leading practitioners in the field of statewide travel demand modeling. The FHWA has a program to support facilitating and funding peer reviews.

Table 2.2-2. Framework implementation of various Mega-region issues

Policy/Action	Required Model Capabilities			Required Data	Comments
	Economic	Land Use	Transportation		
Transportation					
High-speed Rail (or other long distance high-speed transport)	National economic model of long distance travel demand	Accessibility impacts to location choice. (Feedback)	Long distance Mode Choice model sensitive to time, cost and price and includes air travel	Rail station /airport locations, service frequency and costs Networks fully code mode access times (e.g., time between airport/train station and final destination).	Expect denser land use near rail stations
Freight Movement (Freight road/rail expressways; truck only lanes)	Potential productivity gains due to reduced transport costs. (Feedback)		Freight mode selection to estimate change in usage, modified assignment routines	Location/attributes of additional freight links	
Freight Coordination (Improved linkage between ports and networks; highway and/or rail; port expansion)	Economic change if significant effect on global/national shipping routes			Network changes near ports, modification to highway or rail links	May be some change in industry activity at locations of improved access.
Pricing/Tolls (Coordinated Tolls, congestion pricing, VMT fees, operations improvements)		Accessibility impacts to location choice, depending on magnitude of pricing/toll. (Feedback)	Trip Generation rates adjusted for trip suppression and/or trip chaining Mode Choice toll nest and market stratification to capture different values of time Enhanced time of day choice model and route choice in assignment, sensitive to tolls. Include reliability in freight assignment	Magnitude of pricing, location of tolls	Impact on land use larger and more complex with area or cordon pricing Freight can be assumed to pass costs onto customers with some exception for selected commodities over a certain trip length.

Policy/Action	Required Model Capabilities			Required Data	Comments
	Economic	Land Use	Transportation		
Emergency response (Short and Long Term)				Network restrictions/ enhancements to support emergency response (short term) Changes in land use and network based on nature of emergency event (long term)	*Short term Example:* 9/11 or immediate response to Katrina *Long term example:* Long term impact of Katrina
Economic					
Growth and Productivity (employment diversification, local production/consumption, major employer changes)	Assess transportation linkages between economic sectors and resulting multipliers			National and local population and employment forecasts.	Employment location by sector may be needed to assess economic linkages
Subsidies/Incentives (regional coordination at firm- and industry-level)	Modify economic forecast based on regional/sub-regional economic change			Location of zoning	
Workforce/Job Training	Economic forecast (GSP, employment, population) sensitive to income mix			Population forecast by income and location	Could use exogenous forecasts (GSP, employment, & population)
Industry Clustering (Industries agglomerate to one area of mega-region or leave mega-region)	Economic forecast sensitive to inter-industry relationships (e.g., Input/output table)	Employment location decisions sensitive to inter-industry relationships. Sensitivity to jobs-housing balance by income	Freight model sensitive to inter-industry commodity flow relationships	Revised economic forecast representing clustered Industry. Zoning policies if clustering supported by zoning	
Land Use					
Growth management	Growth management measures may affect land prices.	Location decisions sensitive to land use constraints		Zoning policies	Need detailed land use model to analyze growth management
Indicators					

Policy/Action	Required Model Capabilities			Required Data	Comments
	Economic	Land Use	Transportation		
Eco-system (nutrient loading, habitat preservation; resource management)		Forecast change in land cover at detail sufficient for indicator models.		Land use restrictions to preserve habitat	Mega-region & Ecosystem boundaries not always consistent; Nutrient loading changes with land cover
Air Emissions (Climate change, GHG Emissions)			Typical application of MOVES Micro-simulation Assignment or Speed adjustments	Emissions rates derived from MOVES	
Fiscal Impact (public infrastructure costs, toll revenues)		Must locate sufficient detail on population, employment, school age children	Tabulation of use of toll facilities sufficient to estimate revenues (e.g., by time of day and vehicle type)		

3 MEGA-REGION CASE STUDY

To test the concepts recommended in earlier sections of this report, a case study was performed as a proof of concept. The goal of the case study was to exercise an analytical framework following these guidelines to test its usefulness to a hypothetical Mega-Region governing body in addressing the investment and policy questions posed in a U.S. Mega-region. The Chesapeake Bay Mega-region, the southern end of the larger Eastern Seaboard Megapolis was chosen, due to the advanced nature of analysis tools in this region. These tools, already largely customized to the needs of the region, were modified along the lines of the recommended analysis framework and expanded to cover the geographic extent of the mega-region. Initial case study efforts involved an investigation to better understand and characterize the mega-region, the inter-related sub-regions, trends and common issues. Of the issues of importance to the region, resilience of the CBM to a High Energy Price future was the chosen for analysis, a topic of interest to all U.S. mega-regions. A likely policy response by the mega-region board to the scenario findings, highlighting the mega-region view concludes the section. The analysis framework now in place is well positioned to further test such chosen policies, including the value of coordinated policy responses.

This section begins with a regional characterization of the Chesapeake Bay Mega-region, followed by the identification of the chosen High Energy Price scenarios, the analysis results, and concludes with a policy response to these results by a hypothetical Mega-Region board.

3.1 Regional Characterization

This case study demonstrates an application of the framework to the Chesapeake Bay Mega-region (CBM). Since mega-regions do not have specific politically defined boundaries, the CBM must first be defined, then characterized. This section covers the definition of the CBM then provides characteristics of the CBM, identifying factors which unite the CBM.

The characterization includes defining the boundaries of the CBM, commuter sheds, economic linkages, freight linkages, land use characteristics, different types of travel (auto, truck, long distance, short distance), freight movements and environmental conditions. Common issues of concern throughout the CBM are also discussed.

Both current CBM conditions and anticipated future conditions are considered. By understanding all of these considerations a clear picture of the CBM can be drawn and a basis provided for further analysis.

3.1.1 Mega-Region Boundary Definition

Two studies define the Chesapeake Bay area as a Mega-region.[14] Lang and Nelson (2007) construct "megapolitan" areas by projecting commuting patterns to

[14] Lang and Nelson (2007)

the year 2040 and relying on those projected commuting patterns to define estimated Combined Statistical Areas as they would exist in the year 2040. As such, there is an empirical basis for the definition that is consistent with our current understanding of metropolitan areas linked internally by labor market flows. This definition encompasses the anchor metropolitan areas of Baltimore, Washington, Richmond, and Norfolk. Ross (2009)[15] defines a similar geography using cluster analysis. She finds that interactions within the Buffalo-Boston-New York-Philadelphia region and the Washington DC-Virginia region are stronger than between these two regions. This smaller geography also makes policy implementation more feasible, given that collaborative policy solutions require cooperation among a smaller number of states and local governments.

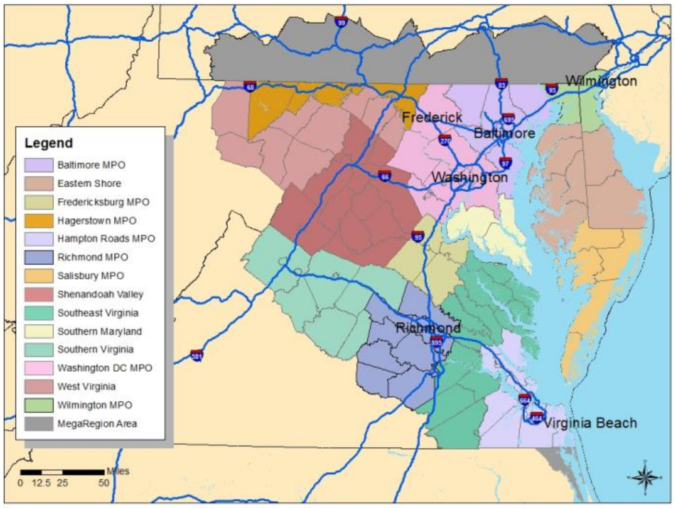
The Chesapeake mega-region is defined by its primary environmental resource, the Chesapeake Bay, an advanced system of rail, ports, and highways that link labor markets and facilitate commodity flows, and linked labor markets that depend heavily on the transportation and government sectors. By 2030, the Chesapeake mega-region is projected to grow the fastest among all other sub-regions within the Northeast Corridor at 40.2 percent[16], giving rise to a range of growth-related policy challenges including traffic congestion and environmental pollution. The widening of the Panama Canal also stands to redirect a substantial portion of international freight flows to the mega-region's major ports of Norfolk and Baltimore. As a result, watershed protection, mega-regional growth management, congestion pricing, and port expansion are all issues that will likely rise in importance over the next several decades.

Figure 3.1-1, provides a map of the CBM with major interstate highway links identified.

[15] Ross (2009)

[16] Land an Nelson (2007)

Figure 3.1-1 Map of the CBM and Sub-regions



Border Definition

The borders for the CBM modeling area were defined by combining the boundaries developed by the Ross analysis[17], the coverage area of the MSTM, and filling in gaps to ensure that border areas could be accounted for in the CBM model. Figure 3.1-2 below illustrates the development of the CBM coverage area. The MSTM provides the red area of the graphic. The maroon area represents the portions areas covered in the Ross definition which are not included in the MSTM. Finally the orange areas were added in to ensure boundary conditions were properly represented for modeling purposes.

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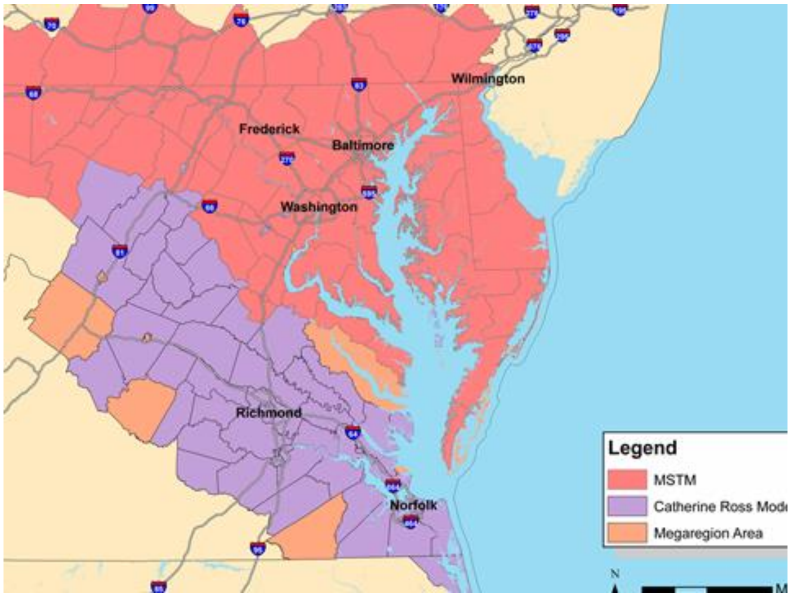
[17] Ross (2009).

Figure 3.1-2 Development of CBM Coverage Area

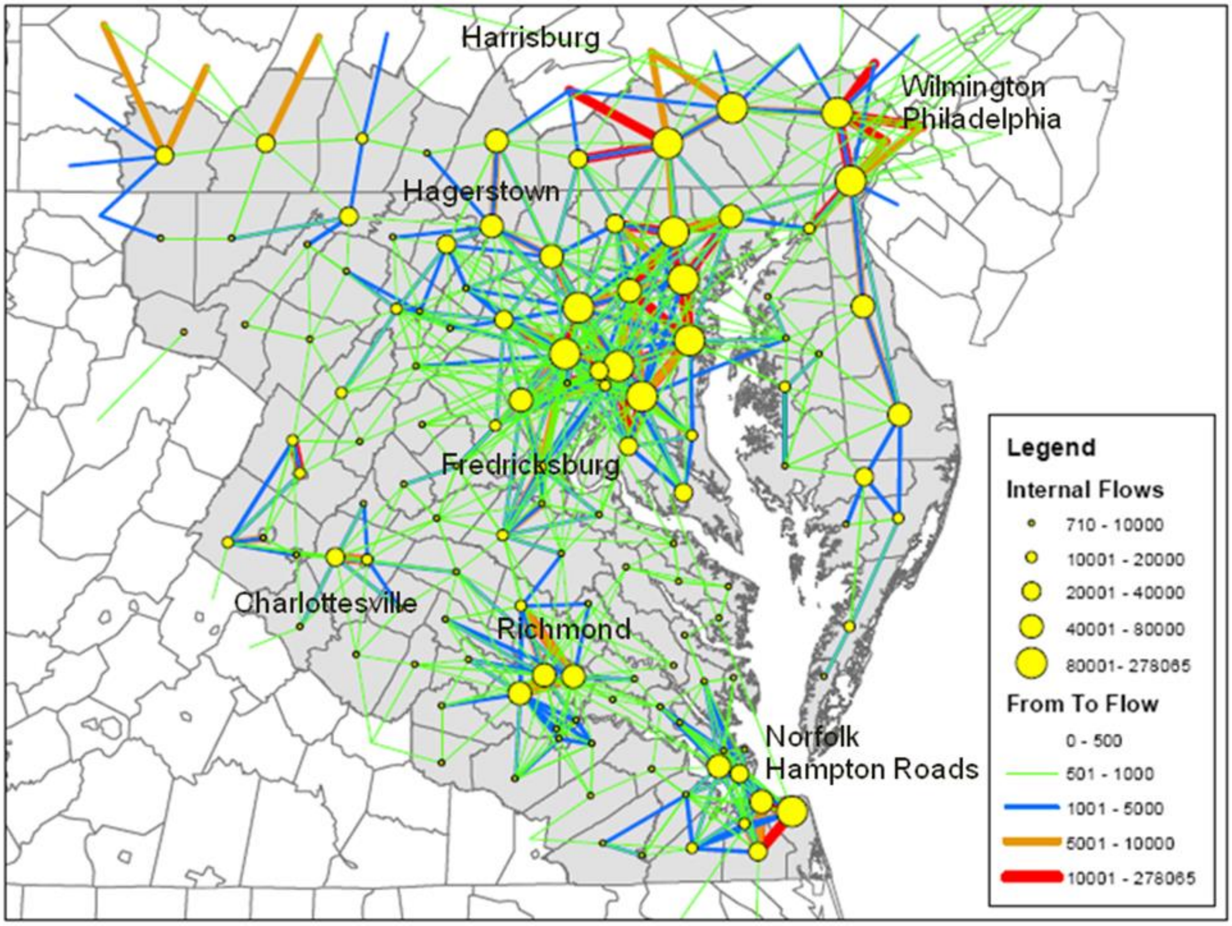


For analysis purposes the region is grouped into 16 sub-regions, following the 6 major MPO boundaries but also includes smaller areas such as Salisbury and Hagerstown and other outlying areas as shown in Figure 3.1-1. The figure also highlights the major interstate highways and airport and port facilities within the CBM.

Commuter Sheds

Figures 3.1-3 illustrate the commuting flows between counties in the Mega-Region; based on 2000 CTPP county-county labor flows. Clearly both Maryland and eastern Virginia are closely tied to Washington DC, with more isolated linkages in western Virginia and weaker links across state lines into Pennsylvania and North Carolina.

Figure 3.1-3 Commute Flows By Mega-Region Residents



Commute flows by mega-region residents

Source: 2000 Census CTPP county-to-county labor flows.

Freight Linkages

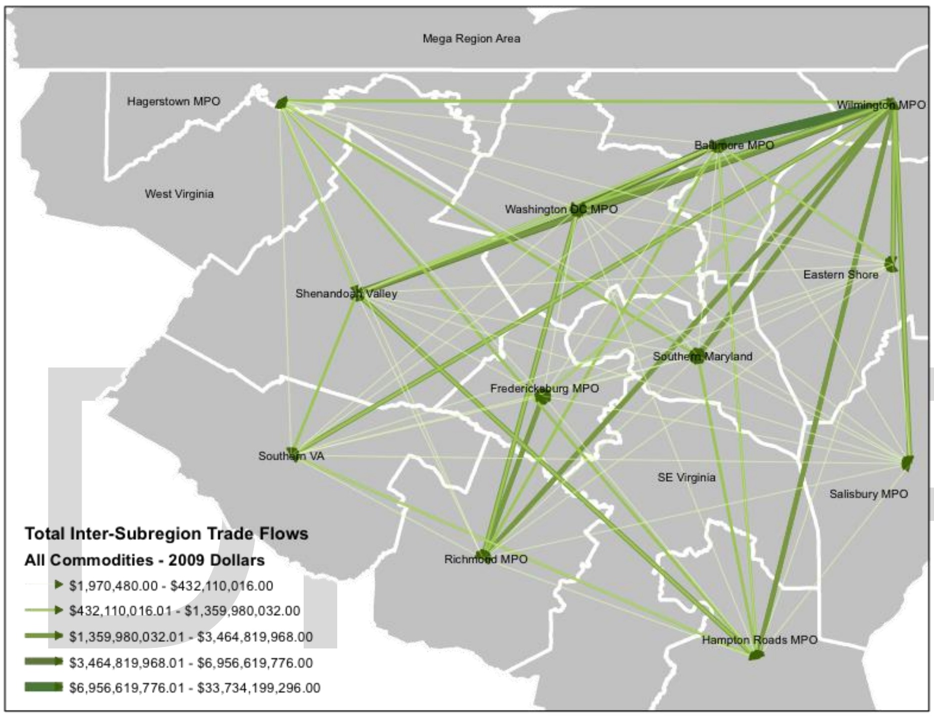
Further supporting the regional boundary are the dominant freight linkages that bind the CBM. Figure 3.1-4 illustrates the dollar value of truck goods movement between the sub-regioins (defined in Figure 3.1-1), based on an IMPLAN-based data set[18]. As can be seen the greatest truck flows by value are

18 IMPLAN/EconNW

http://implan.com/V4/index.php?option=com_multicategories&view=article&id=632:632&Itemid=10

along the northeast corridor, from Wilmington through Baltimore, Washington DC and extending through Fredricksburb to Richmond and then to the seaports in Norfolk. Urban and rural connections to this trunk line are bolstered by agriculture, fisheries, and recreation-tourism.

Figure 3.1-4 – Dollar Value of frieght flows in the CBM



Source: 2000 IMPLAN data, EcoNorthwest Haul-Model of truck-dependent industries.

3.1.2 Economic Characteristics

The region houses a complex mix of industries including government, military, health, and manufacturing, and recreation. Basic industrial employment constitutes about one third of the CBM's employment, dropping to less than 20% in 2030. The USDA ERS[19] uses an economic dependence metric, to show where a county's economy is very reliant on key sectors. Approximating this metric in our CBM sub-regions, finds that overall the CBM is economically dependent upon government employment (16% of the CBM employment in 2007, 19% in 2030). The key sub-areas meeting the 15% threshold of employment include all but 6 of the sub-regions, as listed below. With the forecast shift from industrial to service jobs by 2030, the government dependency spreads to a couple additional sub-regions in 2030. Manufacturing share of CBM employment (a portion of industrial) is only 5%, but the two Pennsylvania sub-regions are more dependant, having over 15% share in 2007:

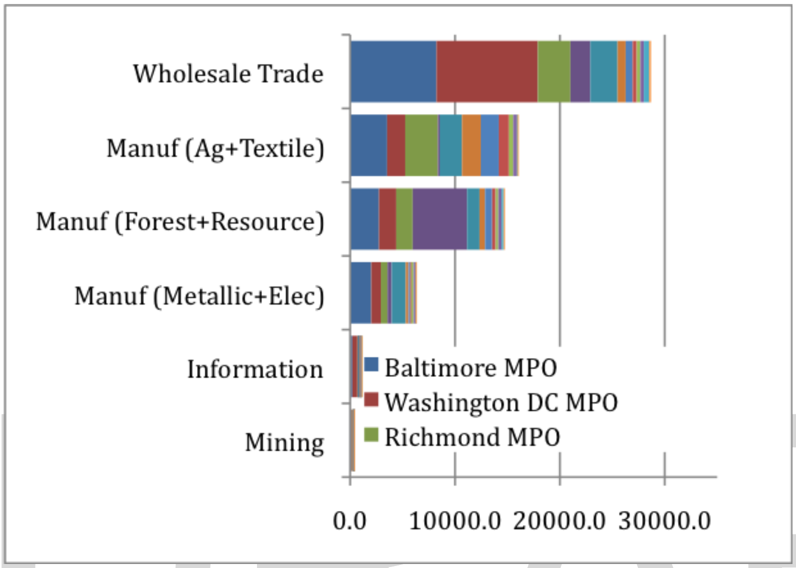
Government Sector Dependency: Baltimore, Washington DC, Fredericksburg MPOs, Hagerstown, and Salisbury MPOs, as well as Eastern Shore, Southern Maryland, SE Virginia, SW Pennsylvania, Shenandoah (2030 only) and SE Pennsylvania (2030 only).

Manufacturing Sector Dependency (2007 only): SW Pennsylvania and SE Pennsylvania.

Figure 3.1-5 provides additional information on six transport-dependent employment types for major areas within the CBM in 2007. As can be seen the Washington and Baltimore areas have large shares of wholesale trade while Wilmington has a large share of CBM manufacturing. It is clear from this figure that different sub-regions dominate in different sectors.

[19] US Department of Agriculture, Economic Research Service, Atlas of Rural and Small-Town America, http://www.ers.usda.gov/data/ruralatlas/about.htm

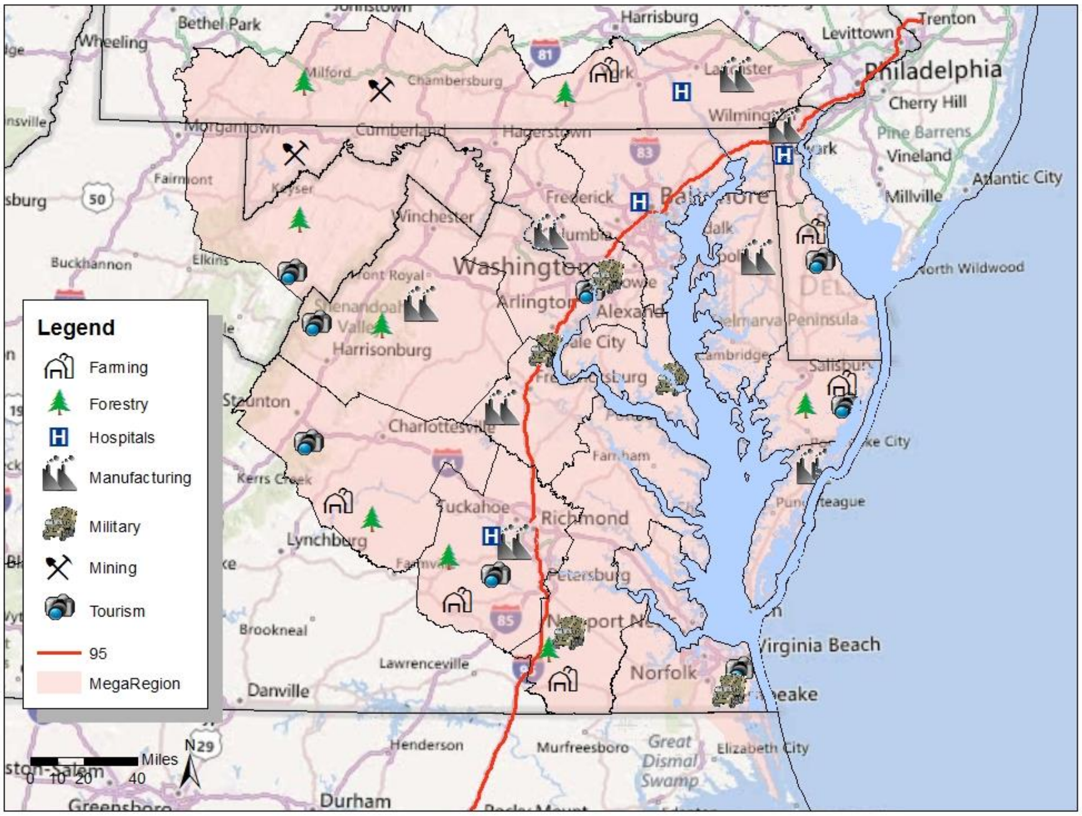
Figure 3.1-5 Transport-Dependent Employment Types



Source: 2000 IMPLAN data, EcoNorthwest Haul-Model of truck-dependent industries.

The mix of industries is further shown geographically in Figure 3.1-6. This illustrates the composition and inter-dependencies in the Mega-Region. There is a dominant MPO core running north-south along the I-95 corridor from Wilmington, DE to Hampton Roads, VA, which houses the urban services of hospitals, military bases, and manufacturing. The manufacturing spills east and west into areas with natural resource (farming, forestry, mining), and recreation services.

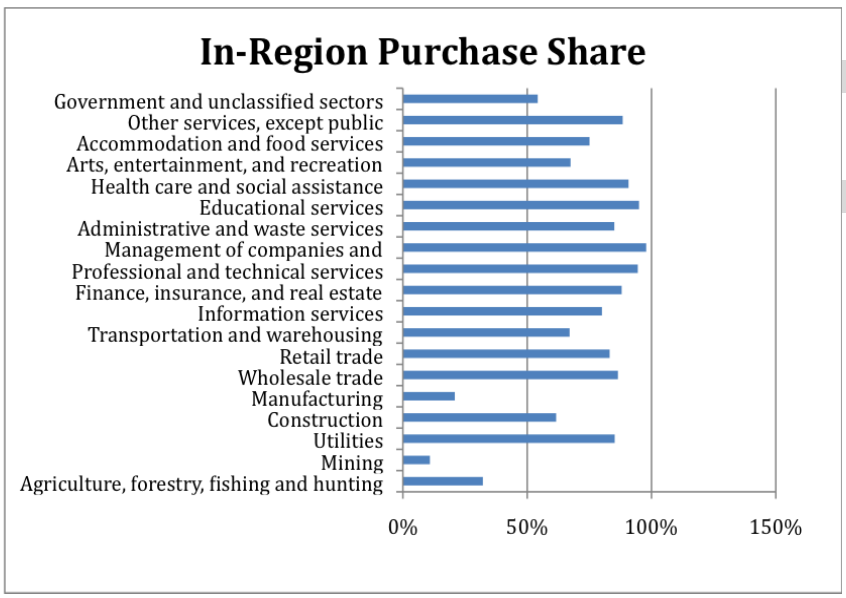
Figure 3.1-6 CBM Inter-dependencies



Source: Above-average industry employment, per CBM 2030 Reference Scenario.

Figure 3.1-7 illustrates what portion of the mega-regions share of each activity's production is purchased within the mega-region. For example, nearly 100% of management activities within the CBM are purchased within the CBM. The CBM internally produces more than 50% of the required products in most industries. The lower share indicates export industries, which for the CBM include manufacturing, resource industries (coal mining, agriculture, forestry, fishing), and federal government services. These highlight the importance of the transportation function of the region along the eastern seaboard and inland, as well as connecting through seaports to global markets.

Figure 3.1-7 Reliance on Export Demand



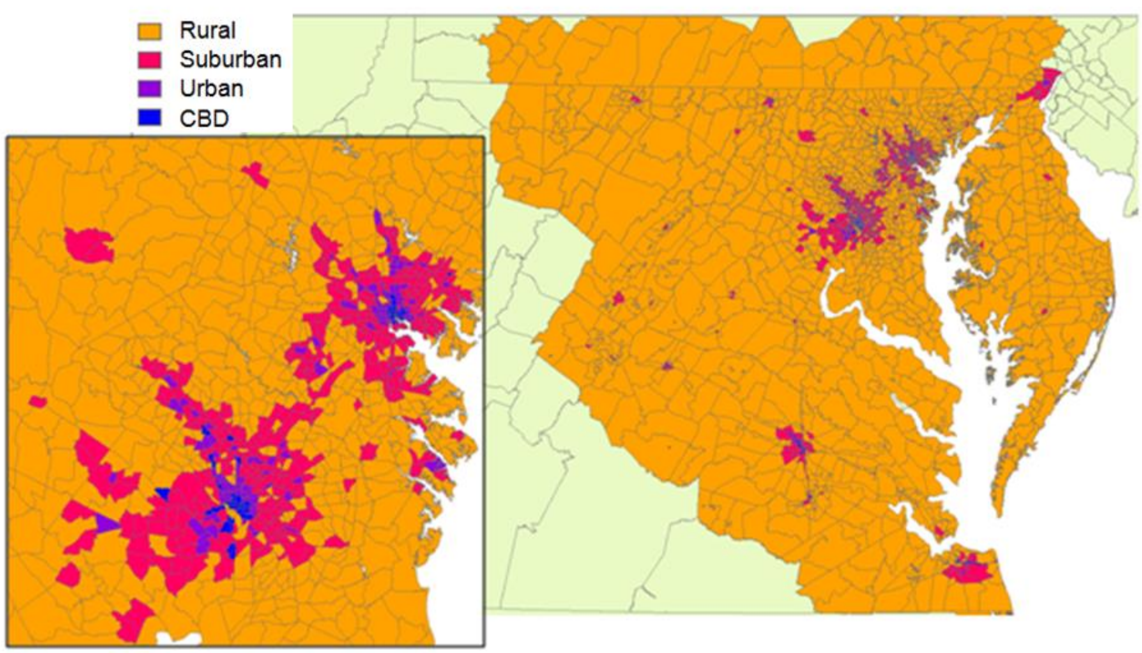
Source: 2000 IMPLAN data, EcoNorthwest Haul-Model of truck-dependent industries.

3.1.3 Land Use Characteristics

The region is home to 6 major metropolitan areas anchored by the Baltimore-Washington-Richmond corridor, along with numerous smaller urban and rural hinterlands. The mega-region consists of 5.7 million households in 2007 and 7.5million by 2030; Employment increases from 9.3 million to 12.3 million by 2030, both roughly 30% over 23 years, at an annual compound average growth rate of 1.2%. This is the fastest growth rate in the Eastern Seaboard and possibly of all US Mega-regions.

Figure 3.1-8 maps the land use density across the region, with an inset of the Baltimore-Washington DC area. The darkest two shades indicate areas of CBD and urbanized areas of high density (an activity density[20] of over 12.0) mix of households and employment (Area Type as calculated in the CBM model). The surrounding pink zones are less dense suburbs, in a sea of gold areas of rural density (below an activity density of 3.5).

Figure 3.1-8 Mega-Region Land Use Type

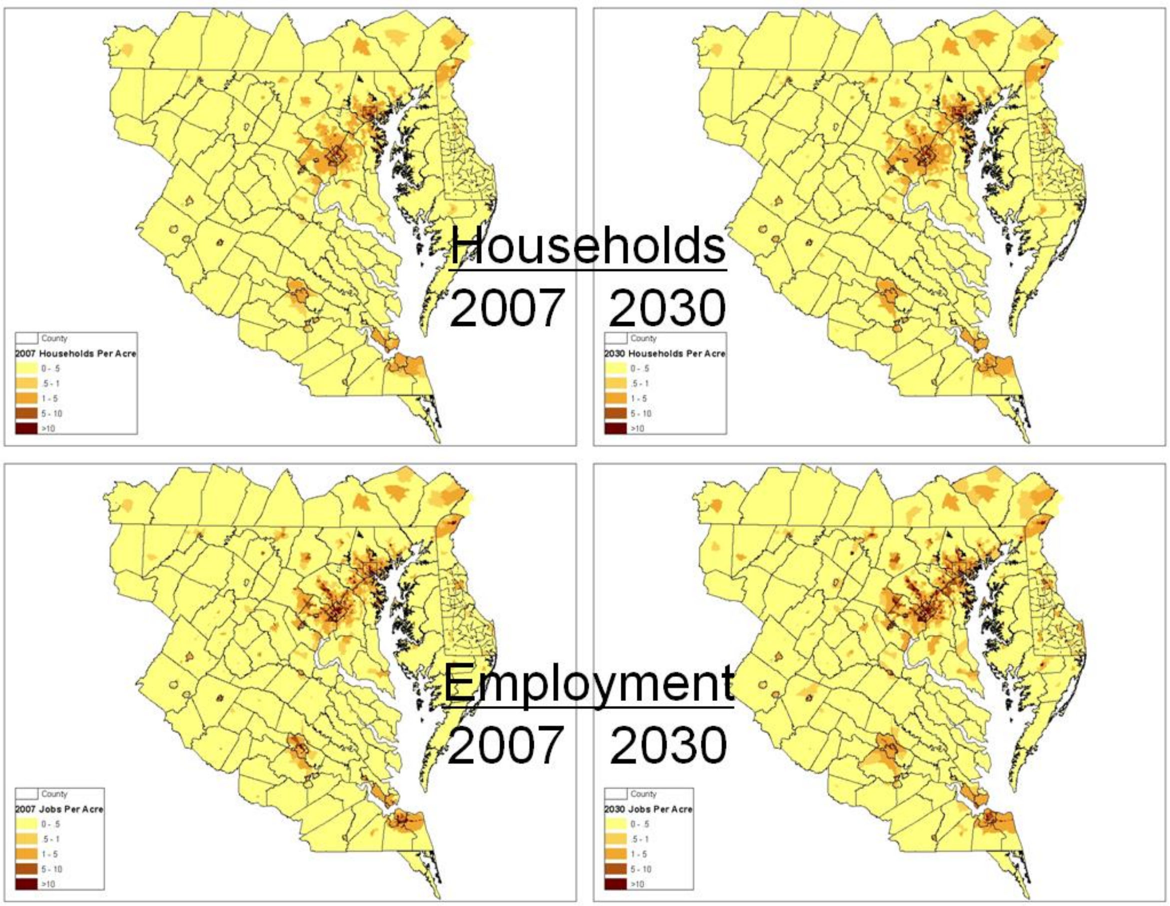


[20] For Zone i: Activity Density$_i$ = (households$_i$ + Retail Employees$_i$ + Total Employees$_i$)/Acreas$_i$

Source: 2007 Base CBM scenario.

The change in household and employment between 2007 Base and 2030 Reference scenario are shown in Figure 3.1-9. The figure shows that both have a more dispersed pattern in baseline future, with employment showing more dispersion.

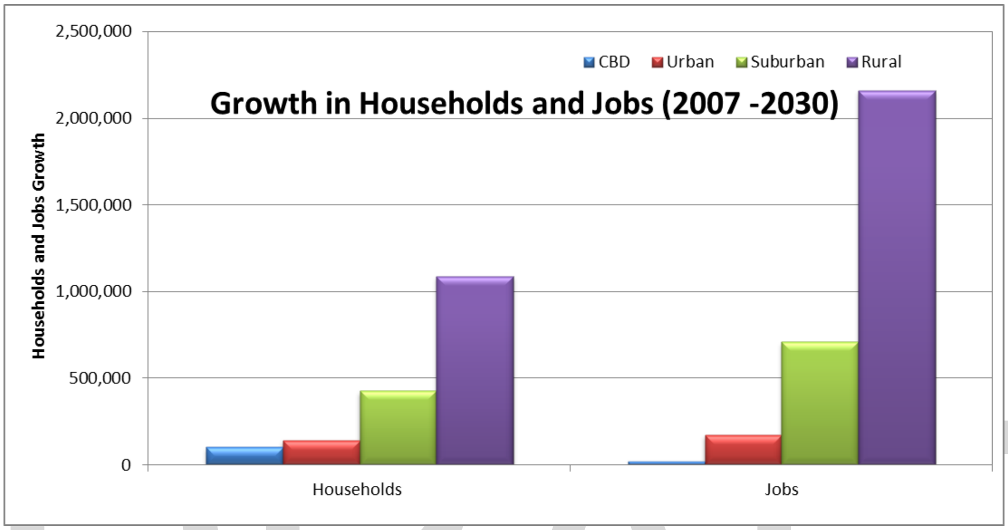
Figure 3.1-9 Mega-Region Demographic Change



Source: 2007 Base and 2030 Reference CBM scenarios

As a result of the more dispersed jobs and stable household growth, the jobs-rich CBD and urban areas become less so. A more balanced jobs-to-household ratio variation occurs in 2030 due to new employmnet locating outside the CBD closer to residences.

Figure 3.1-10 2007-2030 CBM Jobs-to-Household ratio



Source: 2007 Base and 2030 Reference CBM scenarios.

The income split and employment mix of these regions is shown in Figure 3.1-11 (based on forecasts provided by the CBM model). While income trends across the regions remain stable over time. A key trend is the shift of manufacturing/industrial share of employment from 30% to less than 20%, and the corresponding rise in retail employment from below 10% to 20% in 2030, and office gains from 55% to near 65%. The region employment mix also looks more homogenous in 2030.

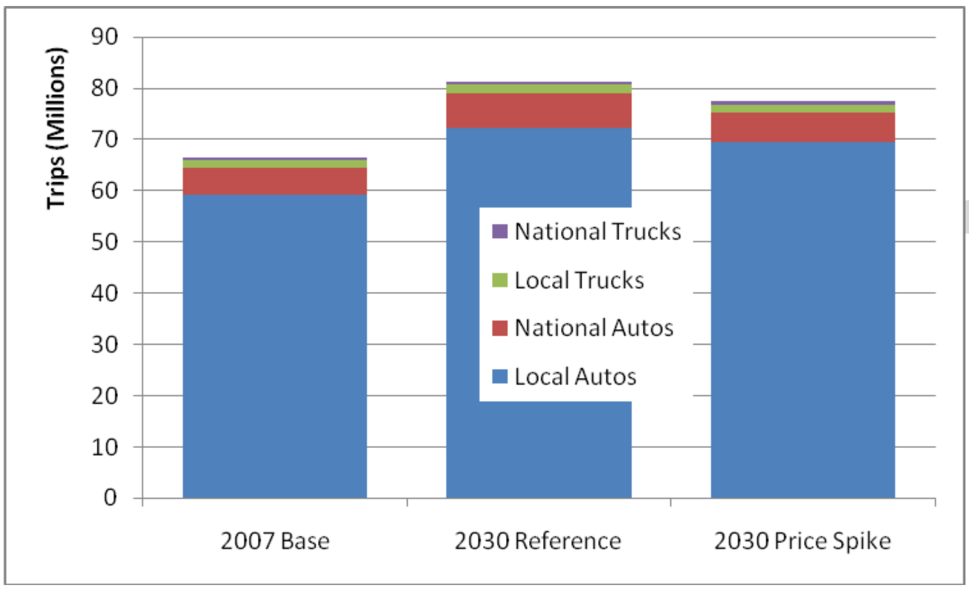
Figure 3.1-11 2007-2030 Change in income and industry mix

Source: 2007 Base and 2030 Reference CBM scenarios.

3.1.4 Travel Characteristics

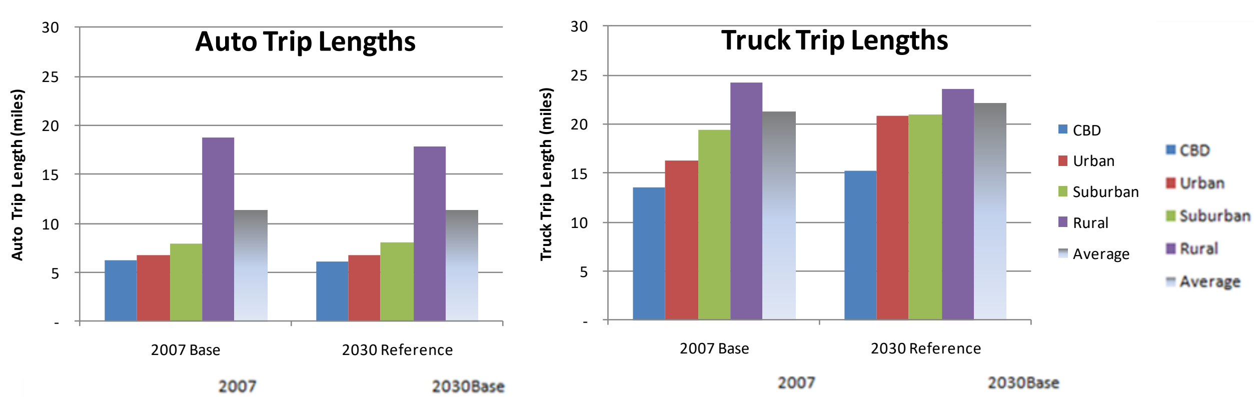
Travel within the CBD is dominated by personal auto trips. As Figure 3.1-12 shows over 90% of the trips in the mega-region are for local auto travel. Although the national trips for truck and auto are longer in length, there are much fewer of them.

Figure 3.1-12 Mega-Region Trips by Type



Source: 2007 Base & 2030 Reference CBM scenarios.

Figure 3.1-13 Mega-Region Trip Lengths



Source: 2007 Base & 2030 Reference CBM scenarios.

Auto Travel

Personal travel within the corridor consists of short distance commuting and other travel, as well as longer distance travel (defined as over 50 miles) for business or recreation between areas within the CBM as well as to points outside the region and accommodating long distance travel by visitors into the region.

In the CBD and urban areas, transit is well established and used by a significant portion of travel. Particularly in the Washington DC area, transit use is used by all incomes. Even in the suburbs and outlying areas, shared ride is used by over 25% of travellers.

Those living in the urban areas tend to take fewer trips on average (4-5 vs. 6-7), with a shorter average trip length (8-9 miles vs. 11 in suburs and 20 in rural areas).

Average auto trip length declined in the 2030 Reference. The decline in the Reference scenario was due to the growth in travel without a corresponding growth in transportation infrastructure, making for more congestion and a higher generalized travel cost due to the additional travel time.

Truck Travel

Freight movement within the corridor consists of long haul shipment of commodities as well as short distance commercial vehicle movements (defined as less than 50 miles). The CBM serves as part of a major freight corridor along I-95 that serves the East coast, connection to sea ports that also transport goods east and west via highway and rail. Trucking accounts for more than 80% of the goods shipped in or out of the area, with the remainder largely on rail and sea, with some air shipments.

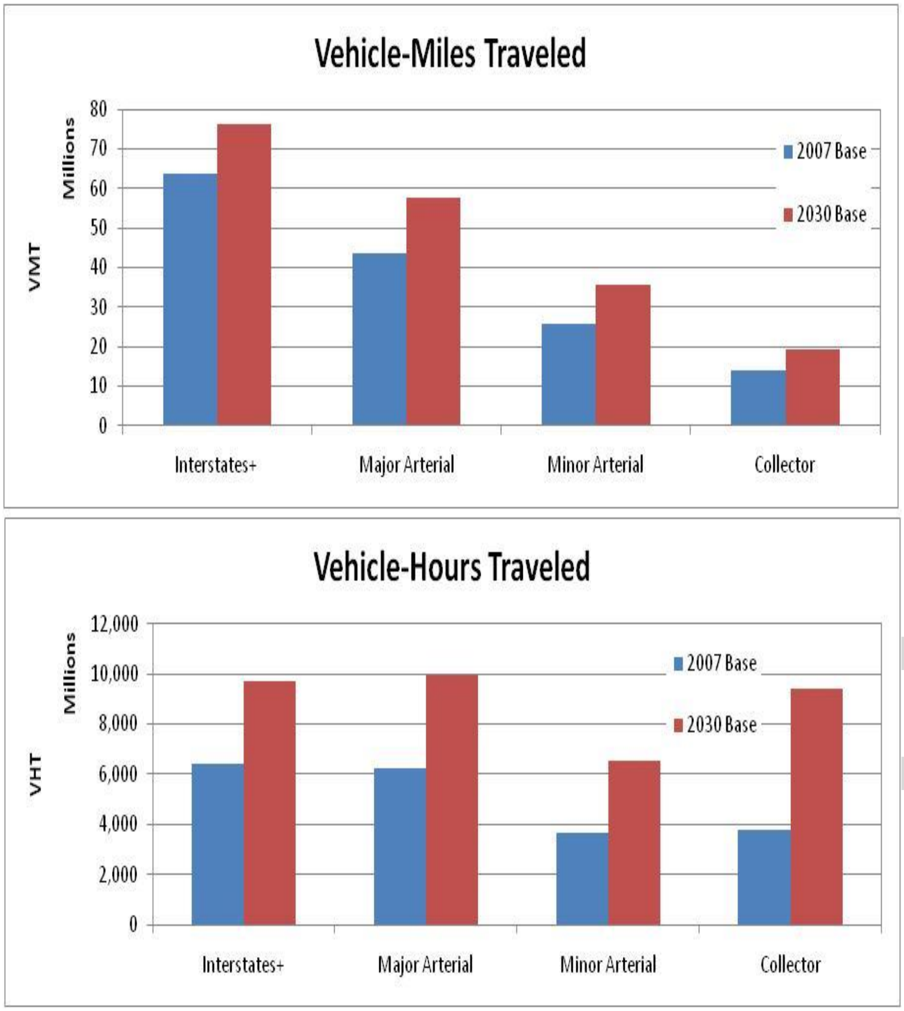
The number of trips for long-distance commodity movements, is almost twice the number of local truck trips, which is a clear indication of the significant freight importance of the region and its connections externally via the I-95 corridor in particular.

The average truck trip length (previously shown in Figure 3-2-11) slightly increases in 2030, a byproduct of more dispersed locations of businesses and other assumptions in the FHWA FAF3 data used as a basis for freight in the CBM analysis framework.

Congestion

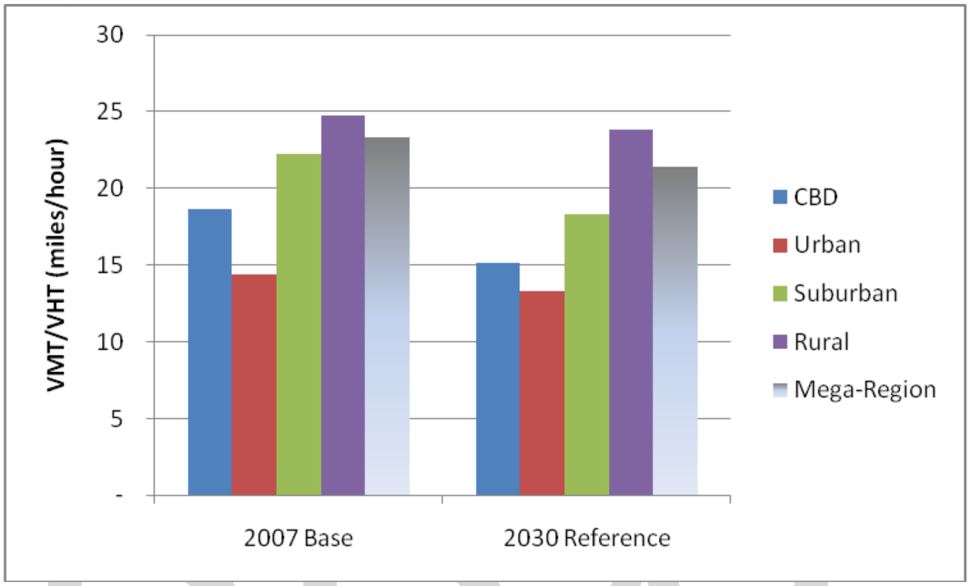
The region currently exhibits many hours of congestion. With the forecasted dispersed travel patterns this appears to worsen in the future. The slight improvement in jobs-per-household balance aross the region is not enough to compensate for the longer trips made by actitivites in these less dense regions. The net effect is increased vehicle miles and vehicle hours travelled (Figure 3.1-14). The heavily travelled I-95 corridor experiences congestion today and has shifted local traffic onto local routes as a result. As the region moves to 2030, analysis shows that the biggest change in VHT is on these collector routes, likely indicating reaching non-linear breakdown conditions on many facilities. The resulting implied speeds (VMT/VHT) shown in Figure 3.1-15 highlights the effect, slower speeds for nearly every region.

Figure 3.1-14 2007 & 2030 Mega-Region VMT and VHT



Source: 2007 Base & 2030 Reference CBM scenarios.

Figure 3.1-15 2007 & 2030 Mega-Region Congested Speed (VMT/VHT)

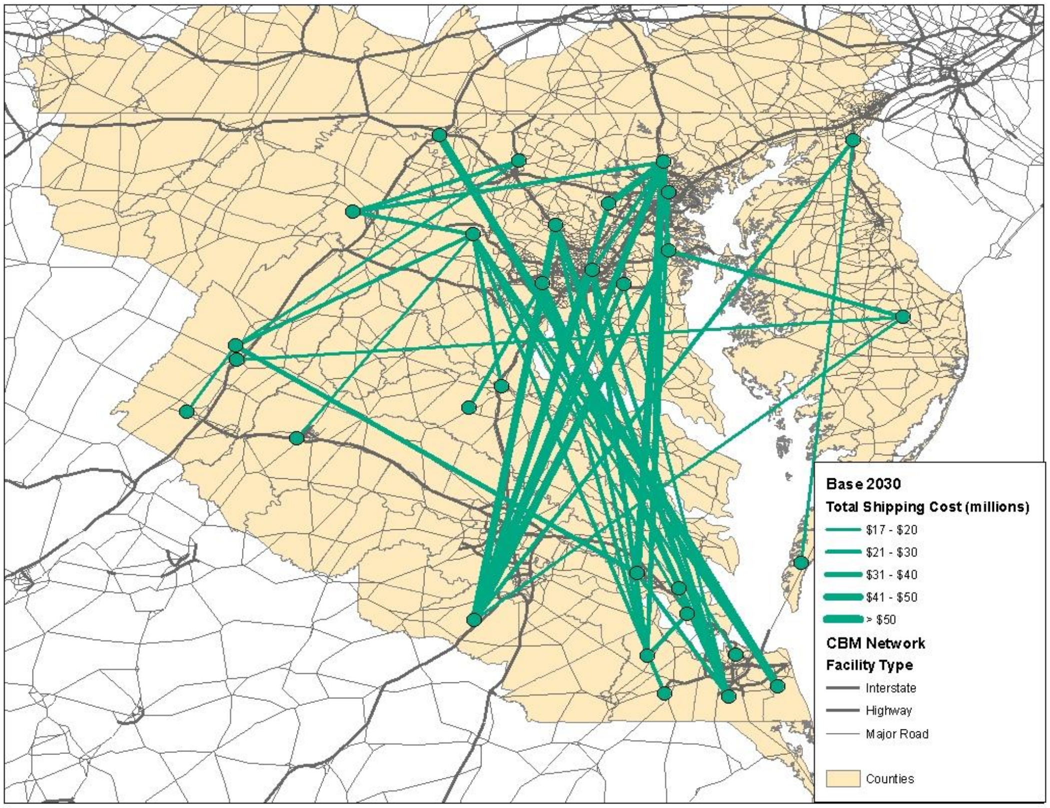


Source: 2007 Base & 2030 Reference CBM scenarios.

3.1.5 Economic Post processor

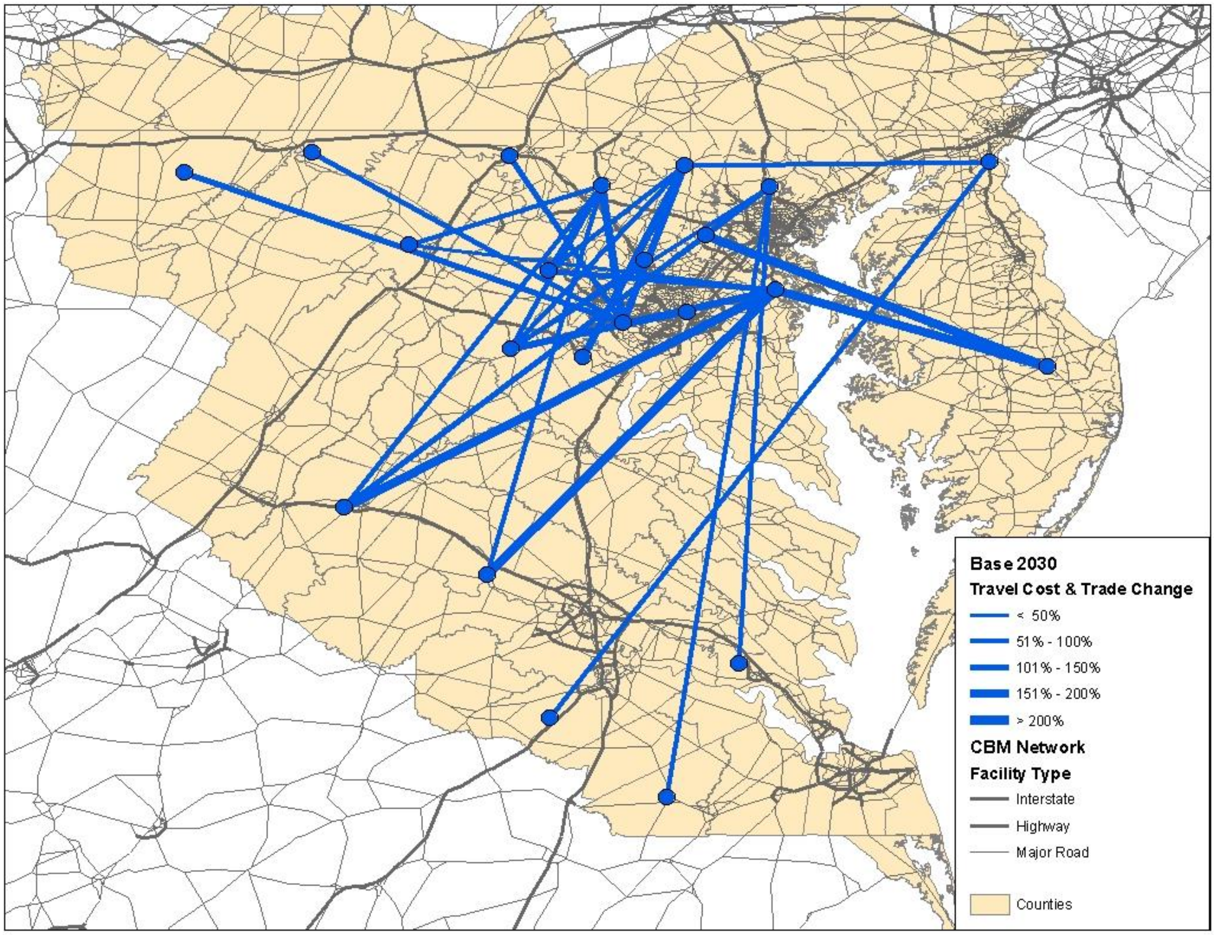
The Economic Post-Processor provides further information on the importance of limiting congestion on the I-95 corridor. Figure 3.1-16 identifies the shipping cost for key county-to-county flows in the Mega-Region in 2030. A generalized cost is used in the calculation which includes time, tolls, and auto operating costs. The figure highlights how the largest flows predominantly utilize the I-95 corridor, at significant cost. The second Figure 3.1-17 highlights the largest 2007-2030 change in shipping costs and tonnage change to the top 25 county-to-county pairs. The corridors shown are those that will most struggle to ship goods in 2030. It is interesting to note that many of these goods flow in an east-west direction that may not be well served by the current roadway network. The need for these east-west goods movement seems to be the result of the more dispersed growth of the 2030 Reference scenario. The Mega-region may have incentive to build infrastructure to accommodate this growth, or alternatively set policies to channel this growth to locations that are better served by existing facilities or has shorter trip lengths.

Figure 3.1-16 2030 Good Shipment Costs (tonnage x generalized cost)



Source: 2007 Base & 2030 Reference CBM scenarios.

Figure 3.1-17 2007-2030 Change in Good Shipment Costs

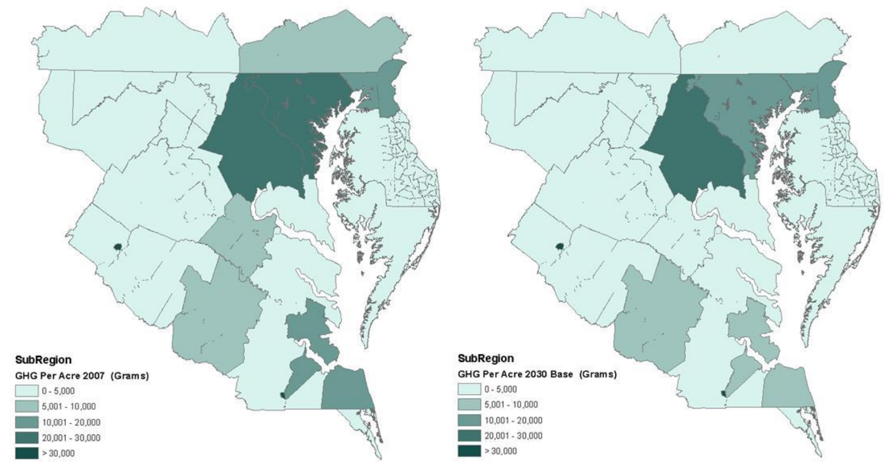


Source: 2007 Base & 2030 Reference CBM scenarios.

3.1.6 Environmental Characteristics

Air Quality. The region's significant traffic both locally and as an east coast freight corridor contributesto energy use and climate change. Figure 3.1-18 maps the transportation-based GHG production across the region (by zone). While total travel will grow between now and 2030, air quality will improve due to the increased CAFÉ standards. Indeed, uisng the current fleet mix with 2030 forecast VMT, the GHG would increase by 12%, when under the expected CAFÉ fleet changes, emissions are expected to drop below 2007 levels by 15%.

Figure 3.1-18 CBM Air Quaility - Greenhouse Gas emissions production



Source: 2007 Base & 2030 Reference CBM scenarios.

Table 3.1-1 CBM Air Quality – GHG Assumptions & Emission

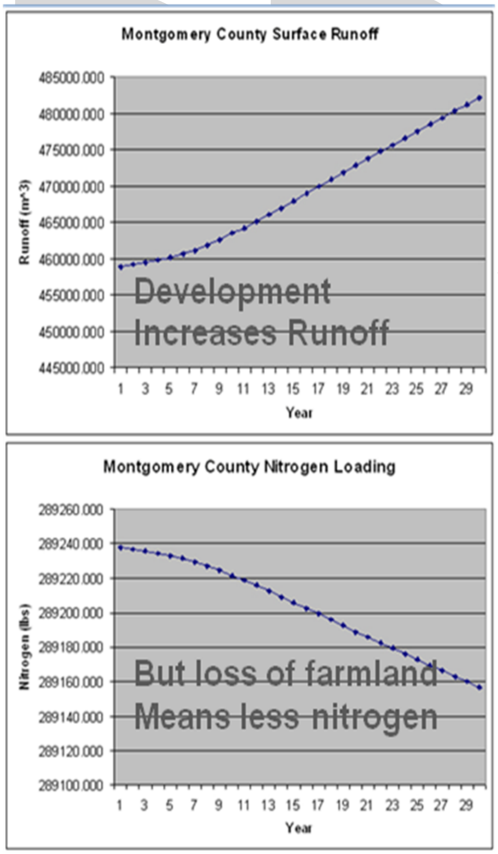
	Fleet Assumptions			GHG Emissions	
Scenario	Cars mpg	Light Trucks mpg	Truck Share	Tonnes*	%Change
2007 Base Scenario	27.4	20.76	55%	180,474	
2030 Reference Scenario – Current CAFE STDS.	34.4 (27.5)	32.2 (32.4)	55%	201,516	11.66%
2030 Reference Scenario – New CAFE STDS.	54.45	35.4	55%	154,353	- 14.47%

*includes LDV+HDV

Source: 2007 Base & 2030 Reference CBM scenarios.

Water Quality. The Chesapeake Bay and associated tributaries are more than a cultural focal point and recreational asset for the CBM. The provision of clean water for residential, farming, fishing, and industry is of key importance to the region's economy, while the sea ports support e the region's links to global markets. The case study included a 2007 analysis of a nutrient loading model for one county, Montgomery county in Maryland. The analysis uses a detailed land use and soil data that is costly to develop for the full Mega-Region. The effort highlighted that the biggest impact to water quality in the region is land use change/develoment as well as the often associated reduction in active agricultural lands. Agricultural uses lead to a significant amount of nitrogen-heavy fertilizer runoff, of great detriment to water quality. The specific impacts are largely dependent on the actual use and soil type of the original land cover., prior to the change. Figure 3.1-19 shows the rise in runoff with development. However the significant loss of farmland due to development and economic forces is forecast to result in a net decline in nutrient runoff.

Figure 3.1-19 2007-2030 Nutrient Loading Modeling Results



Source: 2007 & 2030 Montgomery County LEAM & Nutrient Loading Model

3.1.7 Fiscal Impact

Figure 3.1-20 2007-2030 Fiscal Impact by Type

Model

DELIBERATELY BLANK – Fiscal Impact Model being revised

Figure 3.1-21 2007-2030 Fiscal Impact by County

Source: 2007 & 2030 Maryland Fiscal Impact Model

DELIBERATELY BLANK – FISCAL IMPACT MODEL BEING REVISED

3.1.8 Political Linkages/Local Issues

Political linkages exist today which can be precedents to Mega-region governance. They extend beyond the state, regional MPO, and county jurisdictions. Examples include the I-95 Corridor Coalition[21] that tackles freight movement and the Chesapeake Bay Commission which addresses stewardship of the Bay, the unifying economic and environmental heart of the region[22]. Other

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[21] http://www.i95coalition.org/i95/Default.aspx

[22] http://www.chesbay.us/

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.

3.1.9 Summary

The Chesapeake Bay Mega-region is held together by transportation, economic, environmental and political linkages. Strong economic connections exist among areas within the mega-region, as demonstrated by the value of freight flows in Figure 3.1-5. Further, these economic flows are projected to continue in the North-South direction and expand to the east and west in the 2030 **Reference** scenario. The mega-region contains major highway and rail linkages North and South and also is the terminus of rail and highway linkages to the western part of the United States. All areas share a concern for the health of the Chesapeake Bay, ranging from agriculture to industry to recreation. Finally, political linkages have been formed among the states within the mega-region. The I-95 corridor coalition addresses transportation linkages and the Chesapeake Bay Commission links Pennsylvania, Maryland and Virginia with the intent of improving water quality in the Bay. For the future, 30% economic growth is forecast for 2030 along with a more dispersed land use pattern. VMT is projected to increase faster than economic growth. Congested speeds will further decline as a result. On the upside with increased CAFÉ standards Greenhouse gas emissions, along with criteria pollutants, are likely to decline despite the increased VMT.

3.2 Scenario Selection – High Energy Prices

Over the last several years, gasoline prices have been very volatile, ranging from $2.50 per gallon to $4.50 per gallon and higher across the country. Petroleum and energy prices generally are a critical factor in every aspect of transportation and economic activity. They affect the global and local economies, the amount, type and location of employment, residential location and travel behavior. Petroleum prices have a direct impact on the cost of travel by affecting auto-operating cost. The change in auto operating cost also affects residential location and employment location, since these decisions are based in part on the cost of travel, impacting the accessibility to opportunities capitalized into land values. In this section we first discuss the components of auto operating cost, then identify three alternative scenarios involving changes in energy prices and finally describe the selected scenarios and how the modeling framework was modified to reflect the scenarios.

3.2.1 Auto Operating Costs

Auto operating cost is a function of the price of fuel, fixed operating expenses (generally assumed to be fixed) and the fuel economy of the vehicle or mile per gallon (MPG). Forecasting either the price of fuel or the MPG with any certainty is a risky endeavor. The uncertainties in each of these are described below. A shift from a per gallon to a mileage based taxation system would make such a calculation more straightforward, but is not assumed here.

Price of gasoline - The price of gasoline, as mentioned previously, has been very volatile. National demand, growing international demand, geopolitical instability, natural disasters, ease in accessing available crude oil reserves and refinery capacity all affect the price of gas. While each of these can be forecast to an extent, forecasting them collectively is very risky and uncertain.

Fuel Economy -Like gas prices, forecasting average fleet MPG is also fraught with ambiguity. MPG is a function of many factors:

- **CAFE standards** – the government sets CAFE standards for new automobiles. Vehicle manufacturers must ensure that the new vehicles sold each year, on average, meet the MPG requirements.[23]
- **Fleet turnover** – There is a lagged effect in the vehicle fleet adjusting to CAFÉ standards. New cars enter the vehicle fleet at current CAFÉ standards while older vehicles remain in use until disposed of. It can take ten years or more for the bulk of the vehicle fleet to adjust to higher standards.

[23] On August 9, 2011, the government announced a fuel economy standard for 2025 of 54.5 miles per gallon (MPG) for cars and light trucks. This analysis in this paper is based on the 2025 standard. Current MPG is 24 mpg, and closer to 30 in Europe.

- **Price of gasoline** –Higher gasoline prices act as a market signal to influence the rate of vehicle turnover to higher MPG vehicles. If high enough, prices could move the average new car MPG above the required CAFE, as evidenced by the absence and high price of low MPG vehicles on used car lots during the 2008 increase in fuel prices.

- **Engine technology** – Engine technology is a wild card. The Argonne (Argonne) labs has reported that with today's internal combustion and diesel technology cars could eventually hit 100 MPG. In addition, plug-in hybrids could raise MPG even more. Development of radically new technologies such as fuel cells with very low cost and without range limits, could significantly change the vehicle fleet and effectively remove fuels costs as a factor in travel.

The net effect of the above factors is that oil/energy prices will likely rise, the average MPG will likely rise and forecasting future auto operating cost is highly uncertain.

3.2.2 Expected impacts on the Mega-Region

High-energy prices can impact all aspects of the economy; total employment, the location of residences and jobs and travel behavior. The type of impact on each of these sectors depends on the magnitude of the price increase, and the timing of the increase. A long slow rise in energy prices would allow location and other factors to adjust to changing conditions. A sudden rise in prices force immediate behavioral responses and not allow for adjustments which require longer time period. In order to narrow the possible scenarios, this section provides a more detailed analysis of the expected effects of an energy price rise and its effects on various aspects of the mega-region.

Economy - A rise in energy prices will affect both the United States and global economies. The severity will depend on the timing and the magnitude. Key factors in assessing the economic impact include, shifts in energy efficiency, relative energy efficiency to competitors, and energy substitution. Sectors that use large amounts of energy or rely on the consumer economy will be pinched by high-energy prices and will be likely to be hit hardest. In summary, high-energy prices are likely to have modest impacts on some sectors of the economy, and thus employment, but not in full proportion to the price increase. Substitution of one form of energy for another, gains in efficiency and changes in behavior can mitigate the impact. This mitigation is particularly true for long run impacts where such long-term investments can occur in response to proper price signals. Short run price spikes, like the 1970s, are not likely to have immediate effects on employment but if they remain in place for a reasonable amount of time employment will be jeopardized.

Freight - Long distance freight shipments are determined by the amount and location of freight consumption and freight production. The INFORUM model forecasts these for each state. Similar to the economic forecasts, due to the mitigating factors the changes to consumption and production under a $5.10 price per gallon of gasoline are less than proportional to the change in energy cost, due to assumed productivity gains. For example, under the high petroleum price scenario, goods productions in Maryland decreases by only 1.1%, despite a 1% drop in forecast employment (INFORUM).

Land Use - Land use will respond to changes in travel impedance including auto-operating costs (AOC). As impedance increases people tend to locate closer to places of employment and employment, particularly retail, will locate closer to population centers. As impedance decreases land use becomes more dispersed, seeking lower land costs outside the urbanized areas.

Travel -Under a high energy price future trips are likely to shorten with people changing destinations in order to save on fuels costs, and being more sensitive to distance in their route choice. Also, fewer trips along with more use of transit, walk, bike, and carpools would be expected. Long distance passenger travel would also respond to fuel price changes, but not to the same extent as local travel. In long distance travel other travel costs such as overnight lodging and meals reduce the portion of the trip cost related to fuel. However, the purchase of more fuel-efficient vehicles will lower the impact of higher fuel prices on auto operating costs. In addition as auto-operating costs increase carpooling is also likely to increase. Transit usage may also increase for those who have transit available, and non-motorized is viable for short trips.

A sudden price spike will differ from a steady price rise. Under a spike, employment, land use and freight movements will remain fixed in the short term. However, a large impact on travel behavior can be expected.

3.2.3 Scenarios and overall assumptions

Three possible future high energy price scenarios were identified spanning the possible effects: **Reference**, in which the price of petroleum rises slightly and MPG remains the same; a slow **Steady Price** rise, in which the price of petroleum rises to a high level but slowly over a long period of time, allowing people and the economy to adjust; and a **Price Spike** in which the price of energy remains relatively constant through 2029, then jumps to a very high level in a very short period of time.

Reference - Gasoline is assumed to be $2.90 per gallon in 2030 (EIA forecast, without major shocks to the system), with a federal CAFE standard of 54.2 MPG in 2025. The average MPG is assumed to be 41.8, allowing for the fact that the vehicle fleet would not have turned over sufficiently to bring all vehicles to the 54.2 standard. Due to the MPG gains, this represents an auto operating cost (related to gasoline) of less than half of today's (2011). Under this scenario cars would actually be cheaper to operate than today. This is expected to lead to a more dispersed land use pattern. For the employment and long distance freight forecast we assume a 2030 **Reference** economic forecast.

Steady Price - Petroleum prices are assumed to steadily rise causing gasoline to reach $8.48 per gallon in 2030. The average MPG again adopts CAFÉ standards of 54.2 in 2025, but with an average fleet MPG of 45.1, assuming a faster vehicle turnover and fewer trucks than the **Reference** due to slow and steady price signal of increasing gas prices. The resulting auto operating cost due to gasoline would be slightly higher than current prices. The national economy would expect to be dampened somewhat along with associated freight movement. This scenario also assumes a change in the land use forecast. Responding to the increased auto operating costs, a more compact growth pattern is expected.

Price Spike - Gas prices rise according to the **Reference** scenario until 2029 then spike to $14.00 per gallon in 2030, roughly 4-5 times current prices (2011 at

$3.50). The United States has experienced fuel price spikes of 100% to 150% in the past. From 1979 to 1980 crude oil prices increased from $15.85 per barrel to $39.50.[24] The price of gasoline doubled from $.63 per gallon in 1978 to $1.25 per gallon in 1980.[25] The causes of these changes were a revolution in Iran accompanied by a significant decline in oil production and the deregulation of the domestic petroleum market. For our scenario we do not specify the exact cause of the spike. The average MPG, freight shipments and land use patterns would be the same as the **Reference** due to lack of time and consistent price signals to adjust, with all impacts taken in travel behavior. By using the extreme case of $14.00 per gallon the scenario clearly points out the trend and order of magnitude of potential impacts and helps to identify possible remedies to such a spike in energy prices.

Due to the limited availability of funds, the case study will contrast 2 scenarios: the **Reference** and energy **Price Spike** scenarios. These scenarios focus on the travel behavior side of the energy price impacts. With the current volatility of gasoline prices this scenario is similar to today's rapidly changing energy market. By selecting this scenario the travel behavior effects are isolated for analysis. Addition of the Steady price rise scenario would dampen the transport effect by impacting the economic and land use components as well.

With the selection of this high energy scenario three alternatives are available for comparison; the 2007 **Base**, the 2030 **Reference** scenario and the energy **Price Spike** in 2030. Table 3.2-1, below, provides a summary of the assumptions used each alternative.

The focus of the scenario analysis will be on identifying vulnerabilities in the region under a high-energy price future. This will point to likely policies and investments that have the potential to increase the region's resilience. As such it will provide a good foundation to test future scenarios that would exercise possible mega-region policies and investments, and identify their impacts across the various geographic sub-regions and across economic-land use-transport disciplines.

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[24] Wikipedia – 1979 Energy Prices

[25] Flashback - http://www.1970sflashback.com/1978/Economy.asp

Table 3.2-1: CBM Case Study Scenario Assumptions

Item	2007 Base	2030 Reference	2030 Price Spike	2030 Steady Price (Not funded)
Gas price	$ 2.12/gal	$ 2.90/gal	$ 14.00/gal	$ 8.48/gal
Auto efficiency	24.4 mpg	41.8 mpg	41.8 mpg	45.1 mpg
Auto-operating costs (AOC)	$0.09/mile	$0.08/mile	$0.42/mile	$0.24/mile
Economic model	No adjustments 2007	No adjustments 2030		HEP INFORUM output
Land use model	2007 SE data (AOC $0.09/mile)	Evolved 2007-2030 (AOC$0.09/mile)		Evolved 2007-2030 (AOC $0.24/mile)
Short-distance Person Trip rates	No adjustments (HH Travel Survey)	No adjustments (HH Travel Survey)	Delphi-panel adjusted	Delphi-panel adjusted
Long-distance Person model	No adjustment	Growth-factored based on population	Adjusted to respond to transportation costs	Adjusted to higher transportation costs
Long-distance Trucks model	FAF2007	FAF2030	FAF2030	Adjusted 2030 FAF flows based on INFORUM sensitivities

3.3 Case Study Analysis Framework

Given the geographic extend of the Chesapeake Bay Mega-Region, a single scale model is insufficient to capture relevant activities, travel behavior and their impacts. Instead, a two-layer approach was chosen that distinguishes a mega-regional layer represented in more detail and a national layer capturing relevant activities and flows outside of the main study area. Given the interactions between different mega-regions nationally, and in some respect even globally, the two layer approach facilitates representing the study area in sufficient detail yet acknowledging that mega-regions cannot be treated as monolithic islands.

The remainder of this section summarizes the Chesapeake Bay Mega-Region analysis framework. It demonstrates the recommended framework discussed in Section 2.4 tailored to local region's context. The basic model functionality is followed by adjustments made to ensure the model was sensitive to the high-energy price scenario used in the case study. More detail about the methodology of the various components, as well as key input data, can be found in Appendices A - D.

3.3.1 Basic Methodology

The Chesapeake Bay Mega-Region analysis framework began as an effort by the Maryland State Highway Administration to develop a tool to analyze freight travel, rural travel and travel between MPOs in Maryland. The model was developed to cover the Chesapeake Bay Mega-Region area, upgrading the travel demand models adopted from local MPOs, and adding various indicator models. An economic model was built to inform freight movements. A top-down land-use allocation model was developed to link the economic forecasts to the travel model, while a parcel-based bottom-up model previously developed for individual urban areas was expanded statewide. Several additional upgrades were made to for this case study to ensure model sensitivity to the impact of significant increases in energy prices on transportation, land use and the mega-regional economy.

While not part of the main analysis, a parcel-based model enabled the use of environmental indicator models of water quality by estimating land cover transitions at a detailed level. This is further described in Appendix D.

Figure 3.3-1. Chesapeake Bay Mega-Region Analysis Framework

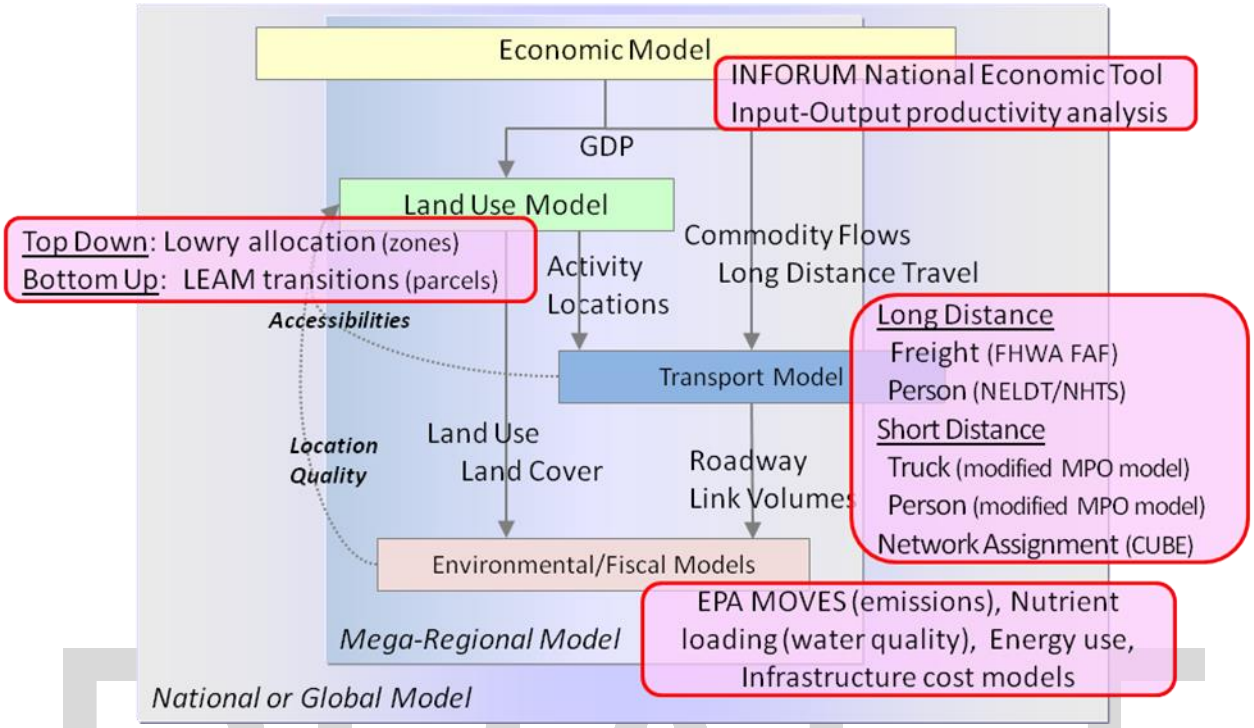


Figure 3.3-1 shows the implemented Chesapeake Bay Mega-Region analysis framework. The modules cover the recommended framework elements by including multi-discipline components (economic, land use, transport, environmental and other indicators); multi-modal freight and passenger (long and short) flows; all within a multi-level geographic approach (national, regional, and with MPO reconciliation).

The implemented components can be summarized as follows:

National Economic Model. A proprietary national economic forecasting model built by the INFORUM group at the University of Maryland was applied. It forecasts marginal consumption and production in 65 economic sectors and allocates these forecasts to states. These allocations are also used to adjust the marginals of the FHWA Freight Analysis Framework multi-modal commodity flows.

Land Use Model: Zonal Level Allocation. State level forecasts of basic employment are allocated to counties based on historic patterns of development. Population, followed by retail and service employment are then allocated to counties in 5-year increments. In the horizon year of

2030, a Lowry (gravity-based) top-down land use model then allocates county population and employment totals to model zones.

Land Use Model: Parcel Level Detail. A Cellular Automata model, (LEAM model) calculates probabilities of the potential for each cell to change from one land-use category to another, influenced by adjacent cells. This model was used only for water quality estimates and is described further in Appendix D, indicator models.

Transport Model: Long-Distance Freight. The truck portion of the economic model's commodity flow output is disaggregated from FHWA FAF zones to model zones using employment data and inter-industry input-output relationships. Truck trips are assigned to a U.S. network with flows within the mega-region added to traffic projected by other model components and assigned to a more detailed network. Exogenous adjustments to mode shares can be applied; reflecting commodity-distance specific rules and local market knowledge (e.g., rail capacities).

Transport Model: Long-Distance Person. The Nationwide Estimate of Long-Distance Travel (NELDT) model using NHTS long-distance travel data and traveler attributes forms a national model of long-distance travel. This travel is assigned to a full U.S. network with flows within the mega-region added to traffic projected by other model components and assigned to a more detailed network.

Transport Model: Short-Distance Person. A 4-step travel model from one of the local MPOs was transferred and applied region-wide. Trip purposes, mode choices, and socio-economic data were standardized and applied region-wide. The gravity-type trip distribution model was upgraded to a destination choice model to better address differences in trip lengths and to incorporate regional differences in modal options. The mode choice model may be updated to include a tolling option, and to cover both short and long distance modal choices, subject to policy scenarios.

Transport Model: Commercial Vehicles. A local MPO model's commercial vehicle model (simulating both service-oriented non-freight trips and freight-carrying truck trips) was transferred and applied region-wide.

Transport Model: Assignment and Time of Day. A local MPO model's roadway, transit networks and volume-delay functions (were borrowed and standardized. Additional US networks were pulled from GIS/travel assignment software packages and intercity rail/air modal options were added. CUBE software is used for assignment consistent with the state's MPO models. Time of day factors were developed from Maryland Department of Transportation traffic count data and MPO models.

Indicator Model: Greenhouse Gas Emissions. The EPA MOVES model uses fleet assumptions, modeled VMT and link-level volumes and speed data output by the travel model to estimate GHG and other mobile emissions.

Indicator Model: Water Quality. A nutrient loading model uses detailed land cover changes from the parcel-based land use model to identify changes in nutrient runoff experienced in each watershed. (Note: The current model estimates impacts only from Montgomery County and not from the entire Chesapeake Bay watershed.)

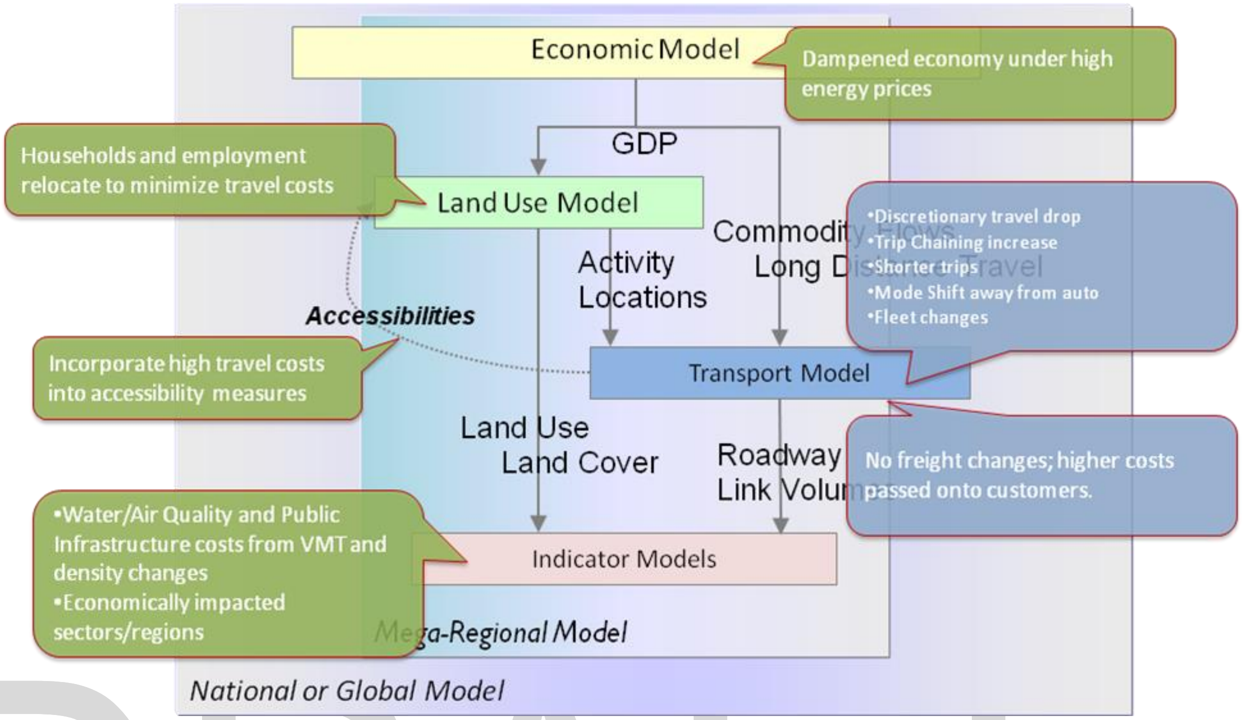
Indicator Model: Infrastructure Costs. An infrastructure cost model forecasts needs based on relationships between urban/rural development and the provision of infrastructure required for the forecast development pattern. The fiscal indicator model has been developed to reflect conditions and costs in Maryland.

Indicator Model: Regional Economy. An input-output analysis was used to determine the connectivity of economic sectors within the mega-region. This enables assessing the feedback of how transportation improvements might affect the economy in particular corridors and industries. **NOTE:** This section will be updated at a later date.

3.3.2 Scenario Assumptions

Several components of the basic Chesapeake Bay Mega-Region Model noted above were enhanced to enable better responsiveness to the policy scenario of interest – high-energy prices. These changes are exhibited in Figure 3.3-2, and summarized below. Many were intended for use in the Steady Price Rise Scenario, which was not fully implemented. This scenario's consistent rise in prices provided market signals to push changes in areas such as the economy, location decisions, and vehicle fuel efficiency. More detail on these changes can be found in the appendices.

Figure 3.3-2. Chesapeake Bay Mega-Region Analysis Framework- High Energy Price Sensitivities

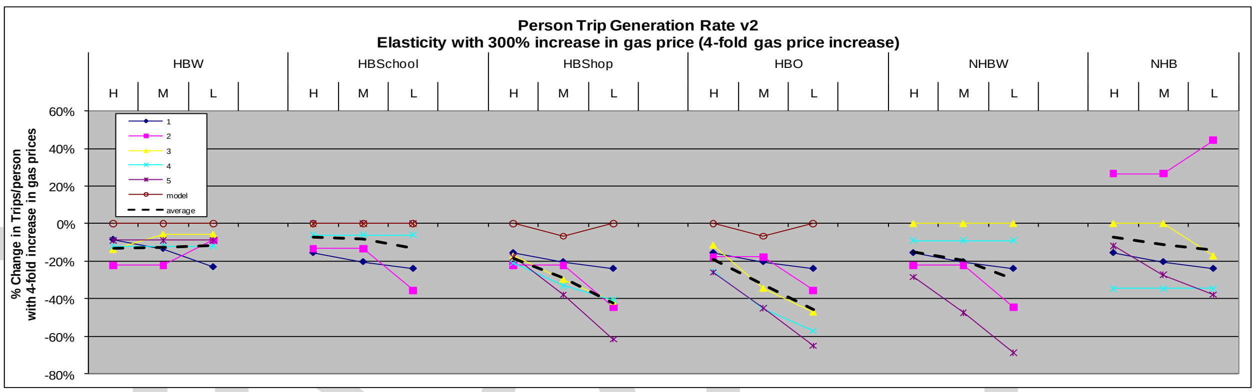


Economy. A high-energy price scenario was developed for the Steady price rise scenario. This indicated a dampening of economic growth nationally, which impacted some sectors more than others leading to some changes in the industry mix within the mega-region.

Land Use. In the Steady price rise scenarios; households and employment are able to relocate to minimize their travel costs, responding to auto operating costs. The model was also enhanced in all scenarios to enable a path-dependent land use method. This enabled only a portion of the new development occurring over the 20-plus year period to make (re)location decisions in any one year. This has been shown to be more realistic, allowing places to boom and bust, in response to more tightly coupled accessibilities. The national economic forecasts at 5-year intervals were allocated to counties, using the Lowry process noted above. In order to save time, the local allocation process from counties to zones was only done in the base and horizon year 2007 and 2030.

Auto Operating Cost (AOC) Sensitivity. Several aspects of the model were modified to improve sensitivity to auto operating cost. In the short distance person model these included: (1) trip generation rates varying with AOC, using elasticities assessed by a Delphi panel of experts in travel demand modeling; indicating higher impact to discretionary travel and increases in trip chaining with more sensitivity found in lower incomes (Figure 3.3-3); (2) asserted Mode Choice model coefficients, incorporating a value of time variable in the utility function, enabling appropriate price response by income group; (3) re-specification of the accessibility measure used in the mode choice and destination choice model to include auto operating cost in addition to traditional time and cost metrics. The accessibilities were also used in the regional economic post-processor. (4)Long-distance person travel was assumed to be limited to a constant travel budget with, increased AOC leading to reduced number of trips and shorter travel distances.

Figure 3.3-3. Delphi Panel Trip Generation Rates



Note: H, M, L = High, Mid, Low income

Source: Delphi Panel Trip Generation Rate Elasticity Input Assumptions

Freight assumptions were not modified. Consistent with the literature, freight movements are less sensitive to costs. They tend to pass costs on to the customer as the price of doing business. They also are subject to longer-term contracts and investment decisions that make it more difficult to change modes and methods. Their higher value of time also makes them less susceptible to price fluctuations. Thus, while high fuel prices may affect the economy leading to changes in demand (i.e., commodity flows), the assumptions regarding how that freight demand would be fulfilled (mode, trip length, routing) were not assumed to change, other than facing a higher operating costs in routing decisions.

Fleet Mix. As noted in the scenario discussion the average fuel efficiency of vehicles was modified to reflect fleet turnover, assumed to be more aggressive under steady rising price signals. This contributed to reduced GHG and auto operating costs.

After these adjustments, a limited validation of the model was completed. This included comparing the model’s county VMT to HPMS data in both Maryland and

Virginia. Additional calibration targets were available in Maryland including traffic and screenline counts covering the two major MPOs (Baltimore and Washington DC), as well as other locations across the state.

3.3.3 Framework Evolution

The analytical framework closely follows the generalized framework noted in Chapter 2.2. However, not all of the recommended components were exercised, and the tools are tailored to address specific issues within the Chesapeake Bay Mega-Region. The following special considerations are noted in the evolution of the Case Study analysis framework:

Model development tailored to Issues/context. A market analysis assessment of the CBM region revealed key issues, urban area strengths, industry clusters, and available data and models. The resulting modeling framework has been designed with sophisticated long distance person and freight components as well as strong short distance person mode choice and pricing components given the region's high transit usage and regional issues of interest. Upgrades to short distance models initially borrowed from MPOs has occurred based on needs identified in validation and sensitivity testing.

Integration with other Models/Data: Use of Baltimore Metro Council (BMC) model, built in CUBE was the basis for several short distance person and freight travel model components. Extensive MPO socio-economic input reconciliation (base and forecast year) as well as consistency checks were made to MPO intermediate and final outputs (i.e., trip rates, overall productions and attractions, trip length distributions, screenline traffic counts, and VMT). The framework made use of adjacent state DOT model data, national economic forecasts and federal data (Census, ES202, FHWA FAF and FHWA NHTS), reconciling different years and category definitions from the various datasets. The model was initially assembled with 2000 data (census), calibration year was 2007 (household survey data), and a forecast year of 2030 (consistent with MPOs). Model maintenance requires continued updates to incorporate new data and remain consistent with the region's MPO models.

Vertical integration. The CBM model is built as a multi-layer approach integrating a national with a mega-regional model. This two layer approach requires close integration of modules to pass on data required by each model, avoid double-counting of aspects simulating, and develop smooth interfaces that facilitate integration even under extreme scenarios.

In the CBM model, Washington D.C. is subdivided at the local level into 85 zones (called MMZ or mega-regional model zones). At the national level, the finest resolution used is counties. While such a pronounced geographic distinction in different model layers most likely is less relevant for urban models, this distinction is helpful when modeling larger study areas, such as a mega-region.

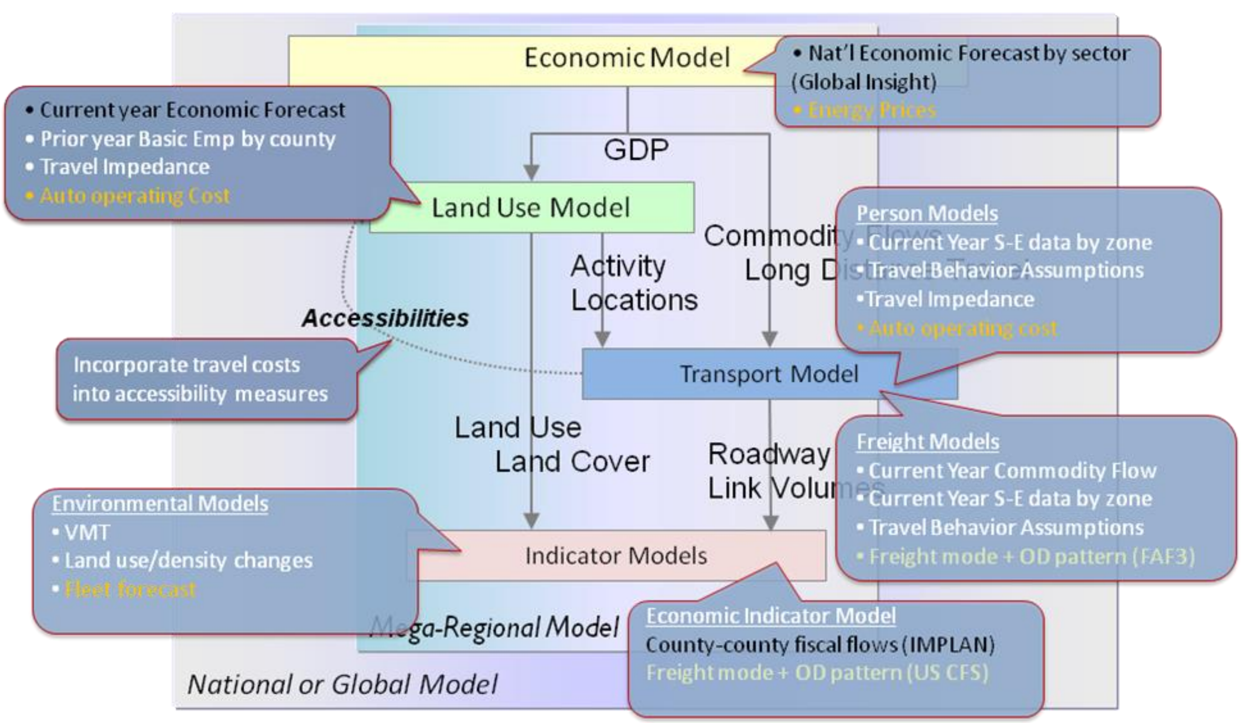
MPO Collaboration. The model is integrated with the two MPO models for Baltimore and Washington. Other regional MPOs may be included in the future. The existing integration works in two dimensions. On the one hand, aggregated results of MSTM are compared with MPO model results to ensure consistency across geographies, including number of trips generated, average trip length, mode split, and VMT by county. Agreement across models provides confidence in both the mega-region and the MPO models. In the interesting case where the two layers do not agree, it is insightful to understand why. For example, the mega-region model did not agree with the MPO models in terms of trip generation. After some research the team found that these models were using different household travel surveys, and the impact of using different surveys could be traced down all the way from trip generation to assignment. Integrating in the other direction, model volumes from the Maryland Statewide Model (the starting point for the mega-region model) are planned to be fed into some of the MPO models as traffic at external stations. In contrast to simple traffic counts, which only provide the total number of vehicles crossing at a certain location, the MSTM volumes specify how many of these external trips are “through” trips (providing the entry and exit point to and from the MPO area), and how many trips have one trip end in the MPO. For scenarios that may affect travel behavior long-distance travel, such as widening the Capital Beltway, the MPO regions may consider implementing this scenario in MSTM to provide updated external volumes under a given scenario.

Consistency between model’s geographic layers. If trips are simulated at several geographic layers, special attention has to be given to minimize inconsistencies at the border between the layers. The CBM model overcomes this inconsistency by applying different models at the more detailed mega-regional zone system and to the coarser zone system at the national level. This way, both models can be calibrated to their respective zonal resolution, creating a more consistent result (e.g., combined trip length frequency distribution).

Tightness of component integration. The CBM model uses a combination of level 1 and level 2 integrations, as noted in Section 2.2.7. While the economic and the land use model are stand-alone modules that are run consecutively (level 1), The long-distance person model, the long-distance truck model and the short-distance truck model are built as one single module that runs efficiently without time-consuming reading and writing of intermediate results (level 2).

Input Consistency. Figure 3.3.4 provides a summary of various exogenous inputs to the model that are repeated at multiple locations. The color coding of the text indicates inputs that are comparable. To ensure consistency, the same value was used in each instance where possible, such as the common fuel price and vehicle efficiency value used in the economic, land use, various transport models, and the air quality model. In other cases consistency checks were made to ensure the inputs were reasonably compatible, such as the base and future year socio-economic forecasts by county in the National Economic model, and the IMPLAN data used in the regional economic model. These were also compared to more official demographic forecasts by jurisdiction. Several other inputs are implicitly consistent as the values are obtained from upstream models, such as the tiered allocation of household control totals from the economic model through the land use model, used in the transport model and again in the indicator models.

Figure 3.3-4. Input Consistency



3.4 Case Study Scenario Results

Two alternative price futures for 2030 have been discussed (Section 2.2), representing bookends of the impact to the Mega-region; a Price Spike in which petroleum prices stay steady for years and then rise very rapidly in a short period of time; and a slow Steady Price Rise to 2030. The **Price Spike** scenario retained the **Reference** scenario's economic and land use, taking all the impact in the transport sector. The **Steady Price** rise scenario would provide more stable price signals for long-term changes in the economy, land use, and vehicle ownership. Although the study team was unable to run the **Steady Price** scenario, some results are available and with our understanding of the modeling process we can estimate the direction of other impacts. This section presents the full collection of findings on a high-energy future, noting their source, as appropriate.

3.4.1 Steady Price Rise - Impacted Industries

A rise in petroleum prices will affect both the United States and the global economy. The severity will depend on the timing and the magnitude. Several key factors in assessing the economic impact include:

Relative energy efficiency of the United State vs. other countries. Unless there is a significant change in U.S. energy efficiency relative to other economies there will not be a major shift in industrial production to other nations, or a major shift from other nations to the United States. Relative to other countries the U.S. is likely to keep the same industrial base. Supply chains spanning multiple continents might be expected to dismantle under high-energy scenario. In fact, for most manufacturing the cost of travel is close to 10%, which is still outweighed by labor rate differences abroad. Thus outsourcing will likely remain an effective business model until energy prices rise precipitously.

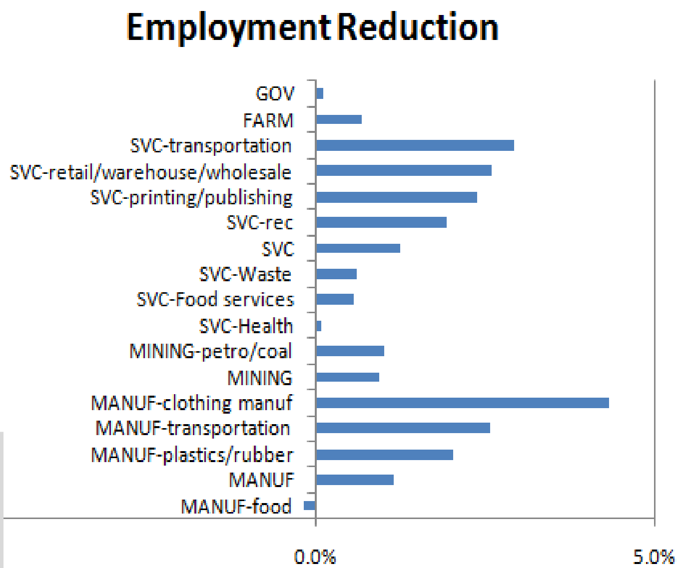
Energy Substitution. While petroleum prices may increase, energy is to some extent fungible, that is one form of energy can be substituted for another. Possible substitutions for petroleum are coal, natural gas, hydroelectric and nuclear. Other possible sources which have not been extensively developed include solar, geothermal and tidal energy generation. Part of any response to high petroleum prices will include a shift among different energy sources. This shift will mitigate the impact of petroleum prices increases but will also raise the cost of other forms of energy.

Energy efficiency. There are efficiencies in all economic sectors which could be implemented if the price is right (i.e. if the cost of energy is high enough to make them viable). An obvious example is the ability to shift to more fuel-efficient vehicles in the transportation sector. Behavioral shifts will also occur to make energy usage more efficient. For example, Germany has a very high-energy tax and German electricity consumers commonly unplug most lights and appliances in the evening to save on electricity costs. Similar types of behavior could occur in the U.S. under very high prices.

Although not run through the full modeling framework, a steady rice rise economic forecast was commissioned and analyzed. Several industries were found to be more sensitive to the high-energy prices, as shown in Figure 3.5-1. These are consistent with the literature which indicates that the largest impact of a price spike is the impact on consumer's disposable income. Higher energy prices act as a tax on purchasing power, and the proceeds of this tax are largely spent outside the mega-region, reducing the purchasing power of the economy as a whole. This tends to dampen the consumer sectors such as wholesale, retail, and construction. A second key economic effect of higher energy prices is to energy-intensive industries. Figure 3.4-2 shows the energy use by sector nationally. In the Mega-region, the most affected industries are Energy, Transportation, Manufacturing (durable goods, others), Pulp/paper, forestry products, agriculture (fertilizer costs) and the Food industry. Other sectors, such as finance and insurance, will be relatively unaffected by energy costs.

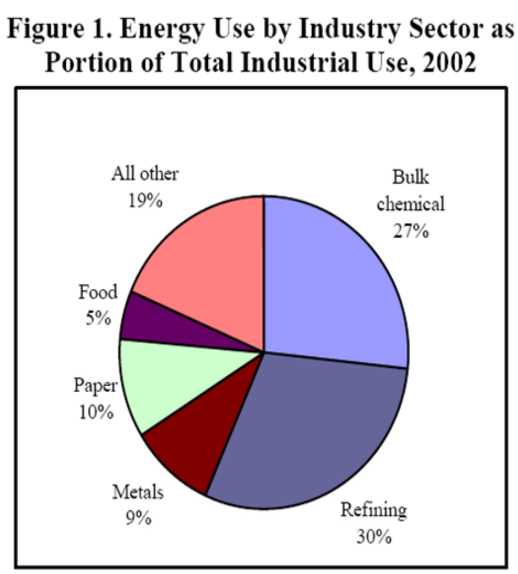
The magnitude of the impacts in Figure 3.4-1 should be used with caution as the work was based on conservative assumptions. These include a much lower increase in energy prices than analyzed elsewhere in this report (150% from 2007); constant energy efficiency of the US relative to the world (minimizes outsourcing), assumed energy efficiency improvements in response to steadily increasing price signals, and use of a long term equilibrium model which allows significant energy source substitution

Figure 3.4-1 Steady Price Rise Impacted Economic Sectors



Source: INFORUM 2030 **Reference** & **High Energy Price** scenarios

Figure 3.4-2 Energy Intensity of Various Economic Sectors

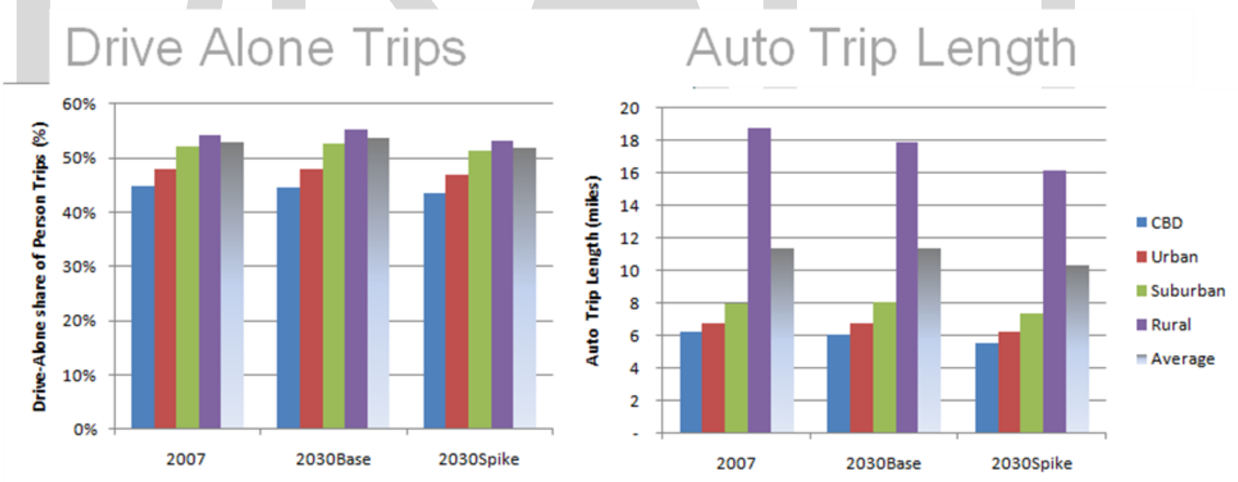


Source: Energy Information Administration. 2002. Manufacturing Energy Consumption Survey (MECS). http://www.eia.doe.gov/emeu/mecs/contents.html. Washington, DC: U.S. Department of Energy.

3.4.2 Price Spike - Vulnerable Populations

Due to the suddenness of the assumed price spike, population and employment do not have sufficient time to shift location. As a result, several communities can be noted for their vulnerability to the price change. These include auto-dependent areas, which as Figure 3.4-3 shows are disproportionately located in the rural/exurban areas of the mega-region. Those regions have the highest tendency to drive alone, less ability to shift modes (carpooling, but limited transit), and their trip lengths are significantly longer on average. Due to sparse populations in rural areas carpooling and transit are not as feasible as in urban areas. People in rural areas would need to rely primarily on shorter trips to respond to higher energy prices. Rural areas, with fewer alternatives, would thus be more vulnerable to higher fuel prices.

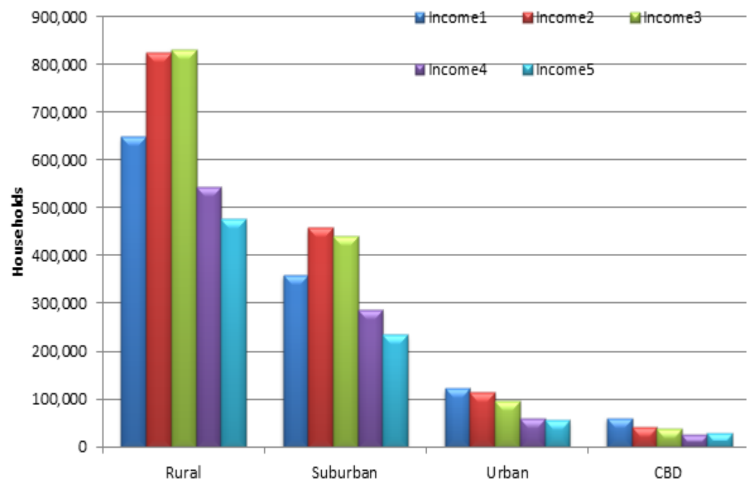
Figure 3.4-3 Vulnerable Communities – Auto dependent



Source: 2007 **Base,** 2030 **Reference** and **Price Spike** CBM scenarios.

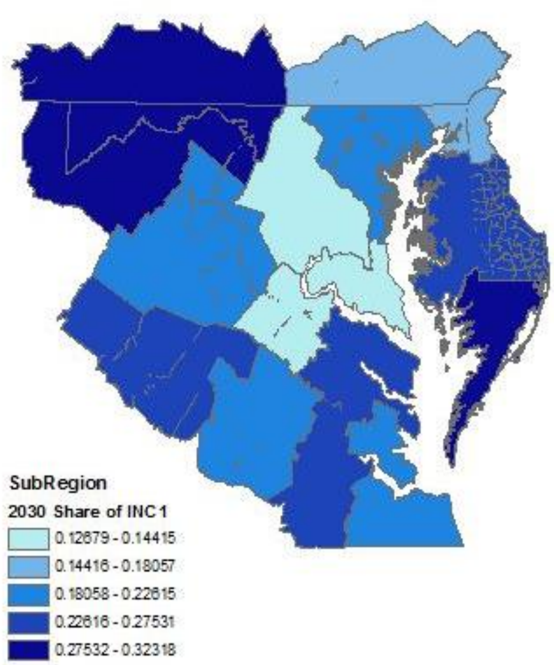
A second community vulnerable to high-energy prices is lower income households. Travel costs constitute a larger share of their household budgets, allowing less flexibility in the face of higher energy costs. As shown in Figure 3.4-3, the share of these households in the CBD and Urban areas is high, but the bulk of the low income households reside outside the urban areas with less access to transit options.

Figure 3.4-4 Vulnerable Communities – Low Income



Source: CBM 2030 **Reference** Scenario

Figure 3.5-5 Vulnerable Communities – Low Income



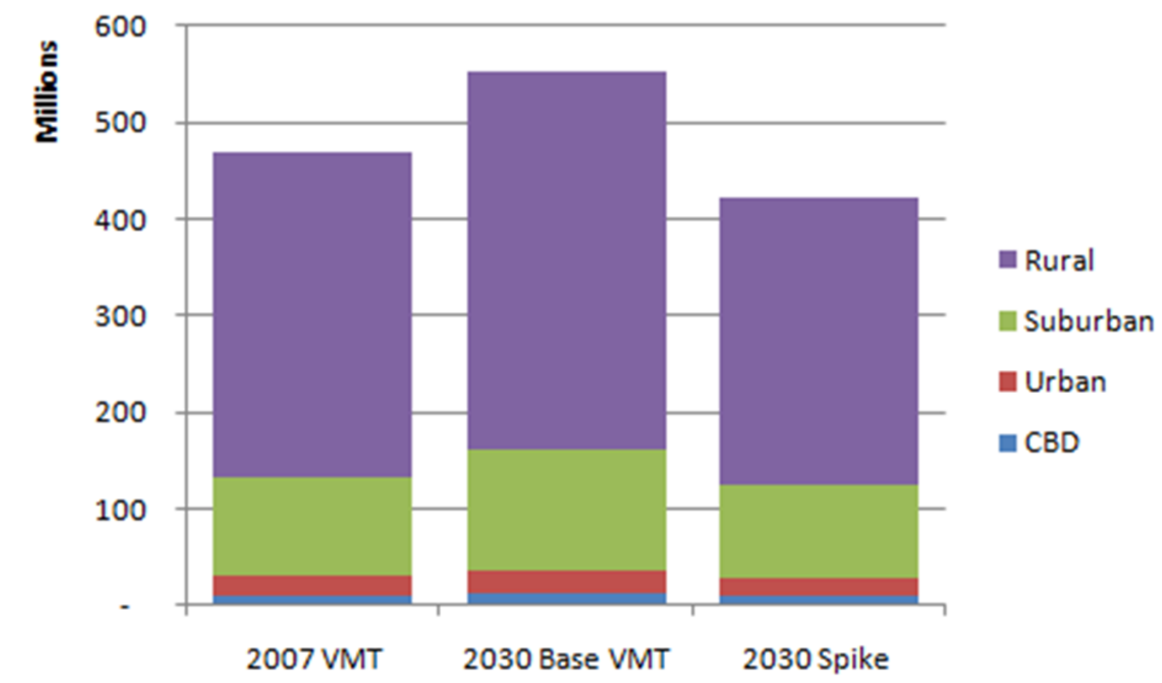
Source: CBM 2030 **Reference** Scenario

These vulnerable communities, particularly those in rural areas, increased in the 2007-2030 Reference case, when auto operating costs were kept low by stable prices and greatly improved fuel efficiency (under federal CAFÉ standards). Although not analyzed, the impacts under a steady price rise, where residents would make land use and vehicle decisions in response to steady rising price signals, would be expected to dampen the number of residents in these vulnerable communities. This and other measures to assist these communities, such as carpooling, or other budget assistance would bolster the full region's resilience to a high energy future.

3.4.3 Travel Demand – Significant VMT reduction

Under our price spike scenario, an unexpected four-fold increase in the cost of fuel led to a significant reduction in vehicle miles traveled within the region. As shown in Figure 3.4-6, the region's travel was 25% below the 2030 **Reference** scenario, and even below that of the 2007 base year. The expansion of the rural/exurban VMT in the 2030 **Reference** scenario was reversed, with this group showing the largest decline.

Figure 3.4-6 Mega-Region Vehicle Miles Travelled



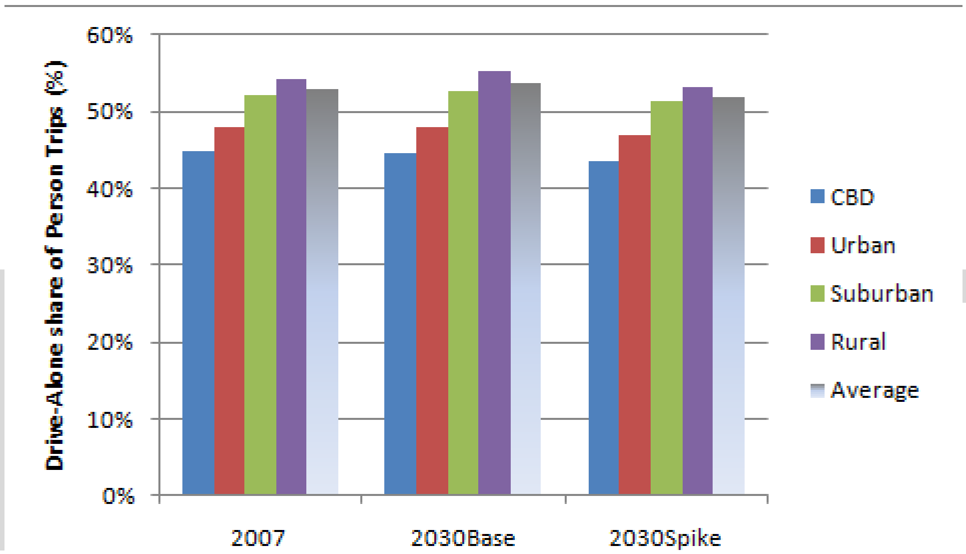
Source: 2007 **Base,** 2030 **Reference** and **Price Spike** CBM scenarios.

The reduction in VMT was attributable to three sources:

- **Slightly Fewer Trips**. A drop of 0.5% trips overall, with a higher 8% drop in long distance trips. As noted in the analysis method (Section 3.3), a Delphi panel of experts assisted in setting elasticity by trip purpose and income. However, the end result had only limited impact on the overall number of trips generated.

- **Some Mode Shifts**. Clearly the analysis found that where transit was available, ridership increased (22% transit ridership increase overall), while carpooling increased (7% overall) across the full region. There was a corresponding reduction in drive alone (dropped by 13%). However, as with most regions, the auto dominates travel, and despite these increases in minor modes, the impact to the overall mode share was less pronounced, as shown in Figure 3.4-6. This applies in all area types, CBD, urban, suburban and rural. While a 22% increase in transit ridership may be small when compared to the impact on the highway network, an increase of this magnitude would strain the capacity of a transit operator to meet the increased demand.

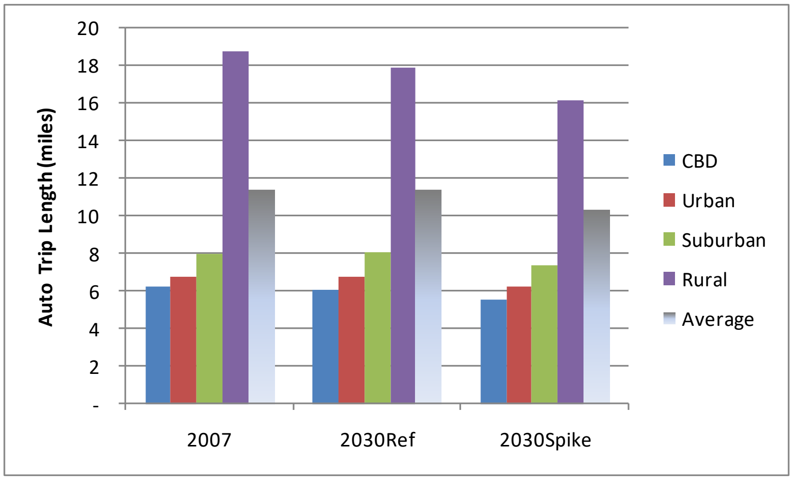
Figure 3.4-6 Drive alone trips as a percent of total trips, by area type



Source: 2007 **Base,** 2030 **Reference** and **Price Spike** CBM scenarios.

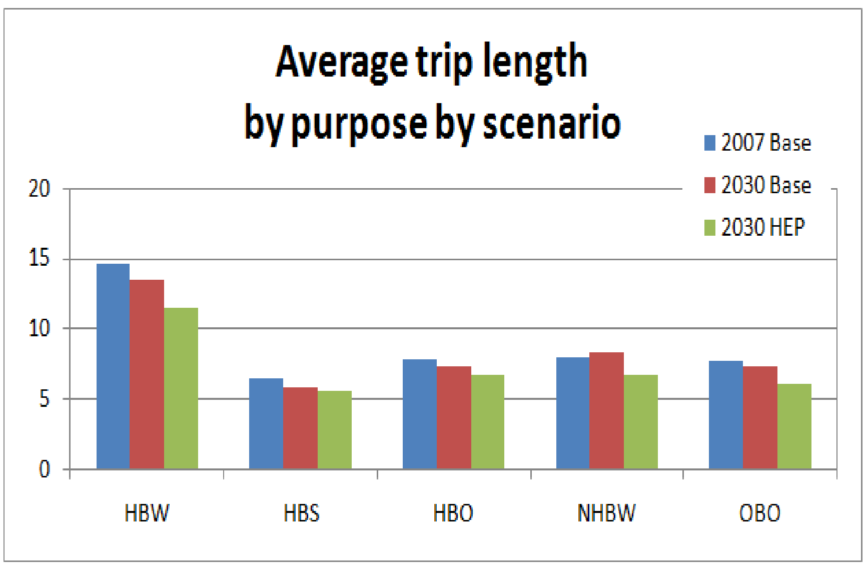
- **Considerably shorter Person Trips**. The average auto trip length declined by 9% on average throughout the mega-region and across all area types (Figure 3.5-7) and all trip purposes (Figure 3.4-8). This decline was most pronounced in rural areas with the least effect in CBD and urban areas. Examining the decrease in trip length by income and purpose (Table 3.4-1) highlights the greatest sensitivity to energy prices and the largest decrease in trip lengths occur for lower income groups. Trip purpose also influenced the response; with the greatest percentage change in work trip length and least change in home based shop trips.

Figure 3.4-7 Change in auto trip length by area type



Source: 2007 Base, 2030 Reference and Price Spike CBM scenarios.

Figure 3.4-8 Change in Average Trip length by purpose



Source: 2007 Base, 2030 Reference and Price Spike CBM scenarios.

Table 3.4-1 Change in average trip length by income and purpose – 2030 Reference compared toPrice Spike

Percent change in average trip length

2030 **Reference** compared to **Price Spike**

Purpose	Income Group				
	1	2	3	4	5
HBW	-22%	-21%	-17%	-13%	-9%
HBS	-7%	-5%	-4%	-3%	-2%
HBO	-12%	-11%	-8%	-7%	-5%

Source: 2030 **Reference** and **Price Spike** CBM scenarios.

The reduction in VMT was largely the result of changes in travel patterns in personal vehicles. Freight, by design, showed little impact in the analysis. Higher energy prices have a different impact on freight than on passenger travel. Freight movements are derived from the FHWA FAF data and were assumed insensitive to changes in accessibility and auto operating cost. Therefore freight (and truck) movements may change routes but were not assumed to change destinations, leaving truck VMT largely unchanged.

As noted in the Framework methodology (Section 3.3), the analysis assumed a fixed economy and mode split (same truck-based demand), and consistent with literature assumed that the increased travel costs they faced would be largely passed onto customers as a cost of doing business. This also reflects the long-term service contracts by freight movers that would be hard to change in the sudden Price Spike scenario in particular. The model assumes a much higher value of time for freight trips that also dampens the impact. As a result, the 2030 Price Spike scenario showed very stable trip lengths (shortened by 0.28 miles on average) and only a slight reduction in truck VMT (-0.5% overall)

3.4.4 Price Spike - Congestion Relief

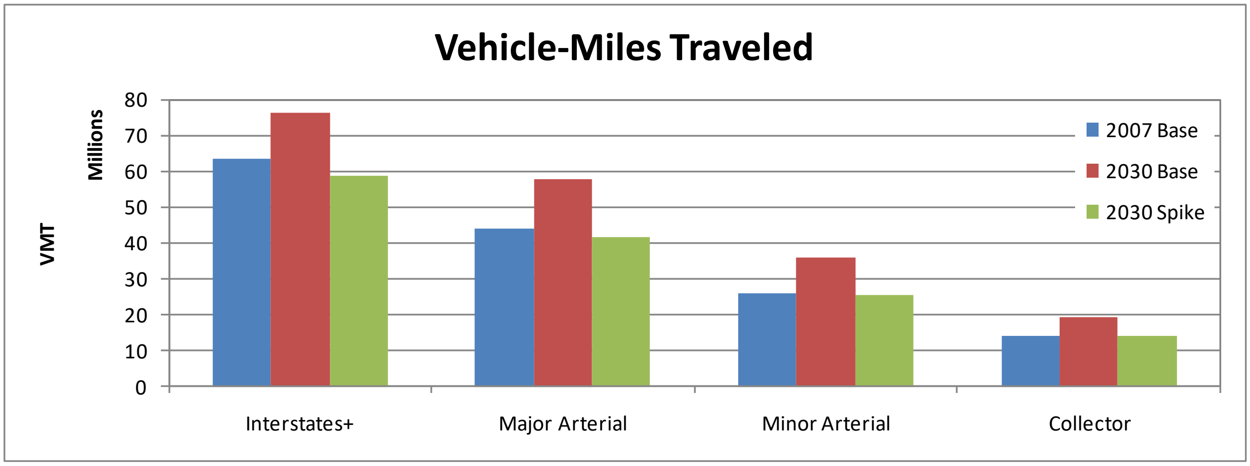
The significant personal vehicle VMT reduction under the **Price Spike** scenario, led to an even more dramatic change in vehicle hours traveled (VHT), providing major congestion relief, at or below in many cases the 2007 base year (Figure 3.4-9). The large increase in VHT on collectors, the lowest level in the system, is attributed to collectors being close to capacity levels in the base year and being unable to absorb the additional traffic in 2030.

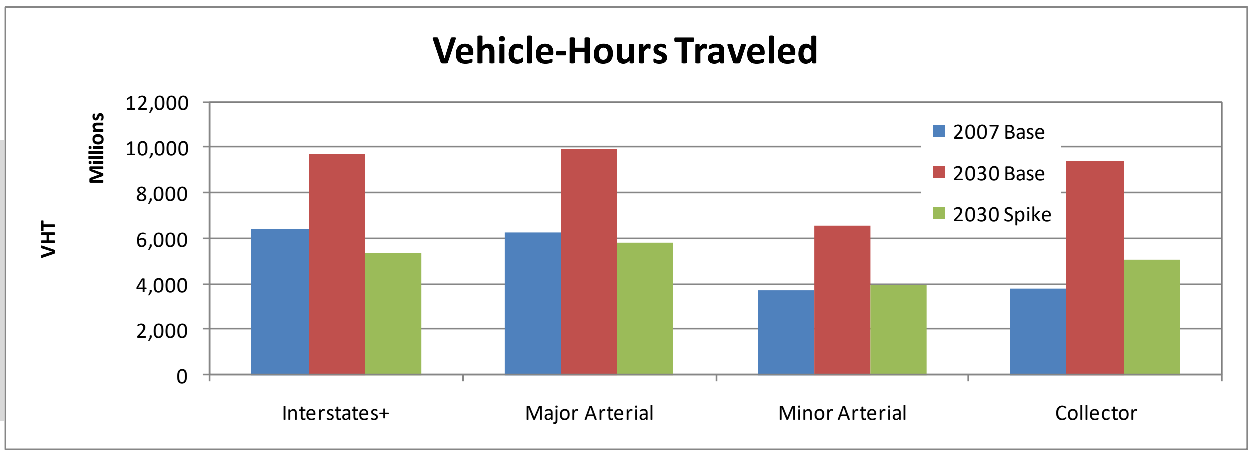
The congestion benefits are highlighted in Figure 3.4-10, where implied average speeds (VMT/VHT) drop by 20% overall, most pronounced in the non-urban areas. The key benefit of this congestion relief is to the freight movement across the Mega-Region, now facing fewer delays and higher speeds, enabling them to take more direct routes. Figure 3.4-11, shows increases and decreases in truck VMT by county. The counties in red are primarily located along the vital I-95 corridor. As travel decreases on the corridor due to increasing energy prices the corridor becomes less congested, allowing freight to take more direct routes.

The positive impact of the Price Spike scenario on the regional economy is also supported by the economic post-processor results. Figure 3.4-11 illustrates the combined impact of changes in travel cost on commodity flows between the 25 county pairs with the largest trade flow. In order to develop this information, the study assumed that the trade relationships between various employment sectors would remain the same in 2030 as in 2007. The 2030 flows were then multiplied by the generalized travel cost (time, tolls, and auto operating cost) from the 2030 **Reference** and **Price Spike** scenarios. The difference in these costs are shown. The results are somewhat non-intuitive. The initial assumption was that higher energy prices would adversely affect the economic flows between counties. However, as illustrated by the green lines in the figure, in many areas, particularly in urban areas and along I-95, the ability to make economic linkages improved due to congestion relief (drop in time portion of generalized cost). At the same time in rural areas, particularly to the west, the cost of making these linkages increased. In the urban areas, where higher energy prices led to shorter personal auto trips and a shift from auto to transit and carpooling, there is less congestion, faster movement and therefore lower travel "cost." Effectively the reduction in travel time compensates for the increase in operating cost. In rural areas, which do not have much congestion, there is little change in travel time and the generalized cost responds only to the increase in fuel cost.

Other studies with tour-based models [ODOT Ref] have noted an additional impact of congestion relief. Logistics managers are able to add a few more stops to a drivers' daily route for the same number of work hours. Thus, while higher fuel prices may have a generally negative effect on a region, they can provide a benefit to freight travel and thus the larger mega-region economy.

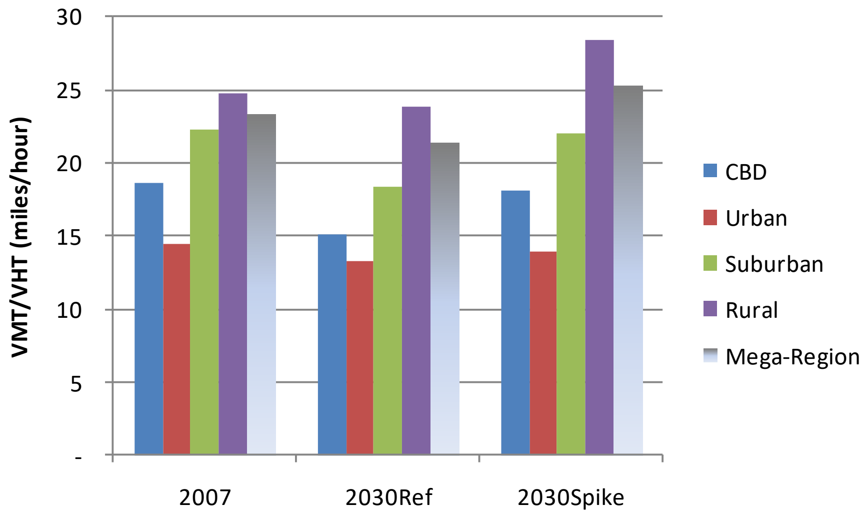
Figure 3.4-9 Vehicle Miles traveled and Vehicle Hours Traveled





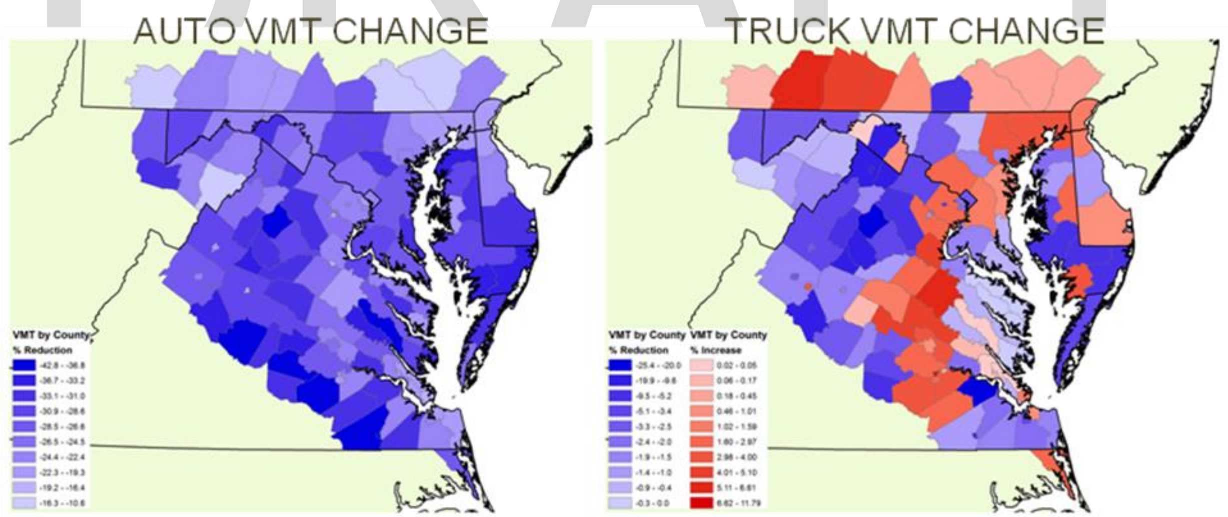
Source: 2007 **Base,** 2030 **Reference** and **Price Spike** CBM scenarios.

Figure 3.4-10 Average speed by area type



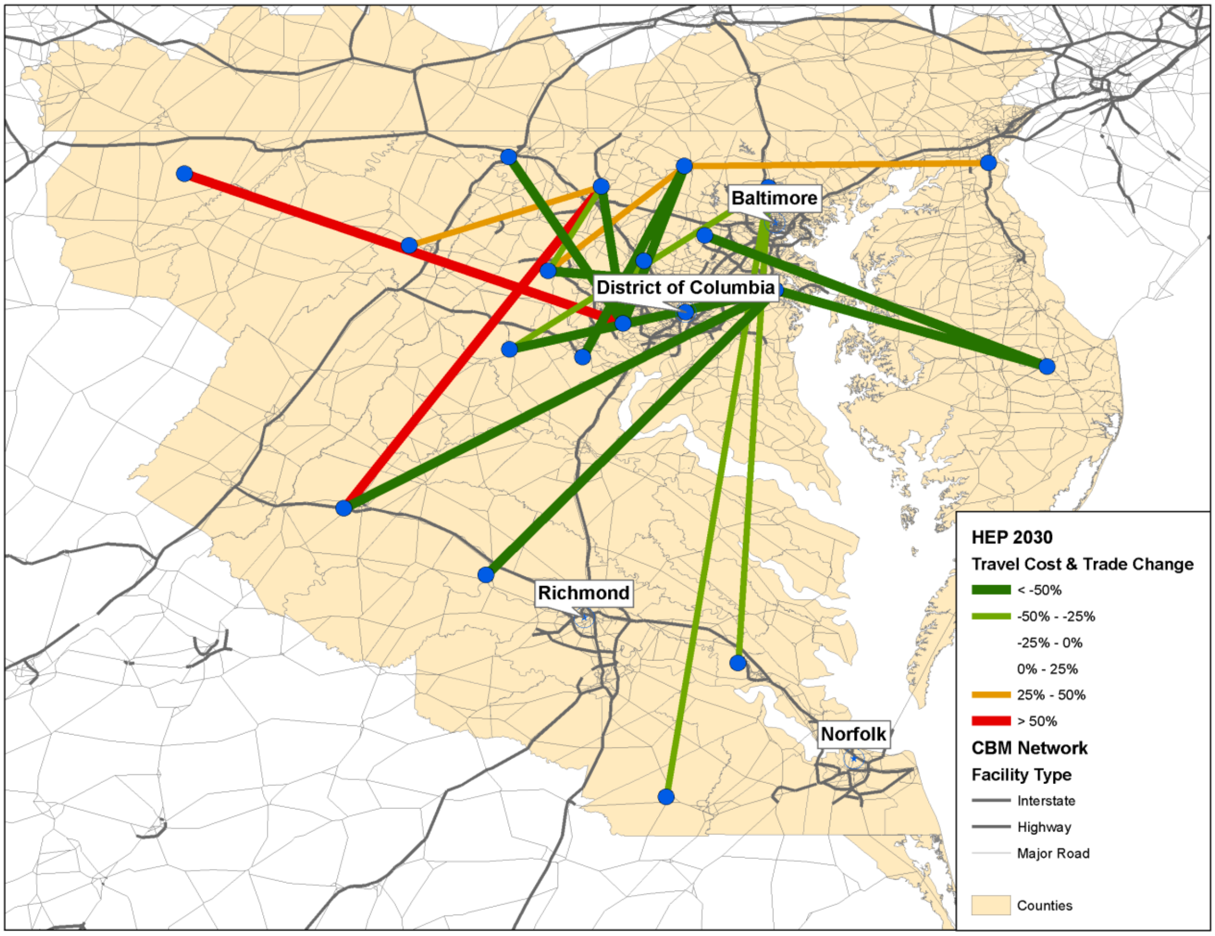
Source: 2007 **Base,** 2030 **Reference** and **Price Spike** CBM scenarios.

Figure 3.4-11 VMT reduction by County – Auto & Truck Trips



Source: 2030 **Reference** and **Price Spike** CBM scenarios.

Figure 3.4-12 Change in percent of travel cost between county pairs with largest activity



Source: 2007 **Base,** 2030 **Reference** and **Price Spike** CBM scenarios., Economic Post Processor

NOTE: THE FINAL REPORT WILL INCLUDE ADDITIONAL ANALYSES.

3.4.5 Indicators

Three indicator models provide a picture of mega-region conditions under high-energy prices beyond transportation.

Air Quality. The study used the MOVES mobile source emission model developed by EPA. Table 3.4-2 compares the 2007 emissions to the 2030 Reference and the 2030 Price Spike scenarios. The biggest decline in Greenhouse gas emissions is between 2007 and 2030 despite the region's growth. The decline results from increased café standards for 2025. This assumes that the 2025 standards have impacted most of the vehicle fleet. The price Spike scenario more than doubles the reduction from 2007 when compared to the 2007 base. This reduction is due to lower VMT combined with lowered congestion.

Table 3.4-2 – Greenhouse Gas Emissions

	Auto mpg	Light truck mpg	composite	VMT (Millions) (Auto + Truck)	C02e Metric tonnes (millions)	Percent change
2007	27.4	20.8	24.4	468.92	180	
2030 Reference	54.5	35.4	41.8	551.59	154	-14%
2030 Price Spike	54.5	35.4	41.8	422.09	122	-32%

Source: 2007 **Base,** 2030 **Reference** and **Price Spike** CBM scenarios.

Water Quality. Nutrient loading depends only on changes in land use. Since the land use did not change in this scenario there is no change in nutrient loading. Unmodeled water quality impacts due to roadway runoff might be expected to improve with the reduced VMT.

Public Infrastructure Fiscal Impact. The impact on local jurisdiction capital infrastructure costs depends solely on land use and is not impacted by changes in travel. Under the Price Spike scenario, with no change in land use, there is no change in capital costs beyond the Reference case.

3.4.6 Conclusions

The case study analysis provides a wealth of information for a mega-region decision body and its resilience to a high-energy price future. Table 3.4-3 provides a summary of the results, both those taken directly from analysis (white cells) and those conjectured (shaded cells) based on our understanding of the modeling tools and work to date. This latter category included the unmodeled Steady Price Rise scenario as well as the full effects of the economic and land use impacts (assumed fixed) and environmental models (analysis too expensive to perform under this effort) of the Price Spike Scenario Analysis showed that the more dispersed land use pattern of the 2030 Base scenario led to an improvement in jobs-housing balance across the region, but put residents in vulnerable locations that reduced their resilience to higher gas prices. The Price Spike scenario had a significant impact on travel, leading to shorter trips, more carpooling, and transit where available. This has the benefit of increasing speed and reducing congestion. In looking at the regional economy the higher energy prices provided a silver lining, allowing freight to move faster in more developed areas and facilitating economic linkages. Under this scenario, building on the benefits of the federal CAFÉ standards air quality further improves due to the decline in VMT.

It is hypothesized that the Steady Price Rise scenario would show less effect. First, the economy is likely to be smaller as industries face higher costs and households spend less. The consistent rising price signal would be expected to lead to long term decisions by businesses and residents that would reduce their vulnerability to higher gas prices. These include more compact development and faster turnover to higher efficiency vehicles. As a result, although we still expect a reduction in travel, it would likely be less than the Price Spike scenario, with less disruption to travel patterns and household budgets. This would mean less congestion relief, and associated impacts to freight movement and the economy.

Table 3.4-3 – High Energy Price Case Study Results Summary

Performance Metric	2030 Base	Price Spike	(not modeled) Steady Price Rise
Economy			
Mega-Region-wide Economy	🟢	(🔴)	(🔴)
Household Growth	🟢	(○)	(🔴)
Regional Economy (impacts freight costs)	🔴🔴💣	🟢&🔴	(🟢&🔴)
Land Use			
Compact/Clustered Growth	🔴	(🔴)	(🟢)
Jobs/housing balance	🟢🟢	(🟢🟢)	(🟢)
Vulnerable areas (low income, no transit)	🔴	(🔴)	(○)
Transportation			
VMT – Person (impacts to safety/health)	🔴	🟢🟢	(🟢)
VMT - Truck	🔴	🔴	(🔴)
Congestion/Speeds	🔴🔴💣	🟢🟢	(🟢)
Environment			
Greenhouse Gas Emissions/Fuel Usage	🟢🟢	🟢🟢🟢	(🟢🟢)
Water Emissions	🟢	(🟢)	(🟢)
Fiscal Costs	🔴🔴	(🔴🔴)	(🔴)

Legend
🟢🟢
🟢 Better
○ relative to 2007
🔴 Worse
🔴🔴
💣 = sleeping time bomb
() indicates not resulting from scenario analysis

Note: Direct analysis results are noted in white cells. Conjecture of the other measures is shown in shaded cells.

4 MEGA-REGION BOARD CONCLUSIONS

This project has identified the development of mega-regions in the United States and throughout the world, developed a framework for the analysis of mega-region issues and demonstrated the application of the framework to a high-energy price case study in the Chesapeake Bay Mega-region.

From the literature review we can see that the world is evolving into a series of mega-regions, large-scale aggregations of population and employment spanning multiple metropolitan areas connected by economic relationships such labor and freight flows. These areas have their unique issues and the analytic framework described in Section 2 can form the basis for analyzing issues of particular concern. A Mega-region tends to have a broader view than just transportation, typically extending to economic, land use, environmental and fiscal performance. The framework is designed to be flexible so it can be easily be tailored to meet a region's specific needs covering a wide range of situations.

In this case study, the generalized analysis framework was implemented in the Chesapeake Bay Mega-region (CBM). The case study assumes the existence of a mega-region board (MRB) which would have oversight on activities within the mega-region. The MRB would have concerns about economic development, transportation, housing, the environment and other issues which play out at a scale larger than traditional urban regions. If such an entity existed, and the results of the case study were presented, several significant issues emerge which the MRB would want to address. These issues include the economy, freight, transportation and land use. The MRB would want to examine these issues from normal growth **Reference** scenario and alternative futures such as **a Price Spike** in energy prices.

The results of the case study also identify other factors which would be significant to a MRB; the fact that the CBM is tied together economically and that in addition to land use, transportation and the economy, the CBM should address some policies at the mega-region level, such as emergency preparedness and the collective impact of individual local policies. The analysis framework can help to identify these policies as well as test their impact of implementing them in a coordinated or uncoordinated way across the jurisdictions within the mega-region.

The remainder of this section summarizes results of the CBM future under a reference and high energy price scenarios, and the need for analysis of emergency preparedness and other collective policies at the mega-region level.

4.1 Reference - 2030

4.1.1 Economy and freight

To understand the mega-region economy and freight movements, the impacts under continuation of trends must be examined, covering economic impacts both nationally as well was economic movements within the mega-region.

The national economy is projected to grow between the present day and 2030. At the same time not all sectors of the economy grow evenly. An MRB would want to strengthen and support those sectors which are likely to grow and support a transition away from those sectors likely to decline. Also, as shown in section 3.1, the regional characterization, the CBM economy is closely knit. Significant economic flows occur between subareas of the mega-region, as measured by the value of shipments. The north south movements, particularly along I-95, are historically important and likely to grow, highlighting linkages along the full north-south spine of the mega-region. At the same time, with the dispersed location of employment growth as transport costs remain low, the need for east-west economic movements increases in the future. An MRB, with concern about the resiliency of the economy, would act to ensure that adequate transportation infrastructure exists in 2030 to support the growth in the east-west economy.

4.1.2 Land use and transportation

In 2030, due to growth under assumed continuation of low transport costs and the challenge of absorbing more growth in the dense urban areas, more development occurs in suburban and rural areas. A proactive MRB would encourage the development of more compact communities by recommending changes in zoning and pricing to allow for higher density development and for mixed land use, allowing trips for multiple purposes to be satisfied within the same general area. Fewer and shorter auto trips work to preserve roadway capacity for higher economic functions such as freight movements.

The Baltimore-Washington area, with densities high enough to support transit, could benefit from additional transit service to help accommodate future growth. While multiple factors influence the location of employment, including accessibility, zoning, and public service provisions, a MRB would want to combine the knowledge of the likely employment changes with an understanding of which areas within the mega-region were most suitable for emerging residential and employment growth, as well as locating transport-dependant economic sectors near adequate roadway capacity over time. The fiscal tool can highlight the regions that can most efficiently accommodate growth, such as established urban areas where secondary road and school systems are already in place.

4.2 HIGH-ENERGY PRICE

4.2.1 Steady Price Rise

While the case study focused primarily on the scenario of an energy price spike, a forecast of the effect of a steady price rise on employment sectors was conducted. The conclusion from this forecast is that with forewarning and appropriate price signals to influence long term decisions such as location decisions and vehicle purchases, the mega-region's economy is resilient and that the long-term impacts of a steady energy price rise will not be catastrophic. However, specific sectors of the economy may be harder hit than others. Agriculture and some manufacturing industries, for example, rely heavily on energy and may experience greater impacts than information technology. Some industries will decline slightly but due to offsetting impacts of energy substitution and the development of more fuel-efficient industrial processes and vehicles the long-term impact will not be severe. Nevertheless, a MRB would use these results to identify industries which are likely to grow, those likely to decline and plan accordingly. For instance, assistance could be provided to help industries transition to more energy efficient processes and vehicles. On the residential side, encouragement could be provided to reduce the energy impact to household budgets, by channeling growth the less-auto dependent areas, as well as assist rural residents in purchasing more efficient vehicles.

4.2.2 Price Spike

A sudden energy price spike, in contrast, would likely have a more immediate impact, primarily on travel but also on the economy.

Land use and transportation

The travel effects of a energy price spike would hit hardest in the pocket-book of the region’s residents. In response, they can be expected to reduce the number of trips, change trip destinations to allow for shorter trips, make more direct routes and chaining of multiple trips, as well as increase the use of any alternative transportation options available to them, such as carpooling and transit services.

An MRB responding to increased energy prices, or anticipating such an increase proactively, could take several steps to ease this pain, while retaining the health, safety, and economic benefits of a significant drop in auto use. One such policy includes promoting more compact and mixed-use development centered around transit systems, which provide options for shorter trips, trips by transit, bike and walking. The simple act of moving children's activities closer to schools limits the need for travel and ability to serve such needs with alternate modes, such as biking or walking.

In the Baltimore-Washington area, where a wide range of transit options are available, the analysis showed a significant increase in transit ridership. In contrast, outside the Washington D.C. suburbs urban areas in Virginia do not have a high level of transit service and did not see a comparable increase in transit usage. This makes residents more vulnerable to rising energy prices. A MRB could also encourage and support the development of alternative transportation options, so that when the higher energy prices hit these options are available. This includes investment in transit service, vanpool and ridesharing programs, and electric vehicle infrastructure such as charging stations in urban area and along major corridors such as I-95. Many of these options take a long lead-time to set up so an MRB would need to be proactive.

Telecommunication can also be a substitute for transportation. In many firms and across many occupations telecommuting is substituting for being at the worksite on a daily basis. An MRB could not only encourage the development of telecommuting policies but also support the deployment of the necessary infrastructure required to make telecommuting available to a larger portion of the population.

Economic Impact

The pinch that high energy prices would have on vulnerable communities can have a pronounced effect on the region's economy, especially if long-term location and vehicle purchase decisions were made without the assurances of a high energy price future. The drop in discretionary spending by households can be expected to impact industries, particularly those related to consumer goods. Tourism will also likely be impacted. A MRB attempting to shore up the economy would look to implement policies to aid household budgets in general, or transport costs specifically such as providing more transportation options, as noted above.

Indeed it speaks to equity issues within the region as many lower middle-income households drive farther to work in less efficient cars and spend more on repairs than their wealthier neighbors. Thus income inequality is deepened and exacerbated by high-energy prices. Reducing auto operating cost is comparable to raising wages. Thus, a MRB might promote policies that reduce the amount of fuel used and/or the cost of owning or driving a car, thus reducing the impact of prices on household budgets and the economy.

For freight movements, the economic impact of a price spike would be mixed. The case study makes two assumptions with respect to freight. First, the cost of shipping is borne primarily by the shippers, not the freight carriers, reflecting long-term contracts. Second, in manufacturing processes, particularly those requiring assembly of intermediate goods and shipment for final assembly, destinations cannot be easily be changed. The capital costs of establishing the origin and destination facilities means that these locations are fixed in the short and intermediate term. Thus, freight trips must maintain their current patterns and modes.

Further, given that the costs are not borne by the carriers and that the origins and destinations remain static, by lowering congestion the decrease in traffic can actually have a net benefit to freight and the economy. This benefit can be particularly important for shipments which are high value and /or time sensitive. They can move quickly without fearing being stuck in traffic.

Providing additional freight rail service, especially to communities not well served would be appropriate for planning for a sudden petroleum price rise. Currently freight trips of less than 400 miles travel primarily by truck, due to the cost of transferring to rail at the origin of the trip and at the final destination. In a very high price scenario some rail trips would become more cost competitive and providing improved rail service would support the shift of mode.

4.2.3 Combined Policy Impacts

In the mega-region view, policies in one jurisdiction can have spillover effects on the rest of the mega-region. Individual areas can develop policies which are optimal for one area but have negative effects on adjacent areas. Within the mega-region, with the linkages spanning many jurisdictions, the spillover effects can be wide ranging. For example, policies which attempt to foster economic development in one area may have the effect of removing development from another area. Further, policies which appear effective in a small area may actually have a negative effect on the entire mega-region. For example, policies in a community which require low density zoning for residential activity but allowing high density zoning for commercial activity may have the effect of generating additional travel but effectively 'exporting' that travel to neighboring jurisdictions.

A MRB, with tools similar to those used in the case study, would be able to analyze policies in isolation or combination, assuming either coordinated or uncoordinated policies, to determine their collective effect on the mega-region and on local jurisdictions.

4.3 Homeland Security

While this study did not address security issues directly, the threat is particularly severe in the Chesapeake Bay Mega-region, home to the nation's capital and numerous military bases. It is clear that homeland security events could have a major impact on the CBM with effects rippling elsewhere. For example, an evacuation from Washington, DC would likely tie up the entire I-95 corridor, affecting traffic flows from Philadelphia to Richmond and beyond. In the event of a natural disaster such as a severe hurricane, travel through the CBM could be disrupted and it would also be critical to move relief supplies in and people out. This type of planning can only be accomplished at the mega-region level, and the CBM analysis tool would provide a great framework for such study.

4.4 Conclusions – Need for mega-region view

This project began with the goal of developing a framework for mega-regional analysis and demonstrating an application of the framework to the CBM. This was successfully completed. On a technical level, the project demonstrated that data from multiple sources can be combined to develop a multi-discipline, multi-level model and that the model can be applied on a large geographic scale encompassing a key US mega-region. On a policy level the project demonstrated the impacts of high-energy prices on the economic, land use, transport, and environment of the region as a whole as well as highlighting vulnerable communities and industries. The case study characterization and scenario analysis of highlighted how the CBM is linked together economically and the value of analyzing a wide range of issues at the mega-region level.

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